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A REPORT TO
LIMEN GROUP CONSTRUCTION (2019) LTD.

A GEOTECHNICAL INVESTIGATION FOR PROPOSED INDUSTRIAL BUILDLINGS, SWM PONDS AND SEPTICS

WOODBINE AVENUE AND AURORA ROAD

TOWN OF WHITCHURCH-STOUFFVILE

REFERENCE NO. 2109-S177

MARCH 2022

DISTRIBUTION

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1.0 INTRODUCTION

In accordance with written authorization dated September 15, 2021, from Mr. Antonio Lima, President, of Limen Group Construction (2019) Ltd., a geotechnical investigation was carried out at a parcel of land located at Woodbine Avenue and Aurora Road, in the Town of Whitchurch-Stouffville, for proposed Industrial Buildings, SWM Ponds and Septics.

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

Whitchurch-Stouffville is located on a till plain where glacial drift predominates the soil stratigraphy. In places, the drift has been modified by the depositing of lacustrine clay, silt, sand and water-laid till by the water action of Peel Ponding (glacial lake).

The investigated site is a weed covered open field, situated at the southeast sector of Woodbine Avenue and Aurora Road, in the Town of Whitchurch-Stouffville. The ground surface is relatively flat and level, with some undulations.

The proposed project consists of the construction of industrial buildings, SWM ponds and septics. The new development will be provided with municipal services, landscaped areas and roadways meeting urban standards.

3.0 FIELD WORK

The field work, consisting of 13 boreholes to depths of 5.0 m and 6.6 m, was performed on December 10, 2021, January 24 and 25, 2022, at the locations shown on the Borehole Location Plan, Drawing No. 1. A total of 3 monitoring wells were also installed at Boreholes 1, 2 and 8, for future groundwater monitoring by others.

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 geodetic elevation at each of the borehole locations was obtained by Soil Engineers Ltd. using the Global Navigation Satellite System (GNSS).

4.0 SUBSURFACE CONDITIONS

Detailed descriptions of the encountered subsurface conditions are presented on the Borehole Logs, comprising Figures 1 to 13, inclusive. The revealed stratigraphy is plotted on the Subsurface Profile, Drawing Nos. 2 and 3, and the engineering properties of the disclosed soils are discussed herein.

This investigation has disclosed that beneath either a layer of granular fill or a veneer of topsoil, the site is underlain by strata of silty clay, silt and silty sand.

4.1 **Granular Fill** (Borehole 2)

A layer of granular fill, 100 mm thick, was found at the ground surface. It consists of a mixture of crushed gravel and silty sand.

The granular fill should be further assessed of its suitability for reuse as bedding material, subgrade stabilization or as a general backfill material.

4.2 **Topsoil** (All Boreholes, except Borehole 2)

The revealed topsoil, ranging from 10 to 36 cm thick, was encountered at the ground surface. It is dark brown in colour, indicating that it contains appreciable amounts of roots and humus. These materials are unstable and compressible under loads; therefore, the topsoil is considered to be void of engineering value. Due to its humus content, it may produce volatile gases and generate an offensive odour under anaerobic conditions. Therefore, the topsoil must not be buried below any structures or deeper than 1.2 m below the finished grade, so that it will not have an adverse impact on the environmental well being of the developed areas.

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

4.3 **Silty Clay** (All Boreholes, except Boreholes 3 and 4)

The silty clay was encountered at various depths and is the predominant soil encountered on site. The clay is laminated with sand and silt seams and layers, showing that it is a glaciolacustrine deposit. The clay layer is weathered to depths from 0.7 to 2.1 m at some of the boreholes.

The obtained 'N' values range from 1 blow per 30 cm to 50 blows per 2 cm, with a median of 22 blows per 30 cm of penetration, indicating that the consistency of the clay is very soft to hard, being generally very stiff. The soft soil is generally restricted to the weathered zone.

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

The Atterberg Limits of 1 representative sample and the water content values of all of the samples were determined. The results are plotted on the Borehole Logs and summarized below:

Liquid Limit	28%
Plastic Limit	17%
Natural Water Content	16% to 29% (median 20%)

The above results show that the clay is a cohesive material with low plasticity. The natural water content values generally lie above its plastic limit and below its liquid limit, confirming the generally very stiff consistency of the clay determined from the 'N' values.

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 over 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 2500 ohm·cm.

4.4 **Silt** (Boreholes 1, 3, 4 and 11)

The silt deposit was encountered at various depths in localized areas and extends to the maximum investigated depth Boreholes 1, 3 and 4. The silt is embedded with seams and layers of silty clay and fine sand and contains a variable amount of clay. The laminated structure shows that the silt is a glaciolacustrine deposit. The silt layer is weathered to a depth of 2.1 m at Boreholes 3 and 4.

The natural water content of the silt samples ranges from 18% to 26%, with a median of 21%, indicating it is in a wet condition.

The obtained 'N' values range from 4 to 86, with a median of 24 blows per 30 cm of penetration, indicating that the relative density of the silt is loose to very dense, being generally compact. The loose soil is generally restricted to the weathered zone.

Grain size analyses were performed on 2 representative samples of the silt and the results are plotted on Figure 15.

Based on the above findings, the engineering properties are given below:

- Highly frost susceptible, with high soil-adfreezing potential.
- Highly water erodible; it is susceptible to migration through small openings under seepage pressure.

- Relatively low to low permeability, with an estimated coefficient of permeability of 10^{-5} to 10^{-6} cm/sec, depending on the clay content, an estimated percolation rate of 45 to 60 min/cm, and runoff coefficients of:

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

- The soil has a high capillarity and water retention capacity.
- A frictional soil, its shear strength is density dependent. Due to the dilatancy, the strength of the wet 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 in shear strength.
- In excavation, the moist silt will be stable in relatively steep cuts, while the wet silt will slough and run slowly with seepage bleeding from the cut face, and the bottom will boil under a piezometric head of 0.3 m.
- A poor pavement-supportive material, with an estimated CBR value of 6%.
- Moderate corrosivity to buried metal, with an estimated electrical resistivity of 4500 ohm·cm.

4.5 **Silty Sand** (Boreholes 3 and 5)

The silty sand deposit was encountered below a veneer of topsoil and sample examinations show that it is non-cohesive and is embedded with silt seams. The laminated structure shows the deposit was derived from a lacustrine environment. The silty sand layer is weathered at both boreholes.

The obtained 'N' values range from 1 to 7, with a median of 5 blows per 30 cm of penetration; therefore, the relative density of the silty sand is very loose to loose.

The natural water content was determined and the results are plotted on the Borehole Logs. The values are 16% and 19%, showing that the sand deposit is in a wet condition. The wet samples are water bearing and displayed appreciable dilatancy when shaken by hand.

Accordingly, the following engineering properties are deduced:

- Highly frost susceptible with high soil-adfreezing potential.
- Highly water erodible.

- Pervious to relatively pervious, with an estimated coefficient of permeability of 10^{-3} to10^{-4} cm/sec, an estimated percolation rate of 12 to 30 min/cm, and runoff coefficients of:

Slope	
0% - 2%	0.04 to 0.07
2% - 6%	0.09 to 0.12
6% +	0.13 to 0.18

- 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 sand 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 sand will be stable in a damp to moist condition, but will slough if it is wet and run with water seepage. The bottom will boil under a piezometric head of 0.3 m.
- A fair material to support pavement, with an estimated CBR value of at least 8%.
- Moderately low corrosivity to buried metal, with an estimated electrical resistivity of 5000 ohm·cm.

4.6 Compaction Characteristics of the Revealed Soils

The obtainable degree of compaction is primarily dependent on the soil moisture and, to a lesser extent, on the type of compactor used and the effort applied. As a general guide, the typical water content values of the revealed soils for Standard Proctor compaction are presented in Table 1.

Table 1 - Estimated Water Content for Compaction

Soil Type	Determined Natural Water Content (%)	Water Content (%) for Standard Proctor Compaction	
		100% (optimum)	Range for 95% or +
Silty Clay	16 to 29 (median 20)	18	14 to 23
Silt	18 to 26 (median 21)	13	8 to 17
Silty Sand	16 and 19	11	6 to 16

The above values show that the silty clay is generally suitable for 95% or + Standard Proctor compaction; whereas, the silt and the silty sand are too wet and will require aeration or mixing with drier soils prior to compaction. Aeration of the wet soils can be effectively carried out by spreading it thinly on the ground in the dry, warm weather.

The silty clay should be compacted using a heavy-weight, kneading-type roller. The granular fill, silt and silty sand 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 silty clay 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 the 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 soil will be necessary to achieve this requirement.

One should be aware that, with considerable effort, a 90%± Standard Proctor compaction of the wet silt and silty sand 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 road construction since each component of the pavement structure is to be placed under dynamic conditions which will induce the rolling action of the subgrade surface and cause structural failure of the new pavement. The foundations or bedding of the sewer and slab-on-grade will be placed on a subgrade which will not be subjected to impact loads. Therefore, the structurally compacted soil mantle with the water content on the wet side or dry side of the optimum will provide an adequate subgrade for the construction.

5.0 **GROUNDWATER CONDITIONS**

The boreholes were checked for the presence of groundwater or the occurrence of cave-in upon their completion. The data are plotted on the Borehole Logs and summarized in Table 2.

Table 2 - Groundwater Levels

Borehole No.	**Borehole Depth (m)**	**Soil Colour Changes Brown to Grey**	**Measured Groundwater/ Cave-in* Level On Completion**	
		Depth (m)	**Depth (m)**	**El. (m)**
1	5.0	4.0	3.7	293.7
2	5.0	5.0+	3.7	293.3
3	5.0	5.0+	4.0	293.2
4	6.6	6.1	Dry	-
5	6.6	3.0	3.0	294.2
6	5.0	4.5	3.0	293.4
7	5.0	4.5	3.0	294.5
8	5.0	2.3	3.0	294.6
9	6.6	6.1	3.0	295.2
10	5.0	4.5	4.3	293.5
11	6.6	4.0	5.5	294.0
12	5.0	4.5	Dry	-
13	5.0	3.0	3.0	295.4

Groundwater was detected at depths ranging from 3.0 to 5.5 m below the prevailing ground surface at 11 of the boreholes; the other 2 boreholes remained dry upon completion of field work. The groundwater level will fluctuate with the seasons.

The yield of groundwater from the silty clay, due to its low permeability, is expected to be small and limited. The yield from the silt and sand will be moderate to appreciable and likely persistent.

6.0 DISCUSSION AND RECOMMENDATIONS

This investigation has disclosed that beneath either a layer of granular fill or a veneer of topsoil, the site is underlain by strata of very soft to hard, generally very stiff silty clay, loose to very dense, generally compact silt and very loose to loose silty sand. The surficial soil is weathered to depths from 0.7 to 2.1 m at some of the boreholes.

Groundwater was detected at depths ranging from 3.0 to 5.5 m below the prevailing ground surface at 11 of the boreholes; the remaining 2 boreholes were dry upon completion of field work. The groundwater level will fluctuate with the seasons.

The geotechnical findings which warrant special consideration are presented below:

1. The topsoil must be stripped for the project construction. This material is unsuitable for structural applications and should be placed in the landscaped areas and should not be buried beneath any structures or 1.2 m below the finished grade.
2. The sound natural soils are suitable for normal spread and strip footing construction. Due to the presence of topsoil and weathered soils, the footing subgrade must be inspected by either a geotechnical engineer, or a geotechnical technician under the supervision of a geotechnical engineer, to ensure that its condition is compatible with the design of the foundation.
3. Slab-on-grade must be placed on sound native soils below the topsoil and weathered soils. Where weathered, soft or loose soils occur, they must be subexcavated, assessed, aerated and properly compacted prior to the placement of the slab.
4. A Class 'B' bedding consisting of compacted 20-mm Crusher-Run Limestone, is recommended for the construction of the underground services. The sewer joints should be leak-proof, or wrapped with an appropriate waterproof membrane, to prevent subgrade migration. If subgrade stabilization is required, lean concrete can be used. In areas where more extensive dewatering is required for sewer construction, a Class 'A' bedding should be considered.

