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City of Mission
c/o Urban Systems Ltd.
405 – 9900 King George Boulevard
Surrey, BC
V3T 0K9

August 22, 2023
File: 22933
R0

Attention: Ryan Li

Re: Geotechnical Investigation Report – Proposed Utility Infrastructure Upgrades Glasgow Avenue and Horne Street, Mission, BC

1.0 INTRODUCTION

We understand that the City of Mission intends to replace the existing water and sanitary infrastructure in the vicinity of the Glasgow Avenue and Horne Street intersection. Preliminary civil drawings provided by Urban Systems indicate utility upgrades at the intersection of Horne Street and Glasgow Avenue consisting of a 450 mm sanitary main and associated manholes installed up to 3.0 m below site grades, and a 350 mm diameter water main installed up to 2.6 m below site grades. We understand you require geotechnical recommendations for the proposed works including slope stability comments for temporary trenches and drainage swales, material re-use recommendations, lateral bearing capacity for thrust blocks, and minimum depth of cover for frost protection purposes.

This report presents the results of a geotechnical investigation of the soil and groundwater conditions in the immediate area of the project and provides recommendations for the proposed works described above. This report has been prepared exclusively for the City of Mission and Urban Systems Ltd. for their use, and the use of others on their design and construction team. We also understand this report will be relied upon by the City during their permitting process. This report remains the property of GeoPacific Consultants Ltd. and any unauthorized use, or duplication, of this report is prohibited.

2.0 SITE DESCRIPTION

The project is located along Horne Street, between Railway Avenue South and Harbour Avenue in Mission, BC. Adjacent lands are generally commercial and/or light industrial properties on the north and south sides of Horne Street. Highway 11 off/on-ramps and the Glasgow Avenue overpass also connect to Horne Street in the immediate area. Based on preliminary information from Urban Systems Ltd., the proposed utility upgrades are shown to span approximately 400 m along Horne Street.

The location of the site and surrounding improvements is shown on our Drawing No. 22933-01 following the text of this report.

3.0 SUBSURFACE CONDITIONS

On July 21, 2023 GeoPacific Consultants Ltd. completed a geotechnical investigation of the area using a truck drill supplied and operated by Southlands Drilling of Delta, BC. The site investigation consisted of four (4) solid stem auger test holes, one (1) Cone Penetration Test (CPT) sounding, one (1) Seismic Cone Penetration Test (SCPT), and two (2) Dynamic Cone Penetration Tests (DCPTs). The augered test holes and DCPTs were advanced to depths of 6.1 m below existing site grades, and the CPT/SCPT to depths of up to 25 m below existing site grades.

The CPT is an in-situ testing device which is pushed into the grounded employing a hydraulic ram on the drill rig. The cone penetrometer records measurements of tip resistance, sleeve resistance, dynamic pore water pressure, temperature, and inclination in 50 mm increments. Shear wave velocities can also be collected in 1 m intervals when required. The data obtained may be correlated to estimate engineering parameters such as shear strength, relative density, soil behaviour type, and consolidation coefficients. The stratigraphic interpretation was verified with the auger test hole as described above.

The test holes were located and logged by a geologist from our office and the test holes were backfilled immediately after logging, sampling, and testing. The location of the test holes are shown on the attached Drawings No. 22933-01. All depths shown in the logs are referenced from ground surface at the locations of the test holes at the time of drilling.

4.0 SUBSURFACE CONDITIONS

4.1 Soil Conditions

The surficial geology map prepared by the Geological Survey of Canada, covering the City of Mission (Mission, Map 1485A), describes the general geology of the region as Fraser River sediments that are underlain by dense Vashon (glacial) and pre-Vashon deposits. The Fraser River sediments are recent post-glacial deposits and increase in thickness to the southeast of the site. The Fraser River sediments in the vicinity of the south end of the City of Mission are typically comprised of overbank silts over channel deposits of fine to medium grained sand with silt layers, underlain by a deep deposit of marine clay silt interbedded with fine sands over dense to very dense and pre-glacial deposits.

In general, the soil conditions encountered at the location of our test holes were consistent with those described on the surficial geology map. The soil profile generally consisted of *asphalt*, overlying compact *silty sand and gravel fills,* overlying lenses of soft organic *silt*, overlying loose to compact *silty sand* extending to the depth of our investigation.

A general description of the soils encountered at the site during our investigation is provided below:

ASPHALT

The ground surface was surfaced with asphalt at all test hole locations, ranging in thickness between 127 and 381 mm.

SILTY SAND AND GRAVEL (FILL)

Silty sand and gravel fills were present underlying the asphalt surface at all test hole locations, ranging in thickness between 0.3 m and 0.7 m. The fill is compact, dry to moist, contains fine to medium grained sand, gravels up to 60 mm in size, and is brown to grey. Moisture content levels vary between 3.7% to 7.7% based on laboratory testing.

SILT

Very soft to firm silt was noted at test hole locations TH23-03 and TH23-04. This stratum varied in thickness from 0.3 m at test hole location TH23-03 and 2.7 m at location TH23-04. The silt contains trace organics with pockets of organic silt and is grey to brown/black. Moisture content levels vary between 23.3% and 136.1% based on laboratory testing.

SILTY SAND to GRAVELLY SAND

Silty sand was observed to underly the silty sand and gravel fills at test hole locations TH23-01, TH23-02, and TH23-03, with gravelly sand noted at a depth of 4.3 m at location TH23-04. This stratum is loose to compact, dry to moist, contains fine to coarse grained sand, gravel sizes up to 30 mm in size, and is grey in colour. Moisture content levels vary between 8.9% and 38.5% based on laboratory testing.

Detailed test hole logs are attached following the text of this report. Bedrock was not encountered to the depths of our investigation.

4.2 Groundwater Conditions

The groundwater level was noted to be at a depth of 5.2 to 5.8 m below site grades, based on our observations during drilling and on CPT dissipation test results. Based on our experience in the area, groundwater levels are directly influenced with Fraser River tidal changes close to the river, becoming less sensitive to tidal changes further away from the river. We also anticipate levels will fluctuate seasonally, with generally higher levels during the wetter months of the year.

5.0 DISCUSSION

5.1 General Comments

Based on preliminary civil drawings provided by Urban Systems, the sanitary main will be installed to depths of approximately 2 m, with manholes extending up to 3 m below site grades. Water main installation depths are also expected to be approximately 2 m, with a deeper section at station 40+130 extending to approximately 3 m below existing site grades. Our test holes indicated the presence soft to firm with trace organics and pockets of organic silt at test holes TH23-03 and TH23-04, extending to depths of 3.8 m below site grades at test hole location TH23-04. This silt stratum was not encountered at test hole location TH23-02, suggesting the noted organic silt may be localized to locations TH23-03 and TH23-04.

The silt varied in moisture content between 23.3% and 136.1% based on laboratory testing, indicating the silt is moderately to highly compressible. Therefore, grade increases and use of denser backfill materials should be avoided. Furthermore, settlements associated with the gradual and ongoing decay of the organic material over time are unavoidable.

5.2 Seismic Analysis

It is generally accepted that loose to compact and saturated non plastic silts and sands are prone to liquefaction or strain softening during cyclic loading caused by large earthquakes. Based on our analysis, the saturated silty sands to gravelly sand would be prone to liquefaction based on the BCBC 2018 design earthquake. Liquefaction may result in settlement and displacement of the road and utilities of up to 55 mm, based on our analysis presented in Appendix D, though we do not anticipate the proposed infrastructure are intended for post-disaster purposes.

6.0 RECOMMENDATIONS

6.1 Site Preparation & Backfill Materials

Prior to fill placement and/or construction, all topsoil, organic soils, refuge, vegetation, loose or disturbed soils, or other deleterious materials should be removed from the construction area. Where very soft to firm silt is encountered within the trench excavation, we recommend 0.6 m of over-excavation be completed prior to placement of pipe-bedding material. Separation between the soft silt and backfill material should be completed with non-woven filter fabric (Nilex 4545 or approved alternative). Where compact mineral fills are encountered, no over-excavation is required.

General grade reinstatement can be completed using *engineered fill*. In the context of this report, engineered fill is defined as clean sand to sand and gravel, with less than 5% by weight passing the 75 µm sieve, compacted to a minimum of 95% Modified Proctor Dry Density (ASTM D1557), in loose lifts not exceeding 300 mm in thickness. These materials should conform to the latest MMCD and/or City of Mission specifications.

GeoPacific should be contacted to review compaction of any placed fill materials prior to placement of subsequent lifts.

6.2 Trench Excavations

In accordance with WorkSafe BC regulations, any excavations in excess of 1.2 m must be shored or excavated under the advice and supervision of a professional geotechnical engineer. Based on provided civil information, excavation depths of approximately 3 m are expected. We expect conventional, pre-fabricated WCB approved shoring cages may be used for the majority of the alignment for shoring purposes to facilitate the construction of the sanitary sewer.

The presence of nearby utilities, vaults, and/or other infrastructure should also be taken into consideration prior to construction. Should the alignment be in close proximity to such infrastructure, additional shoring measures may need to be employed. Support measures for possible utility crossings may also be required.

6.3 Dewatering

As noted above, the static groundwater table was encountered at depths of 5.2 to 5.8 m below ground surface. Based on the proposed pipe installation depths, excavations are expected to be above the groundwater level. We expect that seepage, if encountered, will be light to moderate and can be controlled using conventional sumps and sump pumps.

6.4 Pipe & Manhole Settlement

As mentioned, organic soils are prone to long term settlements associated with the gradual and ongoing decay of the organic material over time. Post-construction settlement estimates are variable and difficult to predict, however, we expect less than 25 mm over a 25-year period, depending on the amount of organic matter within the soft silt lenses.

