Geotechnical Investigation Report

COMMERCIAL DEVELOPMENT

34-35 SOUTH STEYNE, MANLY NSW

Prepared for:

FORTIS

Reference: P2474_01

14 March 2022

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1 PROJECT BACKGROUND

Morrow Geotechnics Pty Ltd has undertaken a Geotechnical Investigation to provide geotechnical advice and recommendations for the proposed development a 34-35 South Steyne, Manly NSW (the site).

1.1 Proposed Development

Architectural Drawings for the proposed development have not been provided at the time of preparation of this report. From discussions with the client, Morrow Geotechnics understands that the proposed development will comprise the construction of a mixed use building over up to three levels of basement parking. Indicative excavation for the basement has been assumed at approximately 3 m below existing ground level (mBGL), however the advice in this report would be relevant for excavations up to 15 mBGL.

1.2 Investigation Intent

The purpose of the investigation is to provide geotechnical advice and recommendations specific to the ground conditions observed at site for the proposed development. These recommendations include:

- Foundation advice along with relevant geotechnical design parameters;
- Excavation and shoring advice along with relevant geotechnical design parameters;
- Approaches to minimise the impact of the proposed development through vibration, ground movement or groundwater drawdown;
- Other relevant geotechnical issues which may impact construction; and
- Recommendations for further geotechnical input.

1.3 Published Geological Mapping

Information on regional sub-surface conditions, referenced from the Department of Mineral Resources Geological Map Sydney 1:100,000 Geological Series Sheet 9130 indicates that the site overlies Quaternary Holocene beach deposits, which typically comprise coarse quartz sand with varying shell fragments.

1.4 Published Soil Landscapes

The Soil Conservation Service of NSW Sydney 1:100,000 Soil Landscapes Series Sheet 9130 (2nd Edition) indicates the site to be underlain by the Narrabeen Landscape. This landscape type typically includes beaches and coastal foredunes on marine sands. Soils are generally deep (> 2.0 m) calcareous sand on beaches and siliceous sands on foredunes. These soils are noted to present extreme wind and wave erosion hazard, non-cohesive soil and high soil permeability.

2 OBSERVATIONS

2.1 Investigation Methods

Fieldwork was undertaken by Morrow Geotechnics on 4 March 2022. Work carried out as part of this investigation includes:

- Review of publicly available information from previous reports in the project area, published geological and soil mapping and government agency websites;
- Site walkover inspection by a Geotechnical Engineer to assess topographical features, condition of surrounding structures and site conditions;
- Dial Before You Dig (DBYD) services search of proposed borehole locations;
- One Cone Penetrometer Test (CPT1) by a truck mounted hydraulic CPT rig. CPTs across the remainder of the site area could not be carried out due to the presence of structures at the time of testing. The CPT refused at a depth of 13.35 m within dense sand. CPT locations are shown on **Figure 1** and CPT logs are presented in **Appendix A**; and
- Groundwater observations were taken within open holes at the conclusion of CPT testing.

2.2 Subsurface Conditions

The stratigraphy at the site is characterised by fill overlying marine sand. The observed ground conditions have been divided into five geotechnical units. A summary of the subsurface conditions at the investigation locations is presented below in **Tables 1** and **2**.

TABLE 1 SUMMARY OF INFERRED SUBSURFACE CONDITIONS

<table>
<tr><th>Unit</th><th>Material</th><th>Approx. Depth Range of Unit [1] at CPT1 Location</th><th>Comments</th></tr>
<tr><td>1</td><td>Fill</td><td>0.0 to 1.0</td><td>Concrete overlying sandy silt or gravel. Unit 1 fill is inferred to be uncontrolled and poorly compacted. Fill thickness is inferred from CPT behavior only.</td></tr>
<tr><td>2</td><td>Loose Sand</td><td>1.0 to 3.7</td><td rowspan="4">Medium to coarse grained SAND inferred from CPT behavior to grade from loose to dense. Occasional clay bands encountered below 6 m depth.</td></tr>
<tr><td>3</td><td>Medium Dense Sand</td><td>3.7 to 5.3</td></tr>
<tr><td>4</td><td>Loose Sand</td><td>5.3 to 9.8</td></tr>
<tr><td>5</td><td>Dense Sand</td><td>9.8 to 13.35</td></tr>
</table>

2.3 Groundwater Observations

Groundwater measurements were taken within the CPT hole immediately following testing. Groundwater was measured at 4.0 mBGL on the completion of testing. It should be noted that groundwater at the site will be tidally influenced.

3 RECOMMENDATIONS

3.1 Excavation Retention

Design of excavation retention systems will need to consider both the soil and groundwater conditions encountered within the investigation. For design of flexible shoring systems a triangular pressure distribution may be employed using the parameters provided in **Table 4**. For design of rigid anchored or braced walls, a trapezoidal earth pressure distribution should be used with a maximum pressure of $0.65.K_a.\gamma.H$ (kPa), where 'H' is the effective vertical height of the wall in metres.

TABLE 4 EARTH PRESSURE PARAMETERS

Material		Unit 1 Fill	Unit 2 Loose Sand	Unit 3 Medium Dense Sand	Unit 4 Loose Sand	Unit 5 Dense Sand
Bulk Unit Weight (kN/m^3)		17	18	19	18	21
Earth Pressure Coefficients	At rest, K_o	0.53	0.50	0.46	0.50	0.41
	Passive, K_p	2.77	3.00	3.39	3.00	3.85
	Active, K_a	0.36	0.33	0.29	0.33	0.26

1 Unit Weight is based on visual assessment only and may vary by ±10%.
2 Earth pressures are provided on the assumption that the ground behind the retaining wall is flat and drained.

In addition, design of retaining walls should consider the following:

- Appropriate surcharge loading from construction equipment, vehicular traffic and neighbouring structures at finished surface level should be taken into account in the retention design. Surcharge loads on retention structures may be calculated using a rectangular stress block with an earth pressure coefficient of 0.5 applied to surcharge loads at ground surface level.
- Anchor design should ignore the contribution of any bonded length within a wedge which extends upwards at 45^o from the base of the excavation to account for a failure wedge forming behind the shoring system.
- If the shoring system is to be tanked slab on ground design must allow for groundwater uplift pressures and shoring must allow for hydrostatic pressures from 2.5 mBGL.

3.2 Excavation Vibration Considerations

As a guide, safe working distances for typical items of vibration intensive plant are listed in **Table 5**. The safe working distances are quoted for both "cosmetic" damage (refer British Standard BS 7385:1993) and human comfort (refer NSW Environmental Protection Agency Vibration Guideline).The safe working distances should be complied with at all times, unless otherwise mitigated to the satisfaction of the relevant stakeholders.

