647 Welham Road, Unit 14
Barrie, Ontario, L4N 0B7
P: (705) 719-7994
F: (888) 558-9424
www.centralearth.ca

GEOTECHNICAL REPORT

Proposed Townhouse Development
910 Veterans Drive
Barrie, Ontario

Prepared For: 2528286 Ontario Inc.
Type of Document: Final Report
Reference Number: 19-1004A
Prepared By: Alexander Winkelmann, P.Eng
Date Issued: August 16, 2019 (Rev. 1)

Table of Contents

Figures

Appendices

1 Introduction

Central Earth Engineering Inc. (CEE) was retained by 2528286 Ontario Inc. c/o Innovative Planning Solutions to complete a geotechnical investigation and report for 910 Veterans Drive in the City of Barrie. The site is bounded by Veterans Drive to the east, a residential property to the south and agricultural land to the north and west. A site location plan is provided as Figure 1. The existing property is approximately 90 metres long (north to south) and 80 metres wide (east to west). The property currently contains a single family detached residential dwelling with a detached shed and garage, with much of the site consisting of manicured lawn with some mature trees.

CEE was provided with the following for the property for review:

- "*Concept Plan 'A', 53 Units, Veteran's Drive and McKay Rd, Salem Secondary Plan*", File 18-769, dated March 20, 2019 by Innovative Planning Solutions.
- "*910 Veterans Drive, City of Barrie 53 Unit Back to Back Townhouse Development Functional Servicing & Storm Water Management Brief*", Project No. 18-11393B, dated March 28th, 2019, by Pinestone Engineering Ltd.

Based on our review of the provided drawings and reports, it is proposed to demolish the existing residential buildings on site and construct four blocks of back to back townhouses for a total of 53 units. The townhouses will be 3 to 4 storeys high. A 12-metre-wide road will run north-south through the centre of the property and exit into the proposed low-density residential development that will eventually surround the site. Though the drawings show an 8-metre-wide road, it is understood that the most recent Draft Plan of Subdivision indicates that a 12-metre-wide road is required. Due to the proposed grading surrounding the site in other adjacent subdivisions, it is likely that approximately 3 metres of filling will be required to raise grades to match, though the exact amount of filling may change slightly during detailed design. Based on our correspondence, the townhomes will not have any underground basement levels (i.e. they will be slab-on-grade) and the depth for site servicing will be of typical depth for similar developments.

This revision (Revision 1, dated August 16, 2019) is prepared to address comments provided by both the Lake Simcoe Region Conservation Authority and the City of Barrie. Further details on the exact comments/questions and are responses are provided in the following letter report: "*Response to Geotechnical and Hydrogeological Comments Proposed 56 Unit Townhouse Development 910 Veterans Drive, Barrie, Ontario*", Reference No. 19-1004A, dated August 16, 2019, by Central Earth Engineering Inc.

2 Procedures and Methodology

Prior to the commencement of drilling activities, the locations of underground utilities including natural gas, electrical, telephone, water, etc. were marked out by public and private utility locating companies. The fieldwork for the drilling program was carried out on February 11, 2018. A total of three boreholes (Borehole 1 through 3) were advanced on site by Drilltech Drilling using a track-mounted drill rig. To advance the boreholes, continuous flight solid stem augers and standard soil sampling equipment was utilized. All samples were collected as per ASTM D1586 to assess the strength characteristics of the substrate.

The boreholes were advanced to 6.6 metres below existing grade (local Elev. 94.3 to 93.52 metres). The horizontal locations were laid out in the field by Central Earth Engineering prior to the drilling operations and were spread evenly across the site. Geodetic elevation measurement of the ground surface of the borehole were measured based off a temporary benchmark chosen by CEE with an assumed Elev. 100.00 metres (centre line of road at centre of driveway to 910 Veterans Dr.) using a laser level. GPS measurements measured with a handheld GPS unit and referenced to the NAD 83 geodetic datum.

