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Geotechnical Investigation
Emerald Subdivision
Jack Pine Crescent
Ottawa, Ontario

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Submitted to:

ARK Engineering and Development
2691 Old Highway 17
Rockland, Ontario
K4K 1W3

Geotechnical Investigation
Emerald Subdivision
Jack Pine Crescent
Ottawa, Ontario

December 20, 2021
Project: 100554.001

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December 20, 2021

File: 100554.001

ARK Engineering and Development
2691 Old Highway 17
Rockland, Ontario
K4K 1W3

Attention: Daniel Payer, P.Eng.

Re: Geotechnical Investigation
Emerald Subdivision
Jack Pine Crescent
Ottawa, Ontario

Please find enclosed our geotechnical investigation report for the above noted project based on the scope of work provided in our proposal dated February 25, 2021. This report was prepared by Mr. Alex Meacoe, P.Eng., and reviewed by Mr. Brent Wiebe, P.Eng.

Do not hesitate to contact the undersigned if you have any questions or require additional information.

Alex Meacoe, P.Eng.

Brent Wiebe, P.Eng.

WAM/BW

Enclosures
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1.0 INTRODUCTION

This report presents the results of a geotechnical investigation carried out for the proposed Emerald subdivision located in Ottawa, Ontario. The purpose of the investigation was to identify the general subsurface conditions at the site by means of a limited number of test pits and boreholes and, based on the factual information obtained, to provide engineering guidelines on the geotechnical design aspects of the project, including construction considerations that could influence design decisions.

2.0 BACKGROUND

2.1 Project Description

Plans are being prepared for the development of the Emerald subdivision located in the Village of Greely in Ottawa, Ontario. Based on the preliminary plan provided, the overall site is irregular in shape with plan dimensions of about 750 metres by 600 metres. It is understood that the residential development will consist of 73 lots.

The site is currently vacant land with heavy tree cover.

2.2 Site Geology

A review of surficial geology maps of the area indicate that the site is underlain by silty clay, peat, and silty sand over glacial till. Bedrock geology maps of the area show that the overburden deposits are underlain by dolostone bedrock of the Oxford formation, at depths ranging from approximately 1 to 10 metres, sloping downwards to the north.

3.0 SUBSURFACE INVESTIGATION

3.1 Geotechnical Investigation

The fieldwork for this investigation was carried out between March 8 and 9, 2021 and on March 19, 2021. During that time, a total of 18 test pits (numbered 21-01 to 21-18, inclusive) and four boreholes (numbered 21-101, 21-103, 21-104, and 21-105) were advanced at the site. Details on the test holes are provided below:

- The test pits were advanced to depths ranging from about 1.6 to 4.6 metres below the existing ground surface;
- The boreholes were advanced to depths of about 4.2 to 6.7 metres below the existing ground surface.

The test pits were excavated using a track mounted excavator supplied by ARK Engineering and Development. The subsurface conditions in the test pits were determined based on visual and tactile examination of the material exposed on the walls of the test pits.

Well screens were sealed in the overburden at test pits 21-02, 21-08, and 21-18, to measure the groundwater levels. The groundwater levels in the remaining test pits were observed during the short time they were left open.

The boreholes were advanced using a track mounted hollow stem auger drill rig supplied and operated by CCC Geotechnical and Environmental Drilling of Ottawa, Ontario.

Standard penetration tests were carried out in the boreholes and samples of the soils encountered were recovered using a 50 millimetre diameter split barrel sampler. In situ vane shear testing was carried out, where possible, in the boreholes to measure the undrained shear strength of the silty clay. Two relatively undisturbed samples of the silty clay deposit were obtained from boreholes for possible oedometer consolidation testing.

Well screens were sealed in the overburden at boreholes 21-101, 21-104, and 21-105, to measure the groundwater levels.

The fieldwork was supervised throughout by a member of our engineering staff who directed the drilling operations, logged the samples and carried out the in-situ testing. Following the fieldwork, the soil samples were returned to our laboratory for examination by a geotechnical engineer. Selected samples of the soil were tested for water content, Atterberg limits, and grain size distribution testing.

The test pit locations were positioned in the field by ARK Engineering personnel. The borehole locations were positioned in the field by GEMTEC personnel using existing site features. The test pit locations were surveyed by ARK Engineering. The borehole locations were subsequently surveyed using our Trimble R10 GPS survey instrument. The elevations are referenced to geodetic datum.

Descriptions of the subsurface conditions logged in the test pits and boreholes are provided on the Record of Test Hole Sheets in Appendix A. The results of the laboratory tests are provided on the borehole logs and in Appendix B. The results of chemical testing completed on one soil sample are provided in Appendix C. The approximate locations of the test holes are shown on the Test Hole Location Plan, Figure 1.

3.2 Geotechnical Fieldwork by ARK Engineering

Two additional test pits numbered 19 and 20 were advanced at the site by ARK Engineering, on Lots 41 and 40, respectively. The test pits were advanced to depths of about 3.5 and 2.2 metres below ground surface in test pits 19 and 20, respectively.

The test pits were advanced at the approximate locations shown on Figure 1.

The test pit information, including location, ground surface elevation, and soil stratigraphy were provided by ARK Engineering.

4.0 SUBSURFACE CONDITIONS

4.1 General

As previously indicated, the soil and groundwater conditions identified in the test holes are given on the Record of Test Hole Sheets in Appendix A. The borehole logs indicate the subsurface conditions at the specific test locations only. Boundaries between zones on the logs are often not distinct, but rather are transitional and have been interpreted. The precision with which subsurface conditions are indicated depends on the method of drilling, the frequency and recovery of samples, the method of sampling, and the uniformity of the subsurface conditions. Subsurface conditions at other than the test locations may vary from the conditions encountered in the test pits and boreholes. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties.

The groundwater conditions described in this report refer only to those observed at the place and time of observation noted in the report. These conditions may vary seasonally or as a consequence of construction activities in the area.

The soil descriptions in this report are based on commonly accepted methods of classification and identification employed in geotechnical practice. Classification and identification of soil involves judgement and GEMTEC does not guarantee descriptions as exact, but infers accuracy to the extent that is common in current geotechnical practice.

The following presents an overview of the subsurface conditions encountered in the test pits and boreholes advanced during this investigation.

4.2 Fill Material

A layer of fill material was encountered at the ground surface in borehole 21-103. The fill material consists of likely reworked brown silty sand and gravel. The fill material has a thickness of about 410 millimetres.

One standard penetration test carried out in the fill material gave an N value of 33 blows per 0.3 metres of penetration, which indicates a dense relative density.

4.3 Topsoil

A layer of topsoil was encountered at the ground surface at all test hole locations, except borehole 21-103. The thickness of the topsoil ranges from about 50 to 150 millimetres.

4.4 Silty Sand to Sand

Native deposits of silty sand to sand with some silt and trace gravel was encountered below the topsoil in all test hole locations. The silty sand to sand deposit was not fully penetrated in all the test holes, but was proven to depths ranging from about 0.2 to 4.6 metres below ground surface.

Standard penetration tests carried out in the silty sand to sand deposits gave N value ranging from 3 to 33 blows per 0.3 metres of penetration, which indicates a very loose to dense relative density.

Two grain size distribution tests were undertaken on samples of the sand from test pits 21-03 and 21-10. The results are provided in Appendix B and are summarized in Table 4.1.

Table 4.1 – Summary of Grain Size Distribution Test (Sand)

Location	Sample Number	Sample Depth (metres)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
21-03	2	0.9 – 1.0	0	93	6	1
21-10	2	1.2 – 1.4	0	96	2	2

The water content of 12 samples of the silty sand to sand ranges from about 6 to 43 percent.

4.5 Silty Clay

Native deposits of silty clay were encountered in test pits 21-04 to 21-12 and 21-18, and all of the boreholes.

The full depth of the silty clay in the test holes is grey in colour. The silty clay was not fully penetrated in the test pits, but was proven to depths ranging from about 4.0 to 4.6 metres below ground surface. The silty clay deposits encountered in the boreholes have a thickness ranging from about 0.6 to 1.4 metres and extend to depths ranging from about 3.1 to 4.6 metres below existing ground surface.

Standard penetration tests carried out in the silty clay gave N values ranging from static weight of hammer (WH) to 2 blows per 0.3 metres of penetration. The results of the in situ testing reflect a firm consistency.

The results of one Atterberg limit test carried out on a sample of the silty clay from test pit 21-04 are provided in Appendix B. The results are summarized in Table 4.2.

Table 4.2 – Summary of Atterberg Limit Test Results (Silty Clay)

Test Pit / Sample No.	Water Content (%)	Liquid Limits (%)	Plastic Limits (%)	Plasticity Index
21-04 / 3	49	34	15	19

This testing indicates that the sample of silty clay tested from the test pit has a low plasticity.

The water content of one sample of the silty clay is about 49 percent.

4.6 Clayey Silt

Native deposits of clayey silt were encountered below the silty clay in the boreholes. The clayey silt has a thickness ranging from about 0.9 to 1.2 metres and extends to depths ranging from about 4.2 to 5.5 metres below ground surface.

Standard penetration tests carried out in the clayey silt gave N values ranging from static weight of hammer (WH) to 12 blows per 0.3 metres of penetration. Two in situ vane shear strength tests carried out in the silty clay gave undrained shear strengths of about 82 and 88 kilopascals. The results of the in situ testing reflects a stiff consistency. The remolded shear strength of the clayey silt was measured to be about 13 and 17 kilopascals. The results indicate a sensitive soil.

4.7 Glacial Till

Native deposits of glacial till were encountered below the silty sand and silty clay, where encountered in test pits 21-09, and 21-12 to 21-17 and boreholes 21-101, 21-103, 21-104, and 21-105. The glacial till was not fully penetrated in all the test holes but was proven to depths ranging from about 1.6 to 6.7 metres below ground surface.

The glacial till is a heterogeneous mixture of all grain sizes, which at this site, can be described as grey silty sand with trace to some gravel with cobbles and boulders.

Standard penetration tests carried out in the glacial till deposit gave N values ranging from 10 to greater than 50 blows per less than 0.3 metres of penetration, which indicates a loose to very dense relative density.

One grain size distribution test was undertaken on a select sample of the glacial till from test pit 21-17. The results are provided in Appendix B and are summarized in Table 4.3.

Table 4.3 – Summary of Grain Size Distribution Test (Glacial Till)

Location	Sample Number	Sample Depth (metres)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
21-17	2	1.0 – 1.2	12	50	33	5

The water content of one sample of the glacial till is about 8.2 percent.