Based on our experience, minor differential pipe settlements can typically be tolerated with the use of flexible connections and steeper gradients, where feasible. Alternatively, the very soft organic silt can be removed from the trench excavation entirely to prevent impacts from long term settlements caused by decomposition of organic materials. We recommend all soft, organic silt material beneath manholes be removed from the excavation.

6.5 Corrosion Potential

Soil corrosion potential is derived from the intrinsic properties of the soils that are in contact with buried utilities. In order to determine these properties, soil samples must be collected from the proposed pipe depth. Based on discussions with Urban Systems Ltd., samples were obtained at approximately 2 m depth below site grades.

Upon retrieval, samples were transported to our lab and tested according to AWWA/ANSI C105/A21.5-05 Standard – Appendix A for Western Canada. This system involves a series of tests, including saturated resistivity, pH, oxidation-reduction potential, sulfide content, moisture content and soil characterization (sieve analysis), whose results are assigned a point value based on their experimentally observed contribution to corrosion potential (See Table A.1). The points are summed to produce an overall corrosion potential for the soil. AWWA/ANSI C105/A21.5-05 – Appendix A recommends that protections be employed to ductile-iron pipe or fittings when the total corrosion potential is +10 or greater. The results of our corrosion potential analysis are summarized below.

Table 1 - Soil Corrosion Potential (AWWA C105 - Appendix A)

Sample ID	Depth (m)	Corrosivity Index	Corrosion Potential
TH23-01	0 – 1.8	4.5	Low
TH23-02	1.5 – 1.8	14.0	Corrosive
TH23-03	0 – 1.8	12.5	Corrosive
TH23-04	1.5 – 1.8	10.5	Corrosive

The tested samples returned corrosivity indices of greater than +10 at test hole locations TH23-02 through TH23-04. As these indices are above recommended value of +10 as outlined in AWWA/ANSI C105/A21.5-05 – Appendix A, we recommend corrosion protections measures be implemented for the construction of ductile-iron pipe and/or fittings.

6.6 Lateral Bearing Capacity

We understand lateral bearing capacity is required for the design of thrust blocks. We have assumed that the pipe surround material will consist of competent granular fills (sands to sand and gravels) and will extend a minimum of 0.3 m around the perimeter of thrust blocks. We recommend a lateral passive pressure of $23H$ kPa be used for the design of thrust blocks, where H is the height of the thrust block in metres.

6.7 Pavement Restoration

We recommend asphalt, base, and subbase thickness conform to the City of Mission's minimum thicknesses, provided our recommendations in Section 6.1 of this report are followed.

Granular base material shall consist of 19 mm minus crushed gravel, free from any organics, foreign matter, or deleterious substances. The gravel shall be durable, uniform in quality, and 100% of the gravel shall have at least one fractured face. The aggregate shall conform to the gradation curve given in MMCD Platinum Edition Section 31 05 17 2.10.1 Granular Base and shall have a minimum soaked CBR (ASTM D1883) of 80 at 95% Modified Proctor Dry Density (MPDD).

Granular subbase material shall consist of 75 mm minus crushed gravel, free from any organics, foreign matter, or deleterious substances. The gravel shall be durable, uniform in quality, and 100% of the gravel shall have at least one fractured face. The aggregate shall conform to the gradation curve given in MMCD Platinum Edition

Section 31 05 17 2.9 Crushed Granular Sub-base and shall have a minimum soaked CBR (ASTM D1883) of 20 at 95% MPDD.

The contractor shall supply GeoPacific with a sample of the proposed base and subbase materials at least 14 days in advance of the work for sieve, modified proctor, and CBR testing to confirm the material properties outlined above are satisfied. The material shall be placed in loose lifts no greater than 300 mm and compacted to not less than 95% MPDD (ASTM D1557). Density testing shall be conducted on each lift placed to confirm adequate compaction levels have been achieved. GeoPacific to also review the subgrade conditions prior to further placement and compaction of backfill materials.

6.8 Temporary & Permanent Cut Slopes or Excavations

Excavations greater than 1.2 m in depth should be reviewed by a Professional Engineer in accordance with WorkSafe BC regulations, prior to worker entry. Due to the expected excavation depths, we expect typical WorkSafe BC approved shoring cages will be used during trench construction, as noted above in Section 6.2. We envision sloping the trench excavation walls will not be feasible due to the proximity of other infrastructure in the area. However, if required, temporary sloped excavations are likely feasible within the fills, silt and silty sand at a maximum slope of 1H:1V above the water table.

Permanent slopes, such as within ditches or road shoulders, should be limited to a maximum of 2H:1V and be vegetated or otherwise protected from erosion.

6.9 Frost Protection

We recommend utilities be constructed a minimum of 460 mm below final grades for frost protection.

7.0 FIELD REVIEWS

The preceding sections make recommendations for the design and construction of the utility upgrades at Horne Street and Glasgow Avenue in Mission, BC. We have recommended the review of certain aspects of the design and construction. It is important that these reviews are carried out to ensure that our intentions have been adequately communicated. It is also important that any contractors working on the site review this document prior to commencing their work.

It is the contractors' responsibility to advise GeoPacific Consultants Ltd. a minimum of 48 hours in advance that a field review is required. Geotechnical field reviews are normally required at the time of the following:

1. Site Stripping	Review of site stripping
2. Subgrade	Review of subgrade conditions prior to further pavement structure fills
3. Excavation	Review of excavations greater than 1.2 m in height
4. Backfill	Review of placement and compaction of backfill materials
5. Temporary Slopes	Review of temporary cut slopes and soil conditions
6. Paving	Review of asphalt compaction and sampling for Marshall/Superpave testing

8.0 CLOSURE

This report has been prepared exclusively for our client for the purpose of providing geotechnical recommendations for the design and construction of the proposed utility infrastructure upgrades. The report remains the property of GeoPacific Consultants Ltd. and unauthorized use, or duplication, of this report is prohibited.

We are pleased to be of assistance to you on this project and we trust that our comments and recommendations are both helpful and sufficient for your current purposes. If you have any questions or require clarification of the above, please do not hesitate to contact the undersigned.

For:
GeoPacific Consultants Ltd.

Reviewed by:

P.M. MARTZ
52736
2023-08-25
Permit to Practice 1000782

Jakub Szary, B.Sc., AScT
Lab Manager

Patrick Martz, B.A.Sc., P.Eng.
Geotechnical Engineer

SITE PLAN

*TEST LOCATIONS ARE APPROXIMATE

LEGEND:

- ⊕ SCPT#-# – SEISMIC CONE PENETRATION TEST (SCPT) LOCATION
- ⊕ DPT#-# – DYNAMIC CONE PENETRATION TEST (DCPT) LOCATION
- △ TH#-# – TEST HOLE (TH) LOCATION

REFERENCE:
GOOGLE MAPS

GEOPACIFIC
VANCOUVER KAMLOOPS CALGARY
1779 West 75th Ave.
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DATE: 2023-07-21		
DRAWN BY: TL	APPROVED BY:	REVIEWED BY:
SCALE: NO SCALE		

PROPOSED UTILITY UPGRADES
HORNE ST AND GLASGOW AVE, MISSION, BC
TEST HOLE SITE PLAN

FILE NO.: 22933
DWG. NO.: 22933 - 01

REVISIONS:
A.
B.
C.

ORIGINAL PAPER SIZE 8.5"x11"

APPENDIX A - TEST HOLE LOGS

Test Hole Log: TH23-01

File: 22933

Project: PROPOSED UTILITY UPGRADES

Client: CITY OF MISSION

Site Location: HORNE ST AND GLASGOW AVE, MISSION, BC

GEOPACIFIC
CONSULTANTS
1779 West 75th Avenue, Vancouver, BC, V6P 6P2
Tel: 604-439-0922 Fax:604-439-9189

INFERRED PROFILE

Depth (m)/Elev (m)	SOIL DESCRIPTION	Moisture Content (%)	DCPT (blows per foot) 20 40 60 80	Groundwater / Well	Remarks
	Ground Surface				
0.0	**ASPHALT**				Asphalt thickness ~127mm
	SILTY SAND AND GRAVAEL (FILL) Brown to grey, compact, SILTY SAND AND GRAVEL (FILL); moist, fine to medium grained sand, gravels up to 40mm in size				
0.6	**SILTY SAND** Brown to grey, loose to compact, SILTY SAND; moist, medium to coarse grained sand	8.9% 18.7%			Water table encountered at ~5.5m
6.1	End of Borehole				

Logged: TL
Method: SOLID STEM AUGER
Date: JULY 21, 2023

Datum: GROUND ELEVATION
Figure Number: A.O1
Page: 1 of 1

Test Hole Log: TH23-02

File: 22933

Project: PROPOSED UTILITY UPGRADES

Client: CITY OF MISSION

Site Location: HORNE ST AND GLASGOW AVE, MISSION, BC

GEOPACIFIC
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Tel: 604-439-0922 Fax:604-439-9189

INFERRED PROFILE

Depth (ft / m)	Symbol	SOIL DESCRIPTION	Depth (m)/Elev (m)	Moisture Content (%)	DCPT (blows per foot) 20 40 60 80	Groundwater / Well	Remarks
0 / 0		Ground Surface					
0 / 0		***ASPHALT***	0.0				Asphalt thickness ~152mm
1		***SILTY SAND AND GRAVAEL (FILL)*** Brown to grey, compact, SILTY SAND AND GRAVEL (FILL); moist, fine to medium grained sand, gravels up to 40mm in size, trace wood fragments		7.7%			
2		***SILTY SAND*** Brown to grey, loose to compact, SILTY SAND; moist, fine to medium grained sand	0.6	28.2% 28.5% 33.0%			Water tabele encountered at ~5.8m
20 / 6.1		End of Borehole	6.1				

Depth scale: ft 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22; m 0 1 2 3 4 5 6