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 and weathered soil onto the sound natural soils. The recommended soil bearing pressures and the corresponding founding levels in the sound natural soils are presented in Table 3.

Table 3 - Founding Levels

Borehole No.	Recommended Maximum Allowable Soil Pressure (SLS)/ Factored Ultimate Soil Bearing Pressure (ULS) and Corresponding Founding Level			
	100 kPa (SLS)/160 kPa (ULS)		200 kPa (SLS)/320 kPa (ULS)	
	Depth (m)	Elevation (m)	Depth (m)	Elevation (m)
3	1.6 or +	295.6 or -	2.4 or +	294.8 or -
4	1.0 or +	297.8 or -	2.4 or +	296.4 or -
5	1.6 or +	295.6 or -	2.4 or +	294.8 or -
6	1.6 or +	294.48or -	2.4 or +	294.0 or -
9	1.0 or +	297.2 or -	1.6 or +	296.6 or -
10	-	-	1.0 or +	296.8 or -
11	1.2 or +	298.3 or -	1.6 or +	297.9 or -
12	1.0 or +	297.9 or -	1.6 or +	297.3 or -

The recommended soil pressures (SLS) for normal foundations incorporate a safety factor of 3. The total and differential settlements of the footings 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.

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

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).

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.

6.2 Slab-On-Grade

Slab-on-grade should be placed on well compacted inorganic earth fill and sound natural soils. After fine grading, the subgrade should be inspected and assessed by proof-rolling prior to slab-on-grade construction. Soft or loose subgrade and any weathered soil should be subexcavated, sorted free of any deleterious material, aerated and uniformly compacted to 98% or + of its maximum Standard Proctor dry density.

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

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

The exterior grading must be such that water is directed away from the building envelope.

6.3 Underground Services

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

A Class ‘B’ bedding, consisting of compacted 20-mm Crusher-Run Limestone, is recommended for the construction of the underground services. The sewer joints should be leak-proof or wrapped with an appropriate waterproof membrane to prevent subgrade migration. If subgrade stabilization is required, lean concrete can be used. 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 and fittings should be protected against corrosion. In determining the mode of protection, an electrical resistivity of 2500 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.

6.4 Backfilling in Trenches and Excavated Areas

The on site inorganic soils are suitable for trench backfill. The wet soils should not be used for backfill unless they are aerated and dried to achieve the optimum moisture content. The backfill in the trenches should be compacted to at least 95% of its maximum Standard Proctor dry density, and increased to 98% or + below the floor slab. In the zone within 1.0 m below the pavement subgrade, the material should be compacted with the water content 2% or 3% drier than the optimum, and the compaction should be increased to 98% of the respective maximum Standard Proctor dry density. This is to provide the required stiffness for pavement construction. In the lower zone, the compaction should be carried out on the wet side of the optimum; this allows a wider latitude of lift thickness.

In normal construction practice, the problem areas of settlement largely occur adjacent to manholes, catch basins, services crossings, columns and foundation walls. 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 natural soils and sand backfill will have to be flooded for a period of several days.

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

One must be aware of 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 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 service construction is carried out during the winter months, prolonged exposure of the trench walls will result in frost heave within the soil mantle of the walls. This may result in some settlement as the frost recedes, and repair costs will be incurred prior to the final surfacing of the new pavement.
- 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 site 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.

6.5 **Stormwater Management Ponds** (Boreholes 2 and 7)

It is understood that the proposed bottom of the two stormwater management ponds is yet to be determined. However, due to the low permeability of the silty clay at these borehole locations, seepage of groundwater into the ponds will be minimal and the impact on the storage volume of the ponds will be negligible, as a results, clay liner will not be required for the proposed SWM ponds.

For stability, the sides of the ponds should be sloped at 1 vertical:4 or + horizontal below the wet perimeter of the ponds, and can be flattened to 1 vertical:3 or + horizontal above the wet perimeter. All the exposed side slopes must be vegetated and/or sodded to prevent erosion. A layer of rip-rap can be placed at the wet perimeter to protect against rapid drawdown and wave erosion.

A Maximum Allowable Soil Pressure (SLS) of 100 kPa and a Factored Ultimate Soil Bearing Pressure (ULS) of 160 kPa can be used for the design of the foundations of the control structures. The footings must be placed onto the sound natural soils below the scouring depth or at a depth providing a minimum earth cover of 1.2 m for protection against frost action, whichever is greater. The footing subgrade must be inspected by a geotechnical engineer, or a geotechnical technician under the supervision of a geotechnical engineer, prior to concrete pouring to ensure its conformity to the design. The inlet and outlet of the ponds must be lined with gabion mats for protection against scouring.

6.6 **Septic Tile Beds** (Boreholes 1, 8 and 13)

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

As noted, the predominant in situ soil consists of silty clay, which is relatively impermeable with an estimated percolation time of 80 min/cm and is unsuitable for the in-ground absorption of sewage effluent; therefore, construction of a raised tile bed will be necessary.

The recommended percolation time (‘T’) for use in the design of the septic tile bed in silty clay is T=80 min/cm. A detailed design of the septic tile bed system can be obtained from the 1997 Ontario Building Code, published by the Ontario Ministry of Municipal Affairs and Housing.

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

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

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

1. All topsoil should be stripped from the tile bed area.
2. For the raised septic tile bed, the sand filter should be keyed into the soil mantle to about 15 cm below the surface of the soil.

3. Grading of the surrounding areas should be such that it directs surface runoff away from the tile bed area.
4. The bed should be located in an unshaded area.
5. The fissured pattern of the underlying soil should not be disturbed, as this would reduce its capacity for in-ground effluent absorption.
6. In the low areas, the septic tile bed should be elevated so that surface runoff will not pond.

The above recommendations are subject to the approval of the local regulatory agency.

6.7 **Pavement Design**

The subgrade will generally consist of silty clay material. Accordingly, the recommended pavement design is given in Table 5.

Table 5 - 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
Granular Sub-base		50-mm Crusher-Run Limestone
Light-Duty	250	
Heavy-Duty	350	

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

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

Earth fill to raise the grade for pavement construction should consist of organic-free soil uniformly compacted to 98% or + of its maximum Standard Proctor dry density.

The subgrade in the zone within 1.0 m below the underside of the granular sub-base should be compacted to at least 98% of its maximum Standard Proctor dry density, with a moisture content 2% to 3% drier than its optimum. Along the perimeter and at ramp-down driveways where surface runoff may drain onto the pavement, or water may seep into the granular bases, a swale and an intercept subdrain system should be installed. Subdrains, consisting of filter-sleeved weepers, should also be installed 0.3 m below the granular sub-base, and they should be connected to the catch basins and storm manholes in the paved areas and backfilled with free-draining granular material.

6.8 Truck Loading Docks

The loading docks will need to be provided with subdrains to relieve possible ponding of water. A concrete apron is recommended at the truck loading areas where loaded trailers are to be parked. The apron should be designed using the Modulus of Subgrade Reaction given for the floor slab, and it should be insulated with 50-mm Styrofoam, or equivalent, on a compacted granular base 300 mm thick. The foundation walls at the truck loading docks should be designed as a retaining structure using the soil parameters presented in Section 6.9 of this report.

6.9 Soil Parameters

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

Table 6 - Soil Parameters

Unit Weight and Bulk Factor			
	Unit Weight (kN/m^3)	**Estimated Bulk Factor**	
	Bulk	**Loose**	**Compacted**
Weathered Soils	20.5	1.20	1.00
Silty Clay	20.5	1.30	1.00
Silt and Silty Sand	20.5	1.20	1.00

Lateral Earth Pressure Coefficients			
	Active K_a	**At Rest K_o**	**Passive K_p**
Weathered Soils/Silty Clay	0.40	0.50	2.50
Silt and Silty Sand	0.33	0.43	3.00

6.10 Excavation

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

Excavations should be sloped at 1 vertical:1 horizontal for stability.

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

Table 7 - Classification of Soils for Excavation

Material	Type
Silty Clay, weathered Soils, Silt and Silty Sand above groundwater	3
Silt and Silty Sand below groundwater	4

The groundwater yield, if any, from the silty clay, due to its low permeability, will be small and can be controlled by pumping from sumps. If groundwater is encountered in the silt and silty sand, the yield is expected to be moderate to appreciable and may be persistent and groundwater may be controllable by pumping from closely spaced sumps. Or by well points.

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

7.0 LIMITATIONS OF REPORT

This report was prepared by Soil Engineers Ltd. for the account of Limen Group construction (2019) Ltd., 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 the report reflects the judgment of Frank Lee, P.Eng., and Bernard Lee, P.Eng, in light of the information available to it at the time of preparation. Any use which a Third Party makes of this report, and/or any reliance on decisions to be made based on it are the responsibility of such Third Parties. Soil Engineers Ltd. accepts no responsibility for damages, if any, suffered by any Third Party as a result of decisions made or actions based on this report.

SOIL ENGINEERS LTD.

Frank Lee, P.Eng.

Bernard Lee, P.Eng.
FL/BL:dd

March 4 [illegible]
F. W. LEE
[illegible]4508

May 3, [illegible]
B. P. Y. LEE
100104568

LIST OF ABBREVIATIONS AND DESCRIPTION OF TERMS

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

SAMPLE TYPES

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

PENETRATION RESISTANCE

Dynamic Cone Penetration Resistance:

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

Plotted as '—●—'

Standard Penetration Resistance or 'N' Value:

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

Plotted as '○'

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

SOIL DESCRIPTION

Cohesionless Soils:

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

Cohesive Soils:

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

Method of Determination of Undrained Shear Strength of Cohesive Soils:

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

△ Laboratory vane test

☐ Compression test in laboratory

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

METRIC CONVERSION FACTORS

1 ft = 0.3048 metres

1lb = 0.454 kg

1 inch = 25.4 mm

1ksf = 47.88 kPa

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JOB NO.: 2109-S177

LOG OF BOREHOLE NO.: 1

FIGURE NO.: 1

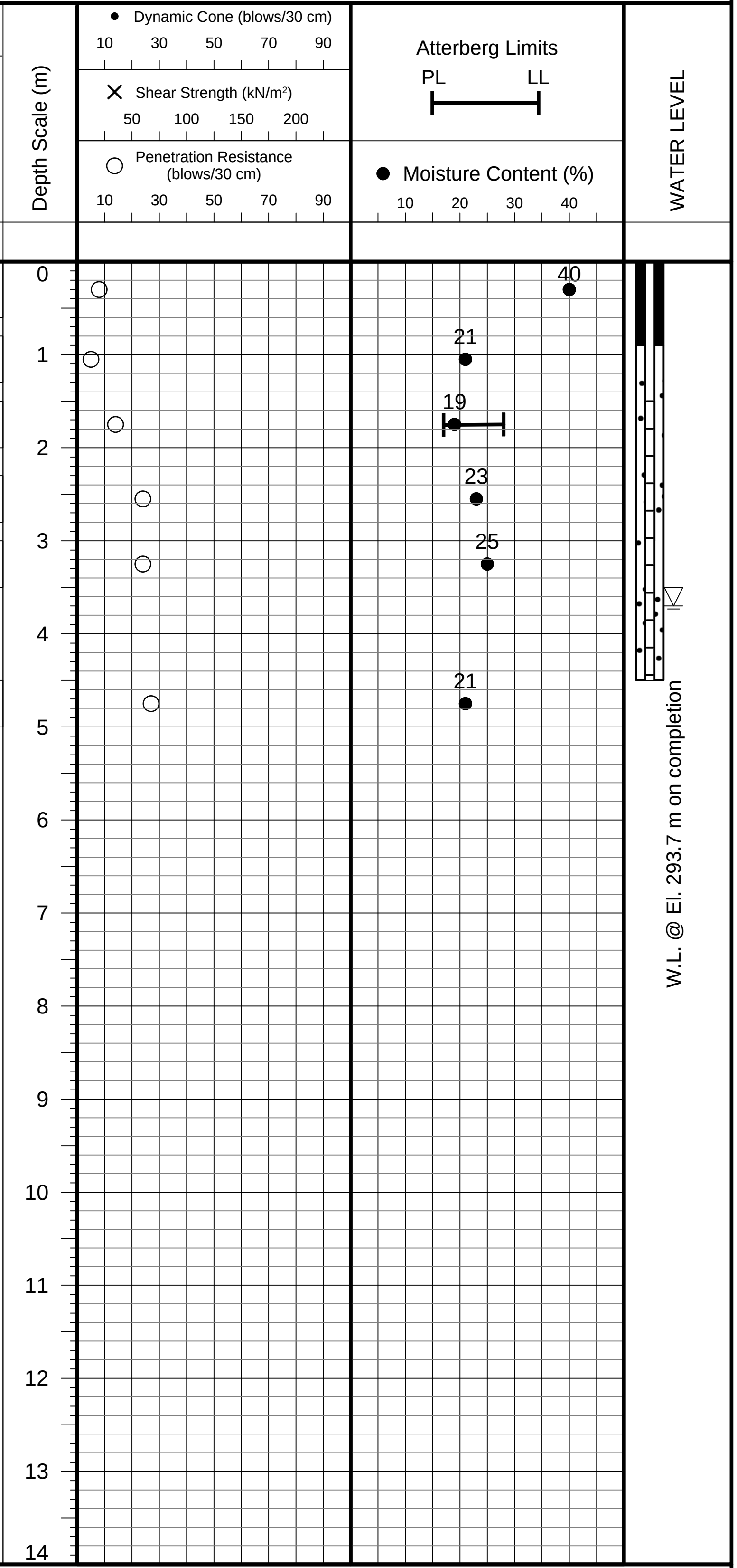
PROJECT DESCRIPTION: Proposed Industrial Buildings, SWM Ponds and Septics

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: Woodbine Avenue and Aurora Road
Town of Whitchurch-Stouffville

DRILLING DATE: January 24, 2022

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
297.4	Ground Surface			
0.0	**30 cm TOPSOIL** Brown, firm to very stiff	1	DO	8
		2	DO	5
	weathered **SILTY CLAY**	3	DO	14
	occ. wet sand and silt seams and layers	4	DO	24
		5	DO	24
293.4 4.0	Grey, compact **SILT**	6	DO	27
292.4 5.0	**END OF BOREHOLE** Installed 50 mm Ø monitoring well to 4.5 m Provided with a protective steel cover.			



Soil Engineers Ltd.

JOB NO.: 2109-S177

LOG OF BOREHOLE NO.: 2

FIGURE NO.: 2

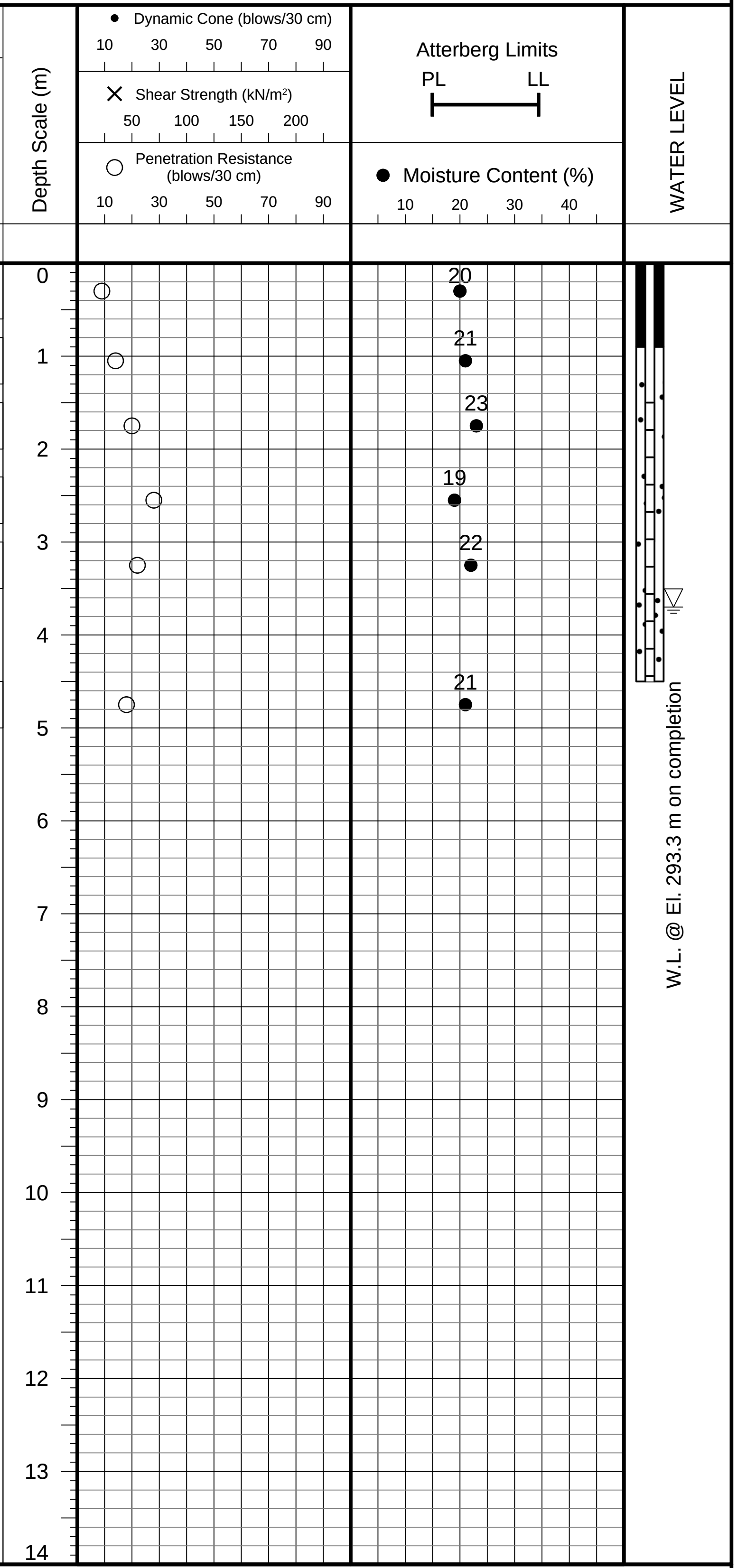
PROJECT DESCRIPTION: Proposed Industrial Buildings, SWM Ponds and Septics

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: Woodbine Avenue and Aurora Road
Town of Whitchurch-Stouffville

DRILLING DATE: December 10, 2021

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
297.0	Ground Surface			
0.0	**100 mm GRANULAR FILL**			
	Brown, stiff to very stiff weathered	1	DO	9
		2	DO	14
		3	DO	20
	SILTY CLAY occ. wet sand and silt seams and layers	4	DO	28
		5	DO	22
		6	DO	18
292.0 5.0	**END OF BOREHOLE** Installed 50 mm Ø monitoring well to 4.5 m Provided with a protective steel cover.			



Soil Engineers Ltd.

JOB NO.: 2109-S177

LOG OF BOREHOLE NO.: 3

FIGURE NO.: 3

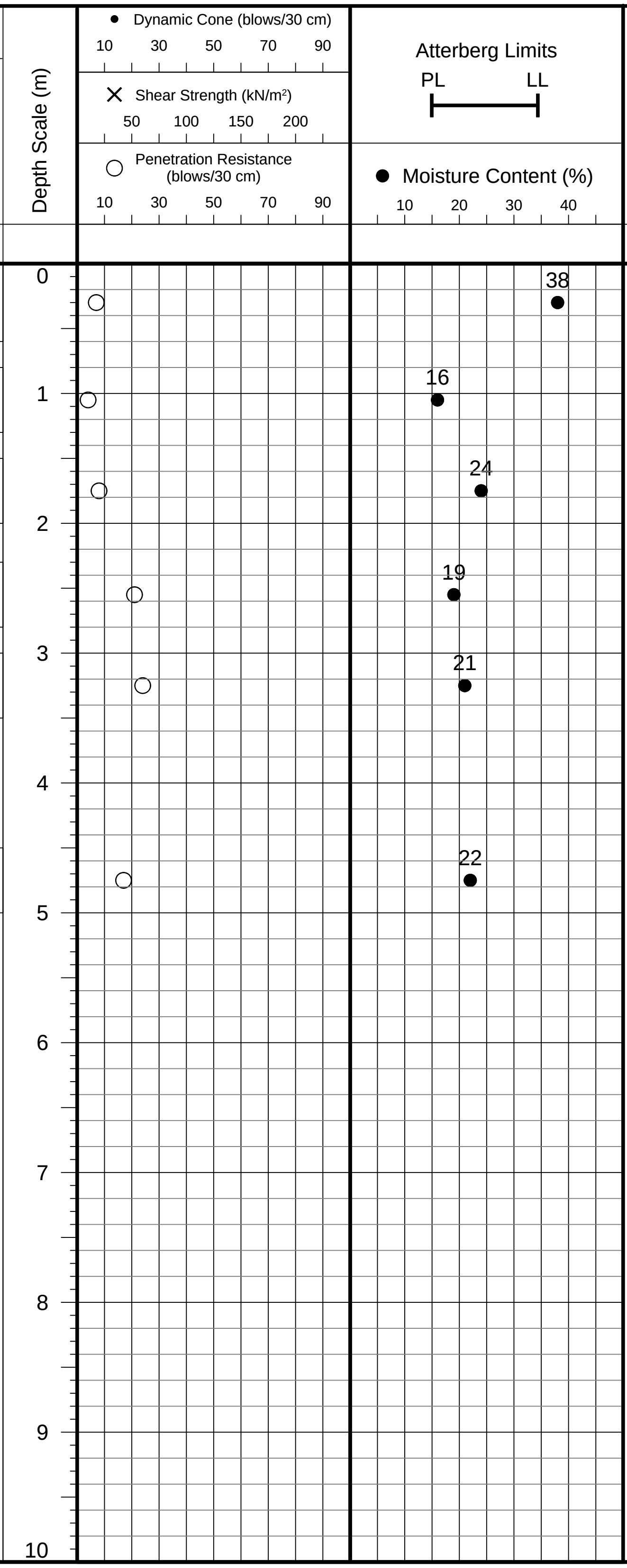
PROJECT DESCRIPTION: Proposed Industrial Buildings, SWM Ponds and Septics

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: Woodbine Avenue and Aurora Road
Town of Whitchurch-Stouffville

DRILLING DATE: January 24, 2022

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
297.2	Ground Surface			
0.0	**30 cm TOPSOIL**	1	DO	7
	Brown, loose, weathered **SILTY SAND**	2	DO	4
295.8 1.4	Brown, loose to compact weathered	3	DO	8
		4	DO	21
	SILT	5	DO	24
		6	DO	17
292.2 5.0	**END OF BOREHOLE**			



WATER LEVEL

W.L. @ El. 293.2 m on completion ∇

Soil Engineers Ltd.