The field staff examined and classified characteristics of the soils encountered in the boreholes, including the presence of fill materials, made groundwater observations during and upon completion of the drilling, recorded observations of borehole construction, and processed the recovered samples. Soil sampling was conducted at regular intervals for the full depth of the borehole. The boreholes were backfilled upon completion. All recovered soil samples were logged in the field, carefully packaged and transported to the laboratory for more detailed examination and classification. In the laboratory, the samples were classified as to their visual and textural characteristics. Stabilized groundwater levels were measured in the three installed monitoring wells on February 13 and March 7, 2019.

3 Subsurface Conditions

3.1 General Overview

The detailed soil profiles encountered in the boreholes are indicated on the attached borehole logs in Appendix A. The borehole locations are shown on both an existing aerial photograph and the proposed site plan on Figures 2A and 2B, respectively. A generalized subsurface profile showing all boreholes is provided as Figure 3. It should be noted that the conditions indicated on the borehole logs are for specific locations only and can vary between and beyond the borehole locations. It should be noted that the soil boundaries indicated on the borehole logs are inferred from non-continuous sampling and observations during drilling. These boundaries are intended to reflect approximate transition zones and should not be interpreted as exact planes of geological change.

In addition, the descriptions provided in the borehole logs are inferred from a variety of factors, including: visual observations of the soil samples retrieved, laboratory testing, measurements prior to and after drilling, and the drilling process itself (speed of drilling, shaking/grinding of the augers, etc.). The passage of time also may result in changes in conditions interpreted to exist at locations where sampling was conducted.

3.2 Stratigraphy

All the boreholes encountered a nominal surficial topsoil layer ranging in thickness between 150 to 600 mm. Underneath the surficial topsoil layer, all three boreholes encountered a sand and silt glacial till deposit with some gravel and trace clay that extended beyond the vertical extent of the investigation for Boreholes 1 and 2 (Elev. 94.2 to 93.6 metres) and to a depth of 3.1 metres below existing grade in Borehole 3 (Elev. 97.9 metres). The glacial till stratum was noted to contain a higher silt content in Boreholes 1 and 2 at a depth of 4.6 metres below existing grade (Elev. 95.6 and 96.2 metres, respectively). The deposit was noted to be brown in color and generally in a moist in-situ state.

SPT “N” Values measured in the deposit ranged between:

- 0 to 1.2 metres below existing grade: 6 to 37 blows per 300 mm of penetration.
- 1.2 to 6.6 metres below existing grade: 33 blows per 300 mm to greater than 50 blows per 150 mm of penetration.

Base on the above information the upper 1.2 metres has a loose to dense relative density, while below 1.2 metres below existing grade the sand and silt glacial till deposit has a dense to very dense relative density.

In Borehole 3 below the sand and silt glacial till deposit a deposit of fine sand with some silt, trace clay and trace gravel was encountered at 3.1 metres below existing grade (Elev. 97.9 metres) and extended to 6.1 metres (Elev. 94.8 metres). The deposit was noted to be brown and moist. SPT "N" Values obtained in the deposit were greater than 50 blows per 150 mm of penetration indicating a very dense relative density. Below the fine sand deposit, the same sand and silt glacial till stratum that was present above the fine sand deposit was encountered at 6.1 metres below existing grade (Elev. 94.8 metres) and extended beyond the depth of the investigation at 6.6 metres below existing grade (Elev. 94.4 metres). The glacial till deposit was noted to be brown and moist. SPT "N" Values obtained in the deposit was greater than 50 blows per 150 mm of penetration indicating a very dense relative density.

3.3 Ground Water

Unstabilized ground water level measurements and cave measurements were taken upon completion of drilling of each borehole. These measurements provide a rough estimate of the possible excavation and temporary ground water control constructability considerations that may arise. All three boreholes were dry upon completion of drilling.

Monitoring wells were installed in each borehole. The monitoring wells were noted to be dry on both February 13 and March 7, 2019. Based on the results of the water levels and the moisture contents of the soil within the boreholes, the prevailing ground water table is expected to relatively deep and beyond 6.2 metres below existing grade (beyond local Elevation 94.0 metres).