TABLE 5 RECOMMENDED SAFE WORKING DISTANCES FOR VIBRATION INTENSIVE PLANT

Plant Item	Description	Safe Working Distance	
		Cosmetic Damage (BS 7385:1993) [1]	Human Response (EPA Vibration Guideline)
Vibratory Roller	< 50 kN (typically 1-2 tonnes)	5 m	15 m to 20 m
	< 100 kN (typically 2-4 tonnes)	6 m	20 m
	< 200 kN (typically 4-6 tonnes)	12 m	40 m
	< 300 kN (typically 7-13 tonnes)	15 m	100 m
	< 300 kN (typically 13-18 tonnes)	20 m	100 m
	< 300 kN (typically >18 tonnes)	25 m	100 m
Small Hydraulic Hammer	300 kg – 5 to 12 t excavator	2 m	7 m
Medium Hydraulic Hammer	900 kg – 12 to 18 t excavator	7 m	23 m
Large Hydraulic Hammer	1600 kg – 18 to 34 t excavator	22 m	73 m
Vibratory Pile Driver	Sheet Piles	2 m to 20 m	20 m
Pile Boring	≤ 800 mm	2m (nominal)	N/A
Jackhammer	Hand held	1 m (nominal)	Avoid contact with structure

Notes:

1 More stringent conditions may apply to heritage buildings or other sensitive structures.

The safe working distances in **Table 5** relate to continuous vibration and apply to residential receivers. For most construction activities, vibration emissions are intermittent in nature and for this reason, higher vibration levels, occurring over shorter periods are permitted, as discussed in British Standard BS 6472-1:2008.

The safe working distances provided in **Table 5** are given for guidance only. Monitoring of vibration levels may be required to ensure vibrations levels remain below threshold values during the construction period. Monitoring thresholds should be set at a peak particle velocity (ppv) of 5 mm/sec to prevent damage to neighbouring structures and infrastructure. Where ppv thresholds are exceeded an alternative excavation methodology should be developed in collaboration with the geotechnical engineer to reduce the likelihood of vibration induced damage.

3.3 Foundation Design

No footings are to found on Unit 1 or Unit 2 material due to the likelihood of excessive settlement of these materials.

The parameters given in **Table 6** may be used for the design of pad footings and bored piles. Morrow Geotechnics recommends that a Preliminary Geotechnical Strength Reduction Factor (GSRF) of 0.4 is used for the design of piles in accordance with AS 2159:2009 if no allowance is made for pile testing during construction. Should pile testing be nominated, the GSRF may be reviewed and a value of 0.55 to 0.65 may be expected.

Ultimate geotechnical strengths are provided for use in limit state design. Allowable bearing pressures are provide for serviceability checks. These values have been determined to limit settlements to an acceptable level for conventional building structures, typically less than 1% of the minimum footing dimension.

TABLE 6 PAD FOOTING AND PILE DESIGN PARAMETERS

Material		Unit 1 Fill	Unit 2 Loose Sand	Unit 3 Medium Dense Sand	Unit 4 Loose Sand (below 5 mBGL)	Unit 5 Dense Sand
Allowable Bearing Pressure (kPa)		-	-	150	150	600
Ultimate Vertical End Bearing Pressure (kPa)		-	-	450	450	1800
Elastic Modulus (MPa)		3	15	30	20	70
Ultimate Shaft Adhesion (kPa)	In Compression	0	10	15	12	20
	In Tension	0	5	7.5	6	10
Susceptibility to Liquefaction during an Earthquake		Medium	Medium	Low	Medium	Low

Notes:

1 End bearing values for Unit 2 Medium Dense Sand may be multiplied by a factor of 2 for footings founded at more than 4.5 m below natural ground level.

2 Side adhesion values given assume there is intimate contact between the pile and foundation material. Design engineer to check both 'piston' pull-out and 'cone' pull-out mechanics in accordance with AS4678-2002 Earth Retaining Structures.

3 Susceptibility to liquefaction during an earthquake is based on the following definition:
Low - Medium to very dense sands, stiff to hard clays, and rock
Medium - Loose to medium dense sands, soft to firm clays, or uncontrolled fill below the water table
High - Very loose sands or very soft clays below the water table

To adopt these parameters we have assumed that the bases of all pile excavations are cleaned of loose debris and water and inspected by a suitably qualified Geotechnical Engineer prior to pile construction to verify that ground conditions meet design assumptions. Where groundwater ingress is encountered during pile excavation, concrete is to be placed as soon as possible upon completion of pile excavation. Pile excavations should be pumped dry of water prior to pouring concrete, or alternatively a tremmie system could be used.

Selection of footing types and founding depth will need to consider the risk of adverse differential ground movements within the foundation footprint and between high level and deeper footings. Unless an allowance for such movement is included in the design of the proposed development we recommend that all new structures found on natural materials with comparable end bearing capacities and elastic moduli.

3.4 AS1170 Earthquake Site Risk Classification

Assessment of the material encountered during the investigation in accordance with the guidelines provided in AS1170.4-2007 indicates:

- an earthquake subsoil class of Class C_e – Shallow Soil for the site; and
- a hazard factor (z) of 0.08 for Sydney.

4 RECOMMENDATIONS FOR FURTHER GEOTECHNICAL SERVICES

Further input from a geotechnical professional during design and construction is advised in order to ensure a cost-effective design which can be constructed safely and efficiently. Areas for geotechnical input should include:

- Additional CPTs will be required to confirm sand density across the central and north-eastern area of the site. A minimum of three additional CPTs should be undertaken across the site prior to the finalisation of detailed design for the development.
- Geotechnical design input during structural design including Finite Element Analysis of ground movements for the protection of adjacent structures and properties.
- Geotechnical inspection of piling works to verify pile socket conditions and confirm the geotechnical site model.
- Geotechnical inspections of foundation of foundation material to confirm allowable bearing pressures.
- Regular inspections of battered and unsupported excavations, where proposed, to assess excavation conditions and confirm the suitability of the proposed methodology.

5 STATEMENT OF LIMITATIONS

The adopted investigation scope was limited by the investigation intent. Further geotechnical inspections should be carried out during construction to confirm both the geotechnical model and the design parameters provided in this report.

Your attention is drawn to the document "Important Information", which is included in **Appendix B** of this report. The statements presented in this document are intended to advise you of what your realistic expectations of this report should be. The document is not intended to reduce the level of responsibility accepted by Morrow Geotechnics, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

6 REFERENCES

AS1726:1993, *Geotechnical Site Investigations*, Standards Australia.

AS2159:2009, *Piling – Design and Installation*, Standards Australia.

AS2870:2011, *Residential Slabs and Footings*, Standards Australia.

AS3798:2007, *Guidelines on Earthworks for Commercial and Residential Developments*, Standards Australia.

NSW Department of Finance and Service, Spatial Information Viewer, maps.six.nsw.gov.au.