Logged: TL

Method: SOLID STEM AUGER

Date: JULY 21, 2023

Datum: GROUND ELEVATION

Figure Number: A.02

Page: 1 of 1

Test Hole Log: TH23-03

File: 22933

Project: PROPOSED UTILITY UPGRADES

Client: CITY OF MISSION

Site Location: HORNE ST AND GLASGOW AVE, MISSION, BC

GEOPACIFIC CONSULTANTS

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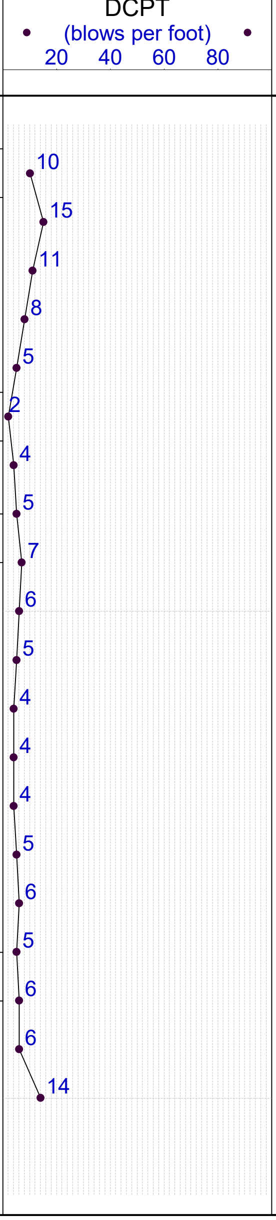
Tel: 604-439-0922 Fax:604-439-9189

INFERRED PROFILE

Depth (m)/Elev (m)	SOIL DESCRIPTION	Moisture Content (%)	Remarks
	Ground Surface		
0.0	**ASPHALT**		Asphalt thickness ~203mm
	SILTY SAND AND GRAVAEL (FILL) Brown to grey, compact, SILTY SAND AND GRAVEL (FILL); dry, medium to coarse grained sand, gravels up to 60mm in size	3.7%	
0.5	**SILTY SAND** Grey, loose to compact, SILTY SAND; dry, medium to coarse grained sand, trace gravels up to 20mm in size, trace wood fragments		
1.7	**SILT** Dark brown to grey, very soft to soft, SILT; moist, trace fine grained sand, trace to some organics	23.3%	
2.0	**SILTY SAND** Grey, loose to compact, SILTY SAND; moist, fine to medium grained sand	13.5% 33.2%	Water table encountered at ~5.0m
6.1	End of Borehole		



Logged: TL
Method: SOLID STEM AUGER
Date: JULY 21, 2023

Datum: GROUND ELEVATION
Figure Number: A.O3
Page: 1 of 1

Test Hole Log: TH23-04

File: 22933

Project: PROPOSED UTILITY UPGRADES

Client: CITY OF MISSION

Site Location: HORNE ST AND GLASGOW AVE, MISSION, BC

GEOPACIFIC
CONSULTANTS

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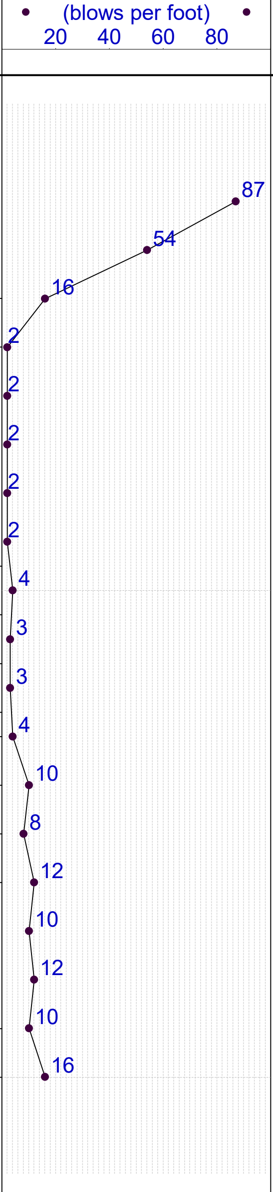
INFERRED PROFILE

Depth (m)/Elev (m)	SOIL DESCRIPTION	Remarks
	Ground Surface	
0.0	***ASPHALT***	Asphalt thickness ~381mm
0.4	***SILTY SAND AND GRAVAEL (FILL)*** Brown to grey, compact, SILTY SAND AND GRAVEL (FILL); dry, medium to coarse grained sand, gravels up to 60mm in size	
1.1	***SILT*** Black to grey, very soft to soft, SILT; wet, trace fine grained sand, variable organic content ranging from trace to significant	
3.8	***SILT AND SAND*** Grey, loose, SILT AND SAND; wet, fine to medium grained sand, trace wood fragments	
4.3	***GRAVELLY SAND*** Grey, loose to compact, GRAVELLY SAND; moist, medium to coarse grained sand, gravels up to 30mm in size, trace silt	Water table encountered at ~5.2m
6.1	End of Borehole	

Depth (ft)	Moisture Content (%)
4–5	69.9%
9.5–10.5	136.1%
11.5–12.5	43.1%
13–14	38.5%
15–16	22.7%
19–20	29.6%

DCPT (blows per foot)



Groundwater / Well

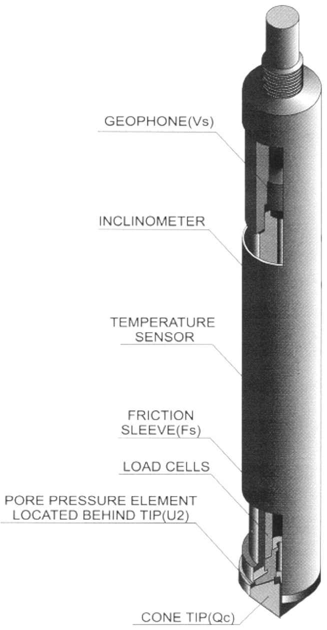
Logged: TL
Method: SOLID STEM AUGER
Date: JULY 21, 2023

Datum: GROUND ELEVATION
Figure Number: A.O4
Page: 1 of 1

APPENDIX B - ELECTRONIC CONE PENETRATION RESULTS

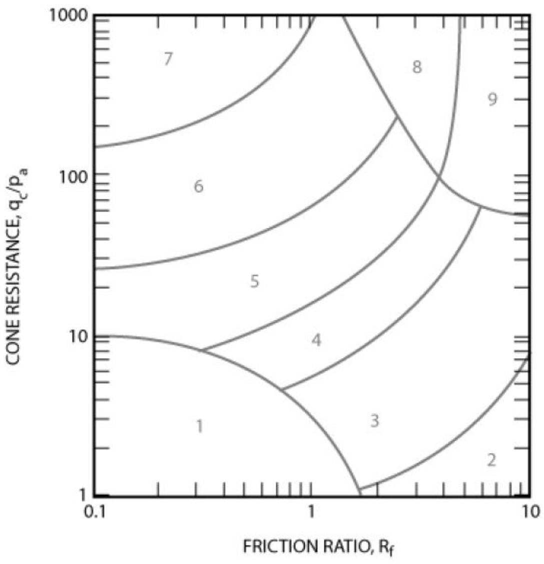
The system used is owned and operated by GeoPacific and employs a 35.7 mm diameter cone that records tip resistance, sleeve friction, dynamic pore pressure, inclination and temperature at 5 cm intervals on a digital computer system. The system is a Hogentogler electronic cone system and the cone used was a 10 ton cone with pore pressure element located behind the tip and in front of the sleeve as shown on the adjacent figure.

Electronic Cone Penetrometer



In addition to the capabilities described above, the cone can be stopped at specified depths and dissipation tests carried out. These dissipation tests can be used to determine the groundwater pressures at the specified depth. This is very useful for identifying artesian pressures within specific layers below the ground surface.

Interpretation of the cone penetration test results are carried out by computer using the interpretation chart presented below by Robertson[1]. Raw data collected by the field computer includes tip resistance, sleeve friction and pore pressure. The tip resistance is corrected for water pressure and the friction ratio is calculated as the ratio of the sleeve friction on the side of the cone to the corrected tip resistance expressed as a percent. These two parameters are used to determine the soil behaviour type as shown in the chart below. The interpreted soil type may be different from other classification systems such as the Unified Soil Classification that is based upon grain size and plasticity.



Zone	*Soil Behavior Type*
1	*Sensitive, fine grained*
2	*Organic soils - clay*
3	*Clay – silty clay to clay*
4	*Silt mixtures – clayey silt to silty clay*
5	*Sand mixtures – silty sand to sandy silt*
6	*Sands – clean sand to silty sand*
7	*Gravelly sand to dense sand*
8	*Very stiff sand to clayey sand**
9	*Very stiff fine grained**