JOB NO.: 2109-S177

LOG OF BOREHOLE NO.: 4

FIGURE NO.: 4

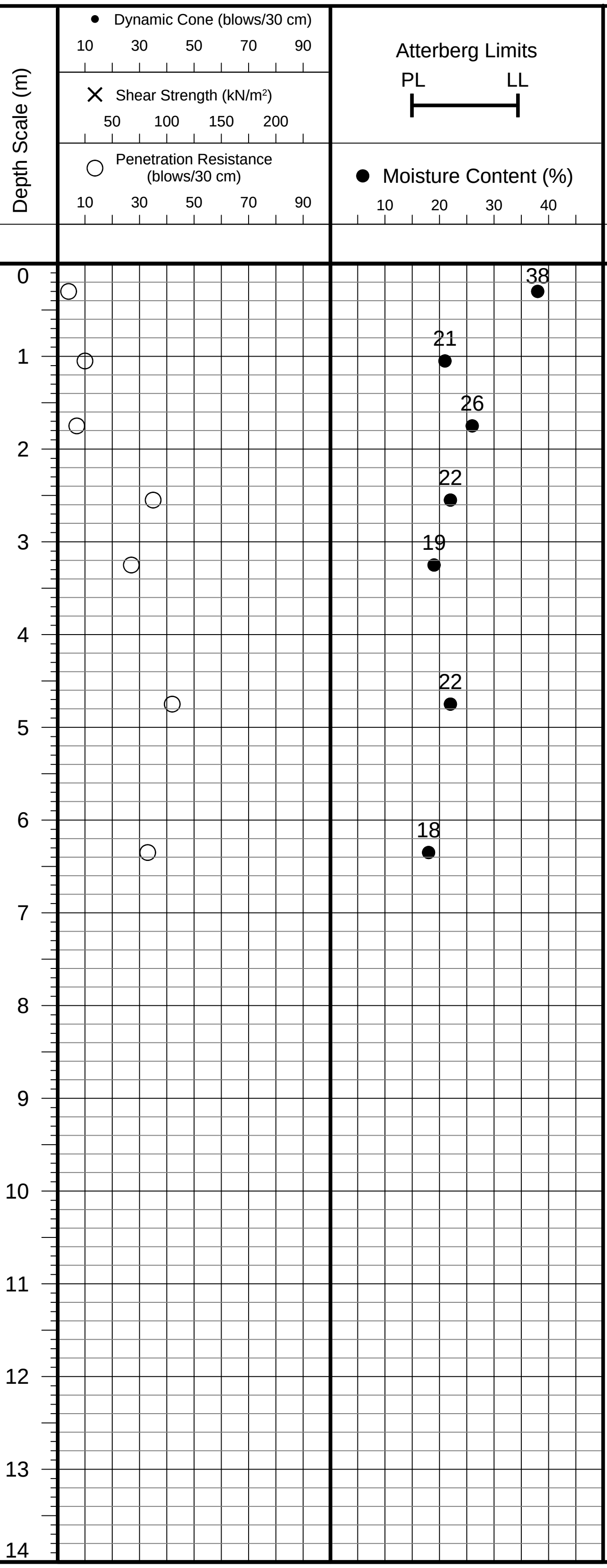
PROJECT DESCRIPTION: Proposed Industrial Buildings, SWM Ponds and Septics

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: Woodbine Avenue and Aurora Road
Town of Whitchurch-Stouffville

DRILLING DATE: January 24, 2022

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value	WATER LEVEL
298.8 0.0	Ground Surface				
	30 cm TOPSOIL	1	DO	4	Dry on completion
	Loose to dense	2	DO	10	
	weathered	3	DO	7	
		4	DO	35	
	SILT	5	DO	27	
		6	DO	42	
	brown grey	7	DO	33	
292.2 6.6	**END OF BOREHOLE**				



Soil Engineers Ltd.

JOB NO.: 2109-S177

LOG OF BOREHOLE NO.: 5

FIGURE NO.: 5

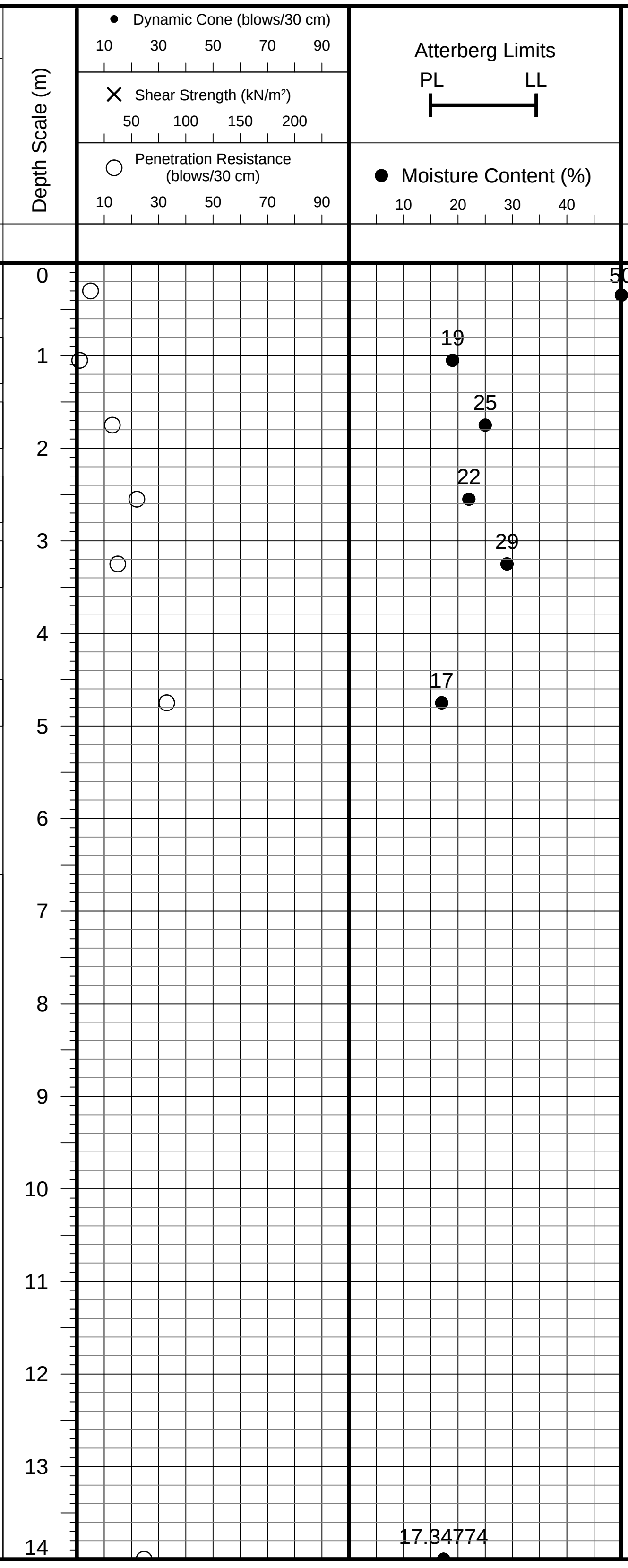
PROJECT DESCRIPTION: Proposed Industrial Buildings, SWM Ponds and Septics

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: Woodbine Avenue and Aurora Road
Town of Whitchurch-Stouffville

DRILLING DATE: January 24, 2022

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
297.2	Ground Surface			
0.0	**30 cm TOPSOIL**			
	Brown, very loose to loose, weathered **SILTY SAND**	1	DO	5
		2	DO	1
295.8 1.4	Stiff to hard	3	DO	13
	weathered	4	DO	22
	brown grey	5	DO	15
	SILTY CLAY occ. wet sand and silt seams and layers	6	DO	33
290.6 6.6	**END OF BOREHOLE**	7	DO	9



WATER LEVEL

W.L. @ El. 294.2 m on completion

Soil Engineers Ltd.

JOB NO.: 2109-S177

LOG OF BOREHOLE NO.: 6

FIGURE NO.: 6

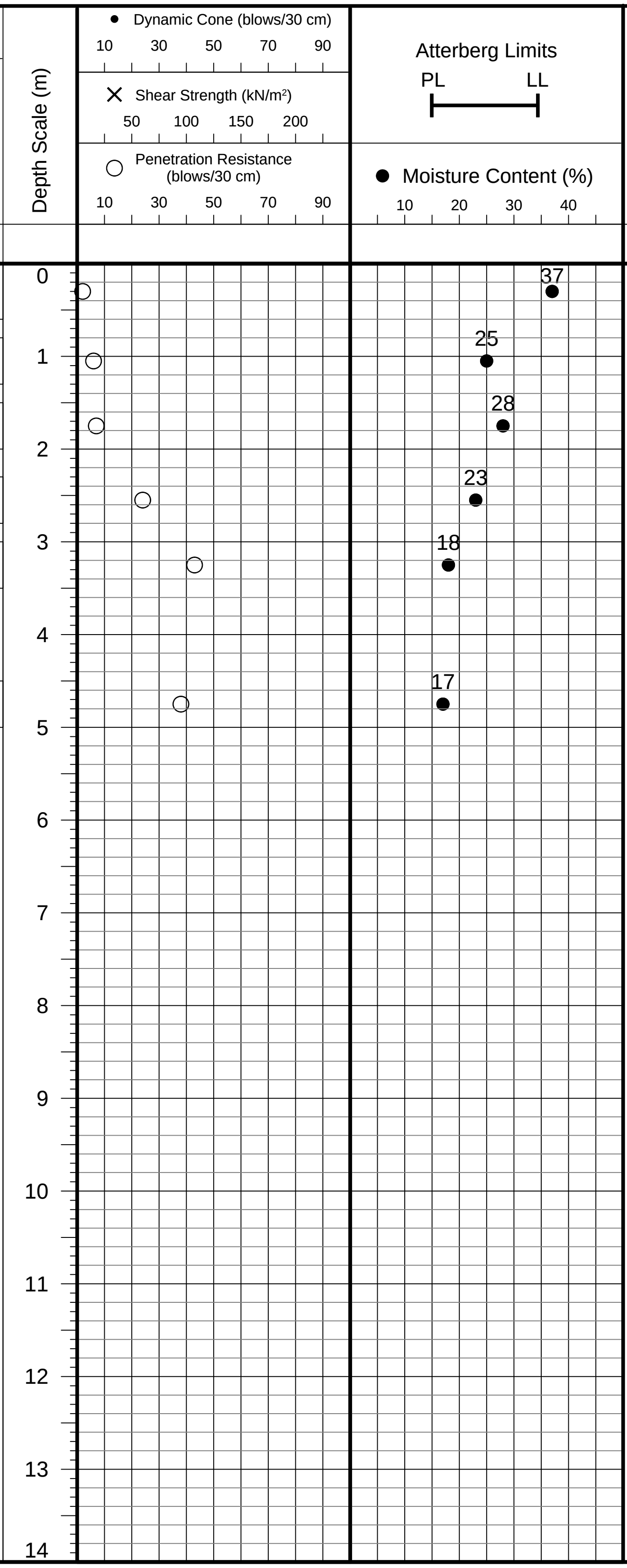
PROJECT DESCRIPTION: Proposed Industrial Buildings, SWM Ponds and Septics

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: Woodbine Avenue and Aurora Road
Town of Whitchurch-Stouffville

DRILLING DATE: January 24, 2022

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
296.4 0.0	Ground Surface **15 cm TOPSOIL**	1	DO	2
	Very soft to hard **SILTY CLAY** occ. wet sand and silt seams and layers	2	DO	6
		3	DO	7
	weathered	4	DO	24
		5	DO	43
	brown grey	6	DO	38
291.4 5.0	**END OF BOREHOLE**			



WATER LEVEL

W.L. @ El. 293.4 m on completion

Soil Engineers Ltd.