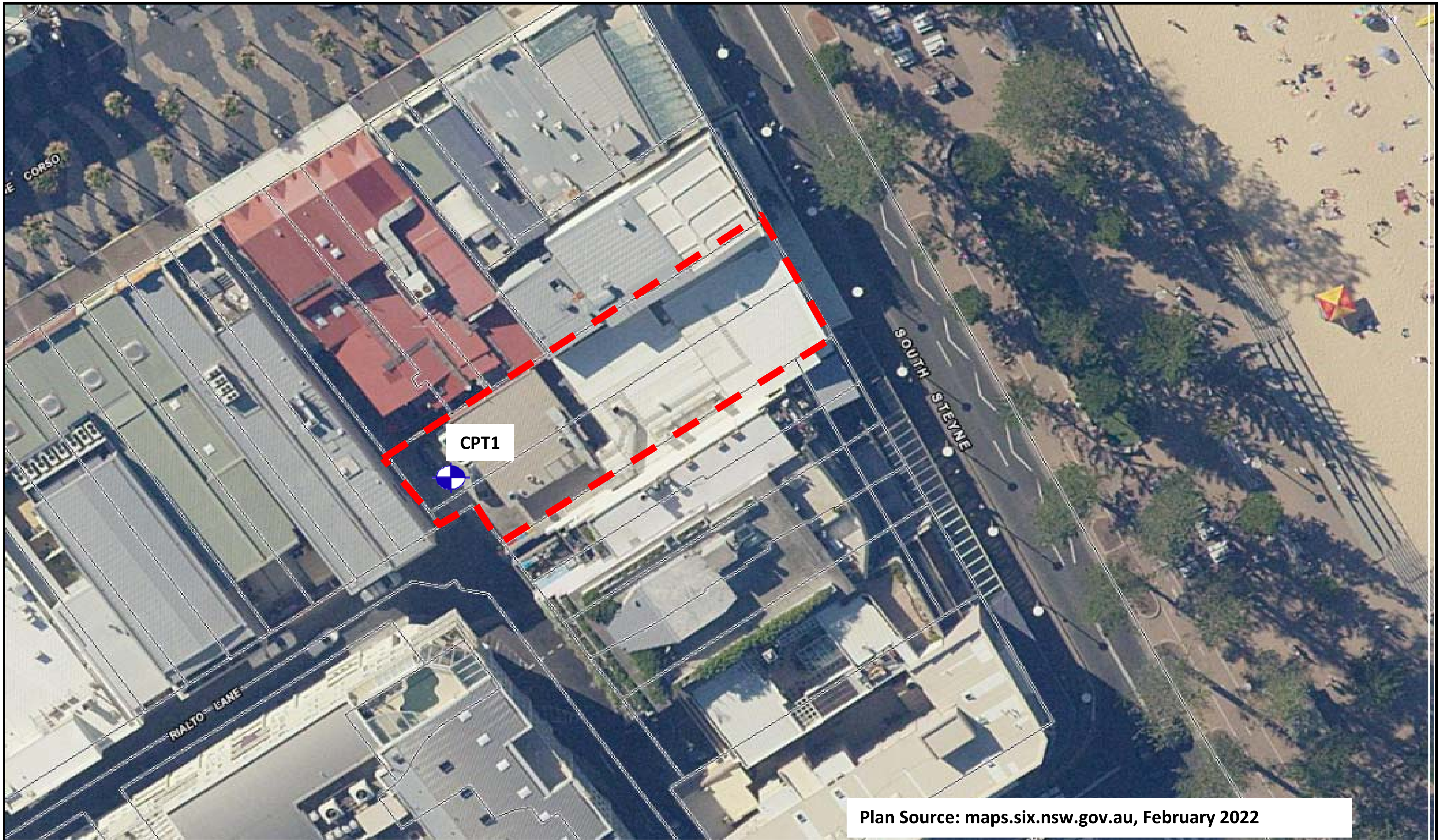
Pells (2004) Substance and Mass Properties for the Design of Engineering Structures in the Hawkesbury Sandstone, Australian Geomechanics Journal, Vol 39 No 3

7 CLOSURE

Please do not hesitate to contact Morrow Geotechnics if you have any questions about the contents of this report.

For and on behalf of Morrow Geotechnics Pty Ltd,

Alan Morrow
Principal Geotechnical Engineer



morrow PO Box 4069, Carlton NSW 2218 P: 0405 843 933 | E: info@morrowgeo.com.au	Drawn	HW	**Fortis** 34-35 South Steyne, Manly NSW Geotechnical Investigation Borehole Location Plan	Figure: **1**
	Approved	RM		
	Date	14/03/2022		
	Scale	NTS		Project: P2474