4.8 Refusal

Refusal to excavator advancement was encountered in test pits 21-12, 21-13, 21-14, 21-16, and 21-17 at depths of about 1.6 to 3.4 metres below the existing ground surface. The refusal likely represents the presence of cobbles or boulders within the glacial till deposit or the bedrock surface.

Two additional test pits, numbered 19 and 20, advanced by ARK Engineering on lots 41 and 40, respectively, encountered refusal at depths of about 3.5 and 2.2 metres, respectively.

A summary of the excavator refusal depths and elevations are provided in Table 4.4 below.

Table 4.4 – Summary of Excavator Refusal Depth and Elevation

Borehole/Test Pit Number	Ground Surface Elevation (metres)	Depth to Refusal (metres)	Refusal Elevation (metres)
21-12	102.7	3.2	99.5
21-13	102.7	3.0	99.7
21-14	102.8	1.6	101.2
21-16	105.0	3.4	101.6
21-17	103.7	3.0	100.7
19	102.7	3.5	99.2
20	102.7	2.2	100.5

4.9 Groundwater Levels

Well screens were installed in the overburden at test pits 21-02, 21-08, and 21-18 and boreholes 21-101, 21-104, and 21-105. The groundwater level in the open test pits were measured at the time of the field investigation on March 8 and 9, 2021.

The groundwater levels were measured in the well screens on March 12 and 29, 2021 and are summarized in Table 4.5.

Table 4.5 – Groundwater Depth and Elevation

Test Hole No.	Groundwater Depth Below Existing Ground Surface (metres)	Groundwater Elevation (metres, geodetic datum)	Date of Reading
21-01	1.1	101.2	March 9, 2021
21-02	1.0	101.5	March 12, 2021
21-03	2.3	100.1	March 8, 2021
21-04	1.4	101.1	March 8, 2021
21-05	Dry	< 98.1	March 8, 2021
21-06	Dry	< 98.3	March 8, 2021
21-07	1.8	100.2	March 8, 2021
21-08	1.9	101.1	March 12, 2021
21-09	Dry	< 98.3	March 8, 2021
21-10	Dry	< 98.4	March 8, 2021
21-11	1.3	101.4	March 8, 2021
21-12	1.5	101.2	March 8, 2021
21-13	Dry	< 99.7	March 8, 2021
21-14	1.4	101.4	March 9, 2021
21-15	Dry	< 100.1	March 9, 2021
21-16	Dry	< 101.6	March 9, 2021
21-17	Dry	< 100.7	March 9, 2021
21-18	0.0	102.3	March 12, 2021
21-101	0.2	102.2	March 29, 2021
21-104	0.0	102.3	March 29, 2021
21-105	0.3	101.9	March 29, 2021

The groundwater levels may be higher during wet periods of the year such as the early spring or following periods of precipitation.

4.10 Soil Chemistry Relating to Corrosion

The results of chemical testing on a soil sample recovered from test pit 21-11 are provided in Appendix D and are summarized in Table 4.6.

Table 4.6 – Summary of Corrosion Testing

Parameter	Test Pit 21-11 Sample No. 1 Depth: 2.1 to 2.4 m
Chloride Content (ug/g)	< 5
Resistivity (Ohm.m)	70.8
pH	7.66
Sulphate Content (ug/g)	51

5.0 GEOTECHNICAL GUIDELINES

5.1 General

The information in the following sections is provided for the guidance of the design engineers and is intended for the design of this project only. Contractors bidding on or undertaking the works should examine the factual results of the investigation, satisfy themselves as to the adequacy of the information for construction, and make their own interpretation of the factual data as it affects their construction techniques, schedule, safety and equipment capabilities.

The professional services retained for this project include only the geotechnical aspects of the subsurface conditions. The implications of possible surface and/or subsurface contamination resulting from previous uses or activities of this site or adjacent properties, and/or resulting from the introduction onto the site from materials from offsite sources are outside the terms of reference for this report and have not been addressed.

5.2 Site Grade Raise Restrictions

The soil conditions across the site are somewhat variable, as such, we have sectioned the site into two assessment areas, Area A and Area B, with respect to site grade raise restrictions.

Area A is underlain by native deposits of silty sand to sand over glacial till. Based on the test hole information, there are no grade raise restrictions in this area, from a geotechnical perspective. The settlement due to compression of the native soils as a result of fill placement should be relatively small and should occur during or shortly after the fill placement.

Area B is underlain by deposits of silty sand over sensitive silty clay, which has a limited capacity to support loads imposed by grade raise fill material, pavement structures and foundations for the houses. The placement of fill material on this site must therefore be carefully planned and controlled so that the stress imposed by the fill material does not result in excessive consolidation of the silty clay deposit. Concrete slabs, granular base materials, overall grade raise and pavement structures are considered grade raise filling. Groundwater lowering also results in a stress increase on the underlying sensitive silty clay deposit.

Based on the results of the subsurface investigation, the maximum thickness of any grade raise filling should be limited to **3.0 metres** above the existing surface grade.

The grade raise restriction for the residential development has been calculated in order to limit the total settlement of the ground to about 25 millimetres in the long term. For design purposes, we have made the following assumptions:

- The groundwater lowering due to the development at this site will be at most 0.5 metres below the underside of footing elevation;
- The unit weight of the grade raise material used in the vicinity of the structures will not be greater than 20.0 kilonewtons per cubic metre; and,
- The grade raise fill material used below the structures, where required, will be composed of compacted granular material having a unit weight of 21.5 kilonewtons per cubic metre.

If heavier grade raise fill material is used, the maximum grade raise will have to be reduced accordingly.

5.3 Proposed Houses

5.3.1 Excavation

The excavations for the foundations will be through the topsoil and any fill material (i.e., any native material that was disturbed during the tree clearing operations) and into the native silty sand, sand, silty clay, and possibly into the glacial till. The sides of the excavations should be sloped in accordance with the requirements in Ontario Regulation 213/91 under the Occupational Health and Safety Act. According to the Act, the shallow native overburden deposits can be classified as Type 3 and, accordingly, allowance should be made for excavation side slopes of 1 horizontal to 1 vertical extending upwards from the base of the excavation.

Based on our previous experience, groundwater inflow from the silty clay deposits into the excavations should be relatively small and controlled by pumping from filtered sumps within the excavations. Conversely, the amount of groundwater inflow from the sandy deposits may be significant and flatter side slopes may be required to prevent sloughing. It is not expected that short term pumping during excavation will have any significant effect on nearby structures and services.

5.3.2 Groundwater Pumping

The groundwater level were measured to be about 0.0 to 0.3 metres below the existing ground surface in the monitoring wells installed in boreholes 21-101, 21-104 and 21-105.

To reduce the potential for long term pumping from basement sump pits, it is recommended that the underside of basement floor slab elevation be set a minimum of 0.3 metres above the high groundwater level.

Any groundwater inflow into the excavations should be handled from within the excavation by pumping from filtered sumps. Suitable detention and filtration will be required before discharging the water to a sewer or ditch. The amount of water entering the excavation for the construction of the foundations at this site should not exceed 50,000 litres per day and therefore it is not anticipated that an Environmental Activity and Sector Registry (EASR) will be required.

5.3.3 Foundation Design

The native overburden deposits of sand, silty sand, silty clay and glacial till are considered suitable for the support of residential structures founded on conventional spread footing foundations. All topsoil, fill material or disturbed material should be removed from the building footprint.

In areas where proposed founding level is above the level of the native soil, or where subexcavation of disturbed material is required below proposed founding level, imported granular material (engineered fill) should be used. The engineered fill should consist of granular material meeting Ontario Provincial Standard Specifications (OPSS) requirements for Granular B Type II and should be compacted in maximum 200 millimetre thick lifts to at least 95 percent of the standard Proctor maximum dry density. In areas where groundwater inflow is encountered, pumping should be carried out from sumps in the excavation during placement of the engineered fill. To allow spread of load beneath the footings, the engineered fill should extend horizontally at least 0.3 metres beyond the footings and then down and out from this point at 1 horizontal to 1 vertical, or flatter. The excavations for the residential dwellings should be sized to accommodate this fill placement. The engineered fill should be placed in accordance with the site grade raise restrictions.

Spread footings founded on or within native undisturbed silty sand, sand, silty clay, or glacial till deposits, or on a pad of compacted granular material above native, undisturbed soil should be sized using an allowable bearing pressure of 75 kilopascals. Provided that any loose or disturbed soil is removed from the bearing surfaces, and the grade raise restrictions provided above are adhered to, the settlement of the footings should be less than 25 millimetres.

5.3.4 Frost Protection of Foundations

All exterior footings should be provided with at least 1.5 metres of earth cover for frost protection purposes. Isolated (unheated) footings that are located in areas that are to be cleared of snow should be provided with at least 1.8 metres of earth cover for frost protection purposes.

Alternatively, the required frost protection could be provided by means of a combination of earth cover and extruded polystyrene insulation. Further details regarding the insulation of foundations could be provided, if necessary.

5.3.5 Backfill and Drainage

5.3.5.1 Basement Foundation Walls

In accordance with the Ontario Building Code, the following alternatives could be considered for drainage of the basement foundation walls:

- Damp proof the exterior of the foundation walls and backfill the walls with free draining, non-frost susceptible sand or sand and gravel such as that meeting OPSS requirements for Granular B Type I or II. OR
- Damp proof the exterior of the foundation walls, install an approved proprietary drainage material on the exterior of the foundation walls and backfill the walls with native material or imported soil.

Where the backfill will ultimately support areas of hard surfacing (pavement, sidewalks or other similar surfaces), the backfill should be placed in maximum 200 millimetre thick lifts and should be compacted to at least 95 percent of the standard Proctor maximum dry density value using suitable compaction equipment. Where future landscaped areas will exist next to the proposed structure and if some settlement of the backfill is acceptable, the backfill could be compacted to at least 90 percent of the standard Proctor maximum dry density value.

A perforated drain should be installed around the basement area at the level of the bottom of the footings. The drain should outlet by gravity to a storm sewer or to a sump pit from which the water is pumped to a suitable outlet.

5.3.5.2 Garage Foundation Walls and Isolated Piers

To avoid adfreeze and possible jacking (heaving) of the foundation walls, the interior and exterior of the garage foundation walls should be backfilled with free draining, non-frost susceptible sand or sand and gravel such as that meeting OPSS requirements for Granular B Type I or II. The backfill within the garage should be compacted in maximum 300 millimetres thick lifts to at least 95 percent of the standard Proctor dry density value using suitable vibratory compaction equipment.

