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Preliminary Geotechnical Investigation
Proposed Site Development
5455 Boundary Road
Ottawa, Ontario

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Submitted to:

D-Squared Construction Limited
6811 Hiram Drive
Ottawa, Ontario
K4P 1A2

Preliminary Geotechnical Investigation
Proposed Site Development
5455 Boundary Road
Ottawa, Ontario

August 14, 2020
Project: 61774.48

GEMTEC Consulting Engineers and Scientists Limited
32 Steacie Drive
Ottawa, ON, Canada
K2K 2A9

August 14, 2020 File: 61774.48

D-Squared Construction Limited
6811 Hiram Drive
Ottawa, Ontario
K4P 1A2

Attention: Dave Meikle

Re: Preliminary Geotechnical Investigation
Proposed Site Development
5455 Boundary Road
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 November 28, 2019. This report was prepared by Mr. Joseph Berkers, and reviewed by Mr. John Cholewa, Ph.D., P.Eng.

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

Joseph Berkers, B.Eng.

John Cholewa, Ph.D., P.Eng.

JB/JC

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1.0 INTRODUCTION

This report presents the results of a geotechnical investigation conducted by GEMTEC Consulting Engineers and Scientists limited (GEMTEC) for the site of a possible a hot mix asphalt plant at 5455 Boundary Road, Ottawa, Ontario. The purpose of the investigation was to identify the general subsurface conditions at the site by means of a limited number of boreholes and cone penetration tests (CPTu) and, based on the factual information obtained, to provide preliminary engineering guidelines on the geotechnical aspects of site development.

This investigation was carried out in accordance with our proposal dated November 28, 2019.

2.0 PROJECT AND SITE DESCRIPTION

2.1 Project Description

It is understood that consideration is being given to constructing a hot mix asphalt plant at 5455 Boundary Road in Ottawa, Ontario. As such, it is anticipated that the development will include the construction of storage silos and other structural components related to the plant. We have also assumed that the development would include lightly loaded administrative buildings and that plant operations will require stockpiling of granular material on-site.

The site is currently being used as a construction works yard, mainly for the storage/supply of construction related materials (i.e., granulars and topsoil).

2.2 Existing Geotechnical Information

Several geotechnical investigations have been carried out in the area of the site by GEMTEC Consulting Engineers and Scientists Limited (GEMTEC) and others. Based on the results of the previous investigations, it is expected that the subsurface conditions at the site generally consist of surficial fill material underlain by about 1 to 2 metres of native sand followed by deposits of silty clay, which extend to about 25 to 30 metres depth. The silty clay generally has a soft consistency to about 10 to 12 metres below ground surface, becoming stiffer with depth. The silty clay is underlain by compact to very dense glacial till at about 25 to 30 metres below ground surface. The bedrock surface is anticipated below the glacial till deposit at about 35 to 40 metres depth.

3.0 SUBSURFACE INVESTIGATION

The fieldwork for the investigation was carried out between December 11, 2019 and December 23, 2019. During this time, the following test holes were advanced at the site using a drill rig supplied and operated by Marathon Underground of Ottawa, Ontario:

- Five (5) boreholes, numbered 19-04, 19-05, 19-09, 19-18, and 19-20, were advanced to a depth of 4.4 metres below ground surface.
- One (1) borehole, numbered 19-07, was advanced to a depth of 15.85 metres in order to obtain relatively undisturbed thin walled Shelby tube samples of the clay deposit.

- Two (2) Nilcon in-situ vane test holes were completed at 19-07 and 19-10 to a depth of 24.7 and 24.5 metres, respectively. The vane testing was carried out in general accordance with ASTM D2573.
- Ten (10) Cone Penetration Tests (CPTu), numbered 19-02, 19-04, 19-05, 19-07, 19-09, 19-10, 19-12, 19-16, 19-17, and 19-20, were advanced to practical push refusal of the geotechnical drill rig at depths ranging from about 20.1 to 25.4 metres below ground surface. The cone penetration testing was carried out in general accordance with ASTM D5578.
- Three (3) dynamic cone penetration tests were carried out at 19-07, 19-09, and 19-20 to refusal at depths ranging from 25.2 to 27.4 metres below ground surface.

Standard penetration tests (SPT) were carried out in the boreholes 19-04, 19-05, 19-09, 19-18, and 19-20 and samples of the soils encountered were recovered using a 50 millimetre diameter split barrel sampler. The standard penetration tests were carried out in general accordance with ASTM D1586.

The field work was observed throughout by a member of our engineering staff who directed the drilling operations and logged the samples and boreholes. Following completion of the drilling, the soil samples were returned to our laboratory for examination by a geotechnical engineer. The soil descriptions are based, in part, on the visual examination and manual test procedures described in ASTM D2488.

The results of the boreholes are provided on the Record of Borehole sheets in Appendix A. The results of the Nilcon vane testing are shown on Figures C1 and C2 in Appendix C. The results of the cone penetrometer investigation are provided in Appendix B.

The test hole locations were selected by GEMTEC and positioned on site relative to existing features, and are shown on the Test Hole Location Plan, Figure 1.

4.0 SUBSURFACE CONDITIONS

4.1 General

As previously indicated, the results of the test holes are provided in Appendices A and B. The 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 and excavation, 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 boreholes and test pits. 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 boreholes advanced as part of this investigation.

4.2 Fill Material

Fill material, generally composed of sand and gravel with some silt, was encountered from ground surface at boreholes 19-5, 19-9, and 19-18. Fill material was also encountered at a number of the CPTu locations. The fill thickness at the test hole locations across the site ranged from 0.2 to 1.5 metres.

4.3 Silty Sand

Silty sand was encountered either from ground surface or beneath the fill material at all test hole locations. The silty sand extended to depths ranging from 1.0 to 2.8 metres below ground surface.

SPT N values recorded within the silty sand range from weight of hammer to 17 blows per 0.3 metres of penetration, indicating very loose to compact material.

4.4 Silty Clay

Silty clay was encountered beneath the silty sand at all borehole and CPTu locations at depths ranging from 1.0 to 2.8 metres below ground surface. The CPTu data indicates that the silty clay extends to depths ranging from 22.3 to 25.0 metres below ground surface.

Nilcon vane testing was carried out at 19-07 and 19-10 to provide accurate shear strength profiles of the silty clay.

Using the results of the in-situ Nilcon vane tests, the shear strength of the clay was also evaluated from the CPTu data, using the following equation:

$S_u = (q_t - \sigma_{vo}) / N_{kt}$

Where: S_u = Calculated undrained shear strength (kPa);

q_t = Measured net tip resistance (kPa);

σ_{vo} = Calculated total vertical stress (kPa);

N_{kt} = Correlation factor, which was taken as 14 for this site.

The results of the Nilcon vane and CPTu tests indicate that the shear strength at the top of the silty clay ranges from 15 to 35 kilopascals, which corresponds to a soft to firm consistency. Below this zone, the shear strength of the silty clay generally increases with depth to about 80 to 90 kilopascals at the bottom of the silty clay layer, which corresponds to a stiff consistency (refer to shear strength profiles on Figures C1 and C2 in Appendix C).

A 0.3 to 1.1 metre thick layer of silty sand was encountered within the upper portion of the silty clay deposits at all borehole and CPT locations, at depths ranging from about 3.4 to 4.7 metres below ground surface.

One (1) laboratory oedometer test was carried out on one of the Shelby tube samples collected from borehole 19-7. The consolidation testing was carried out in general accordance with ASTM D2435. The results are summarized in table 4.1.

Table 4.1 – Summary of Oedometer Testing

Test Hole	Sample Depth (metres)	Estimated Apparent Past Preconsolidation Pressure, P_c', (kilopascals)	Initial Void Ratio, e_o	Recompression Index, C_r	Compression Index, C_c
19-7	7.7 – 8.2	105	1.72	0.07	1.55

A plot of the variation in void ratio with applied stress from the consolidation test is presented on Figure D1 in Appendix D.

4.5 Refusal Depths

Table 4.2 below provides refusal depths and elevations of the cone penetration tests and the dynamic cone penetration tests performed at the test locations

Table 4.2: Summary of Refusal Depths

Test Location	Cone Penetration Test Refusal[1]		Dynamic Cone Penetration Test Refusal[2]	
	Depth (m)	Elevation (m)	Depth (m)	Elevation (m)
19-02	23.6	53.6	-	-
19-04	23.0	53.9	-	-
19-05	25.4	52.2	-	-
19-07	23.6	53.1	25.2	51.5
19-09	-	-	27.4	49.9
19-10	24.0	53.4	-	-
19-12	25.4	52.0	-	-
19-16	23.3	54.0	-	-
19-20	22.8	54.2	26.6	50.4

Notes:

1. CPTu refusal could occur on compact to dense soil, cobbles, or boulders and may not necessarily be on the surface of bedrock.
2. DCPT refusal could be on cobbles or boulders and may not necessarily be on the surface of the bedrock.

4.6 Groundwater Conditions

Groundwater monitoring wells were installed at boreholes 19-04, 19-05, 19-09, 19-18, and 19-20. Measured groundwater depths and elevations are provided in Table 4.3 below.

Table 4.3: Summary of Groundwater Measurements

Monitoring Well ID	Groundwater Depth (mbgs)		Groundwater Elevation (m, elevation)	
	Dec 13, 2019	Dec 16, 2019	Dec 13, 2019	Dec 16, 2019
MW19-04	1.50	1.32	75.43	75.61
MW19-05	1.06	0.95	76.57	76.68
MW19-09	1.19	1.04	76.14	76.29

Monitoring Well ID	Groundwater Depth (mbgs)		Groundwater Elevation (m, elevation)	
	Dec 13, 2019	Dec 16, 2019	Dec 13, 2019	Dec 16, 2019
MW19-18	0.93	0.92	76.47	76.48
MW19-20	0.98	0.94	76.01	76.05

The groundwater levels are expected to vary seasonally and may be higher during wet periods of the year such as the early spring or following periods of precipitation.

5.0 PRELIMINARY GEOTECHNICAL DESIGN GUIDELINES

5.1 General

The information in the following sections is provided for preliminary planning and design purposes 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 presence or 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 off site sources are outside the terms of reference for this report.

5.2 Site Grade Raise Restriction

This site is underlain by thick deposits of silty clay, which have a reduced capacity to support loads imposed by grade raise fill material, pavement structures and foundations for the buildings. 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 silty clay deposit.

Based on the boreholes and CPTus advanced at the site, it was found that the northern portion of the site was more sensitive to loading and grade raise filling than the southern portion. The site has therefore been divided into two zones: Zone 1 and Zone 2, as indicated on Figure 1. This allows separate and more precise grade raise restrictions to be applied to each zone.

Based on the results of the subsurface investigation, including settlement parameters estimated from the results of the consolidation testing, the site grade raise restrictions for each zone are provided below.

- Zone 1 - the grade should not be raised above an elevation of 77.0 metres.
- Zone 2 - the grade should not be raised above an elevation of 77.5 metres.

The grade raise restrictions for this site have been calculated in order to limit the total settlement of the ground to about 50 millimetres in the long term.

It is important to note that if the grade raise restrictions are exceeded the long-term settlement of the ground could be significant.

In areas where the thickness of the existing fill material on the property exceeds the site grade raise restriction, and where ground settlements in excess of 50 millimetres cannot be tolerated, it may be necessary to remove the fill material such that the thickness of the remaining fill material is at, or below, the site grade raise restriction. The requirement to remove fill material at the site will be assessed by GEMTEC as the design progresses.

In areas where the grade raise restriction cannot be achieved, consideration could be given to the use of expanded polystyrene (EPS) blocks, which are specifically manufactured for this purpose, to make up the additional depth of grade raise. Depending on the project schedule, site pre-loading could also be considered. Additional guidelines for the use of EPS and site pre-loading could be provided at the development plans progress.