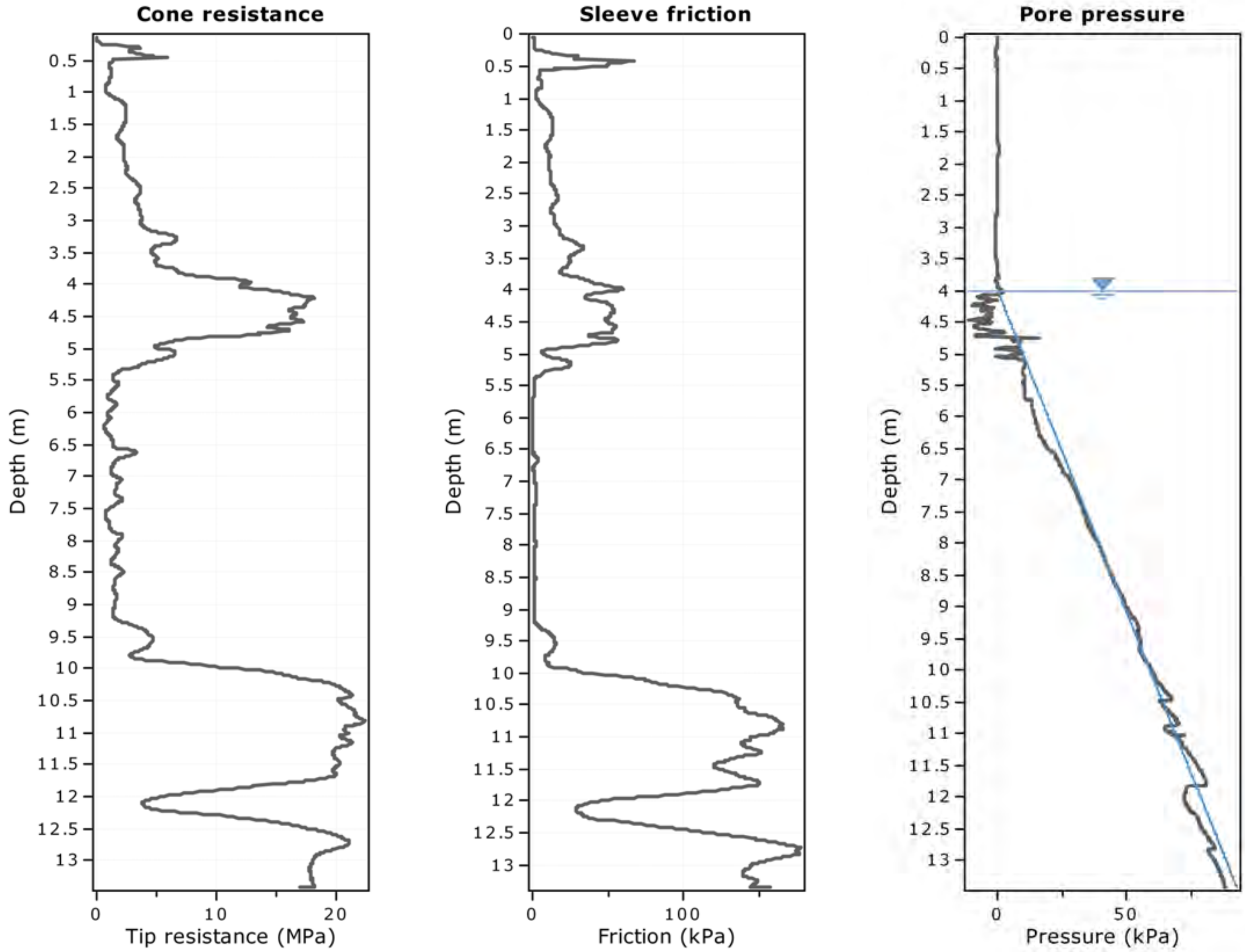
Appendix A

CPT Test Reports

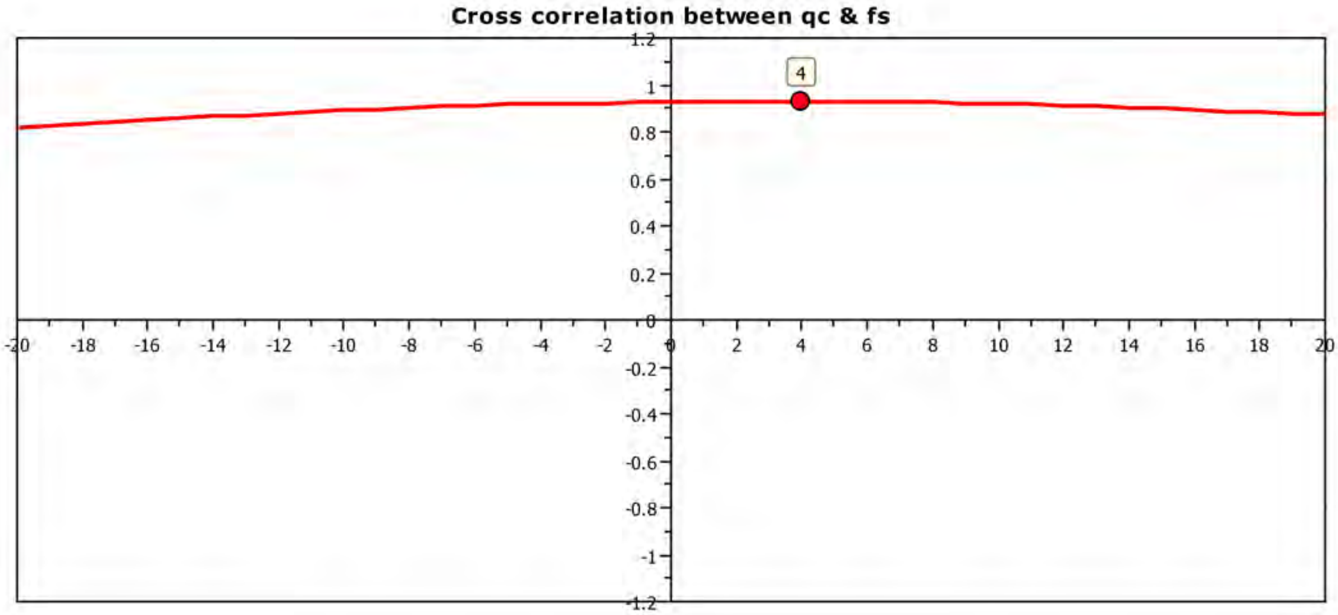
Morrow Geotechnics Pty Ltd
PO Box 4069
Carlton NSW 2218
http://www.morrowgeo.com.au

CPT: P2474_CPT-01
Total depth: 13.42 m, Date: 9/03/2022
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

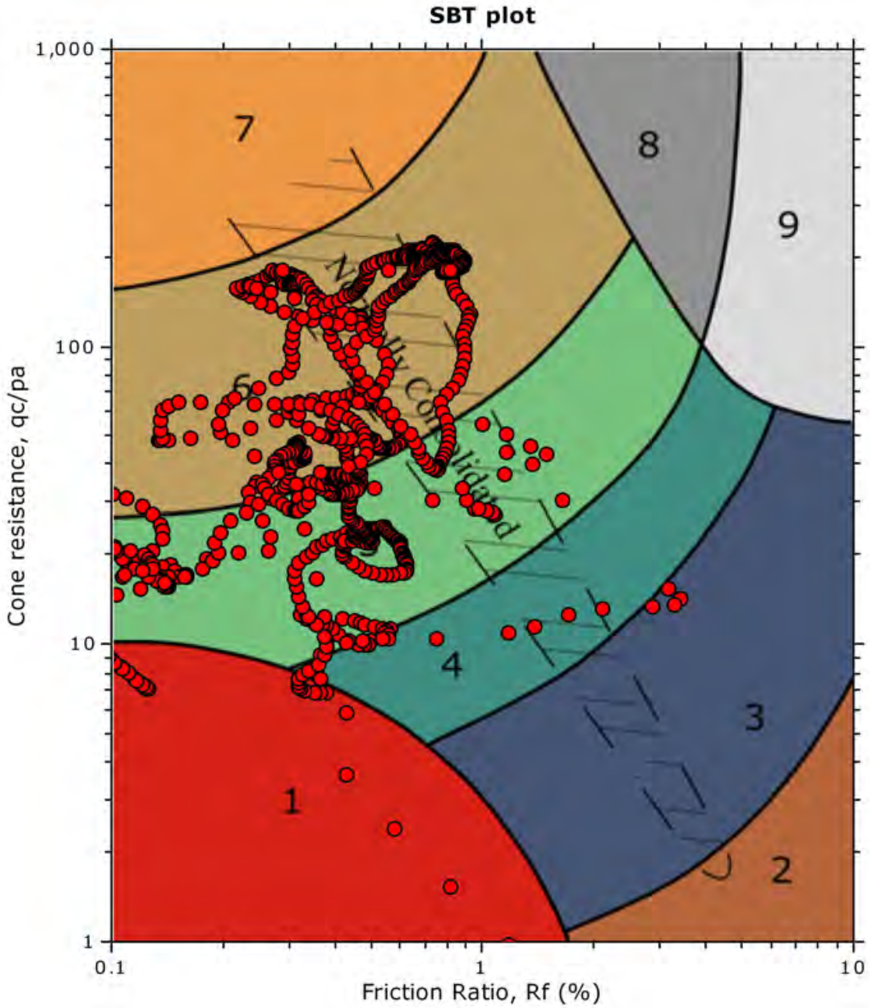
Project: **P2474**
Location: **34-35 South Steyne, Manly NSW**