The backfill against isolated (unheated) walls or piers should consist of free draining, non-frost susceptible material, such as sand or sand and gravel meeting OPSS Granular B Type I or II requirements. Other measures to prevent frost jacking of these foundation elements could be provided, if required.

5.3.6 Lateral Earth Pressures

Foundation walls that are backfilled with granular material such as that meeting OPSS Granular B Type I or II requirements should be designed to resist "at rest" earth pressures calculated using the following formula:

$P_o = 0.5\ K_o\ \gamma\ H^2$

where;

- P_o: Static "At Rest" thrust (kilonewtons per metre);
- γ: Moist material unit weight (kilonewtons per cubic metre);
- K_o: "At Rest" earth pressure coefficient;
- H: Wall height (metre).

Seismic shaking can increase the forces on the retaining wall. The total "At Rest" thrust acting on the walls (P_{oe}) during a seismic event is composed of a static component (P_o) and a dynamic component (P_e), that is:

$P_{oe} = P_o + P_e$

The dynamic at rest thrust component (P_e), which acts only during seismic loading conditions, should be calculated using the following formula:

$P_e = 0.5\ (K_{oe} - K_o)\ \gamma\ H^2$

where;

- P_e: Total "At Rest" thrust (kilonewtons per metre);
- γ: Moist material unit weight (kilonewtons per cubic metre);
- K_o "At Rest" earth pressure coefficient
- K_{oe}: Dynamic "At Rest" earth pressure coefficient;
- H: Wall height (metre).

The static thrust component (P_o) acts at a point located H/3 above the base of the wall. During seismic shaking, the dynamic at rest thrust component (P_o) acts at a point located about 0.6H above the base of the wall.

For design purposes, the parameters provided in Table 5.1 can be used to calculate the thrust acting on the walls during static and seismic loading conditions.

Table 5.1 – Summary of Design Parameters (Building Foundation Walls)

Parameter	OPSS Granular B Type I	OPSS Granular B Type II
Material Unit Weight, γ (kilonewtons per cubic metre)	22	22
Estimated Friction Angle (degrees)	34	38
"At Rest" Earth Pressure Coefficient, K_o, assuming horizontal backfill behind the structure	0.44	0.38
Dynamic "At Rest" Earth Pressure Coefficient, K_{oe}, assuming horizontal backfill behind the structure	0.50[1]	0.43[1]

Notes:

1) According to the 2015 National Building Code of Canada, the peak ground acceleration (PGA) for this site is 0.31 for Site Class D. The dynamic at rest earth pressure coefficient was calculated using the method suggested by Mononobe and Okabe, assuming a horizontal seismic coefficient, kh, of 0.16 and assuming that the vertical seismic coefficient, kv, is zero.

Heavy construction traffic should not be allowed to operate adjacent to foundation walls (within about 2 metres horizontal) during construction, without the approval of the designers.

5.3.7 Basement Floor Slabs

To provide predictable settlement performance of basement slabs, all topsoil, fill material, or disturbed soil should be removed from the slab area. The base of the floor slab should consist of at least 200 millimetres of 19 millimetre clear crushed stone. Any necessary grade raise fill should consist of either 19 millimetre clear crushed stone or OPSS Granular B Type II. OPSS documents allow recycled asphaltic concrete and concrete to be used in Granular B Type II material. Since the source of recycled material cannot be determined or controlled, it is suggested that any imported Granular B Type II materials be composed of 100 percent crushed rock only.

The clear crushed stone should be nominally compacted in maximum 300 millimetre thick lifts with at least 3 passes of a diesel plate compactor. The Granular B Type II should be compacted in maximum 200 millimetre thick lifts to at least 95 percent of the standard Proctor maximum dry density value using suitable vibratory compaction equipment.

The ACI 302.1R-04 "Guide for Concrete Floor and Slab Construction" should be referenced for design purposes.

A polyethylene vapour retarder is recommended below the floor slabs.

5.3.8 Corrosion of Buried Concrete and Steel

According to Canadian Standards Association (CSA) "Concrete Materials and Methods of Concrete Construction", the concentration of sulphate in the soil sample recovered from borehole 21-11 can be classified as low. For low exposure conditions, any concrete that will be in contact with the native soil or groundwater could be batched with General Use (GU) type cement. The effects of freeze thaw in the presence of de-icing chemical (sodium chloride) near the building should be considered in selecting the air entrainment and the concrete mix proportions for any exposed concrete.

Based on the resistivity and pH of the soil sample tested the soil can be generally classified as non-aggressive toward unprotected steel. It is noted that the corrosivity of the soil could vary throughout the year due to the application sodium chloride for de-icing.

5.4 Roadway Construction

5.4.1 Subgrade Preparation

In preparation for roadway construction at this site, all surficial topsoil and any soft, wet or deleterious materials should be removed from the proposed roadways. Any subexcavated areas could be filled with compacted earth borrow. Similarly, should it be necessary to raise the roadway grades at this site, material which meets OPSS specifications for Select Subgrade Material or Earth Borrow could be used. The Select Subgrade Material or Earth Borrow should be placed in maximum 300 millimetre thick lifts and compacted to at least 95 percent of the standard Proctor maximum dry density value using vibratory compaction equipment. Prior to placing granular material for the roadway, the exposed subgrade should be heavily proof rolled and inspected and approved by geotechnical personnel. Any soft areas evident from the proof rolling should be subexcavated and replaced with suitable earth borrow approved by the geotechnical engineer.

The roadway subgrade surfaces should be made smooth and crowned or sloped prior to placing the granular materials to promote drainage of the roadway base and subbase materials.

5.4.2 Pavement Design

The following minimum pavement structure is suggested for local roadways at this site, assuming that the roadways will not be used as collector roads or bus routes:

- 90 millimetre thick layer of asphaltic concrete (40 millimetres of Superpave 12.5 Traffic Level B over 50 millimetres of Superpave 19.0 Traffic Level B); over,
- 150 millimetre thick layer of base (OPSS Granular A); over,
- 400 millimetre thick layer of subbase (OPSS Granular B Type II).

5.4.3 Effects of Subgrade Disturbance

If the roadway subgrade surface becomes disturbed or wetted due to construction operations or precipitation, or the granular pavement materials are to be used by construction traffic, the Granular B Type II thicknesses provided above may not be adequate and it may be necessary to increase the thickness of the Granular B Type II subbase. The contractor should be responsible for providing suitable access for construction equipment.

The required thickness of the subbase materials will depend on a number of factors, including contractor workmanship and schedule, contractor methodology, soil types and weather conditions, and should be assessed by geotechnical personnel at the time of construction. In our opinion, the preferred approach from a geotechnical point of view is to:

- Proof roll the subgrade conditions at the time of construction under the supervision of experienced geotechnical personnel.
- Adjust the thickness of the subbase material and include a woven geotextile separator, as required. Unit rate allowances should be made in the contract for subexcavation and replacement with OPSS Granular B Type II.

5.4.4 Granular Material Placement

The pavement granular materials should be compacted in maximum 300 millimetre thick lifts to at least 99 percent of standard Proctor maximum dry density using suitable vibratory compaction equipment.

5.4.5 Asphaltic Cement

Performance graded PG 58-34 asphaltic cement is recommended for local roadways.

5.4.6 Transition Treatments

In areas where the new pavement structure will abut existing pavements (e.g., Jack Pine Crescent), the depths of the granular materials should taper up or down at 5 horizontal to 1 vertical, or flatter, to match the depths of the granular material(s) exposed in the existing pavement.

5.4.7 Pavement Drainage

In order to provide drainage of the granular base and subbase, the granular material should extend to the roadside ditch. The bottom of the granular subbase layer should be at least 0.3 metres above the bottom of the ditch.

If storm sewers and catch basins are installed, it is suggested that catch basins be provided with perforated stub drains extending about 3 metres out from the catch basins in two directions parallel to the roadway. These drains should be installed at the bottom of the subbase layer.

5.5 Sensitive Marine Clay – Effects of Trees

Portions of the site are underlain by silty clay, a material which is known to be susceptible to shrinkage with a change/reduction in moisture content. Research by the Institute for Research in Construction (formerly the Division of Building Research) of the National Research Council of Canada has shown that trees can cause a reduction of moisture content in the silty clays in the Ottawa area, which can result in significant settlement/damage to nearby buildings supported on shallow foundations, or hard surfaced areas. Therefore, deciduous tree planting should be carried in accordance with the guidelines identified in the City of Ottawa document titled: "*Tree Planting in Sensitive Marine Clay Soils – 2017 Guidelines*".

The City of Ottawa Tree Planting Guidelines indicates that sensitive marine clay soils with a modified plasticity index of less than 40 percent are considered to have a low/medium potential for soil volume change. Clay soils with a modified plasticity index that exceeds 40 percent are considered to have a high potential for soil volume change.

The modified plasticity index of one sample tested was about 19 percent. As such, the potential for soil volume change, as defined by the City of Ottawa, is low/medium in areas where clay soils were encountered at this site.

In accordance with the City of Ottawa Tree Planting Guidelines, tree planting restrictions apply where clay soils with low/medium potential for volume change are present between the underside of footing and a depth of 3.5 metres below finished grade (refer to the City of Ottawa document titled: "Tree Planting in Sensitive Marine Soils - 2017 Guidelines").

According to the City of Ottawa 2017 Tree Planting Guidelines, the tree to foundation setbacks within the development can be reduced to 4.5 metres for small to medium sized trees (i.e., trees with a mature height of less than 14 metres), provided that all the following conditions are met:

- For footings within 10 metres of the proposed tree, the underside of footing must be 2.1 metres or greater below finished grade;
- The foundations are reinforced with a minimum of two upper and two lower 15M bars in the foundation wall;
- Grading surrounding the tree must promote draining to the tree root zone; and,
- A small size tree (i.e., a tree with a mature height of less than 7.5 metres) must be provided with a minimum of 25 cubic metres of available soil volume. For medium size trees (i.e., trees with a mature height of between 7.5 and 14 metres), a minimum soil volume of 30 cubic metres must be provided.

It is noted that the above guidelines are only applicable where silty clay soils exist in the zone between the underside of footing and 3.5 metres below finished grade. Based on the subsurface conditions encountered and the fact that the finished grade will be raised across the majority of the site, it is considered likely that silty clay soils will not be within this zone and that tree planting setback restrictions will not apply.

6.0 ADDITIONAL CONSIDERATIONS

6.1 Effects of Construction Induced Vibration

Some of the construction operations (such as granular material compaction, excavation, etc.) will cause ground vibration on and off of the site. The vibrations will attenuate with distance from the source, but may be felt at nearby structures. The magnitude of the vibrations will be much less than that required to cause damage to the nearby structures or services in good condition.