5.3 Foundation Design

5.3.1 Strip Footings

The native silty sand and silty clay are considered suitable to support lightly loaded spread footing foundations with maximum load and minimum depth requirements. All organic material, topsoil, and loose or water softened soils should be removed from within the proposed footing areas. The existing fill material should also be removed from within the footprint of the proposed building.

In areas where the proposed founding level is above the level of the native soil, or where subexcavation of disturbed material is required below proposed founding level, the following comments are provided:

- Imported granular material meeting OPSS requirements for Ontario Provincial Standard Specifications (OPSS) requirements for Granular B Type I, Granular B Type II, or Granular A could be used below the footings. The use of 19 millimetre clear stone could also be considered. Any clear stone should be tightly wrapped in a non-woven geotextile where it is in direct contact with sandy soils.
- The imported granular material should be placed in accordance with the site grade raise restrictions.
- OPSS Granular B Type I, Granular B Type II, and Granular A should be compacted in maximum 200 millimetre thick lifts to at least 95 percent of the standard Proctor maximum

dry density. The clear stone should be nominally compacted in maximum 300 millimetre thick lifts with at least 2 passes of a diesel plate compactor.

- Where subexcavation of greater than 0.5 metres of native soil is required, and where the native soil is replaced with heavier OPSS Granular B Type I, Granular B Type II, and Granular A, the net stress increase on the underlying silty clay should be reviewed by geotechnical personnel to confirm that the recommendations provided in this report are still valid.
- To allow spread of load beneath the footings, the imported granular material 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 should be sized to accommodate this fill placement.

The bearing pressures for strip footing foundations at this site are based on the necessity to limit the stress increase on the softer silty clay layer to an acceptable level so that foundation settlements will not be excessive. Four important parameters in calculating the stress increase on the grey silty clay are:

- The thickness of the soil beneath the base of the foundation and the surface of the grey silty clay;
- The size, type and loading of the foundation;
- The amount of surcharge (fill, etc.) in the vicinity of the foundation; and
- The amount of post-development groundwater lowering at the site.

From a spread footing design perspective, it is preferable to maximize the vertical separation between the underside of the footings and the surface of the softer, grey silty clay to distribute the foundation loads onto the softer, silty clay at depth. This can be achieved by founding the structures as high as practical within the soil profile and minimizing the amount of fill (surcharge) on the site.

For preliminary planning and design purposes, the parameters listed in Table 5.1 could be considered for the design of the foundations.

Table 5.1 – Bearing Capacity for Spread Footing Foundations

Zone	Type of Footing	Underside of Footing Elevation (metres)	Maximum Size of Strip or Pad Footing (metres)	Net Geotechnical Reaction at Serviceability Limit State[1,2] (kilopascals)	Factored Geotechnical Resistance at Ultimate Limit State (kilopascals)
1	Spread Footing	76.5 or above	0.6	60	120
2	Spread Footing	77.0 or above	0.6	60	120

Notes:
1. Provided that any loose or disturbed soil is removed from the bearing surfaces, the total settlement of the foundation at SLS should be less than 50 millimetres. These settlements, and the bearing capacities provided in Table 5.1, assume that the fill materials are placed in accordance with the site grade raise restrictions and that the interior floor slab will be lightly loaded.
2. From a geotechnical perspective, it is acceptable to size the footings using 100 percent of the dead and snow loads, and 50 percent of the live load.

5.3.2 Deep Foundations

For higher loads, or where strip footings are not suitable, structures could be founded on deep foundations. Comments on deep foundations have been provided below.

- The piles should be driven to refusal on bedrock. The bedrock surface was not encountered in the boreholes advanced as part of the geotechnical investigation. The cone penetrometers advanced as part of the geotechnical investigation encountered refusal at depths ranging from 22.3 to 25.0 metres below ground surface. Well records close to the site indicate bedrock depths ranging from 23.5 to 33.2 metres below ground surface. A supplemental investigation could be considered to assist with estimating pile lengths and capacities.
- Cobbles and boulders should be anticipated in the glacial till, which is expected below the silty clay deposit. As such, difficult pile driving conditions should be anticipated through the glacial till. Some of the piles may be bent, driven off plumbness or location tolerance, or may break. Allowance should be made in the contract to replace any defective piles and enlarge the pile caps, as required. The use of a pipe pile with a thick wall, or H-piles fitted with a driving shoe, may allow penetration of the glacial till with less damage.
- Pile capacities at this site will depend on pile type, pile dimensions, and pile material. As an example, preliminary pile capacities have been calculated for closed ended pipe piles and H piles driven to refusal within sound bedrock (refer to Table 5.2 below).

- A resistance factor of 0.4 should be applied to ULS resistance. In order to increase the resistance factor from 0.4 to 0.5, dynamic pile testing using a pile driving analyzer (PDA) should be undertaken on a minimum of 10 percent of the driven piles.
- ULS resistance will govern the design since the stresses required to induce Serviceability Limit State (SLS) criteria for piles terminated on bedrock will exceed those at ULS.
- Full time inspection of pile driving by qualified geotechnical personnel is recommended.

For design purposes, preliminary pile capacities are provided in Table 5.2.

Table 5.2 - Preliminary Pile Capacities

Pile Type (size)	End Bearing Material	Factored Geotechnical Resistance at Ultimate Limit State[1] (kilonewtons)
Closed ended steel pipe pile[2] (244 mm diameter by 12 mm thick)	Sound Bedrock	1,350
Steel H piles[3] (HP310x79)	Sound Bedrock	1,200

Notes:

1. Assuming that the steel has a minimum yield strength of 340 megapascals and that the pipe is filled with 30 megapascal concrete.
2. Pipe piles should be driven closed ended and fitted with 20 millimetre (minimum) thick end plates.
3. The tips of H-piles should be reinforced with steel plates to reduce the potential for damage.

The contractor should be required to submit the pile design and pile driving criteria for review prior to pile driving at this site. Mill certificates should be provided for the steel piling. An allowance should be made in the specification for re-striking all of the piles at least once after a minimum period of two (2) days to confirm the permanence of the pile set. Additional rounds of re-striking will be required for piles that do not meet the set criteria during the first round of re-striking. Further, allowance should be made to check for upward displacement due to driving of adjacent piles.

The specifications should make provision for dynamic testing of selected piles by the piling sub-contractor during the early stages of the pile driving operations to verify the transferred energies and pile capacities.

5.3.3 Frost Protection of Foundations

At least 1.5 metres of earth cover should be provided for frost protection purposes for footings, exterior pile caps and grade beams. Isolated, exterior footings, or grade beams constructed in

areas that are to be cleared of snow during the winter period should be provided with at least 1.8 metres.

Given the grade raise restriction and the founding depth requirements for strip footings, the frost protection requirements for the strip footings cannot be entirely provided by soil cover. In this case, and generally where less than the required depth of soil cover can be provided, the pile caps, grade beams, and footings can be protected from frost by using a combination of earth cover and extruded polystyrene insulation. An insulation detail could be provided upon request.

5.3.4 Seismic Design

5.3.4.1 Potential for Liquefaction

The subject site is underlain by deposits of silty sand, followed by deposits of silty clay to depths of greater than 20 metres below ground surface. We have assessed the risk of liquefaction at the site based on a seismic load with a probability of exceedance of 2 percent over a 50 year period.

The extent and probability of liquefaction at the site is considered to be very low to the point of having little impact on the dynamic response of the site and the performance of the foundation elements.

5.3.4.2 Seismic Site Class

In accordance with the 2012 Ontario Building Code, seismic Site Class E should be used for design purposes.

6.0 ADDITIONAL CONSIDERATIONS

6.1 Excavation

Excavations for foundations at this site are expected to be relatively shallow and will mainly be carried out through fill material and native silty sand. It is not expected that the excavations will extend into the underlying silty clay.

For excavation exceeding 1.2 metres in depth, the sides of 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 fill material and native silty sand 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 the measured groundwater levels, and assuming that a perched groundwater table will likely be present within the fill material and silty sand above the silty clay deposits, excavation below the groundwater level may be required, which could present some constraints. There is potential for disturbance to the silty sand on the sides and bottom of the excavation and relatively flat side slopes may be required to prevent sloughing of material into the excavation. The

groundwater inflow should be controlled throughout the excavation by pumping from sumps within the excavation. Notwithstanding, some disturbance and loosening of the subgrade materials could occur where excavation below the groundwater level is required. To avoid disturbance of these sandy soils, a 50 to 75 millimetre thick mud mat of low strength concrete should be placed over the subgrade surface immediately after exposure and inspection.

6.2 Foundation Backfill

The native soil deposits at this site are highly frost susceptible and should not be used as backfill against foundations, piers, etc. To avoid frost adhesion and possible heaving, the foundations should be backfilled with imported, free-draining, non-frost susceptible granular material meeting OPSS Granular B Type I or II requirements. The use of 19 millimetre clear stone could also be considered. Any clear stone should be tightly wrapped in a non-woven geotextile where it is in direct contact with sandy soils. The imported granular material should be placed in accordance with the site grade raise restrictions.

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 vibratory 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. The clear stone should be nominally compacted in maximum 300 millimetre thick lifts with at least 2 passes of a diesel plate compactor

Where areas of hard surfacing (concrete, sidewalk, pavement, etc.) abut the proposed building, a gradual transition should be provided between those areas of hard surfacing underlain by non-frost susceptible granular wall backfill and those areas underlain by existing frost susceptible native materials to reduce the effects of differential frost heaving. It is suggested that granular frost tapers be constructed from the bottom of the excavation or 1.5 metres below finished grade, whichever is less, to the underside of the granular base/subbase material for the hard surfaced areas. The frost tapers should be sloped at 1 horizontal to 1 vertical, or flatter.

Perimeter foundation drainage is not considered necessary for any slab on grade structures at this site provided that the floor slab level is above the finished exterior ground surface level at the building.

6.3 Slab on Grade

To provide predictable settlement performance of any slabs on grade, all loose soil, fill, disturbed soil and organic soil should be removed from below the slab areas. The adequacy of the existing fill material could be assessed during excavation by geotechnical personnel. However,

preliminary design and costing purposes, allowance should be made for full removal of the existing fill material below the slabs on grade.

If necessary, the grade below the floor slabs could be raised, where necessary, with granular material meeting OPSS requirements for Granular A, Granular B Type II, or 19 millimetre clear stone. The base for the floor slab should consist of at least 150 millimetres of OPSS Granular A. The placement of the engineered fill below the slabs should comply with the site grade raise restrictions. It is noted that the concrete for the slab on grade is considered grade raise fill.

Underfloor drainage is not considered necessary provided that the floor slab level is above the finished exterior ground surface level. If any areas of the building are to remain unheated during the winter period, thermal protection of the materials beneath the slab on grade may be required. Further details on the insulation requirements could be provided, if necessary.

Depending on the proposed grades, ground floor loading, and foundation loads, a conventional slab on grade may not be feasible and a structural floor slab, supported on deep foundations, may be required.

6.4 Material Stockpiling

Stockpiling restrictions should be anticipated due to the anticipated compression of the underlying silty clay due to stockpiling loads. In order to avoid settlement of nearby structures or adjacent properties due to stockpiling, restrictions will be required on the height and geometry of any stockpiles and the minimum required offset from the stockpiles to any nearby structures or property boundaries. Stockpile restrictions could be assessed as the development plans progress.

There is a risk of instability and slippage of stockpiles at this site due to the low shear resistance of underlying silty clay deposit. Construction staging requirements and stockpile geometry restrictions may be required to mitigate the risk of instability and slippage of large stockpiles.

