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A REPORT TO
LOCKHART AND LOCKHART II

A GEOTECHNICAL INVESTIGATION FOR PROPOSED RESIDENTIAL DEVELOPMENT

LOCKHART AND LOCKHART II

LOCKHART ROAD
CITY OF BARRIE

REFERENCE NO. 1901-S077

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1.0 INTRODUCTION

In accordance with authorization from Mr. Rick McConnell of Matson, McConell Ltd. dated January 26, 2019, a geotechnical investigation was carried out on a parcel of land located on the north side of Lockhart Road in the City of Barrie.

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 a proposed residential development.

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

2.0 SITE AND PROJECT DESCRIPTION

The City of Barrie is located within the periphery of Lake Simcoe basin where the glacial till has been partly eroded in places, by glacial Lake Algonquin and filled with lacustrine silts, sands and clay.

The subject property is almost rectangular in shape, comprising an approximate area of 50.6 hectares. It is located on the north side of Lockhart Road and approximately 1000 m west of Yonge Street in the City of Barrie. The property is currently a farm field with treed areas. The existing site gradient is undulating, dropping gently towards a ditch bisecting the property in the north-south direction.

We understand that the property will be developed into a residential subdivision of residential lots and townhouse blocks, with stormwater management facilities. The development will consist of municipal services and roadways meeting urban standards. The existing treed areas, however, will be preserved as a natural heritage system.

3.0 FIELD WORK

The field work, consisting of twenty-two (22) sampled boreholes extending to depths of 5.0 to 10.8 m from the prevailing ground surface, was performed between February 19 and March 5, 2019, at the locations shown on the Borehole Location Plan, Drawing No. 1.

The boreholes 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 were recorded by a Geotechnical Technician.

Upon completion of drilling and sampling, groundwater monitoring wells were installed in six (6) selected boreholes to facilitate a hydrogeological assessment by R.J. Burnside & Associates Limited. The remaining boreholes were backfilled with auger cuttings to the ground level.

The location and ground elevation at each borehole or monitoring well location were provided and marked in the field by Jones Consulting Group Ltd., as shown on the Conceptual Borehole Location Plan dated July 10, 2018.

4.0 SUBSURFACE CONDITIONS

The investigation revealed that beneath the topsoil and ploughed soil, the site is underlain by strata of silty sand till and silty clay till, with intermittent layers of sand and silty clay.

Detailed descriptions of the encountered subsurface conditions are presented on the Logs of Boreholes, comprising Figures 1 to 22, inclusive. The revealed stratigraphy is plotted on the Subsurface Profile, Drawing Nos. 2, 3 and 4. The engineering properties of the disclosed soils are discussed herein.

4.1 Topsoil/Ploughed Soil (All Boreholes)

A layer of topsoil or ploughed soil was contacted at the ground surface. The thickness of topsoil ranges from 25 to 38 cm at Boreholes 4, 9, 19 and 21 locations. At the location of Borehole 8, topsoil mixed with organic peat was recorded at 1.7 m in thickness. In the farm field, the ploughed soil extends to a depth of 0.7 to 1.0 m from grade.

The thickness of topsoil and ploughed soil varies across the site. Thicker topsoil or ploughed soil may be contacted beyond the borehole location in the low-lying area.

The topsoil and ploughed soils are dark brown in color and permeated with roots and humus.

They are unstable and compressible, and should be removed for site development. They can only be reused in landscaped areas where future settlement has no consequence.

4.2 **Earth Fill** (Boreholes 2, 5, 7, 14, 16, 18, 19 and 20)

A layer of earth fill was contacted below the topsoil or ploughed soil. The fill extends to depths of 1.1 to 2.8 m from the prevailing ground surface. It consists of a mixture of sand and silt, with clay, gravel, occasional topsoil and organic inclusions.

4.3 **Silty Sand Till** (All Boreholes, except Borehole 9)

Native silty sand till deposit was predominant in the boreholes. It consists of a random mixture of soil particle sizes ranging from clay to gravel, with sand and silt being the predominant fraction. Grain size analyses were performed on 2 representative samples and the results are plotted on Figure 23.

The obtained 'N' values range from 4 to more than 100, with a median of 33 blows per 30 cm of penetration, indicating the relative density of the deposit is loose to very dense, being generally dense. The loose till generally occurs near the ground surface, representing the reworked till or the result of weathering.

Hard resistance to augering was encountered in places, showing cobbles and boulders in the till stratum. Boreholes 4 and 15 were terminated upon refusal to augering on suspected boulder at a depth of 6.9 m and 6.4 m from grade, respectively.

The natural water content of the till samples was determined, and the results are plotted on the Borehole Logs; the values range from 5% to 16%, with a median of 10%, showing moist to very moist conditions.

The engineering properties of the till deposit relating to the project are given below:

- High frost susceptibility with moderate soil-adfreezing potential.
- Moderately low water erodibility.
- Relatively low permeability, with an estimated coefficient of permeability of 10^{-5} to 10^{-6} cm/sec, a percolation rate of 35 to 60 minute/cm, and runoff coefficients of:

Slope	
0% - 2%	0.15

2% - 6%	0.20
6% +	0.28

- Frictional soil, the shear strength is derived from internal friction, thus being density dependent.
- The till will be stable in a relatively steep cut; however, prolonged exposure will allow the sand seams to slough, which may lead to localized sliding.
- A fair pavement-supportive material, with an estimated California Bearing Ratio (CBR) value of 8%.
- Moderately low corrosivity to buried metal, with an estimated electrical resistivity of 5000 ohm·cm.

4.4 **Silty Clay** (Boreholes 5, 6, 8, 9, 10 and 11) and **Silty Clay Till** (Borehole 9)

The silty clay deposit was contacted at various depths below the topsoil and peat, ploughed soil or earth fill. It is laminated with sand and silt seams, showing a lacustrine deposit. Grain size analyses were performed on 2 representative samples; the results are plotted on Figure 24.

A deposit of silty clay till was also contacted below the silty clay at Borehole 9 location, at a depth of 4.0 m from grade. The clay till consists of a random mixture of soils, with the clay fraction exerting the dominant influence on the soil properties.

The obtained 'N' values range from 3 to 16 blows per 30 cm of penetration, indicating the consistency of the silty clay is soft to very stiff and the clay till is generally stiff in consistency.

The Atterberg Limits of 2 representative samples of the silty clay were conducted and the results are summarized below:

Borehole No.	**Borehole 8**	**Borehole 9**
Depth	**4.6 m**	**2.3 m**
Liquid Limit	49%	50%
Plastic Limit	25%	25%
Plasticity Index	24%	25%

The above values show that the silty clay is cohesive with medium to high plasticity.
The natural water content of the clay samples were determined in the range of 16% to 37%.

The natural water content of the clay till samples were 11% and 18%. They were generally in moist conditions.

The soft clay stratum may undergo long-term settlement under excessive surcharge loading. Based on the Atterberg Limits and the recorded 'N' values in the soft clay, the Overconsolidation Ratio (OCR) is estimated at 2 to 3. The allowable surcharge at the vicinity of Boreholes 8 and 9 is recommended to limit at 30 kPa.

The following engineering properties of the silty clay and clay till are deduced:

- High frost susceptibility and high soil-adfreezing potential.
- Low water erodibility.

- The high plastic clay is sensitive to moisture changes. It expands or contracts markedly upon changes in water content.
- Very low permeability, with an estimated coefficient of permeability less than 10^{-7} cm/sec, a percolation rate of 80+ minutes/cm and runoff coefficients of:

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

- Cohesive soils, the shear strength is derived from the consistency which is inversely related to the moisture content. The shear strength is also augmented by internal friction.
- In excavation, the clay and clay till will be relatively stable with steep slope.
- A poor pavement-supportive material, with an estimated CBR value of 3% to 6%.
- Moderately high corrosivity to buried metal, with an estimated electrical resistivity of 3000 ohm·cm.

4.5 **Sand** (Boreholes 1, 6, 7, 9, 12, 13, 16, 18, 19, 20 and 22)

The sand deposit was encountered intermittently within the silty sand till or in the lower stratigraphy of boreholes. Sample examinations show that the deposit is either well graded or fine to medium grained, with silt and gravel. Grain size analyses were performed on 2 representative samples; the results are plotted on Figures 25 and 26.

The natural water content values of the sand samples were determined at 5% to 25%. The collected samples are generated saturated. Due to its perviousness, water could have drained from the samples as they were taken.

The obtained ‘N’ values range from 7 to 95, with a median of 33 blows per 30 cm of penetration, indicating loose to very dense, generally dense in relative density. The low ‘N’ values can represent the disturbance by the hydrostatic pressure at the time of drilling and sampling below the saturation level.

The following engineering properties of the sand deposit are deduced:

- High water erodibility.
- Pervious, with an estimated coefficient of permeability of 10^{-3} to 10^{-4} cm/sec, a percolation rate of 10 to 15 minutes/cm and runoff coefficients of:

Slope	
0% - 2%	0.05
2% - 6%	0.10
6% +	0.15

- A frictional soil, the shear strength is derived from its internal friction angle and is soil density dependent.
- In excavation, the sand will slough and run slowly with seepage bleeding from the cut face. It will boil with a piezometric head of 0.3 m.
- A fair pavement-supportive material, with an estimated CBR value of 15%.
- Moderately low corrosivity to buried metal, with an estimated electrical resistivity of 6000 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 Sand Till	5 to 16 (median 10)	12	7 to 15
Silty Clay/Clay Till	11 to 37 (median 14)	24	20 to 30
Sand	5 to 125	10	5 to 13

Based on the above findings, the majority of the on-site material is suitable for 95% + Standard Proctor compaction. However, the saturated sand and part of the silty clay are generally on the wet side, which will require aeration prior to compaction. Aeration can be achieved by spreading the wet soil thinly on the ground during the dry and warm weather. Saturated sand can also be stockpiled on site to drain the excess water prior to placement and compaction.

In using the earth fill for structural backfill, or in pavement construction, it should be subexcavated, inspected, sorted free of topsoil inclusions and any deleterious materials, and aerated before compaction.

The till and silty clay should be compacted using a heavy-weight kneading-type roller. The sand can be compacted by a smooth drum 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.

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.

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

5.0 GROUNDWATER CONDITIONS

The boreholes were checked for the presence of groundwater or the occurrence of cave-in during and upon completion of the field work. The records are summarized in Table 2.

Table 2 - Groundwater Record upon Completion

Borehole No.	**Ground Elevation (m)**	**Groundwater/Cave-In* Upon Completion**	
		Depth (m)	**Elevation (m)**
1	253.0	1.2/1.8*	251.8/251.2*
2 (MW)	259.6	Dry	below 248.8
3	262.8	4.0/4.6*	258.8/258.2*
4	258.5	6.1	252.4
5	254.9	7.0	247.9
6	253.3	2.4/2.6*	250.9/250.7*
7	252.6	3.0/3.3*	249.6/249.3*
8 (MW)	252.4	Dry	below 245.9
9	252.6	Dry	below 246.1
10 (MW)	252.1	Dry	below 247.1
11	252.1	4.3	247.8
12 (MW)	253.5	4.2	249.3
13	252.1	3.2	248.9
14	250.5	2.4	248.1
15 (MW)	251.5	Dry	below 245.1
16	256.2	3.7/4.3*	252.5/251.9*
17	254.9	2.9/3.0*	252.0/251.9*

Table 2 - Groundwater Record upon Completion (cont'd)

Borehole No.	Ground Elevation (m)	Groundwater/Cave-In* Upon Completion	
		Depth (m)	**Elevation (m)**
18	256.1	5.5	250.6
19 (MW)	261.2	2.4	258.8
20	264.6	Dry	below 259.6
21	259.5	Dry	below 254.5
22	254.4	1.5/4.3*	252.9/250.1*

Due to the undulation, most of the boreholes located in the high ground are recorded dry upon the completion of drilling.

Free groundwater and/or cave-in were recorded in Boreholes 1, 3 to 7, 11 to 14, 16 to 19, inclusive, and 22, between El. 247.8 m and 258.8 m upon completion of drilling. The groundwater levels appear to drop towards the ditch. It is subject to seasonal fluctuation.

6.0 DISCUSSION AND RECOMMENDATIONS

The investigation revealed that beneath the topsoil and ploughed soil, the site is underlain by strata of loose to very dense silty sand till or stiff silty clay till, with intermittent layers of loose to very dense sand and soft to very stiff silty clay.

Free groundwater and/or cave-in were recorded in most of the boreholes between El. 247.8 m and 258.8 m upon completion of drilling. The groundwater levels appear to drop towards the ditch. It is subject to seasonal fluctuation.

The property will be developed into a residential subdivision of residential lots and townhouse blocks, with stormwater management facilities. The subdivision will consist of municipal services and roadways meeting urban standards. The existing treed areas, however, will be preserved as a natural heritage system.

The geotechnical findings which warrant special consideration are presented below:

1. The topsoil and ploughed soil should be removed for site development. Thicker topsoil or ploughed soil may be contacted beyond the borehole locations in the low-lying area.

In order to prevent overstripping, a diligent control of the stripping operation will be required.

2. The topsoil and ploughed soil can only be used for landscaping and landscape contouring purposes where future settlement has no consequence.
3. The site gradient is undulating, dropping gently towards a ditch bisecting the property in the north-south direction. It is anticipated that the site will be regraded for development.
4. It will be more economical to place an engineered fill for normal footing, sewer and road construction. The site grading should also take into consideration of the high groundwater in the low-lying areas so that the proposed basement structures will not be below the saturation levels. In the vicinity of Boreholes 8 and 9, the additional surcharge should be limited to 1.5 m so that the clay stratum will not be overstressed and long-term settlement will not occur.
5. The native subsoil and the engineered fill are suitable for conventional footing construction. The footing subgrade must be inspected by a geotechnical engineer, or a geotechnical technician under the supervision of a geotechnical engineer.
6. Any excavation into the saturated soils will require vigorous pumping from closely spaced sump-wells or well points.
7. A Class ‘B’ bedding, consisting of compacted 20-mm Crusher-Run Limestone or equivalent, is recommended for the construction of the underground services. In water-bearing sand or in areas where dewatering is necessary, a Class ‘A’ concrete bedding should be used.

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 Site Preparation

The site will be regraded for development. It is generally more economical to place an engineered fill for house footings, underground services and pavement construction.

The design of the site grading plan should consider the high groundwater in the low-lying areas so that the proposed basement structures are not below the saturation levels. In addition, any additional surcharge fill in the vicinity of Boreholes 8 and 9 should be limited to 1.5 m so that the clay stratum is not overstressed and long-term settlement will not occur.

The engineering requirements for a certifiable fill are presented below:

1. All topsoil, ploughed soil and earth fill must be removed and the subgrade must be inspected and proof-rolled prior to any fill placement. Badly weathered soils should also be subexcavated.
2. Inorganic soils must be used for the engineered fill. They must be uniformly compacted in lifts 20 cm thick to 98% or + of their maximum SPDD up to the proposed finished grade. The soil moisture must be properly controlled on the wet side of the optimum. If the foundations are to be built soon after the fill placement, the densification process for the engineered fill must be increased to 100% of the maximum SPDD.
3. 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.
4. In areas where significant engineered fill (fill more than 3.0 m) is to be placed, settlement plates must be installed and monitored on a weekly basis to assess any consolidation progress in the fill and the underlying strata. No construction of site services or house foundations can commence in these areas until the settlement records have confirmed that the settlement is reduced to a tolerable level and there is no risk of long-term settlement. Where the readings remain the same for a period of 3 consecutive months, no further monitoring will be required and there is no risk for long-term settlement. The settlement of the engineered fill is anticipated to be reduced to a tolerable limit of 25 mm.
5. 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.
6. The engineered fill must extend over the entire graded area; the engineered fill envelope and the finished elevations must be clearly and accurately defined in the field, and must be precisely documented by qualified surveyors.
7. 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.
8. Where the ground is wet due to subsurface water seepage, an appropriate subdrain scheme must be implemented prior to the fill placement, particularly if it is to be carried out on sloping ground.
9. Where the fill is to be placed on a bank steeper than 1 vertical (V):

3 horizontal (H) , 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. The fill operation must be inspected on a full-time basis by a technician under the direction of a geotechnical engineer. In this case, the effect of long-term settlement is expected to be negligible as the fill material will be compacted to achieve an appropriate strength and capacity for structural support.
11. The footing and underground services subgrade must be inspected by the geotechnical consulting firm that inspected the engineered fill placement. This is to ensure that the foundations are placed within the engineered fill envelope, and the integrity of the fill has not been compromised by interim construction, environmental degradation and/or disturbance by the footing excavation.
12. Once the engineered fill is certified, any excavation carried out in the certified fill area must be reported to the geotechnical consultant who inspected the fill placement, in order to document the locations of excavation and/or to inspect reinstatement of the excavated areas to engineered fill status. If construction on the engineered fill does not commence within a period of 2 years from the date of certification, the status must be assessed for re-certification.
13. Despite stringent control in the placement of engineered fill, variations in soil type and density may occur in the engineered fill. Therefore, the strip footings and the upper section of the foundation walls constructed on the engineered fill may require continuous reinforcement with steel bars, depending on the uniformity of the soils in the engineered fill and the thickness of the engineered fill underlying the foundations. Should the footings and/or walls require reinforcement, the required number and size of reinforcing bars must be assessed by considering the uniformity as well as the thickness of the engineered fill beneath the foundations. In sewer construction, the engineered fill is considered to have the same structural proficiency as a natural inorganic soil.

6.2 **Foundations**

Conventional footings are recommended for the proposed structures. They should be placed onto the sound natural soils or engineered fill. The requirements for engineered fill construction are discussed in Section 6.1 above. The recommended soil bearing pressures for use in the design of conventional strip and spread footings, are given below:

- Maximum Allowable Bearing Pressure (SLS) = 100 kPa
- Factored Ultimate Bearing Pressure (ULS) = 150 kPa

The total and differential settlements of footings are estimated at 25 mm and 20 mm, respectively.

Higher design bearing pressures are available in some particular areas for special structures, if necessary. They can be reviewed individually by the geotechnical engineers once the design of the development is finalized. Additional boreholes may be required to verify the soil capacity for the design of these structures.

One must be aware that the recommended bearing pressures are given as a guide for foundation design and the footing subsoil must be confirmed by a geotechnical engineer at the time of construction.

If groundwater seepage is encountered during excavation, or where the subgrade of the footing is water bearing, the subgrade should be protected by a concrete mud-slab immediately after exposure. This will prevent construction disturbance and costly rectification.

Footings exposed to weathering, or in unheated areas, should have at least 1.5 m of earth cover for protection against frost action.

The building foundation must meet the requirements specified in the latest Ontario Building Code. As a guide, the structure should be designed to resist an earthquake force using Site Classification ‘D’ (stiff soil).

6.3 Basement and Slab-On-Grade

The basement floor should be at a depth at least 0.5 m above the highest groundwater level. The soil parameters outlined in Section 6.9 can be used for calculating the lateral earth pressure imposed on the basement walls.

In conventional design, perimeter subdrains and dampproofing of the foundation walls will be required in order to provide a dry basement. All the subdrains should be encased in a fabric filter to protect them against blockage by silting.

If the basement floor is less than 1.0 m above the highest detected groundwater elevation, underfloor subdrains should be provided in the granular bedding below the basement floor. The subdrains should be connected to the drainage or sump pits where water can be removed.

In addition, vapour barrier of 6 mil polyethylene sheet should be placed above the granular bedding to alleviate wetting of the basement floor due to moisture upfiltration. A typical design of the bedding and the under-floor weepers is provided in Drawing No. 5.

The slab should be constructed on a granular base of 20 cm thick, consisting of 20-mm Crusher-Run Limestone, or equivalent, compacted to 100% of its maximum SPDD. Where under-floor weepers are required, the thickness of bedding should be increased to 30 cm.

The subgrade for slab-on-grade must consist of sound natural soil or properly compacted inorganic engineered fill. The subgrade should be inspected and assessed by proof-rolling prior to slab-on-grade construction. Where the subgrade consists of soft or weathered soils, it should be subexcavated, sorted free of topsoil inclusions, if any, aerated and uniformly compacted to 98% or + of its maximum Standard Proctor dry density.