6.2 Monitoring Well Abandonment

All monitoring wells installed as part of this investigation should be decommissioned by a licensed well technician. The well abandonment could be carried out in advance of or during construction.

6.3 Disposal of Excess Soil

It is noted that the professional services retained for this project include only the geotechnical aspects of the subsurface conditions at this site. The presence or implications of possible surface and/or subsurface contamination, including naturally occurring source of contamination, are outside the terms of reference for this report. This report does not constitute a Phase II Environmental Site Assessment (ESA) nor does it constitute a contaminated material management plan.

6.4 Design Review and Construction Observation

The engagement of the services of the geotechnical consultant during construction is recommended to confirm that the subsurface conditions throughout the proposed excavations do not materially differ from those given in the report and that the construction activities do not adversely affect the intent of the design. The subgrade surfaces for the houses, services, and roadways should be inspected by experienced geotechnical personnel to ensure that suitable materials have been reached and properly prepared. The placing and compaction of earth fill and imported granular materials should be inspected to ensure that the materials used conform to the grading and compaction specifications.

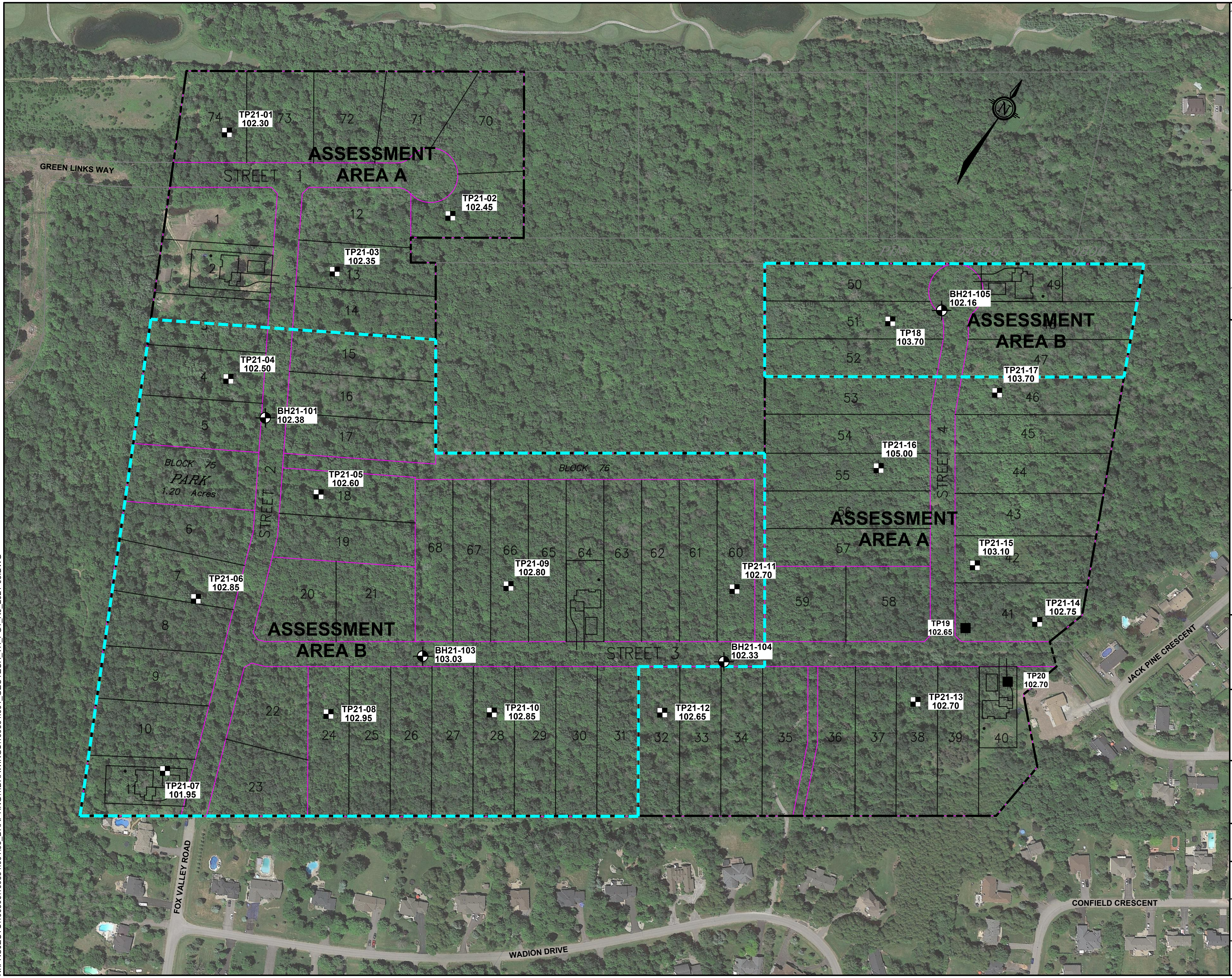
7.0 CLOSURE

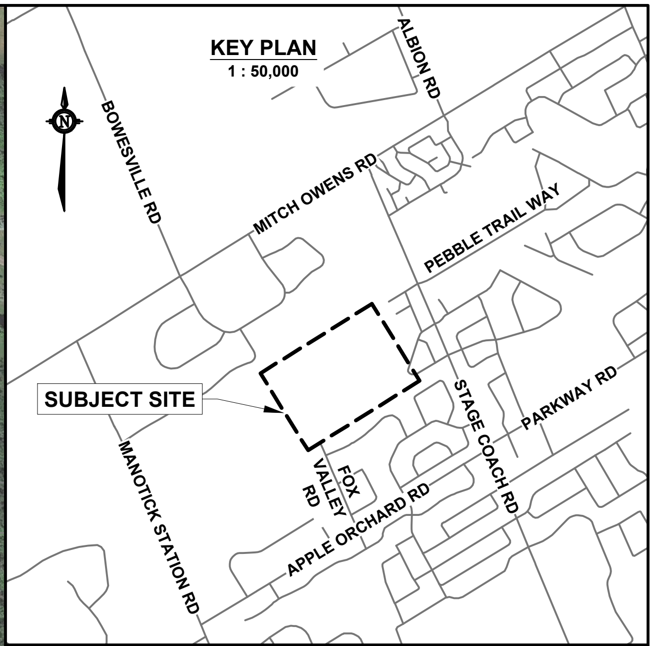
We trust this report provides sufficient information for your present purposes. If you have any questions concerning this report, please do not hesitate to contact our office.

Alex Meacoe, P.Eng.
Geotechnical Engineer

Brent Wiebe, P.Eng.
VP Operations - Ontario

LICENSED PROFESSIONAL ENGINEER
B.D. WIEBE
100060438
December 20, 2021
PROVINCE OF ONTARIO





LEGEND

BH/TP #	BOREHOLE/ TEST PIT ID
XX.XX	GROUND SURFACE ELEVATION, IN METRES GEODETIC DATUM
	BOREHOLE LOCATION (current investigation by GEMTEC)
	TEST PIT LOCATION (current investigation by GEMTEC)
	APPROXIMATE LOCATION OF TEST PIT (current investigation by ARK ENGINEERING)
	PROPERTY DEVELOPMENT BOUNDARY
	ASSESSMENT AREA BOUNDARY

Scale
1:3000
0 100 200m

GEMTEC
CONSULTING ENGINEERS AND SCIENTISTS

32 Steacie Drive
Ottawa, ON K2K 2A9
Tel: (613) 836-1422
www.gemtec.ca
ottawa@gemtec.ca

Drawing	TEST HOLE LOCATION PLAN
Client	ARK ENGINEERING AND DEVELOPMENT
Project	100554.001
Drwn by	S.L.
Chkd by	W.A.M.
	PROPOSED EMERALD SUBDIVISION JACK PINE CRESCENT OTTAWA, ONTARIO
Date	JULY, 2021
Rev.	0
	FIGURE 1

N:\PROJECTS\100500\100554.001\08_DRAFTING\1.DRAWINGS\100554.001_GEOTECH_TH_FG1_R0_2021-06.DWG

APPENDIX A

Record of Test Hole Logs
List of Abbreviations and Symbols

RECORD OF TEST PIT 21-01

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 9 2021

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE	WATER LEVEL IN OPEN TEST PIT OR STANDPIPE INSTALLATION
0	Ground Surface	102.30			
	TOPSOIL	0.05			Native backfill
	Dark brown SAND, with rootlets	0.20			
	Brown SAND		1	GS	
	Grey SAND	101.60 0.70			
1			2	GS	
2	Grey SILTY SAND, with shells	100.30 2.00			
3					
4	End of Test Pit Sidewalls caving in	98.40 3.90			Groundwater level at 1.1 mbgs upon completion
5					
6					
7					
8					
9					
10					

SHEAR STRENGTH (Cu), kPA: + NATURAL ⊕ REMOULDED
WATER CONTENT, %: W_P — W — W_L
10 20 30 40 50 60 70 80 90

ADDITIONAL LAB. TESTING

GROUNDWATER OBSERVATIONS

DATE	DEPTH (m)	ELEV. (m)
21-03-09	1.1 ▽	101.2

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Consulting Engineers and Scientists

LOGGED: M.L.
CHECKED: W.A.M.

RECORD OF TEST PIT 21-02

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 9 2021

DEPTH SCALE METRES	DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE	WATER LEVEL IN OPEN TEST PIT OR STANDPIPE INSTALLATION
0	Ground Surface	102.45			
	TOPSOIL	0.10			Native backfill
	Dark brown SAND, with rootlets	0.30			
	Brown SAND		1	GS	
1	Grey SAND	101.45 1.00	2	GS	
2	Grey SAND, with shells	100.45 2.00			32mm Diameter Screen
3					Native backfill
	End of Test Pit Sidewalls caving in	99.10 3.35			

SHEAR STRENGTH (Cu), kPA: + NATURAL ⊕ REMOULDED — 10 20 30 40 50 60 70 80 90

WATER CONTENT, %: W_P — W — W_L

ADDITIONAL LAB. TESTING

GROUNDWATER OBSERVATIONS

DATE	DEPTH (m)	ELEV. (m)
21-03-12	1.0 ▽	101.5

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LOGGED: M.L.

CHECKED: W.A.M.