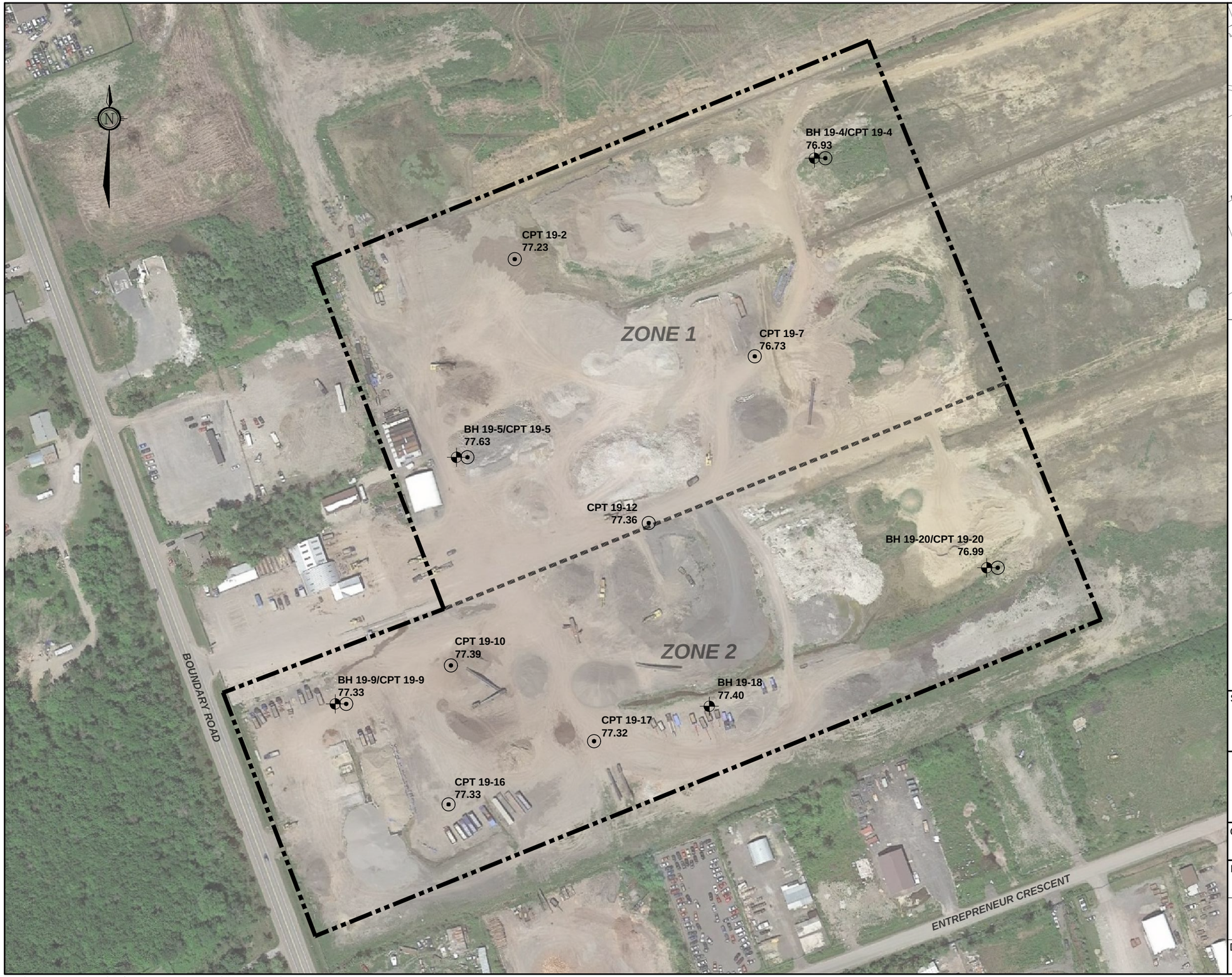
6.5 Effects of Construction Induced Vibration

Some of the construction operations (such as granular material compaction, excavation, pile driving, 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. We recommend that preconstruction surveys be carried out on the adjacent structures to mitigate potential claims.

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.

Joseph Berkers, B.Eng.

Johnathan A. Cholewa, Ph.D., P.Eng.
Senior Geotechnical Engineer



KEY PLAN
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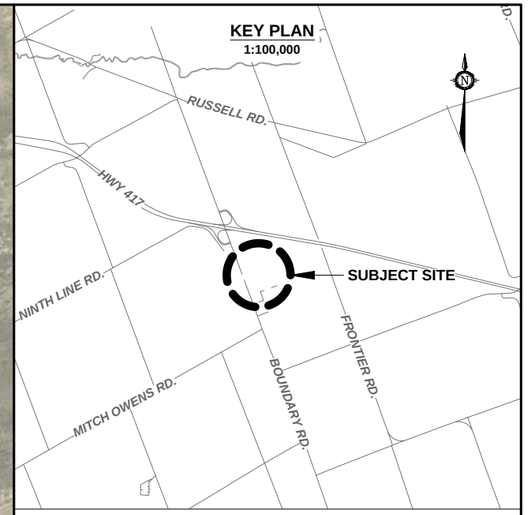

LEGEND

- SUBJECT SITE
- ZONE DELINEATION
- **BOREHOLE LOCATION** (current investigation by GEMTEC)
- **CONE PENETROMETER TEST LOCATION** (current investigation by GEMTEC)
- BH/CPT # ← TEST HOLE ID
- XX.XX ← GROUND SURFACE ELEVATION, IN METRES GEODETIC DATUM

Scale 1:2000

0 40 80 120m

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Client	D-SQAURED CONSTRUCTION LIMITED	Project 61774.48
Location	5455 BOUNDARY ROAD OTTAWA, ON	
Drwn by P.C.	Chkd by J.B.	TEST HOLE LOCATION PLAN
Date JANUARY 2020	Rev. 0	**FIGURE 1**

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APPENDIX A

Record of Borehole Sheets
List of Abbreviations and Terminology

ABBREVIATIONS AND TERMINOLOGY USED ON RECORDS OF BOREHOLES AND TEST PITS

SAMPLE TYPES	
AS	Auger sample
CA	Casing sample
CS	Chunk sample
BS	Borros piston sample
GS	Grab sample
MS	Manual sample
RC	Rock core
SS	Split spoon sampler
ST	Slotted tube
TO	Thin-walled open shelby tube
TP	Thin-walled piston shelby tube
WS	Wash sample

SOIL TESTS	
w	Water content
PL, w_p	Plastic limit
LL, w_L	Liquid limit
C	Consolidation (oedometer) test
D_R	Relative density
DS	Direct shear test
G_S	Specific gravity
M	Sieve analysis for particle size
MH	Combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	Organic content test
UC	Unconfined compression test
γ	Unit weight

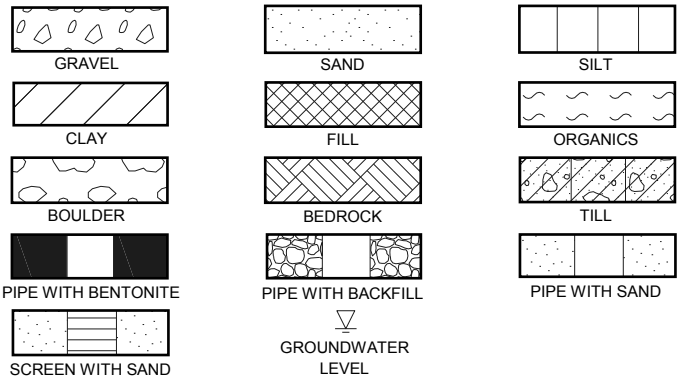
PENETRATION RESISTANCE

Standard Penetration Resistance, N
The number of blows by a 63.5 kg (140 lb) hammer dropped 760 millimetres (30 in.) required to drive a 50 mm split spoon sampler for a distance of 300 mm (12 in.). 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.

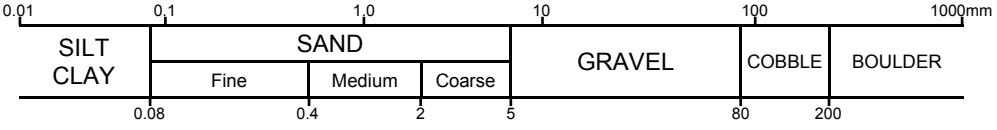
Dynamic Penetration Resistance
The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive a 50 mm (2 in.) diameter 60° cone attached to 'A' size drill rods for a distance of 300 mm (12 in.).

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

COHESIONLESS SOIL Compactness		COHESIVE SOIL Consistency	
SPT N-Values	**Description**	**Cu, kPa**	**Description**
0-4	Very Loose	0-12	Very Soft
4-10	Loose	12-25	Soft
10-30	Compact	25-50	Firm
30-50	Dense	50-100	Stiff
>50	Very Dense	100-200	Very Stiff
		>200	Hard

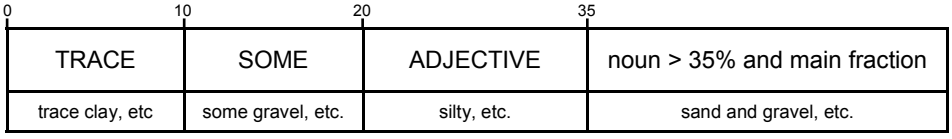


GRAIN SIZE



DESCRIPTIVE TERMINOLOGY

(Based on the CANFEM 4th Edition)



RECORD OF BOREHOLE 19-04

CLIENT: D-Squared Construction
PROJECT: Geotechnical Investigation
JOB#: 61774.48
LOCATION: 5455 Boundary Road

SHEET: 1 OF 1
DATUM: CGVD2013
BORING DATE: Dec 11 2019

DEPTH SCALE METRES	DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	NUMBER	TYPE	RECOVERY, mm	BLOWS/0.3m
0	Ground Surface		76.93				
	Compact, dark grey brown SILTY SAND, with organics			1	SS	508	15
			76.02				
1	Compact, light grey brown fine SAND, some silt		0.91	2	SS	406	13
			75.41				
	Grey brown SILTY CLAY		1.52	3	SS	152	2
2				4	SS	0	W.H.
3				5	SS	610	W.H.
			73.27				
	Very loose, grey SAND, some silt		3.66	6	SS	610	3
4							
			72.51				
	End of borehole		4.42				
5							

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
Filter sand
Screen

GROUNDWATER OBSERVATIONS

DATE	DEPTH (m)	ELEV. (m)
19/12/13	1.5 ▽	75.4
19/12/16	1.3 ▼	75.6

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Consulting Engineers and Scientists

LOGGED: M.L.
CHECKED: J.B.

GEO - BOREHOLE LOG 61774.48_GINT_V01_2019-12-19.GPJ GEMTEC 2018.GDT 10/1/20

RECORD OF BOREHOLE 19-05

CLIENT: D-Squared Construction
PROJECT: Geotechnical Investigation
JOB#: 61774.48
LOCATION: 5455 Boundary Road

SHEET: 1 OF 1
DATUM: CGVD2013
BORING DATE: Dec 12 2019

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	RECOVERY, mm	BLOWS/0.3m	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)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
0		Ground Surface		77.63							
		Very dense, grey sand and gravel (ROADWAY BASE/SUBBASE)			1	SS	203	50 for 130mm			
				76.87							
1		Compact, grey sand, some gravel, some silt (FILL MATERIAL)		0.76	2	SS	203	15			
				76.11							
		Loose, grey brown SILTY SAND		1.52	3	SS	457	5			
2											
					4	SS	457	W.H.			
				74.83							
		Grey SILTY CLAY		2.80							
3					5	SS	610	W.H.			
4					6	SS	610	14			
				73.36							
		Grey SILTY SAND		4.27							
				73.21							
		End of borehole		4.42							
5											

PIEZOMETER OR STANDPIPE INSTALLATION: Bentonite; Filter sand; Screen

GROUNDWATER OBSERVATIONS

DATE	DEPTH (m)	ELEV. (m)
19/12/13	1.1	76.6
19/12/16	1.0	76.7

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LOGGED: M.L.
CHECKED: J.B.

