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PROJECT NO.: SM 301724-G October 25, 2020

RUDANCO HOSPITALITY CORPORATION
4728 DORCHESTER ROAD – UNIT 11B, 2ND FLOOR
Niagara Falls, Ontario
L2E 7H9

Attention: Jeremia Rudan

GEOTECHNICAL INVESTIGATION
PROPOSED HIGH RISE DEVELOPMENT
LOT 175 PORTAGE ROAD
NIAGARA FALLS, ONTARIO

Dear Mr. Rudan,

Further to your authorisation, SOIL-MAT ENGINEERS has prepared this geotechnical investigation report in connection with the above noted project. The fieldwork, reporting, and laboratory testing were conducted in general accordance with our proposal P301724, dated April 27, 2021. Our comments and recommendations, based on our findings at the borehole locations, are presented in the following paragraphs.

1. INTRODUCTION

We understand that the project will involve the construction of two high-rise structures, on the order of 55 storeys in height, potentially higher, with a shared parking podium and up to 3 underground parking levels located at the property located at Lot 175 Portage Road in Niagara Falls, Ontario. The purpose of this geotechnical investigation work was to assess the subsurface soil, bedrock, and groundwater conditions, and to provide our comments and recommendations with respect to the design and construction of the foundations for the proposed development, from a geotechnical point of view.

This report is based on the above summarised project description, and on the assumption that the design and construction will be performed in accordance with applicable codes and standards. Any significant deviations from the proposed project design may void the recommendations given in this report. If significant changes are made to the proposed design, this office must be consulted to review the new design with respect to the results of this investigation. It is noted that SOIL-MAT ENGINEERS has also conducted Phase One and Two Environmental Site Assessments (ESAs) for the subject site, which have been reported under a separate cover.

2. PROCEDURE

The subsurface conditions were assessed in a total of thirteen [13] sampled boreholes advanced at the locations illustrated in the attached Drawing No. 1, Borehole Location Plan. It is noted that some of these boreholes were advanced as part of the Phase Two Environmental Site Assessment. The boreholes were advanced between June 8 and July 22, 2021 cased, mud rotary drilling equipment under the direction of a representative of SOIL-MAT ENGINEERS to termination or auger refusal on inferred bedrock at depths of between approximately 1.3 and 34.0 metres below the existing grade. Upon completion of drilling the boreholes were backfilled in general accordance with Ontario Regulation 903, and the grade reinstated even with the surrounding ground surface.

Representative samples of the subsoils were recovered from the borings at selected depth intervals using split barrel sampling equipment driven in accordance with the requirements of the ASTM test specification D1586, Standard Penetration Resistance Testing. After undergoing a general field examination, the soil samples were preserved and transported to the SOIL-MAT laboratory for visual, tactile, and olfactory classifications. Routine moisture content tests were performed on all soil samples recovered from the borings, with hand penetrometer testing conducted on cohesive samples. In addition, six [6] selected samples were subjected to grain size analyses. The results of this testing have been presented in the attached Grain Size Analysis Nos. 1 to 6, inclusive, appended to the end of this report.

Upon completion of drilling, groundwater monitoring wells were installed at Borehole Nos. 101, 104, 105, 106, 107, and 108 to allow for the future monitoring of the groundwater level. The monitoring wells consisted of 50-millimetre PVC pipe screened in the lower 3.0 metres. The monitoring wells were encased in well filter sand up to approximately 0.3 metres above the screened portion, then with bentonite ‘hole plug’ to the surface and fitted with a protective steel ‘stick up’ casing. The remaining boreholes were backfilled in general accordance with Ontario Regulation 903, and the ground surface was reinstated even with the surrounding grade.

Additionally, the bedrock was cored a distance of approximately 4.9 metres using Hq diamond barrel coring equipment at Borehole No. 1. It is noted that attempts to core the bedrock at other borehole locations were unsuccessful, indicating a highly weathered/fractured condition of the upper levels of the bedrock. Recovered core samples of the bedrock were preserved and returned to the SOIL-MAT laboratory for testing including Rock Quality Designation [RQD] and unconfined compressive strength testing. The results of this testing, along with photographic record of the recovered core samples can be found appended to the end of this report.

The boreholes were located in the field by representatives of SOIL-MAT ENGINEERS, based on accessibility over the site and clearance of underground services, as well as based on the requirements of the Phase Two ESA. The ground surface elevation at the borehole locations has been referenced to a site-specific temporary benchmark, described as the top of the manhole lid located on Portage Road as illustrated in the attached Drawing No. 1. This temporary benchmark has been assigned an elevation of 100.0 metres for convenience.

Details of the conditions encountered in the boreholes are presented in the Log of Borehole Nos. 1, 2, and 101 to 109, following the text of this report. It is noted that the boundaries of soil types indicated on the borehole logs are inferred from non-continuous soil sampling and observations made during drilling. These boundaries are intended to reflect transition zones for the purpose of geotechnical design and therefore should not be construed as the exact planes of geological change.

3. SITE DESCRIPTION AND SUBSURFACE CONDITIONS

The subject site consists of an irregular shaped parcel of land on the west side of Portage Road, between Marineland Parkway and McLeod Road in Niagara Falls, Ontario. At the time of the fieldwork, the site was noted to be predominantly grass-surfaced with scrub vegetation, bordered by a tree line to the west, relatively flat and even with the adjacent roadway. In addition, the site was noted to have an asphaltic-concrete surfaced entranceway with associated parking areas and a small gravel surfaced area to the north of the parking areas. A transmission tower was noted to stand at the northwest corner of the site. The subject site is bordered to the north by an undeveloped parcel of land, to the west by a railway line, to the south by a power generation station, and to the east by Portage Road, assuming north-south orientation of Portage Road.

The subsurface conditions encountered at the borehole locations are summarised as follows:

Topsoil

A surficial veneer of topsoil approximately 50 to 300 millimetres in thickness was encountered at Borehole Nos. 1, 2, and 103 through 107. It is noted that the depth of topsoil may vary across the site and from the depths encountered at the borehole locations. It is also noted that the term ‘topsoil’ has been used from a geotechnical point of view, and does not necessarily reflect the materials nutrient content or ability to support plant life.

Sand and Gravel Fill

A thin layer of sand and gravel fill was encountered at the surface of Borehole Nos. 101 and 108 and beneath the surficial veneer of topsoil at Borehole Nos. 1 and 107. The sand and gravel fill was generally noted to be in a compact to dense condition, predominately associated with gravel surfaced area just north of the asphalt paved parking areas.

Pavement Structure

Borehole Nos. 102 and 109 were advanced through the existing pavement structure which was noted to consist of approximately 60 to 75 millimetres of asphaltic concrete, overlying approximately 340 to 430 millimetres of compact granular base.

Silty Sand/Sandy Silt Fill

A deposit of silty sand/sandy silt fill was encountered beneath the topsoil layer and clayey silt/silty clay fill layer within Borehole Nos. 2 and 107, respectively. The fill material was noted to be brown in colour, contained trace to some gravel, and was generally noted to be in a loose to dense state. The silty sand/sandy silt fill was proven to depths of up to approximately 1 to 4 metres where encountered.

Clayey Silt/Silty Clay Fill

Clayey silt/silty clay fill was encountered beneath the topsoil layer and sand and gravel fill layer within Borehole Nos. 2 and 107. The fill material encountered was brown in colour, contained trace to some sand and gravel, with organic staining and debris in the upper levels in Borehole No. 107. The material was generally noted to be soft in consistency. The fill material encountered was proven to depths of up to approximately 2.5 to 2.3 metres where encountered.

Clayey Silt/Silty Clay

Native clayey silt/silty clay was encountered beneath the surficial topsoil, fill materials, and pavement structure at all of the borehole locations. The native cohesive soil is brown to reddish brown in colour, had a ‘reworked’ appearance in the upper levels, contained trace sand and gravel, and was generally firm to hard in consistency in the upper levels, becoming firm to soft below a depth of approximately 6 to 8 metres, approximately coincident with a transition in colour from brown to grey. The native clayey silt/silty clay was noted to exhibit intermittent sandy silt/silty sand layers. The clayey silt/silty clay soil was proven to termination at depths of between approximately

1.3 to 12.2 metres below the existing ground surface within Borehole Nos. 101 to 109. In Borehole Nos. 1 and 2, the native cohesive soil was proven to a depths of approximately 9.1 and 12.2 metres, and then encountered again at depth of approximately 27.4 metres to practical auger refusal on inferred bedrock at a depth of approximately 28 to 33.5 metres below the existing ground surface.

Sandy Silt/Silty Sand

Native sandy silt/silty sand was encountered beneath the native clayey silt/silty clay in Borehole Nos. 1 and 2. The native fine grained cohesionless soil was brown in colour, contained trace gravel in the lower levels, some clayey inclusions in the upper levels, and was generally in a compact to very dense condition. The sandy silt/silty sand was proven to a depth of approximately 26 metres at Borehole Nos. 1 and 2. It is noted that a veneer of coarser sand/silty sand with fine gravel and cobbles was also encountered above the limestone bedrock.

Grain size analyses testing were conducted on selected samples of the native soils recovered from the boreholes. The results of this grain size and Atterberg limits testing can be found appended to the end of this report, and are summarized as follows:

Table A
Grain Size Analyses

Sample ID	Depth	% Clay	% Silt	% Sand	% Gravel	Hydraulic Conductivity, k [cm/s]	Estimated Infiltration Rate, [mm/hr]
BH01A SS5	3.0 m	17	67	10	6	10^{-6}	<10
BH01A SS9	9.1 m	39	46	15	0	10^{-7}	<10
BH01A SS11	15.2 m	4	15	81	0	10^{-4}	50 to 60
BH2 SS6	4.6 m	19	76	5	1	10^{-6}	<10
BH2 SS8	7.6 m	38	53	2	7	10^{-7}	<10
BH2 SS11	21.3 m	3	20	77	0	10^{-4}	50 to 60

The field and laboratory testing demonstrate the native soils in the upper levels to consist of a silt with some clay, with traces of sand and gravel, increasing in clay content with depth becoming a silt and clay mixture with some sand. According to the Unified Soil Classification System (USCS), the soils are classified as M.H. – Inorganic silts, with slight plasticity in the upper levels, becoming C.L. – Inorganic clays of low to medium plasticity, silty clays with increasing depth. These soils would generally behave as a low permeability to an effectively impermeable cohesive material, with occasional more permeable seams.

The field and laboratory testing demonstrate the native soils in the lower levels to consist of silty sand/sandy silt mixtures with traces of clay. According to the Unified Soil Classification System (USCS), the soils are classified as S.M. – Silty sands, sand-silt mixtures to S.P. – Poorly graded sands, and would be considered relatively permeable.

A review of available published information [Quaternary Geology of Ontario, Southern Sheet Map 2556] indicate the subsurface soils to consist of fine-textured glaciolacustrine deposits of silt and clay, with minor sand and gravel, consistent with our experience in the area and observations during drilling.

Limestone/Dolostone Bedrock

Limestone/dolostone bedrock was encountered/inferred from auger refusal at depths of between approximately 32 to 34 metres below the existing grade at Borehole Nos. 1 and 2. The depths and elevations at which bedrock was encountered/inferred from auger refusal have been summarised as follows:

Table B
Summary of Bedrock Depths

Borehole No.	Ground Surface Elevation	Bedrock Depth	Bedrock Elevation
1	*99.50 m	33.6 m	*65.9 m
2	*99.82 m	32.0 m	*67.8 m

*Elevations based on reference to temporary benchmark was an assumed elevation of 100.00 metres

As previously noted, the above elevations are based on reference to a temporary benchmark with an assumed elevation of 100.00 metres, and should not be considered the geodetic elevation of the ground surface or bedrock.

The bedrock was cored at Borehole No. 1, while multiple attempts to core the bedrock were unsuccessful at Borehole No. 2. The bedrock cores were noted to yield recoveries of approximately 75 to 100 per cent, with a Rock Quality Designation [RQD] of approximately 46 to 65 per cent, indicating a relatively poor to fair quality bedrock. Unconfined compressive strength testing on selected portions of the recovered core samples yielded compressive strengths of approximately 30.8 to 96.3 MPa, with an average of 52.3 MPa. The results of this testing can be found appended to the end of this report, and have been summarised as follows:

Table C
Summary of Bedrock Coring

Borehole No. 1					
Depth of Core (m)	Elevation of Core (m)	Recovery	Rock Quality Designation (RQD)	Depth, Elevation of Tested Core Sample	Unconfined Compressive Strength
33.9 to 34.5	65.6 to 65.0	75%	52%	34.2 m, 65.3 m	40.7 MPa
35.4 to 35.6	64.1 to 63.9	100%	65%	35.5 m, 64.0 m	40.9 MPa
35.7 to 36.0	63.8 to 63.5	100%	65%	35.9 m, 59.7 m	41.0 MPa
36.7 to 36.9	62.8 to 62.6	86%	57%	36.8 m, 58.7 m	96.3 MPa
38.1 to 38.2	61.4 to 61.3	78%	59%	38.2 m, 61.4 m	64.3 MPa
38.3 to 38.5	61.2 to 61.0	78%	59%	38.4 m, 57.1 m	30.8 MPa

Based on a review of the recovered core samples, as well as available published literature and past experience in the area, the bedrock consists of limestone and dolostone of the Guelph formation. The limestone/dolostone bedrock is grey, generally fractured and weathered in the upper levels, with occasional vugs and solution cavities. The bedrock is considered competent in terms of the foundation/excavation requirements for the proposed project, although occasional fissures and/or solution cavities have historically been encountered.

It is noted that the bedrock in the area has historically been noted to contain horizontal fissures or fractures. While not explicitly encountered in Borehole No. 1, the unsuccessful attempts to core the bedrock at Borehole No. 2 were the result of a loss of coring water, fractures and layering of the bedrock with soil. As such, the presence of such horizontal fissures within the bedrock should not be ruled out. In the event that the bedrock is to be utilised for foundations such as caissons, further assessment of the bedrock may be prudent to confirm the condition of the upper levels of the bedrock.

Groundwater Observations

All of the boreholes were recorded as open and ‘dry’ upon completion with the exception of Borehole Nos. 1 and 2, which were noted to be wet at various depths upon completion of drilling. It is noted that insufficient time would have passed for the static groundwater level to stabilise in the open boreholes. As noted above, Borehole Nos. 101, and 104 through 108 were fitted with groundwater monitoring wells to allow for future monitoring of the groundwater levels. Manual monitoring well readings were taken from all of the installed monitoring well locations across the site on March 12, March 15, and September 10, 2021 and have been summarized in the following charts:

Table D
Summary of Groundwater Levels

Monitoring Well No.	Monitoring Well Depth [m]	Ground Surface Elevation [m]	July 22, 2021		August 11, 2021	
			Groundwater Depth [m]	Groundwater Elevation [m]	Groundwater Depth [m]	Groundwater Elevation [m]
101	4.6	99.61	0.70	98.9	2.77	96.8
104	4.6	99.57	1.06	98.5	1.85	97.7
105	12.0	99.48	Dry	<87.5	Dry	<87.5
106	4.6	99.77	0.72	99.1	1.30	98.5
107	12.0	99.59	Dry	<87.6	Dry	<87.6
108	4.6	99.62	1.26	98.4	2.39	97.2

The groundwater readings summarised above indicate shallower ‘perched’ groundwater levels in Monitoring Well Nos. 101, 104, 106, and 108, which were installed to depths of approximately 5 metres, screened within predominately clayey soils, while Monitoring Well Nos. 105 and 107, installed to depths of approximately 12 metres and screened within more permeable sandy soils. Based on these readings and corresponding monitoring well depths and screened intervals, it is likely the shallower groundwater levels observed are reflective of a shallower aquifer or perched water conditions.

As such, shallower local perched water deposits should be expected across the site, however the static groundwater level is below depths of 12 metres, and estimated to be as much as 15 to 18 metres or more, below the anticipated depths of construction. This is consistent with our experience on other nearby properties. The perched/shallower groundwater conditions would be relatively limited, and may result in initial greater flows of infiltration, however would not be considered to result in significant infiltration into open excavations.

4. FOUNDATION CONSIDERATIONS

SHALLOW FOUNDATIONS

It is understood that the project will involve the construction of a high-rise development with multiple underground levels extending to depths of up to approximately 12 metres. While the use of spread footings will not likely be feasible for the loads associated with the high rise buildings, the native sandy silt/silty sand soils present at the anticipated founding depth, below about 9 to 10 metres, would be considered capable of supporting bearing capacities of up to 500 kPa [~10,000 psf] SLS and 750 kPa [~15,000 psf] ULS for the use of design of spread footings. Where spread footings using the above bearing capacities would result in a spread footing coverage of more than 50 per cent, consideration should be given to a raft slab to support the proposed building, utilising the above bearing capacities. If a flexible design approach is used, a conservatively value of subgrade modulus of k = 70 MN/m^3 [~275 pci] may be considered.

CAISSONS

In the event that spread footings or a raft slab are not feasible for the support of the proposed structure, deep foundations extending to the limestone/dolostone bedrock may be required to support the proposed high-rise structures. Caissons extending to the competent limestone/dolostone bedrock encountered at depths of approximately 28 to 34 metres below the existing grade, below any significantly fractured or weathered surface layers, may be designed considering a SLS and ULS bearing capacity of 3,500 kPa [~70, 000 psf], based on the results of the unconfined compressive strength testing of the recovered bedrock core samples. Higher bearing capacities may be available within the competent limestone/dolostone bedrock, however confirmation of such bearing capacities would require additional coring of the bedrock. Where caissons are socketed into the competent bedrock, a minimum of 1.0 metre into the bedrock, skin friction may also be considered, using a value of 500 kPa [~10,000 psf].

Caisson excavations should be provided a steel liner to maintain the integrity of the open hole and prevent the infiltration of water. The contractor should be prepared to provide such a steel liner over the entire length of the caisson.