RECORD OF TEST PIT 21-03

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 8 2021

DEPTH SCALE METRES	SOIL PROFILE – DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE	SHEAR STRENGTH (Cu), kPA (+ NATURAL ⊕ REMOULDED); WATER CONTENT, % (W_P — W — W_L) 10 20 30 40 50 60 70 80 90	ADDITIONAL LAB. TESTING	WATER LEVEL IN OPEN TEST PIT OR STANDPIPE INSTALLATION
0	Ground Surface		102.35					
	TOPSOIL		0.05					Native backfill
	Dark brown SAND, with rootlets			1	GS			
	Brown SAND, trace silt		101.75 0.60					
1				2	GS		MH	
2								
	Grey SILTY SAND, with shells		99.61 2.74					
3				3	GS			
4								
	End of Test Pit Sidewalls caving in		97.78 4.57					Groundwater level at 2.25 mbgs upon completion
5								
6								
7								
8								
9								
10								

GROUNDWATER OBSERVATIONS

DATE	DEPTH (m)	ELEV. (m)
21-03-08	2.3 ∇	100.1

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CONSULTING ENGINEERS AND SCIENTISTS

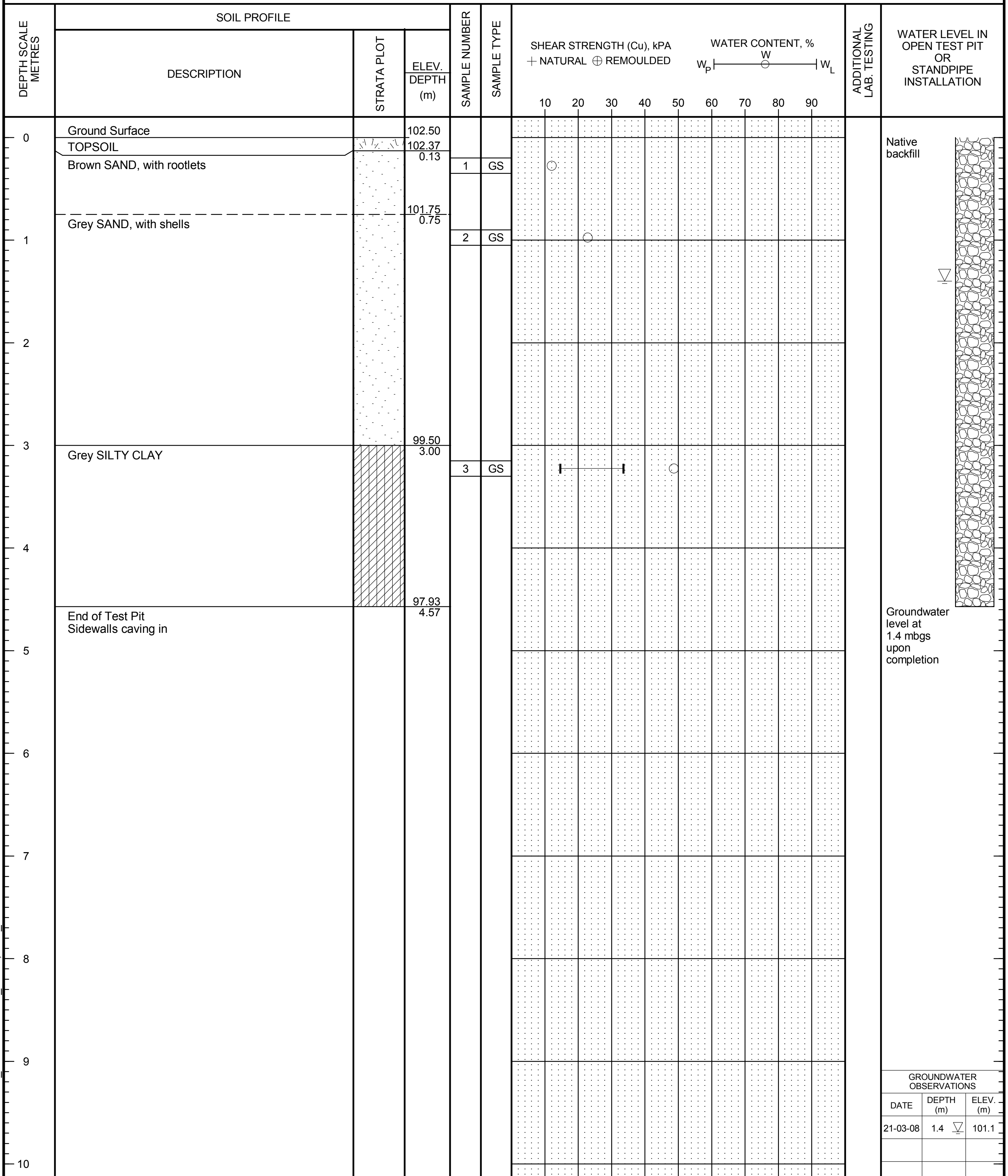
LOGGED: M.L.
CHECKED: W.A.M.

GEO - TESTPIT LOG 100554.001_EMERLDLINKS_MAR8,2021_TESTPITS.GPJ GEMTEC 2018.GDT 7-7-21

RECORD OF TEST PIT 21-04

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 8 2021



GROUNDWATER OBSERVATIONS		
DATE	DEPTH (m)	ELEV. (m)
21-03-08	1.4 ▽	101.1

GEMTEC
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LOGGED: M.L.
CHECKED: W.A.M.

RECORD OF TEST PIT 21-05

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 8 2021

DEPTH SCALE METRES	DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE	WATER LEVEL IN OPEN TEST PIT OR STANDPIPE INSTALLATION
0	Ground Surface	102.60			
	TOPSOIL	0.05			Native backfill
	Dark brown SAND, with rootlets		1	GS	
	Grey brown SAND	102.20 0.40	2	GS	
1					
2	Grey SILTY SAND, with shells	100.50 2.10			
3			3	GS	
4	Grey SILTY CLAY	98.60 4.00	4	GS	
	End of Test Pit Sidewalls caving in	98.10 4.50			Test Pit dry upon completion
5					
6					
7					
8					
9					
10					

SOIL PROFILE; STRATA PLOT; ADDITIONAL LAB. TESTING

SHEAR STRENGTH (Cu), kPA: + NATURAL ⊕ REMOULDED

WATER CONTENT, %: W_P — W — W_L

10 20 30 40 50 60 70 80 90

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LOGGED: M.L.
CHECKED: W.A.M.

RECORD OF TEST PIT 21-06

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 8 2021

DEPTH SCALE METRES	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE	SHEAR STRENGTH (Cu), kPA + NATURAL ⊕ REMOULDED / WATER CONTENT, % W_P W W_L (10 20 30 40 50 60 70 80 90)	ADDITIONAL LAB. TESTING	WATER LEVEL IN OPEN TEST PIT OR STANDPIPE INSTALLATION
0	Ground Surface		102.85					
	TOPSOIL		0.05					Native backfill
	Dark brown SAND, with rootlets		0.25	1	GS			
	Red brown SAND							
1	Grey brown SAND		101.95 0.90	2	GS			
2	Grey SILTY SAND, with shells		100.75 2.10	3	GS			
3	Grey SILTY CLAY		99.35 3.50	4	GS			
4	End of Test Pit Sidewalls caving in		98.28 4.57					Test Pit dry upon completion
5								
6								
7								
8								
9								
10								

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LOGGED: M.L.
CHECKED: W.A.M.

RECORD OF TEST PIT 21-07

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 8 2021

DEPTH SCALE METRES	SOIL PROFILE – DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE	WATER LEVEL IN OPEN TEST PIT OR STANDPIPE INSTALLATION
0	Ground Surface	101.95			Native backfill
	TOPSOIL	0.05			
	Dark brown SAND, with rootlets	0.20	1	GS	
	Brown SAND	0.40			
	Grey SAND				
1			2	GS	
	Grey SILTY SAND, with shells	100.15 / 1.80			
2			3	GS	
	Grey SILTY CLAY	99.45 / 2.50			
3			4	GS	
4	End of Test Pit Sidewalls caving in	97.95 / 4.00			Groundwater level at 1.8 mbgs upon completion

SHEAR STRENGTH (Cu), kPA: + NATURAL ⊕ REMOULDED

WATER CONTENT, %: W_P — W — W_L

10 20 30 40 50 60 70 80 90

ADDITIONAL LAB. TESTING

GROUNDWATER OBSERVATIONS

DATE	DEPTH (m)	ELEV. (m)
21-03-08	1.8 ∇	100.2

GEMTEC Consulting Engineers and Scientists

LOGGED: M.L.

CHECKED: W.A.M.

RECORD OF TEST PIT 21-08

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 8 2021

DEPTH SCALE METRES	DESCRIPTION (SOIL PROFILE)	ELEV. DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE	WATER LEVEL IN OPEN TEST PIT OR STANDPIPE INSTALLATION
0	Ground Surface	102.95			
	TOPSOIL	0.05			Native backfill
	Dark brown SAND, with rootlets	0.20	1	GS	
	Red brown SAND	102.35 0.60			
1	Grey brown SAND		2	GS	
2	Grey SILTY SAND, with shells	100.95 2.00	3	GS	32mm Diameter Screen
3	Grey SILTY CLAY	99.95 3.00			
4			4	GS	Native backfill
	End of Test Pit Sidewalls caving in	98.45 4.50			
5					
6					
7					
8					
9					
10					

SHEAR STRENGTH (Cu), kPA: + NATURAL ⊕ REMOULDED

WATER CONTENT, %: W_P — W — W_L

10 20 30 40 50 60 70 80 90

ADDITIONAL LAB. TESTING

GROUNDWATER OBSERVATIONS

DATE	DEPTH (m)	ELEV. (m)
21-03-12	1.9 ▽	101.1

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CHECKED: W.A.M.

RECORD OF TEST PIT 21-09

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 8 2021

DEPTH SCALE METRES	SOIL PROFILE – DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE	SHEAR STRENGTH (Cu), kPA + NATURAL ⊕ REMOULDED / WATER CONTENT, % W_P W W_L (10 20 30 40 50 60 70 80 90)	ADDITIONAL LAB. TESTING	WATER LEVEL IN OPEN TEST PIT OR STANDPIPE INSTALLATION
0	Ground Surface		102.80					
	TOPSOIL		0.05					Native backfill
	Dark brown SAND, with rootlets			1	GS			
	Brown SAND		102.10 0.70	2	GS			
1	Grey SILTY SAND, with shells		101.70 1.10					
2	Grey SILTY SAND		100.50 2.30	3	GS			
3	Grey SILTY CLAY		99.50 3.30	4	GS			
4	Grey SILTY SAND, some gravel, with cobbles and boulders (GLACIAL TILL)		98.80 4.00					
	End of Test Pit Sidewalls caving in		98.30 4.50					Test Pit dry upon completion
5								
6								
7								
8								
9								
10								

GEO - TESTPIT LOG 100554.001_EMERLDLINKS_MAR8,2021_TESTPITS.GPJ GEMTEC 2018.GDT 7-7-21

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CHECKED: W.A.M.