GEO - BOREHOLE LOG 61774.48_GINT_V01_2019-12-19.GPJ GEMTEC 2018.GDT 10/1/20

RECORD OF BOREHOLE 19-07

CLIENT: D-Squared Construction
PROJECT: Geotechnical Investigation
JOB#: 61774.48
LOCATION: 5455 Boundary Road

SHEET: 1 OF 1
DATUM: CGVD2013
BORING DATE: Dec 16 2019

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. / DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: RECOVERY, mm	SAMPLES: BLOWS/0.3m	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)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
0		Ground Surface		76.73							
		Refer to CPT 19-07 for Soil Stratigraphy									
5					1	TO				C	
8					2	TO				C	
16				60.88	3	TO				C	
		End of borehole		15.85							

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

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LOGGED: M.L.
CHECKED: J.B.

GEO - BOREHOLE LOG 61774.48_GINT_V01_2019-12-19.GPJ_GEMTEC 2018.GDT 10/1/20

RECORD OF BOREHOLE 19-09

CLIENT: D-Squared Construction
PROJECT: Geotechnical Investigation
JOB#: 61774.48
LOCATION: 5455 Boundary Road

SHEET: 1 OF 1
DATUM: CGVD2013
BORING DATE: Dec 11 2019

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	RECOVERY, mm	BLOWS/0.3m	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)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
0		Ground Surface		77.33					10 20 30 40 50 60 70 80 90		
		Compact, grey sand and gravel (ROADWAY BASE/SUBBASE)		77.10							
		Grey brown SILTY SAND, with organics		0.23	1	SS	406	22	●		
1		Reddish brown SILTY CLAY		76.29 1.04	2	SS	406	16	●		
		Grey SILTY CLAY		75.81 1.52	3	SS	305	1	●		
2					4	SS	457	W.H.			
3					5	SS	610	W.H.			
		Very loose, grey SANDY SILT		73.52 3.81	6	SS	610	1	●		
4		Grey SILTY CLAY		73.22 4.11							
		End of borehole		72.91 4.42							
5											

Bentonite
Filter sand
Screen

GROUNDWATER OBSERVATIONS

DATE	DEPTH (m)	ELEV. (m)
19/12/13	1.2 ▽	76.1
19/12/16	1.0 ▼	76.3

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LOGGED: M.L.
CHECKED: J.B.

GEO - BOREHOLE LOG 61774.48_GINT_V01_2019-12-19.GPJ GEMTEC 2018.GDT 10/1/20

RECORD OF BOREHOLE 19-18

CLIENT: D-Squared Construction
PROJECT: Geotechnical Investigation
JOB#: 61774.48
LOCATION: 5455 Boundary Road

SHEET: 1 OF 1
DATUM: CGVD2013
BORING DATE: Dec 11 2019

DEPTH SCALE METRES	DESCRIPTION	ELEV. DEPTH (m)	NUMBER	TYPE	RECOVERY, mm	BLOWS/0.3m
0	Ground Surface	77.40				
	Compact, brown silty clay, some sand, some gravel (FILL MATERIAL)		1	SS	356	27
		76.71				
	Dense, grey brown silt and gravel, some sand (FILL MATERIAL)	0.69	2	SS	76	33
		75.95				
	Loose, brown SILTY SAND	1.45	3	SS	229	5
		75.19				
	Grey SILTY CLAY	2.21	4	SS	610	W.H.
			5	SS	610	W.H.
		73.29	6	SS	610	14
	Compact, grey SILTY SAND	4.11				
		72.98				
	End of borehole	4.42				

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
Filter sand
Screen

GROUNDWATER OBSERVATIONS

DATE	DEPTH (m)	ELEV. (m)
19/12/13	0.9	76.5
19/12/16	0.9	76.5

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LOGGED: M.L.
CHECKED: J.B.

GEO - BOREHOLE LOG 61774.48_GINT_V01_2019-12-19.GPJ GEMTEC 2018.GDT 10/1/20

RECORD OF BOREHOLE 19-20

CLIENT: D-Squared Construction
PROJECT: Geotechnical Investigation
JOB#: 61774.48
LOCATION: 5455 Boundary Road

SHEET: 1 OF 1
DATUM: CGVD2013
BORING DATE: Dec 11 2019

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	RECOVERY, mm	BLOWS/0.3m	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)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
0		Ground Surface		76.99							
		Compact, brown SILTY SAND			1	SS	457	16			Bentonite
											Filter sand
1					2	SS	457	17			
				75.44							
		Grey SILTY CLAY		1.55	3	SS	76	1			
2											
					4	SS	610	W.H.			Screen
3											
					5	SS	610	W.H.			
4				72.88							
		Very loose, grey SILTY SAND		4.11	6	SS	152	1			
				72.57							
		End of borehole		4.42							
5											

GROUNDWATER OBSERVATIONS

DATE	DEPTH (m)	ELEV. (m)
19/12/13	1.0	76.0
19/12/16	0.9	76.0

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LOGGED: M.L.
CHECKED: J.B.

GEO - BOREHOLE LOG 61774.48_GINT_V01_2019-12-19.GPJ GEMTEC 2018.GDT 10/1/20

APPENDIX B

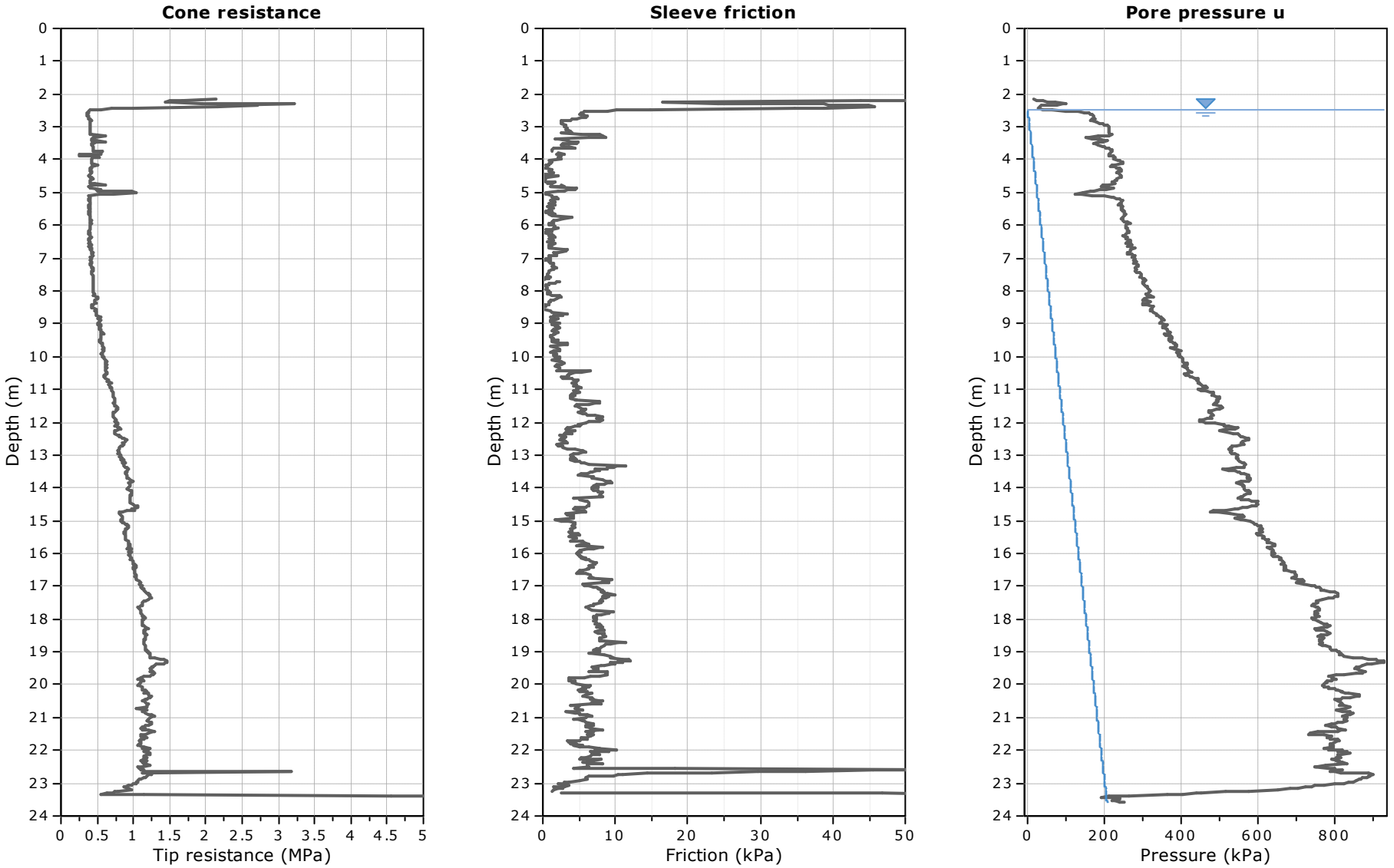
Cone Penetrometer Testing Results

GEMTEC
Consulting Engineers and Scientists
www.gemtec.ca

CPT: 19-02

Project: **61774.48**
Location: **5455 Boundary Road**

Total depth: 23.60 m, Date: 19/12/16
Surface Elevation: 77.23 m



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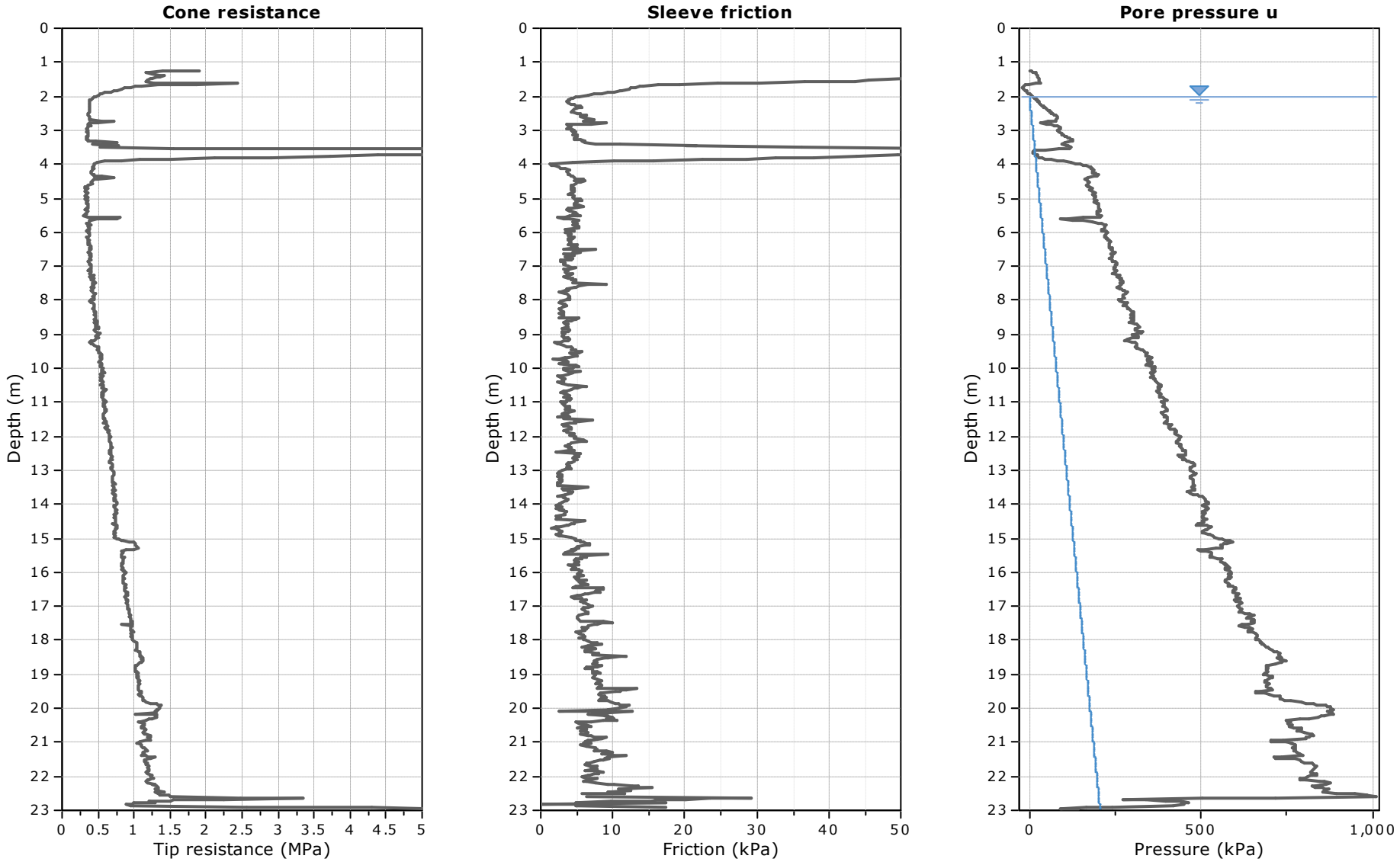
CPT: 19-04