In the event that it is not possible to fully dewater the open caissons, the contractor should be prepared to place concrete by means of a ‘tremmie’ pipe method. The contractor should maintain a positive head of concrete in the liner while it is being removed to avoid the intrusion of loose materials [known as ‘necking’] into the caisson. The base of the caissons should be thoroughly cleaned to remove all loose or disturbed material immediately prior to the placement of concrete. The installation of caissons should be monitored by a representative of SOIL-MAT ENGINEERS & CONSULTANTS LTD.

GENERAL FOUNDATION COMMENTS

It is noted that the SLS value represents the Serviceability Limit State, which is governed by the tolerable deflection [settlement] based on the proposed building type, using unfactored load combinations. The ULS value represents the Ultimate Limit State and is intended to reflect an upper limit of the available bearing capacity of the founding soils in terms of geotechnical design, using factored load combinations. There is no direct relationship between ULS and SLS; rather they are a function of the soil type and the tolerable deflections for serviceability, respectively. Evidently, the bearing capacity values would be lower for very settlement sensitive structure and larger for more flexible buildings. It is also noted that the SLS and ULS bearing capacities are equivalent for the limestone bedrock, as in order for serviceability limits to be realised, ultimate failure of the bedrock would have to occur.

All footings, caisson caps, grade beams, etc., exposed to the environment must be provided with a minimum of 1.2 metres of earth cover or equivalent insulation to protect against frost damage. This frost protection would also be required if construction were undertaken during the winter months. All footings and foundations should be designed and constructed in accordance with the current Ontario Building Code.

With foundations designed as outlined above and as required by the Building Code, and with careful attention paid to construction detail, total and differential settlements should be small, and certainly well within normally tolerated limits of 25 and 20 millimetres, respectively, for the type of building and occupancy expected.

It is noted that the performance of deep foundation schemes is greatly dependent on the method, equipment, and workmanship utilized during construction. It is therefore essential that installation procedures for the deep foundations be monitored/evaluated by SOIL-MAT ENGINEERS.

It is imperative that a soils engineer be retained from this office to provide geotechnical engineering services during the excavation and foundation construction phases of the project. This is to observe compliance with the design concepts and recommendations of this report and to allow changes to be made in the event that subsurface conditions differ from the conditions identified at the borehole locations.

It is recommended that our office be consulted during the detailed design stage of the foundations for various structures and given an opportunity to review the foundation design scheme to ensure it is consistent with the recommendations of this report.

5. LATERAL EARTH PRESSURE

The design of underground basement foundation walls, shoring, etc. should take into consideration the different parameters for the various soil conditions encountered, which have been summarised as follows:

Table E
Soil Parameters

Soil Strata	Depth	Unit weight γ	Friction angle ϕ	Cohesion c	ko	k_A	k_P
Clayey Silt/ Silty Clay	0 to 12 m	18.5 kN/m^3	32	10	0.47	0.31	3.3
Sandy Silt/ Silty Sand	12 to 30 m	19.5 kN/m^3	36	0	0.41	0.26	3.8

6. SEISMIC DESIGN CONSIDERATIONS

The structure shall be designed according to Section 4.1.8 of the Ontario Building Code, Ontario Regulation 332/12. It is noted that surface shear wave velocity testing was conducted by Geophysics GPR International Inc., the results of which have been appended to the end of this report. Based on the results of this shear wave velocity testing, a seismic Site Classification of C – very dense soil and soft rock, may be used for foundations greater than 10 metres below the ground surface. Where foundations are situated shallower than 10 metres, a Site Classification of D – Stiff Soil, should be considered.

The seismic data from Supplementary Standard SB-1 of the Ontario Building Code for Niagara Falls are as follows:

$S_a(0.2)$	$S_a(0.5)$	$S_a(1.0)$	$S_a(2.0)$	$S_a(5.0)$	$S_a(10.0)$	PGA	PGV
0.321	0.157	0.072	0.0320	0.0076	0.0030	0.207	0.121

7. EXCAVATIONS AND EXCAVATION SUPPORT CONSIDERATIONS

Excavations for the installation of foundations and underground services are expected to extend to depths of up to about 12 metres below the existing grade, in order to accommodate the up to 3 underground parking levels. Open excavations through the clayey silt/silty clay above the groundwater level should be relatively straightforward, with the sides remaining stable for the short construction period at 45 to 60 degrees to the horizontal, while excavations through the fine-grained granular soils and fill material would be expected to remain stable of up to angles of 45 degrees to the horizontal. During periods of heavy precipitation, where perched wet seams are encountered, or where excavations extend near to below the static groundwater level, the excavation sides should be expected to ‘slough-in’ to as flat as 3 horizontal to 1 vertical, or flatter.

All excavations must comply with the current Occupational Health and Safety Act and Regulations for Construction Projects.

Depending on the final design and limits of the new building, excavation support measures are expected to be required in order to maintain the stability of the excavations in proximity to adjacent roadways and structures. A speciality contractor or shoring consultant should be consulted with respect to the design of such a shoring system. The soil parameters outlined above should be considered in the design of shoring systems, such as soldier piles and timber lagging or caisson wall. Caissons may be designed for end bearing using the values provided above for the limestone bedrock, or a bearing capacity of 300 kPa [~6,000 psf] SLS and 400 kPa [~8,000 psf] ULS for the overburden soils. The shoring system should be monitored during construction, and the contractor should have a contingency plan in place to be implemented should deflections of the shoring system exceed the tolerable limits.

The shoring can be supported either by anchors extending into the overburden soil or by rakers extending into the excavation, although from a contractor's point of view, tie-back anchors would be preferred, provided they can be installed to avoid adjacent foundations and underground utilities. The shoring must be monitored for movements, and a plan must be available before the excavations begin, to rectify the shoring system should movements become apparent. It is noted that significant movements of the shoring system may take place if conventional rakers are used to support the shoring system since compression of the members and the supporting footings must occur before the rakers can begin to carry load. In this regard, anchors are preferred since they allow pre-stressing of the shoring system to the design load even before the excavations reach their final grade. Alternatively, the rakers can be designed to allow jacking in the design load, and thus minimising movements. The design bearing capacity of the footings supporting inclined rakers should be limited to one half of the bearing capacities presented above for spread footing foundations.

It is anticipated that the general excavation for the structure will extend into the native silty sand. The base of the excavation in the compact to dense sandy silt soils should remain firm and stable, however may be prone to localized disturbance from construction traffic, exposure to the elements, etc. It is recommended that the excavation base be provided with a layer of coarse crushed granular material, such as Ontario Provincial Standard Specification [OPSS] Granular 'B', Type II [crushed bedrock], perhaps 200 to 300 millimetres thick and compacted to 100 per cent of its standard Proctor maximum dry density [SPMDD] to provide a stable 'clean' working surface.

As noted above, the groundwater level is estimated at a depth of approximately 15 metres or more below the existing ground surface, however would be expected to fluctuate seasonally, generally below the anticipated depth of excavation. As noted above it is anticipated that shallower perched groundwater deposits in the more permeable seams will be encountered. As such, some infiltration of groundwater from permeable seams into open excavations as well as from surface runoff should be anticipated. It should be possible to control groundwater infiltration via typical construction dewatering techniques such as pumping from sumps and ditches in the base of the excavation. Where such perched water deposits are encountered, a greater initial rate of infiltration should be expected, however would be expected to exfiltrate from the base of the excavation within the more permeable sandy soils, and/or be readily handled with a series of dewatering pumps.

8. FLOOR SLAB AND PERMANENT DRAINAGE

Where a raft slab is not utilised, the building floor slabs may be constructed using conventional slab-on-grade techniques on a prepared subgrade. The exposed subgrade surface should be well compacted in the presence of a representative of SOIL-MAT ENGINEERS. Any soft 'spots' delineated during this work must be sub-excavated and replaced with quality backfill material compacted to 100 per cent of its standard Proctor maximum dry density. The subgrade level can then be raised to the design level with granular soils compacted to 100 per cent of its standard Proctor maximum dry density. Granular fill, such as an imported Ontario Provincial Standard Specification [OPSS] Granular 'B', Type II (crushed limestone bedrock) product, is preferred within the building footprint due to its relative insensitivity to weather conditions, ease in achieving the required degree of compaction, and its quick response to applied stresses.

As with all concrete floor slabs, there is a tendency for the floor slabs to crack. The slab thickness, concrete mix design, the amount of steel and/or fibre reinforcement and/or wire mesh placed into the concrete slab, if any, will therefore be a function of the owner's tolerance for cracks in, and movements of, the slabs-on-grade, etc. The 'saw-cuts' in the concrete floors, for crack control, should extend to a minimum depth of 1/3 of the thickness of the slab.

A moisture barrier will be required under the floor slabs such as the placement of at least 200 millimetres of compacted 20-millimetre clear crushed stone. At a minimum the moisture barrier material should contain no more than 10 per cent passing the No. 4 sieve. Where 'non-damp' floor slabs are required, as for instance under sheet vinyl floor coverings, etc., extra efforts will be required to damp proof the floor slab, as with the additional provision of a heavy 'poly' sheet, damp proofing sprays/membranes, drainage board products, etc. Where ‘poly’ sheets are used care should be taken to prevent puncturing and tearing and a sufficiently heavy gauge material be provided.

Curing of the slab-on-grade must be carefully specified to ensure that slab curl is minimised. This is especially critical during the hot summer months of the year when the surface of the slab tends to dry out quickly while high moisture conditions in the moisture barrier or water trapped on top of any ‘poly’ sheet at the saw cut joints and cracks, and at the edges of the slabs, maintains the underside of the slab in a moist condition.

It is important that the concrete mix design provide a limiting water/cement ratio and total cement content, which will mitigate moisture related problems with low permeance floor coverings, such as debonding of vinyl and ceramic tile. It is equally important that excess free water not be added to the concrete during its placement as this could increase the potential for shrinkage cracking and curling of the slab.

All basement foundation walls should be suitably damp proofed, including the provision of a ‘dimple type’ drainage board to promote rapid drainage to a perimeter drainage system. This may require the use of foundation wall systems intended for ‘blind side’ or ‘single face’ application, depending on the feasibility of open cuts and need for excavation shoring. The perimeter drainage system should consist of 100-millimetre diameter perforated pipe, encased in a geofabric sock and covered with a minimum of 200 millimetres of a 20-millimetre clear crushed stone product, and the clear crushed stone in turn encased by a heavy filter geotextile product. The suppliers of the filter geotextile should be consulted as to the type best suited for this project. This office should examine the installation of the drains. Even a small break in the filtering materials could result in loss of fines into the drains with attendant performance difficulties, including settlements of the ground surface. The perimeter drains should outlet to a sump pit or retention tank a minimum of 150 millimetres below the underside of finished floor. The exterior grade around the structure should be sloped away from the structure to prevent the ponding of water against the foundation walls. The enclosed Drawing No. 2 shows schematics of the typical requirements for foundation construction with a basement level.

9. BACKFILL CONSIDERATIONS

The majority of excavated material will consist of the native clayey silt/silty clay, sandy silt/silty sand, and fill deposits encountered in the boreholes, as described above. These materials are generally considered suitable for use as engineered fill, service trench backfill, etc., provided the moisture content can be controlled to within 3 per cent of the material’s standard Proctor optimum value, and the material is free of organics, construction debris, and otherwise deleterious materials. It is recommended that the cohesive clayey silt/silty clay soils and sand and gravel fill materials be kept separate during excavation, to maintain the favourable somewhat granular nature of the sandier soils, which would be more suitable for use in areas of restricted access. Depending on the weather conditions at the time of construction, some moisture condition of the excavated materials may be required to achieve acceptable compaction densities and minimise long-term settlement. Compaction of the cohesive clayey silt/silty clay soils will prove to be difficult in areas where access with compaction equipment is restricted.

It is noted that the clayey silt/silty clay soils encountered are not considered to be free draining and should not be used where this characteristic is necessary. The sandy silt soils are generally considered to be moderately well draining, however may be affected by variation in the silt content, and may present some difficulty in achieving effective compaction in areas of restricted access. The use of a free draining, well-graded granular material, such as an Ontario Provincial Standard Specification [OPSS] Granular ‘B’, Type II (crushed limestone bedrock) is recommended for backfill against foundation walls or to raise the interior grade to the design subgrade level. This material is more readily compacted in restricted access areas, and generally presents a more positive support condition for concrete floor slabs and exterior pavement. As noted above the sandier soil deposits encountered may be suitable for such applications, however this would be best assessed at the time of construction.

It is very important that the placement moisture content of the backfill soils be within 3 per cent of its standard Proctor optimum moisture content during placement and compaction to minimise long term subsidence [settlement] of the fill mass. Any imported fill required in service trenches or to raise the subgrade elevation should have its moisture content within 3 per cent of its optimum moisture content and meet the necessary environmental guidelines.

A representative of SOIL-MAT should be present on-site during the backfilling and compaction operations to confirm the provision of uniform compaction of the backfill material to project specification requirements. Close supervision is prudent in areas that are not readily accessible to compaction equipment, for instance near the end of compaction 'runs'. All structural fill should be compacted to 100 per cent of its standard Proctor maximum dry density [SPMDD]. Backfill within service trenches, areas to be paved, etc., should be compacted to a minimum of 98 per cent of SPMDD. The appropriate compaction equipment should be employed based on soil type, i.e. pad-toe for cohesive soils and smooth drum/vibratory plate for granular soils. A method should be developed to assess compaction efficiency employing the on-site compaction equipment and backfill materials during construction.

10. PAVEMENT DESIGN CONSIDERATIONS

All areas to be paved should be stripped of all organic or otherwise unsuitable materials. The exposed subgrade should be proofrolled with 3 to 4 passes of a loaded tandem truck in the presence of a representative of SOIL-MAT ENGINEERS & CONSULTANTS LTD., immediately prior to the placement of the sub-base material. Any areas of distress revealed by this or other means must be sub-excavated and replaced with suitable backfill material. Alternatively, the soft areas may be stabilised by placing coarse crushed stone and 'punching' it into the soft areas. Where the subgrade condition is poorer it may be necessary to implement more aggressive stabilisation methods, such as the use of coarse aggregate [50-millimetre clear stone, 'rip rap', etc.] 'punched' into the soft areas. The need for the treatment of softened subgrade will be reduced if construction is undertaken during the dry summer months and careful attention is paid to the compaction operations. The fill over shallow utilities cut into or across paved areas such as telephone, hydro, gas, etc. must also be compacted to 100 per cent of its standard Proctor maximum dry density.

Good drainage provisions will optimise the long-term performance of the pavement structure. The subgrade must be properly crowned and shaped to promote drainage to the subdrain system. Subdrains should be installed to intercept excess subsurface water and mitigate softening of the subgrade material. Surface water should not be allowed to pond adjacent to the outer limits of the paved areas.

The most severe loading conditions on the subgrade typically occur during the course of construction, therefore precautionary measures may have to be taken to ensure that the subgrade is not unduly disturbed by construction traffic. SOIL-MAT should be given the opportunity to review the final pavement structure design and subdrain scheme prior to construction to ensure that they are consistent with the recommendations of this report.

If construction is conducted under adverse weather conditions, additional subgrade preparation may be required. During wet weather conditions, such as during the Fall and Spring months, or during colder winter weather, it should be anticipated that additional subgrade preparation will be required, such as additional depth of Ontario Provincial Standard Specification [OPSS] Granular 'B', Type II (crushed limestone bedrock) sub-base material. It is also important that the sub-base and base granular layers of the pavement structure be placed as soon as possible after exposure, preparation, and approval of the exposed subgrade.

The suggested pavement structures outlined in Table F below are based on subgrade parameters estimated on the basis of visual and tactile examinations of the on-site soils and past experience. The outlined pavement structure may be expected to have an approximate ten to fifteen-year life, assuming that regular maintenance is performed. Should a more detailed pavement structure design be required, site specific traffic information would be needed, together with detailed laboratory testing of the subgrade soils.

Table F
Recommended Pavement Structures

LAYER DESCRIPTION	COMPACTION REQUIREMENTS	LIGHT DUTY SECTIONS	HEAVY DUTY [TRUCK ROUTE]
Asphaltic Concrete Wearing course OPSS HL 3 or HL 3A	Min. 92 % Marshall MRD	65 millimetres	40 millimetres
Binder Course OPSS HL 8	Min. 92 % Marshall		80 millimetres
Base Course OPSS Granular A	100% SPMDD	150 millimetres	150 millimetres
Sub-base Course OPSS Granular B Type II	100% SPMDD	300 millimetres	450 millimetres

* Marshall MRD denotes Maximum Relative Density.
* SPMDD denotes Standard Proctor Maximum Dry Density, ASTM-D698.

Depending on the arrangement of light duty and heavy duty pavement sections, the transition between sections may present some difficulty for contractors. In this regard, consideration might be given to a slightly increased light duty pavement structure consisting of 50 millimetres of HL8 binder course and 40 millimetres of HL3 surface course asphaltic concrete. This structure will provide for a continuous depth of surface course asphalt allowing for ease of construction. As well, such a structure would have an improved performance over an increased design life. Such an arrangement of asphalt layers would also allow for future rehabilitation with a ‘mill and pave’ type operation.

Where asphalt pavement is to be constructed above the roof deck of the below grade parking level, the granular base layers recommended for the light duty pavement structure recommended above may be considered for both light duty and heavy duty areas. It is noted that in such cases the roof deck slab should be sufficiently sloped and/or provided with suitable subdrains, in order to promote rapid drainage of water from beneath the pavement. As well the roof slab should be provided with a suitable water proofing system.

To minimise segregation of the finished asphalt mat, the asphalt temperature must be maintained uniform throughout the mat during placement and compaction. All too often, significant temperature gradients exist in the delivered and placed asphalt with the cooler portions of the mat resisting compaction and presenting a honeycomb surface. As the spreader moves forward, a responsible member of the paving crew should monitor the pavement surface, to ensure a smooth uniform surface. The contractor can mitigate the surface segregation by ‘back-casting’ or scattering shovels of the full mix material over the segregated areas and raking out the course particles during compaction operations. Of course, the above assumes that the asphalt mix is sufficiently hot to allow the ‘back-casting’ to be performed.