JOB NO.: 2109-S177

LOG OF BOREHOLE NO.: 7

FIGURE NO.: 7

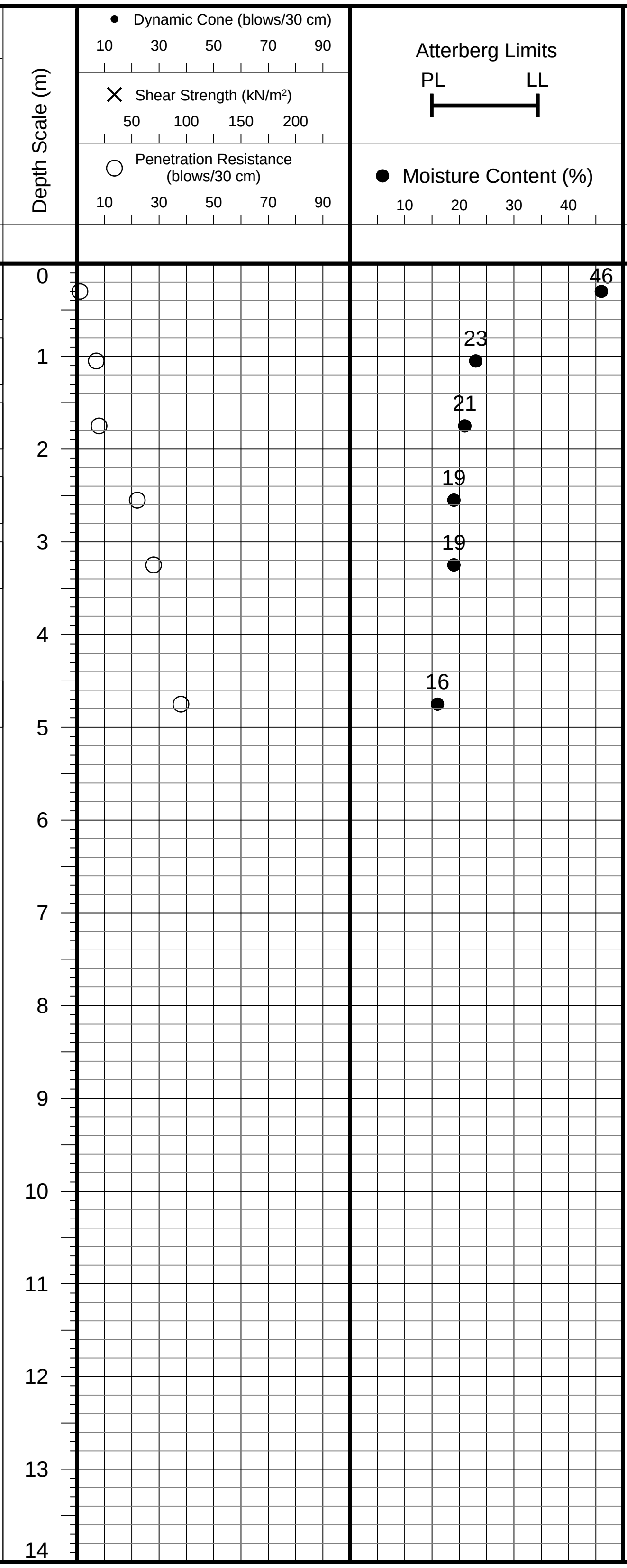
PROJECT DESCRIPTION: Proposed Industrial Buildings, SWM Ponds and Septics

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: Woodbine Avenue and Aurora Road
Town of Whitchurch-Stouffville

DRILLING DATE: January 24, 2022

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	Moisture Content (%)
297.5	Ground Surface				
0.0	**10 cm TOPSOIL** Very soft to hard	1	DO	1	46
		2	DO	7	23
	weathered	3	DO	8	21
	SILTY CLAY occ. wet sand and silt seams and layers	4	DO	22	19
		5	DO	28	19
	brown grey	6	DO	38	16
292.5 5.0	**END OF BOREHOLE**				



WATER LEVEL

∇ W.L. @ El. 294.5 m on completion

Soil Engineers Ltd.

JOB NO.: 2109-S177

LOG OF BOREHOLE NO.: 8

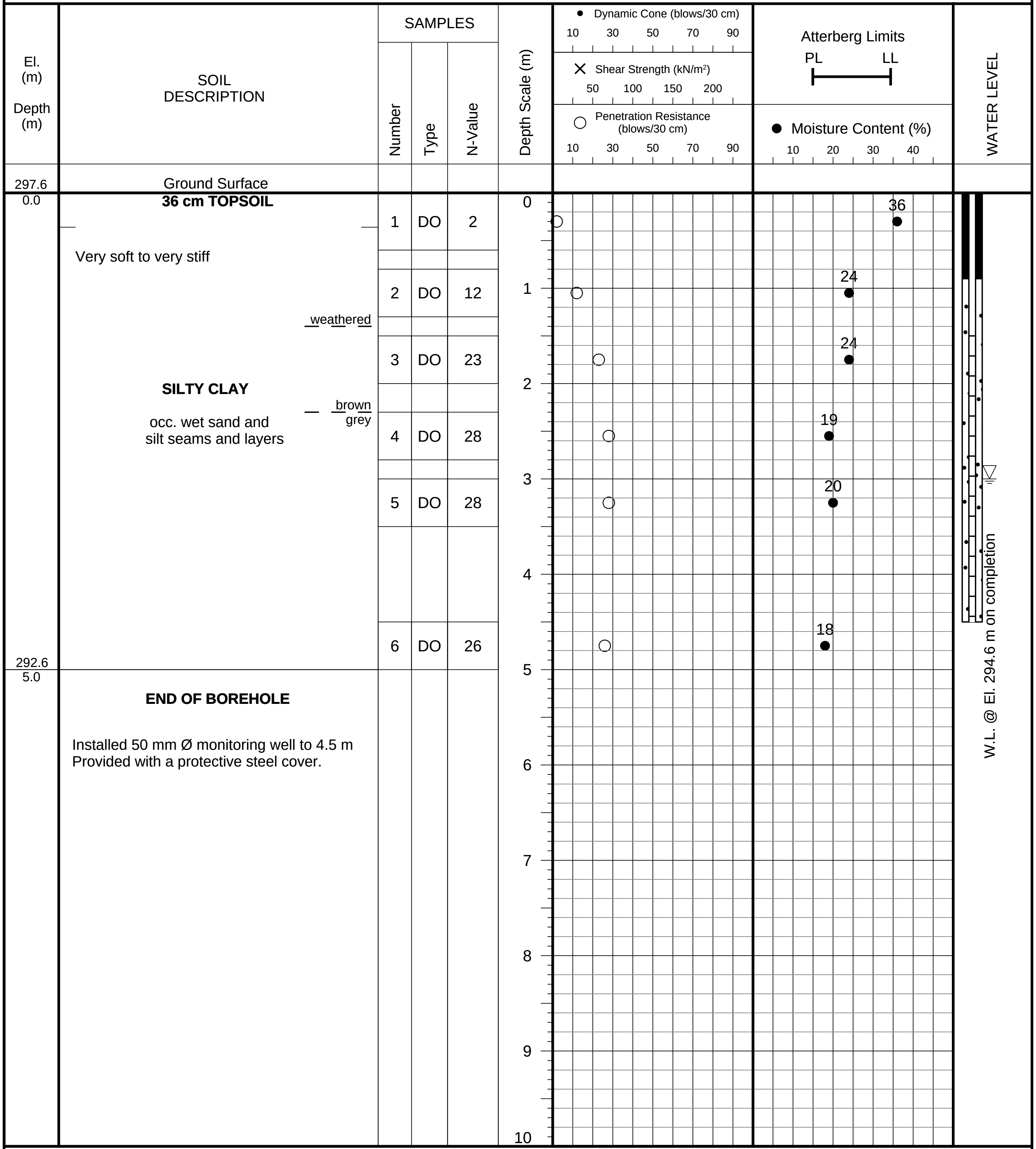
FIGURE NO.: 8

PROJECT DESCRIPTION: Proposed Industrial Buildings, SWM Ponds and Septics

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: Woodbine Avenue and Aurora Road
Town of Whitchurch-Stouffville

DRILLING DATE: January 25, 2022



El. (m) Depth (m)	SOIL DESCRIPTION	Number	Type	N-Value
297.6 0.0	Ground Surface **36 cm TOPSOIL**	1	DO	2
	Very soft to very stiff	2	DO	12
	weathered	3	DO	23
	SILTY CLAY occ. wet sand and silt seams and layers brown grey	4	DO	28
		5	DO	28
		6	DO	26
292.6 5.0	**END OF BOREHOLE**			

Installed 50 mm Ø monitoring well to 4.5 m
Provided with a protective steel cover.

Soil Engineers Ltd.

JOB NO.: 2109-S177

LOG OF BOREHOLE NO.: 9

FIGURE NO.: 9

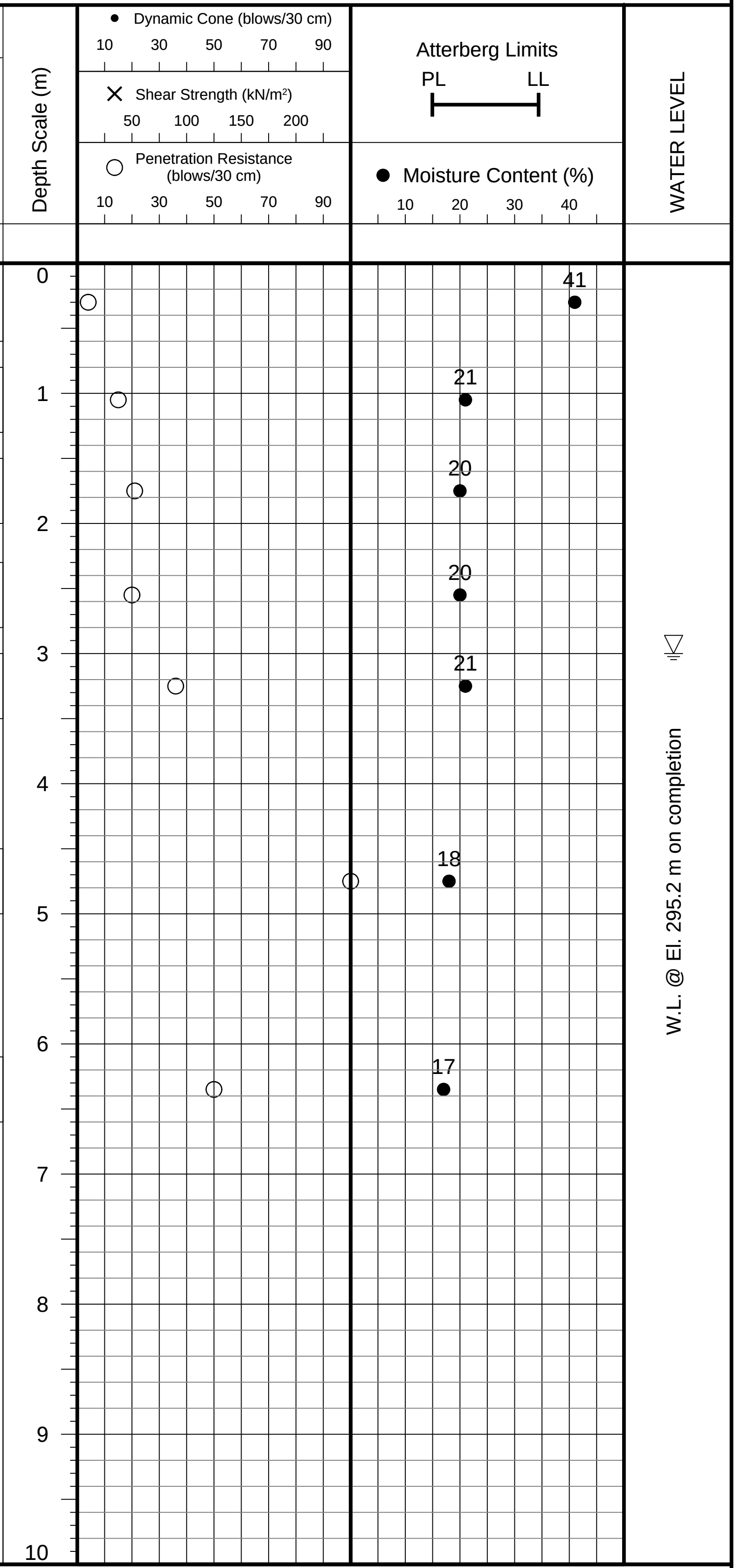
PROJECT DESCRIPTION: Proposed Industrial Buildings, SWM Ponds and Septics

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: Woodbine Avenue and Aurora Road
Town of Whitchurch-Stouffville

DRILLING DATE: January 25, 2022

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
298.2 0.0	Ground Surface			
	25 cm TOPSOIL	1	DO	4
	Soft to hard weathered			
		2	DO	15
		3	DO	21
		4	DO	20
	SILTY CLAY occ. wet sand and silt seams and layers	5	DO	36
		6	DO	50/15
	brown grey	7	DO	50
291.6 6.6	**END OF BOREHOLE**			



Soil Engineers Ltd.