RECORD OF TEST PIT 21-10

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 8 2021

DEPTH SCALE METRES	SOIL PROFILE – DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE	SHEAR STRENGTH (Cu), kPA + NATURAL ⊕ REMOULDED / WATER CONTENT, % W_P — W — W_L (10 20 30 40 50 60 70 80 90)	ADDITIONAL LAB. TESTING	WATER LEVEL IN OPEN TEST PIT OR STANDPIPE INSTALLATION
0	Ground Surface		102.85					
	TOPSOIL		0.05					Native backfill
	Dark brown SAND, with rootlets		102.45 0.40					
	Brown SAND			1	GS	W ≈ 10		
1	Grey brown SAND, trace silt		101.75 1.10	2	GS	W ≈ 22	MH	
2	Grey SILTY SAND, with shells		100.55 2.30	3	GS	W ≈ 22		
3	Grey SILTY CLAY		99.65 3.20	4	GS			
4	End of Test Pit Sidewalls caving in		98.35 4.50					Test Pit dry upon completion

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LOGGED: M.L.
CHECKED: W.A.M.

RECORD OF TEST PIT 21-11

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 8 2021

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE	SHEAR STRENGTH (Cu), kPA + NATURAL ⊕ REMOULDED / WATER CONTENT, % W_P W W_L (10 20 30 40 50 60 70 80 90)	ADDITIONAL LAB. TESTING	WATER LEVEL IN OPEN TEST PIT OR STANDPIPE INSTALLATION
0	Ground Surface	102.70					
	TOPSOIL	0.05					Native backfill
	Dark brown SAND, with rootlets						
	Brown SAND	0.30					
1	Grey SAND	101.40 1.30					∇
	Grey SILTY SAND, some gravel, with shells	101.00 1.70					
2			1	GS			
	Grey SILTY CLAY	99.90 2.80					
3			2	GS			
4	End of Test Pit Sidewalls caving in	98.20 4.50					Groundwater level at 1.3 mbgs upon completion
5							
6							
7							
8							
9							
10							

GROUNDWATER OBSERVATIONS

DATE	DEPTH (m)	ELEV. (m)
21-03-08	1.3 ∇	101.4

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Consulting Engineers and Scientists

LOGGED: M.L.
CHECKED: W.A.M.

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RECORD OF TEST PIT 21-12

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 8 2021

DEPTH SCALE METRES	DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE	WATER LEVEL IN OPEN TEST PIT OR STANDPIPE INSTALLATION
0	Ground Surface	102.65			Native backfill
	TOPSOIL	0.05			
	Dark brown SAND, with rootlets	102.35 / 0.30			
	Brown SAND		1	GS	
1	Grey SAND	101.55 / 1.10	2	GS	
2	Grey SILTY SAND, with shells	100.45 / 2.20	3	GS	
	Grey SILTY CLAY	99.85 / 2.80	4	GS	
3	Grey SILTY SAND, some gravel with cobbles and boulders (GLACIAL TILL)	99.65 / 3.00			
	End of Test Pit Refusal on boulders in GLACIAL TILL	99.45 / 3.20			Groundwater level at 1.5 mbgs upon completion

Chart columns: SHEAR STRENGTH (Cu), kPA — + NATURAL ⊕ REMOULDED; WATER CONTENT, % — W_P W W_L; scale 10 20 30 40 50 60 70 80 90. ADDITIONAL LAB. TESTING. STRATA PLOT.

Depth scale: 0 1 2 3 4 5 6 7 8 9 10

GROUNDWATER OBSERVATIONS

DATE	DEPTH (m)	ELEV. (m)
21-03-08	1.5 ∇	101.2

GEMTEC
Consulting Engineers and Scientists

LOGGED: M.L.
CHECKED: W.A.M.

RECORD OF TEST PIT 21-13

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 8 2021

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE	SHEAR STRENGTH (Cu), kPA + NATURAL ⊕ REMOULDED / WATER CONTENT, % W_P W W_L (10 20 30 40 50 60 70 80 90)	ADDITIONAL LAB. TESTING	WATER LEVEL IN OPEN TEST PIT OR STANDPIPE INSTALLATION
0	Ground Surface		102.70					
	TOPSOIL		0.10					Native backfill
	Dark brown SAND, with rootlets		0.30					
	Brown SAND		102.00					
1	Grey SILTY SAND, some gravel, with cobbles and boulders (GLACIAL TILL)		0.70					
2								
				1	GS			
3	End of Test Pit Refusal in GLACIAL TILL		99.70 3.00					Test Pit dry upon completion
4								
5								
6								
7								
8								
9								
10								

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Consulting Engineers and Scientists

LOGGED: M.L.
CHECKED: W.A.M.

RECORD OF TEST PIT 21-14

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 9 2021

DEPTH SCALE METRES	DESCRIPTION (SOIL PROFILE)	STRATA PLOT	ELEV. DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE	SHEAR STRENGTH (Cu), kPA + NATURAL ⊕ REMOULDED / WATER CONTENT, % W_P W W_L (10 20 30 40 50 60 70 80 90)	ADDITIONAL LAB. TESTING	WATER LEVEL IN OPEN TEST PIT OR STANDPIPE INSTALLATION
0	Ground Surface		102.75					
	TOPSOIL		0.05					Native backfill
	Dark brown SAND, with rootlets		102.45 0.30					
	Brown SAND, trace gravel			1	GS			
	Grey SILTY SAND, trace gravel, with shells		0.50	2	GS			
	Grey SILTY SAND, some gravel, with cobbles and boulders (GLACIAL TILL)		0.65	3	GS			
1								
	End of Test Pit Refusal on bedrock		101.15 1.60					Groundwater level at 1.4 mbgs upon completion
2								
3								
4								
5								
6								
7								
8								
9								
10								

GROUNDWATER OBSERVATIONS

DATE	DEPTH (m)	ELEV. (m)
21-03-09	1.4 ▽	101.4

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CONSULTING ENGINEERS AND SCIENTISTS

LOGGED: M.L.
CHECKED: W.A.M.

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RECORD OF TEST PIT 21-15

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 9 2021

DEPTH SCALE METRES	SOIL PROFILE: DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE	SHEAR STRENGTH (Cu), kPA + NATURAL ⊕ REMOULDED / WATER CONTENT, % W_P W W_L (10 20 30 40 50 60 70 80 90)	ADDITIONAL LAB. TESTING	WATER LEVEL IN OPEN TEST PIT OR STANDPIPE INSTALLATION
0	Ground Surface	103.10					
	TOPSOIL	0.05					Native backfill
	Dark brown SAND, with rootlets	102.86 0.24					
	Grey brown SILTY SAND, some gravel, with cobbles and boulders (GLACIAL TILL)		1	GS			
1							
2		100.80 2.30					
	Grey SILTY SAND, some gravel, with cobbles and boulders (GLACIAL TILL)		2	GS			
3	End of Test Pit	100.10 3.00					Test Pit dry upon completion
4							
5							
6							
7							
8							
9							
10							

GEMTEC
CONSULTING ENGINEERS AND SCIENTISTS

LOGGED: M.L.
CHECKED: W.A.M.

RECORD OF TEST PIT 21-16

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 9 2021

DEPTH SCALE METRES	SOIL PROFILE – DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE	SHEAR STRENGTH (Cu), kPA + NATURAL ⊕ REMOULDED; WATER CONTENT, % W_P W W_L (10 20 30 40 50 60 70 80 90)	ADDITIONAL LAB. TESTING	WATER LEVEL IN OPEN TEST PIT OR STANDPIPE INSTALLATION
0	Ground Surface		105.00					
	TOPSOIL		0.05					Native backfill
	Dark brown SAND, with rootlets		0.20					
	Red brown SAND			1	GS			
1	Grey brown SILTY SAND, some gravel, with cobbles and boulders (GLACIAL TILL)		104.00 1.00	2	GS			
2								
3	End of Test Pit Refusal in GLACIAL TILL		101.60 3.40					Test Pit dry upon completion
4								
5								
6								
7								
8								
9								
10								

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LOGGED: M.L.
CHECKED: W.A.M.

RECORD OF TEST PIT 21-17

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 9 2021

DEPTH SCALE METRES	DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE	ADDITIONAL LAB. TESTING	WATER LEVEL IN OPEN TEST PIT OR STANDPIPE INSTALLATION
0	Ground Surface	103.70				
	TOPSOIL	0.05				Native backfill
	Dark brown SAND, with rootlets	103.40 / 0.30				
	Red brown SAND	103.05 / 0.65	1	GS		
1	Grey brown SILTY SAND, some gravel, with cobbles and boulders (GLACIAL TILL)		2	GS	MH	
3	End of Test Pit Refusal on boulders with GLACIAL TILL	100.70 / 3.00				Test Pit dry upon completion

SHEAR STRENGTH (Cu), kPA: + NATURAL ⊕ REMOULDED
WATER CONTENT, %: W_P — W — W_L
10 20 30 40 50 60 70 80 90

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LOGGED: M.L.
CHECKED: W.A.M.

RECORD OF TEST PIT 21-18

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 9 2021

DEPTH SCALE METRES	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE
0	Ground Surface	102.25		
	TOPSOIL	102.10 / 0.15		
	Dark brown SAND, with rootlets	0.30		
	Brown SAND	101.60 / 0.65	1	GS
	Grey SAND		2	GS
2	Grey SILTY SAND, some gravel, with shells	100.25 / 2.00	3	GS
	Grey SILTY SAND	99.95 / 2.30	4	GS
4	End of Test Pit Sidewalls caving in	98.25 / 4.00		

SHEAR STRENGTH (Cu), kPA: + NATURAL ⊕ REMOULDED
WATER CONTENT, %: W_P — W — W_L
10 20 30 40 50 60 70 80 90

ADDITIONAL LAB. TESTING

WATER LEVEL IN OPEN TEST PIT OR STANDPIPE INSTALLATION

Native backfill

32mm Diameter Screen

Native backfill

GROUNDWATER OBSERVATIONS

DATE	DEPTH (m)	ELEV. (m)
21-03-12	0.0 ▽	102.25

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LOGGED: M.L.

CHECKED: W.A.M.