** Heavily overconsolidated or cemented*

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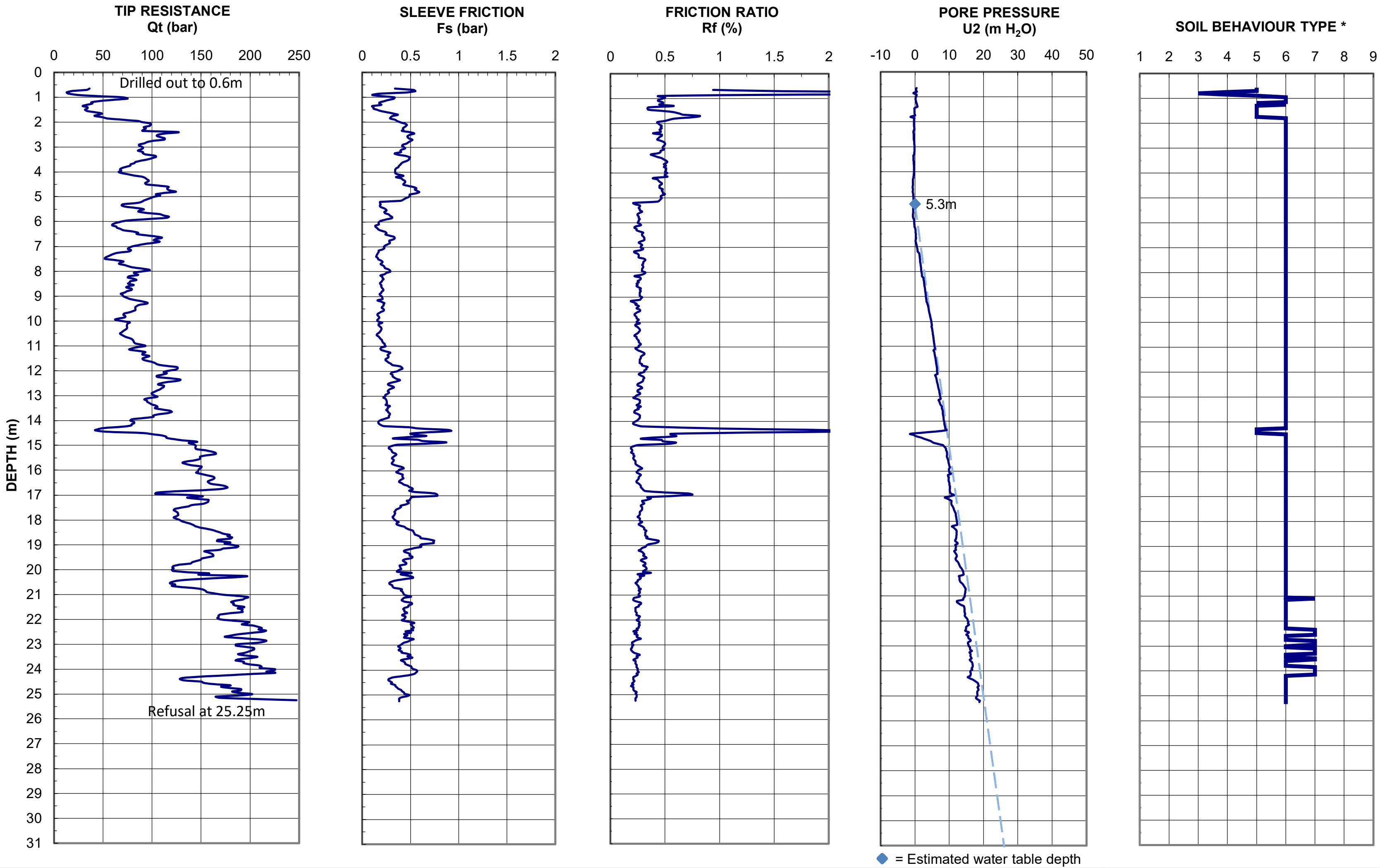
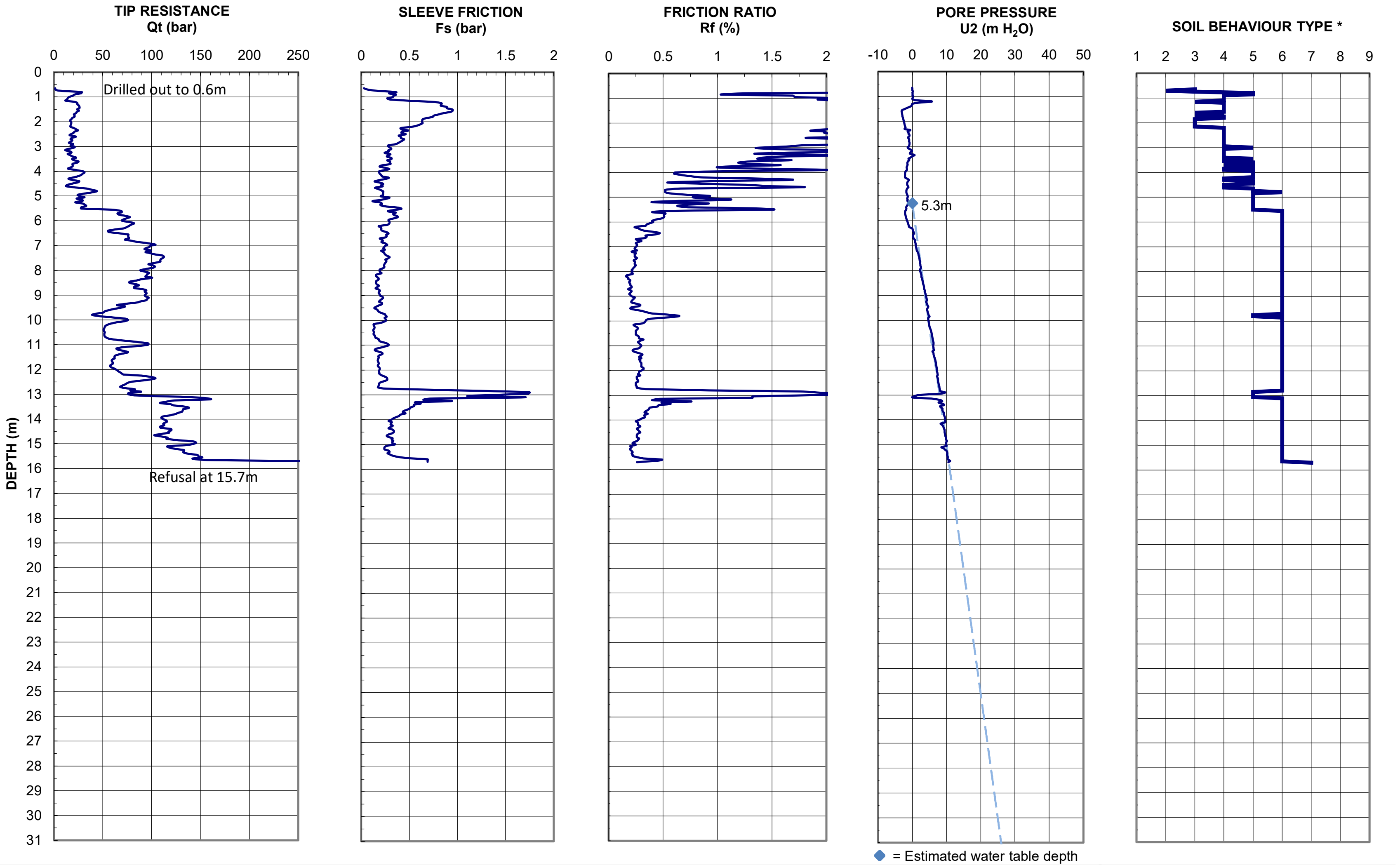
[1] Robertson, P.K., 2010, "Soil behaviour type from the CPT: an update.", 2nd *International Symposium on Cone Penetration Testing,* CPT'10, Huntington Beach, CA, USA.

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	**2023-Jul-21**	**URBAN SYSTEMS**	**GeoPacific Project #: 22933**
	Sounding: CPT23-01	**HORNE STREET AND GLASGOW AVENUE, MISSION**	**Figure: B.01**



1: Sensitive, Fine Grained	4: Silt Mixtures - Clayey Silt to Silty Clay	7: Gravelly Sand to Dense Sand	* Based on Robertson, 2010
2: Organic Soils - Clay	5: Sand Mixtures - Silty Sand to Sandy Silt	8: Very Stiff Sand to Clayey Sand**	
3: Clay - Silty Clay to Clay	6: Sands - Clean Sand to Silty Sand	9: Very Stiff Fine Grained**	** Heavily overconsolidated or cemented

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2023-Jul-21	URBAN SYSTEMS	GeoPacific Project #: 22933
	Sounding: CPT23-02	HORNE STREET AND GLASGOW AVENUE, MISSION	Figure: B.02



1: Sensitive, Fine Grained
2: Organic Soils - Clay
3: Clay - Silty Clay to Clay

4: Silt Mixtures - Clayey Silt to Silty Clay
5: Sand Mixtures - Silty Sand to Sandy Silt
6: Sands - Clean Sand to Silty Sand

7: Gravelly Sand to Dense Sand
8: Very Stiff Sand to Clayey Sand**
9: Very Stiff Fine Grained**

* Based on Robertson, 2010

** Heavily overconsolidated or cemented

APPENDIX C - OVER CONSOLIDATION RATIO ANALYSIS

The over consolidation ratio (OCR) is defined as the ratio between the maximum past vertical pressure on the soil versus the current in-situ vertical pressure. The maximum past vertical pressure is typically caused by the presence of excess overburden which is removed by either natural or man-made reasons. Soil ageing and other chemical precipitation affects can also cause a soil to behave as if it has a higher maximum past pressure, which is sometimes described as pseudo-overconsolidation.