11. SOIL EXPORT CONSIDERATIONS

As noted above, it is understood that the subject development will incorporate up to three underground parking levels, which would require the off-site disposal of surplus soil generated during construction. Ontario Regulation 406/19 has recently come into effect, which governs the management of excess soils. Management of surplus soils requires the developer to conduct an assessment of the subject site, along with rigorous sampling and analysis, based on volume of surplus soil generated, to support acceptance at off-site location. Such testing can be conducted once development details have been finalised, based on volume of surplus soils to be generated, as well as the results of the Phase One and Two Environmental Site Assessments, currently being conducted.

11. GENERAL COMMENTS

The comments provided in this document are intended only for the guidance of the design team. The material in it reflects SOIL-MAT ENGINEERS' best judgement in light of the information available at the time of preparation. The subsurface descriptions and borehole information are intended to describe conditions at the borehole locations only. It is the contractors' responsibility to determine how these conditions will affect the scheduling and methods of construction for the project. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. SOIL-MAT ENGINEERS accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

We trust that this geotechnical report is sufficient for your present requirements. Should you require any additional information or clarification as to the contents of this document, please do not hesitate to contact the undersigned.

Yours very truly,
SOIL-MAT ENGINEERS & CONSULTANTS LTD.

Scott Wylie, B. Eng., EIT

Kyle Richardson, P. Eng.
Project Engineer

LICENSED PROFESSIONAL ENGINEER
Oct 25/21
S.K. RICHARDSON
100179716
PROVINCE OF ONTARIO

Ian Shaw, P.Eng., QP_{ESA}
Senior Engineer

Enclosures: Drawing No. 1, Borehole Location Plan
Log of Borehole Nos. 1, 2, and 101 to 109
Grain Size Analyses
Unconfined Compressive Strength Testing
Shear Wave Velocity Testing [GPR File T213211]
Drawing No. 2 – Basement Perimeter Drainage

LEGEND

BH#	Borehole Location
TP#	Test Pit Location
TBM #	Temporary Benchmark Top of Manhole Cover. Assigned Elevation of 100.00 m

NOTES

1. This drawing should be read in conjunction with Soil-Mat Engineers & Consultants Ltd. Report No. SM 301724-G.

2. Borehole locations are approximate.

SOIL-MAT
ENGINEERS & CONSULTANTS LTD.

Proposed High Rise
Development
Lot 175 Portage Road
Niagara Falls, Ontario

Borehole Location Plan

Project No. SM 301724-G

Date: July 2021

Drawn: MA | Checked: KR

SM 301724-G Borehole Location Plan

Drawing No. 1

Log of Borehole No. 1

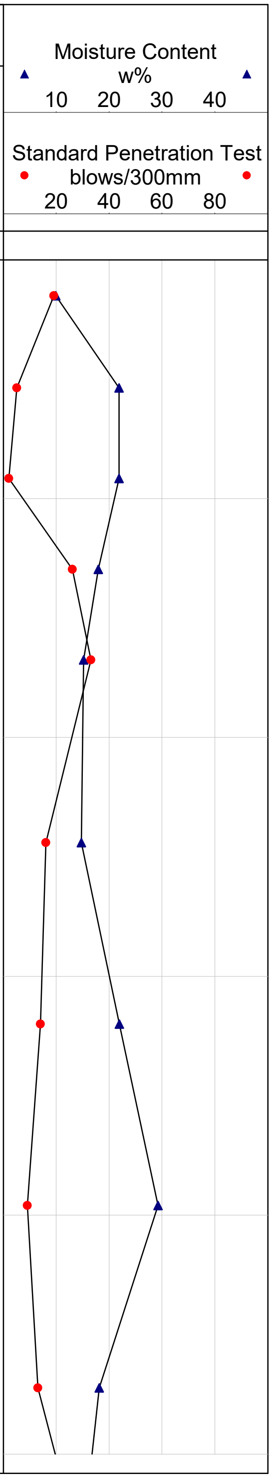
Project No: SM 301724-G-E
Project: Proposed High Rise Development
Location: Niagara Falls, Ontario
Client: Rudanco Hospitality Corporation

Project Manager: Kyle Richardson, P.Eng
Borehole Location: See Drawing No.1
UTM Coordinates - N: 4770409
E: 656392

Elevation (m)	Description
99.50	Ground Surface
	Topsoil Approximately 100 millimeters of topsoil.
98.90	**Sand and Gravel Fill** Brown, loose.
	Clayey Silt/Silty Clay Reddish brown, trace sand and gravel, trace organics and reworked in the upper levels, sandy silt/silty sand seam inclusions in lower levels, hard to stiff.
93.20	Transition in colour to grey.

SAMPLE

Type	Number	Blow Counts	Blows/300mm	Recovery	PP (kgf/cm2)	U.Wt.(kN/m3)
SS	1	12,11,8,9	19	▨		
SS	2	2,2,3,2	5	▨		
SS	3	2,1,1,5	2	▨		
SS	4	7,13,13,15	26	▨	2.0	
SS	5	15,15,18,15	33	▨	>4.5	
SS	6	7,8,8,10	16	▨	2.5	
SS	7	7,7,7,10	14	▨	2.0	
SS	8	4,4,5,6	9	▨	1.0	
SS	9	10,6,7,8	13	▨	1.0	



Drill Method: H.S.A./ M.R./C.B.
Drill Date: July 8, 2021
Hole Size: 250 Millimeters
Drilling Contractor: Elements Geo Drilling

Soil-Mat Engineers & Consultants Ltd.
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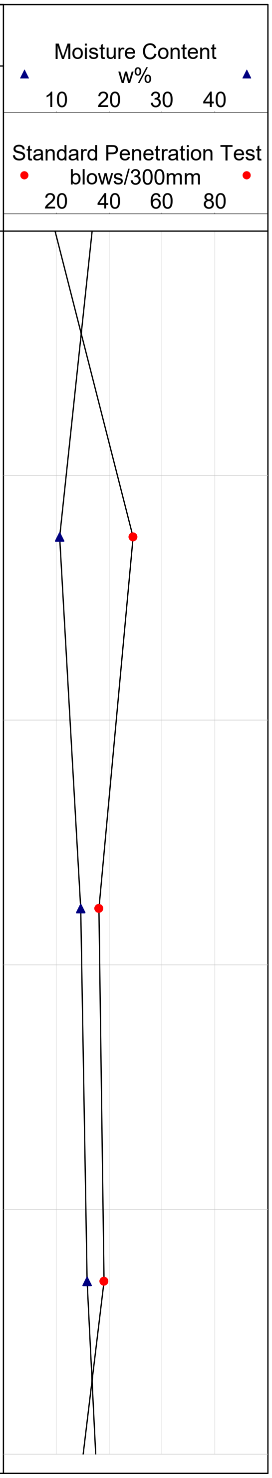
Datum: Temporary Benchmark
Field Logged by: MA
Checked by: KR
Sheet: 1 of 4

Log of Borehole No. 1

Project No: SM 301724-G-E
Project: Proposed High Rise Development
Location: Niagara Falls, Ontario
Client: Rudanco Hospitality Corporation

Project Manager: Kyle Richardson, P.Eng
Borehole Location: See Drawing No.1
UTM Coordinates - N: 4770409
E: 656392

Depth	Elevation (m)	Symbol	Description	Well Data	SAMPLE Type	Number	Blow Counts	Blows/300mm	Recovery	PP (kgf/cm2)	U.Wt.(kN/m3)
	89.10										
			Sandy Silt/Silty Sand Reddish brown, trace gravel in lower levels, dense to compact.								
41					SS	10	18,21,28,33	49	▨		
51					SS	11	17,18,18,20	36	▨		
61					SS	12	14,17,21,25	38	▨		



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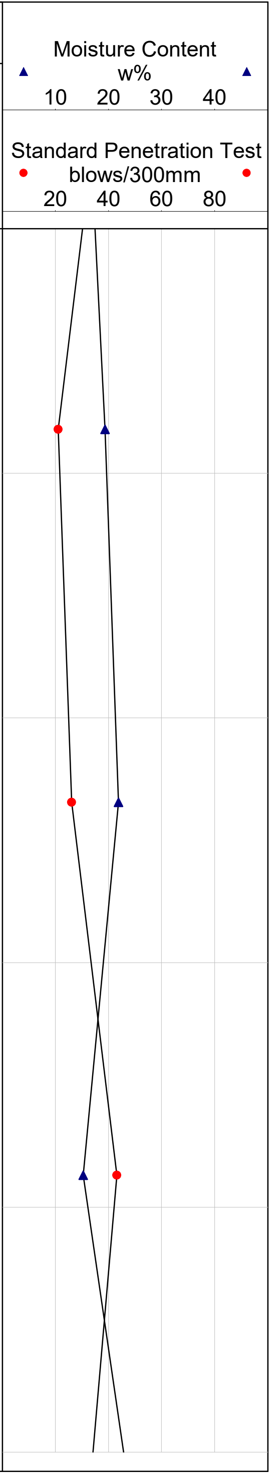
Location: Niagara Falls, Ontario
Client: Rudanco Hospitality Corporation

Project Manager: Kyle Richardson, P.Eng
Borehole Location: See Drawing No.1
UTM Coordinates - N: 4770409
E: 656392

Depth	Elevation (m)	Symbol	Description	Well Data	Type	Number	Blow Counts	Blows/300mm	Recovery	PP (kgf/cm2)	U.Wt.(kN/m3)
66											
67											
68											
69 21											
70											
71					SS	13	10,11,10,8	21	▨		
72 22											
73											
74											
75 23											
76											
77											
78											
79 24											
80											
81					SS	14	12,12,14,15	26	▨		
82 25											
83											
84											
85 26											
86	73.10										
87			**Clayey Silt/Silty Clay** Brown, to grey, trace gravel, hard.								
88											
89 27											
90											
91					SS	15	20,24,19,20	43	▨	>4.5	
92 28											
93											
94											
95 29											
96											
97											
98											



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Log of Borehole No. 1

Project No: SM 301724-G-E
Project: Proposed High Rise Development
Location: Niagara Falls, Ontario
Client: Rudanco Hospitality Corporation

Project Manager: Kyle Richardson, P.Eng
Borehole Location: See Drawing No.1
UTM Coordinates - N: 4770409
E: 656392

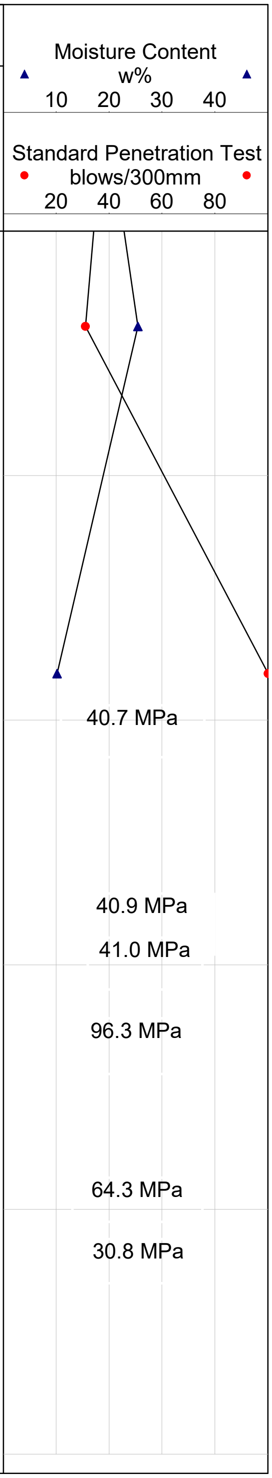
Depth	Elevation (m)	Symbol	Description	Well Data	SAMPLE Type	SAMPLE Number	SAMPLE Blow Counts	SAMPLE Blows/300mm	SAMPLE Recovery	SAMPLE PP (kgf/cm2)	SAMPLE U.Wt.(kN/m3)
99 00 01 02 03 04 05 06 07 08 09	31 32 33 66.00				SS	16	14,12,19,23	31			
10			sandy layer		SS	17	37,50/3"	100			
11 12 13 14 15	34 35		**Limestone** Grey, highly fractured and weathered in upper levels.		HQ	1	65% RQD				
16 17 18	36				HQ	2	46% RQD				
19 20 21	37				HQ	3	57% RQD				
22 23 24 25 26	38 60.99				HQ	4	59% RQD				
27 28 29 30 31	39		End of Borehole								

NOTES:

1. Boreholes was advanced using mud rotary equipment between July 5 and 8 2021 to termination at a depth of 33.6 metres. The bedrock was cored using HQ diamond barrel equipment to a depth of 38.5 metres.

2. Borehole has fitted with a seismic well upon completion of drilling.

3. Soil and bedrock samples will be discarded after 3 months unless otherwise directed by our client.



Drill Method: H.S.A./ M.R./C.B.
Drill Date: July 8, 2021
Hole Size: 250 Millimeters
Drilling Contractor: Elements Geo Drilling

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Log of Borehole No. 2

Project No: SM 301724-G-E
Project: Proposed High Rise Development
Location: Niagara Falls, Ontario
Client: Rudanco Hospitality Corporation

Project Manager: Kyle Richardson, P.Eng
Borehole Location: See Drawing No.1
UTM Coordinates - N: 4770370
E: 656499

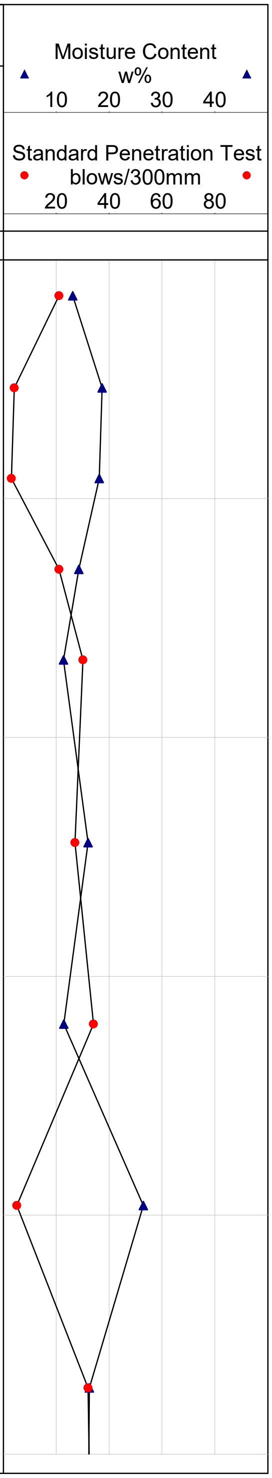
Depth ft: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Depth m: 0 1 2 3 4 5 6 7 8 9

Elevation (m)	Description
99.82	Ground Surface
99.52	**Topsoil** Approximately 300 millimetres of topsoil.
98.80	**Silty Sand/Sandy Silt Fill** Brown, trace to some gravel, loose.
97.30	**Clayey Silt/Silty Clay Fill** Brown, trace to some gravel, soft.
	Clayey Silt/Silty Clay Reddish brown, trace sand and gravel, trace organics and reworked in the upper levels, sandy silt/silty sand seam inclusions in lower levels, very stiff to hard.
92.70	Transition in colour to grey.
91.20	**Sandy Silt/Silty Sand** Brown, trace gravel, clayey silt/silty clay inclusions in upper levels, dense to very dense.