6.4 **Underground Services**

The subgrade for underground services should consist of natural soils or engineered fill. In areas where the subgrade consists of unsuitable material, it should be subexcavated and replaced with properly compacted inorganic soil and/or bedding material compacted to at least 95% + Standard Proctor dry density.

Excavation for service trenches must be carried out in accordance with Ontario Regulation 213/91. In areas where a vertical cut is necessary, the use of a trench box is necessary. The recommended lateral earth pressure coefficients presented in Section 6.9 can be used for the design of trench box or shoring.

A Class ‘B’ bedding is recommended for construction of the underground services. The bedding material should consist of compacted 20-mm Crusher-Run Limestone, or equivalent, as approved by a geotechnical engineer. Where saturated soils are present or extensive dewatering is required, a Class ‘A’ bedding will likely be required, and the pipe joints should be leak-proof or wrapped with a waterproof membrane.

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

The pipes connecting into manholes and catch basins must be connected by leak-proof joints to prevent subgrade upfiltration through the joints. Openings to subdrains and catch basins should be shielded with a fabric filter to prevent blockage by silting.

The underground services should be protected against soil corrosion. For estimation of anode weight requirements, the estimated electrical resistivity of 4500 ohm·cm can be used. This should be confirmed by testing the soil along the water main alignment at the time of construction.

6.5 **Backfilling in Trenches and Excavated Areas**

The backfill in service trenches should be compacted to at least 95% of the maximum Standard Proctor dry density (SPDD). In the zone within 1.0 m below the road subgrade, the material should be compacted with the water content 2% to 3% drier than the optimum; and the compaction should be increased to 98% of the respective maximum SPDD to provide the required stiffness for road construction.

In normal construction practice, the problem areas of settlement largely occur adjacent to foundation walls, columns, manholes, catch basins and services crossings. In areas which are inaccessible to a heavy compactor, sand backfill should be used. Unless compaction of the backfill is carefully performed, settlement will occur. Often, the interface of the native soils and sand backfill will have to be flooded for a period of several days.

Narrow trenches for services crossings should be cut at 1V:2H, so that the backfill in the trenches can be effectively compacted. Otherwise, soil arching in the trenches will prevent the achievement of proper compaction. The lift of each backfill layer should be limited to a thickness of 20 cm.

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

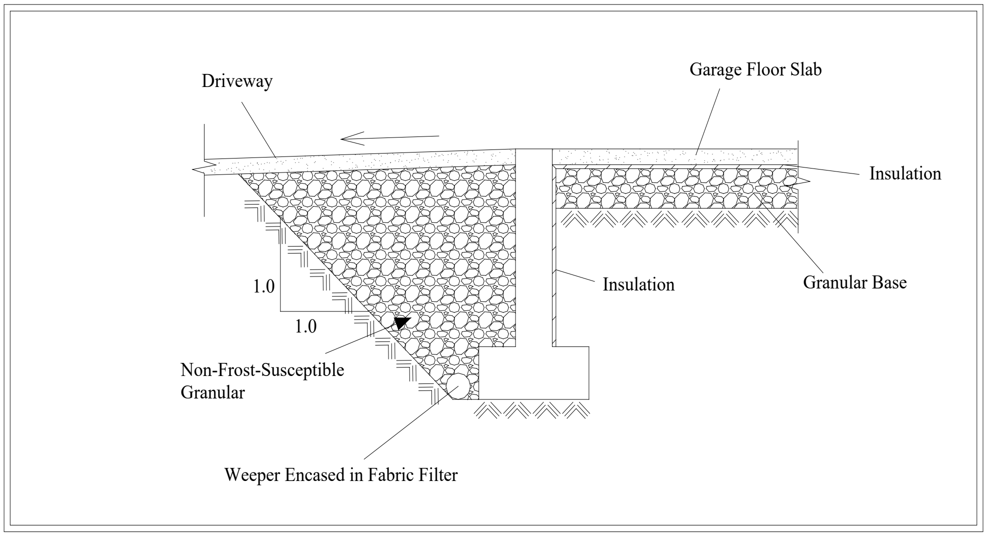
- When construction is carried out in freezing winter weather, allowance should be made for these following conditions. Despite stringent backfill monitoring, frozen soil layers may inadvertently be mixed with the structural trench backfill. Should the in situ soil have a water content on the dry side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

- In areas where the underground services construction is carried out during winter months, prolonged exposure of the trench walls will result in frost heave within the soil mantle of the walls. This may result in some settlement as the frost recedes, and repair costs will be incurred prior to final surfacing of the new pavement.
- To backfill a deep trench, one must be aware that future settlement is to be expected, unless the side of the cut is flattened to at least 1V:1.5+H, 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 SPDD, 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.

6.6 Garages, Driveways and Landscaping

The subgrade soils can be frost susceptible. The ground is expected to heave during the freezing season. In order to minimize frost heaving, the driveway at the entrance to the garage should be backfilled with non-frost-susceptible granular material, with a frost taper at a slope of 1V:1H. The garage floors and the interior of the foundation walls should be insulated by 50-mm Styrofoam (or its equivalent), or a Granular ‘B’ backfill should be used for the garage construction. The recommended scheme is illustrated in Diagram 1.

Diagram 1 - Frost Protection Measures (Garage)



The slab-on-grade or sidewalk in open areas should be designed to tolerate frost heave. The grading around the slab-on-grade and house structures must be such that it directs runoff away from the structures. In areas where ground movement due to frost heave cannot be tolerated, the slab-on-grade or sidewalks must be constructed on a free-draining granular base, 0.3 to 1.5 m thick, depending on the degree of tolerance for settlement. These measures, with proper drainage, will prevent water from accumulating in the granular base. Alternatively, they can be insulated with 50-mm Styrofoam, or equivalent.

6.7 Pavement Design

The recommended pavement design for local roads and collectors is presented in Table 3.

Table 3 - Pavement Design

Course	Thickness (mm)	OPS Specifications
Asphalt Surface	40	HL-3
Asphalt Binder Local Roads Collectors	 50 65	HL-8
Granular Base	150	OPSS Granular ‘A’ or equivalent
Granular Sub-base Local Roads Collectors	 300 400	OPSS Granular ‘B’ or equivalent

In preparation of road subgrade, the topsoil, ploughed soil and compressible earth fill must be removed. Any new fill should consist of organic free material, compacted to 95% + 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 the Standard Proctor dry density, with the water content 2% to 3% drier than the optimum. The final subgrade should be inspected and proof-rolled. Any soft spots should be subexcavated, and replaced by properly compacted inorganic earth fill.

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

The pavement 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 and road design:

- If 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 road structure should be properly graded to prevent the ponding of large amounts of water during the interim construction period.
- If the road is to be constructed during the wet seasons and extremely soft subgrade occurs, the granular sub-base may require thickening. This can be further assessed during construction.
- Fabric filter-encased curb subdrains are required to meet the Municipal road requirements.

6.8 **Stormwater Management Facilities** (Boreholes 1, 7, 8, 9, 10, 11, 14 and 15)

Stormwater management facilities are considered at various locations. In areas where permeable sand layers are evident, an imperable liner will be required. Any hydrostatic pressure below the pond liner should also be established to design the thickness of liner to overcome any basal heaving at the time the pond is emptied for maintenance.

The presence of soft and firm clay stratum in the vicinity of Boreholes 8 and 9 will have no significant adverse impact to the performance of the pond.

For the construction of earth berm and access road, topsoil must be removed and the subgrade must be proof-rolled. Inorganic on-site material can be used, compacted to at least

98% of the Standard Proctor dry density. A 300 mm granular course, consisting of 50-mm Crusher-Run Limestone, topped with 50 mm of limestone screening, should be provided on the access road.

The preparation of bearing subsoil and the design soil capacities listed in Sections 6.1 and 6.2 can be used for the design of control structures. The inlet and outlet of the pond must be lined with gabion mats for protection against scouring.

6.9 Soil Parameters

The recommended soil parameters for the project design are given in Table 4.

Table 4 - Soil Parameters

Unit Weight and Bulk Factor	**Unit Weight (kN/m^3)**		**Estimated Bulk Factor**	
	Bulk	**Submerged**	**Loose**	**Compacted**
Sound Tills	22.0	12.0	1.33	1.05
Silty Clay	21.0	11.0	1.30	1.00
Sand	20.5	12.5	1.25	1.05
Lateral Earth Pressure Coefficients		**Active K_a**	**At Rest K_o**	**Passive K_p**
Sound Tills/Sand		0.35	0.50	3.00
Silty Clay		0.40	0.60	2.50
Coefficients of Friction				
Between Concrete and Granular Base			0.50	
Between Concrete and Sound Native Soils			0.35	

6.10 Excavation

Excavation should be carried out in accordance with Ontario Regulation 213/91. For excavation purposes, the types of soils are classified in Table 5.

Table 5 - Classification of Soils for Excavation

Material	Type
Sound Till and Clay	2
Drained Sand and Silt	3
Saturated Soils	4

Free groundwater and/or cave-in were recorded in Boreholes 1, 3 to 7, 11 to 14, 16 to 19, inclusive, and 22, between El. 247.8 m and 258.8 m upon completion of drilling. The groundwater levels appear to drop towards the ditch. It is subject to seasonal fluctuation.

In excavation, groundwater yield from the till and clay will be slow in rate and limited in quantity. Where the excavation extends into saturated sand layers, the possibility of flowing sides dictates that the ground should be predrained by vigorous pumping from closely spaced sump wells, or if necessary, by a well point dewatering system.

Prospective contractors can be asked to assess the in situ subsurface conditions for soil cuts by digging test pits to at least 0.5 m below the sewer subgrade. 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 Lockhart and Lockhart II, for review by the designated consultants, financial institutions and government agencies. Use of this report is subject to the conditions and limitations of the contractual agreement.

The material in the report reflects the judgment of Nislin Andani, B.Eng., and Bennett Sun, P.Eng., in light of the information available to it at the time of preparation. Any use which a Third Party makes of this report, 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.

Nislin Andani, B.Eng.

Bennett Sun, P.Eng.
NA/BL:dd

LICENSED PROFESSIONAL ENGINEER
CHUN C. B. SUN
May 7, 2021
PROVINCE OF ONTARIO

LIST OF ABBREVIATIONS AND DESCRIPTION OF TERMS

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

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.: 1901-S077

LOG OF BOREHOLE NO.: 1

FIGURE NO.: 1

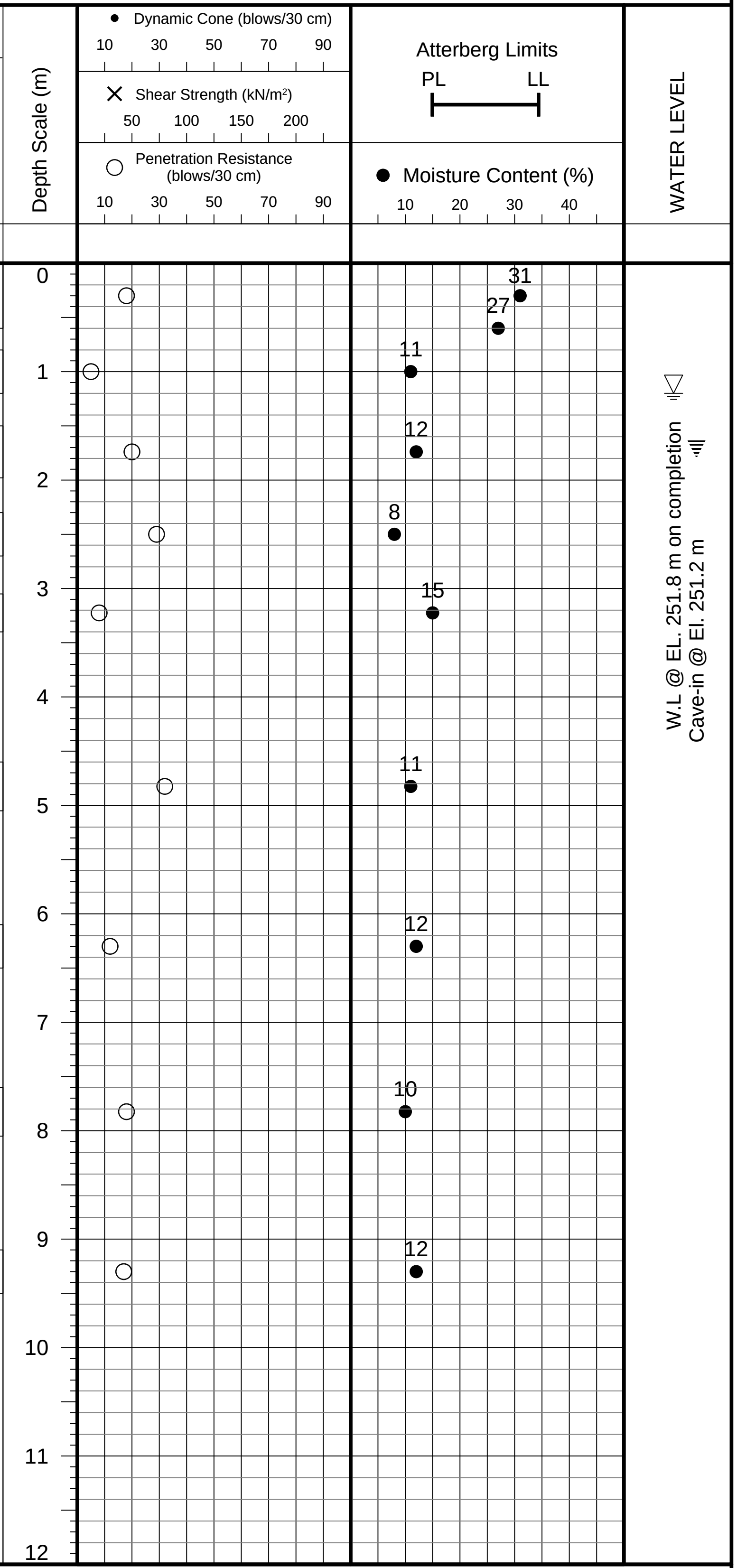
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: March 4, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
253.0	Ground Surface			
0.0	**PLOUGHED SOIL** brown sandy silt with topsoil inclusions Frost	1A 1B	DO	18
252.3 0.7	Brown, loose to compact **SILTY SAND TILL** some clay, trace of gravel occ. sand seams and layers, cobbles and boulders	2	DO	5
		3	DO	20
		4	DO	29
250.1 2.9	Brown, loose to dense **SAND** well graded some gravel, some to silty occ. silt and clay seams below 6 m	5	DO	8
		6	DO	32
		7	DO	12
245.8 7.2	Brown, compact **SILTY SAND TILL** some clay, trace gravel occ. cobbles and boulders	8	DO	18
		9	DO	17
243.5 9.5	**END OF BOREHOLE**			



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JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: BH/MW 2

FIGURE NO.: 2

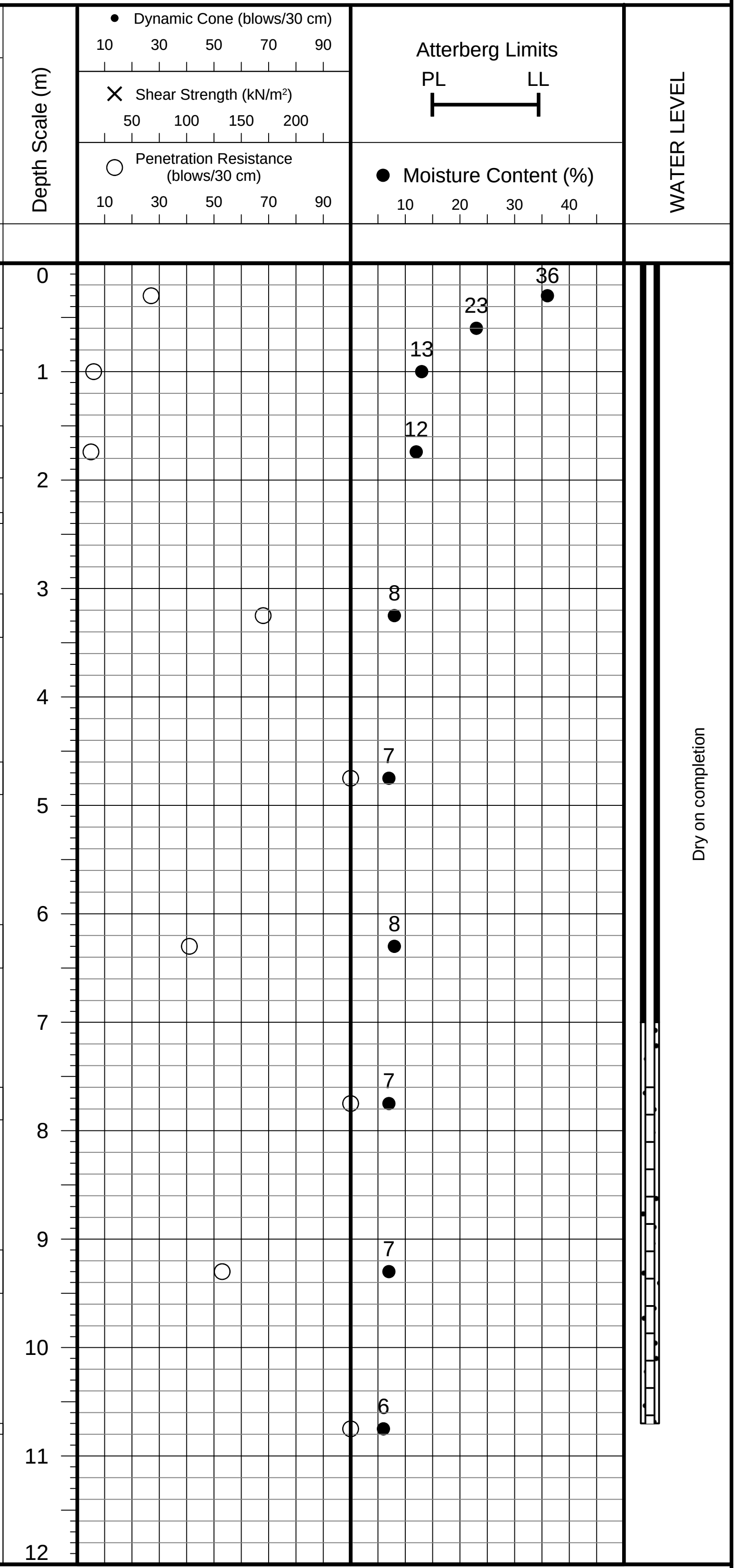
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: March 1, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
259.6	Ground Surface			
0.0	**PLOUGHED SOIL** brown sandy silt with topsoil inclusions Frost	1A 1B	DO	27
258.9 0.7	**EARTH FILL** brown sandy silt some clay and gravel, some organic inclusions	2	DO	6
		3	DO	5
257.4 2.2	Very dense **SILTY SAND TILL** trace to some clay, trace gravel occ. cobbles and boulders	4		50/NP
		5	DO	68
	brown grey	6	DO	50/15
		7	DO	41
		8	DO	50/15
	Installed 50mm Ø monitoring well to 10.7 m 3.0 m screen from 7.6 to 10.7 m Sand backfill from 7.0 to 10.7 m Bentonite seal from 0.0 to 7.0 m Provided with a 4x4 steel casing	9	DO	53
248.8 10.8	**END OF BOREHOLE**	10	DO	50/15



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JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 3