Research by Schmertmann (1974) showed the following equation reasonably approximates the OCR of medium plastic to clayey soils:

$$OCR = \left(\frac{\left(\frac{Su / p'oc}{Su / p'nc} \right)^{5/3} + 0.82}{1.82} \right)$$

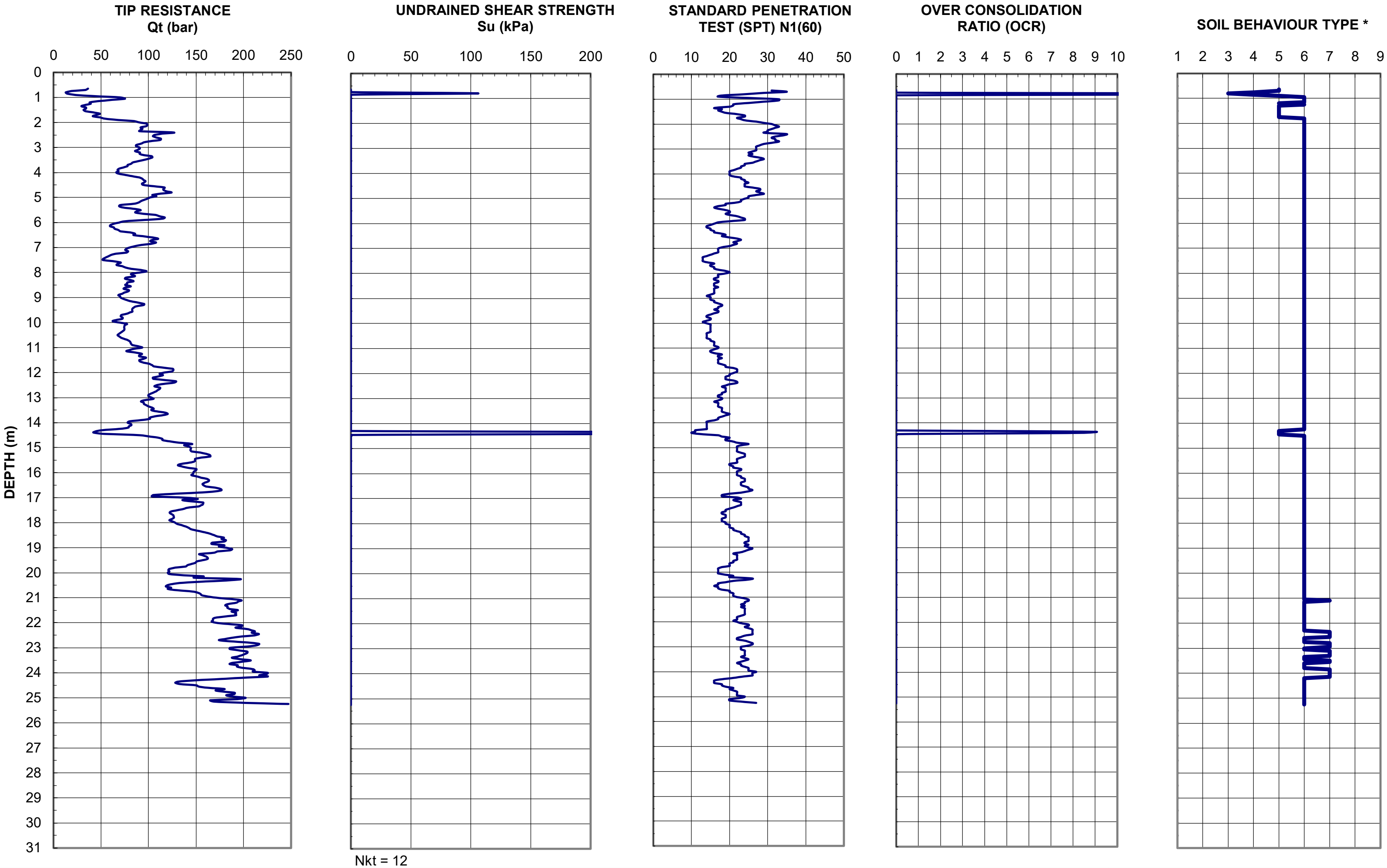
Su/p’oc = The undrained shear strength to effective stress ratio of the over consolidated soil

Su/p’nc = The undrained shear strength to effective stress ratio of a normally consolidated soil (OCR = 1). Typically = ~0.2

Soils which are subject to loads less than the maximum past pressure of the soil are typically subject to relatively small elastic settlements. Loads which exceed the maximum past pressure on the soil typically cause consolidation which is the gradual settlement of the ground as a result of expulsion of water from the pores of the soil. The rate of settlement and the time to complete consolidation is a function of the permeability of the soil.

The Schmertman equation has been employed to estimate the OCR of the soils with depth employing the CPT data provided in Appendix B and C.

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2023-Jul-21	URBAN SYSTEMS	GeoPacific Project #: 22933
	Sounding: CPT23-01	HORNE STREET AND GLASGOW AVENUE, MISSION	Figure: C.01

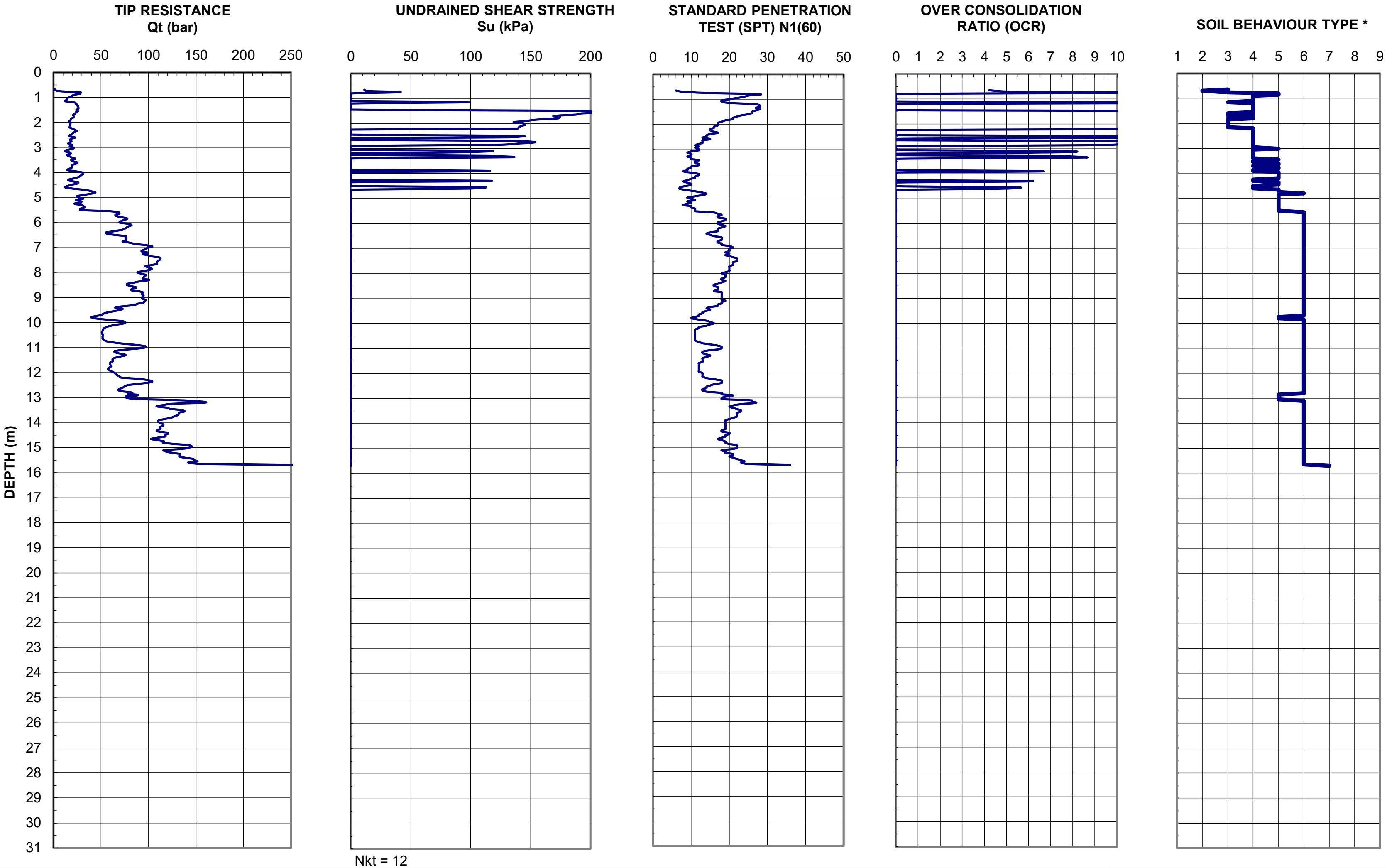


1: Sensitive, Fine Grained
2: Organic Soils - Clay
3: Clay - Silty Clay to Clay
4: Silt Mixtures - Clayey Silt to Silty Clay
5: Sand Mixtures - Silty Sand to Sandy Silt
6: Sands - Clean Sand to Silty Sand
7: Gravelly Sand to Dense Sand
8: Very Stiff Sand to Clayey Sand**
9: Very Stiff Fine Grained**

* Based on Robertson, 2010

** Heavily overconsolidated or cemented

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2023-Jul-21	URBAN SYSTEMS	GeoPacific Project #: 22933
	Sounding: CPT23-02	HORNE STREET AND GLASGOW AVENUE, MISSION	Figure: C.02



1: Sensitive, Fine Grained
2: Organic Soils - Clay
3: Clay - Silty Clay to Clay

4: Silt Mixtures - Clayey Silt to Silty Clay
5: Sand Mixtures - Silty Sand to Sandy Silt
6: Sands - Clean Sand to Silty Sand

7: Gravelly Sand to Dense Sand
8: Very Stiff Sand to Clayey Sand**
9: Very Stiff Fine Grained**

* Based on Robertson, 2010

** Heavily overconsolidated or cemented

APPENDIX D - LIQUEFACTION ANALYSIS

Assessment of the liquefaction potential of the ground has been determined by the Seismic Cone Penetration Test (SCPT). The method of analysis is presented in the following sections.

FACTOR OF SAFETY AGAINST LIQUEFACTION

The factor of safety against liquefaction calculated here is the ratio of the cyclic resistance of the soil (CRR) to the cyclic stresses induced by the design earthquake (CSR). Where the ratio of CRR/CSR is greater than unity the soils ability to resist cyclic stresses is greater than the cyclic stresses induced by the earthquake and liquefaction will be unlikely. Where the CRR/CSR is less than unity then liquefaction could occur. This ratio is presented as the FOS against Liquefaction on the following charts. Calculation of the factor of safety is based on NCEER (1998)1 which evaluates the CRR directly from cone penetration test sounding data. The value of the cyclic stress ratio has been calculated based on peak horizontal ground acceleration of the 2015 National Building Code interpolated seismic hazard value.