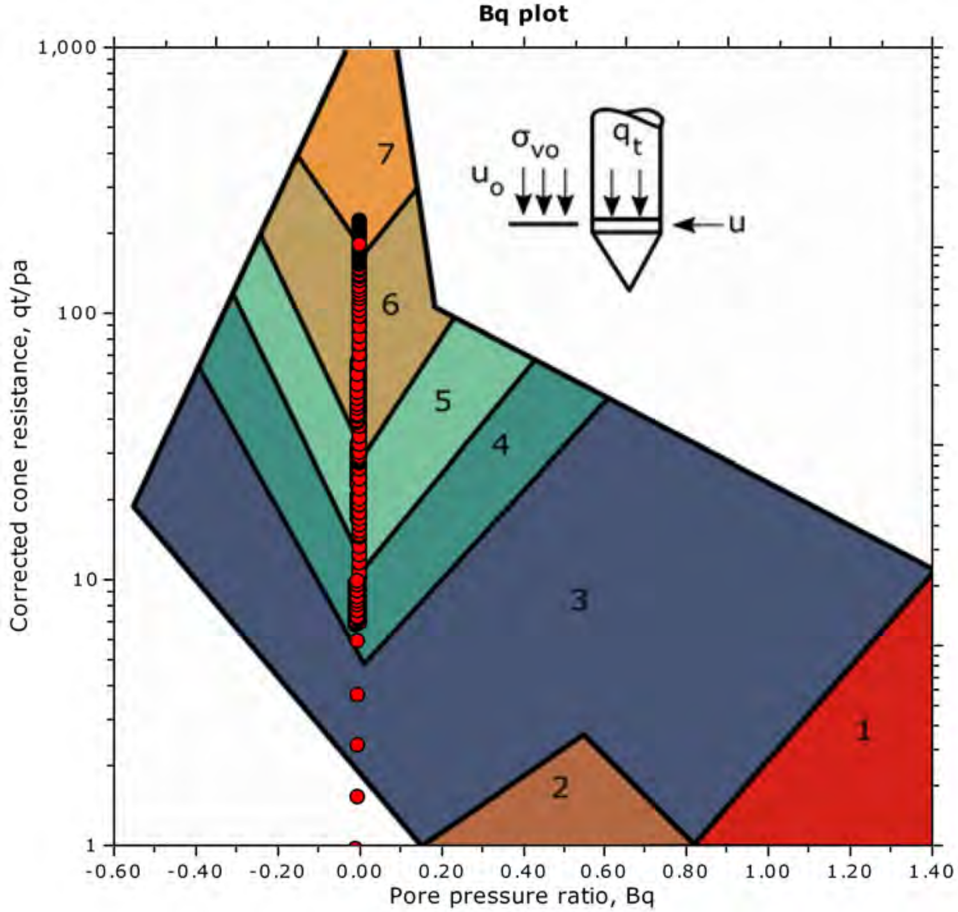


The plot below presents the cross correlation coeficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two sucessive CPT measurements).



SBT - Bq plots





SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty clay
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravelly sand to sand
8. Very stiff sand to clayey sand
9. Very stiff fine grained

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Cone Operator:

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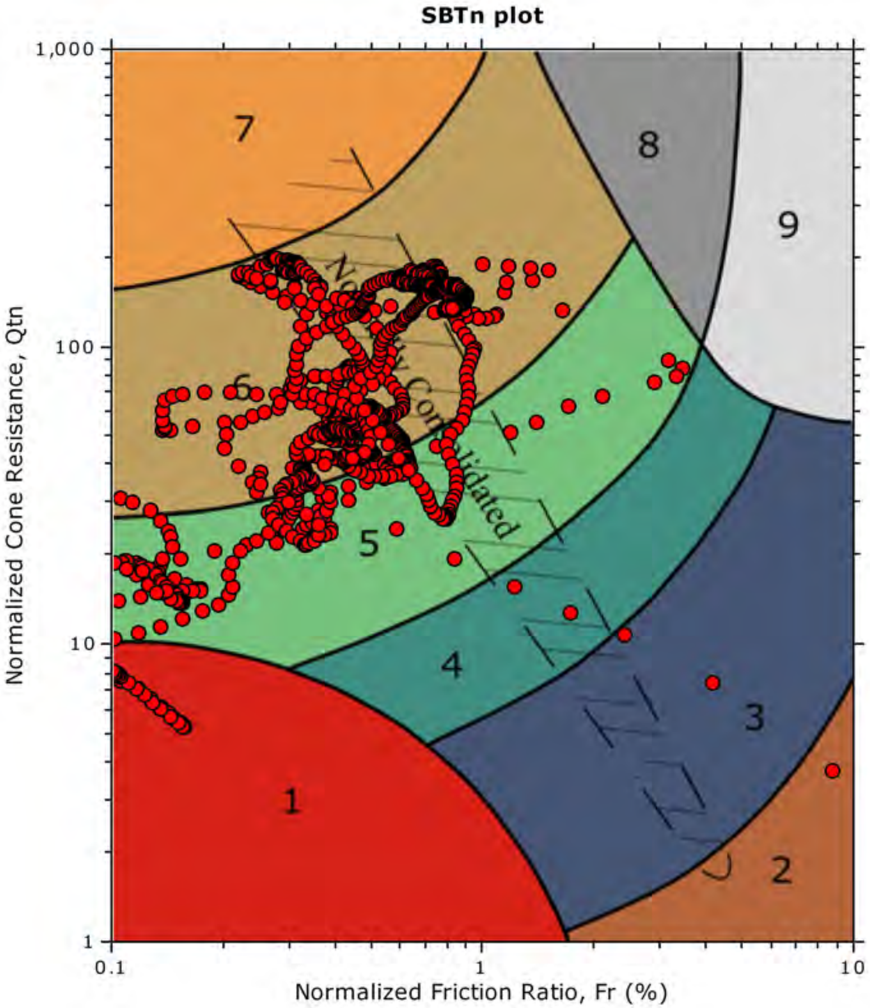
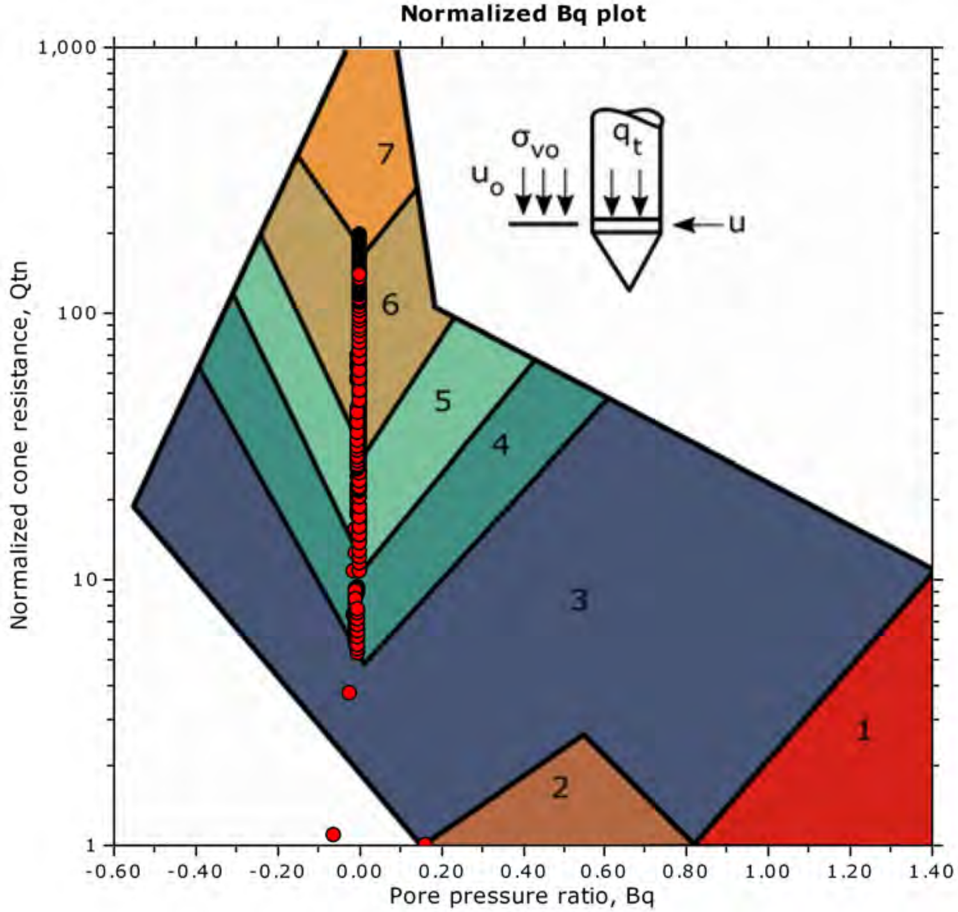
SBT - Bq plots (normalized)