FIGURE NO.: 3

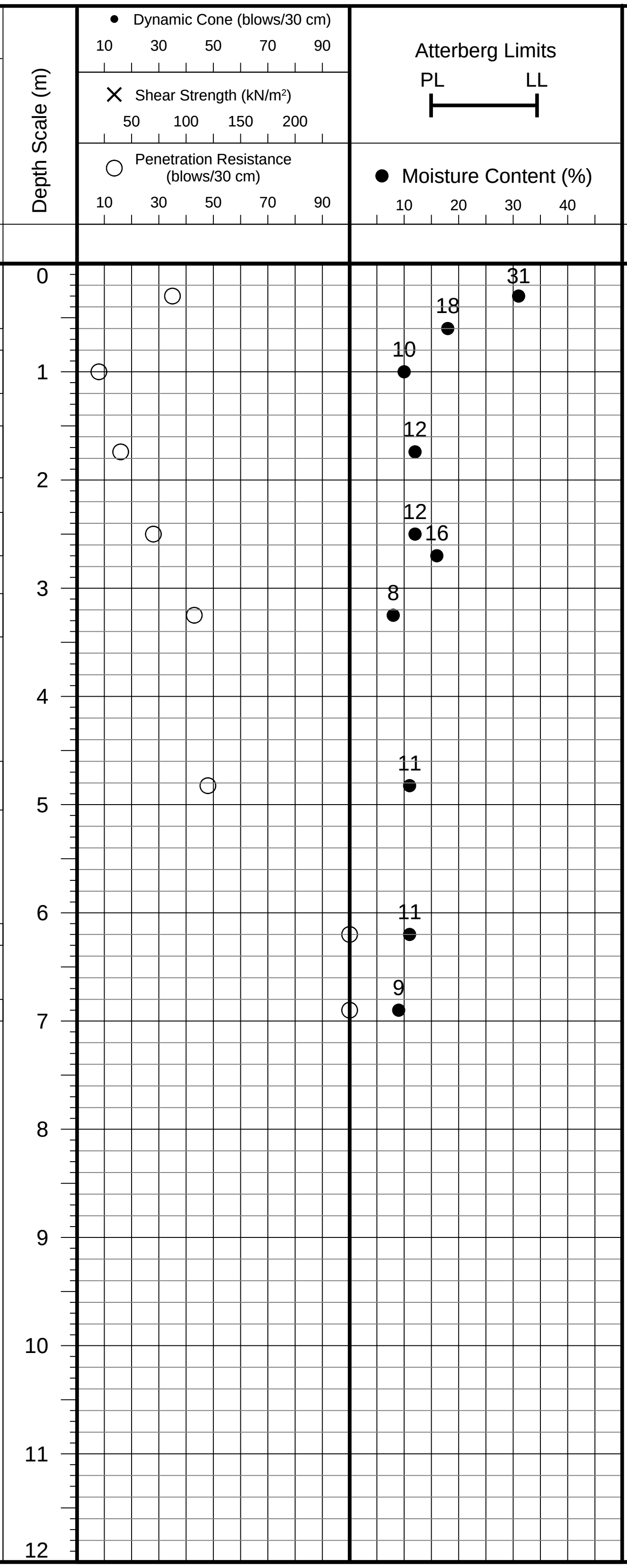
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: March 4, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
262.8	Ground Surface			
0.0	**PLOUGHED SOIL** brown sandy silt with topsoil inclusions Frost	1A 1B	DO	35
262.1 0.7	Brown, loose to very dense **SILTY SAND TILL** trace of clay and gravel occ. sand and clay layers, cobbles and boulders	2	DO	8
		3	DO	16
		4A 4B	DO	28
		5	DO	43
		6	DO	48
		7	DO	50/15
		8	DO	60/15
255.8 7.0	**END OF BOREHOLE**			



WATER LEVEL

W.L @ EL. 258.8 m on completion

Cave-in @ El. 258.2 m

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JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 4

FIGURE NO.: 4

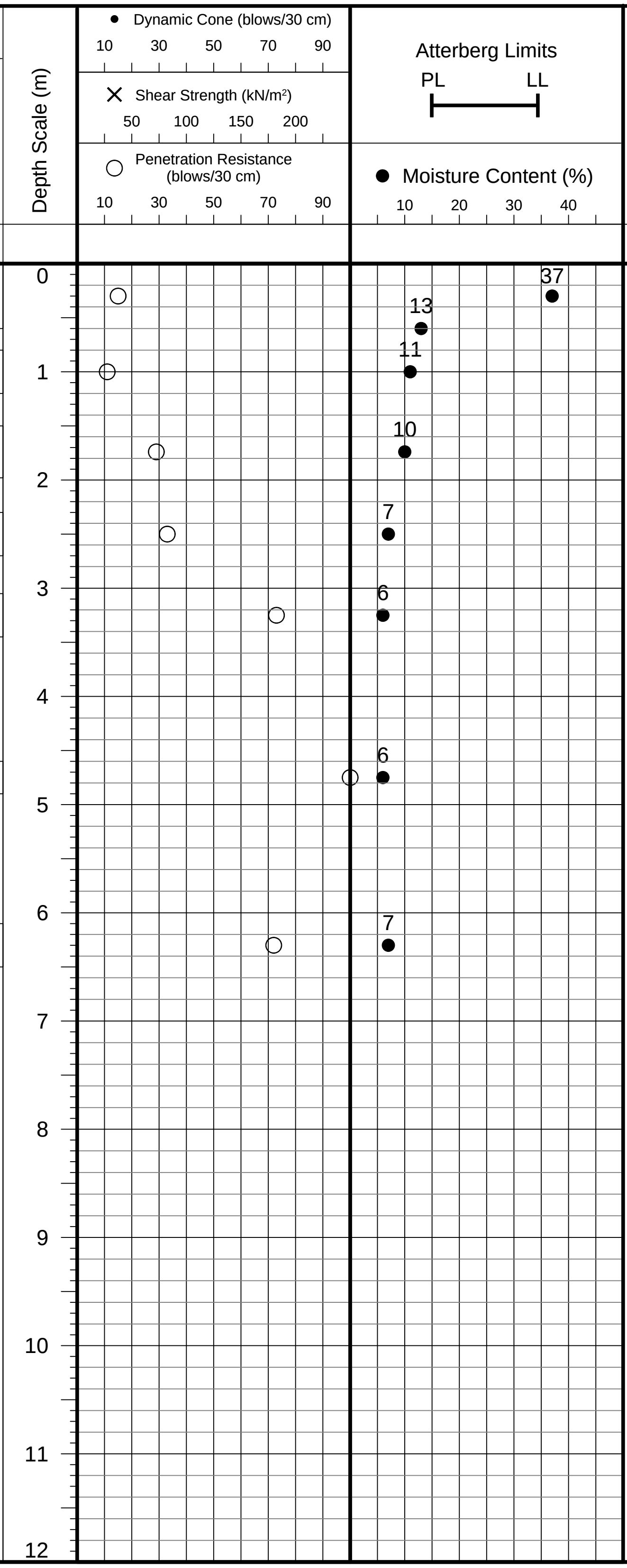
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: March 4, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	Moisture Content (%)	WATER LEVEL
258.5 0.0	Ground Surface **38 cm TOPSOIL**	1A 1B	DO	15	37 13	
	Compact to very dense Frost **SILTY SAND TILL** trace to some clay, trace gravel occ. cobbles and boulders	2	DO	11	11	
		3	DO	29	10	
	brown grey	4	DO	33	7	
		5	DO	73	6	
		6	DO	50/15	6	
		7	DO	72	7	∇ W.L @ EL. 252.4 m on completion
251.6 6.9	**END OF BOREHOLE** **Refusal to augering on propable boulder**					



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JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 5

FIGURE NO.: 5

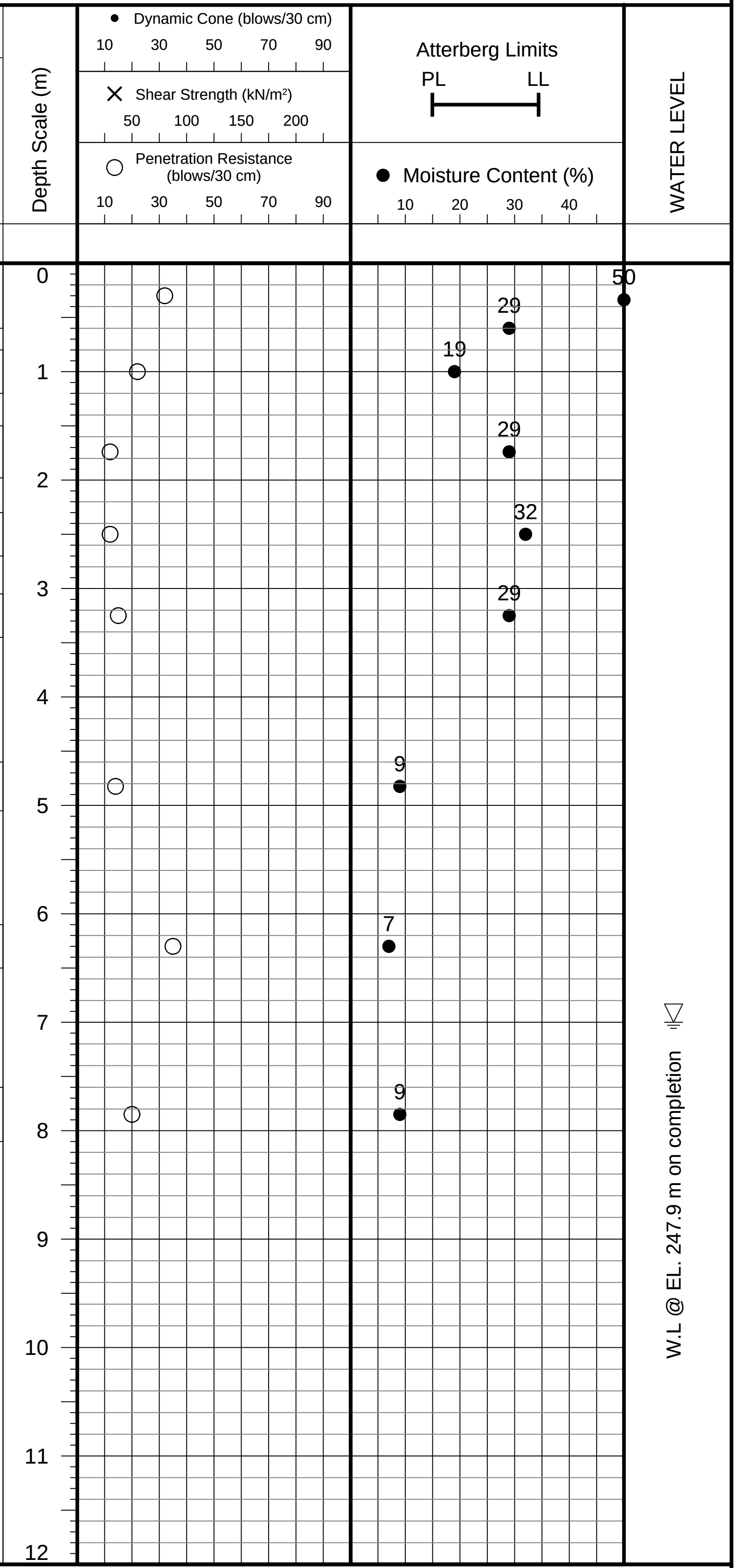
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: March 5, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
254.9	Ground Surface			
0.0	**PLOUGHED SOIL** brown silty sand Frost	1A 1B	DO	32
254.2 0.7	**EARTH FILL** brown sand and clay scattered topsoil	2	DO	22
253.7 1.2	Brown, stiff **SILTY CLAY** occ. sand seams	3	DO	12
		4	DO	12
		5	DO	15
251.4 3.5	Grey, compact to dense **SILTY SAND TILL** trace to some clay, trace gravel occ. cobbles and boulders	6	DO	14
		7	DO	35
		8	DO	20
246.8 8.1	**END OF BOREHOLE**			



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JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 6

FIGURE NO.: 6

PROJECT DESCRIPTION: Proposed Residential Development

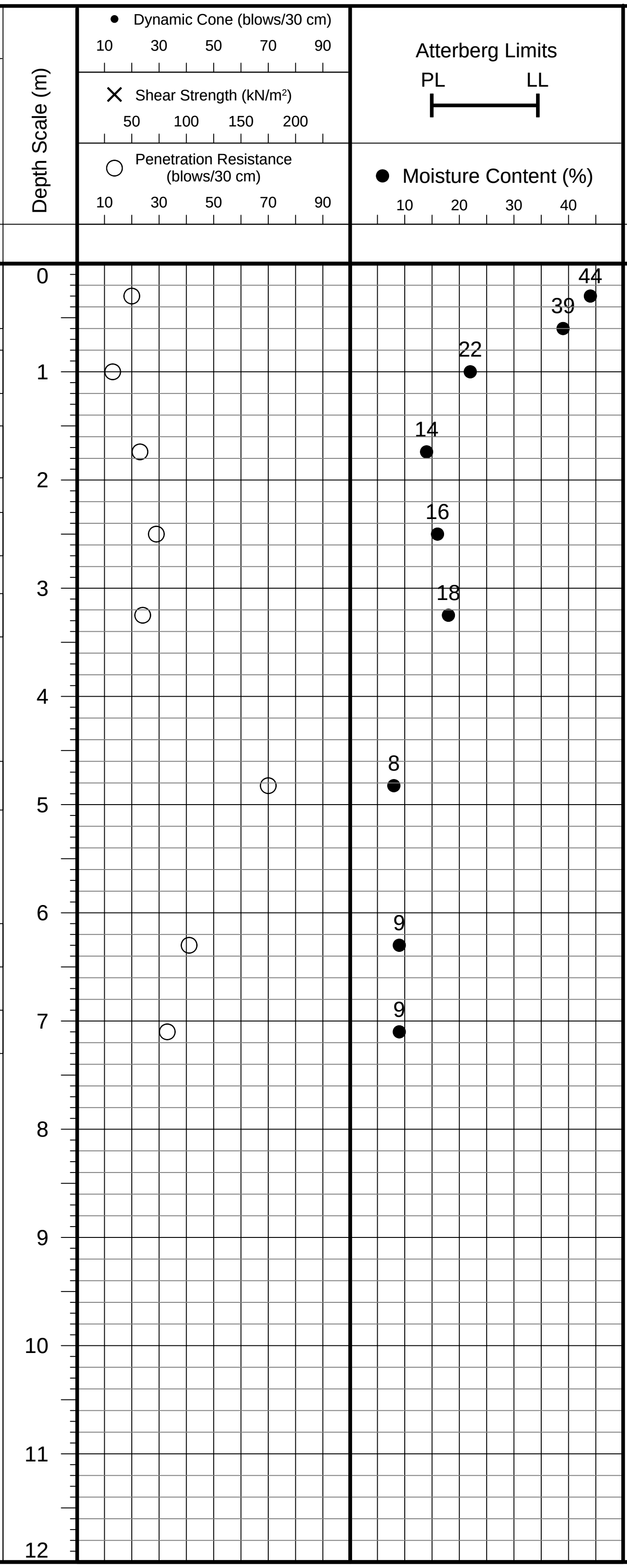
METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: March 5, 2019

El. (m) Depth (m)	SOIL DESCRIPTION
253.3	Ground Surface
0.0	**PLOUGHED SOIL** brown sandy silty with topsoil inclusions
252.6 0.7	Frost Brown, stiff **SILTY CLAY** occ. sand seams
251.9 1.4	Brown, compact **SILTY SAND TILL** trace of clay and gravel occ. sand layers, cobbles and boulders
251.1 2.2	Brown, compact **SAND** fine to medium grained, some silt trace of fine gravel
249.3 4.0	Dense to very dense **SILTY SAND TILL** trace of clay and gravel occ. cobbles and boulders brown grey
246.0 7.3	**END OF BOREHOLE**

SAMPLES		
Number	Type	N-Value
1A 1B	DO	20
2	DO	13
3	DO	23
4	DO	29
5	DO	24
6	DO	70
7	DO	41
8	DO	33



WATER LEVEL

W.L @ EL. 250.9 m on completion
Cave-in @ El. 250.7 m

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JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 7

FIGURE NO.: 7

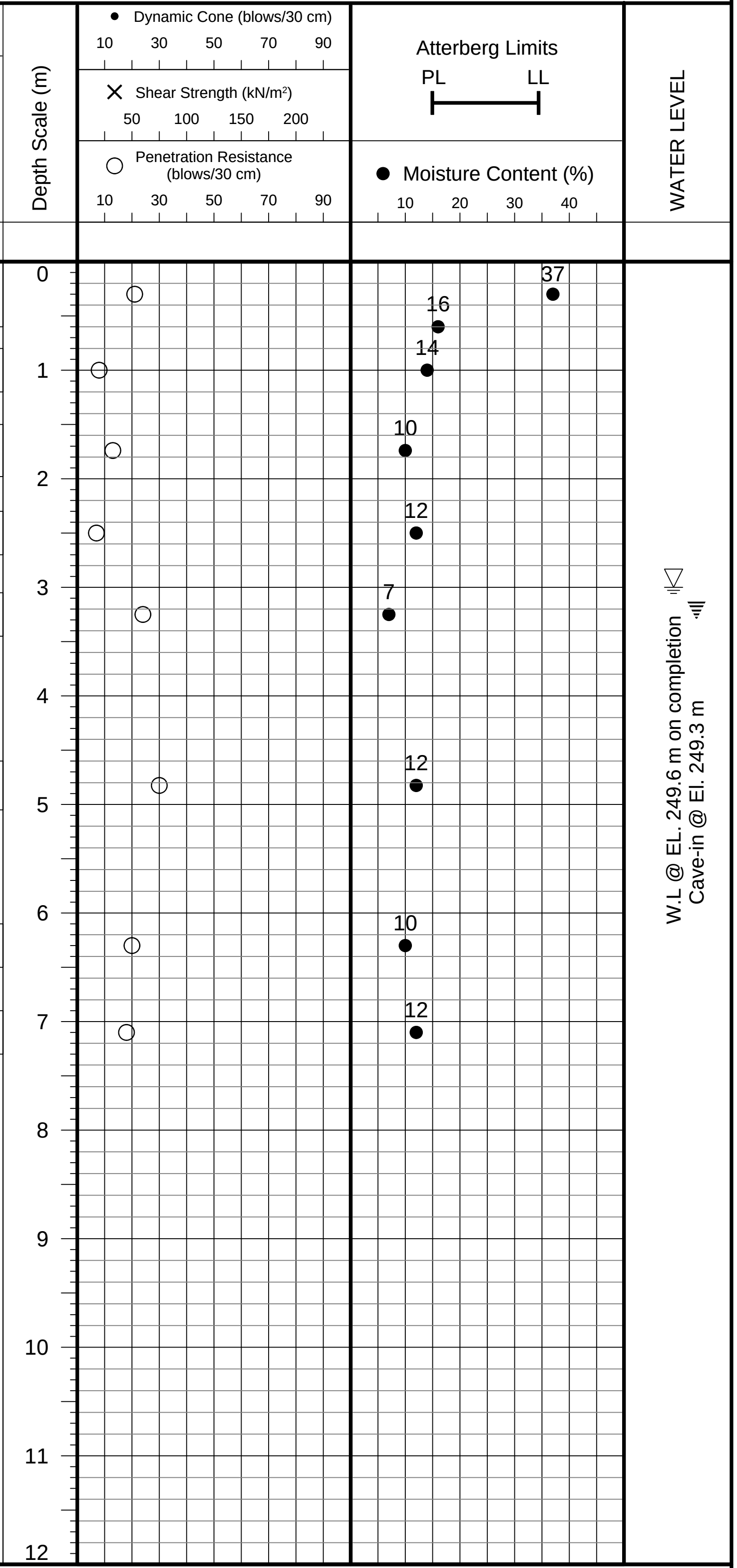
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 28, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
252.6	Ground Surface			
0.0	**PLOUGHED SOIL** brown silty sand with topsoil inclusions Frost	1A 1B	DO	21
251.9 0.7	**EARTH FILL** brown to grey silty clay some sand and gravel trace organics	2	DO	8
		3	DO	13
		4	DO	7
249.8 2.8	Brown, compact **SILTY SAND TILL** trace to some clay, trace gravel occ. sand seams and layers, cobbles and boulders	5	DO	24
		6	DO	30
		7	DO	20
245.9 6.7	Grey, compact **SAND** fine to medium grained trace of gravel and clay	8	DO	18
245.3 7.3	**END OF BOREHOLE**			



W.L @ EL. 249.6 m on completion
Cave-in @ El. 249.3 m

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JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: BH/MW 8