SEISMIC INDUCED SETTLEMENT

In the event of a significant earthquake, settlement of the ground surface could occur as a result of densification of the looser soil layers as a result of liquefaction or due to the expulsion of sand in the form of sand dykes or sills from beneath the site. Tokimatsu and Seed (1987)[3] suggest a method of analysis for estimating vertical settlements as a result of earthquake induced accelerations. In this method the normalized standard penetration blow counts ($N_{1(60)}$) is compared with the cyclic stress ratio for the induced earthquake to determine the volumetric strain resulting from the earthquake shaking. The volumetric strain is assumed to result in only vertical settlement. The vertical settlement is summed for each depth at which settlement is predicted to occur and accumulated from the bottom of the test hole. The results are presented on the following charts labeled as Settlement.

HORIZONTAL DISPLACEMENT

Horizontal ground displacements known as "free field" displacements occur as a result of liquefaction of the ground and are assumed to occur without the influence of any structures. The horizontal displacements presented in our report are generally based upon the lateral spread method by of Youd, Bartlett, & Hansen (2002)[4]. Displacements are calculated based on an empirical relationship developed from observations from other earthquake sites on sloping ground or near a free face, such as an abrupt slope. The presence of the proposed embankment on-site is expected to induce a static bias within the soils at the margin of the embankment making the soils and embankment in this area subject to lateral spread induced movements. In the event of a real earthquake of significant magnitude to cause limited liquefaction, actual movements will be influenced by a wide variety of factors including the characteristics of the earthquake including duration, number of significant cycles, variations in peak particle velocity, wavelength, amplitude and frequencies as well as soil damping and variations in density and continuity of the soil layers.

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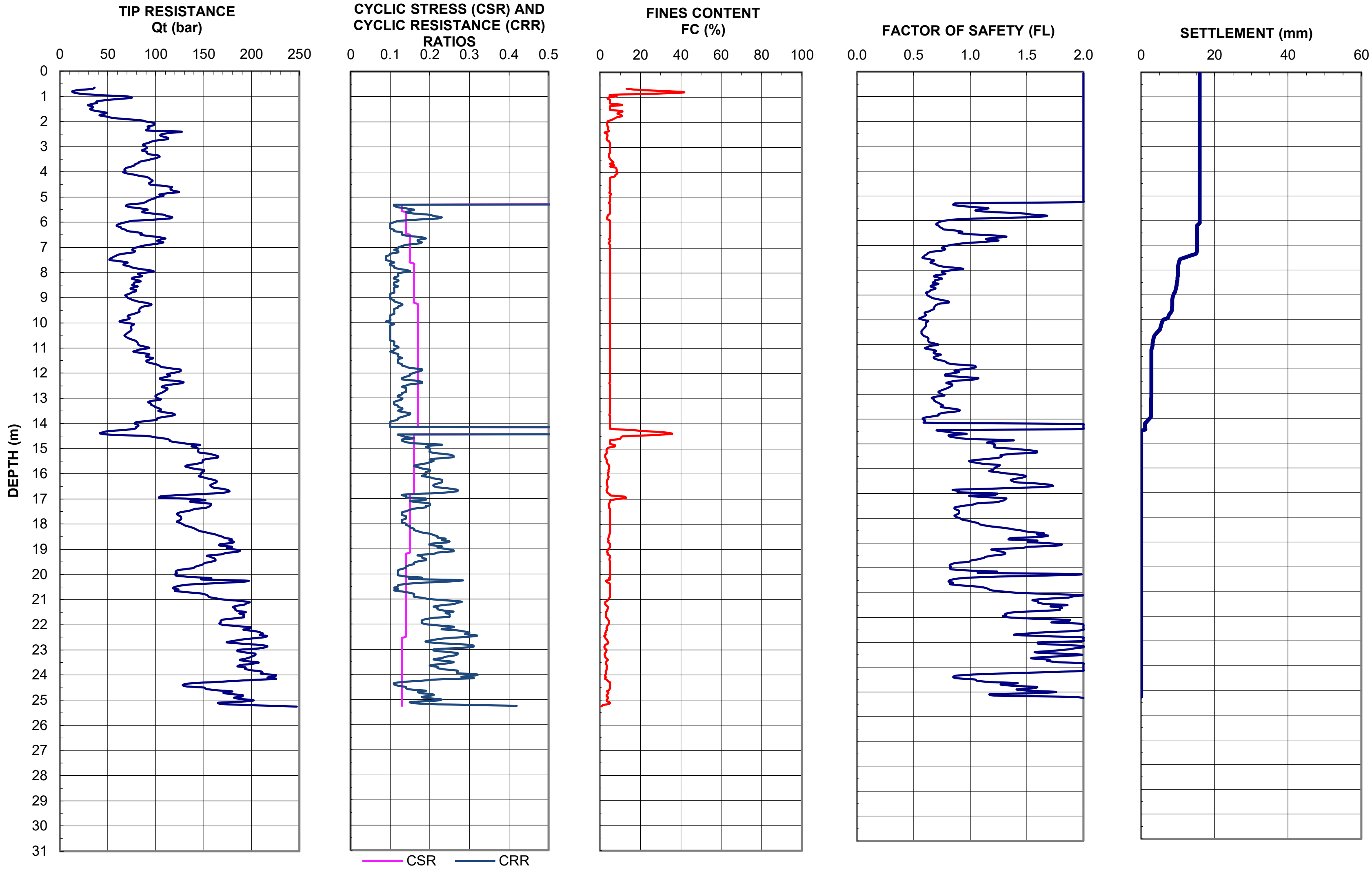
1 Youd, T.L., Idriss, I.M. (2001) "Liquefaction Resistance of Soils: Summary Report from the 1996 and 1998 NCEER/NSF Workshop on Evaluation of Liquefaction Resistance of Soils", Journal of Geotechnical & Geoenvironmental Engineering, Vol. 127, 10, pp 817-833

2 Tokimatsu, K.A.M. and Seed, H.B., 1987. "Evaluation of Settlement in Sands Due to Earthquake Shaking", Journal of Geotechnical Engineering, ASCE, Vol. 113, No. 8, pp. 861-878.

3 Youd, T.L., Bartlett, S.F., Hansen, C.M. (2002), "Revised MultiLinear Regression Equations for Prediction of Lateral Spread Displacements", Journal of Geotechnical and GeoEnvironmental Engineering, Vol. 128, No. 12, pp. 1007-1017.

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	**2023-Jul-21**	**URBAN SYSTEMS**	**GeoPacific Project #: 22933**
	Sounding: CPT23-01	**HORNE STREET AND GLASGOW AVENUE, MISSION**	**Figure: D.01**



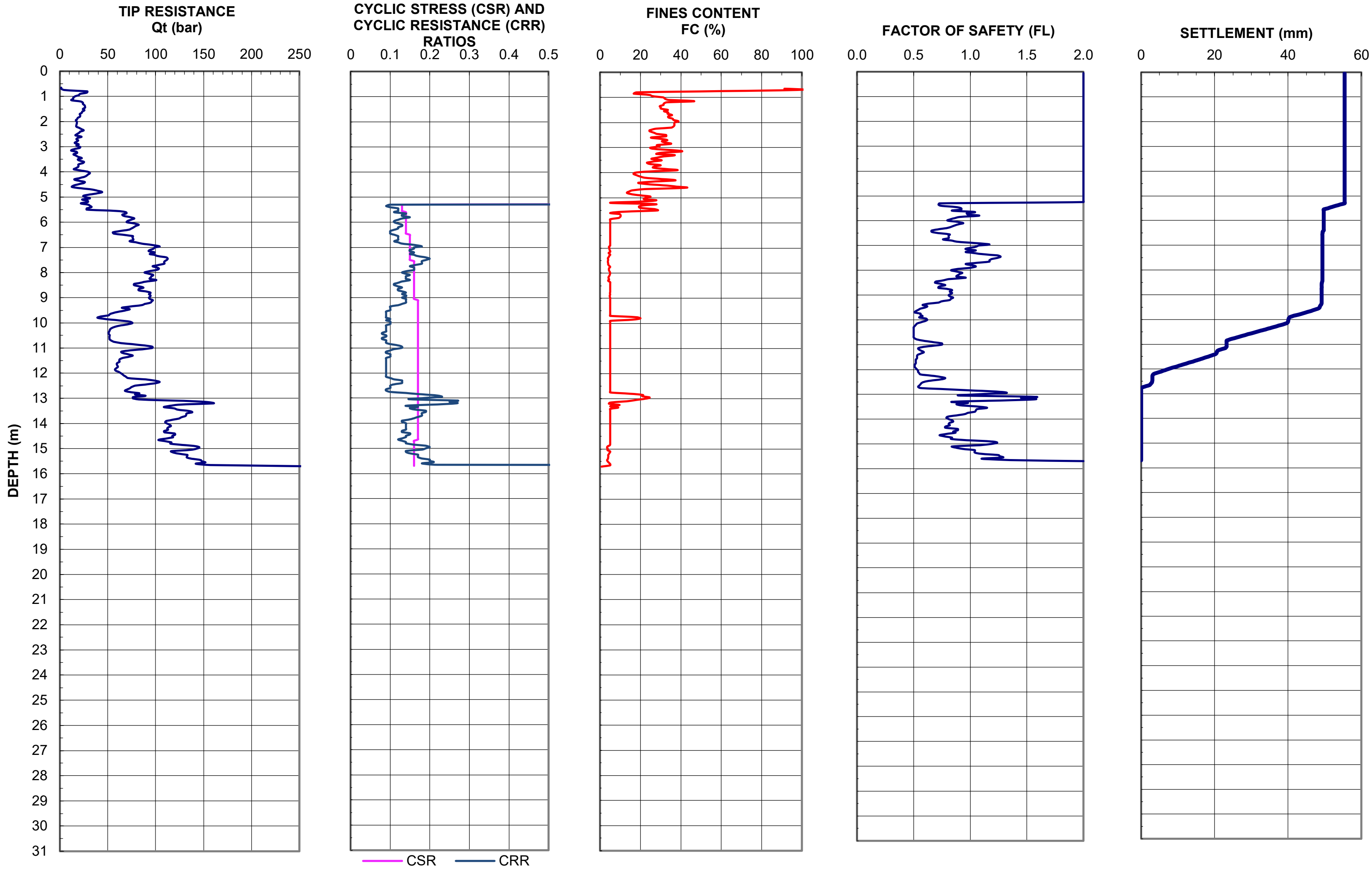
Liquefaction interpretation parameters:

PGA = 0.25

Magnitude = 7.0

Settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	**2023-Jul-21**	**URBAN SYSTEMS**	**GeoPacific Project #: 22933**
	Sounding: CPT23-02	**HORNE STREET AND GLASGOW AVENUE, MISSION**	**Figure: D.02**



Liquefaction interpretation parameters:

PGA = 0.25

Magnitude = 7.0

Settlement accumulation max depth = 15m

APPENDIX E - SHEAR WAVE VELOCITY DATA (Vs)

GEOPACIFIC
VANCOUVER KAMLOOPS CALGARY

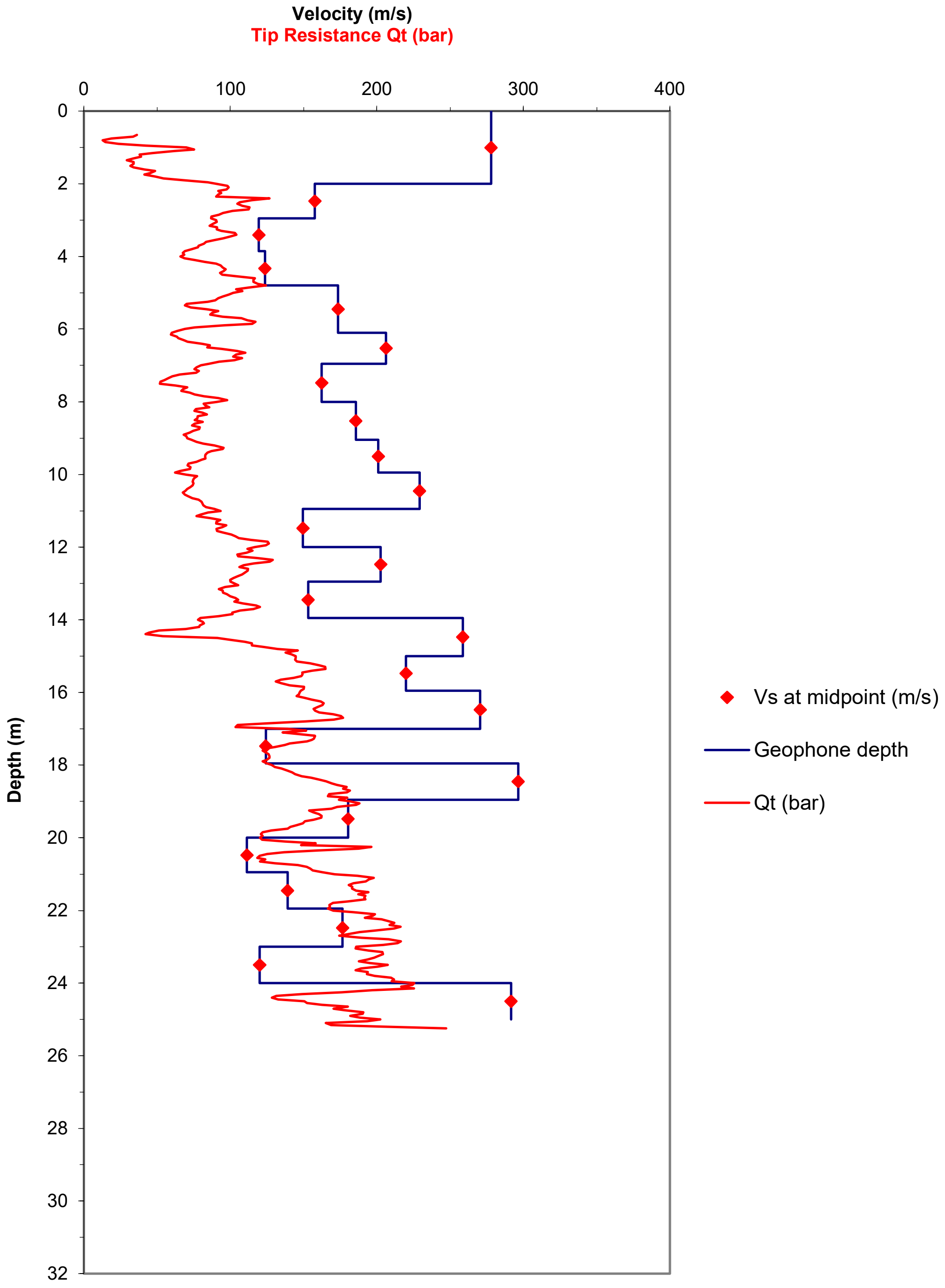
File: 22933
Project: PROPOSED UTILITY UPGRADES
Client: URBAN SYSTEMS
Location: HORNE STREET AND GLASGOW AVENUE
MISSION, BC
Sounding: SCPT23-01
Date: 2023-Jul-21

Seismic Source: Beam
Source to cone (m): 0.4

Shear Wave Velocity Data (Vs)

Depth (m)	Geophone Depth (m)	Ray Path (m)	Ray Path Difference d (m)	Midpoint (m)	Time Difference (ms)	Shear Wave Velocity Vs (m/s)	d/Vs
2.20	2.00	2.04	2.04	1.00	7.34	278	0.0073
3.15	2.95	2.98	0.94	2.48	5.95	158	0.0060
4.05	3.85	3.87	0.89	3.40	7.49	119	0.0075
5.00	4.80	4.82	0.95	4.33	7.66	124	0.0077
6.30	6.10	6.11	1.30	5.45	7.47	173	0.0075
7.15	6.95	6.96	0.85	6.53	4.11	206	0.0041
8.20	8.00	8.01	1.05	7.48	6.46	162	0.0065
9.25	9.05	9.06	1.05	8.53	5.65	186	0.0057
10.15	9.95	9.96	0.90	9.50	4.48	201	0.0045
11.15	10.95	10.96	1.00	10.45	4.36	229	0.0044
12.20	12.00	12.01	1.05	11.48	7.02	150	0.0070
13.15	12.95	12.96	0.95	12.48	4.69	203	0.0047
14.15	13.95	13.96	1.00	13.45	6.53	153	0.0065
15.20	15.00	15.01	1.05	14.48	4.06	259	0.0041
16.15	15.95	15.96	0.95	15.48	4.32	220	0.0043
17.20	17.00	17.00	1.05	16.48	3.88	271	0.0039
18.15	17.95	17.95	0.95	17.48	7.66	124	0.0077
19.15	18.95	18.95	1.00	18.45	3.37	296	0.0034
20.20	20.00	20.00	1.05	19.48	5.82	180	0.0058
21.15	20.95	20.95	0.95	20.48	8.54	111	0.0085
22.15	21.95	21.95	1.00	21.45	7.19	139	0.0072
23.20	23.00	23.00	1.05	22.48	5.95	176	0.0060
24.20	24.00	24.00	1.00	23.50	8.34	120	0.0083
25.20	25.00	25.00	1.00	24.50	3.43	292	0.0034
						Σ(d/Vs)	0.1418
						Average Vs = Σd / Σ(d/Vs)	176