SBTn legend

- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty clay
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravelly sand to sand
- 8. Very stiff sand to clayey sand
- 9. Very stiff fine grained

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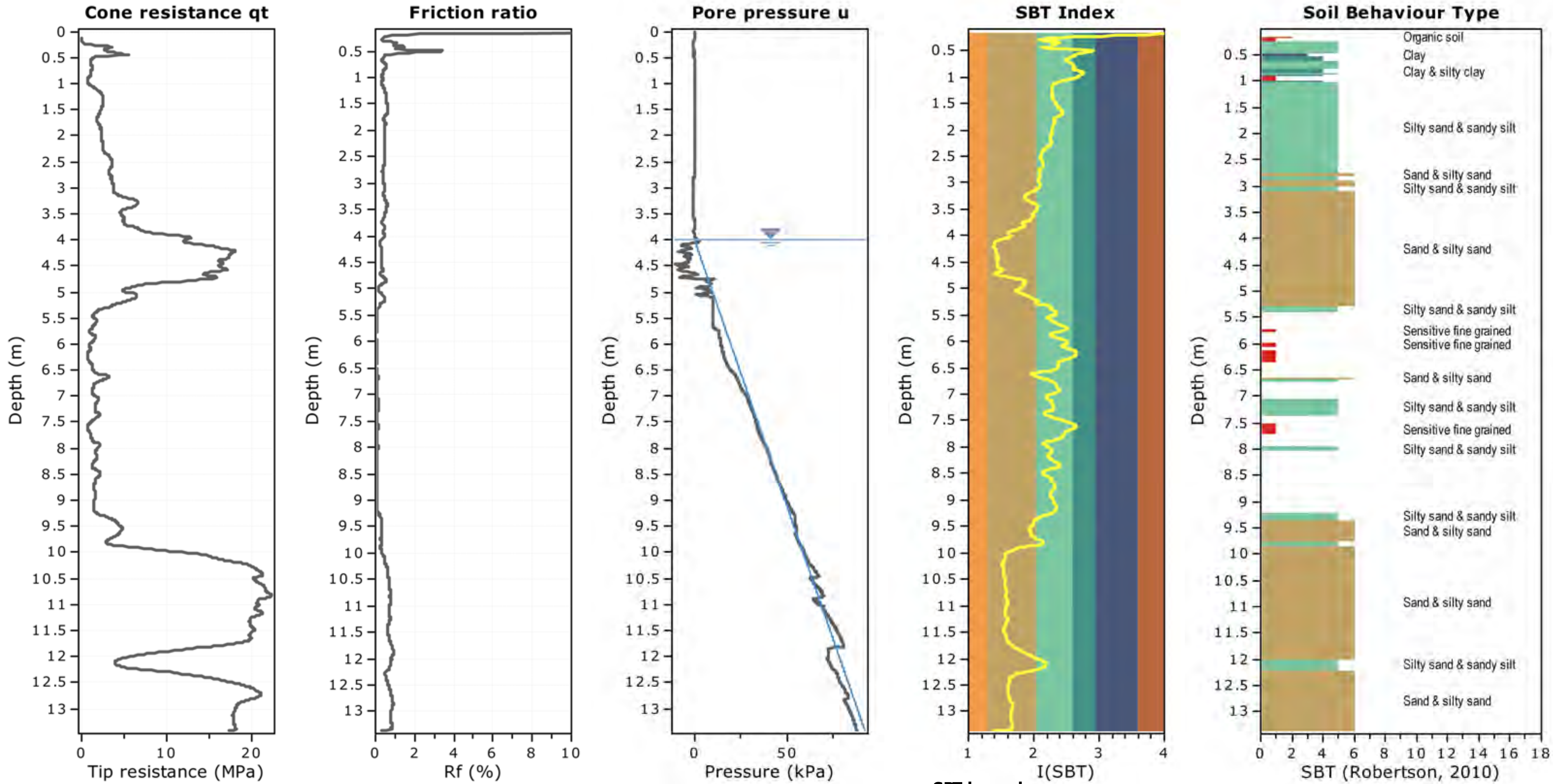

SBT legend

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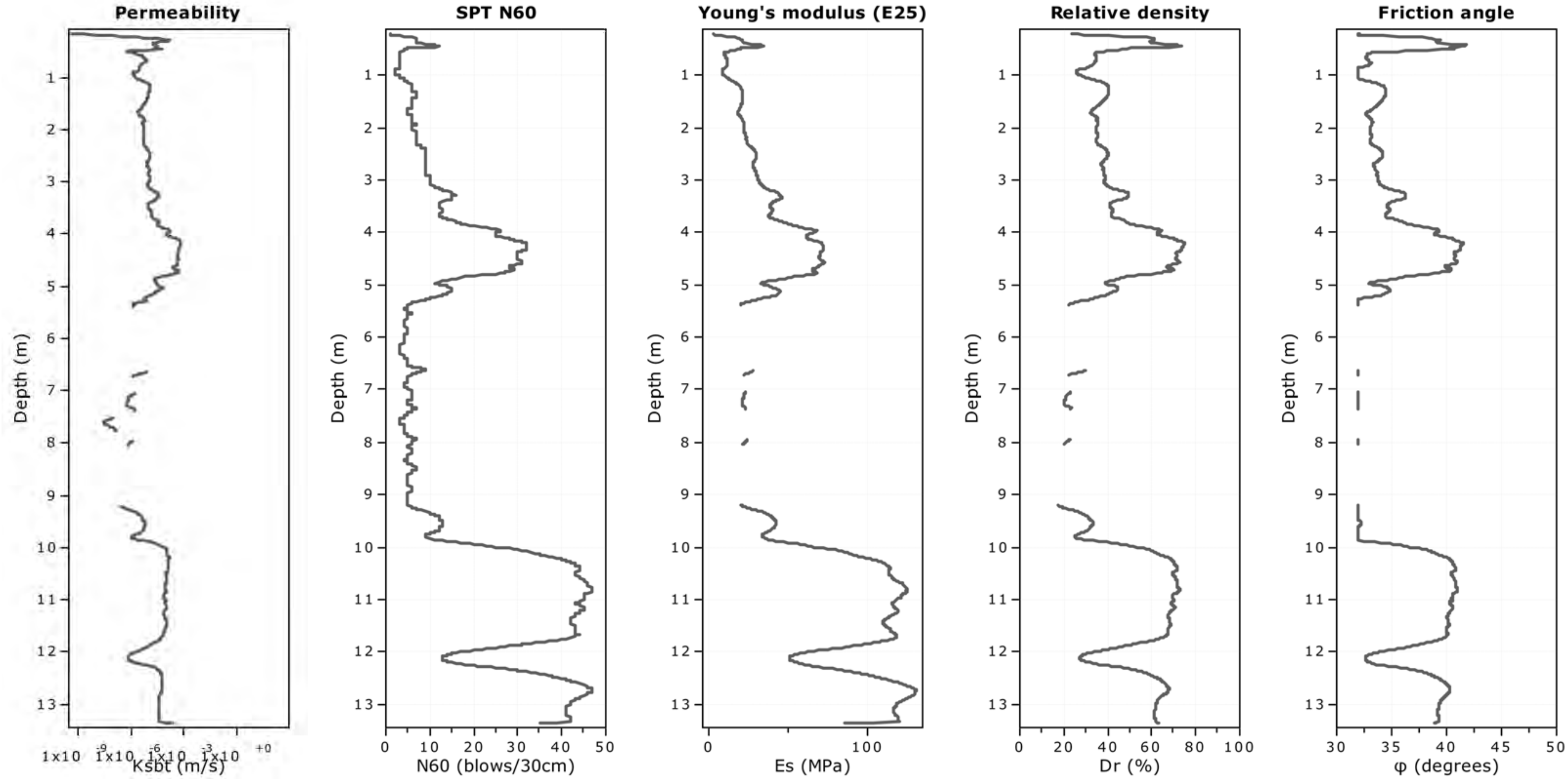