FIGURE NO.: 8

PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

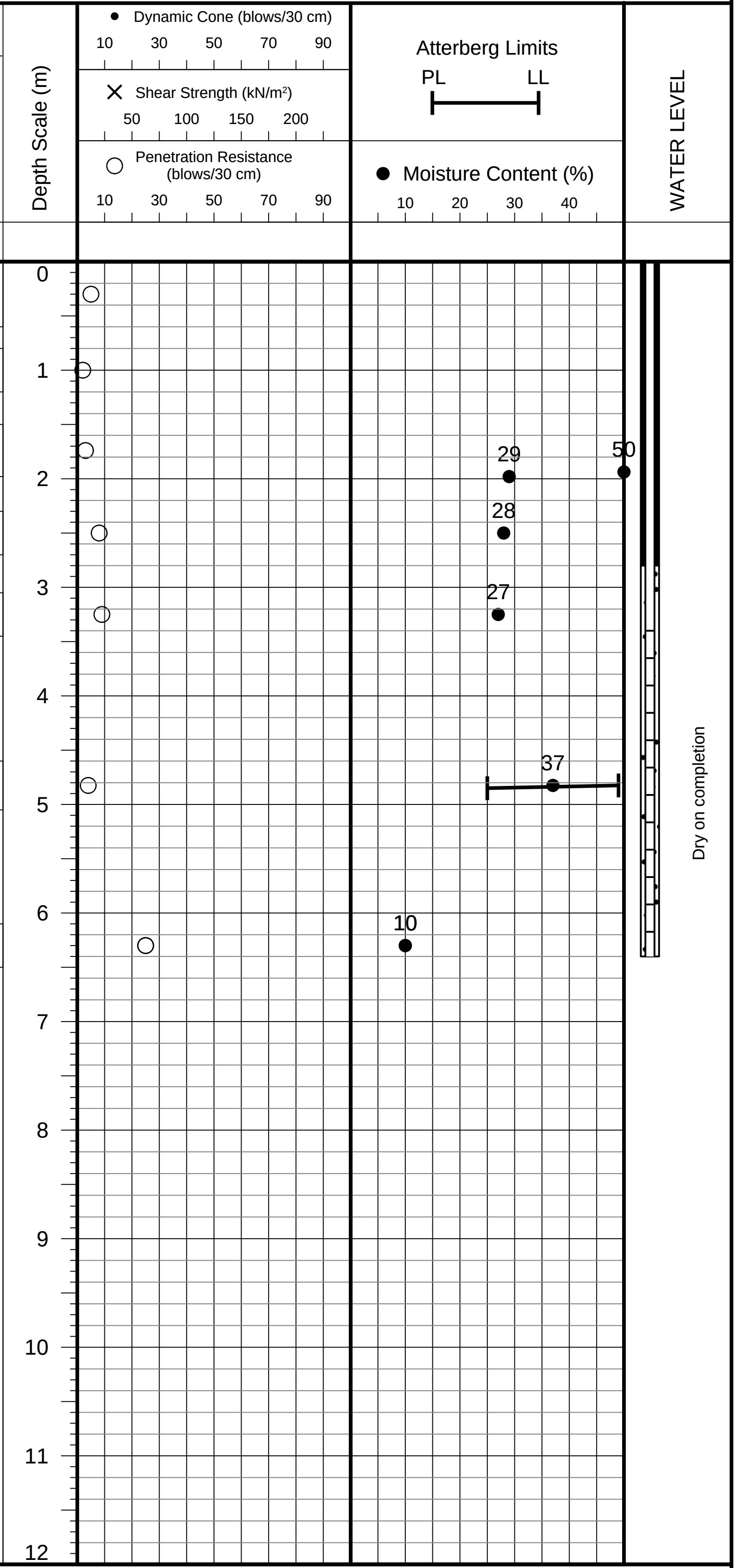
PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: March 5, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
252.4	Ground Surface			
0.0	**TOPSOIL AND PEAT** occ. wood chips	1	DO	5
		2	DO	2
250.7 1.7	Grey, soft to stiff **SILTY CLAY** occ. sand seams and layers	3A 3B	DO	3
		4	DO	8
		5	DO	9
		6	DO	4
246.4 6.0	Grey, compact **SILTY SAND TILL** trace clay and gravel occ. cobbles and boulders	7	DO	25
245.9 6.5				

END OF BOREHOLE

Installed 50mm Ø monitoring well to 6.4 m
3.0 m screen from 3.4 to 6.4 m
Sand backfill from 2.8 to 6.4 m
Bentonite seal from 0.0 to 2.8 m
Provided with a 4x4 steel casing



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JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 9

FIGURE NO.: 9

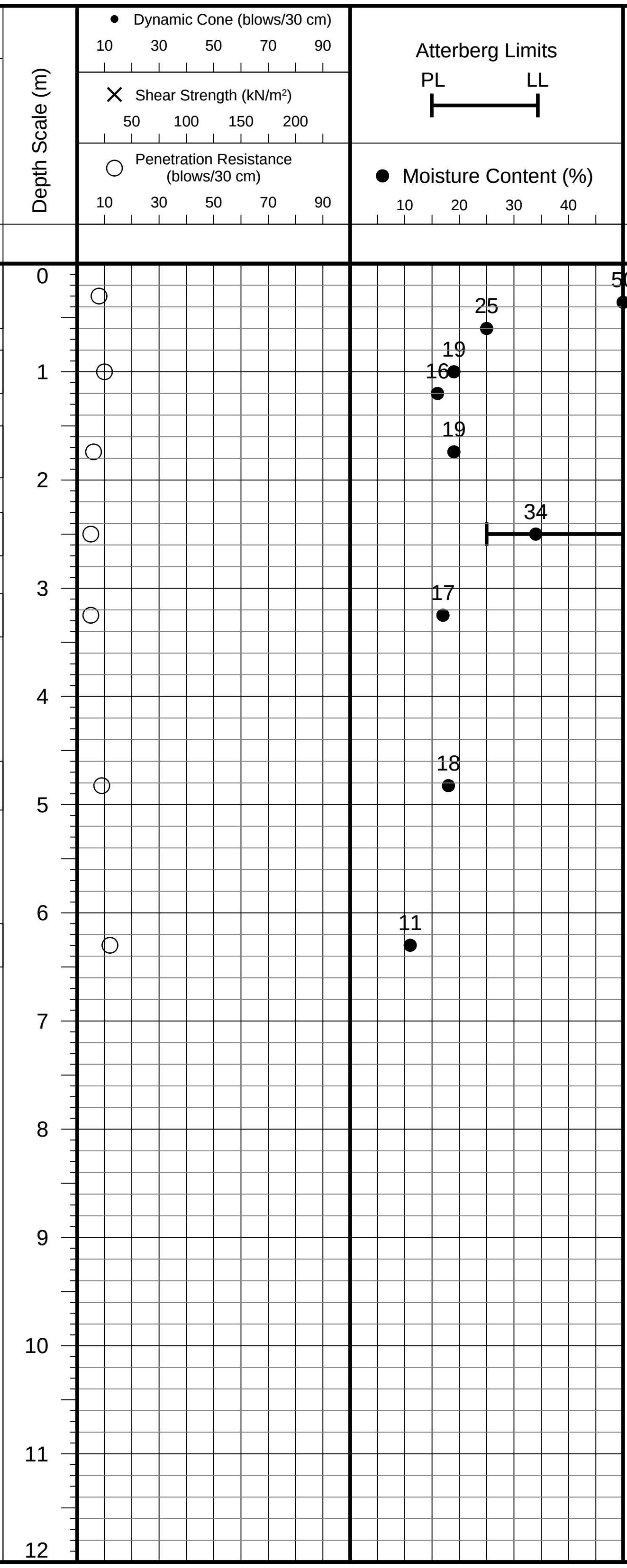
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: March 5, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
252.6	Ground Surface			
0.0	**30 cm TOPSOIL**	1A 1B	DO	8
	Brown, loose **SAND** weathered fine grained, some silt			
251.7 0.9		2A 2B	DO	10
	Firm to stiff **SILTY CLAY** occ. sand seams and layers — brown / grey	3	DO	6
		4	DO	5
		5	DO	5
248.6 4.0	Grey, stiff **SILTY CLAY TILL** trace of gravel occ. sand seams and layers, cobbles and boulders	6	DO	9
		7	DO	12
246.1 6.5	**END OF BOREHOLE**			



WATER LEVEL

Dry on completion

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Page: 1 of 1

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: BH/MW 10

FIGURE NO.: 10

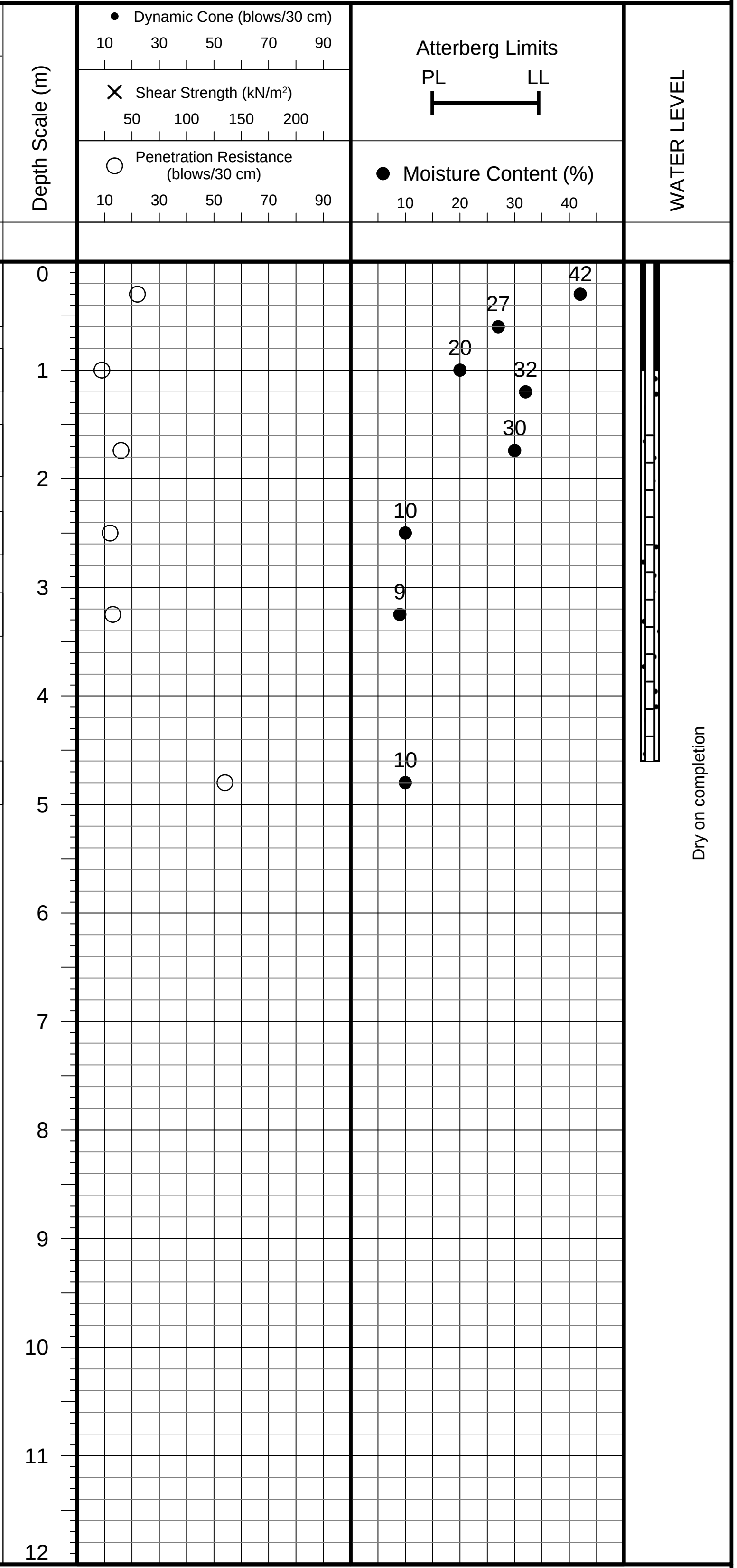
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 26, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
252.1	Ground Surface			
0.0	**PLOUGHED SOIL** brown sand and silt with topsoil inclusions Frost	1A 1B	DO	22
251.2 0.9	Brown, very stiff **SILTY CLAY** occ. sand seams and layers	2A 2B	DO	9
		3	DO	16
250.0 2.1	Grey, compact to very dense **SILTY SAND TILL** trace to some clay, trace gravel occ. cobbles and boulders	4	DO	12
		5	DO	13
		6	DO	54
247.1 5.0	**END OF BOREHOLE** Installed 50mm Ø monitoring well to 4.6 m 3.0 m screen from 1.6 to 4.6 m Sand backfill from 1.0 to 4.6 m Bentonite seal from 0.0 to 1.0 m Provided with a 4x4 steel casing			



JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 11

FIGURE NO.: 11

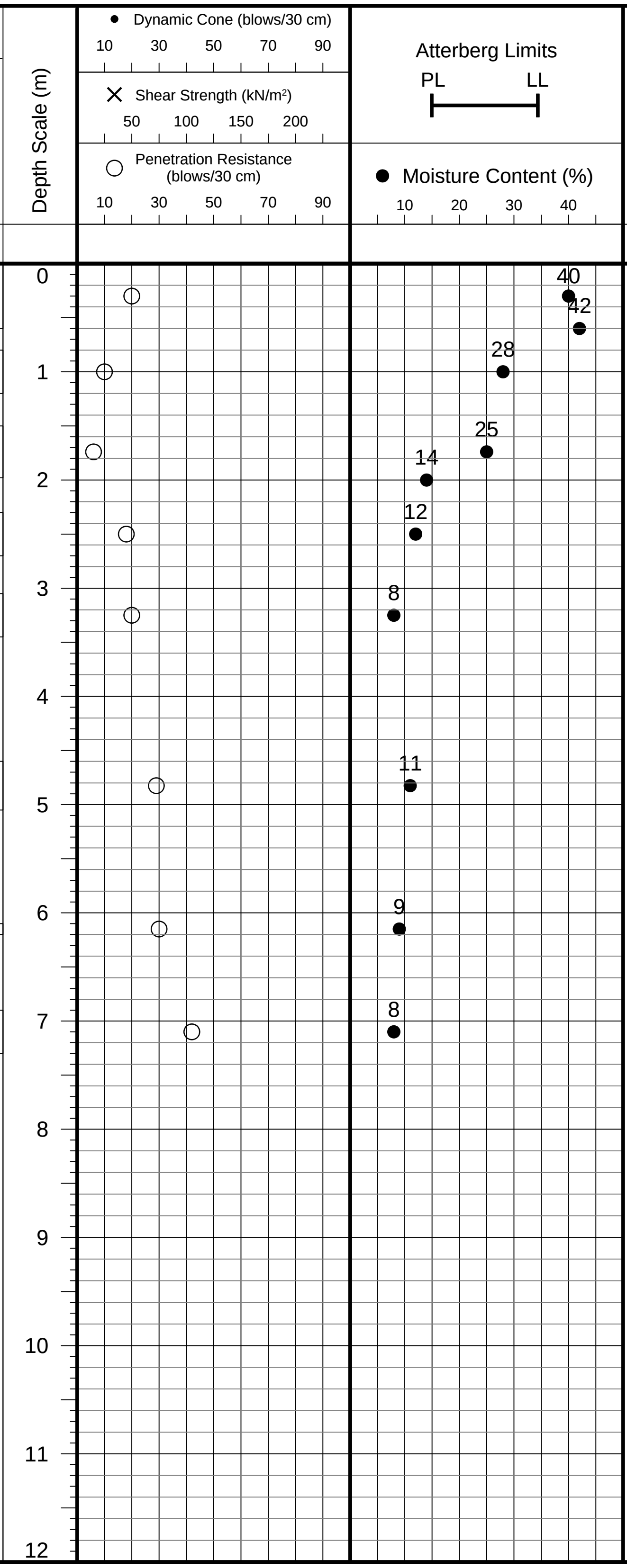
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 26, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
252.1	Ground Surface			
0.0	**PLOUGHED SOIL** brown silty sand with topsoil inclusions	1A 1B	DO	20
251.4 0.7	Frost Brown, compact **SILTY CLAY** occ. sand seams and layers	2	DO	10
		3A 3B	DO	6
250.3 1.8	Grey, loose to dense **SILTY SAND TILL** trace of gravel, some clay occ. sand seams and layers, cobbles and boulders	4	DO	18
		5	DO	20
		6	DO	29
	boulder	7	DO	30/NP
		8	DO	42
244.8 7.3	**END OF BOREHOLE**			



WATER LEVEL

W.L @ EL. 247.8 m on completion ▽

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JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: BH/MW 12

FIGURE NO.: 12

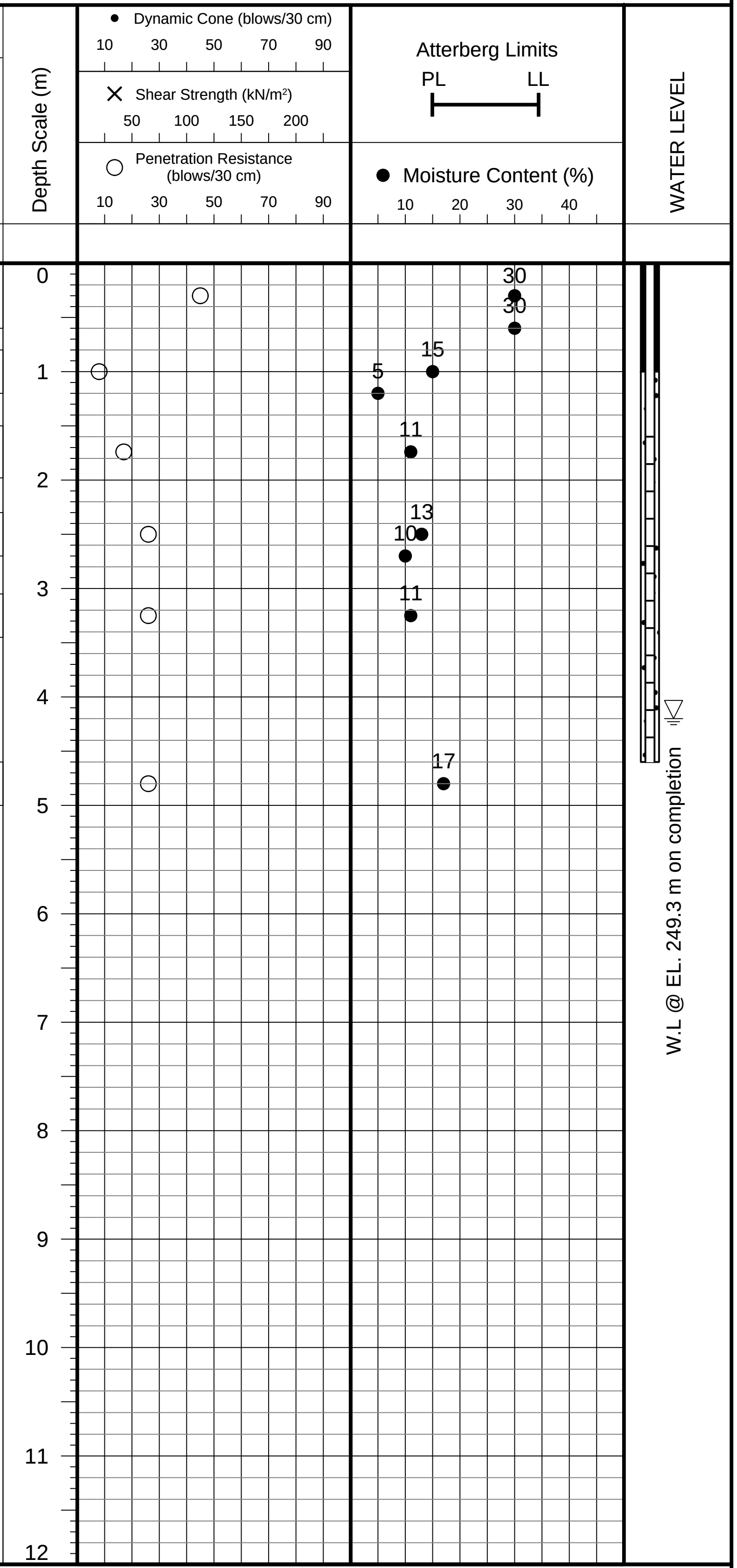
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 27, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES		
		Number	Type	N-Value
253.5	Ground Surface			
0.0	**PLOUGHED SOIL** brown silty sand with topsoil inclusions Frost	1A 1B	DO	45
252.5 1.0	Brown, loose to compact **SILTY SAND TILL** trace of clay, some gravel occ. sand layers, cobbles and boulders	2A 2B	DO	8
		3	DO	17
		4A 4B	DO	26
		5	DO	26
249.5 4.0	Brown, compact **SAND** fine to medium grained, some silt to silty	6	DO	26
248.5 5.0	**END OF BOREHOLE** Installed 50mm Ø monitoring well to 4.6 m 3.0 m screen from 1.6 to 4.6 m Sand backfill from 1.0 to 4.6 m Bentonite seal from 0.0 to 1.0 m Provided with a 4x4 steel casing			



Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 13

FIGURE NO.: 13

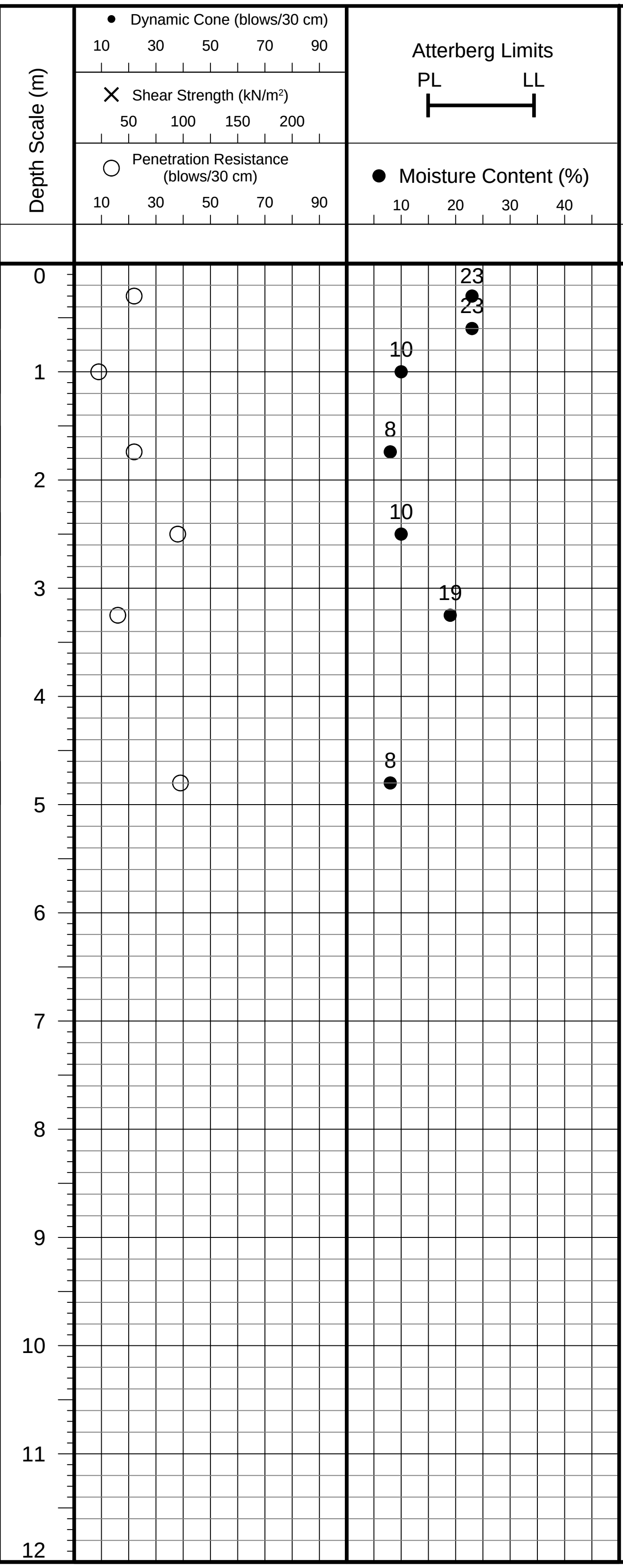
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 27, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
252.1	Ground Surface			
0.0	**PLOUGHED SOIL** brown silty sand	1A 1B	DO	22
251.4 0.7	Frost Brown, loose to dense **SILTY SAND TILL** trace of clay and gravel occ. sand layers, cobbles and boulders	2	DO	9
		3	DO	22
249.6 2.5	Brown, compact **SAND** fine to medium grained trace of gravel occ. cobbles	4	DO	38
		5	DO	16
248.3 3.8	Brown, dense **SILTY SAND TILL** trace of clay and gravel occ. cobbles and boulders	6	DO	39
247.1 5.0	**END OF BOREHOLE**			



WATER LEVEL

W.L @ EL. 248.9 m on completion

Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 14

FIGURE NO.: 14

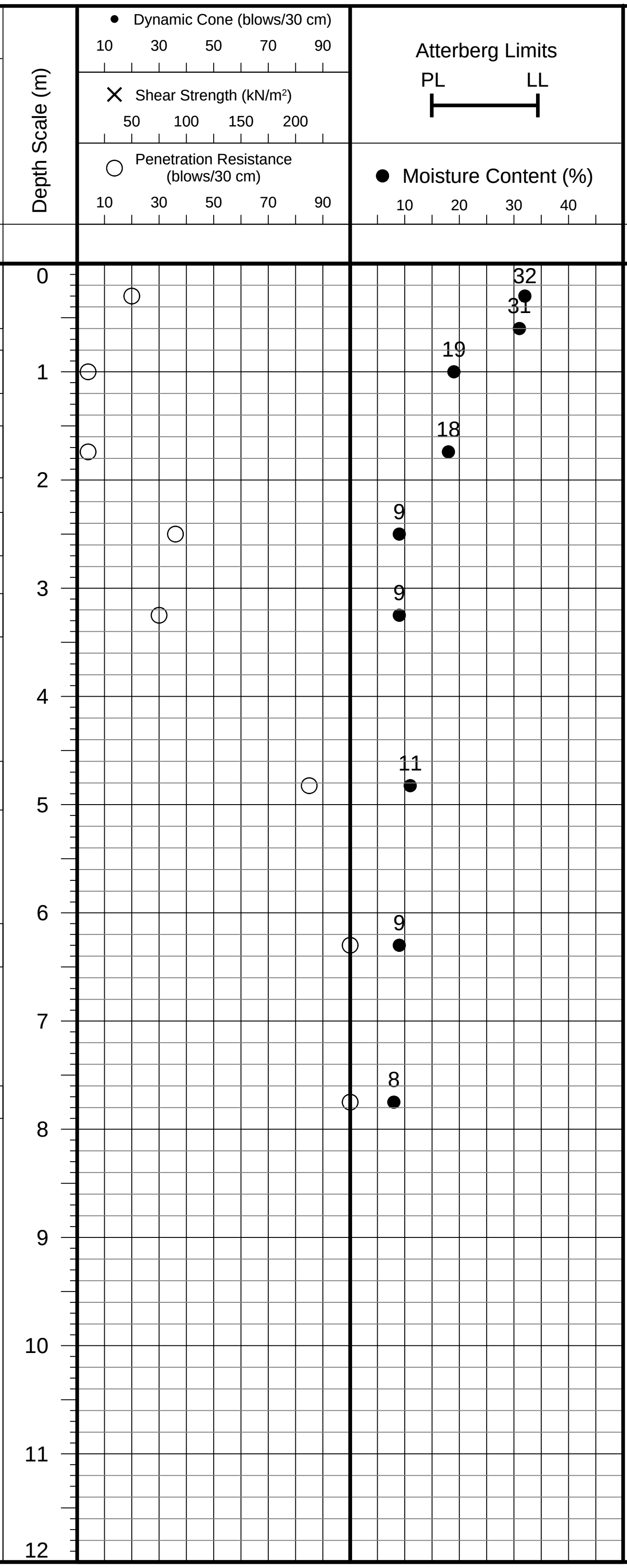
PROJECT DESCRIPTION: Proposed Residential Development

PROJECT LOCATION: Lockhart Road, City of Barrie

METHOD OF BORING: Flight-Auger Hollow Stem

DRILLING DATE: February 27, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
250.5	Ground Surface			
0.0	**PLOUGHED SOIL** brown silty sand Frost	1A 1B	DO	20
249.8 0.7	**EARTH FILL** brown sand and clay scattered topsoil	2	DO	4
		3	DO	4
248.4 2.1	Brown, dense to very dense **SILTY SAND TILL** trace to some clay, trace gravel occ. sand layers, cobbles and boulders	4	DO	36
		5	DO	30
		6	DO	85
		7	DO	50/15
		8	DO	55/15
242.6 7.9	**END OF BOREHOLE**			



WATER LEVEL

W.L @ EL. 248.1 m on completion

Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: BH/MW 15

FIGURE NO.: 15

PROJECT DESCRIPTION: Proposed Residential Development

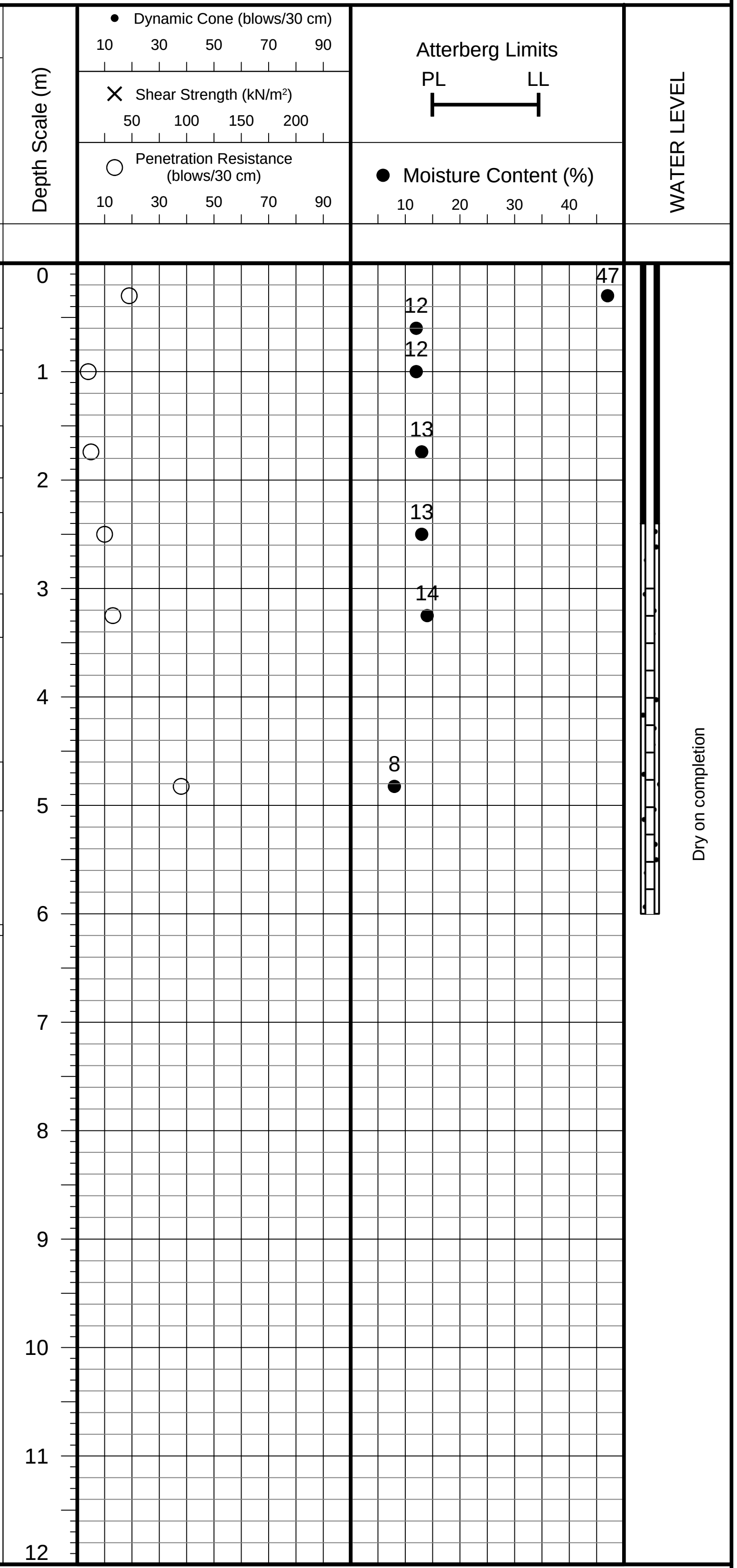
METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 28, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
251.5	Ground Surface			
0.0 250.8	**PLOUGHED SOIL** brown silty sand Frost	1A 1B	DO	19
0.7	Brown, dense to very dense **SILTY SAND TILL** trace of clay and gravel occ. cobbles and boulders	2	DO	4
		3	DO	5
		4	DO	10
		5	DO	13
		6	DO	38
		7	DO	50/NP
245.1 6.4	**END OF BOREHOLE** **Refusal to augering on probable boulder**			

Installed 50mm Ø monitoring well to 6.0 m
3.0 m screen from 3.0 to 6.0 m
Sand backfill from 2.4 to 6.0 m
Bentonite seal from 0.0 to 2.4 m
Provided with a 4x4 steel casing



Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 16

FIGURE NO.: 16

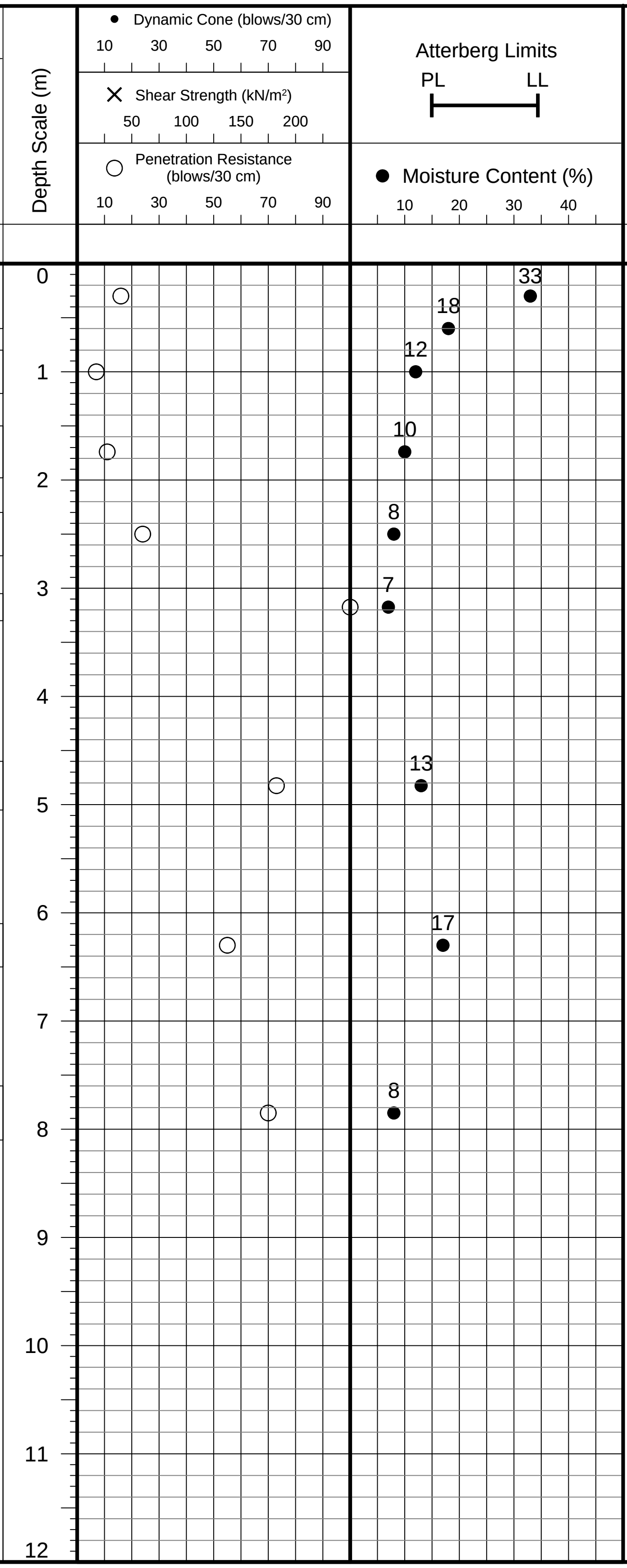
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 28, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
256.2	Ground Surface			
0.0	**PLOUGHED SOIL** brown silty sand Frost	1A 1B	DO	16
255.5 0.7	**EARTH FILL** brown sand and clay scattered topsoil	2	DO	7
254.5 1.7	Brown, compact to very dense **SILTY SAND TILL** trace of clay and gravel occ. cobbles and boulders	3	DO	11
		4	DO	24
		5	DO	50/15
252.3 3.9	Brown, very dense **SAND** fine to medium grained trace of gravel occ. cobbles	6	DO	73
		7	DO	55
249.2 7.0	Brown, very dense **SILTY SAND TILL** trace of clay and gravel occ. cobbles and boulders	8	DO	70
248.1 8.1	**END OF BOREHOLE**			



WATER LEVEL

W.L @ EL. 252.5 m on completion
Cave-in @ El. 251.9 m

Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 17

FIGURE NO.: 17

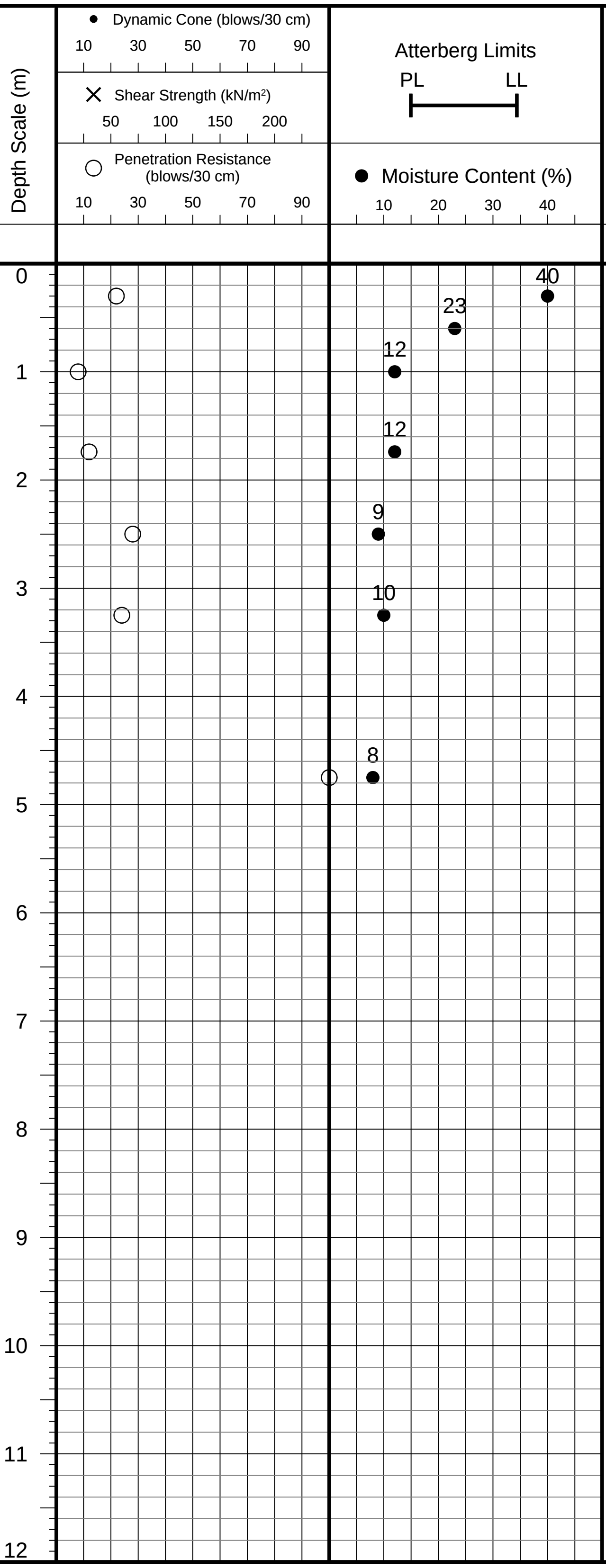
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 28, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
254.9	Ground Surface			
0.0	**PLOUGHED SOIL** brown silty sand Frost	1A 1B	DO	22
254.2 0.7	Brown, loose to very dense **SILTY SAND TILL** trace of clay and gravel occ. sand layers, cobbles and boulders	2	DO	8
		3	DO	12
		4	DO	28
		5	DO	24
250.0		6	DO	50/15
4.9	**END OF BOREHOLE**			