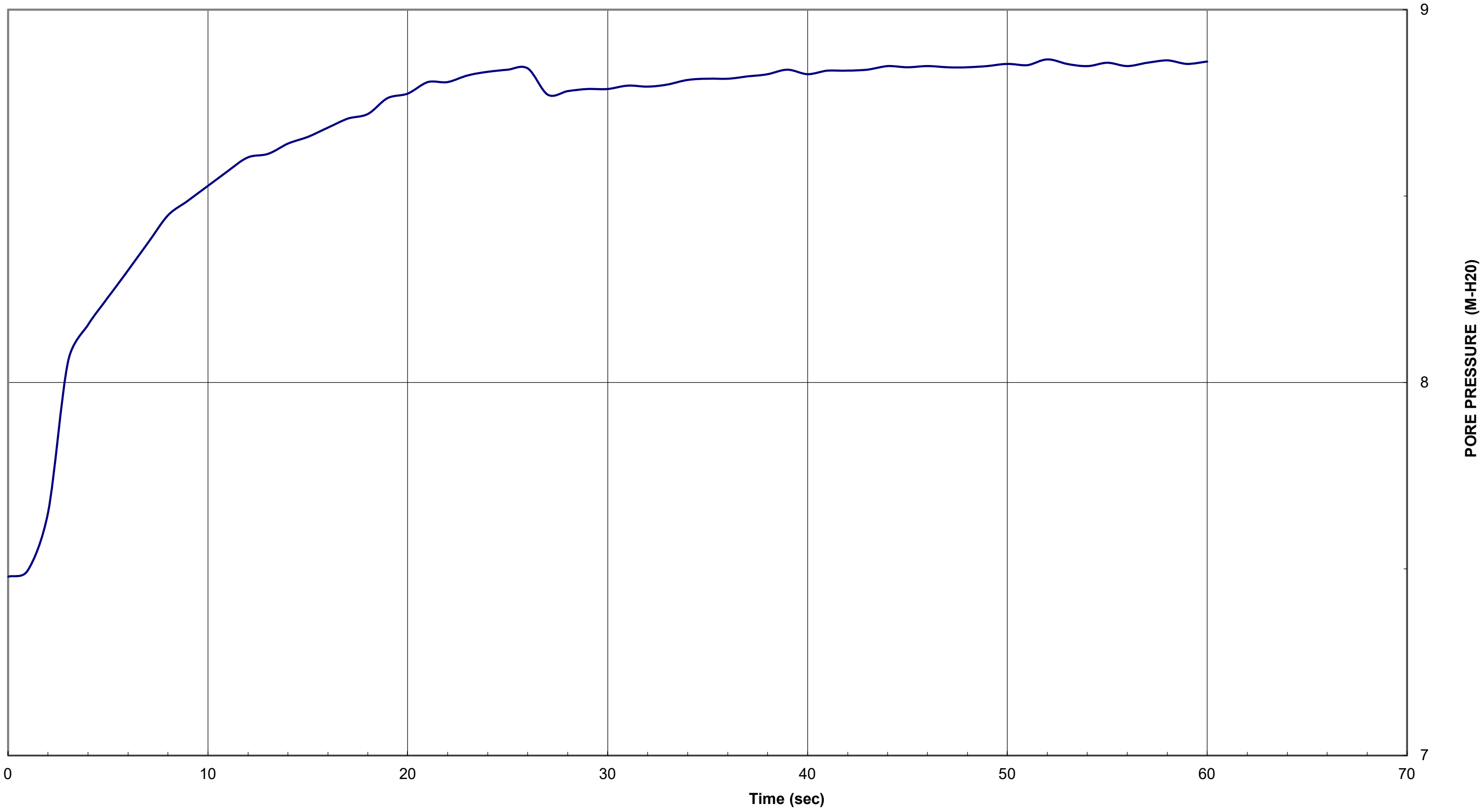
File: 22933
Project: PROPOSED UTILITY UPGRADES
Client: URBAN SYSTEMS
Location: HORNE STREET AND GLASGOW AVENUE
MISSION, BC
Sounding: SCPT23-01
Date: 2023-Jul-21



APPENDIX F – DISSIPATION TEST RESULTS

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2023-Jul-21	URBAN SYSTEMS	GeoPacific Project #: 22933
	Sounding: CPT23-01	HORNE STREET AND GLASGOW AVENUE, MISSION	Figure: F.01

PORE PRESSURE DISSIPATION TEST



Test depth:	14.15	m
Final pore pressure:	8.86	m-H2O
Estimated water table depth:	5.29	m

APPENDIX G – CORROSION POTENTIAL RESULTS

GEOPACIFIC
CONSULTANTS

Vancouver Lab
1779 West 75th Avenue
Vancouver, B.C V6P 6P2

CORROSION POTENTIAL REPORT
(AWWA C105/A21.5-10 - APPENDIX A)

CLIENT:	URBAN SYSTEMS	PROJECT #:	22933
PROJECT NAME:	UTILITY UPGRADES		
PROJECT LOCATION:	HORNE STREET AND GLASGOW AVENUE, MISSION		
SAMPLED BY:	TL	DATE SAMPLED:	21-Jul-23
TESTED BY:	CM	DATE TESTED:	24-Jul-23

HOLE / SAMPLE ID:	TH23-01
DEPTH / LOCATION:	0-6 ft

	TEST METHOD	TEST RESULT	CRITERIA	INDEX
SATURATED RESISTIVITY [Ω·cm]:	ASTM G57	11000	≥3000	0.0
OXIDATION REDUCTION POTENTIAL (mV)	ASTM G200	201.4	> 100 mV	0.0
pH	ASTM G51	7.19	6.5 - 7.5	0.0
SULFIDE CONTENT		POSITIVE	POSITIVE	3.5
MOISTURE CONTENT	ASTM D2216	7.8%	FAIR DRAINAGE, GENERALLY MOIST	1
SOIL DESCRIPTION	ASTM C136 & C117	SAND, SOME GRAVEL, SOME SILT		

TOTAL (SATURATED)	ANSI C105 APPENDIX A	4.5	**CORROSION POTENTIAL (SATURATED)**	**LOW**

Comments: THE OVERALL CORROSION POTENTIAL OF THE SAMPLE IS LOW

Per: Darragh Fitzgerald, B.Sc.

Reviewed by: Cindy Marinovic, B.Sc.

Lab Technician

Lab Supervisor

GEOPACIFIC
CONSULTANTS

CORROSION POTENTIAL REPORT
(AWWA C105/A21.5-10 - APPENDIX A)

Vancouver Lab
1779 West 75th Avenue
Vancouver, B.C V6P 6P2

CLIENT:	URBAN SYSTEMS	PROJECT #:	22933
PROJECT NAME:	UTILITY UPGRADES		
PROJECT LOCATION:	HORNE STREET AND GLASGOW AVENUE, MISSION		
SAMPLED BY:	TL	DATE SAMPLED:	21-Jul-23
TESTED BY:	CM	DATE TESTED:	24-Jul-23

HOLE / SAMPLE ID:	TH23-02			
DEPTH / LOCATION:	5-6 ft			
	TEST METHOD	TEST RESULT	CRITERIA	INDEX
SATURATED RESISTIVITY [Ω·cm]:	ASTM G57	1000	<1500	10.0
OXIDATION REDUCTION POTENTIAL (mV)	ASTM G200	107.9	> 100 mV	0.0
pH	ASTM G51	6.63	6.5 - 7.5	0.0
SULFIDE CONTENT		TRACE	TRACE	2.0
MOISTURE CONTENT	ASTM D2216	28.2%	POOR DRAINAGE, CONTINUOUSLY WET	2
SOIL DESCRIPTION	ASTM C136 & C117	SILT, TRACE SAND		

TOTAL (SATURATED)	ANSI C105 APPENDIX A	14.0	**CORROSION POTENTIAL (SATURATED)**	**CORROSIVE**

Comments: THE OVERALL CORROSION POTENTIAL OF THE SAMPLE IS CORROSIVE

Per: Darragh Fitzgerald, B.Sc.

Reviewed by: Cindy Marinovic, B.Sc.

Lab Technician

Lab Supervisor

GEOPACIFIC
CONSULTANTS

Vancouver Lab
1779 West 75th Avenue
Vancouver, B.C V6P 6P2

CORROSION POTENTIAL REPORT
(AWWA C105/A21.5-10 - APPENDIX A)

CLIENT:	URBAN SYSTEMS	PROJECT #:	22933
PROJECT NAME:	UTILITY UPGRADES		
PROJECT LOCATION:	HORNE STREET AND GLASGOW AVENUE, MISSION		
SAMPLED BY:	TL	DATE SAMPLED:	21-Jul-23
TESTED BY:	CM	DATE TESTED:	24-Jul-23

HOLE / SAMPLE ID:	TH23-03			
DEPTH / LOCATION:	0-6 ft			
	TEST METHOD	TEST RESULT	CRITERIA	INDEX
SATURATED RESISTIVITY [Ω·cm]:	ASTM G57	1600	≥1500 - 1800	8.0
OXIDATION REDUCTION POTENTIAL (mV)	ASTM G200	129.9	> 100 mV	0.0
pH	ASTM G51	7.06	6.5 - 7.5	0.0
SULFIDE CONTENT		POSITIVE	POSITIVE	3.5
MOISTURE CONTENT	ASTM D2216	9.7%	FAIR DRAINAGE, GENERALLY MOIST	1
SOIL DESCRIPTION	ASTM C136 & C117	SAND, SILTY, TRACE GRAVEL		

TOTAL (SATURATED)	ANSI C105 APPENDIX A	12.5	**CORROSION POTENTIAL (SATURATED)**	**CORROSIVE**

Comments: THE OVERALL CORROSION POTENTIAL OF THE SAMPLE IS CORROSIVE

Per: Darragh Fitzgerald, B.Sc.

Reviewed by: Cindy Marinovic, B.Sc.

Lab Technician

Lab Supervisor

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CONSULTANTS

CORROSION POTENTIAL REPORT
(AWWA C105/A21.5-10 - APPENDIX A)

Vancouver Lab
1779 West 75th Avenue
Vancouver, B.C V6P 6P2

CLIENT:	URBAN SYSTEMS	PROJECT #:	22933
PROJECT NAME:	UTILITY UPGRADES		
PROJECT LOCATION:	HORNE STREET AND GLASGOW AVENUE, MISSION		
SAMPLED BY:	TL	DATE SAMPLED:	21-Jul-23
TESTED BY:	CM	DATE TESTED:	24-Jul-23

HOLE / SAMPLE ID:	TH23-04
DEPTH / LOCATION:	5-6 ft

	TEST METHOD	TEST RESULT	CRITERIA	INDEX
SATURATED RESISTIVITY [Ω·cm]:	ASTM G57	3700	≥3000	0.0
OXIDATION REDUCTION POTENTIAL (mV)	ASTM G200	-8.0	<0	5.0
pH	ASTM G51	6.29	4 - 6.5	0.0
SULFIDE CONTENT		POSITIVE	POSITIVE	3.5
MOISTURE CONTENT	ASTM D2216	58.1%	POOR DRAINAGE, CONTINUOUSLY WET	2
SOIL DESCRIPTION	ASTM C136 & C117	SAND AND SILT, TRACE GRAVEL		

TOTAL (SATURATED)	ANSI C105 APPENDIX A	10.5	**CORROSION POTENTIAL (SATURATED)**	**CORROSIVE**

Comments: THE OVERALL CORROSION POTENTIAL OF THE SAMPLE IS CORROSIVE

Per: Darragh Fitzgerald, B.Sc.

Reviewed by: Cindy Marinovic, B.Sc.

Lab Technician

Lab Supervisor