Calculation parameters
Permeability: Based on SBT_n
SPT N_{60}: Based on I_c and q_t
Young's modulus: Based on variable alpha using I_c (Robertson, 2009)

Relative density constant, C_{Dr}: 350.0
Phi: Based on Kulhawy & Mayne (1990)
User defined estimation data

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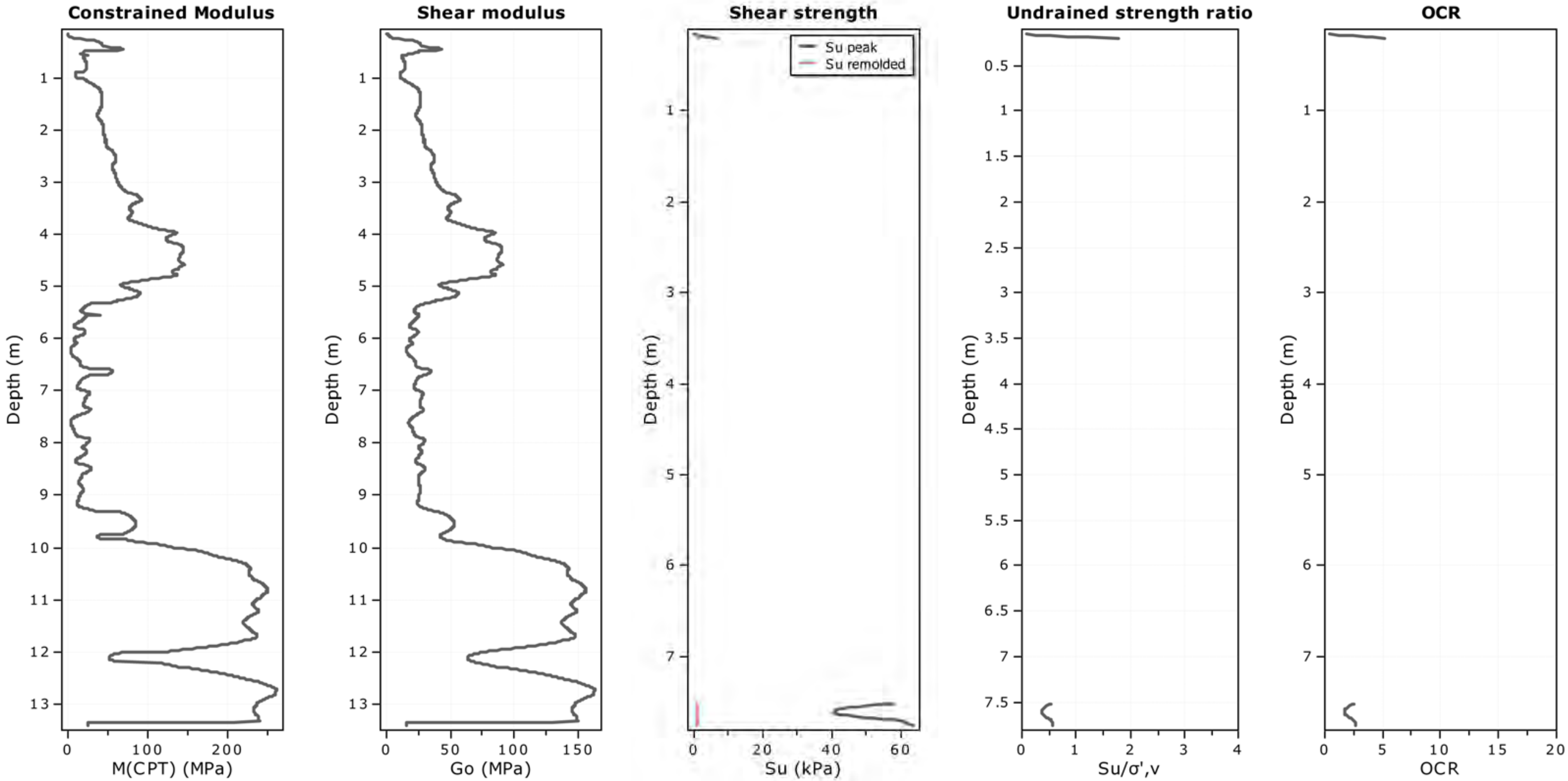

Calculation parameters
Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable alpha using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 14

OCR factor for clays, N_{kt}: 0.33
User defined estimation data
Flat Dilatometer Test data

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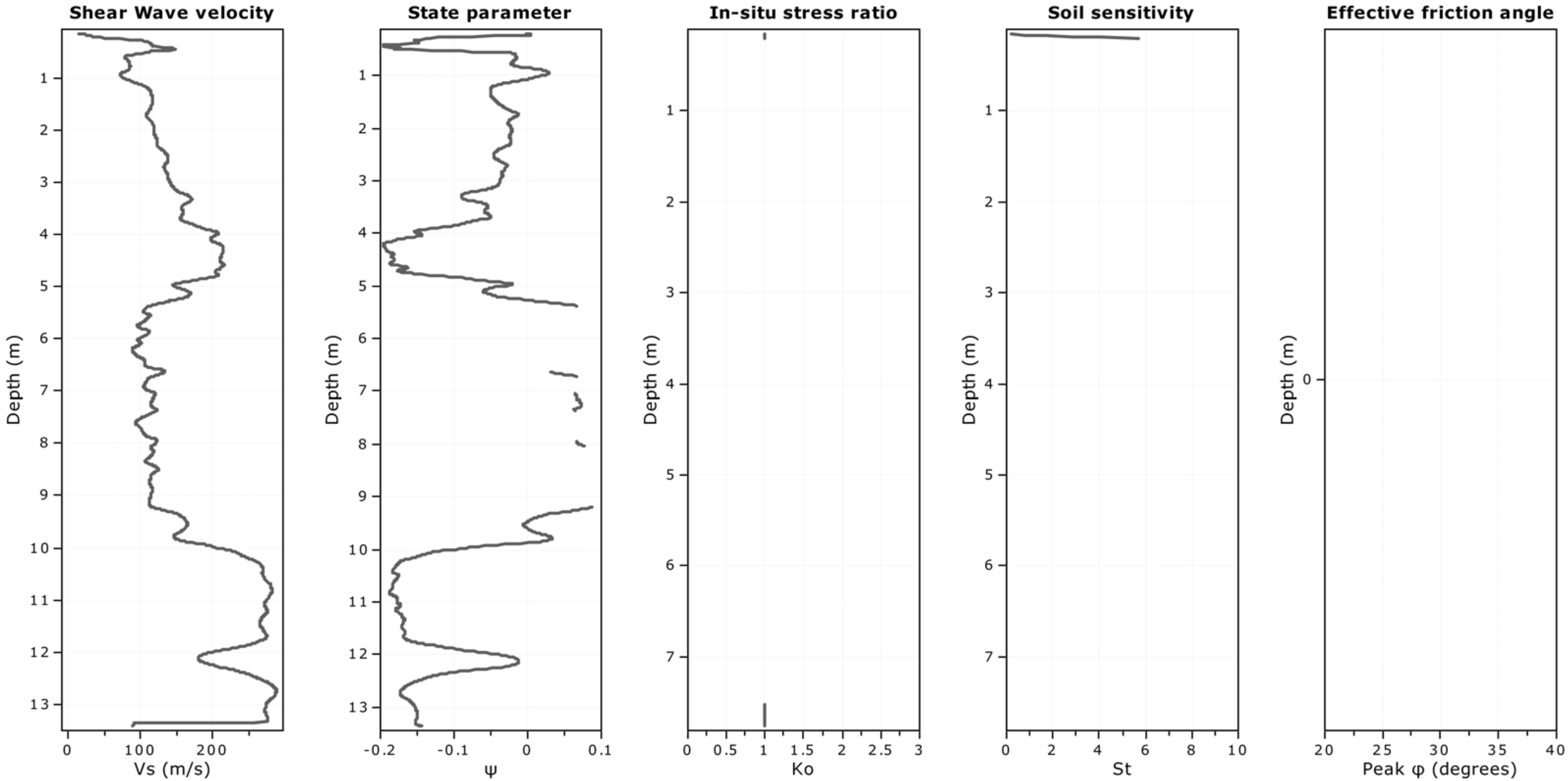