RECORD OF BOREHOLE 21-101

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 19 2021

BORING METHOD: Power Auger, 200 mm DIAMETER HOLLOW STEM

DESCRIPTION	ELEV. / DEPTH (m)	NUMBER	TYPE	RECOVERY, mm	BLOWS/0.3m
Ground Surface	102.38				
TOPSOIL	102.25 / 0.13				
Loose, brown SAND, with rootlets		1	SS	150	5
		2	SS	305	7
Compact, grey SAND some silt	100.86 / 1.52	3	SS	380	10
		4	SS	610	26
Firm, grey SILTY CLAY	98.57 / 3.81	5	SS	305	WH
Stiff, grey CLAYEY SILT	97.81 / 4.57	6	SS	610	1
Very dense, grey SILTY SAND, some gravel, with cobbles and boulders (GLACIAL TILL)	96.94 / 5.44	7	SS	100	>50 for 125mm
End of Borehole	96.16 / 6.22				

PENETRATION RESISTANCE (N), BLOWS/0.3m
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m
SHEAR STRENGTH (Cu), kPA: + NATURAL ⊕ REMOULDED
WATER CONTENT, %: W_P — W — W_L
10 20 30 40 50 60 70 80 90

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION: Bentonite, Backfill, Bentonite, Sand, Screen

GROUNDWATER OBSERVATIONS

DATE	DEPTH (m)	ELEV. (m)
21/03/29	0.2 ∇	102.2

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LOGGED: A.S.
CHECKED: W.A.M.

RECORD OF BOREHOLE 21-103

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 19 2021

Boring method: Power Auger, 200mm Diameter Hollow Stem

DESCRIPTION	ELEV. / DEPTH (m)
Ground Surface	103.03
Very dense, brown SILTY SAND, some gravel (FILL MATERIAL)	102.62 / 0.41
Compact, brown SAND	101.51 / 1.52
Compact to dense, grey SILTY SAND, with shells	99.78 / 3.25
Firm grey SILTY CLAY	99.07 / 3.96
Stiff, grey CLAYEY SILT	97.85 / 5.18
Compact to loose, grey SILTY SAND, some gravel, with cobbles and boulders (GLACIAL TILL)	96.32 / 6.71
End of Borehole	

NUMBER	TYPE	RECOVERY, mm	BLOWS/0.3m
1	SS	455	33
2	SS	455	12
3	SS	405	15
4	SS	455	33
5	SS	510	1
6	SS	305	9
7	SS	355	21
8	SS	305	10

PENETRATION RESISTANCE (N), BLOWS/0.3m
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m
SHEAR STRENGTH (Cu), kPA + NATURAL ⊕ REMOULDED
WATER CONTENT, % W_P W W_L
10 20 30 40 50 60 70 80 90

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

Native Backfill

DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10

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LOGGED: A.S.
CHECKED: W.A.M.

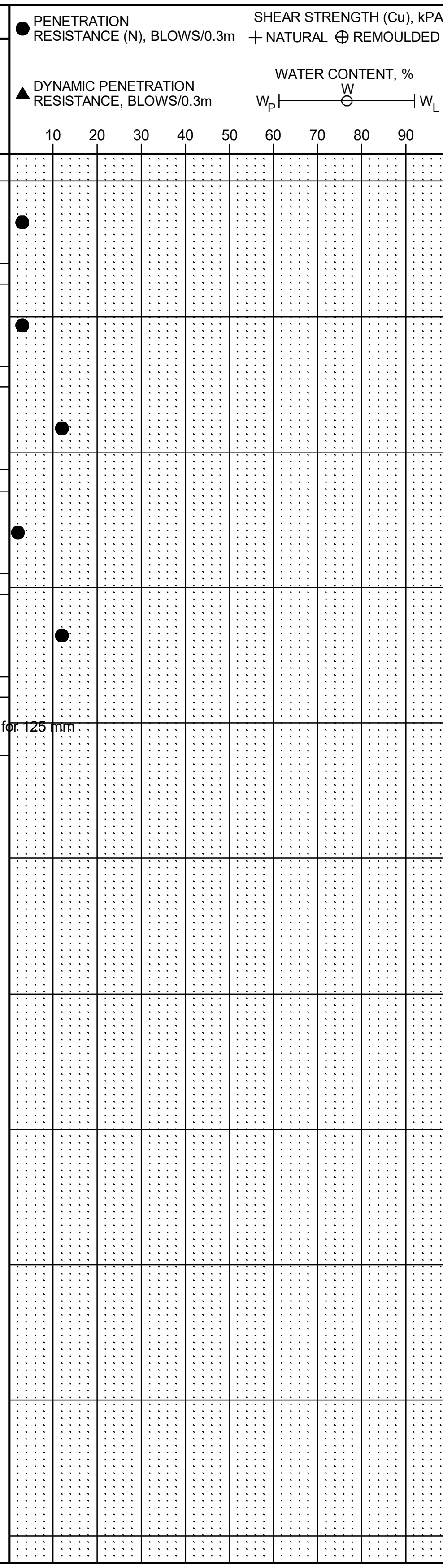
GEO - BOREHOLE LOG 100554.001_EMERLDLINKS_MAR9,2021_BH.GPJ GEMTEC 2018.GDT 12/16/21

RECORD OF BOREHOLE 21-104

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

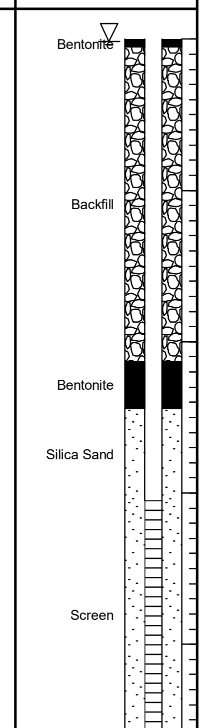
SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 19 2021

DEPTH SCALE METRES	DESCRIPTION	ELEV. DEPTH (m)	NUMBER	TYPE	RECOVERY, mm	BLOWS/0.3m
0	Ground Surface	102.33				
	TOPSOIL	0.08				
	Very loose to compact, grey brown SAND		1	SS	75	3
1			2	SS	380	3
			3	SS	610	12
2	Firm, grey SILTY CLAY	99.84 2.49	4	SS	610	2
3	Stiff, grey CLAYEY SILT	99.28 3.05	5	SS	250	12
4			6	SS	250	>50 for 125 mm
	Grey, SILTY SAND, some gravel, with cobbles and boulders (GLACIAL TILL)	98.14 4.24				
	End of Borehole					



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION



GROUNDWATER OBSERVATIONS

DATE	DEPTH (m)	ELEV. (m)
21/03/29	0.0 ∇	102.3

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LOGGED: A.S.
CHECKED: W.A.M.

RECORD OF BOREHOLE 21-105

CLIENT: Ark Engineering and Development
PROJECT: Geotechnical Investigation, Proposed Emerald Subdivision
JOB#: 100554.001
LOCATION: See Test Hole Location Plan, Figure 1

SHEET: 1 OF 1
DATUM: CGVD28
BORING DATE: Mar 19 2021

BORING METHOD: Power Auger, 200mm Diameter Hollow Stem

DESCRIPTION	ELEV. / DEPTH (m)	NUMBER	TYPE	RECOVERY, mm	BLOWS/0.3m
Ground Surface	102.16				
TOPSOIL	0.08				
Very loose to loose, grey brown SAND		1	SS	230	3
		2	SS	355	5
Compact, grey SAND, some silt	100.64 / 1.52	3	SS	405	14
Firm grey SILTY CLAY	99.87 / 2.29	4	SS	305	2
		5	ST	610	PM
Stiff, grey CLAYEY SILT	98.50 / 3.66	6	SS	305	WH
Compact, grey SILTY SAND, some gravel with cobbles and boulders (GLACIAL TILL)	97.44 / 4.72	7	SS	203	11
		8	SS	75	11
		9	SS	203	13
End of Borehole	95.45 / 6.71				

DEPTH SCALE METRES: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

PENETRATION RESISTANCE (N), BLOWS/0.3m
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m
SHEAR STRENGTH (Cu), kPA: + NATURAL ⊕ REMOULDED
WATER CONTENT, %: W_P — W — W_L
10 20 30 40 50 60 70 80 90

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION: Bentonite, Silica Sand, Screen, Silica Sand

GROUNDWATER OBSERVATIONS

DATE	DEPTH (m)	ELEV. (m)
21/03/29	0.3 ∇	101.9

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LIST OF ABBREVIATIONS AND TERMINOLOGY

SAMPLE TYPES

AS	auger sample
CA	casing sample
CS	chunk sample
BS	Borros piston sample
DO	drive open
MS	manual sample
RC	rock core
ST	slotted tube
TO	thin-walled open Shelby tube
TP	thin-walled piston Shelby tube
WS	wash sample

PENETRATION RESISTANCE

Standard Penetration Resistance, N

The number of blows by a 63.5 kg hammer dropped 760 millimetre required to drive a 50 mm drive open sampler for a distance of 300 mm. For split spoon samples where less than 300 mm of penetration was achieved, the number of blows is reported over the sampler penetration in mm.

Dynamic Penetration Resistance

The number of blows by a 63.5 kg hammer dropped 760 mm to drive a 50 mm diameter, 60^{o} cone attached to 'A' size drill rods for a distance of 300 mm.

WH

Sampler advanced by static weight of hammer and drill rods.

WR

Sampler advanced by static weight of drill rods.

PH

Sampler advanced by hydraulic pressure from drill rig.

PM

Sampler advanced by manual pressure.