Subsequent monthly monitoring ground water level readings were conducted until June 25, 2019, with details provided in the following report: "*Monthly Water Level Readings, Proposed 56 Unit Townhouse Development, 910 Veterans Drive, Barrie, Ontario*", Reference No. 19-1004A, dated August 6, 2019, by Central Earth Engineering. No ground water was noted in any of the monitoring wells during this monitoring, and therefore the seasonal high ground water level is also considered to be beyond 6.2 metres below existing grade (beyond local Elevation 94.0 metres) as the monitoring was conducted during the spring months.

4 Engineering Design Parameters & Analysis

It is proposed to demolish the existing residential buildings on site and construct four blocks of back to back townhouses for a total of 53 units. The townhouses will be 3 to 4 storeys high. A 12-metre-wide road will run north-south through the centre of the property and exit into the proposed low-density residential development that will eventually surround the site. Though the drawings show an 8-metre-wide road, it is understood that the most recent Draft Plan of Subdivision indicates that a 12-metre-wide road is required. Due to the proposed grading surrounding the site in other adjacent subdivisions, it is likely that approximately 3 metres of filling will be required to raise grades to match, though the exact amount of filling may change slightly during detailed design. Based on our correspondence, the townhomes will not have any underground basement levels (i.e. they will be slab-on-grade) and the depth for site servicing will be of typical depth for similar developments.

For low-rise residential structures, all buildings must be designed in accordance with the requirements of Part 3 or Part 9 of the 2012 Ontario Building Code. Reference should be made to the following sections of the 2012 Ontario Building Code which stipulate the geotechnical design and construction requirements for the type of residential structures being proposed at this site.

4.1 Site Grading

Due to the proposed grading surrounding the site in other adjacent subdivisions, it is likely that approximately 3 metres of filling will be required to raise grades to match, though the exact amount of filling may change slightly during detailed design. Grading plans should be provided to CEE when they are available to ensure the recommendations below remain valid.

In areas where the grade of the site will be raised in the footprint of any infrastructure (servicing, roads, slab-on-grade for buildings, sidewalks, driveways, etc.), the subgrade must be stripped of all topsoil, soil with high organic content or other deleterious material. The exposed surface should be compacted to 98% Standard Proctor Maximum Dry Density (SPMDD), proof-rolled, and then inspected by the geotechnical engineering prior to raising grades. Weak or soft areas identified during the proof-roll and inspection should be sub-excavated. Once approved, all new earth fill placed to raise the grades shall be suitable imported fill compacted to a minimum of 98% SPMDD. The purpose of this compaction specification is to provide uniform support and to mitigate the potential of significant differential settlements. Additional soil compaction recommendations are provided in Section 5.2 Compaction Specifications.

Although it is not a requirement for a geotechnical engineer to inspect compacted fill on a full-time basis, it is recommended for this site to ensure proper compaction across the site due to the relatively large amount of grade change that is anticipated to occur. Post-construction settlement of about 1% of the height of fill placed will occur. Typically, it is recommended to use cohesionless soils meeting the requirements of OPSS.MUNI 1010 for Select Subgrade Material (SSM), as this soil typically allows for better compaction and a shorter time period for post-construction settlements. Provided SSM material is used, it is recommended to wait for 1 month following grading activities prior to installing services or paving to reduce potential issues caused by differential settlement due to post-construction settlements that may occur of up to 1% of the height of the fill placed.

In areas where filling is required to the underside of foundation elevation, the recommendations provided in Section 4.2.2 Foundations on Engineered Fill must be followed.

4.2 Foundation Design

4.2.1 Foundations on Native Soil

The competent soil deposits located at 1.2 metres below existing grade can support conventional spread and strip footing foundations. Spread or strip footing foundations set below 1.2 metres below existing grade or lower and bearing on the undisturbed native soil deposits can be designed using a geotechnical reaction at SLS of 150 kPa for a maximum of 25 mm of settlement. The factored geotechnical resistance at ULS is 225 kPa.

4.2.2 Foundations on Engineered Fill

Due to the amount of grade raise required at this site, foundations may be envisioned to be set directly on the fill instead of extending down to the native soil. If this is the case, grades beneath all structures and foundations must be raised using engineered fill, on which conventional spread and strip footings can be made to bear on upon. Once grading plans are available for this site, they should be provided to CEE for review to ensure the recommendations below remain valid.