Well Data

SAMPLE

Type	Number	Blow Counts	Blows/300mm	Recovery	PP (kgf/cm2)	U.Wt.(kN/m3)
SS	1	4,10,11,14	21	▨		
SS	2	3,2,2,1	4	▨		
SS	3	0,2,1,1	3	▨		
SS	4	4,5,16,19	21	▨		
SS	5	12,15,15,22	30	▨	>4.5	
SS	6	9,11,16,17	27	▨	>4.5	
SS	7	11,16,18,20	34	▨	>4.5	
SS	8	3,2,3,4	5	▨	<1.0	
SS	9	11,13,19,21	32	▨		



Drill Method: S.S.A./H.S.A./M.R.
Drill Date: June 10, 2021
Hole Size: 250 Millimeters
Drilling Contractor: Elements Geo Drilling

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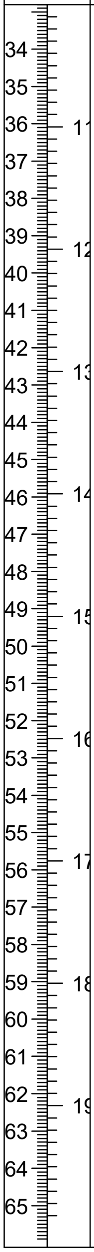
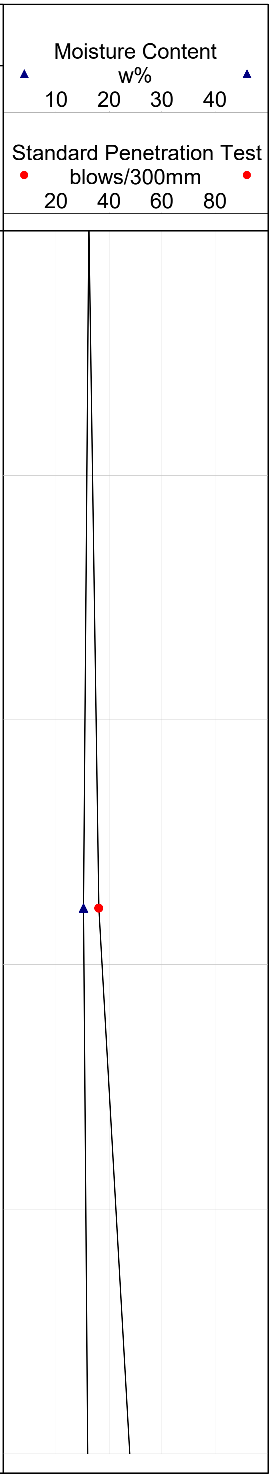
Log of Borehole No. 2

Project No: SM 301724-G-E
Project: Proposed High Rise Development
Location: Niagara Falls, Ontario
Client: Rudanco Hospitality Corporation

Project Manager: Kyle Richardson, P.Eng
Borehole Location: See Drawing No.1
UTM Coordinates - N: 4770370
E: 656499

Depth	Elevation (m)	Symbol	Description	Well Data	SAMPLE Type	Number	Blow Counts	Blows/300mm	Recovery	PP (kgf/cm2)	U.Wt.(kN/m3)
					SS	10	15,16,20,21	36	▆		





Drill Method: S.S.A./H.S.A./M.R.
Drill Date: June 10, 2021
Hole Size: 250 Millimeters
Drilling Contractor: Elements Geo Drilling

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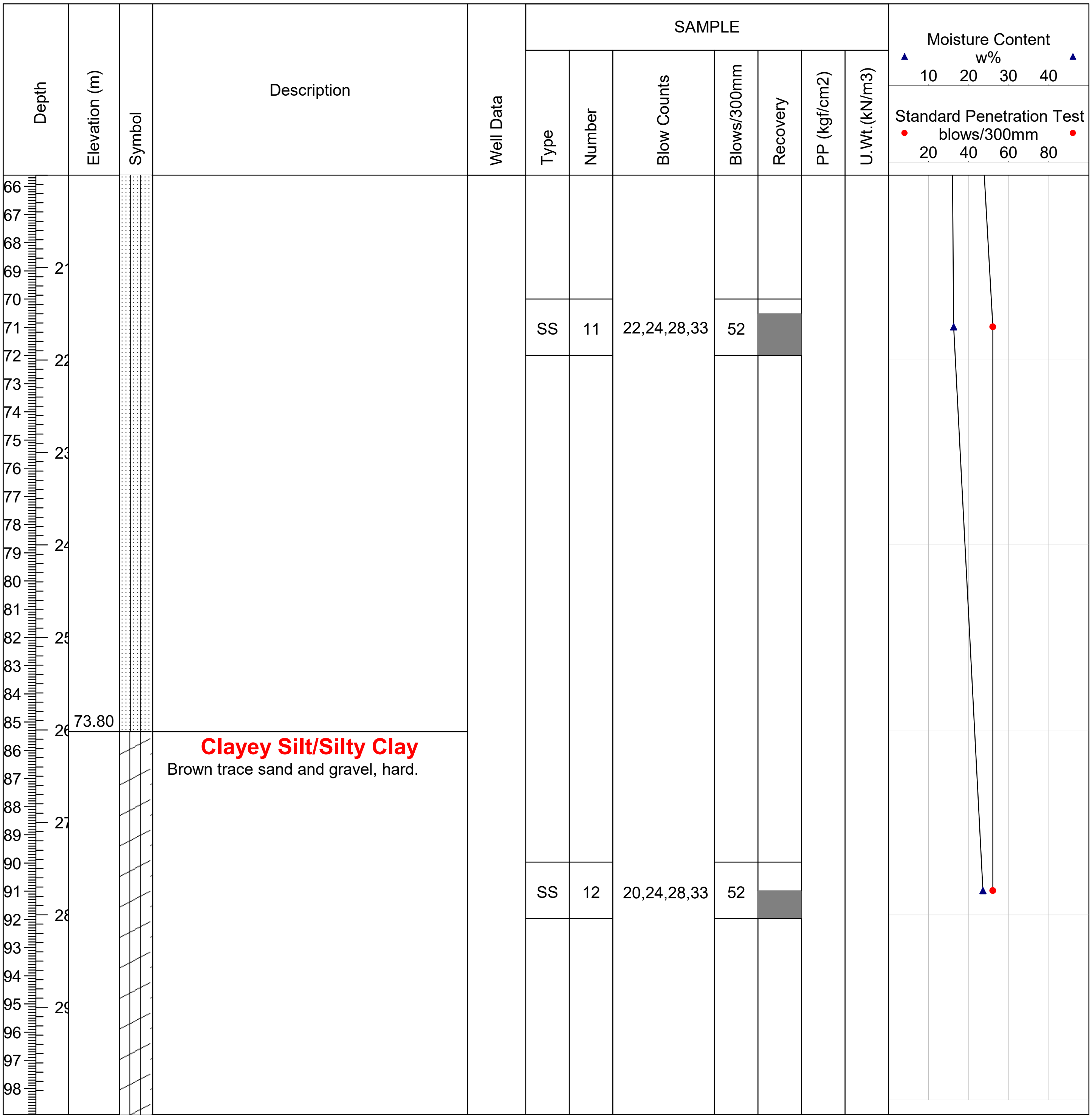
Log of Borehole No. 2

Project No: SM 301724-G-E
Project: Proposed High Rise Development
Location: Niagara Falls, Ontario
Client: Rudanco Hospitality Corporation

Project Manager: Kyle Richardson, P.Eng
Borehole Location: See Drawing No.1
UTM Coordinates - N: 4770370
E: 656499



Depth	Elevation (m)	Description	Type	Number	Blow Counts	Blows/300mm
71			SS	11	22,24,28,33	52
85	73.80	**Clayey Silt/Silty Clay** Brown trace sand and gravel, hard.				
91			SS	12	20,24,28,33	52

Drill Method: S.S.A./H.S.A./M.R.
Drill Date: June 10, 2021
Hole Size: 250 Millimeters
Drilling Contractor: Elements Geo Drilling

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Log of Borehole No. 2

Project No: SM 301724-G-E
Project: Proposed High Rise Development
Location: Niagara Falls, Ontario
Client: Rudanco Hospitality Corporation

Project Manager: Kyle Richardson, P.Eng
Borehole Location: See Drawing No.1
UTM Coordinates - N: 4770370
E: 656499

Depth	Elevation (m)	Symbol	Description	Well Data	SAMPLE Type	Number	Blow Counts	Blows/300mm	Recovery	PP (kgf/cm2)	U.Wt.(kN/m3)	Moisture Content w% ▲ 10 20 30 40 / Standard Penetration Test blows/300mm ● 20 40 60 80
99 00 01 02 03 04	31											Stopped mud rotary drilling at approximately 32.6 meters due to water loss (approximately 2500 liters from 30.48 to 32.6 meters), suspected highly fractured
05 06 07	32 67.80	▦	**Limestone** Grey, highly fractured and weathered in upper levels.		DC	12	100/2"	100				
	67.20		End of Borehole									
08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31	33 34 35 36 37 38 39											

NOTES:

1. Borehole was advanced using solid stem auger and mud rotary equipment on June 10, 2021 and June 11, 2021 to termination at a depth of 32.6 meters.

2. Borehole was recorded as open to a depth of 32.0 meters upon completion and backfilled as per Ontario Regulation 903.

3. Soil samples will be discarded after 3 months unless otherwise directed by our client.

Drill Method: S.S.A./H.S.A./M.R.
Drill Date: June 10, 2021
Hole Size: 250 Millimeters
Drilling Contractor: Elements Geo Drilling

Soil-Mat Engineers & Consultants Ltd.
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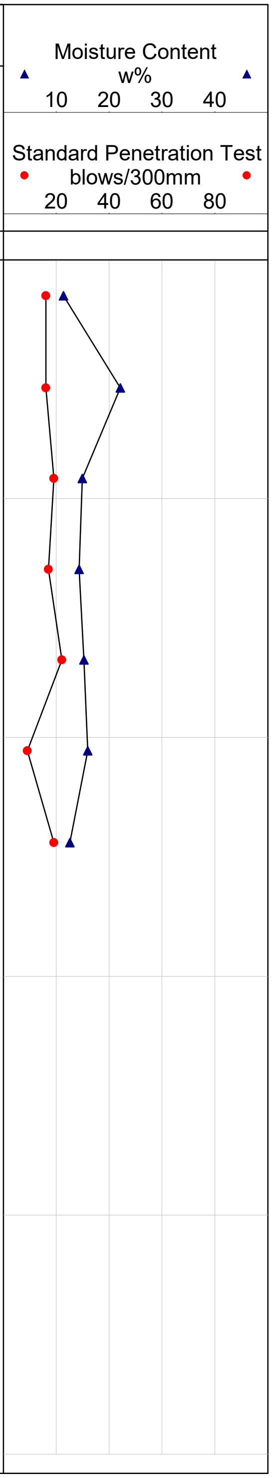
Checked by: KR
Sheet: 4 of 4

Log of Borehole No. 101

Project No: SM 301724-G-E
Project: Proposed High Rise Development
Location: Niagara Falls, Ontario
Client: Rudanco Hospitality Corporation

Project Manager: Kyle Richardson, P.Eng
Borehole Location: See Drawing No.1
UTM Coordinates - N: 4770406
E: 656381

Depth (m)	Elevation (m)	Description	Type	Number	Blow Counts	Blows/300mm	Recovery	PP (kgf/cm2)	U.Wt.(kN/m3)
0	99.61	Ground Surface							
	99.30	**Sand and Gravel Fill** Brown, loose.	SS	1	11,11,5,6	16			
		Clayey Silt/Silty Clay Reddish brown, trace sand and gravel, reworked in the upper levels, very stiff to stiff.	SS	2	4,7,9,12	16		>4.5	
			SS	3	5,8,11,14	19		>4.5	
			SS	4	3,8,9,15	17		3.5	
			SS	5	5,10,12,11	22		2.5	
			SS	6	2,3,6,10	9		2.5	
			SS	7	6,7,12,11	19		>4.5	
	94.40	End of Borehole							



NOTES:

1. Borehole was advanced using solid stem auger equipment on July 6, 2021 to termination at a depth of 5.2 meters.

2. Borehole was recorded as open and 'dry' upon completion and backfilled as per Ontario Regulation 903.

3. Soil samples will be discarded after 3 months unless otherwise directed by our client.

4. A monitoring well was installed. The following free groundwater level readings have been measured:

July, 22, 2021 - 0.70 meters

August, 11, 2021 - 2.77 meters

Drill Method: Hollow Stem Augers
Drill Date: July 6, 2021
Hole Size: 250 Millimeters
Drilling Contractor: Elements Geo Drilling

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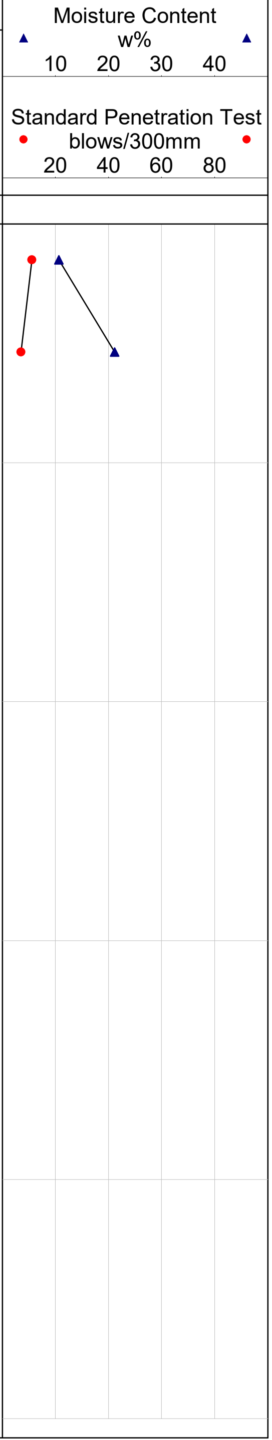
Datum: Temporary Benchmark
Field Logged by: MA
Checked by: KR
Sheet: 1 of 1

Log of Borehole No. 102

Project No: SM 301724-G-E
Project: Proposed High Rise Development
Location: Niagara Falls, Ontario
Client: Rudanco Hospitality Corporation

Project Manager: Kyle Richardson, P.Eng
Borehole Location: See Drawing No.1
UTM Coordinates - N: 4770355
E: 656443

Depth (ft / m)	Elevation (m)	Symbol	Description	Well Data	SAMPLE Type	Number	Blow Counts	Blows/300mm	Recovery	PP (kgf/cm2)	U.Wt.(kN/m3)
0 / 0	99.24		Ground Surface								
1	98.80		**Pavement Structure** Approximately 60 millimeters of asphaltic concrete over 340 millimeters of compact granular base.		SS	1	8,7,4,4	11	▨		
4	97.90		**Clayey Silt/Silty Clay** Reddish brown, trace sand and gravel, reworked in the upper levels, firm.		SS	2	2,3,4,7	7	▨		
			End of Borehole								



NOTES:

1. Borehole was advanced using hollow stem auger equipment on July 6, 2021 to termination at a depth of 1.34 meters.

2. Borehole was recorded as open and 'dry' upon completion and backfilled as per Ontario Regulation 903.

3. Soil samples will be discarded after 3 months unless otherwise directed by our client.

Drill Method: Hollow Stem Augers
Drill Date: July 6, 2021
Hole Size: 250 Millimeters
Drilling Contractor: Elements Geo Drilling

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Datum: Temporary Benchmark
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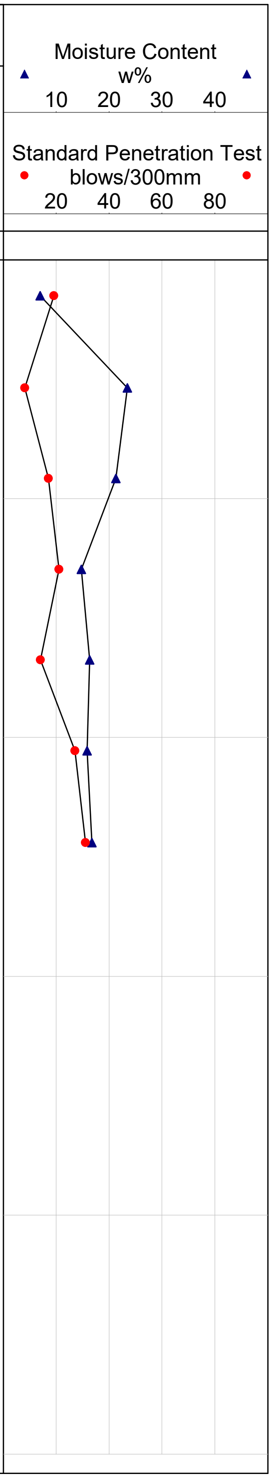
Sheet: 1 of 1

Log of Borehole No. 103

Project No: SM 301724-G-E
Project: Proposed High Rise Development
Location: Niagara Falls, Ontario
Client: Rudanco Hospitality Corporation

Project Manager: Kyle Richardson, P.Eng
Borehole Location: See Drawing No.1
UTM Coordinates - N: 4770347
E: 656424

Depth (ft / m)	Elevation (m)	Symbol	Description	Well Data	SAMPLE Type	Number	Blow Counts	Blows/300mm	Recovery	PP (kgf/cm2)	U.Wt.(kN/m3)
0 / 0	99.51		Ground Surface								
			Topsoil Approximately 50 millimeters of topsoil.		SS	1	5,11,8,12	19	■		
			Clayey Silt/Silty Clay Reddish brown, trace sand and gravel, reworked in the upper levels, stiff to hard.		SS	2	2,3,5,7	8	■	>4.5	
					SS	3	4,6,11,13	17	■	>4.5	
					SS	4	3,9,12,10	21	■	4.0	
					SS	5	7,5,9,13	14	■	3.5	
					SS	6	7,13,14,20	27	■	>4.5	
					SS	7	10,15,16,22	31	■	>4.5	
	94.30		End of Borehole								



NOTES:

1. Borehole was advanced using hollow stem auger equipment on July 6, 2021 to termination at a depth of 5.2 meters.

2. Borehole was recorded as open and 'dry' upon completion and backfilled as per Ontario Regulation 903.

3. Soil samples will be discarded after 3 months unless otherwise directed by our client.

Drill Method: Hollow Stem Augers
Drill Date: July 6, 2021
Hole Size: 250 Millimeters
Drilling Contractor: Elements Geo Drilling

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Log of Borehole No. 104

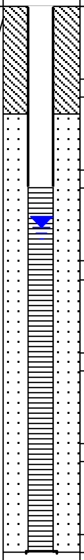
Project No: SM 301724-G-E
Project: Proposed High Rise Development
Location: Niagara Falls, Ontario
Client: Rudanco Hospitality Corporation

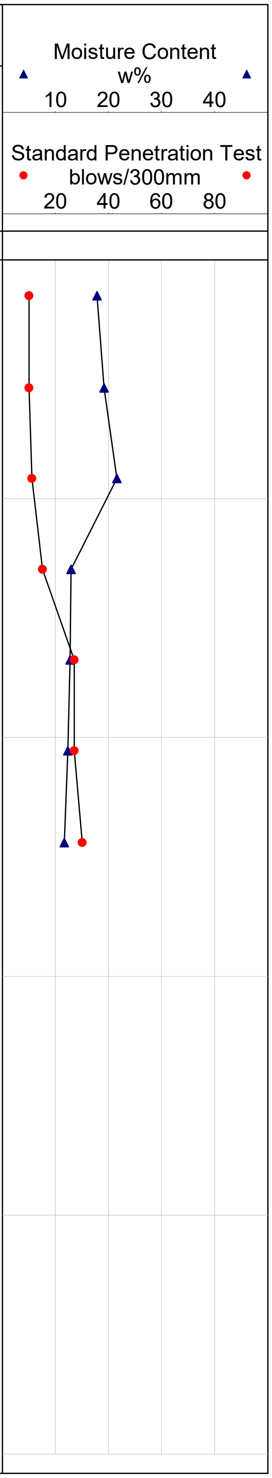
Project Manager: Kyle Richardson, P.Eng
Borehole Location: See Drawing No.1
UTM Coordinates - N: 4770316
E: 656447

Depth (ft / m)	Elevation (m)	Description
0 / 0	99.57	Ground Surface
		Topsoil Approximately 100 millimeters of topsoil.
		Clayey Silt/Silty Clay Reddish brown, trace sand and gravel, reworked in the upper levels, stiff to hard.
	94.40	End of Borehole