SOIL TESTS

C	consolidation test
H	hydrometer analysis
M	sieve analysis
MH	sieve and hydrometer analysis
U	unconfined compression test
Q	undrained triaxial test
V	field vane, undisturbed and remoulded shear strength

SOIL DESCRIPTIONS

Relative Density	'N' Value
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	over 50

Consistency	Undrained Shear Strength (kPa)
Very soft	0 to 12
Soft	12 to 25
Firm	25 to 50
Stiff	50 to 100
Very Stiff	over 100

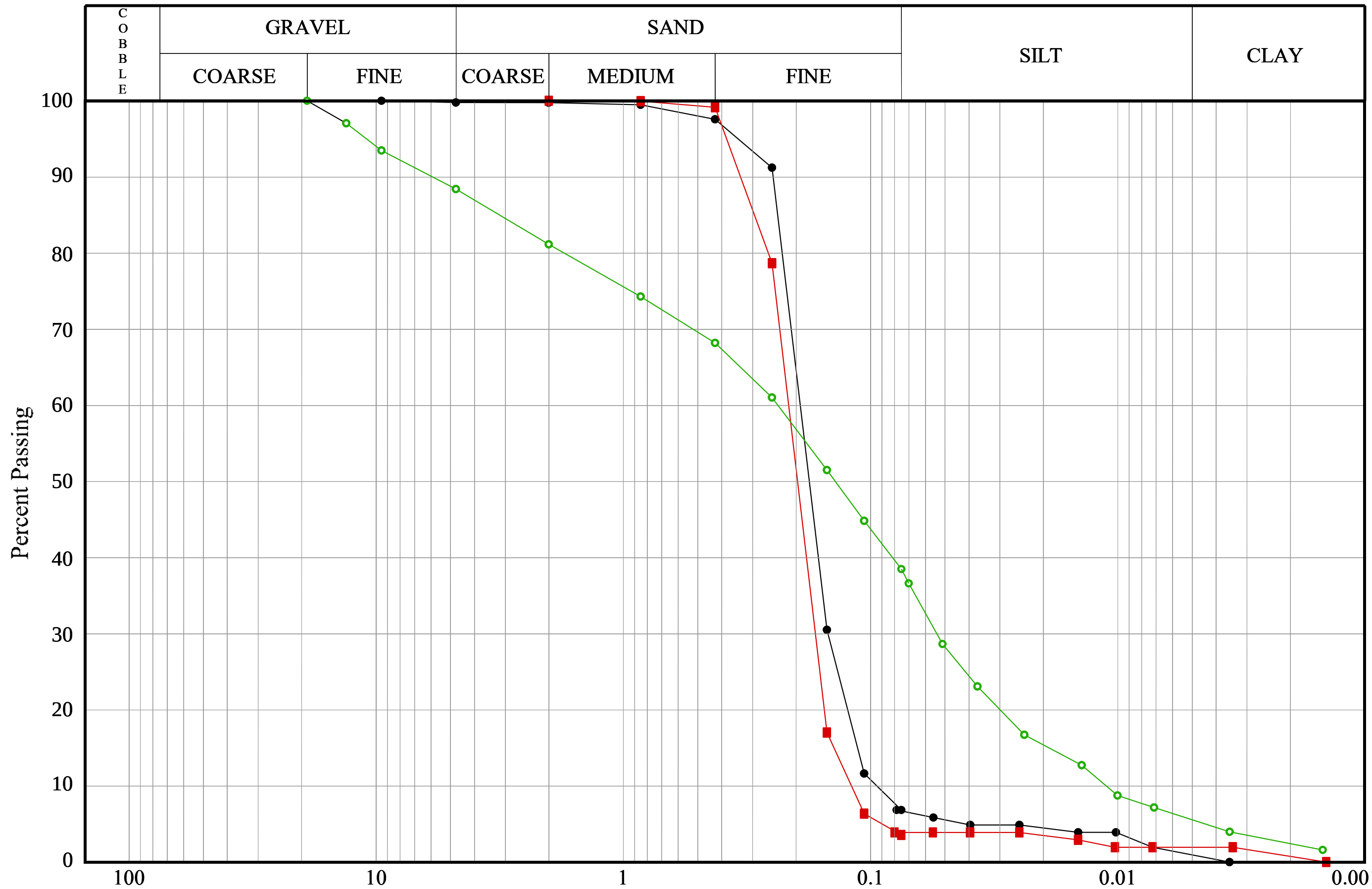
LIST OF COMMON SYMBOLS

c_u	undrained shear strength
e	void ratio
C_c	compression index
c_v	coefficient of consolidation
k	coefficient of permeability
I_p	plasticity index
n	porosity
u	pore pressure
w	moisture content
w_L	liquid limit
w_P	plastic limit
ϕ^1	effective angle of friction
γ	unit weight of soil
γ^1	unit weight of submerged soil
σ	normal stress

APPENDIX B

Laboratory Test Results

GEMTEC Consulting Engineers and Scientists	Client: ARK Engineering Project: Geotechnical and Hydrogeological Services, Emerald Project #: 100554001	Soils Grading Chart

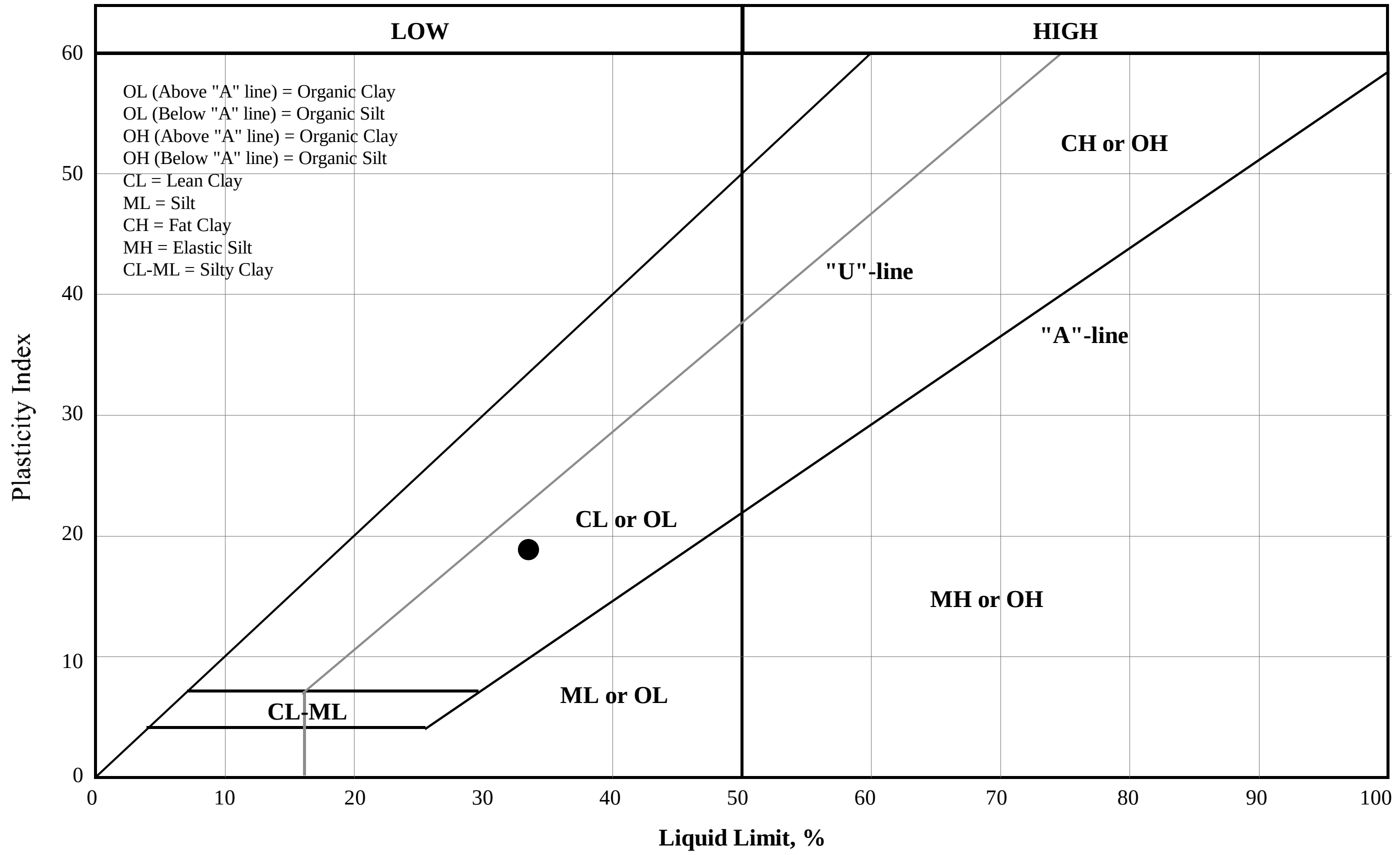


Limits Shown: None

Line Symbol	Sample	Borehole/ Test Pit	Sample Number	Depth	% Cob.+ Gravel	% Sand	% Silt	% Clay
black ●	Sand, trace silt	21-03	GS-2	0.90-1.05	0.2	92.9	5.9	1.0
red ■	Sand	21-10	GS-2	1.20-1.35	0.0	96.4	1.6	1.9
green ○	Glacial Till	21-17	GS2	1.00-1.15	11.6	49.9	32.9	5.6

Line Symbol	CanFEM Classification	USCS Symbol	D_{10}	D_{15}	D_{30}	D_{50}	D_{60}	D_{85}	% 5-75µm
black ●	Sand , trace gravel, trace silt, trace clay	N/A	0.09	0.11	0.15	0.18	0.19	0.24	5.9
red ■	Sand , trace silt, trace clay	SP	0.12	0.14	0.17	0.20	0.21	0.29	1.6
green ○	Silty sand , some gravel , trace clay	N/A	0.01	0.02	0.05	0.14	0.24	3.17	32.9

GEMTEC Consulting Engineers and Scientists	Client: ARK Engineering Project: Geotechnical and Hydrogeological Services, Emerald Project #: 100554001	Plasticity Chart



Symbol	Borehole /Test Pit	Sample Number	Depth	Liquid Limit	Plastic Limit	Plasticity Index	Non-Plastic	Moisture Content, %
●	21-04	GS-3	3.15-3.30	33.5	14.6	18.8	☐	48.66

APPENDIX C

Chemical Analysis of Soil Sample
Sample Relating to Corrosion
(Paracel Laboratories Ltd. Order No. 2111534)

Report to: ARK Engineering and Development
Project: 100554.001 (December 20, 2021)

PARACEL LABORATORIES LTD.

Order #: 2111534

Certificate of Analysis

Client: GEMTEC Consulting Engineers and Scientists Limited

Client PO:

Report Date: 18-Mar-2021

Order Date: 11-Mar-2021

Project Description: 100554.001

	Client ID:	TP 21-11 GS1	-	-	-
	Sample Date:	11-Mar-21 11:41	-	-	-
	Sample ID:	2111534-01	-	-	-
	MDL/Units	Soil	-	-	-
Physical Characteristics					
% Solids	0.1 % by Wt.	89.3	-	-	-
General Inorganics					
Conductivity	5 uS/cm	141	-	-	-
pH	0.05 pH Units	7.66	-	-	-
Resistivity	0.10 Ohm.m	70.8	-	-	-
Anions					
Chloride	5 ug/g dry	<5	-	-	-
Sulphate	5 ug/g dry	51	-	-	-

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field services
materials testing

civil
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environnementale
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service de laboratoire des matériaux

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