WATER LEVEL

▽ W.L @ EL. 252 m on completion

Cave-in @ El. 251.9 m

Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 18

FIGURE NO.: 18

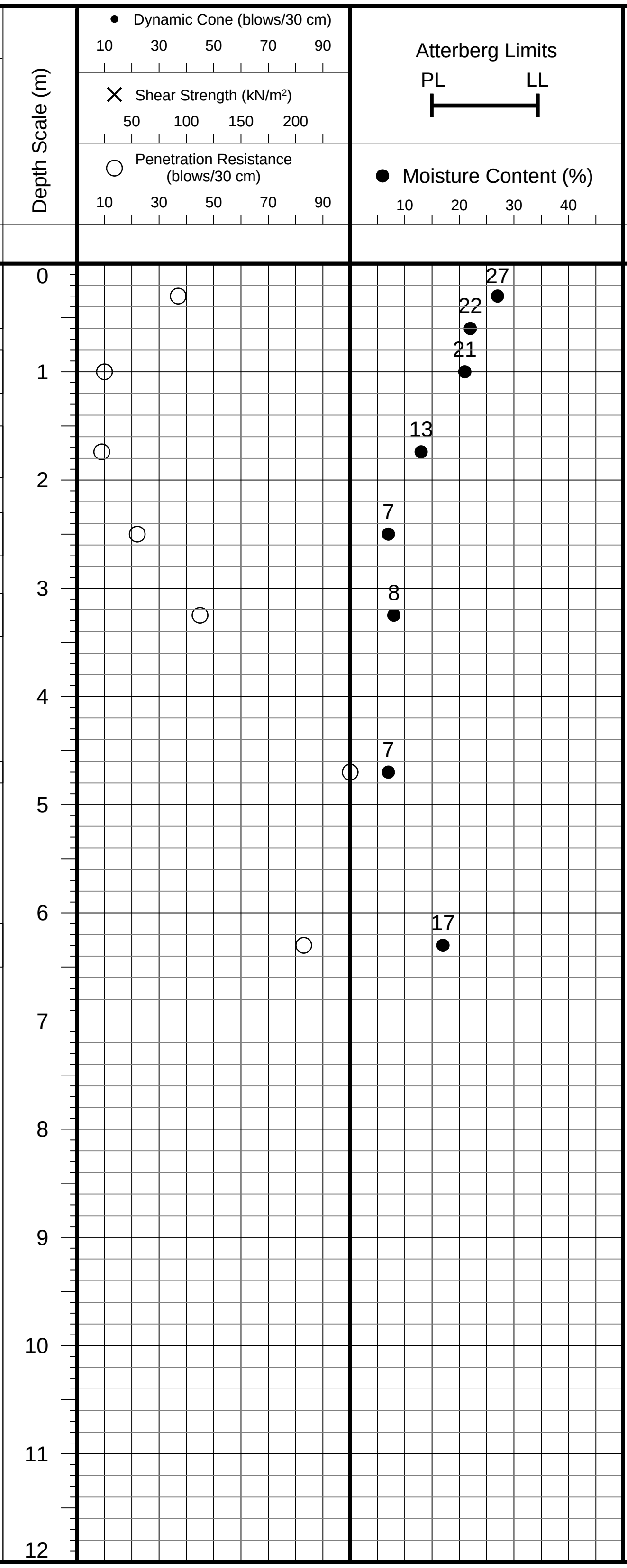
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 26, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	WATER LEVEL
256.1	Ground Surface				
0.0	**PLOUGHED SOIL** brown silty sand Frost	1A 1B	DO	37	
255.4 0.7	**EARTH FILL** brown sand and clay scattered topsoil	2	DO	10	
		3	DO	9	
254.0 2.1	Brown, compact to very dense **SILTY SAND TILL** trace of clay and gravel occ. cobbles and boulders	4	DO	22	
		5	DO	45	
		6	DO	50/15	
250.6 5.5	Brown, very dense **SAND** well graded, some silt trace of gravel	7	DO	83	▽ W.L @ EL. 250.6 m on completion
249.6 6.5	**END OF BOREHOLE**				



Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: BH/MW 19

FIGURE NO.: 19

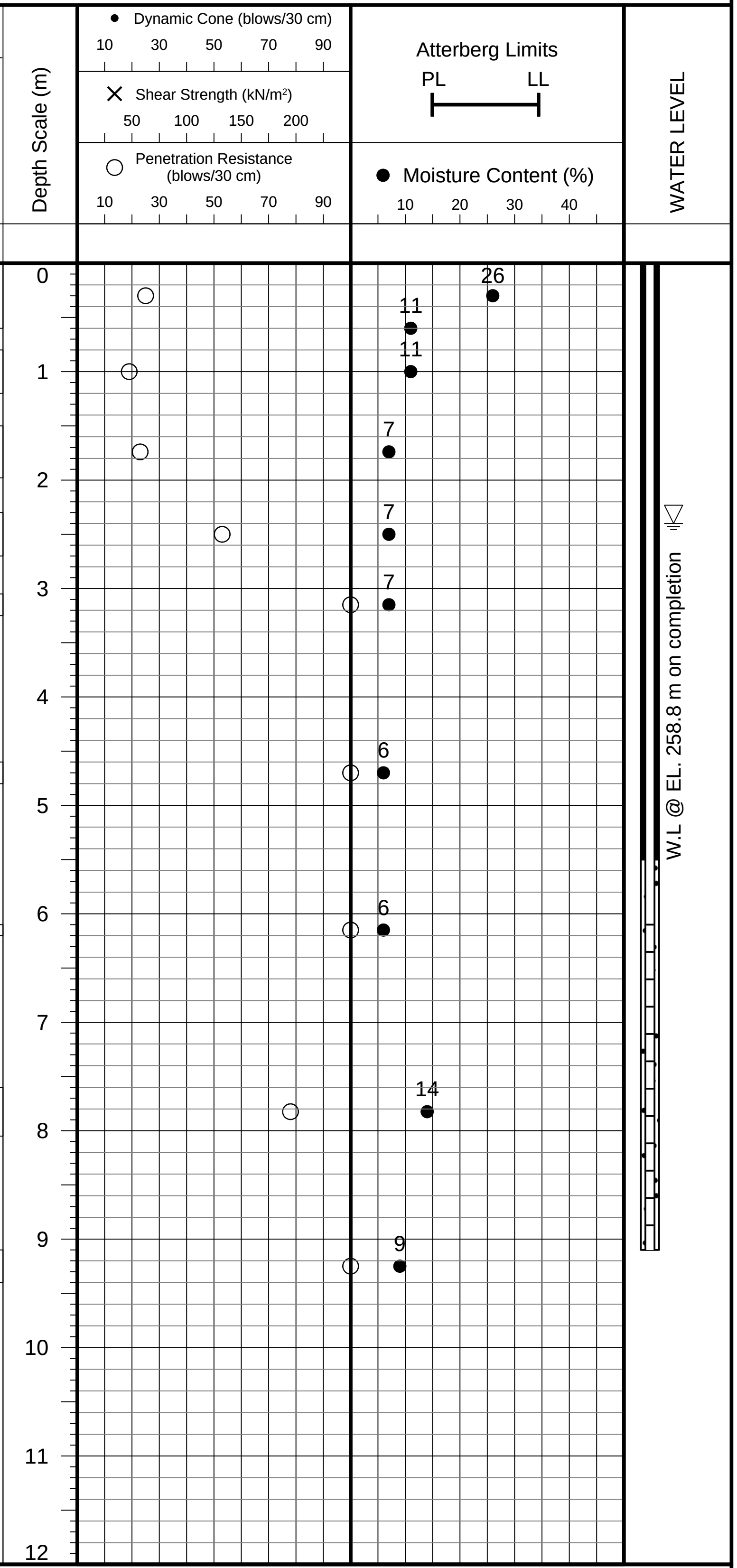
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 26, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
261.2	Ground Surface			
0.0	**35 cm TOPSOIL**	1A 1B	DO	25
	EARTH FILL brown sand and clay scattered topsoil Frost	2	DO	19
260.1 1.1	Brown, compact to very dense **SILTY SAND TILL** trace of clay, some gravel occ. sand layers, cobbles and boulders	3	DO	23
		4	DO	53
		5	DO	50/15
		6	DO	70/15
		7	DO	50/10
254.2 7.0	Brown, very dense **SAND** fine to medium grained trace of gravel, some silt	8	DO	78
		9	DO	50/15
251.8 9.4	**END OF BOREHOLE** Installed 50mm Ø monitoring well to 9.1 m 3.0 m screen from 6.1 to 9.1 m Sand backfill from 5.5 to 9.1 m Bentonite seal from 0.0 to 5.5 m Provided with a 4x4 steel casing			



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JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 20

FIGURE NO.: 20

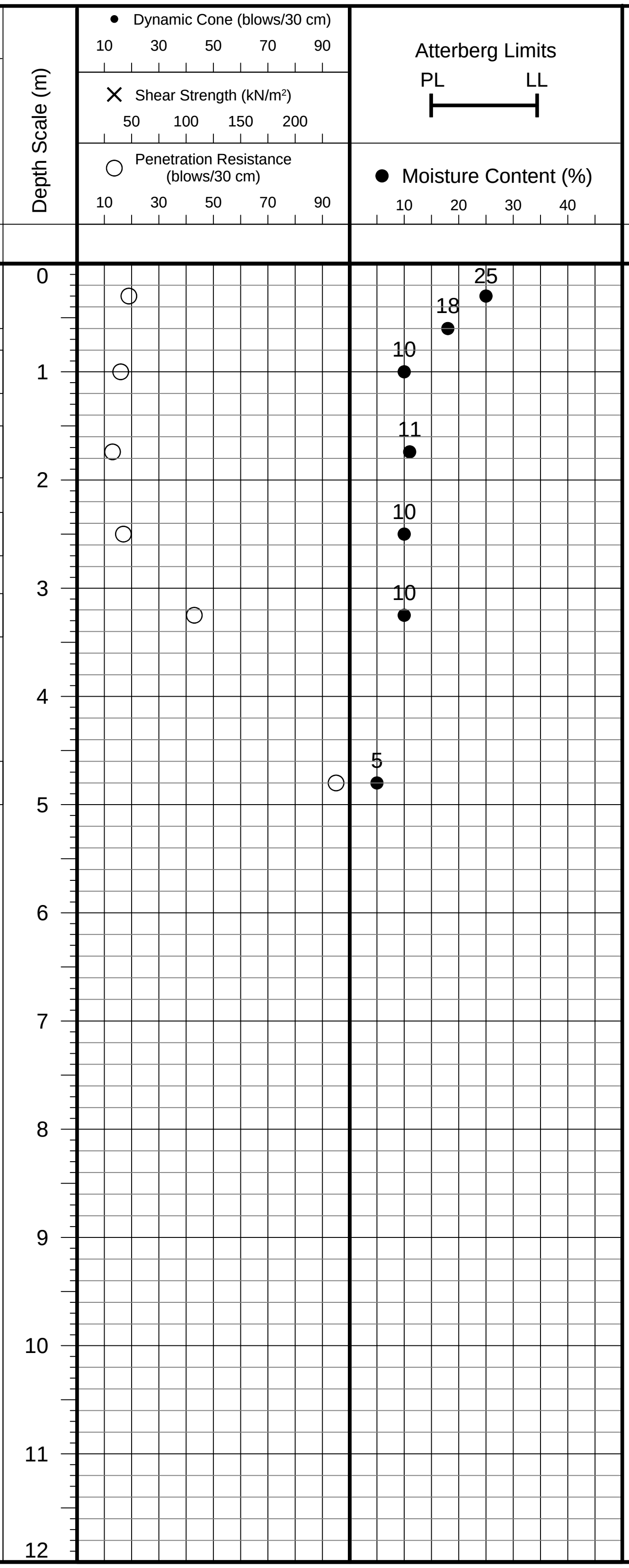
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 19, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	Number	Type	N-Value
264.6	Ground Surface			
0.0	**PLOUGHED SOIL** brown silty sand Frost	1A 1B	DO	19
263.9 0.7	**EARTH FILL** brown sandy silt, some clay occ. organic inclusions	2	DO	16
263.2 1.4	Brown, compact to dense **SILTY SAND TILL** trace of clay and gravel occ. pockets of sand, cobbles and boulders	3	DO	13
		4	DO	17
		5	DO	43
260.6 4.0	Brown, very dense **SAND** well graded some silt and gravel occ. cobbles	6	DO	95
259.6 5.0	**END OF BOREHOLE**			



WATER LEVEL

Dry on completion

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 21

FIGURE NO.: 21

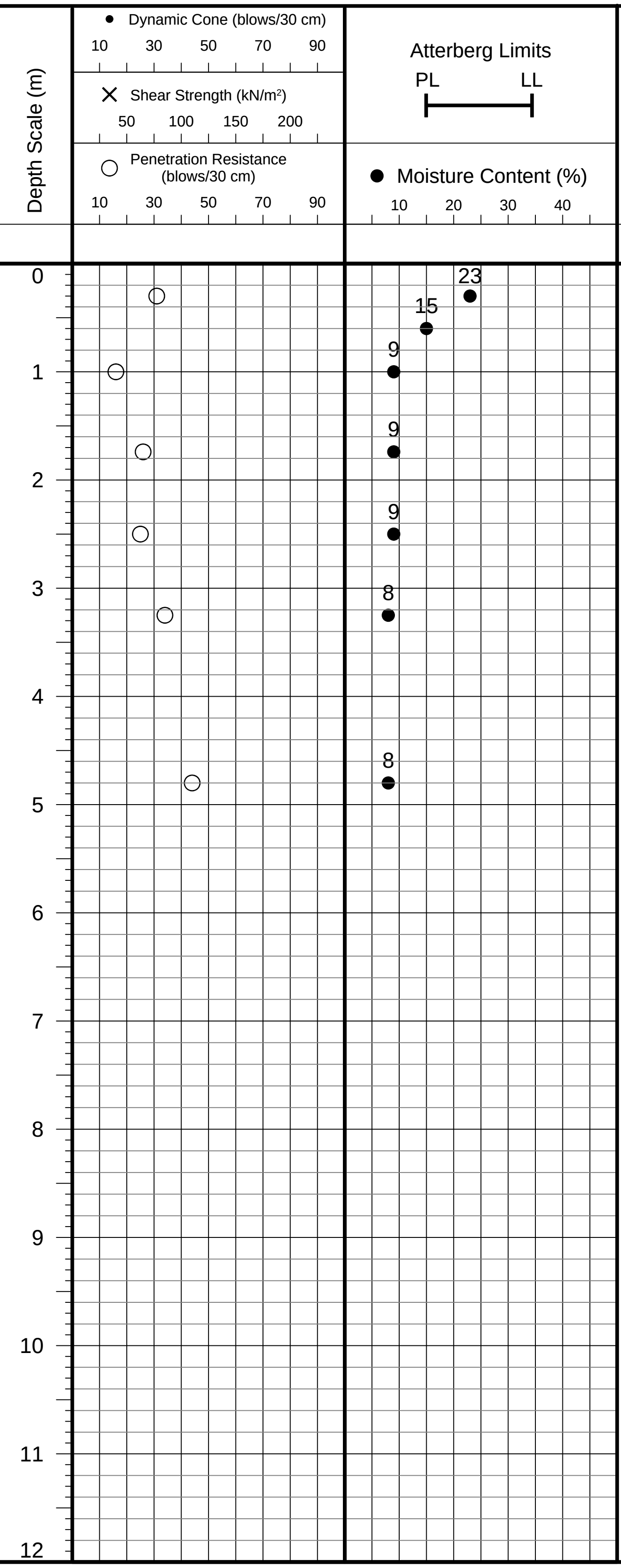
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 19, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value	WATER LEVEL
259.5	Ground Surface				
0.0	**25 cm TOPSOIL** Brown, compact to dense Frost **SILTY SAND TILL** trace clay and gravel occ. cobbles and boulders	1A 1B	DO	31	Dry on completion
		2	DO	16	
		3	DO	26	
		4	DO	25	
		5	DO	34	
		6	DO	44	
254.5 5.0	**END OF BOREHOLE**				



Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 22

FIGURE NO.: 22

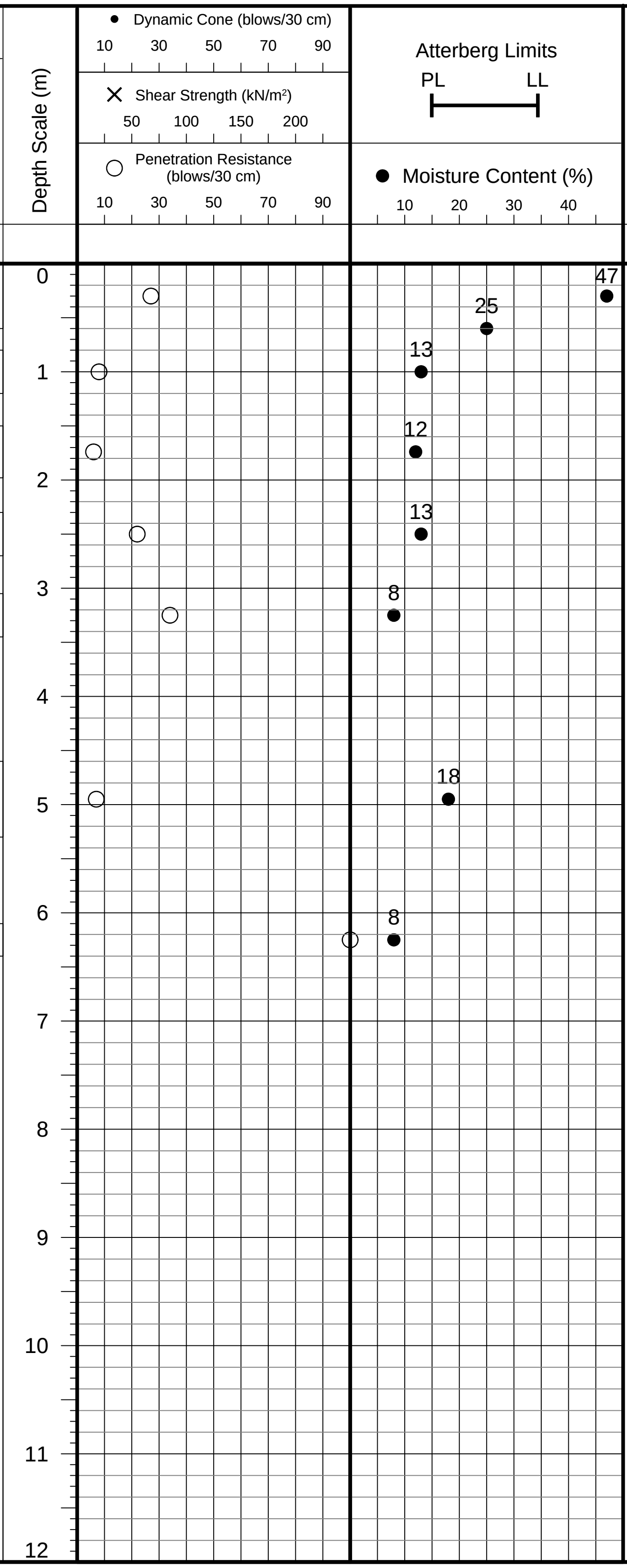
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 26, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
254.4	Ground Surface			
0.0	**PLOUGHED SOIL** brown silty sand Frost	1A 1B	DO	27
253.7 0.7	Brown, loose to dense **SILTY SAND TILL** trace to some clay occ. cobbles and boulders	2	DO	8
		3	DO	6
		4	DO	22
		5	DO	34
250.2 4.2	Brown, loose **SAND (disturbed)** fine to medium grained, some silt	6	DO	7
248.9 5.5	Brown, very dense **SILTY SAND TILL** trace of clay and gravel occ. cobbles and boulders	7	DO	50/15
248.0 6.4	**END OF BOREHOLE**			