SAMPLE

Type	Number	Blow Counts	Blows/300mm	Recovery	PP (kgf/cm2)	U.Wt.(kN/m3)
SS	1	3,3,7,5	10	▇		
SS	2	4,4,6,9	10	▇	>4.5	
SS	3	3,5,6,7	11	▇	>4.5	
SS	4	3,5,10,23	15	▇	>4.5	
SS	5	9,12,15,17	27	▇	>4.5	
SS	6	7,12,15,19	27	▇	>4.5	
SS	7	11,12,18,25	30	▇	>4.5	





NOTES:

1. Borehole was advanced using hollow stem auger equipment on July 7, 2021 to termination at a depth of 5.2 meters.

2. Borehole was recorded as open and 'dry' upon completion and backfilled as per Ontario Regulation 903.

3. Soil samples will be discarded after 3 months unless otherwise directed by our client.

4. A monitoring well was installed. The following free groundwater level readings have been measured:

July, 22, 2021 - 1.06 meters

August, 11, 2021 - 1.85 meters

Drill Method: Solid Stem Augers
Drill Date: July 7, 2021
Hole Size: 150 Millimeters
Drilling Contractor: Elements Geo Drilling

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130 Lancing Drive, Hamilton, ON L8W 3A1
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Log of Borehole No. 105

Project No: SM 301724-G-E
Project: Proposed High Rise Development
Location: Niagara Falls, Ontario
Client: Rudanco Hospitality Corporation

Project Manager: Kyle Richardson, P.Eng
Borehole Location: See Drawing No.1
UTM Coordinates - N: 4770339
E: 656470

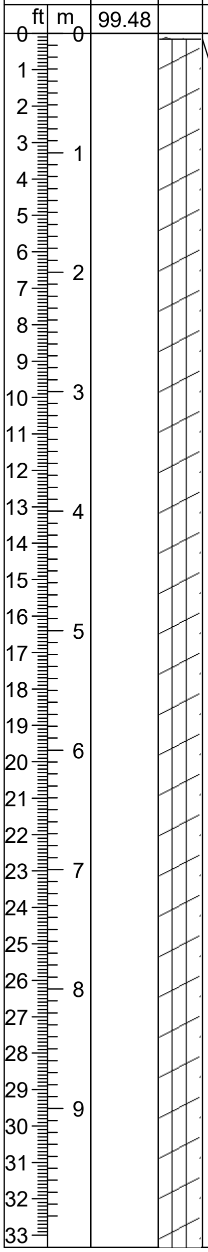
Ground Surface: 99.48

Topsoil

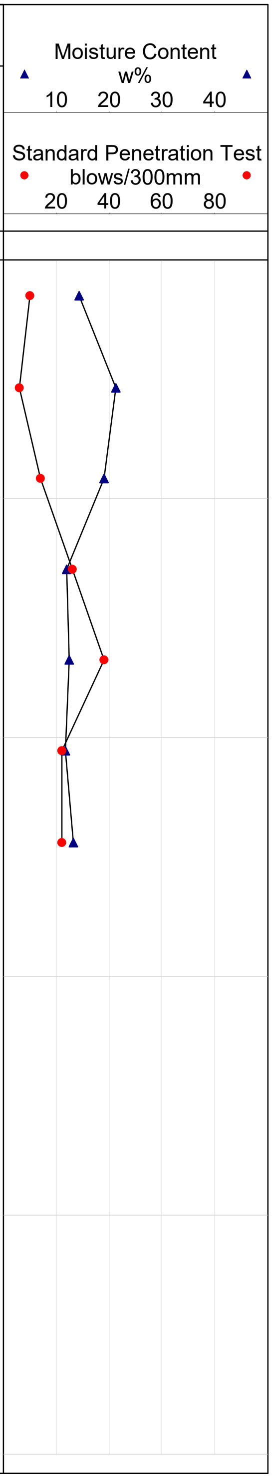
Approximately 50 millimeters of topsoil.

Clayey Silt/Silty Clay

Reddish brown, trace sand and gravel, trace organics and reworked in the upper levels, firm to hard.



Type	Number	Blow Counts	Blows/300mm	Recovery	PP (kgf/cm2)	U.Wt.(kN/m3)
SS	1	6,6,4,5	10			
SS	2	2,3,3,5	6			
SS	3	5,4,10,13	14			
SS	4	8,11,15,19	26		4.0	
SS	5	11,16,22,23	38		>4.5	
SS	6	7,10,12,11	22		>4.5	
SS	7	6,9,13,15	22		>4.5	



Drill Method: Solid Stem Augers
Drill Date: July 7, 2021
Hole Size: 150 Millimeters
Drilling Contractor: Elements Geo Drilling

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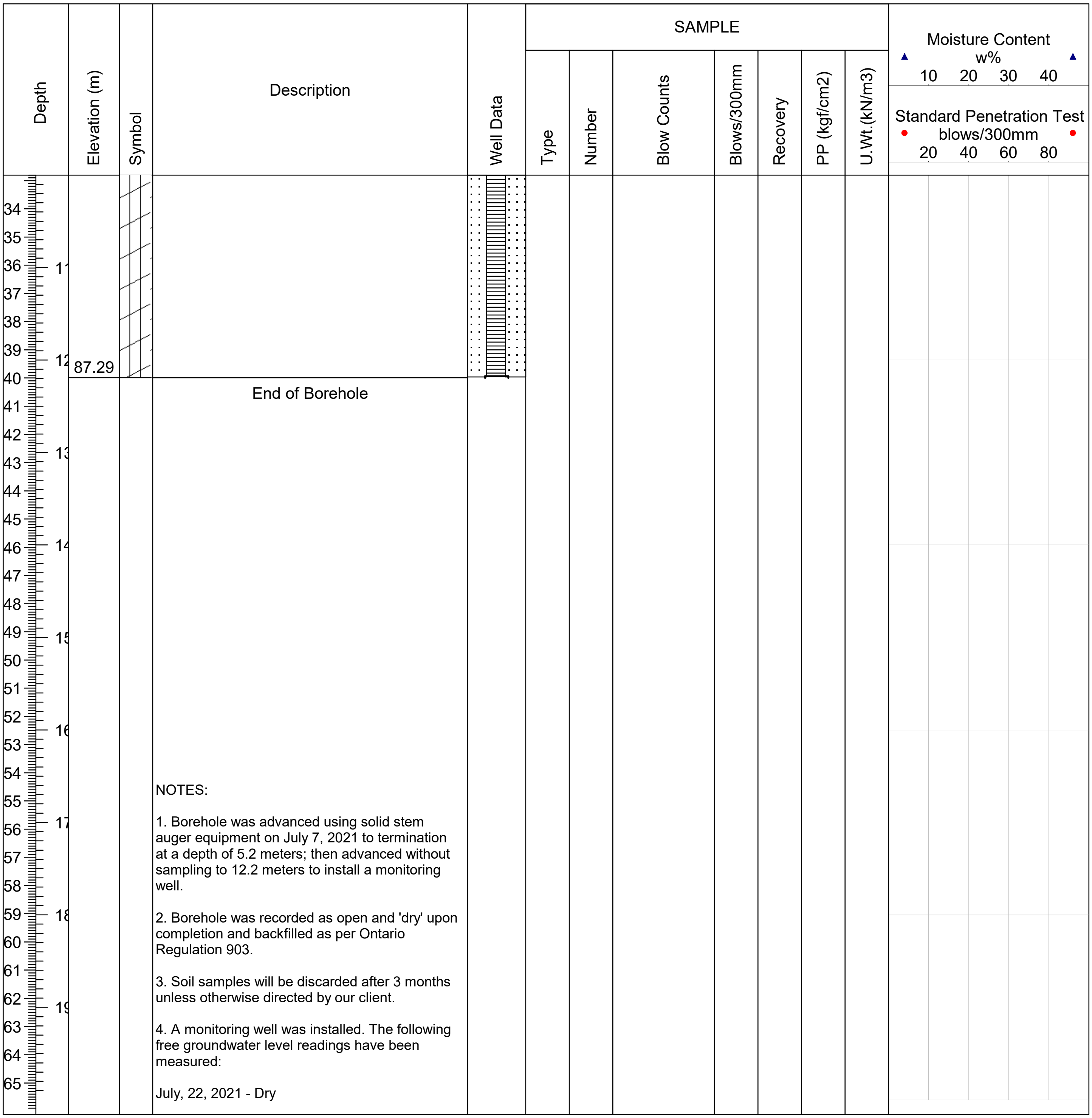
Sheet: 1 of 2

Log of Borehole No. 105

Project No: SM 301724-G-E
Project: Proposed High Rise Development
Location: Niagara Falls, Ontario
Client: Rudanco Hospitality Corporation

Project Manager: Kyle Richardson, P.Eng
Borehole Location: See Drawing No.1
UTM Coordinates - N: 4770339
E: 656470



NOTES:

1. Borehole was advanced using solid stem auger equipment on July 7, 2021 to termination at a depth of 5.2 meters; then advanced without sampling to 12.2 meters to install a monitoring well.

2. Borehole was recorded as open and 'dry' upon completion and backfilled as per Ontario Regulation 903.

3. Soil samples will be discarded after 3 months unless otherwise directed by our client.

4. A monitoring well was installed. The following free groundwater level readings have been measured:

July, 22, 2021 - Dry

Drill Method: Solid Stem Augers
Drill Date: July 7, 2021
Hole Size: 150 Millimeters
Drilling Contractor: Elements Geo Drilling

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Datum: Temporary Benchmark
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Sheet: 2 of 2

Log of Borehole No. 106

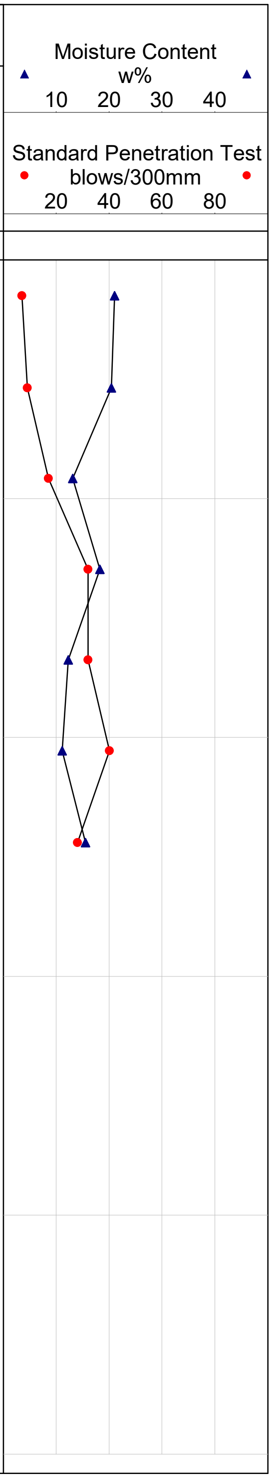
Project No: SM 301724-G-E
Project: Proposed High Rise Development
Location: Niagara Falls, Ontario
Client: Rudanco Hospitality Corporation

Project Manager: Kyle Richardson, P.Eng
Borehole Location: See Drawing No.1
UTM Coordinates - N: 4770364
E: 656505

Depth (m)	Elevation (m)	Description
0	99.77	Ground Surface
0		**Topsoil** Approximately 100 millimeters of topsoil.
		Clayey Silt/Silty Clay Reddish brown, trace sand and gravel, trace organics and reworked in the upper levels, sandy silt/silty sand inclusions in the mid-levels, stiff to hard.
5.2	94.60	End of Borehole

SAMPLE

Type	Number	Blow Counts	Blows/300mm	Recovery	PP (kgf/cm2)	U.Wt.(kN/m3)
SS	1	1,3,4,4	7			
SS	2	3,4,5,7	9			
SS	3	5,6,11,11	17			
SS	4	10,17,15,18	32		>4.5	
SS	5	10,15,17,20	32		>4.5	
SS	6	13,19,21,25	40		>4.5	
SS	7	12,12,16,17	28		>4.5	



NOTES:

1. Borehole was advanced using solid stem auger equipment on July 7, 2021 to termination at a depth of 5.2 meters.

2. Borehole was recorded as open and 'dry' upon completion and backfilled as per Ontario Regulation 903.

3. Soil samples will be discarded after 3 months unless otherwise directed by our client.

4. A monitoring well was installed. The following free groundwater level readings have been measured:

July, 22, 2021 - 0.72 meters

Drill Method: Solid Stem Augers
Drill Date: July 7, 2021
Hole Size: 150 Millimeters
Drilling Contractor: Elements Geo Drilling

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Checked by: KR
Sheet: 1 of 1

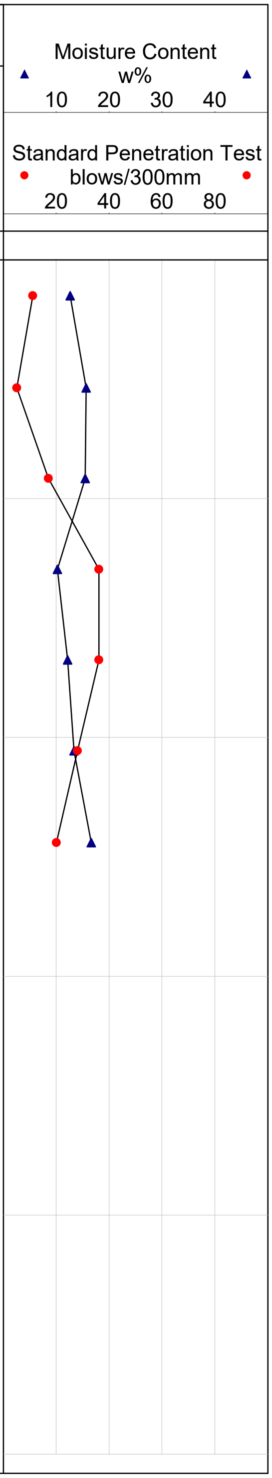
Log of Borehole No. 107

Project No: SM 301724-G-E
Project: Proposed High Rise Development
Location: Niagara Falls, Ontario
Client: Rudanco Hospitality Corporation

Project Manager: Kyle Richardson, P.Eng
Borehole Location: See Drawing No.1
UTM Coordinates - N: 4770389
E: 656402

Elevation (m)	Description
99.59	Ground Surface
99.30	**Topsoil** Approximately 100 millimetres of topsoil.
	Sand and Gravel Fill Brown, loose.
97.30	**Clayey Silt/Silty Clay Fill** Brown, trace sand and gravel, black staining and some black burnt wood in upper levels, soft.
95.70	**Silty Sand/Sandy Silt Fill** Brown, trace gravel, dense.
	Clayey Silt/Silty Clay Reddish brown, trace sand and gravel, reworked in the upper levels, very stiff.

SAMPLE						
Type	Number	Blow Counts	Blows/300mm	Recovery	PP (kgf/cm2)	U.Wt.(kN/m3)
SS	1	7,5,6,4	11			
SS	2	2,2,3,3	5			
SS	3	5,7,10,13	17			
SS	4	11,18,18,20	36			
SS	5	21,19,17,18	36			
SS	6	9,13,15,16	28		>4.5	
SS	7	5,7,13,22	20		>4.5	



Drill Method: Solid Stem Augers
Drill Date: July 7, 2021
Hole Size: 150 Millimeters
Drilling Contractor: Elements Geo Drilling

Soil-Mat Engineers & Consultants Ltd.
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Datum: Temporary Benchmark
Field Logged by: MA
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Sheet: 1 of 2

Log of Borehole No. 107

Project No: SM 301724-G-E
Project: Proposed High Rise Development
Location: Niagara Falls, Ontario
Client: Rudanco Hospitality Corporation

Project Manager: Kyle Richardson, P.Eng
Borehole Location: See Drawing No.1
UTM Coordinates - N: 4770389
E: 656402

Depth	Elevation (m)	Symbol	Description	Well Data	SAMPLE Type	Number	Blow Counts	Blows/300mm	Recovery	PP (kgf/cm2)	U.Wt.(kN/m3)	Moisture Content w% ▲ 10 20 30 40 ▲ Standard Penetration Test blows/300mm ● 20 40 60 80 ●
34 35 36 — 11 37 38	87.70	▨		▤								
39 — 12 40 41 42 43 — 13 44 45 46 — 14 47 48 49 — 15 50 51 52 — 16 53 54 55 56 — 17 57 58 59 — 18 60 61 62 — 19 63 64 65			End of Borehole									

NOTES:

1. Borehole was advanced using solid stem auger equipment on July 7, 2021 to termination at a depth of 5.2 meters; then advanced without sampling to 11.9 meters to install a monitoring well.