Project: **61774.48**
Location: **5455 Boundary Road**

Total depth: 22.97 m, Date: 19/12/17
Surface Elevation: 76.92 m



GEMTEC
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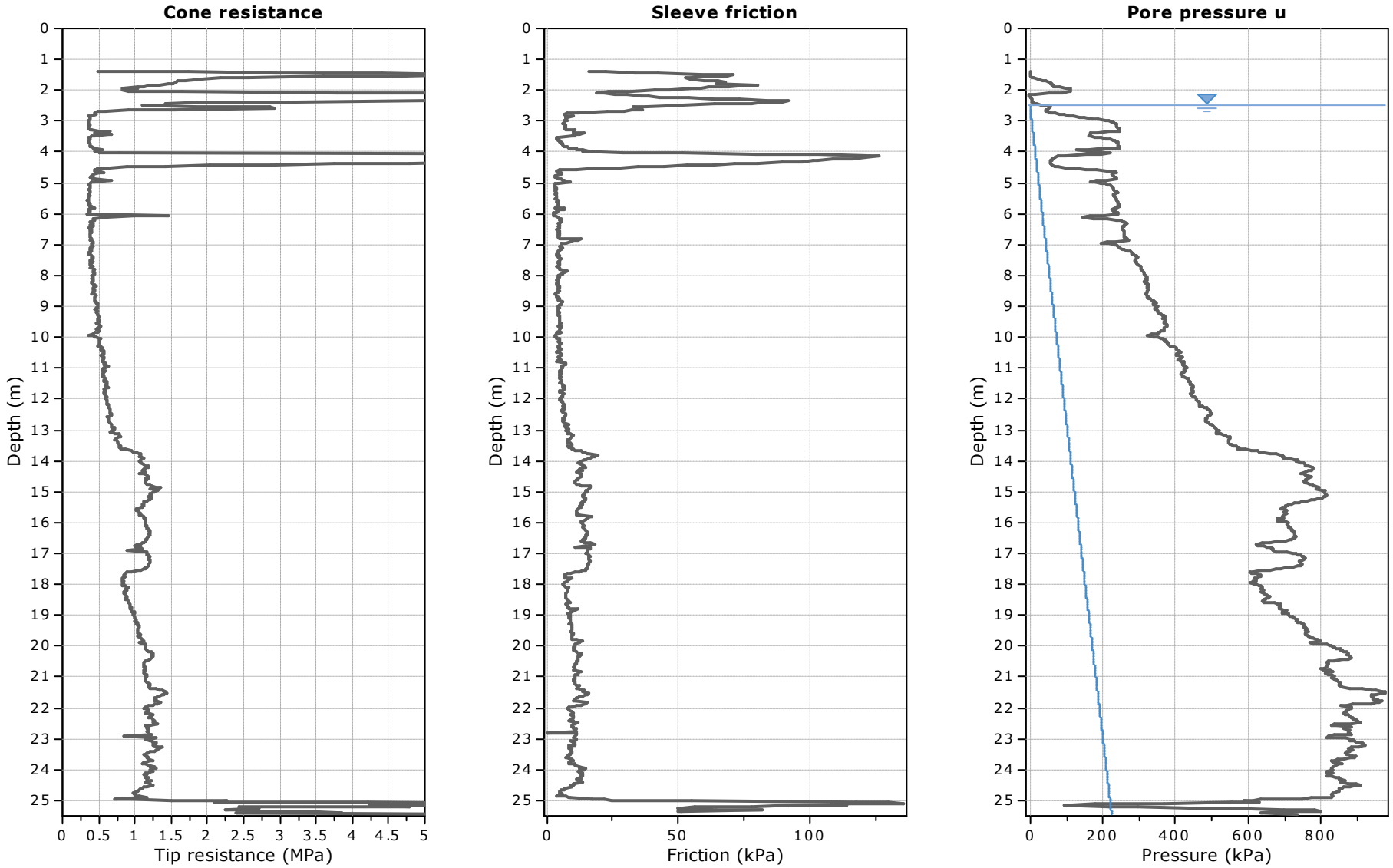
www.gemtec.ca

CPT: 19-05

Project: **61774.48**
Location: **5455 Boundary Road**

Total depth: 25.43 m, Date: 20/01/06
Surface Elevation: 77.64 m



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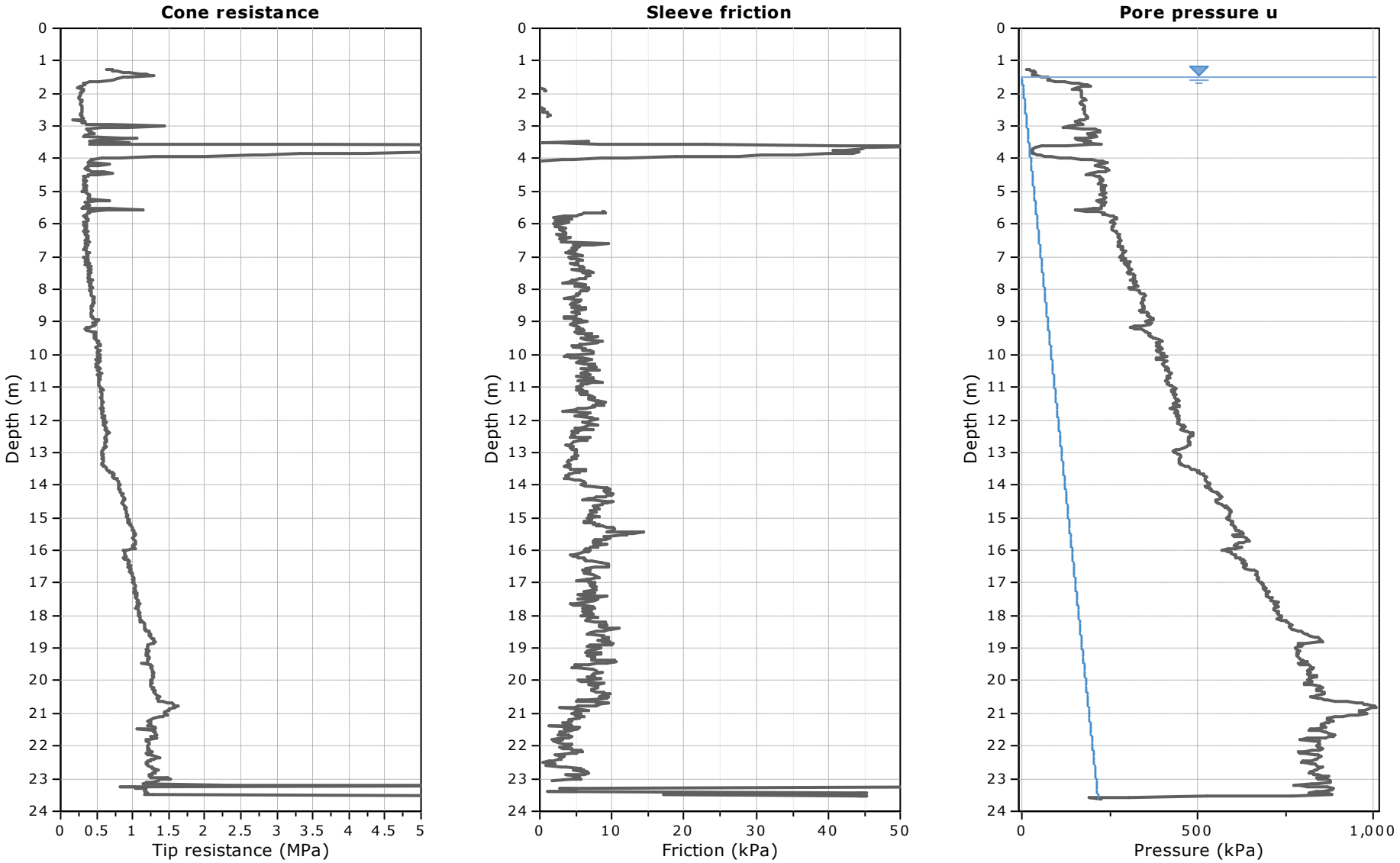
CPT: 19-07