WATER LEVEL

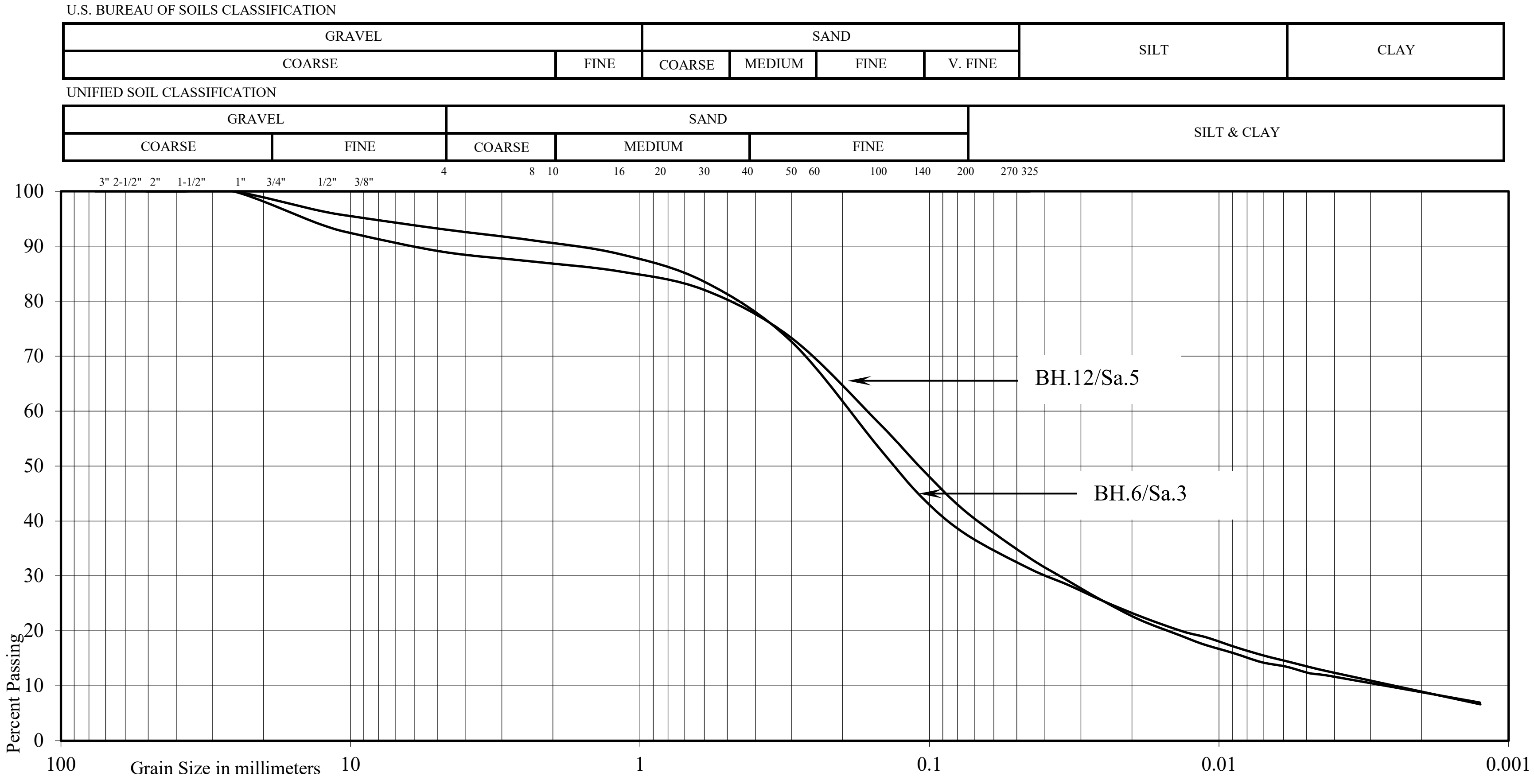
W.L @ El. 252.9 m on completion

Cave-in @ El. 250.1 m

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1901-S077



Project: Proposed Residential Development

Location: Lockhart Road, City of Barrie

Borehole No:	6	12
Sample No:	3	5
Depth (m):	1.7	3.3
Elevation (m):	251.6	250.2

BH./Sa.	6/3	12/5
Liquid Limit (%) =	-	-
Plastic Limit (%) =	-	-
Plasticity Index (%) =	-	-
Moisture Content (%) =	14	11
Estimated Permeability (cm./sec.) =	10^{-6}	10^{-3}

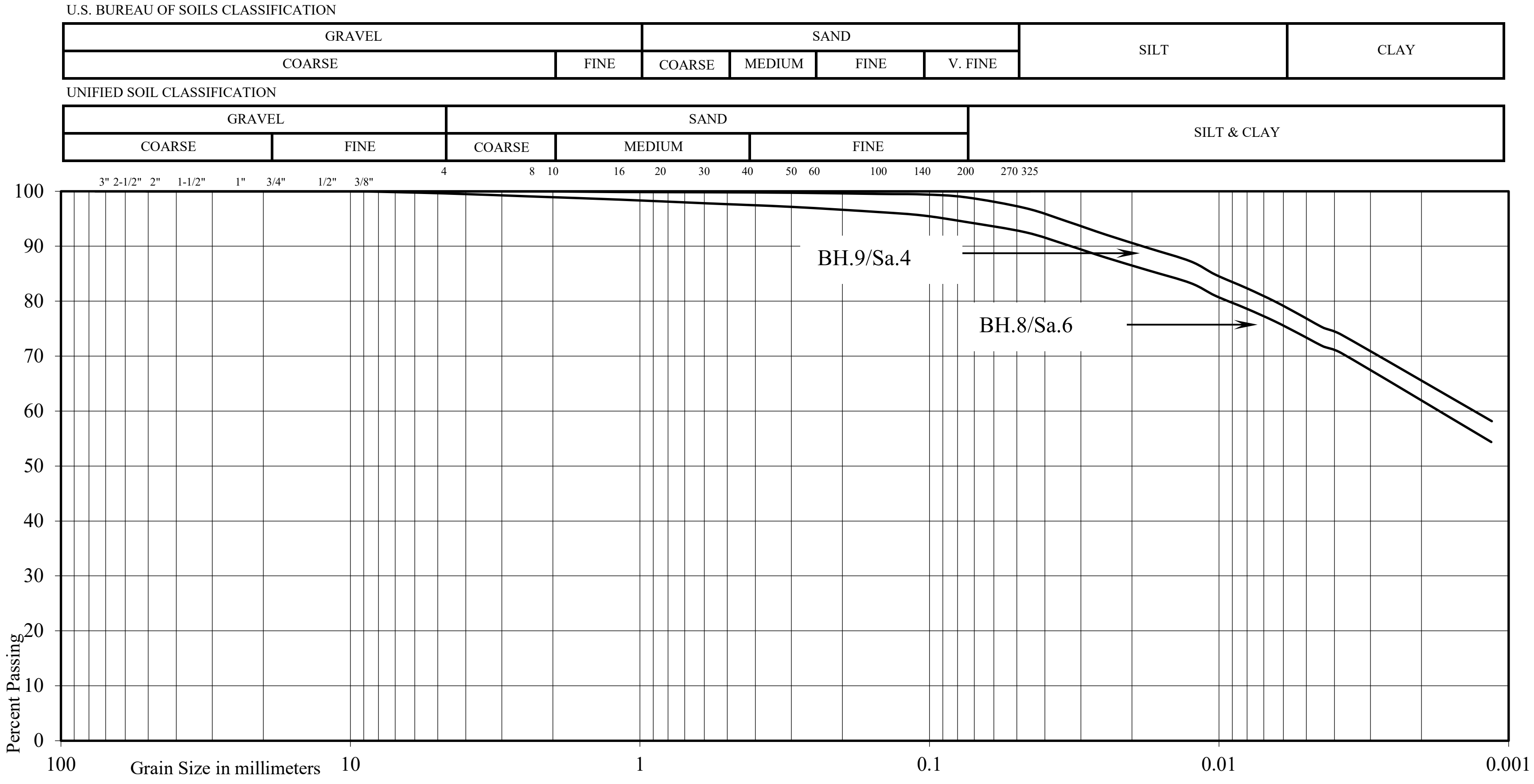
Classification of Sample [& Group Symbol]: SILTY SAND TILL, a trace to some gravel, a trace of clay

Figure: 23

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1901-S077



Project:	Proposed Residential Development	
Location:	Lockhart Road, City of Barrie	
Borehole No:	8	9
Sample No:	6	4
Depth (m):	4.8	2.5
Elevation (m):	247.6	250.1

BH./Sa.	8/6	12/5
Liquid Limit (%) =	49	-
Plastic Limit (%) =	25	-
Plasticity Index (%) =	24	-
Moisture Content (%) =	37	11
Estimated Permeability (cm./sec.) =	$>10^{-7}$	$>10^{-7}$

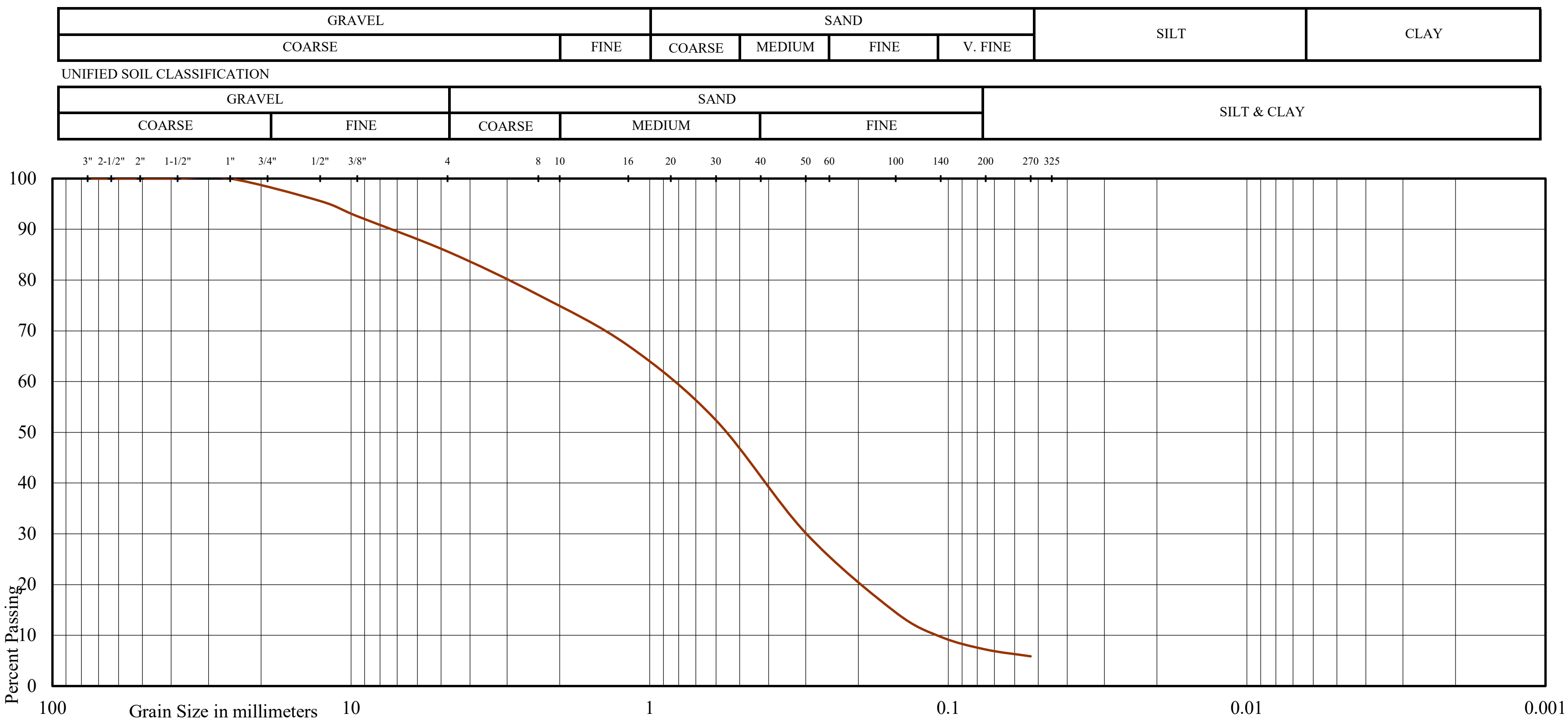
Classification of Sample [& Group Symbol]: SILTY CLAY, traces of sand and fine sand

Figure: 24

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1901-S077



Project: Proposed Residential Development

Location: Lockhart Road, City of Barrie

Liquid Limit (%) = -

Plastic Limit (%) = -

Borehole No: 1

Plasticity Index (%) = -

Sample No: 5

Moisture Content (%) = 15

Depth (m): 3.3

Estimated Permeability

Elevation (m): 249.7

(cm./sec.) = 10^{-3}

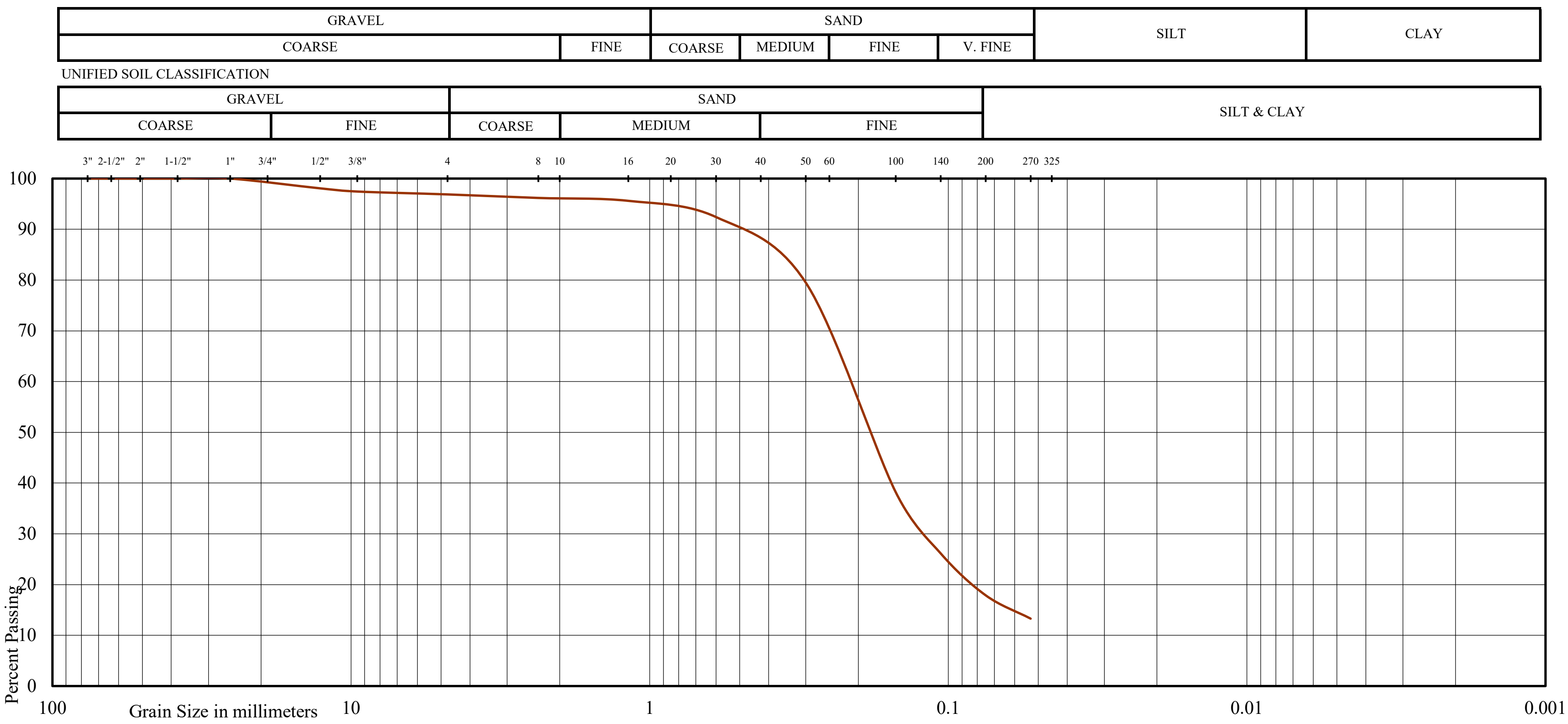
Classification of Sample [& Group Symbol]: SAND, well graded, some gravel and a trace of silt

Figure: 25

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1901-S077



Project: Proposed Residential Development

Location: Lockhart Road, City of Barrie

Liquid Limit (%) = -

Plastic Limit (%) = -

Plasticity Index (%) = -

Moisture Content (%) = 14

Estimated Permeability (cm./sec.) = 10^{-4}

Borehole No: 19

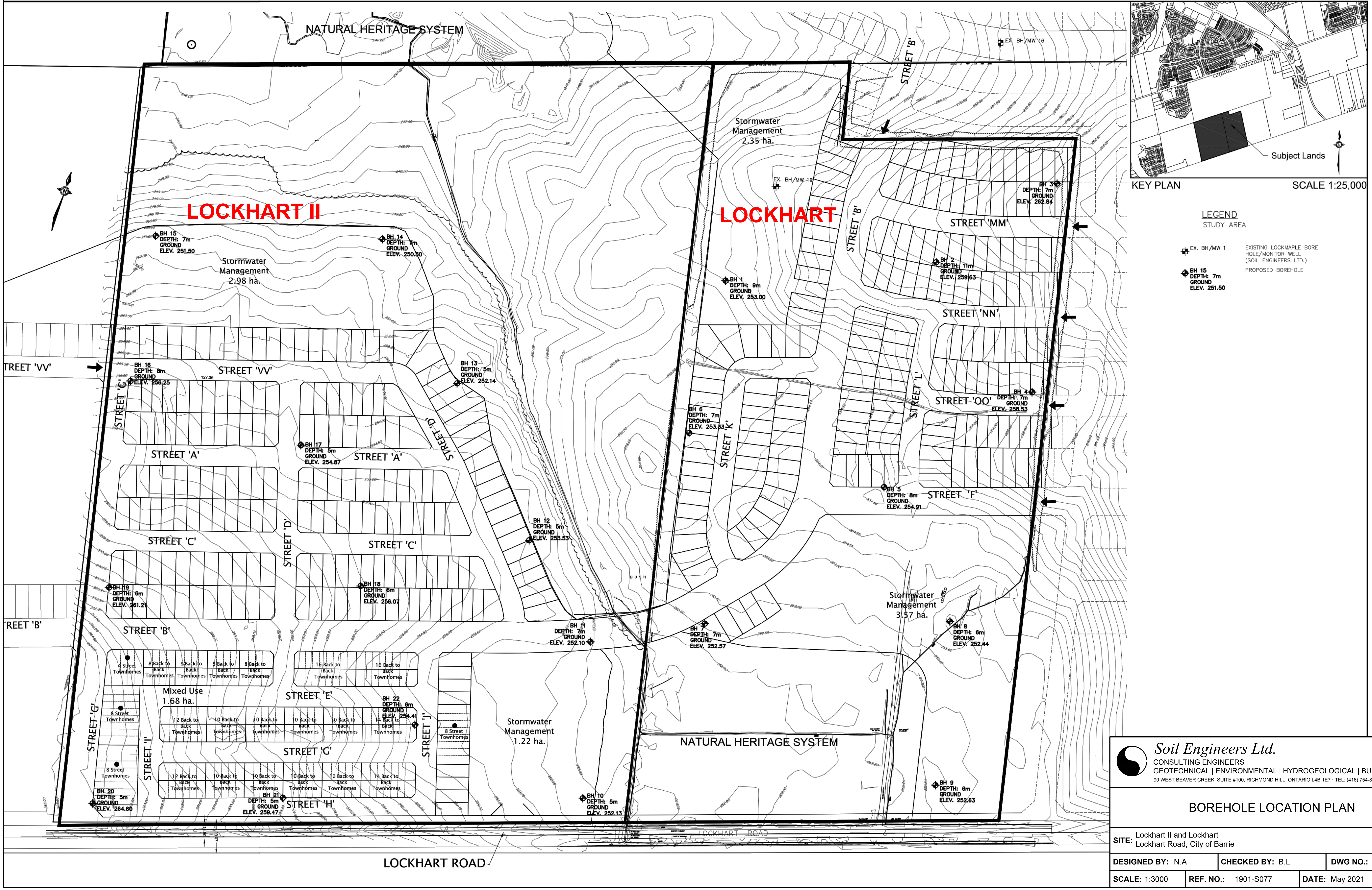
Sample No: 8

Depth (m): 7.8

Elevation (m): 253.4

Classification of Sample [& Group Symbol]: FINE TO MEDIUM SAND, some silt

Figure: 26



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90 WEST BEAVER CREEK, SUITE #100, RICHMOND HILL, ONTARIO L4B 1E7 · TEL: (416) 754-8515 · FAX: (905) 881-8335