2. Borehole was recorded as open and 'dry' upon completion and backfilled as per Ontario Regulation 903.

3. Soil samples will be discarded after 3 months unless otherwise directed by our client.

4. A monitoring well was installed. The following free groundwater level readings have been measured:

July, 22, 2021 -Dry

Drill Method: Solid Stem Augers
Drill Date: July 7, 2021
Hole Size: 150 Millimeters
Drilling Contractor: Elements Geo Drilling

Soil-Mat Engineers & Consultants Ltd.
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Datum: Temporary Benchmark
Field Logged by: MA
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Sheet: 2 of 2

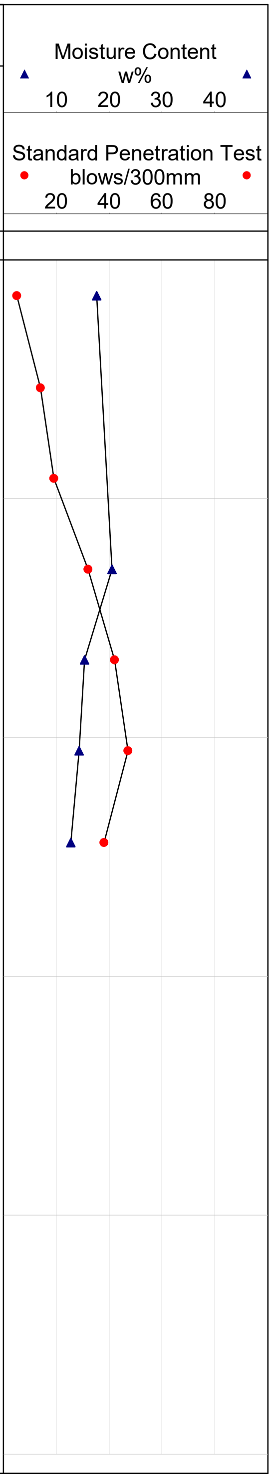
Log of Borehole No. 108

Project No: SM 301724-G-E
Project: Proposed High Rise Development
Location: Niagara Falls, Ontario
Client: Rudanco Hospitality Corporation

Project Manager: Kyle Richardson, P.Eng
Borehole Location: See Drawing No.1
UTM Coordinates - N: 4770395
E: 656430

Depth (ft)	Depth (m)	Elevation (m)	Description
0	0	99.62	Ground Surface
0 – 2			**Sand and Gravel Fill** Brown, loose.
2 – 17			**Clayey Silt/Silty Clay** Reddish brown, trace sand and gravel, trace construction debris and reworked in the upper levels, stiff to hard.
17	5.2	94.40	End of Borehole

Type	Number	Blow Counts	Blows/300mm	Recovery	PP (kgf/cm2)	U.Wt.(kN/m3)
SS	1	4,3,2,2	5	▨		
SS	2	3,7,7,10	14	▨	>4.5	
SS	3	4,8,11,12	19	▨	>4.5	
SS	4	10,14,18,25	32	▨	2.0	
SS	5	17,19,23,30	42	▨	1.75	
SS	6	12,17,30,32	47	▨	3.25	
SS	7	16,20,18,29	38	▨		



NOTES:

1. Borehole was advanced using solid stem auger equipment on July 7, 2021 to termination at a depth of 5.2 meters.

2. Borehole was recorded as open and 'dry' upon completion and backfilled as per Ontario Regulation 903.

3. Soil samples will be discarded after 3 months unless otherwise directed by our client.

4. A monitoring well was installed. The following free groundwater level readings have been measured:

July, 22, 2021 - 1.26 meters

August, 11, 2021 - 2.39 meters

Drill Method: Solid Stem Augers
Drill Date: July 7, 2021
Hole Size: 150 Millimeters
Drilling Contractor: Elements Geo Drilling

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Datum: Temporary Benchmark
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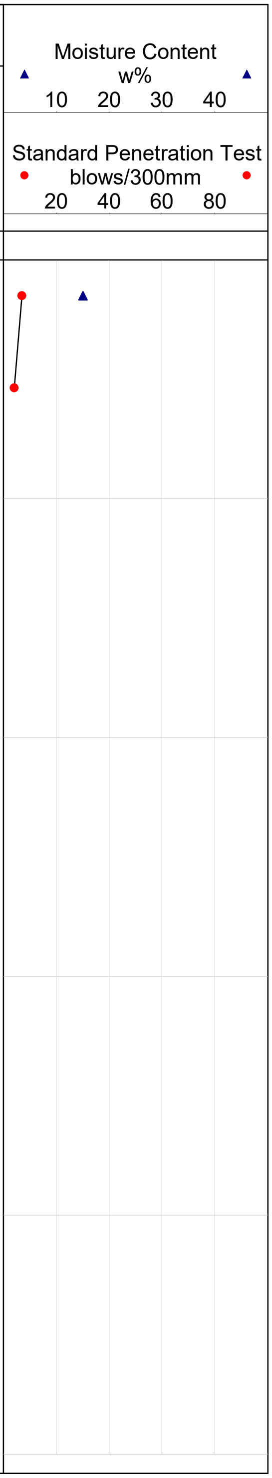
Sheet: 1 of 1

Log of Borehole No. 109

Project No: SM 301724-G-E
Project: Proposed High Rise Development
Location: Niagara Falls, Ontario
Client: Rudanco Hospitality Corporation

Project Manager: Kyle Richardson, P.Eng
Borehole Location: See Drawing No.1
UTM Coordinates - N: 4770375
E: 656419

Depth (ft / m)	Elevation (m)	Symbol	Description	Well Data	SAMPLE Type	Number	Blow Counts	Blows/300mm	Recovery	PP (kgf/cm2)	U.Wt.(kN/m3)
0 / 0	99.45		Ground Surface								
	98.90		**Pavement Structure** Approximately 75 millimeters of asphaltic concrete over 430 millimeters of compact granular base.		SS	1	4,5,2,1	7	▨		
	98.10		**Clayey Silt/Silty Clay** Reddish brown, trace sand and gravel, reworked in the upper levels, firm.		SS	2	5,2,2,2	4	▨		
			End of Borehole								



NOTES:

1. Borehole was advanced using solid stem auger equipment on July 7, 2021 to termination at a depth of 1.4 meters.

2. Borehole was recorded as open and 'dry' upon completion and backfilled as per Ontario Regulation 903.

3. Soil samples will be discarded after 3 months unless otherwise directed by our client.

Drill Method: Solid Stem Augers
Drill Date: July 7, 2021
Hole Size: 150 Millimeters
Drilling Contractor: Elements Geo Drilling

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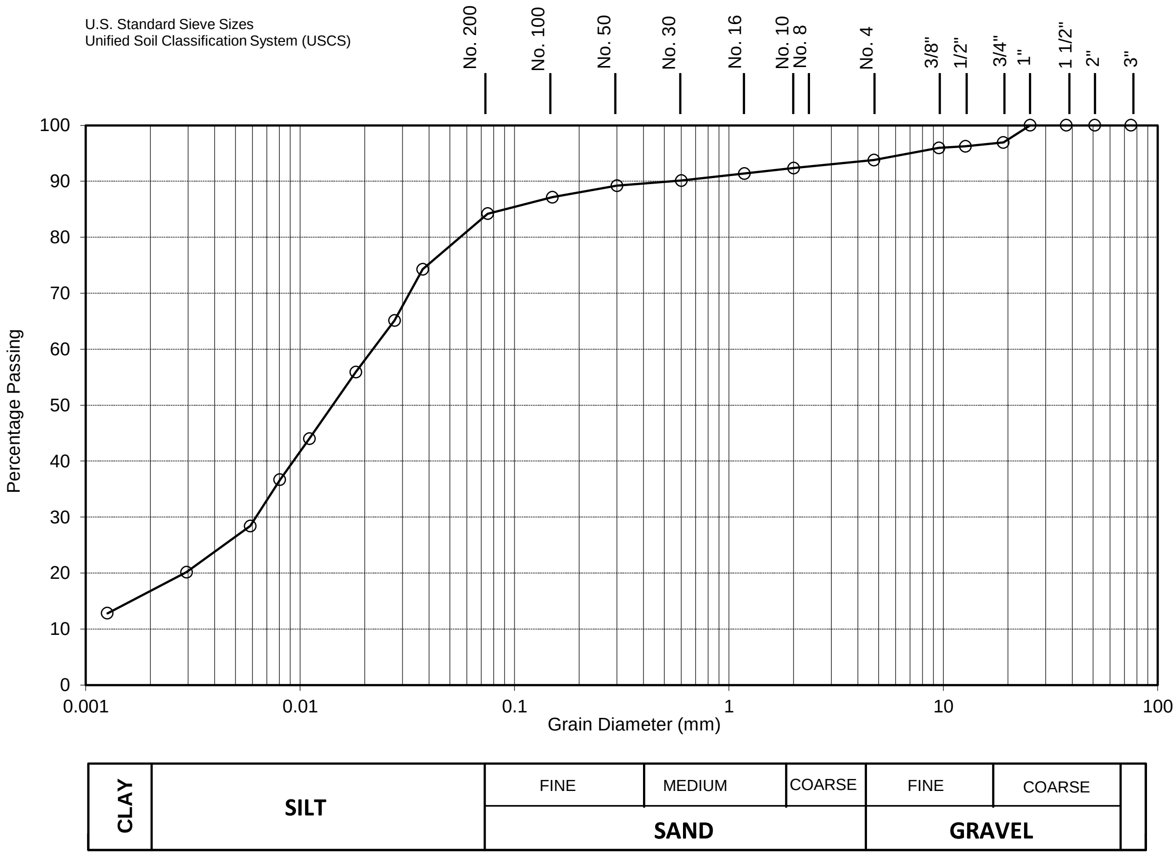
Mechanical & Hydrometer Analyses



Lab No.: **21-267**

Borehole No.: **01A**

Sample No.: **5**

CLAY [%]: **17**

SILT [%]: **67**

SAND [%]: **10**

GRAVEL [%]: **6**

D_{10} (Effective Diam. in mm): **0.0010**

Notes: Depth 10'

Soil Description: **Brown Silt w/ some Clay and Sand with a trace of Gravel**

M.H. - Inorganic silts, clayey silts with slight plasticity

Estimated Infiltration Rate [mm/hr] : **<10**

Estimated Permeability, k [cm/s] **10^{-6}**

Coefficient of Uniformity C_U: **22.0**

Coefficient of Curvature C_C: **1.7**

SOIL-MAT ENGINEERS & CONSULTANTS LTD.

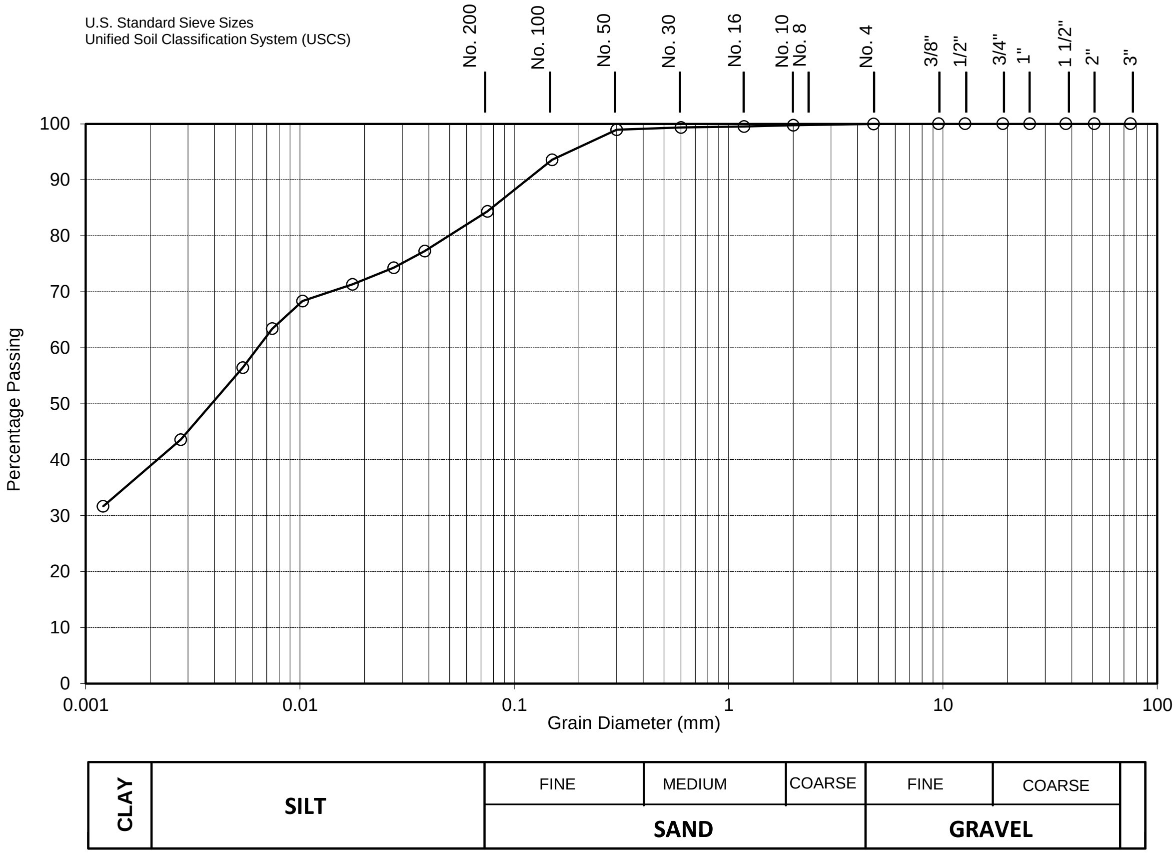
Lot 175 Portage Road, Niagara Falls, Ontario

July 2021

Grain Size Analysis No. 1

Project No.: SM 301724-T

Mechanical & Hydrometer Analyses



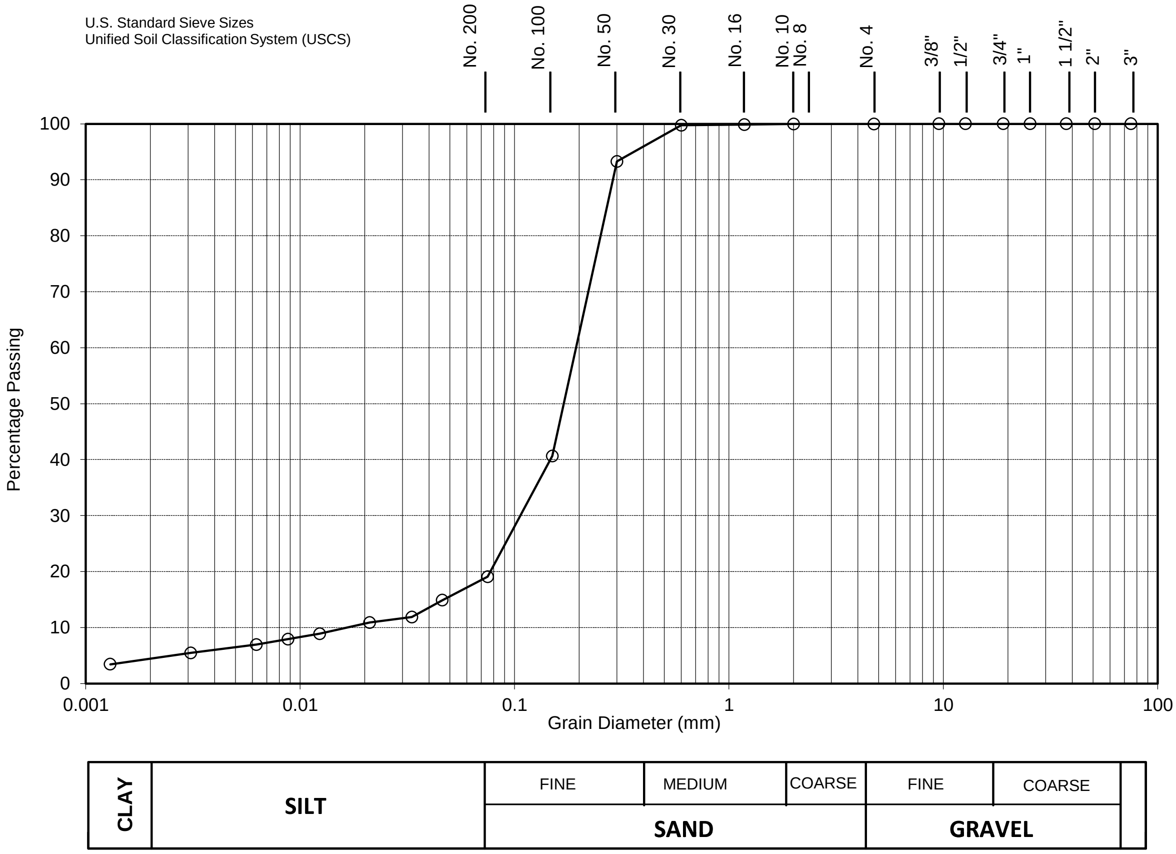
Lab No.:	21-250	Notes: Depth 30'			
Borehole No.:	01A				
Sample No.:	9				
CLAY [%]:	39	Soil Description: **Brown Clay and Silt w/ some Sand** **C.L. - Inorganic clays of low to medium plasticity, silty clays**			
SILT [%]:	46				
SAND [%]:	15				
GRAVEL [%]:	0	Estimated Infiltration Rate [mm/hr] :	< 10	Estimated Permeability, k [cm/s]	10^{-7}
D_{10} (Effective Diam. in mm):	0.0005	Coefficient of Uniformity C_U:	12.4	Coefficient of Curvature C_C:	0.5

SOIL-MAT ENGINEERS & CONSULTANTS LTD.