Engineered fill must be placed under the full-time supervision of a geotechnical engineer as required in the 2012 Ontario Building Code. Prior to placement of the engineered fill, all topsoil, existing earth fill, organics, deleterious materials, and disturbed soil must be removed from within the excavation area. The exposed subgrade must be surface compacted to 98% SPMDD using large compaction equipment, proof-rolled, and inspected by a qualified geotechnical staff member of CEE to ensure all unsuitable material was removed prior to commencement of engineered fill placement.

The engineered fill may consist of the excavated on-site soils provided they have a moisture content within 2% of optimum moisture content. Engineered fill must be compacted to a minimum of 98% Standard Proctor Maximum Dry Density (SPMDD). The engineered fill must extend a minimum of 1 metre out from all sides of the foundations and extend at a 1H : 1V slope down to the exposed subgrade. The engineered fill must be placed to be 0.3 metres higher than the proposed underside of foundation elevations.

Foundations placed on engineered fill as specified above can be designed using a geotechnical reaction at SLS of 100 kPa, for an estimated settlement of 25 mm or less. The maximum factored geotechnical resistance at ULS is 125 kPa.

It is recommended that nominal reinforcing steel for stiffening of the foundation walls made on engineered fill be provided to help mitigate minor cracking due to differential settlement. The reinforcing steel in the poured concrete foundation walls may consist of 2-15M bars continuous at the top of the foundation wall, and 2-15M bars continuous at the bottom of the foundation walls. Typically, these bars are placed 100 to 200 mm from the top or bottom of the foundation wall, respectively. The reinforcing steel should extend a minimum of 3 metres past any transition zones between engineered fill and native soil. The recommended nominal reinforcing steel should not be considered a structural design. The need for different or additional reinforcement should be reviewed by a structural engineer to ensure the original structural design intent of the structure is maintained.

4.2.3 General Foundation Considerations

The minimum strip and spread footing widths to be used shall be dictated as per the Ontario Building Code, regardless of loading considerations. Footings stepped from one level to another must be at a slope not exceeding 7 vertical to 10 horizontal. This concept should also be applied to excavations for new foundations in relation to existing footings or underground services unless rigid shoring is provided. All footings exposed to ambient air temperature throughout the year must be provided with a minimum of 1.2 metres of earth cover or equivalent insulation for frost protection.

The foundation design parameters provided below are predicated on the assumption that the foundation subgrade surface is undisturbed, and that all deleterious, softened, disturbed, organic, and caved material is removed. The foundation excavation must be done in such a way that ground water is controlled to prevent any disturbance to the foundation base.

The foundation subgrade must be reviewed prior to concrete placement to ensure the below foundation design parameters are applicable, and to provide remedial recommendations if necessary. If the foundation excavation will be open for a prolonged period of time, the foundation subgrade should be protected with a skim coat of lean mix concrete (after inspection by the geotechnical engineer), to ensure that no deterioration will occur due to weather effects.

4.3 Earth Pressures

Underground levels, basements, retaining walls, cantilevered shoring walls and shoring walls with a single level of earth anchors all must be designed to resist unbalanced lateral earth pressures imparted from the weight of adjacent soils. Lateral earth pressures are calculated using the following equation:

$$\boldsymbol{P = K[\gamma h + q]}$$

where,
P = the horizontal pressure at depth, **h** (m)
K = the earth pressure coefficient (dimensionless)
h = depth below surface in metres
γ = the bulk unit weight of soil, (kN/m^3)
q = surcharge loading (kPa)

The above equation assumes that a drainage system is present which prevents the build up of any hydrostatic pressure behind the structure subjected to the unbalanced lateral earth pressures. If this is not the case, the equation must be revised to also incorporate the submerged unit weight of the soil multiplied by the earth pressure coefficient, in addition to the water pressure itself.