JOB NO.: 2109-S177

LOG OF BOREHOLE NO.: 10

FIGURE NO.: 10

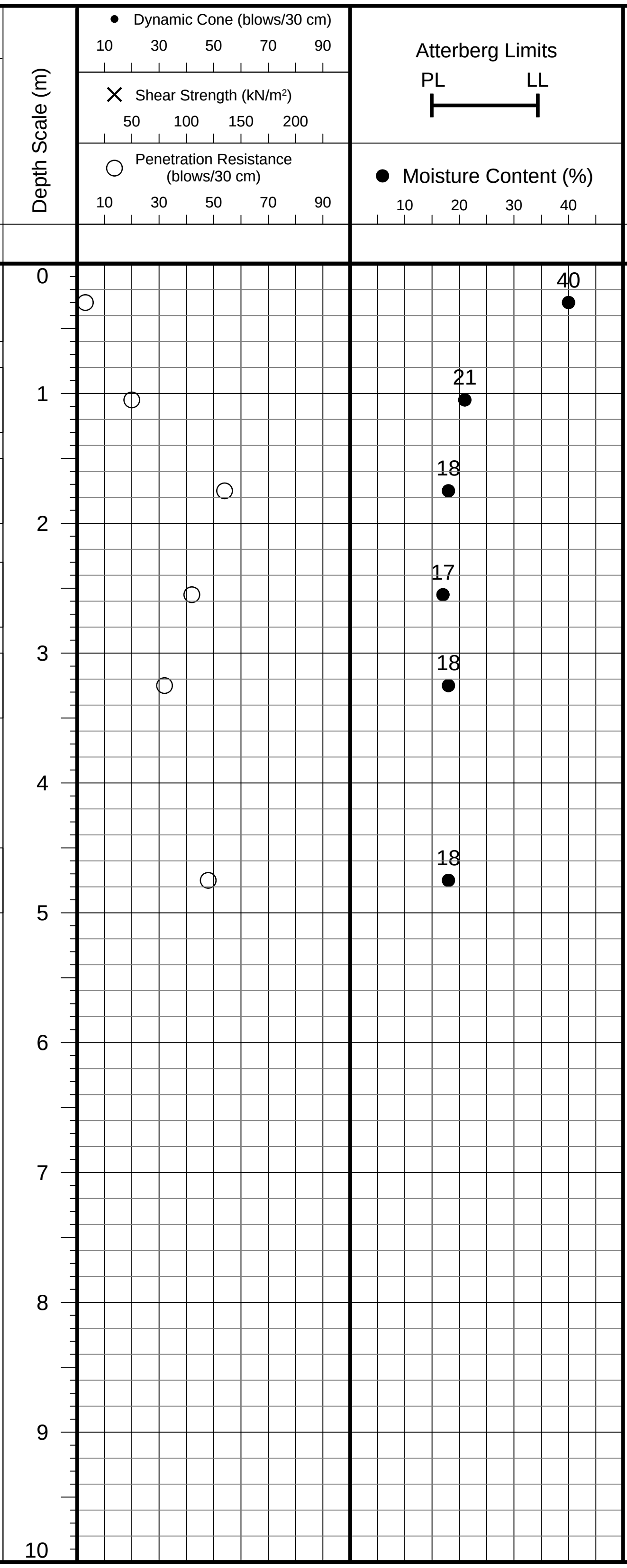
PROJECT DESCRIPTION: Proposed Industrial Buildings, SWM Ponds and Septics

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: Woodbine Avenue and Aurora Road
Town of Whitchurch-Stouffville

DRILLING DATE: January 25, 2022

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
297.8 0.0	Ground Surface			
	25 cm TOPSOIL	1	DO	3
	Very soft to hard weathered			
		2	DO	20
		3	DO	54
	SILTY CLAY occ. wet sand and silt seams and layers	4	DO	42
		5	DO	32
	brown grey	6	DO	48
292.8 5.0	**END OF BOREHOLE**			



WATER LEVEL

W.L. @ El. 293.5 m on completion ∇

Soil Engineers Ltd.

JOB NO.: 2109-S177

LOG OF BOREHOLE NO.: 11

FIGURE NO.: 11

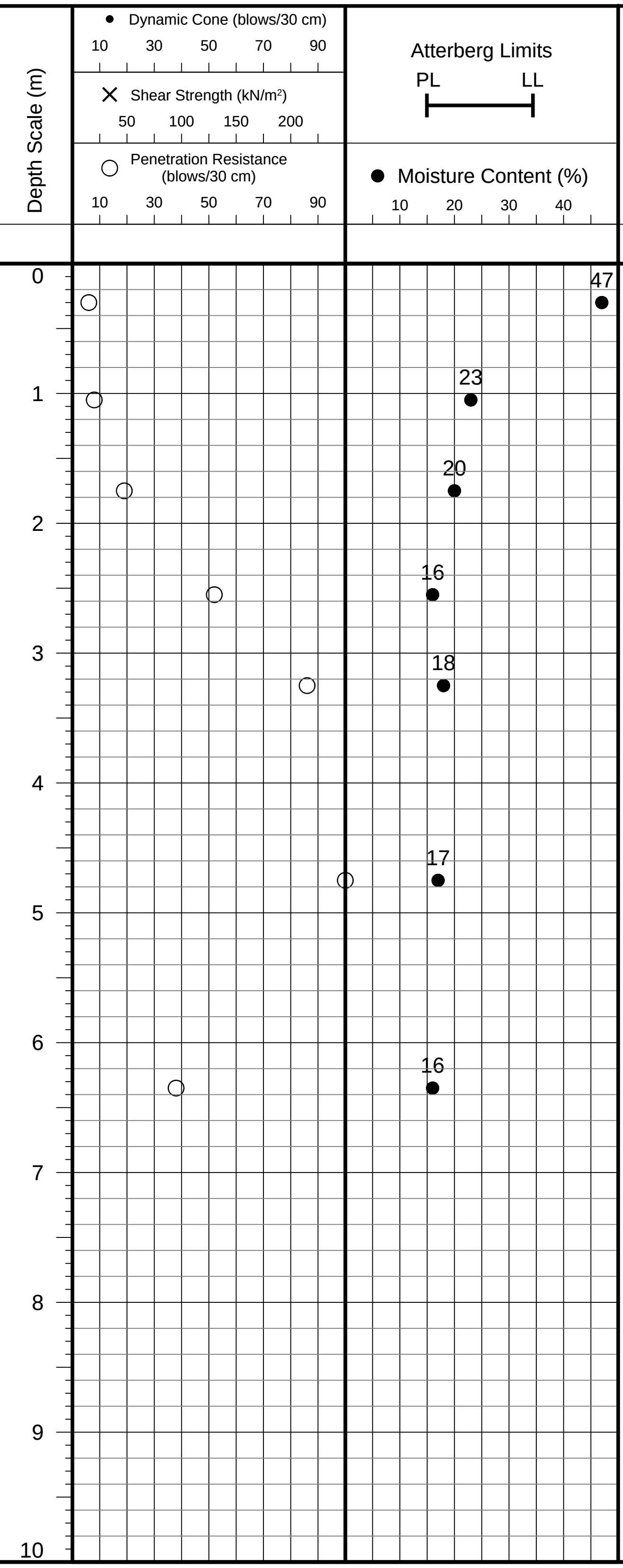
PROJECT DESCRIPTION: Proposed Industrial Buildings, SWM Ponds and Septics

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: Woodbine Avenue and Aurora Road
Town of Whitchurch-Stouffville

DRILLING DATE: January 25, 2022

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
299.5	Ground Surface			
0.0	**25 cm TOPSOIL**	1	DO	6
	Brown, firm to hard **SILTY CLAY** weathered occ. wet sand and silt seams and layers	2	DO	8
		3	DO	19
		4	DO	52
296.6 2.9	Brown, very dense **SILT**	5	DO	86
295.5 4.0	Grey, hard **SILTY CLAY**	6	DO	50/2
		7	DO	38
292.9 6.6	**END OF BOREHOLE**			



WATER LEVEL

W.L. @ El. 294.0 m on completion ▽

Soil Engineers Ltd.

JOB NO.: 2109-S177

LOG OF BOREHOLE NO.: 12

FIGURE NO.: 12

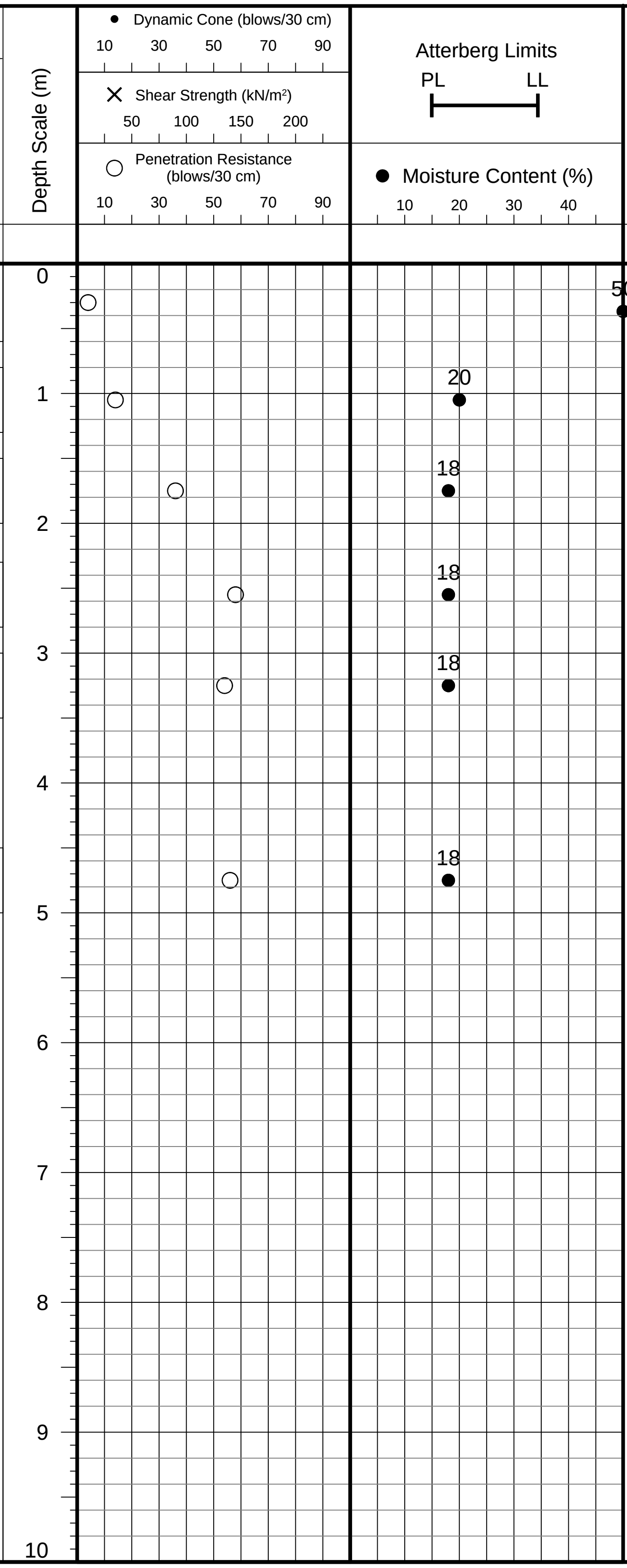
PROJECT DESCRIPTION: Proposed Industrial Buildings, SWM Ponds and Septics