Lot 175 Portage Road, Niagara Falls, Ontario

June 2021	**Grain Size Analysis No. 2**	**Project No.: SM 301724-T**

Mechanical & Hydrometer Analyses



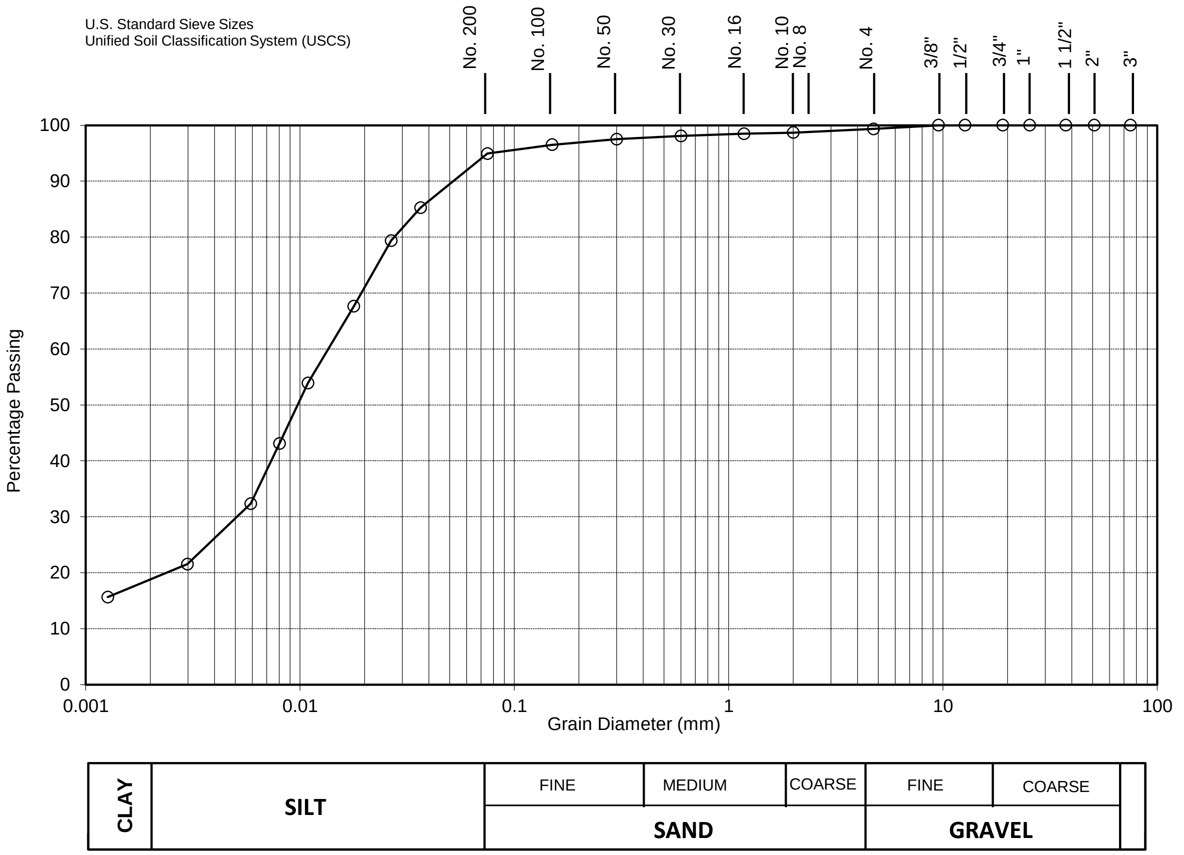
Lab No.:	21-249	Notes: Depth 50'			
Borehole No.:	01A				
Sample No.:	11				
CLAY [%]:	4	Soil Description:	**Brown Sand with some Silt and traces of Clay** **S.P. - Poorly graded sands**		
SILT [%]:	15				
SAND [%]:	81				
GRAVEL [%]:	0	Estimated Infiltration Rate [mm/hr] :	50 to 60	Estimated Permeability, k [cm/s]	10^{-4}
D_{10} (Effective Diam. in mm):	0.020	Coefficient of Uniformity C_U:	9.5	Coefficient of Curvature C_C:	3.8

Soil-Mat Engineers & Consultants Ltd.

Lot 175 Portage Road, Niagara Falls, Ontario

June 2021	**Grain Size Analysis No. 3**	**Project No.: SM 301724-T**

Mechanical & Hydrometer Analyses



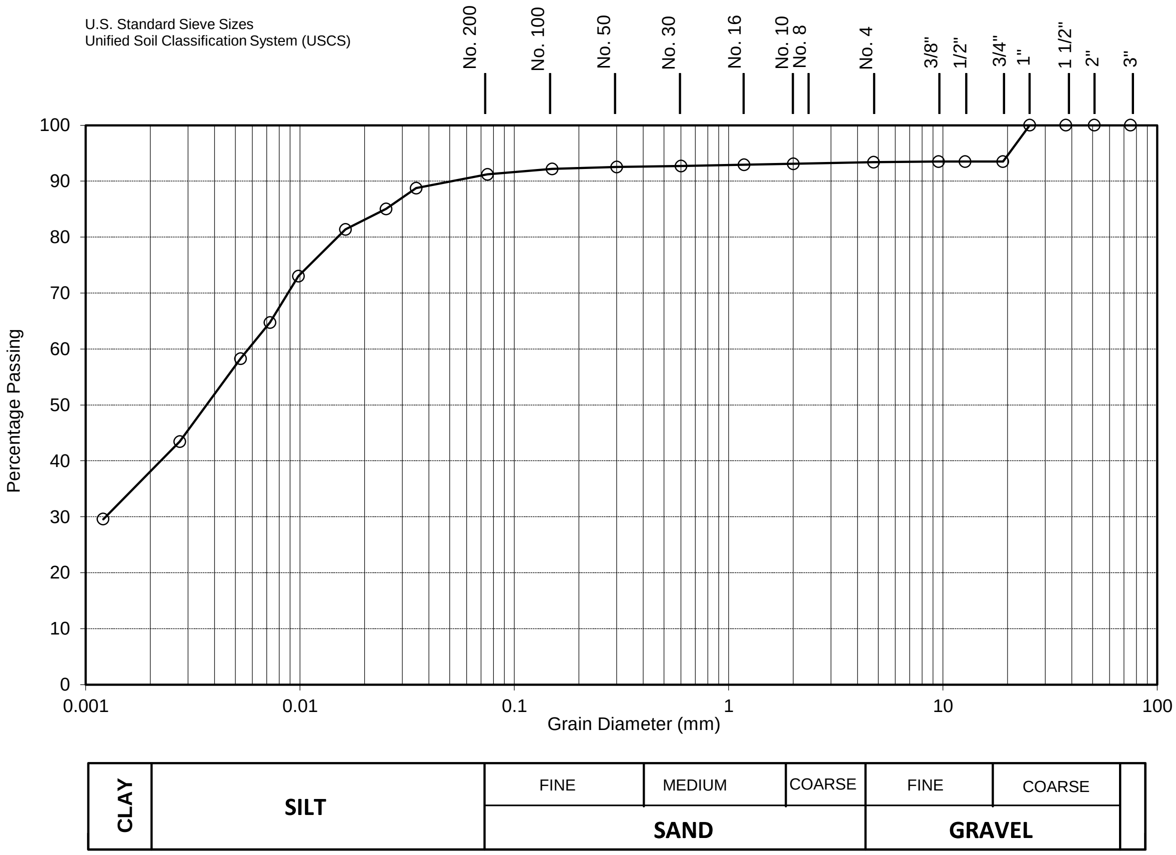
Lab No.:	**21-252**	Notes: Depth 15'			
Borehole No.:	**2**				
Sample No.:	**6**				
CLAY [%]:	**19**	Soil Description:	**Brown Silt w/ some Clay and traces of Sand and Gravel** **M.L. - Inorganic silts, clayey silts with slight plasticity**		
SILT [%]:	**76**				
SAND [%]:	**5**				
GRAVEL [%]:	**1**	Estimated Infiltration Rate [mm/hr] :	**< 10**	Estimated Permeability, k [cm/s]	**10^{-6}**
D_{10} (Effective Diam. in mm):	**0.0007**	Coefficient of Uniformity C_U:	**20.0**	Coefficient of Curvature C_C:	**2.7**

SOIL-MAT ENGINEERS & CONSULTANTS LTD.

Lot 175 Portage Road, Niagara Falls, Ontario

June 2021	**Grain Size Analysis No. 4**	**Project No.: SM 301724-T**

Mechanical & Hydrometer Analyses



Lab No.: **21-251**
Borehole No.: **2**
Sample No.: **8**
CLAY [%]: **38**
SILT [%]: **53**
SAND [%]: **2**
GRAVEL [%]: **7**
D_{10} (Effective Diam. in mm): **0.0005**

Notes: Depth 25'

Soil Description: **Brown Clay and Silt w/ traces of Gravel and Sand**
C.L. - Inorganic clays of low to meduim plascity, silty clays

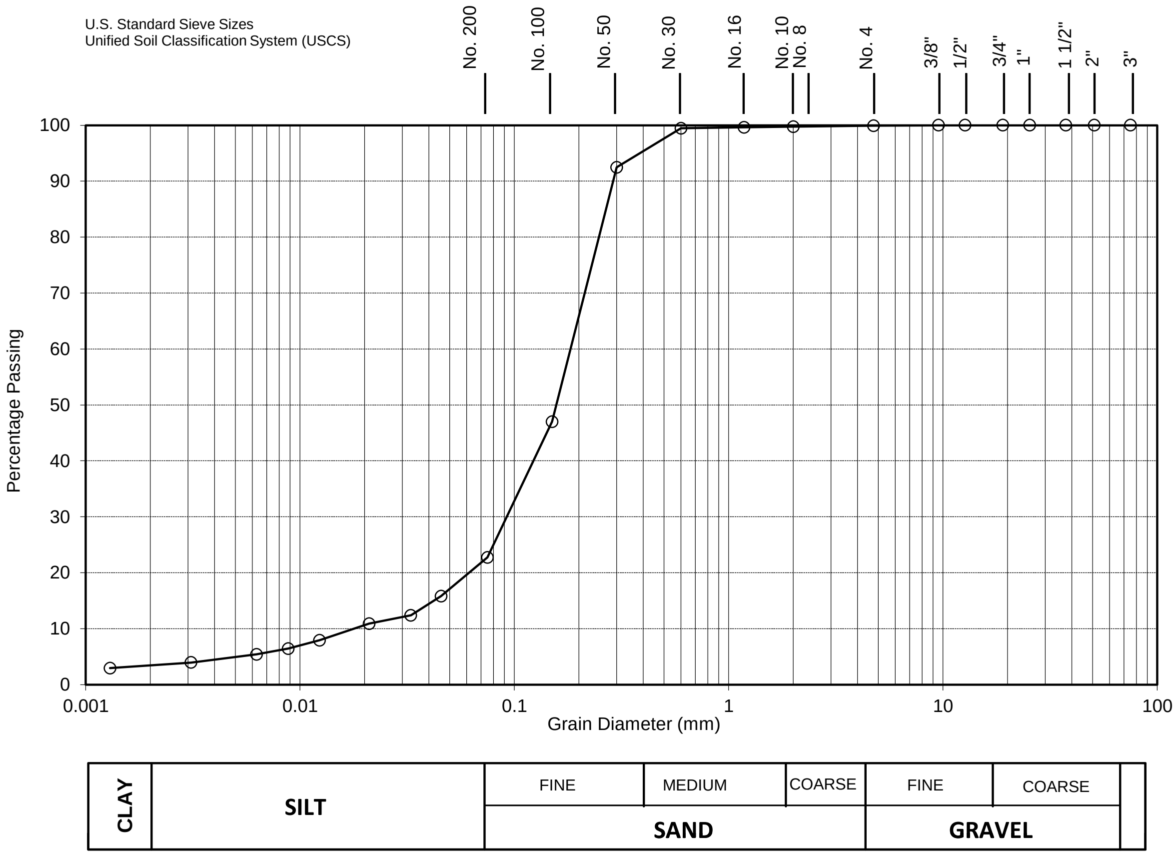
Estimated Infiltration Rate [mm/hr] : **< 10**
Estimated Permeability, k [cm/s] **10^{-7}**
Coefficient of Uniformity C_U: **11.6**
Coefficient of Curvature C_C: **0.6**

SOIL-MAT ENGINEERS & CONSULTANTS LTD.

Lot 175 Portage Road, Niagara Falls, Ontario

June 2021 | **Grain Size Analysis No. 5** | **Project No.: SM 301724-T**

Mechanical & Hydrometer Analyses



Lab No.:	**21-266**
Borehole No.:	**2**
Sample No.:	**11**
CLAY [%]:	**3**
SILT [%]:	**20**
SAND [%]:	**77**
GRAVEL [%]:	**0**
D_{10} (Effective Diam. in mm):	**0.020**

Notes: Depth 70'

Soil Description: **Brown Silty Sand with a trace of Clay**

S.M. - Silty sands, sand-silt mixtures to S.P. - Poorly graded sands

Estimated Infiltration Rate [mm/hr] :	**50 to 60**	Estimated Permeability, k [cm/s]	**10^{-4}**
Coefficient of Uniformity C_U:	**9.0**	Coefficient of Curvature C_C:	**2.3**

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Lot 175 Portage Road, Niagara Falls, Ontario

July 2021	**Grain Size Analysis No. 6**	**Project No.: SM 301724-T**

Core		Date Tested	Average Diameter D	Average Height H	Dry Weight (mass)	Break Load Q_{ult}		Aspect Ratio Factor	Cross-Sectional Area A	Calculated Volume V	Calculated Unit Weight γ_{conc}	Calculated Density ρ_{conc}	Unconfined Compressive Strength
			[mm]	[mm]	[g]	[lb]	[N]	C_F	[m^2]	[m^3]	[kN/m^3]	[kg/m^3]	[MPa]
A	C1	July-12-21	68.0	149	1189.4	33190	147629.1	1.00	0.00363	0.00054	21.6	2198.0	40.7
B	C2	July-12-21	68.0	125	1050.4	33700	149897.6	0.99	0.00363	0.00045	22.7	2313.9	40.9
C	C3	July-12-21	68.0	120	978.3	34140	151854.7	0.98	0.00363	0.00044	22.0	2244.8	41.0
D	C4	July-12-21	68.0	107	993.3	81100	360732.8	0.97	0.00363	0.00039	25.1	2556.2	96.3
E	C5	July-12-21	68.0	132	1089.0	52480	233431.0	1.00	0.00363	0.00048	22.3	2271.7	64.3
F	C6	July-12-21	68.0	104	878.9	25160	111911.7	1.00	0.00363	0.00038	22.8	2327.0	30.8

Date cast:
Date cored:
Date received: July 2021
Project/Contract No.: 301724
Structure:

SOIL-MAT ENGINEERS & CONSULTANTS LTD.

COMPRESSIVE STRENGTH TEST - BEDROCK CORES

Project No.: **301724** **Lab Number:** **21-782** July 2021

GEOPHYSICS GPR INTERNATIONAL INC.

6741 Columbus Road
Unit 14
Mississauga, Ontario
Canada, L5T 2G9

Tel.: 905-696-0656
Fax: 905-696-0570
info@geophysicsgpr.com
www.geophysicsgpr.com

September 7, 2021 GPR file: T213211

Kyle Richardson, P.Eng.
Soil-Mat Engineers & Consultants Ltd.
130 Lancing Dr.
Hamilton, ON
L8W 3A1

RE: Shear-wave velocity sounding at Portage Road, Niagara Falls, ON

Dear Mr Richardson,

Geophysics GPR International Inc. has been requested by Soil-Mat Engineers & Consultants Ltd. to carry out a shear-wave velocity sounding at the above site in Niagara Falls. Figure 1 shows the location of the test profile.

The survey was performed on August 27th, 2021.

The investigation included the multi-channel analysis of surface waves (MASW), the micro-tremor array measurements (MAM) and the refraction methods to generate a shear-wave velocity model (Figure 4).

The following paragraphs describe the survey design, the principles of the test method, the methodology for interpreting the data, and provide a culmination of the results in table format.

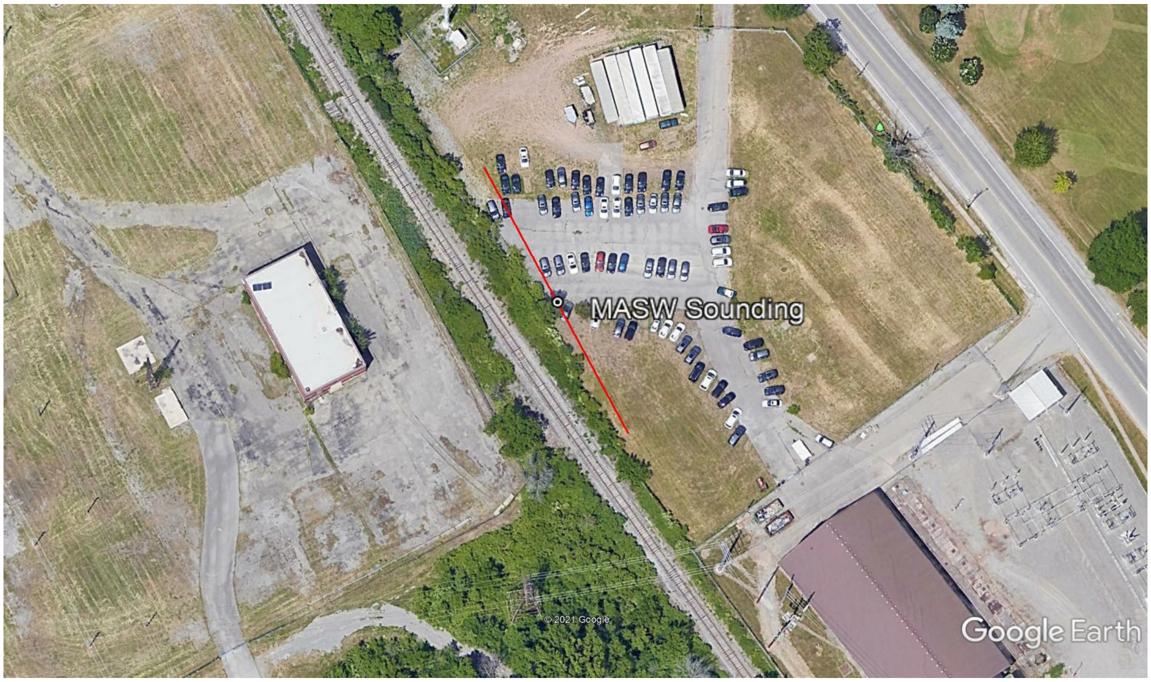


Figure 1: Approximate location of the shear-wave velocity sounding

MASW and MAM Surveys

Basic Theory

The Multi-channel Analysis of Surface Waves (MASW) and the Micro-tremor Array Measurements (MAM) are seismic methods used to evaluate the shear-wave velocities of subsurface materials through the analysis of the dispersion properties of Rayleigh surface waves (“ground roll”). The dispersion properties are measured as a change in phase velocity with frequency. Surface wave energy will decay exponentially with depth. Lower frequency surface waves will travel deeper and thus be more influenced by deeper velocity layering than the shallow higher frequency waves. Inversion of the Rayleigh wave dispersion curve yields a shear-wave (V_s) velocity depth profile (sounding). Figure 2 outlines the basic operating procedure for the MASW method. Figure 3 is an example image of a typical MASW record and resulting 1D V_s model. A more detailed description of the method can be found in the paper *Multi-channel Analysis of Surface Waves,* Park, C.B., Miller, R.D. and Xia, J. Geophysics, Vol. 64, No. 3 (May-June 1999); P. 800–808.