The values for use in the design of structures subjected to unbalanced lateral earth pressures at this site are as follows:

Soil Type	γ - Bulk Unit Weight (kN/m3)	φ - Friction Angle (degrees)	Earth Pressure Coefficient (dimensionless)		
			K_a - Active	K_o – At-Rest	K_p - Passive
Granular ‘B’ (OPSS 1010)	21.0	32	0.31	0.48	3.25
Sand and Silt Glacial Till	21.0	35	0.27	0.43	3.69

The calculation of the earth pressure coefficients is based on Rankine theory, which provides a conservative estimate as no friction between the soil and the structure is accounted for. The earth pressure coefficients provided above are only applicable for flat ground surfaces beyond the structure and must be increased for sloping ground surfaces.

The earth pressure coefficients referenced within the above table are a function of the friction angle of the adjacent soil, and both the degree and direction of movement of the structure subjected to unbalanced lateral earth pressures. For structures that are restrained at the top (such as basement walls), the at-rest earth pressure coefficient will apply. For structures that allow for 0.1 to 1% of movement away from the soil, the full active earth pressure coefficient will apply. For structures that allow for 1 to 10% of movement into the soil, the full passive earth pressure coefficient will apply. The percentage movement is based on the height of the structure.

Other types of structures such as shoring walls with multiple rows of tiebacks and soil nail walls are subject to different loading conditions and must be analyzed separately.

4.4 Slab-on-Grade & Drainage Design

The modulus of subgrade reaction appropriate for design of the basement slab on compacted fill is 50,000 kPa/m. It is necessary that the floor slabs be provided with a capillary moisture barrier and drainage layer. This is made by placing the slab on a minimum 200 mm layer of clear stone compacted by vibration to a dense state. The upper 50 mm of clear stone can be replaced with 19 mm crusher run limestone for a working surface.

The ground surface should be sloped on a positive grade away from the structure to promote surface water run-off and to reduce groundwater infiltration adjacent to underground levels and foundations. To minimize infiltration of surface water, the upper 150 mm of backfill should comprise compacted relatively impervious soil material, where possible.

Perimeter drainage at the foundation level is not required, provided that the underside of concrete slab is at least 200 mm above the prevailing grade of the site and the surrounding surfaces slope away from the building at a gradient of at least 2 percent. For the portions of the building below prevailing grade, and for any pits or chambers made below grade level, perimeter drainage or waterproofing is required.

4.5 Site Servicing

4.5.1 Bedding

The type of material and depth of granular bedding below the pipe will, to some extent, depend on the method of construction used by the contractor. Pipe bedding for flexible pipes should follow the requirements in Ontario Provincial Standard Drawing 802.010 or applicable municipal standards. Pipe bedding for rigid pipes should follow the requirements in Ontario Provincial Standard Drawings 802.030 to 802.032 or applicable municipal standards.

The sand and silt glacial till subgrade will provide adequate support for pipes with the bedding requirements as laid out in the above referenced OPS drawings. Where disturbance of the trench base has occurred from groundwater seepage, construction traffic, etc., the disturbed soils should be sub-excavated and replaced with suitably compacted granular fill. If weak zones are encountered, additional bedding materials and differing construction practices may be required and should be determined during construction.

Regardless of whether flexible or rigid pipes are implemented, granular bedding and cover material should consist of a well graded, free draining material, such as Granular “A” (OPSS.MUNI 1010). All granular bedding must be compacted to a minimum of 95% SPMDD. Clear stone or high-performance bedding is permitted at this site provided it is fully wrapped in a non-woven filter fabric.

4.5.2 Backfill

The sand and silt glacial till encountered on site is expected to be suitable as backfill in trenches. The backfill should compacted to a minimum of 95% SPMDD. In confined areas the layer thickness will have to be reduced to utilize smaller compaction equipment efficiently or by using granular material instead of locally sourced fill. Any backfill that is frozen, contains a high percentage of organic material (topsoil, peat, etc.), or has otherwise unsuitable deleterious inclusion should not be used as backfill. The maximum cobble or boulder size should not exceed half of the loose lift thickness (i.e. all particles with a diameter greater than 150 mm should be removed).