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: Woodbine Avenue and Aurora Road
Town of Whitchurch-Stouffville

DRILLING DATE: January 25, 2022

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
298.9	Ground Surface			
298.6	**25 cm TOPSOIL**			
	Soft to hard weathered	1	DO	4
		2	DO	14
		3	DO	36
	SILTY CLAY occ. wet sand and silt seams and layers	4	DO	58
		5	DO	54
	brown grey	6	DO	56
293.9 5.0	**END OF BOREHOLE**			



WATER LEVEL

Dry on completion

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Page: 1 of 1

JOB NO.: 2109-S177

LOG OF BOREHOLE NO.: 13

FIGURE NO.: 13

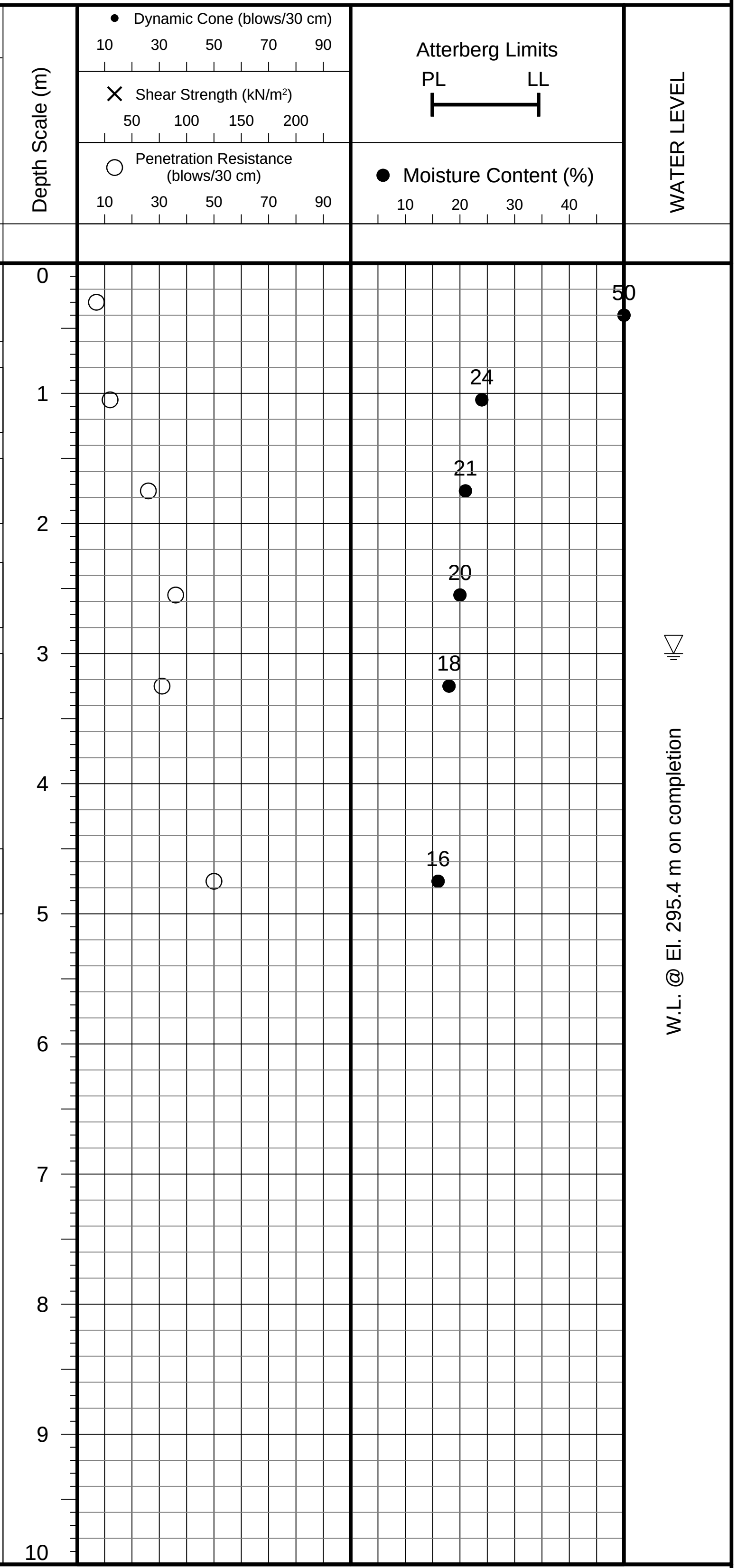
PROJECT DESCRIPTION: Proposed Industrial Buildings, SWM Ponds and Septics

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: Woodbine Avenue and Aurora Road
Town of Whitchurch-Stouffville

DRILLING DATE: January 25, 2022

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
298.4 0.0	Ground Surface			
	30 cm TOPSOIL	1	DO	7
	Firm to hard	2	DO	12
	weathered	3	DO	26
	SILTY CLAY occ. wet sand and silt seams and layers	4	DO	36
	brown grey	5	DO	31
		6	DO	50
293.4 5.0	**END OF BOREHOLE**			



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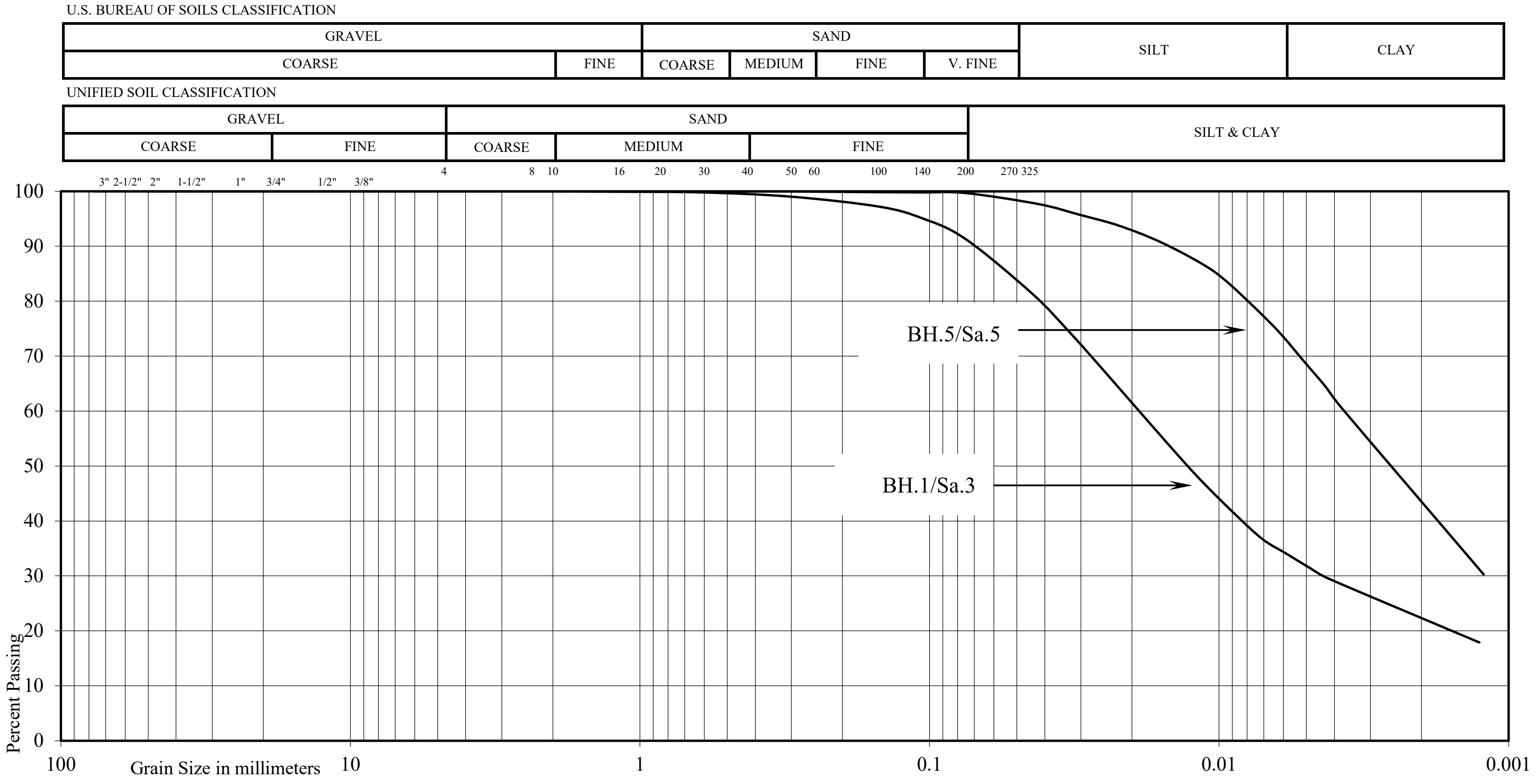
GRAIN SIZE DISTRIBUTION

Reference No: 2109-S177



Project: Proposed Industrial Buildings, SWM Ponds and Septics

Location: Woodbine Avenue and Aurora Road, Town of Whitchurch-Stouffville

Borehole No:	1	5
Sample No:	3	5
Depth (m):	1.7	3.3
Elevation (m):	295.7	293.9

BH./Sa.	1/3	5/5
Liquid Limit (%) =	28	-
Plastic Limit (%) =	17	-
Plasticity Index (%) =	11	-
Moisture Content (%) =	19	29
Estimated Permeability (cm./sec.) =	10^{-7}	10^{-7}

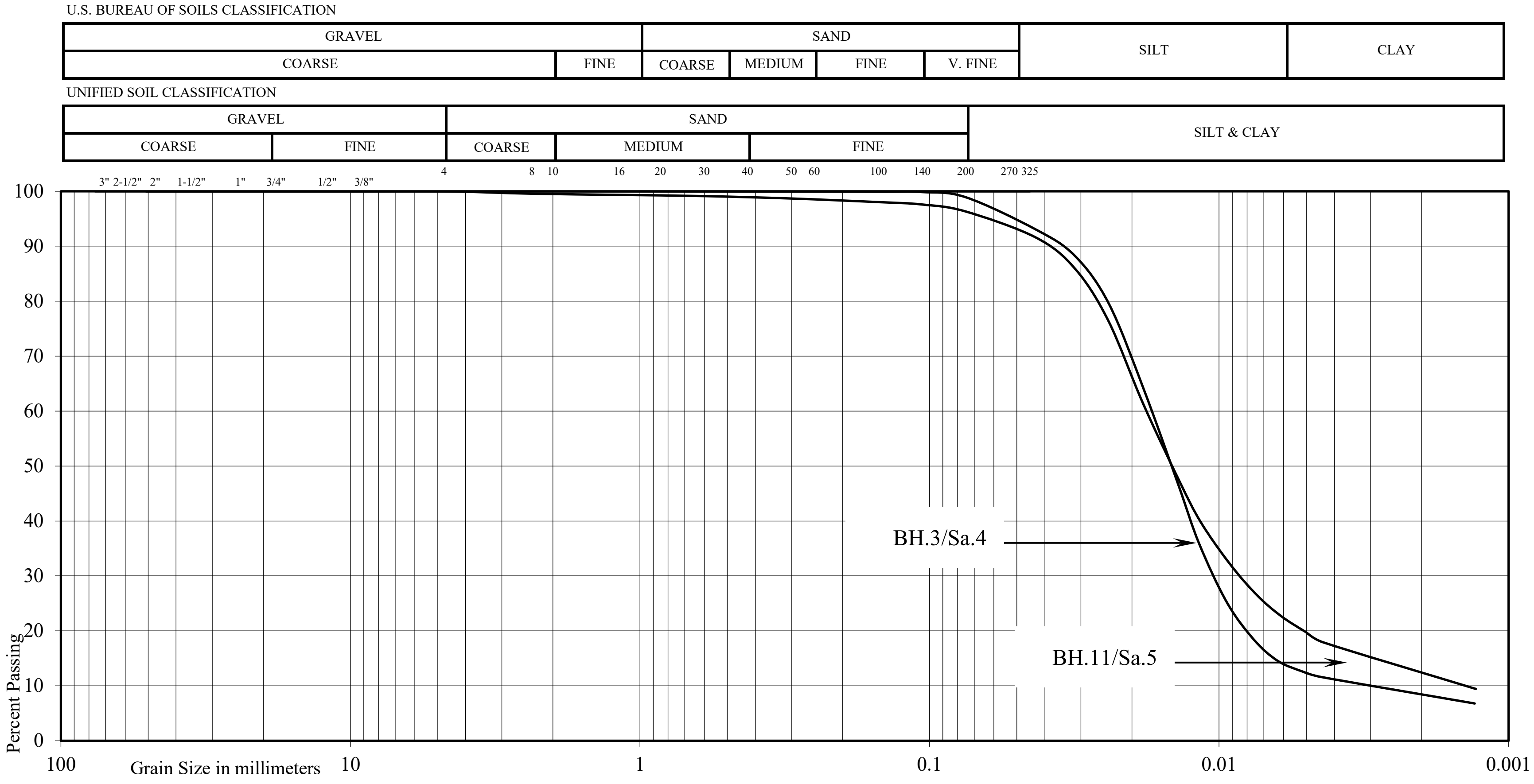
Classification of Sample [& Group Symbol]: SILTY CLAY, a trace of fine sand