BOREHOLE LOCATION PLAN

SITE: Lockhart II and Lockhart
Lockhart Road, City of Barrie

DESIGNED BY: N.A
CHECKED BY: B.L
DWG NO.: 1
SCALE: 1:3000
REF. NO.: 1901-S077
DATE: May 2021
REV -

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SUBSURFACE PROFILE
DRAWING NO. 2
SCALE: AS SHOWN

JOB NO.: 1901-S077
REPORT DATE: May 2021
PROJECT DESCRIPTION: Proposed Residential Development

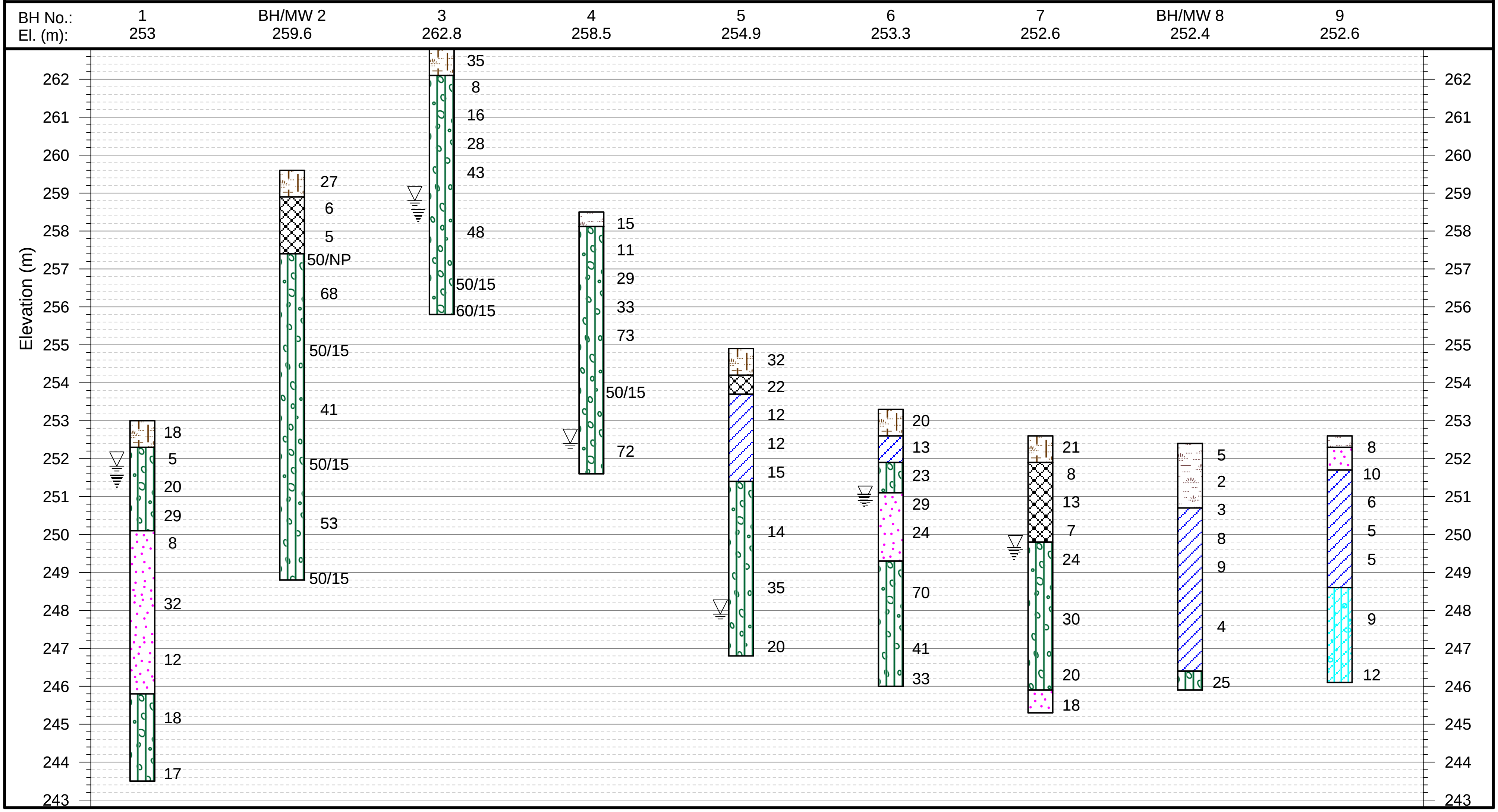
PROJECT LOCATION: Lockhart and Lockhart II
Lockhart Road, City of Barrie

LEGEND

- TOPSOIL
- FILL
- SILTY SAND TILL
- SILTY CLAY TILL
- PLOUGHED SOIL
- SAND
- SILTY CLAY

∇ WATER LEVEL (END OF DRILLING)

≡ CAVE-IN



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SUBSURFACE PROFILE
DRAWING NO. 3
SCALE: AS SHOWN

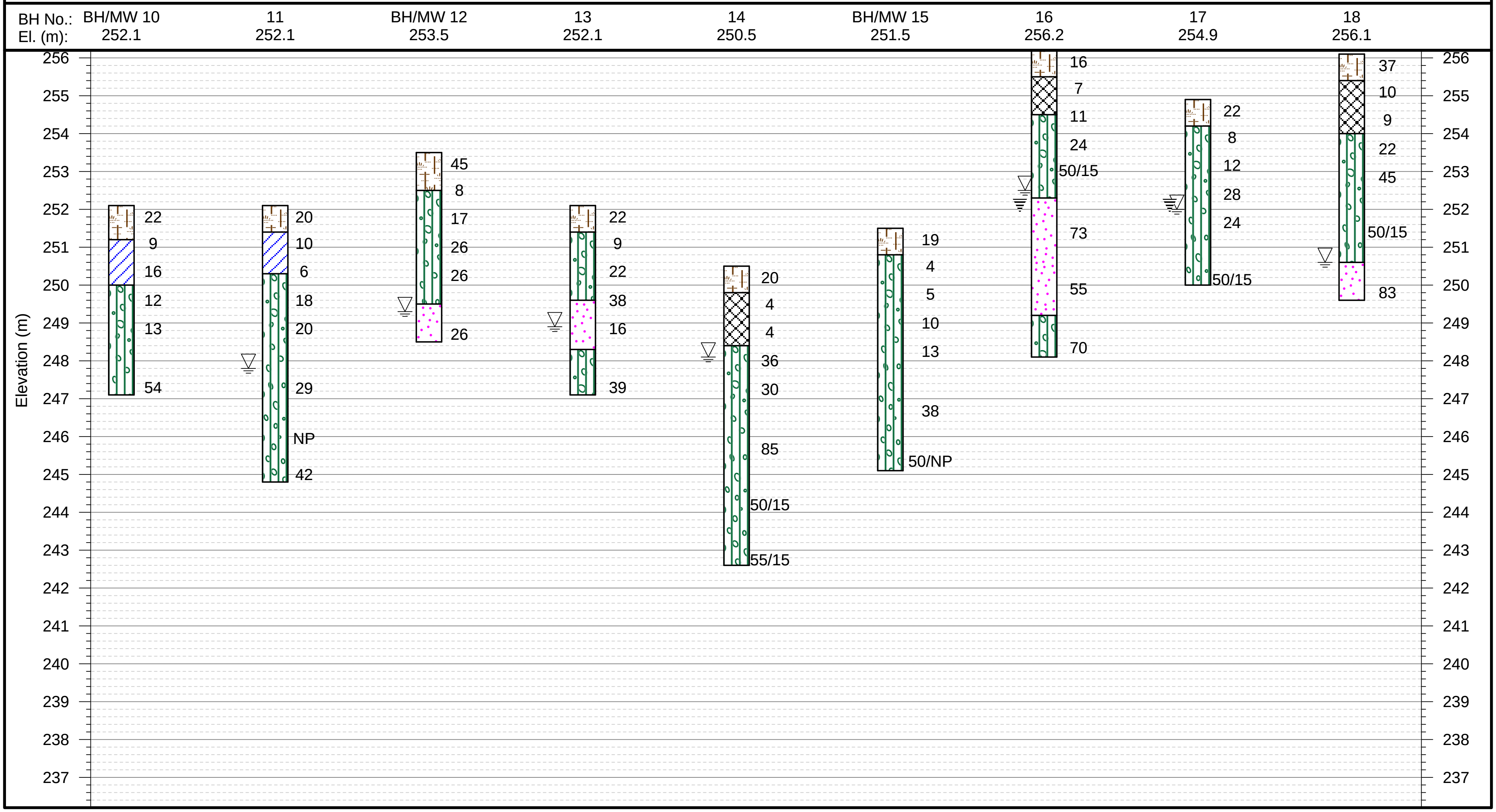
JOB NO.: 1901-S077
REPORT DATE: May 2021
PROJECT DESCRIPTION: Proposed Residential Development

PROJECT LOCATION: Lockhart and Lockhart II
Lockhart Road, City of Barrie

LEGEND

▨ PLOUGHED SOIL ▨ SAND ▨ SILTY SAND TILL ▨ SILTY CLAY
▨ FILL

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



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SUBSURFACE PROFILE
DRAWING NO. 4
SCALE: AS SHOWN

JOB NO.: 1901-S077

REPORT DATE: May 2021

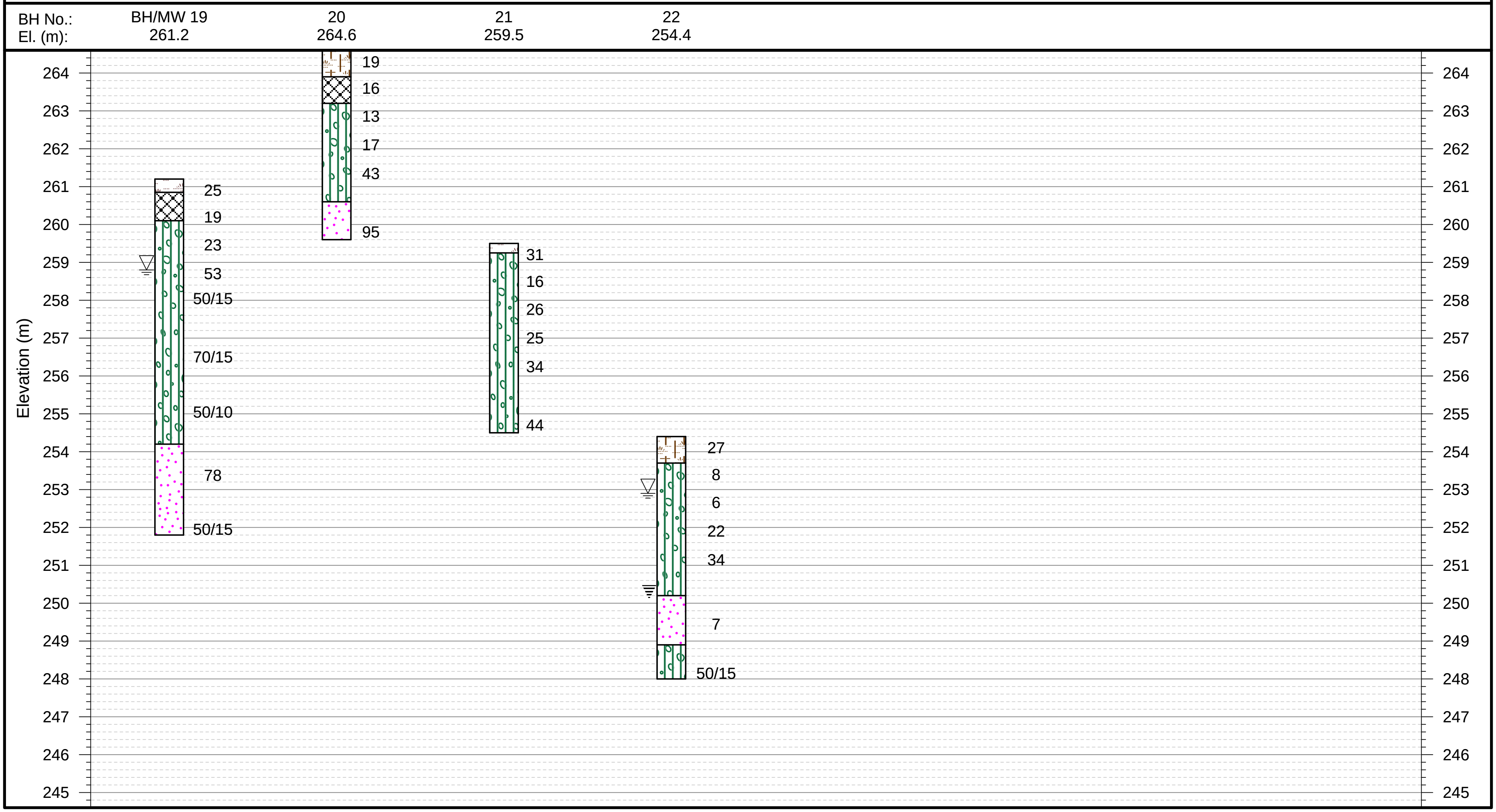
PROJECT DESCRIPTION: Proposed Residential Development

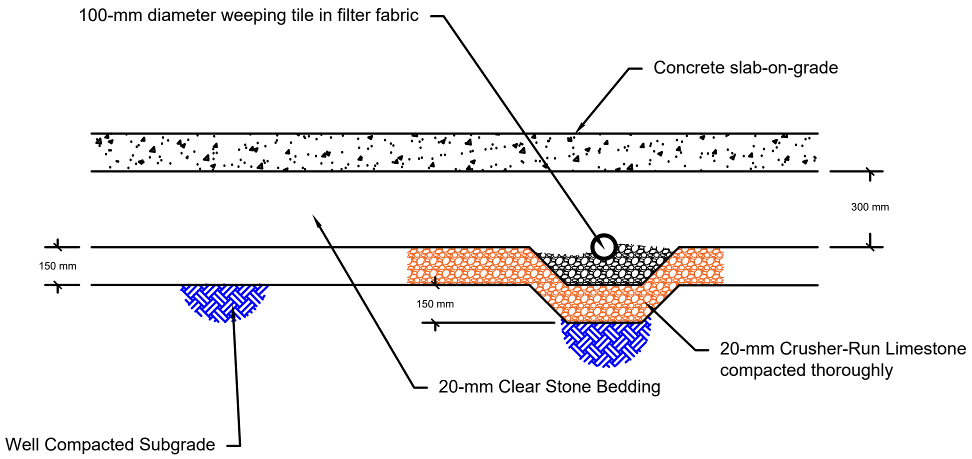
PROJECT LOCATION: Lockhart and Lockhart II
Lockhart Road, City of Barrie

LEGEND

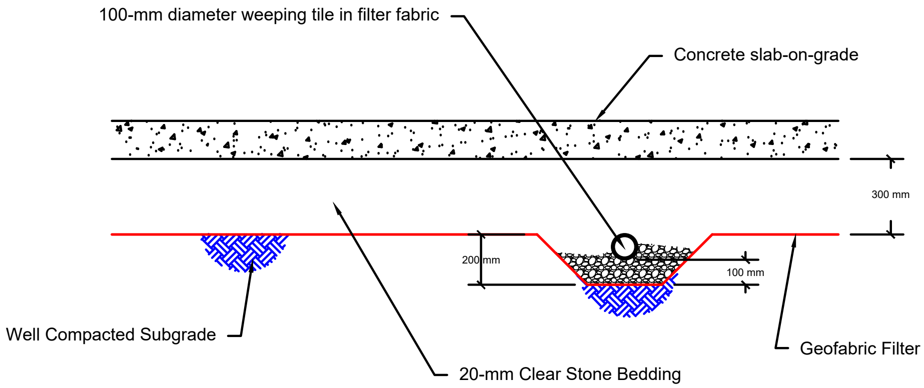
- ▤ TOPSOIL
- ▩ FILL
- ⁘ SAND
- ▥ SILTY SAND TILL
- ▦ PLOUGHED SOIL

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

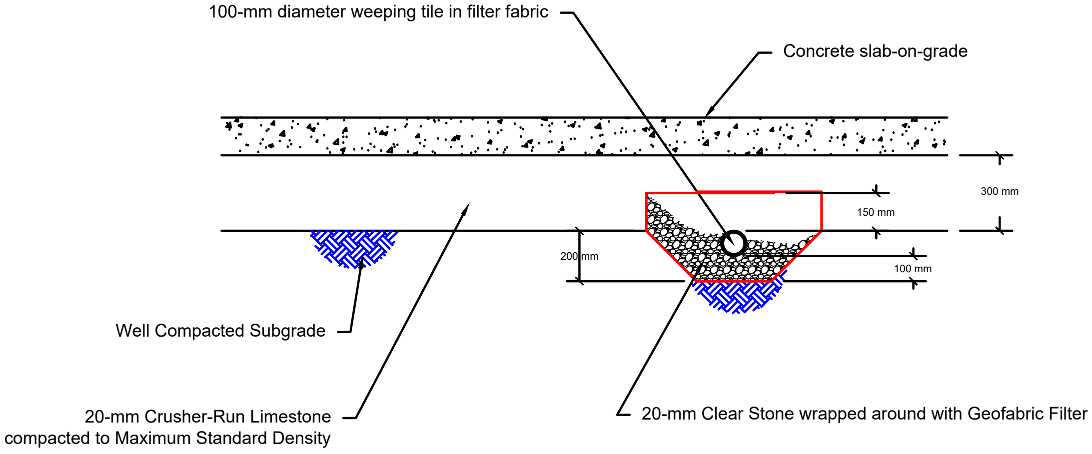




Option 'A'



Option 'B'



Option 'C'

Note:

1. Weepers should be placed in 5 m grids, draining in a positive gradient towards an outlet or a sump pit for removal by pumping.
2. A 6-mil polyethylene sheet should be specified between the gravel bedding and concrete slab.

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100 NUGGET AVENUE, TORONTO, ONTARIO M1S 3A7 · TEL: (416) 754-8515 · FAX: (416) 754-8516

Details of Under-Floor Weepers

SITE: Lockhart II and Lockhart
Lockhart Road, City of Barrie

DESIGNED BY: N.A
CHECKED BY: B.L
DWG NO.: 5
SCALE: N.T.S.
REF. NO.: 1901-S077
DATE: May 2021
REV -