Where trenches are within the traveled portions of a parking lot or driveway, backfill within the frost penetration depth of 1.2 metres should consist of native, non-organic, excavated material consistent with the soils surrounding the trench. If this technique is not undertaken, then frequently problems arise with yearly differential frost heave movements between the trench backfill and the adjacent native soil. This would occur, for example, if imported granular fill was used to backfill the trenches, which would be less frost susceptible than the majority of the earth fill and glacial till soils currently underlying the proposed parking and driveway areas. Alternatively, if different soil is used as the backfill, a frost taper of 5H:1V can be implemented to help mitigate the potential for differential settlement and frost heave.

4.6 Pavement Design

4.6.1 Subgrade Preparation

A review of the borehole data suggests that the proposed road subgrade will consist of a sand and silt glacial till. This type of soil is an adequate subgrade for the support of a pavement structure, provided the subgrade is approved by a geotechnical engineer at the time of construction and does not contain excessive amounts of organics or deleterious materials (as may be the case for zones within the any earth fill).

The pavement subgrade fill should be compacted to a minimum of 98% SPMDD. It is anticipated that the subgrade bearing modulus for the silt and sand glacial till deposit will be 50,000 kPa/m.

The long-term performance of the pavement structure is highly dependent upon the subgrade support conditions. Stringent construction control procedures must be maintained to ensure that uniform subgrade moisture and density conditions are achieved as much as possible when fill is placed, and the natural subgrade is not disturbed or weakened after it is exposed.

4.6.2 Drainage

Control of surface water is an important factor in achieving a good pavement life. The need for adequate subgrade drainage cannot be over-emphasized. The subgrade must be free of depressions and sloped (at a minimum grade of 3 percent) to provide effective drainage toward subgrade drains. Grading adjacent to pavement areas should be designed to ensure that water is not allowed to pond adjacent to the outside edges of the pavement.

Continuous pavement subdrains should be provided along both sides of the driveway/access routes and drained into respective catchbasins to facilitate drainage of the subgrade and the granular materials. The subdrain invert should be maintained at least 0.3 metres below subgrade level. To minimize the problems of differential movement between the pavement and catchbasins/manhole due to frost action, the backfill around the structures should consist of free-draining granulars.

4.6.3 Pavement Structure

The industry pavement design methods are based on a design life of 15 to 20 years for typical weather conditions depending on actual traffic volumes. The following pavement thickness design is provided on the above noted considerations and subgrade basis and meets the recommended pavement minimums as specified within Appendix C of the City of Barrie's "*Transportation Design Manual, Engineering Department*".

The following pavement thickness design is provided on the above noted considerations and subgrade basis.

Pavement Layer	Compaction Requirements	Minimum Component Thickness
Surface Course Asphaltic Concrete: HL3 (OPSS 1150) with PG 58-28 Asphalt Cement (OPSS.MUNI 1101)	OPSS 310	40 mm
Binder Course Asphaltic Concrete: HL-8 (OPSS 1150) with PG 58-28 Asphalt Cement (OPSS.MUNI 1101)	OPSS 310	70 mm
Base Course: Granular A (OPSS.MUNI 1010)	100% Standard Proctor Maximum Dry Density (ASTM-D698)	150 mm
Subbase Course: Granular B Type I or II (OPSS.MUNI 1010)	100% Standard Proctor Maximum Dry Density (ASTM- D698)	450 mm*

*This granular thickness assumes an average annual daily traffic (AADT) of 2,500. If the AADT is more than this value, the granular subbase course should be increased to 530mm as per City of Barrie standards.

The granular materials should be placed in lifts 200 mm thick or less and be compacted to a minimum of 100% SPMDD for both granular base and subbase. Asphalt materials should be rolled and compacted as per OPSS 310. The granular and asphalt pavement materials and their placement should conform to OPSS 310, 501, 1010 and 1150.

If the pavement construction occurs in wet, winter or inclement weather, it may be necessary to provide additional subgrade support for heavy construction traffic by increasing the thickness of the granular subbase, base or both. Further, traffic areas for construction equipment may experience unstable subgrade conditions. These areas may be stabilized utilizing additional thickness of granular materials.