Figure: 14

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 2109-S177



Project: Proposed Industrial Buildings, SWM Ponds and Septics

Location: Woodbine Avenue and Aurora Road, Town of Whitchurch-Stouffville

Borehole No:	3	11
Sample No:	4	5
Depth (m):	2.5	3.3
Elevation (m):	295.7	296.2

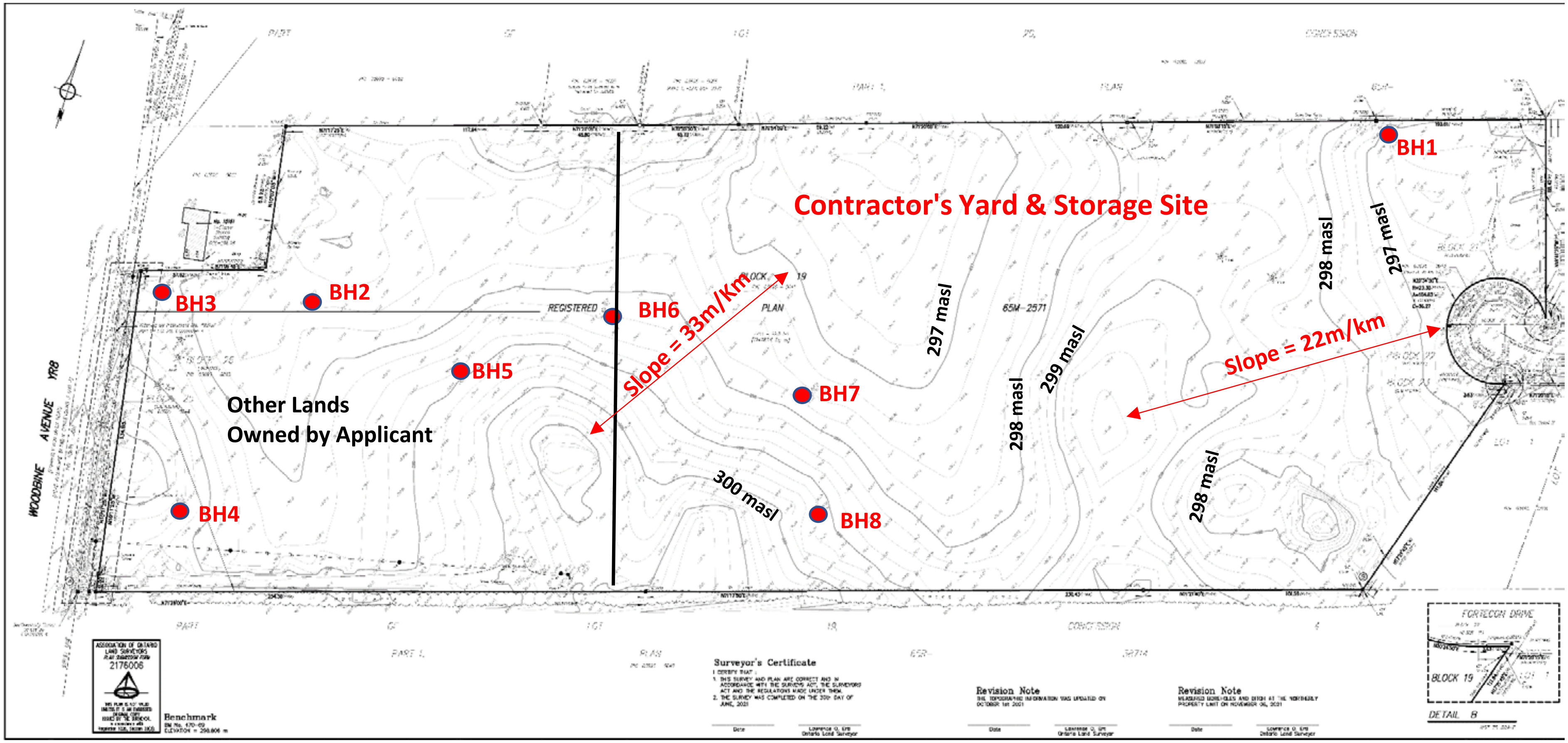
BH./Sa.	3/4	11/5
Liquid Limit (%) =	-	-
Plastic Limit (%) =	-	-
Plasticity Index (%) =	-	-
Moisture Content (%) =	19	18
Estimated Permeability (cm./sec.) =	10^{-5}	10^{-6}

Classification of Sample [& Group Symbol]: SILT, a trace to some clay, a trace of fine sand

Figure: 15

BH Location Plan

Soil Engineers Ltd.
Reference No. 2109-S117
Drawing No. 1



NOTES

BH8 ● Borehole location and designation

300 masl topographic contour metres above sea level

Existing Boreholes and Topography

Water Balance Evaluation, Limen Contractor's Yard & Storage Building, Fortecon Drive

For Limen & Scal Properties Ltd

Date:	Dec-21	Scale:	as shown
Project:	21013.00	Ref No:	

GAMAN Consultants Inc.

Figure C-1

Soil Engineers Ltd.
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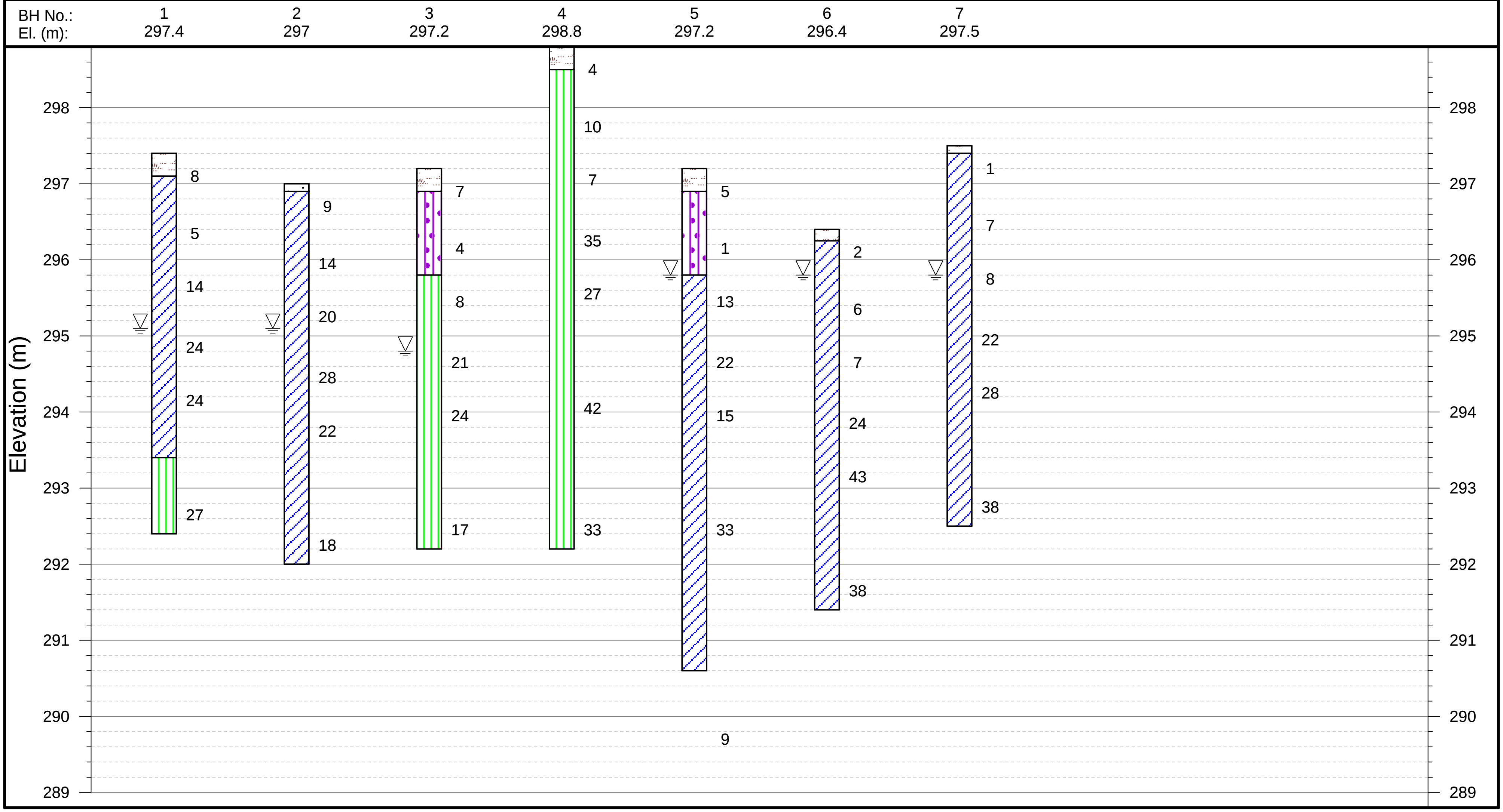
SUBSURFACE PROFILE
DRAWING NO. 2
SCALE: AS SHOWN

JOB NO.:	2109-S177
REPORT DATE:	March 2022
PROJECT DESCRIPTION:	Proposed Industrial Buildings, SWM Ponds and Septics
PROJECT LOCATION:	Woodbine Avenue and Aurora Road Town of Whitchurch-Stouffville

LEGEND

▨ TOPSOIL ▨ SILTY SAND ▨ SILT ▨ SILTY CLAY
▨ GRANULAR

▽ WATER LEVEL (END OF DRILLING)



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GEOTECHNICAL | ENVIRONMENTAL | HYDROGEOLOGICAL | BUILDING SCIENCE

SUBSURFACE PROFILE
DRAWING NO. 3
SCALE: AS SHOWN

JOB NO.: 2109-S177
REPORT DATE: March 2022
PROJECT DESCRIPTION: Proposed Industrial Buildings, SWM Ponds and Septics

PROJECT LOCATION: Woodbine Avenue and Aurora Road
Town of Whitchurch-Stouffville

LEGEND

▨ TOPSOIL 🟩 SILT ▨ SILTY CLAY

∇ WATER LEVEL (END OF DRILLING)

BH No.:	8	9	10	11	12	13
El. (m):	297.6	298.2	297.8	299.5	298.9	298.4