Calculation parameters

Soil Sensitivity factor, N_S: 7.00
User defined estimation data

Presented below is a list of formulas used for the estimation of various soil properties. The formulas are presented in SI unit system and assume that all components are expressed in the same units.

:: Unit Weight, g (kN/m³) ::

$$g = g_w \cdot \left(0.27 \cdot \log(R_f) + 0.36 \cdot \log\left(\frac{q_t}{p_a}\right) + 1.236 \right)$$

where g_w = water unit weight

:: Permeability, k (m/s) ::

$I_c < 3.27$ and $I_c > 1.00$ then $k = 10^{0.952-3.04 \cdot I_c}$

$I_c \leq 4.00$ and $I_c > 3.27$ then $k = 10^{-4.52-1.37 \cdot I_c}$

:: N_{SPT} (blows per 30 cm) ::

$$N_{60} = \left(\frac{q_c}{P_a}\right) \cdot \frac{1}{10^{1.1268-0.2817 \cdot I_c}}$$

$$N_{1(60)} = Q_{tn} \cdot \frac{1}{10^{1.1268-0.2817 \cdot I_c}}$$

:: Young's Modulus, Es (MPa) ::

$$(q_t - \sigma_v) \cdot 0.015 \cdot 10^{0.55 \cdot I_c + 1.68}$$

(applicable only to $I_c < I_{c\_cutoff}$)

:: Relative Density, Dr (%) ::

$$100 \cdot \sqrt{\frac{Q_{tn}}{k_{DR}}}$$

(applicable only to SBT_n: 5, 6, 7 and 8 or $I_c < I_{c\_cutoff}$)

:: State Parameter, ψ ::

$$\psi = 0.56 - 0.33 \cdot \log(Q_{tn,cs})$$

:: Drained Friction Angle, φ (°) ::

(applicable only to SBT_n: 5, 6, 7 and 8 or $I_c < I_{c\_cutoff}$)

:: 1-D constrained modulus, M (MPa) ::

If $I_c > 2.20$
$\alpha = 14$ for $Q_{tn} > 14$
$\alpha = Q_{tn}$ for $Q_{tn} \leq 14$
$M_{CPT} = \alpha \cdot (q_t - \sigma_v)$

If $I_c \geq 2.20$

:: Small strain shear Modulus, Go (MPa) ::

$$G_0 = (q_t - \sigma_v) \cdot 0.0188 \cdot 10^{0.55 \cdot I_c + 1.68}$$

:: Shear Wave Velocity, Vs (m/s) ::

$$V_s = \left(\frac{G_0}{\rho}\right)^{0.50}$$

:: Undrained peak shear strength, Su (kPa) ::

$N_{kt} = 10.50 + 7 \cdot \log(F_r)$ or user defined

$$S_u = \frac{(q_t - \sigma_v)}{N_{kt}}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Remolded undrained shear strength, Su(rem) (kPa) ::

$S_{u(rem)} = f_s$ (applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Overconsolidation Ratio, OCR ::

$$k_{OCR} = \left[\frac{Q_{tn}^{0.20}}{0.25 \cdot (10.50 \cdot + 7 \cdot \log(F_r))}\right]^{1.25}$$ or user defined

$$OCR = k_{OCR} \cdot Q_{tn}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: In situ Stress Ratio, Ko ::

$$K_O = (1 - \sin\varphi') \cdot OCR^{\sin\varphi'}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Soil Sensitivity, S_t ::

$$S_t = \frac{N_S}{F_r}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Peak Friction Angle, φ' (°) ::

$$\varphi' = 29.5° \cdot B_q^{0.121} \cdot (0.256 + 0.336 \cdot B_q + \log Q_t)$$

(applicable for 0.10<Bq<1.00)

References

• Robertson, P.K., Cabal K.L., Guide to Cone Penetration Testing for Geotechnical Engineering, Gregg Drilling & Testing, Inc., 5th Edition, November 2012

• Robertson, P.K., Interpretation of Cone Penetration Tests - a unified approach., Can. Geotech. J. 46(11): 1337–1355 (2009)

Appendix A

Important Information

morrow

Important Information

This Document has been provided by Morrow Geotechnics Pty Ltd subject to the following limitations:

This Document has been prepared for the particular purpose outlined in Morrow Geotechnics' proposal and no responsibility is accepted for the use of this Document, in whole or in part, in other contexts or for any other purpose.

The scope and the period of Morrow Geotechnics' Services are as described in Morrow Geotechnics' proposal, and are subject to restrictions and limitations. Morrow Geotechnics did not perform a complete assessment of all possible conditions or circumstances that may exist at the site referenced in the Document. The scope of services may have been limited by such factors as time, budget, site access or other site conditions. If a service is not expressly indicated, do not assume it has been provided. If a matter is not addressed, do not assume that any determination has been made by Morrow Geotechnics in regards to it. Any advice given within this document is limited to geotechnical considerations only. Other constraints particular to the project, including but not limited to architectural, environment, heritage and planning matters may apply and should be assessed independently of this advice.

Conditions may exist which were undetectable given the limited nature of the enquiry Morrow Geotechnics was retained to undertake with respect to the site. Variations in conditions may occur between investigatory locations, and there may be special conditions pertaining to the site which have not been revealed by the investigation and which have not therefore been taken into account in the Document. Accordingly, additional studies and actions may be required. No geotechnical investigation can provide a full understanding of all possible subsurface details and anomalies at a site.

In addition, it is recognised that the passage of time affects the information and assessment provided in this Document. Morrow Geotechnics' opinions are based upon information that existed at the time of the production of the Document. It is understood that the Services provided allowed Morrow Geotechnics to form no more than an opinion of the actual conditions of the site at the time the site was visited and cannot be used to assess the effect of any subsequent changes in the quality of the site, or its surroundings, or any laws or regulations.

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