It should be noted that in addition to adherence of the above pavement design recommendations, a close control on the pavement construction process will also be required in order to obtain the desired pavement life. Therefore, it is recommended that regular inspection and testing should be conducted during the pavement construction to confirm material quality, thickness, and to ensure adequate compaction.

5 Constructability Considerations

5.1 Excavations & Ground Water Control

Excavations must be carried out in accordance with the Occupational Health and Safety Act, Ontario Regulation 213/91 (as amended), Construction Projects, Part III - Excavations, Section 222 through 242.

Where workers must enter a trench or excavation the soil must be suitably sloped and/or braced in accordance with the OHSA. These regulations designate four (4) broad classifications of soils to stipulate appropriate measures for excavation safety. For this site, the sand is classified as a Type 3 soil, which requires excavation sidewalls to be constructed no steeper than 1 horizontal to 1 vertical from the base of the excavation.

Minimum support system requirements for steeper excavations are stipulated in Sections 235 through 238 and 241 of the OHSA and include provisions for timbering, shoring and moveable trench boxes. In order to reduce the potential for instability of the trench excavations, materials excavated from the service trenches and/or other fill materials or heavy equipment should not be placed near the crest of the trench excavations.

As excavations are expected to be above the prevailing ground water table, there should be limited ground water control issues present. During times of high precipitation, some water may collect at the base of the excavation. Local sumps placed at the base of the excavation can typically control groundwater seepage in this scenario.

It is important to note that soils encountered in the construction excavations may vary significantly across the site. Our preliminary soil classifications are based solely on the materials encountered in the one borehole advanced on site. The contractor should verify that similar conditions exist throughout the proposed area of excavation. If different subsurface conditions are encountered at the time of construction, we recommend that CEE be contacted immediately to evaluate the conditions encountered.

It is important to note that soils encountered in the construction excavations may vary significantly across the site. Our preliminary soil classifications are based solely on the materials encountered in widely spaced explorations. The contractor should verify that similar conditions exist throughout the proposed area of excavation. If different subsurface conditions are encountered at the time of construction, we recommend that Central Earth Engineering be contacted immediately to evaluate the conditions encountered.

5.2 Compaction Specifications

Standard Proctor Maximum Dry Density (SPMDD) is the level to which a soil or aggregate is compacted. To achieve the specified SPMDD as indicated in the subsequent sections of this report, all soils or aggregates must be placed in lift thicknesses no greater than 200 mm. If this is not the case, only the upper portion of the lift will be adequately compacted, and the lower portion of the lift has a high probability of not meeting compaction specifications. In addition, industry standard equipment used to determine the degree of compaction consists of nuclear densometers. These devices have an inherent limitation in that they cannot test beyond 300 mm in depth, and so the degree of compaction beyond this depth cannot be quantitatively determined.

Along with lift thickness, ensuring that the soil or aggregate is within 2% of its optimum moisture content ensures that the specified compaction can be reached. If the soil or aggregate is too dry/wet, it is either very difficult or impossible to reach the specified compaction. This is especially true for when higher compaction specifications such as 98% and 100% SPMDD are required. Based on our review of the soil types encountered in the boreholes and associated moisture contents, the vast majority of the soils on site can be re-used without significant moisture conditioning and are within a few percentage points of optimum moisture content.

In addition to the above compaction specifications, in any areas where compacted fill will be placed over the exposed native soil subgrade, any loose, soft, wet or unstable areas should be sub-excavated, and backfilled with clean earth fill of Granular 'B' (OPSS.MUNI 1010) compacted to a minimum of 98% SPMDD. This recommendation applies to site servicing and pavement subgrades.

5.3 Quality Verification Services

On-site quality verification services are an integral part of the geotechnical design function, and for foundations and retaining walls, are required under the Ontario Building Code. Quality verification services are used to confirm that construction is being conducted in general conformance with the requirements as outlined in the drawings, reports and specifications prepared for the proposed development.