Project: **61774.48**
Location: **5455 Boundary Road**

Total depth: 23.62 m, Date: 19/12/16
Surface Elevation: 76.73 m

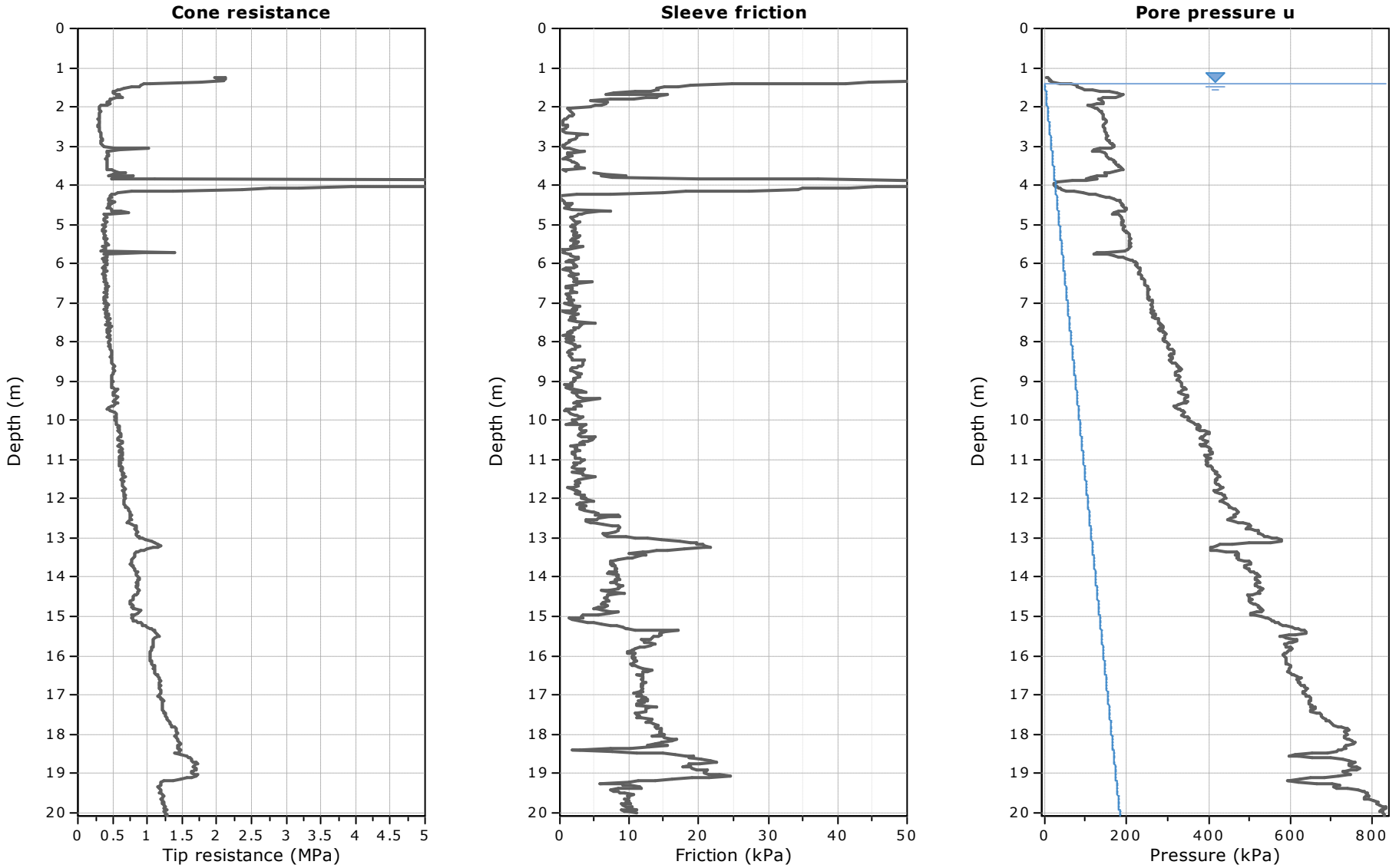


GEMTEC
Consulting Engineers and Scientists
www.gemtec.ca

CPT: 19-09

Project: **61774.48**
Location: **5455 Boundary Road**

Total depth: 20.09 m, Date: 19/12/17
Surface Elevation: 77.28 m



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Consulting Engineers and Scientists
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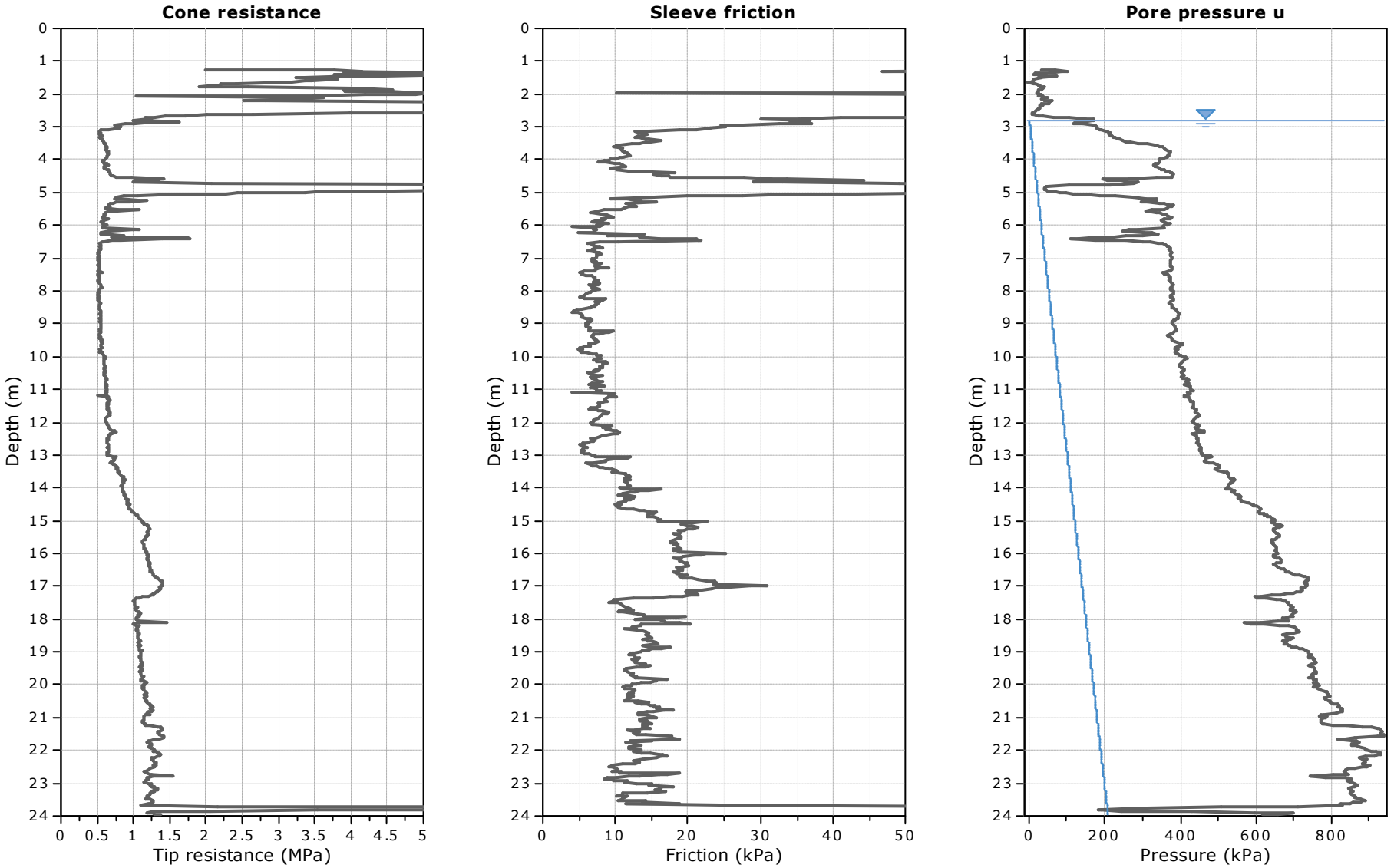
CPT: 19-10

Project: **61774.48**
Location: **5455 Boundary Road**

Total depth: 23.97 m, Date: 19/12/16
Surface Elevation: 77.39 m



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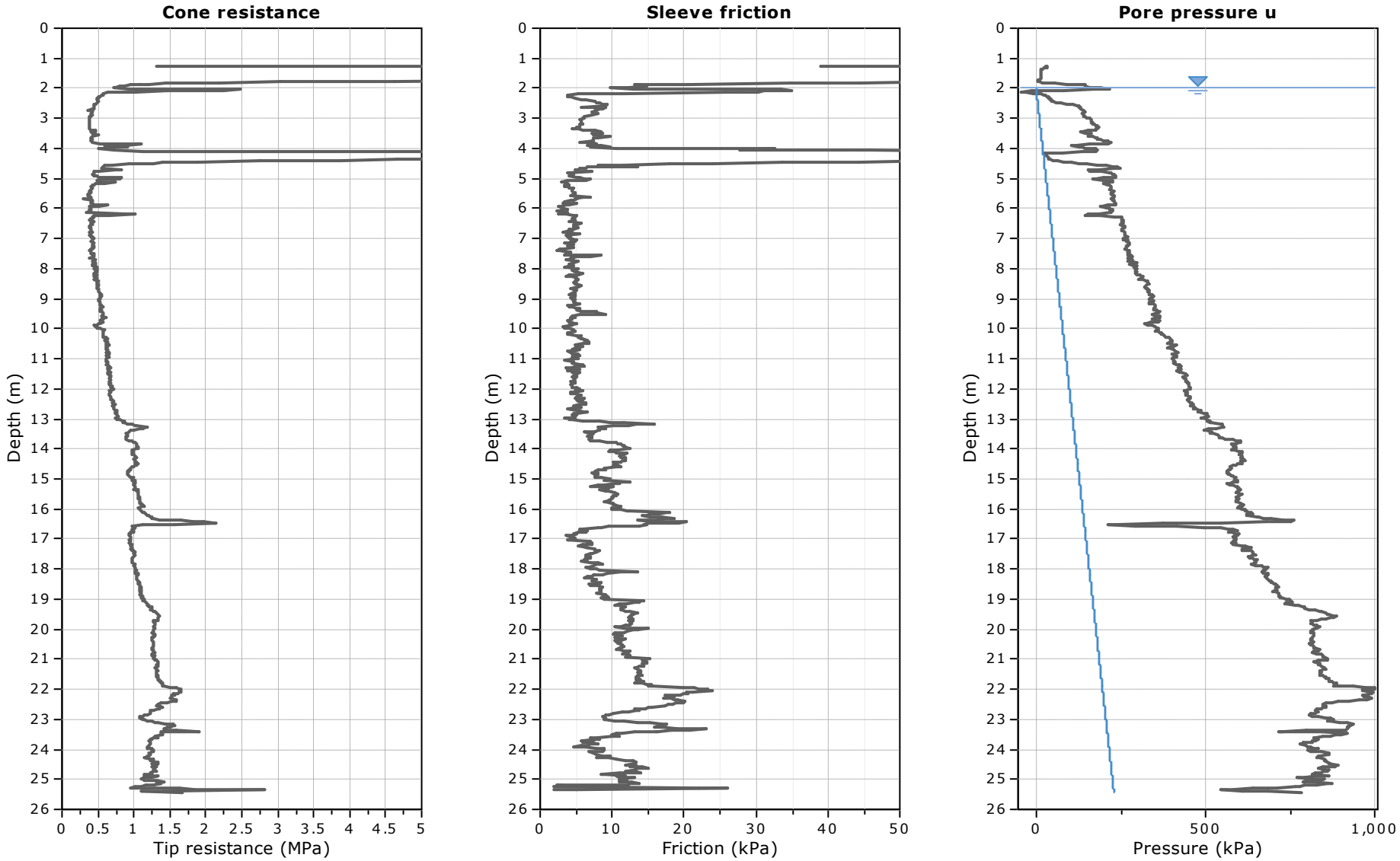
CPT: 19-12