Survey Design

The geometry of an MASW survey is similar to that of a seismic refraction investigation (i.e. 24 geophones in a linear array). The fundamental principle involves intentionally generating an acoustic wave at the surface and digitally recording the surface waves from the moment of source impact with a linear series of geophones on the surface. This is referred to as an “active source” method. An elastic-wave hammer was used as the primary energy source with traces being recorded at 6 locations: approximately 6 m off both ends, 25 to 30 m off both ends, and in the middle of the spread. Data were collected with geophones spacing of 3m and 1m for a total of 10 shot records per sounding.

Unlike the refraction method, which produces a data point beneath each geophone, the shear-wave depth profile is the average of the bulk area within the middle third of the geophone spread.

The theoretical maximum depth of penetration (34.5m) is half of the maximum seismic array length (69 m), in practice the maximum depth of penetration is often influenced by the geology.

The MAM/passive survey used the same geophone array set up as for the MASW survey. Unlike the MASW survey, the MAM method is considered a "passive source" method in that there is no time break and the motions recorded are from ambient energy generated by cultural noise such as traffic, wind, wave motion, etc. Data collection for the passive method involves recording approximately 10 minutes of background "noise." The records generated by the MAM method contain lower frequency data, thus increasing the data resolution at greater depths of investigation. Typically the MAM results aid in clarifying the MASW results for depths greater than 20 m; however, the direction of noise propagation relative to the spread orientation can influence the results.

Interpretation Method and Accuracy of Results

The main processing sequence involved plotting, picking, and 1-D inversion of the MASW/MAM shot records using the SeisimagerSW™ software package. In theory, all MASW shot records should produce a similar shear-wave velocity profile. In practice, however, differences can arise due to energy dissipation and localized surface variations. The results of the inversion process are inherently non-unique and the final model must be judged to be geologically realistic. The inversion modelling also assumes that all layering is flat/horizontal and laterally uniform.

The results of the MASW/MAM tests are presented in chart format as Figure 4. The chart presents the 1-D shear wave velocity values from the inversion models of the passive and active seismic records.

The V_s30 values for the sounding are presented in Table 1. The V_s30 values are based on the harmonic mean of the shear wave velocities over the upper 30 m. The V_s30 value is calculated by dividing the total depth of interest (e.g. 30 m) by the sum of the time spent in each velocity layer up to that depth. This harmonic mean value reflects the equivalent single layer response.

The estimated error in the average V_s30 value determined through MASW tests is typically +/-10 to 15% for overburden sites. The shear-wave velocities modelled through the MASW method within bedrock have a higher estimated error.

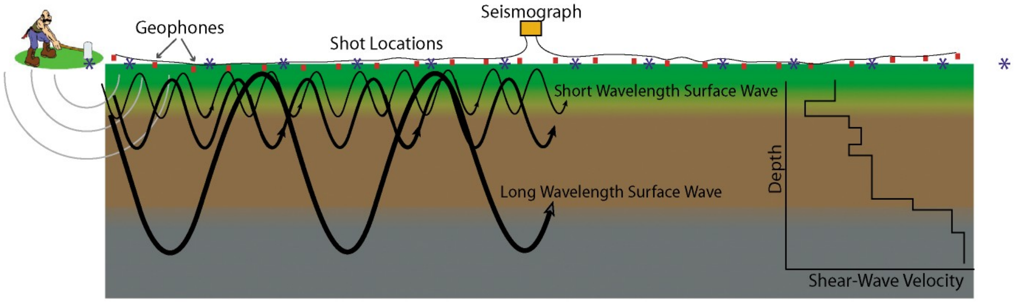
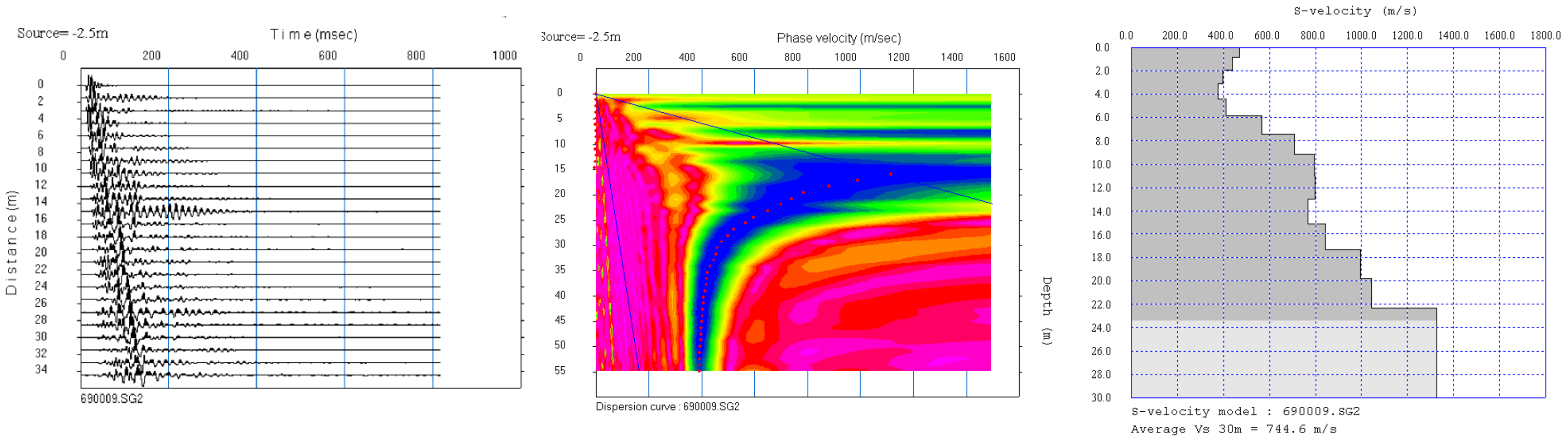


Figure 2: MASW Operating Principle



Raw Seismic Shot Record

Phase Velocity-Frequency Transformation indicating Dispersion Curve

1D Shear-Wave Velocity Profile from Inversion of Dispersion Curve

Figure 3: Example of a typical MASW shot record, phase velocity/frequency curve and resulting 1D shear-wave velocity model.

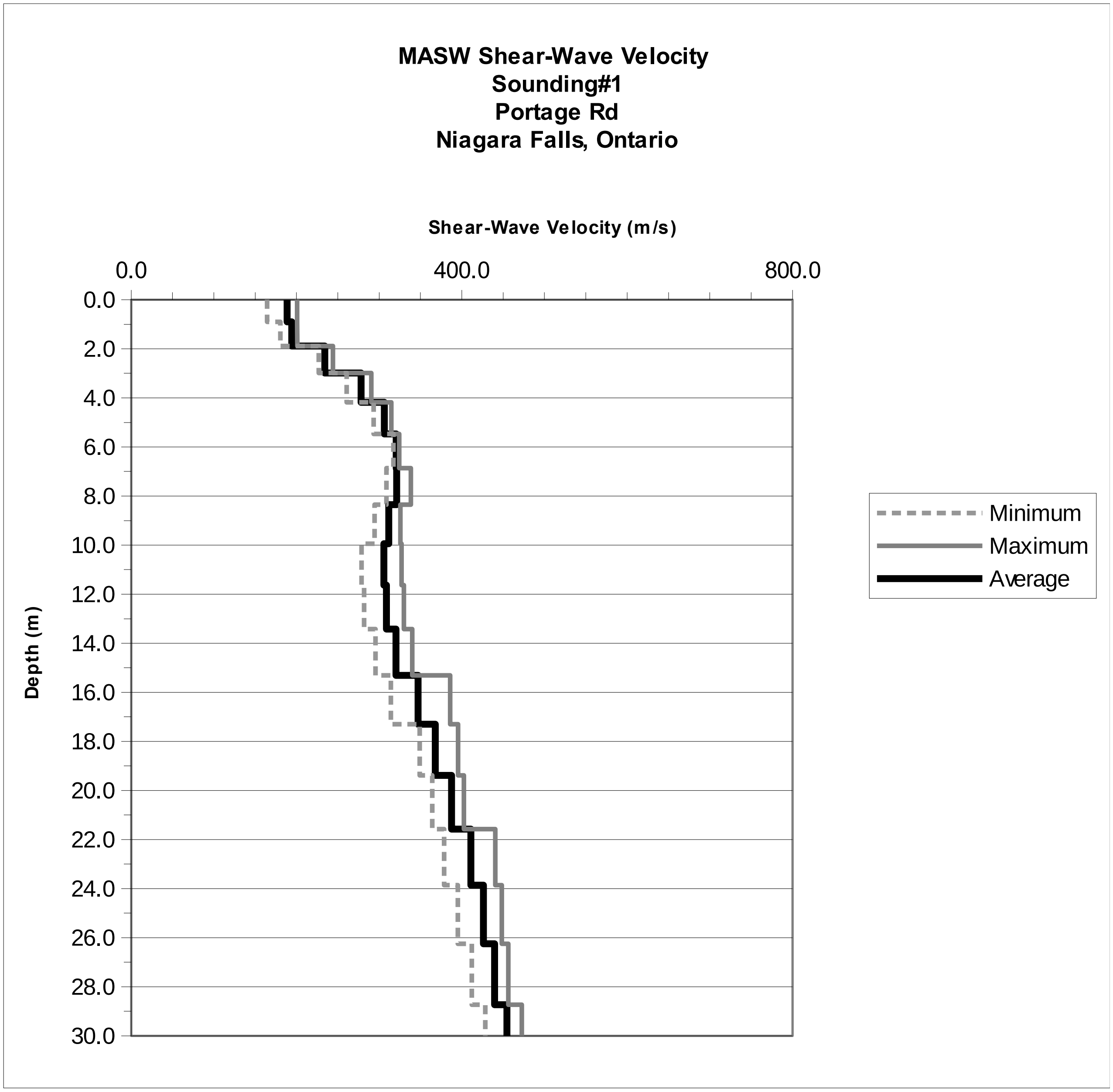


Figure 4: MASW Shear-wave Velocity Sounding

CONCLUSIONS

The approximate location of the shear-wave sounding is indicated in Figure 1.

The MASW shear-wave models are presented in Figure 4. The results are summarized in Table 1. The background seismic noise levels at this site were moderate. The quality of the seismic records and the resulting dispersions curves was good.

Simple critical distance calculations from refracted P-waves show that the water table could be at 2m deep.

The boreholes provided by the client confirmed the general overburden soils type.

Table 1: Calculated V_s30 values (m/s) from the MASW data (0 to 30m)

Sounding	Minimum	Average	Maximum	Site Class
1	308	**330**	348	**D**

The calculated average V_s30 values from the 1D MASW soundings collected was 330m/s +/-10% to 15%.

The V_s30 values calculated for the minimum and the maximum envelopes ranged from 308 to 348m/s.

Based on the average V_s30 values (as determined through the MASW method) and table 4.1.8.4.A of the National Building Code of Canada, 2015 Edition, the investigated area is site class "D" ($180< V_S30 \leq 360$ m/s).

At the request of the client, the V_s30 values have also been re-calculated taking in to consideration the proposed excavation/basement level of 7m and 10 m below survey grade. The application of these recalculated Vs30* value is discussed below and the validity of these assumptions is at the discretion of the design engineer. The recalculated Vs30* values are presented in Tables 2 and 3.

Table 2: Calculated V_s30* values (m/s) from the MASW data (7 to 37m)

Sounding	Minimum	Average	Maximum	Site Class
1	358	**384**	406	**D/C***

* Given the estimate error of 10%

Based on the average V_s30* values (as determined through the MASW method), taking into consideration the proposed excavation depth as provided by the client, and table 4.1.8.4.A of the National Building Code of Canada, 2010 Edition, the investigated area is site class "D" ($180 < V_S30 \leq 360$ m/s).

Table 3: Calculated V_s30* values (m/s) from the MASW data (10 to 40m)

Sounding	Minimum	Average	Maximum	Site Class
1	372	**400**	422	**C**

Based on the average V_s30* values (as determined through the MASW method), taking into consideration the proposed excavation depth as provided by the client, and table 4.1.8.4.A of the National Building Code of Canada, 2010 Edition, the investigated area is site class "C" ($360 < V_S30 \leq 760$ m/s). It is recommended that the design engineer rules out any possible side wall effects due to the deeper footing.

It must be noted that the site classification provided in this report is based solely on the V_s30 value as derived from the MASW method and that it can be superseded by other geotechnical information. This geotechnical information includes, but is not limited to, the presence of sensitive and/or liquefiable soils, more than 3m of soft clays, high moisture content, etc. The reader is referred to section 4.1.8.4 of the National Building Code of Canada, 2015 Edition for more information on the requirements for site classification.

This report has been written by Lhoucin Taghya, P.Geo.

Lhoucin Taghya

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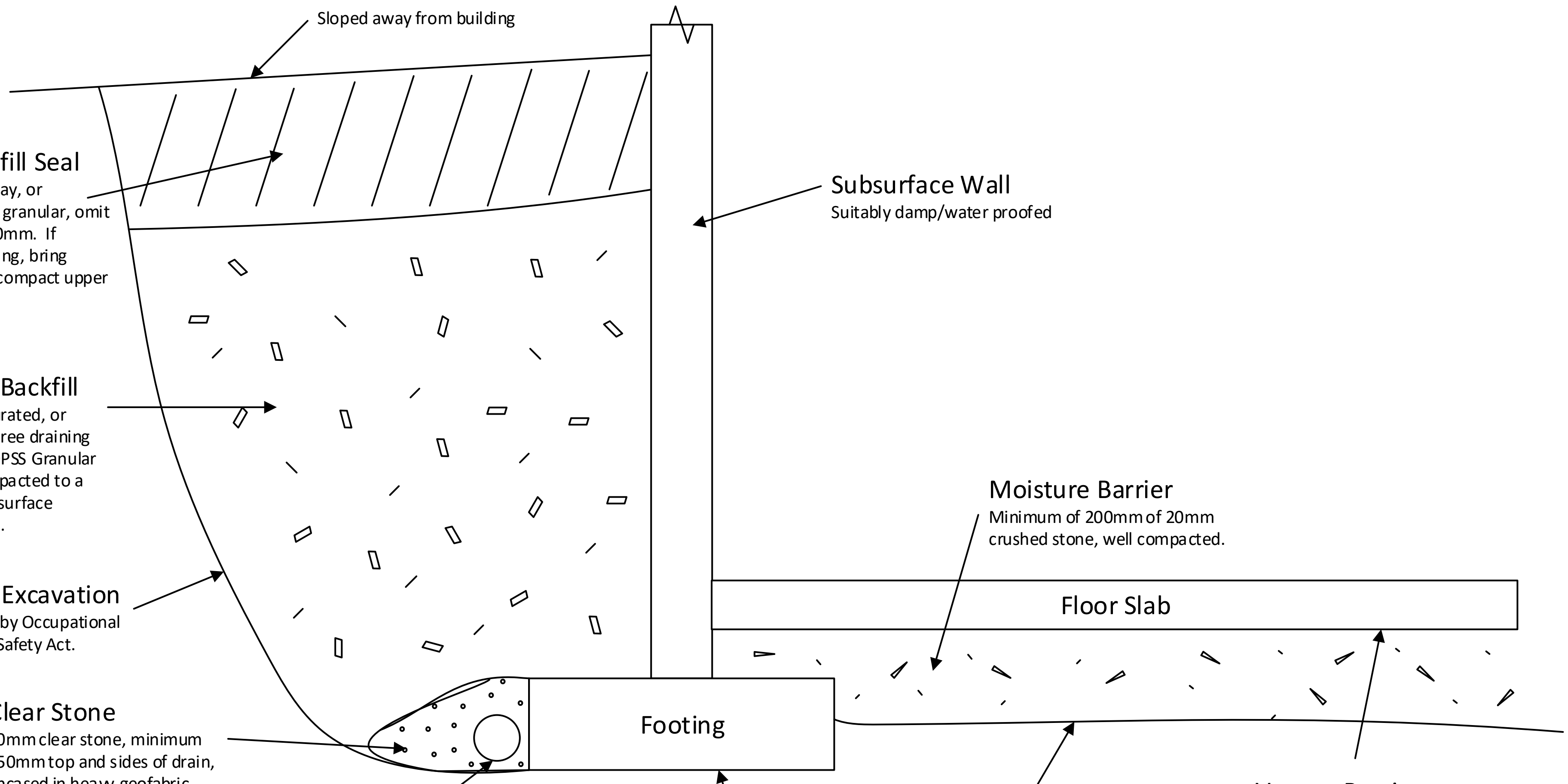

Ground Surface
Sloped away from building

Impermeable Backfill Seal
Well compacted clay/silty clay, or equivalent. If original soil is granular, omit seal and compact upper 600mm. If pavement adjacent to building, bring Granular 'B' to surface and compact upper 1 metre to 100% SPMDD.

Subsurface Wall
Suitably damp/water proofed

Select Compacted Backfill
Free of organic, frozen, saturated, or otherwise unsuitable soil. Free draining granular material, such as OPSS Granular 'B' (Type II) preferred. Compacted to a minimum of 95% SPMDD if surface settlement can be tolerated.

Moisture Barrier
Minimum of 200mm of 20mm crushed stone, well compacted.

Limit of Excavation
As required by Occupational Health and Safety Act.

Clear Stone
20mm clear stone, minimum 150mm top and sides of drain, encased in heavy geofabric.

Perimeter Drain
150mm diameter weeping tile or pipe equivalent, leading to positive sump or outlet. Invert at least 150mm below underside of floor slab.

Pour flush with original undisturbed soil.

Subgrade
Competent native soil or well compacted fill.

Vapour Barrier
Where 'non-damp' floors are required, provide heavy poly sheeting.

NOT TO SCALE

Soil-Mat

Soil-Mat Engineers & Consultants Ltd.

Project No.: SM 301724-G
Date: October 2021

Typical Design Requirements
Drainage and Backfill for Basement Walls

Drawing No. 2