Central Earth Engineering can provide all the on-site quality verification services outlined below:

- Engineered fill construction in which foundations will be placed upon must be inspected on a full-time basis by the geotechnical engineer. The subgrade for shallow foundations may be field reviewed by the geotechnical engineer as required by the municipal regulating authority.
- Installation of retaining structures over 1.0 metres high and related backfilling operations must be field reviewed on a continuous basis by the geotechnical engineer as required in the OBC.
- Part-time monitoring of the subgrade support capabilities, material quality, lift thickness, moisture content, degree of compaction, etc. is recommended for the following areas to ensure the recommendations within this report are followed and they perform adequately in the long-term:
    - General grade raises;
    - Slab-on-grades;
    - Pavement structure (granulars and asphalt); and
    - Bedding/backfilling of site servicing.
- Testing of the concrete (compressive strength, slump, air content, etc.) and testing of the asphalt (asphalt content and gradation) are recommended to ensure that the quality of the materials being brought to site meet the requirements of the project.

5.4 Site Work

The soils found at this site may become weakened when subjected to traffic, particularly when wet. If there is site work carried out during periods of wet weather, then it can be expected that the subgrade will be disturbed unless an adequate granular working surface is provided to protect the integrity of the subgrade soils from construction traffic. Subgrade preparation works cannot be adequately accomplished during wet weather and the project must be scheduled accordingly. The disturbance caused by the traffic can result in the removal of disturbed soil and use of granular fill material for site restoration or underfloor fill that is not intrinsic to the project requirements.

The most severe loading conditions on the subgrade may occur during construction. Consequently, special provisions such as end dumping and forward spreading of earth and aggregate fills, restricted construction lanes, and half-loads during paving and other work may be required, especially if construction is carried out during unfavourable weather.

If construction proceeds during freezing weather conditions, adequate temporary frost protection for the founding subgrade and concrete must be provided. The soil at this site is highly susceptible to frost damage. Consideration must be given to frost effects, such as heave or softening, on exposed soil surfaces in the context of this particular project development.

6 Limitations and Conclusion

6.1 Limitations

The recommendations and comments provided are necessarily on-going as new information of underground conditions becomes available. More specific information with respect to the conditions between samples, or the lateral and vertical extent of materials may become apparent during excavation operations. The interpretation of the borehole information must, therefore, be validated during excavation operations. Consequently, conditions not observed during this investigation may become apparent. Should this occur, Central Earth Engineering Inc. should be contacted to assess the situation and additional testing and reporting may be required.

Central Earth Engineering Inc. should be retained for a general review of the final design drawings and specifications to verify that this report has been properly interpreted and implemented. If not accorded the privilege of making this review, Central Earth Engineering Inc. will assume no responsibility for interpretation of the recommendations in the report.

The comments given in this report are intended only for the guidance of the design engineers. The number of boreholes required to determine the localized underground conditions between boreholes affecting construction costs, techniques, sequencing, equipment, scheduling, etc. could be greater than has been carried out for design purposes. Contractors bidding on or undertaking the works should, in this light, decide on their own investigations, as well as their own interpretations of the factual borehole results, so that they may draw their own conclusions as to how the subsurface conditions may affect them.

This report was prepared by Central Earth Engineering Inc. for the account of 2528286 Ontario Inc. 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. Central Earth Engineering Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this project

6.2 Conclusion

It is recognized that municipal/regional governing bodies, in their capacity as the planning and building authority under Provincial statues, will make use of and rely upon this report, cognizant of the limitations thereof, both as are expressed and implied.

We trust this report is complete within our terms of reference, and the information presented is sufficient for your present purposes. If you have any questions, or when we may be of further assistance, please do not hesitate to contact our office.

Yours Truly,

Central Earth Engineering Inc.

Alexander Winkelmann, P.Eng.
President

LICENSED PROFESSIONAL ENGINEER
A.WINKELMANN
100150146
Aug. 16, 2019
PROVINCE OF ONTARIO

Figures –

SITE LOCATION PLAN

BOREHOLE LOCATION PLANS

GENERALIZED SUBSURFACE PROFILE

Appendix A –

BOREHOLE LOGS

Appendix B –

GEOTECHNICAL LABORATORY DATA