Project: **61774.48**
Location: **5455 Boundary Road**

Total depth: 25.42 m, Date: 19/12/16
Surface Elevation: 77.36 m



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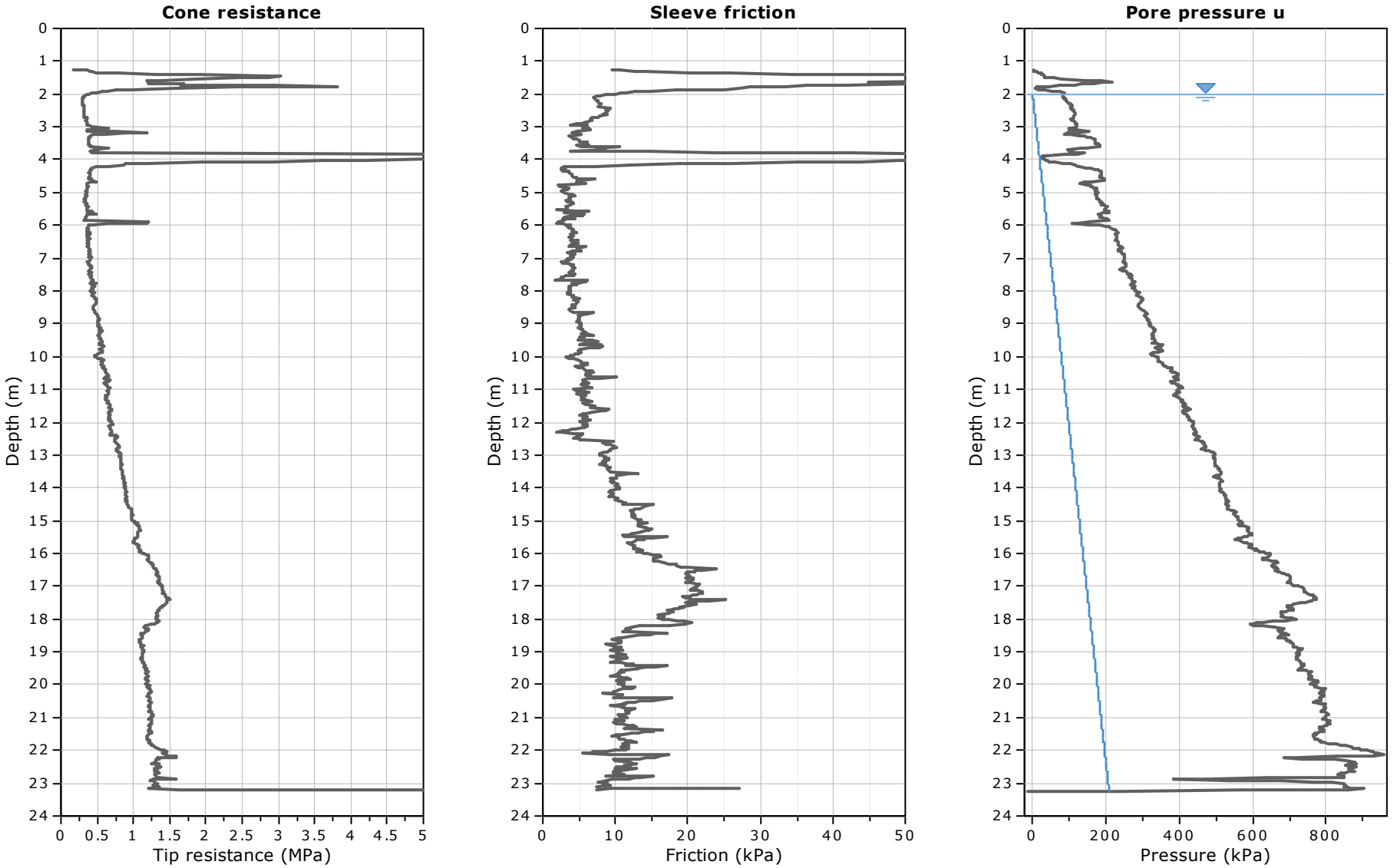
CPT: 19-16

Project: **61774.48**
Location: **5455 Boundary Road**

Total depth: 23.27 m, Date: 19/12/16
Surface Elevation: 77.34 m



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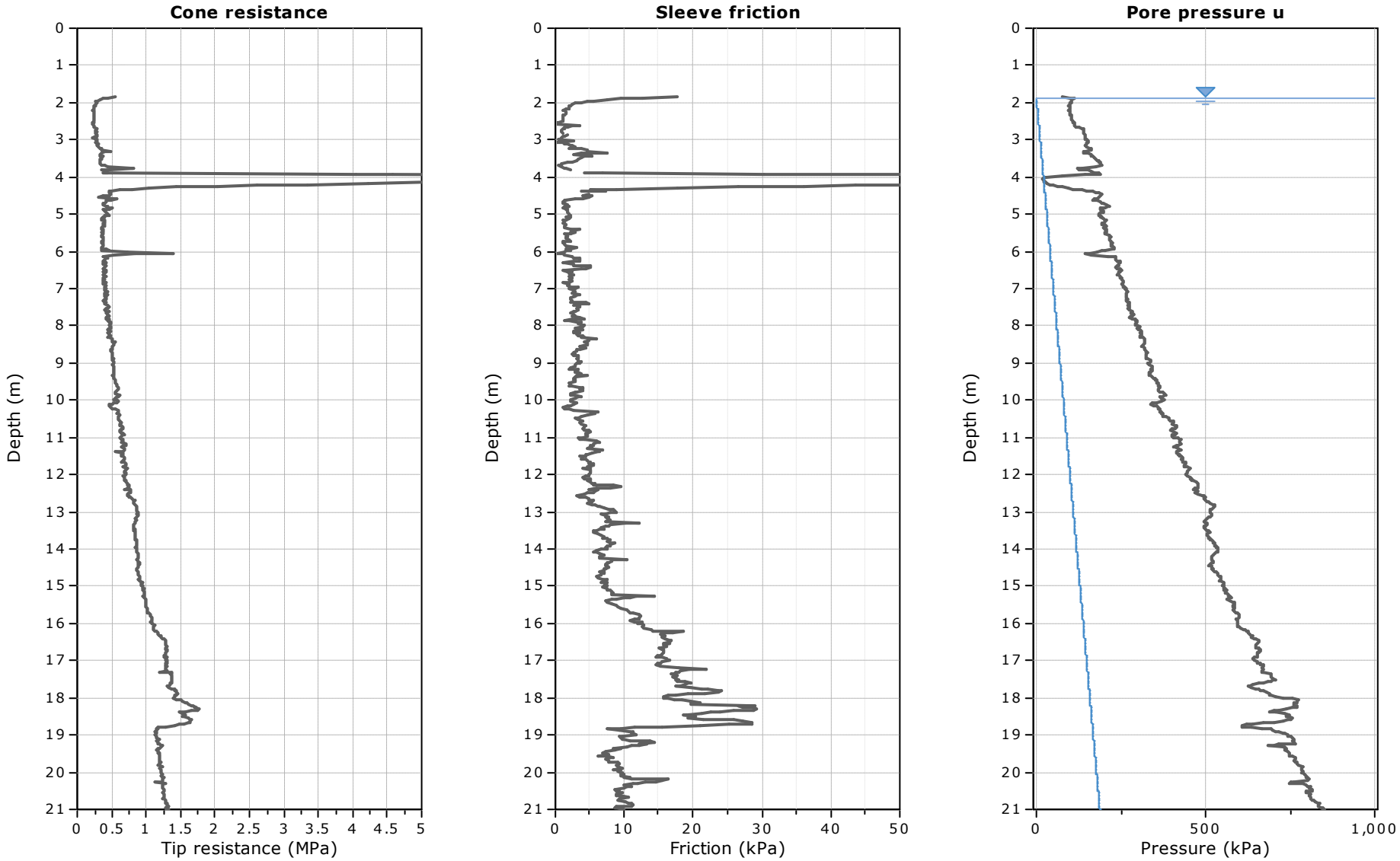
CPT: 19-17

Project: **61774.48**
Location: **5455 Boundary Road**

Total depth: 22.22 m, Date: 19/12/16
Surface Elevation: 77.32 m



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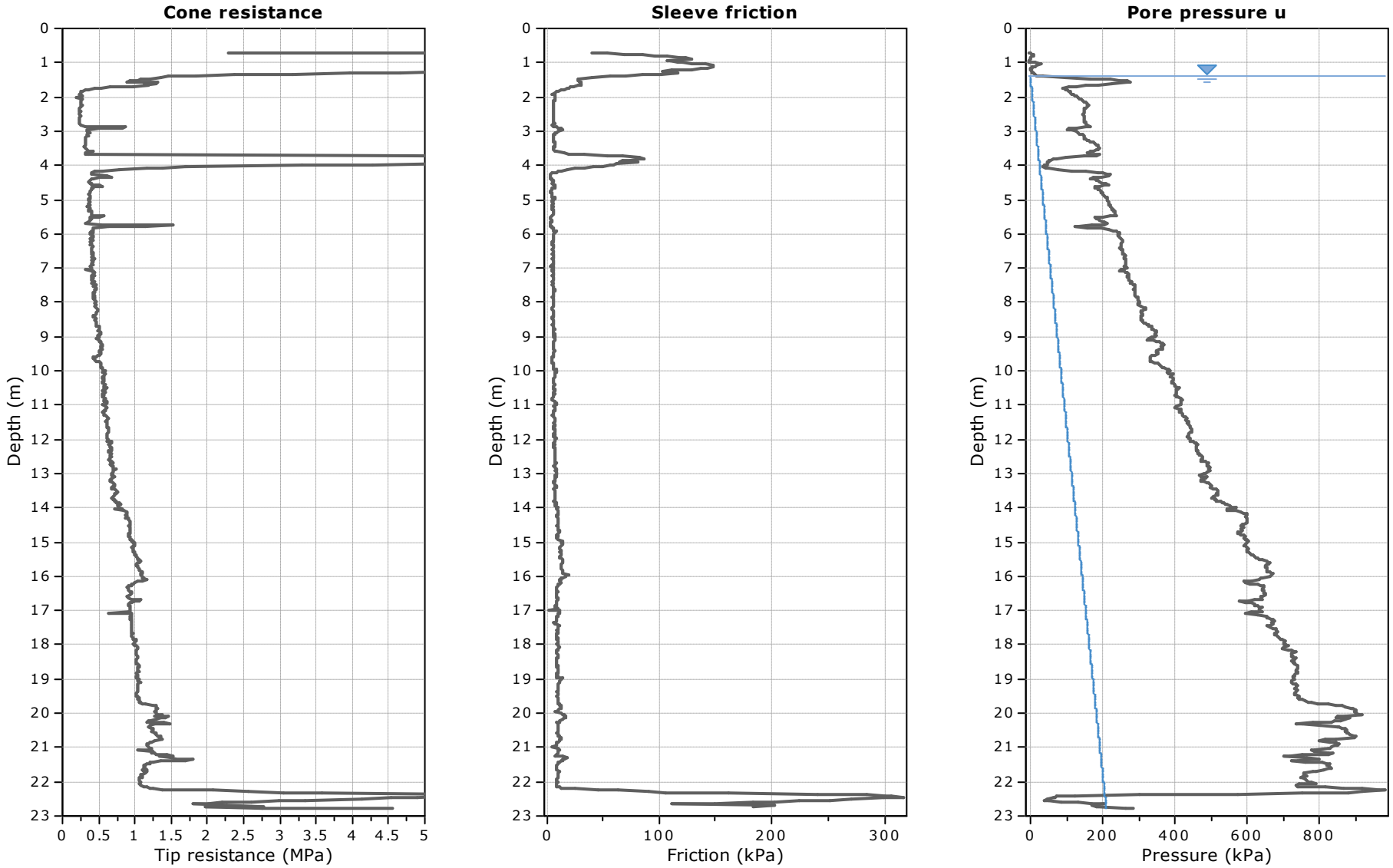
CPT: 19-20

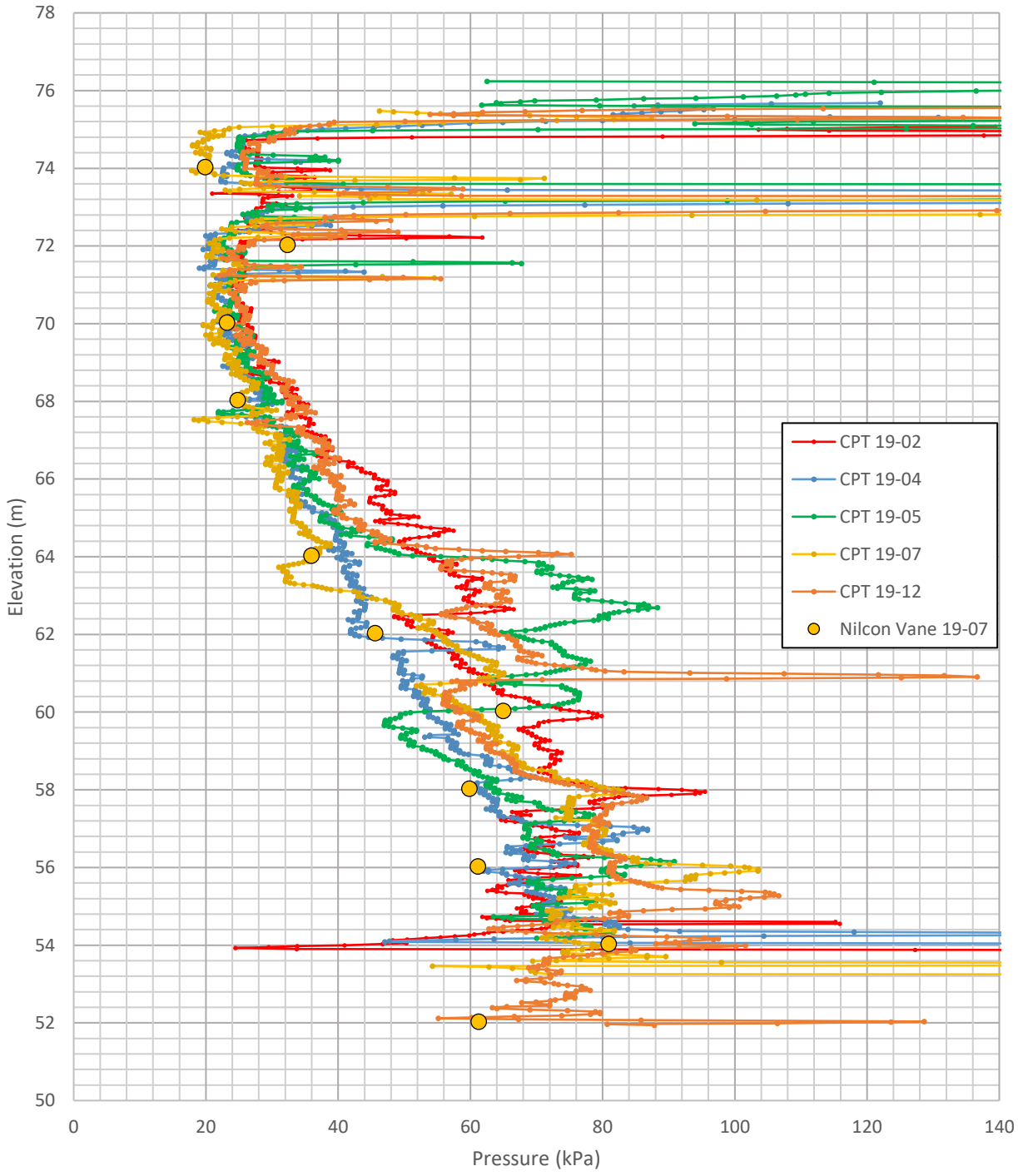
Project: **61774.48**
Location: **5455 Boundary Road**

Total depth: 22.79 m, Date: 20/01/06
Surface Elevation: 76.99 m



APPENDIX C

Shear Strength Profiles



GEMTEC
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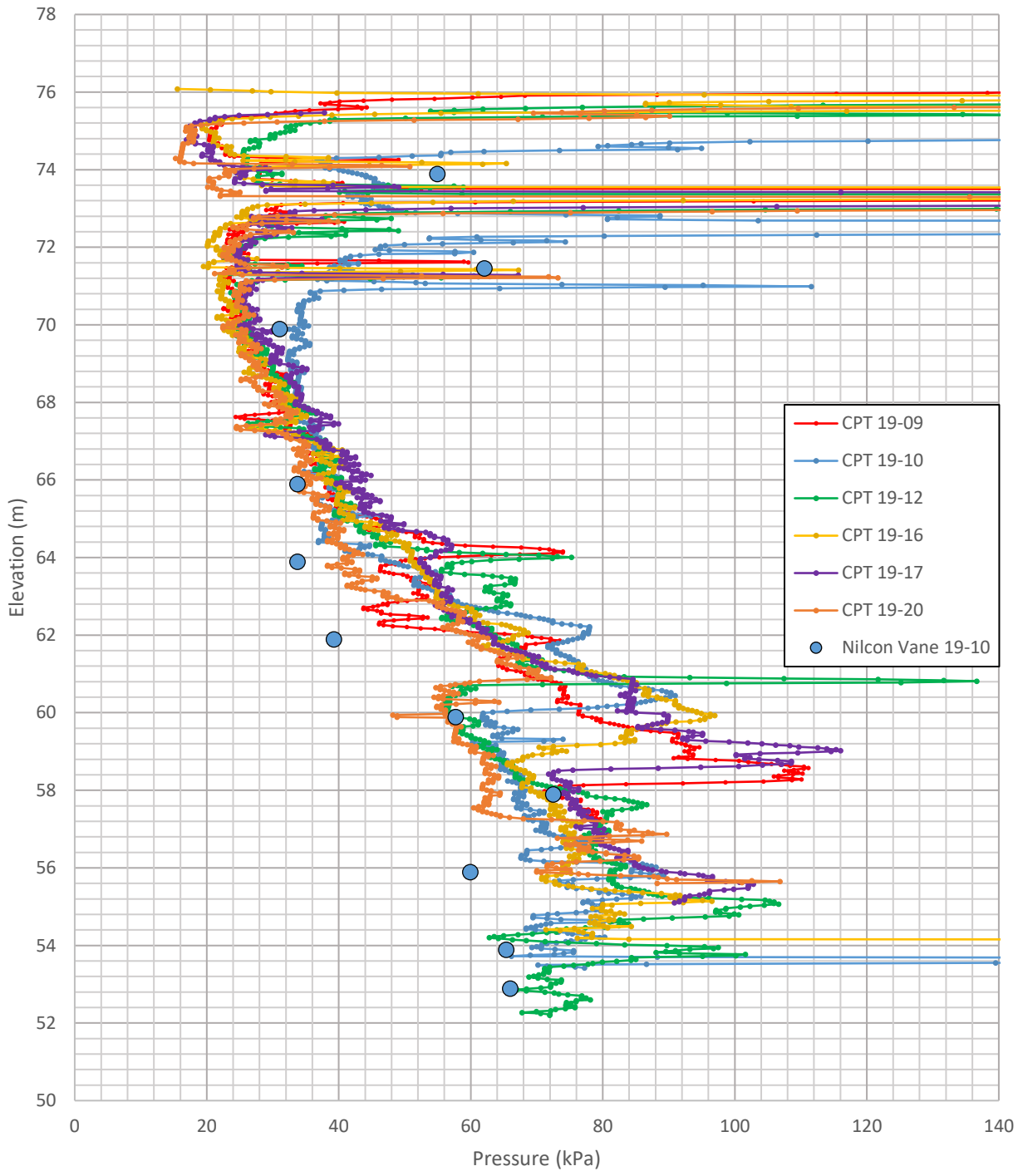
5545 Boundary Road

Geotechnical Investigation

Ottawa, Ontario

Figure C1



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5545 Boundary Road

Geotechnical Investigation

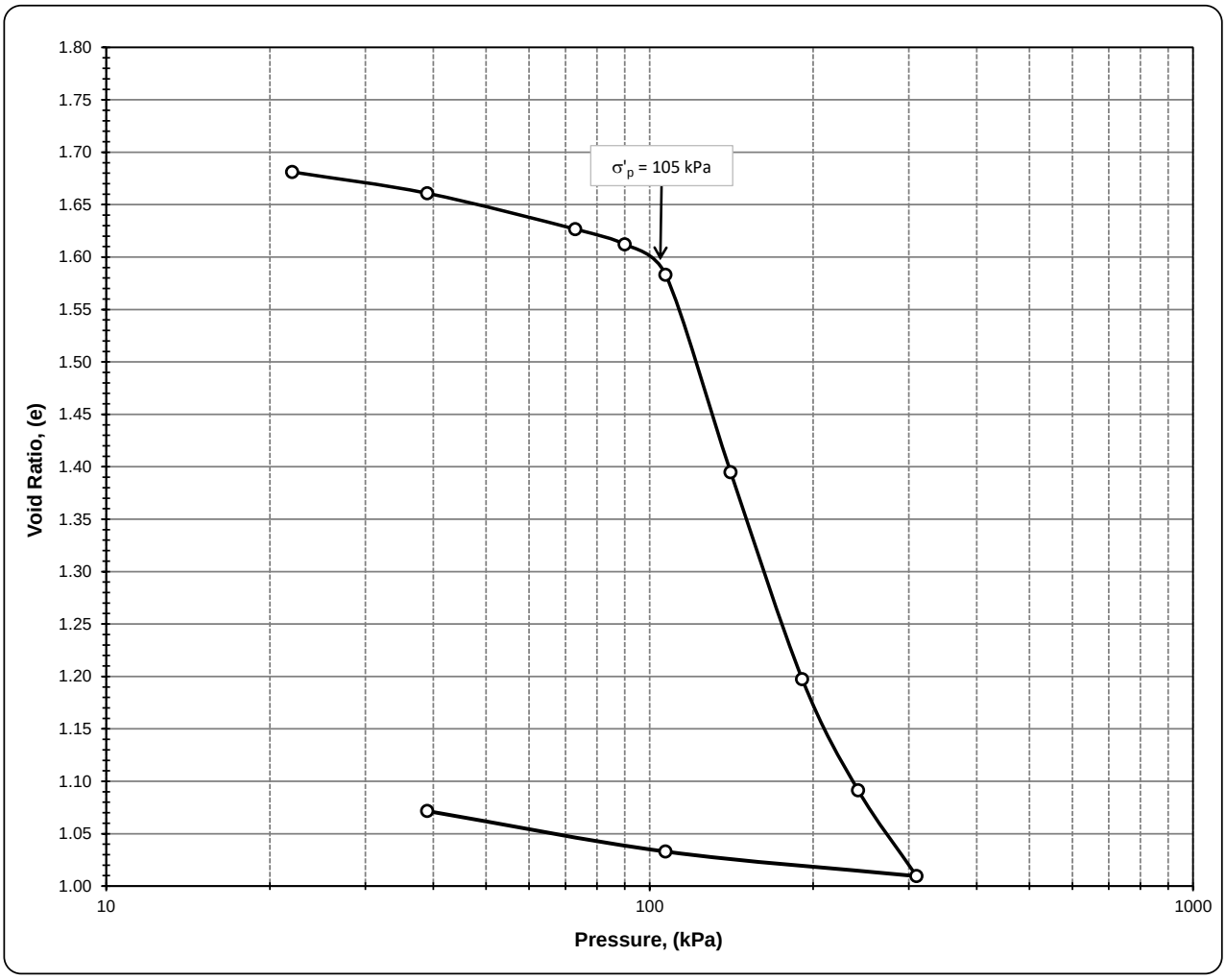
Ottawa, Ontario

Figure C2

APPENDIX D

Oedometer Testing

CONSOLIDATION ANALYSIS	FIGURE D1



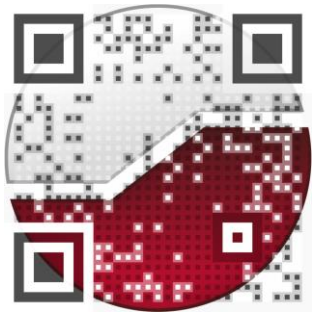
Borehole	Sample	Depth (m)
19-7	TW-2	25 to 27 feet

Determined Properties:			Test Results:		
W	70	percent	C_r	0.07	
			C_c	1.55	
e_o	1.72		σ'_p	105	kPa

GEMTEC
Consulting Engineers and Scientists

Date: Jan 2020
Project: 61774.48

experience • knowledge • integrity



civil	civil
geotechnical	géotechnique
environmental	environnementale
field services	surveillance de chantier
materials testing	service de laboratoire des matériaux

expérience • connaissance • intégrité