

GEOTECHNICAL ASSESSMENT
PROPOSED PLAN CHANGE
RANGITIKEI LINE AND FLYGERS LINE
PALMERSTON NORTH

Engineers and Geologists



GEOTECHNICAL ASSESSMENT PROPOSED PLAN CHANGE RANGITIKEI LINE AND FLYGERS LINE, PALMERSTON NORTH

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GEOTECHNICAL ASSESSMENT PROPOSED PLAN CHANGE RANGITIKEI LINE AND FLYGERS LINE, PALMERSTON NORTH

1.0 Introduction

Riley Consultants Ltd (RILEY) has prepared the following report at the request of Resonant Consulting Limited (RCL) on behalf of Flygers Line Investment Group Limited. This geotechnical assessment has been prepared as part of an overall submission to Palmerston North City Council (PNCC) to rezone the existing rural site as residential land.

Our brief has not included potential flooding hazards. A ground contamination investigation has also been carried out on this site as part of the proposed plan change submission (RILEY Ref:170672-B, dated 13 February 2019).

2.0 Scope of Work

The scope of work has included the following main elements:

- Desktop review of historical aerial photographs, data available from the New Zealand Geotechnical Database (NZGD), and the GNS report for Palmerston North¹.
- Subsurface geotechnical investigations including 12 cone penetrometer tests (CPT), three machine boreholes, and three standpipe piezometers. Shallow hand auger boreholes, drilled as part of the ground contamination investigation, also give additional information.
- Laboratory testing of selected samples recovered from the machine boreholes to assist interpretation.
- Assess the extent of liquefaction susceptibility and associated risks to the proposed residential land.
- Comment on options for mitigation measures where required for future development.
- Assess any other geotechnical hazards that may have an impact on residential development.

3.0 Site Description

The site proposed for re-zoning, legally described as Lots 1 and 2 DP 389924, is located beyond the present northern urban limit of Palmerston North and is bordered by Flygers Line, Rangitikei Line, residential housing to the south-east, and rural farmland to the south-west. Aerial photography and LiDAR data show that the site is relatively flat with a stream running north to south through the middle of the site. The site is currently used as farmland and cropping.

¹ Assessment of liquefaction and related ground failure hazards in Palmerston North, New Zealand. GNS Science Consultancy Report 2011/108 July 2011.





4.0 Geology

From a review of the 1:250,000 Geological Map, together with our experience of the surrounding area, we infer that the site is underlain by Holocene river deposits comprising gravel, sand, silt, mud, and clay with local peat. A review of the New Zealand Geotechnical Database (NZGD) yielded no investigations within the site itself, but a few deep wells just outside the site boundaries are shown in the GNS report.

5.0 Geotechnical Investigations

To assess the subsurface conditions, 12 CPTs were carried out on 29 June 2018 to a maximum depth of 6.5m where practical refusal was reached in all tests. A tractor rig supplied and operated by Geotech Drilling Limited (Geotech Drilling) was used to push the CPTs.

Initial analyses of the shallow CPTs indicated moderate liquefaction potential, therefore, a further three machine holes (MH1 to MH3) were drilled on 16 January 2019 to depths of 10m to 15m where the target depth was reached. Material recovered from the boreholes were logged in accordance with the NZGS Guideline for the Field Classification and Description of Soil and Rock for Engineering Purposes. In-situ standard penetrometer testing (SPT) was carried out at 1.5m intervals. Standpipe piezometers were installed in each machine hole targeting depths between 6m and 15m. A sonic rig supplied and operated by Geotech Drilling was used to drill the machine holes.

14 hand auger boreholes were drilled to a maximum depth of 1m as part of the ground contamination investigation and are summarised in the Preliminary and Detailed Site Investigation Contaminated Land report (RILEY Ref:170672-B, dated 13 February 2019).

The machine hole, CPT, and hand auger borehole locations are shown on RILEY Dwg: 170672-1, attached, and machine hole, hand auger, and CPT logs are included within Appendix A.

6.0 Laboratory Testing

Laboratory testing was undertaken by Opus Laboratory on a sample selected from MH3. Atterburg Limit tests were carried out to provide a comparison to soil type from descriptions and inferred from CPT tests. Further testing was not considered necessary because the soil types from CPT and machine hole logs were consistent.

Results of the Atterburg Limit test gives a liquid limit of 69 and a plasticity Index of 42, which plots on the Casagrande Plasticity Chart as a highly plastic, inorganic, non-dilatant clay (CH). This soil can, therefore, be classified as non-liquefiable. Laboratory test results are presented within Appendix B.

7.0 Results of Subsurface Investigation

Subsoil conditions typically comprise firm sandy and clayey silts and sands from the surface to approximately 5m below ground level (bgl) to 7m bgl, where very dense gravels were encountered and on which the CPTs terminated. The machine boreholes below this depth largely encountered gravels with lenses of stiff clayey silt and very dense sandy gravel in places.

Subsoil conditions encountered at the test locations are summarised below and detailed descriptions of the soils encountered during drilling are given on the appended logs.

Table 1: Geological Model

Layer no.	Geological Unit	Description	Depth to top of layer (m)	Layer thickness (m)	Typical SPT 'N' value	Typical CPT tip resistance qc (MPa)
1	Topsoil	Brown, trace fine rootlets.	0	0.15 to 0.2	N/A	
2	Holocene River Deposits	Silt/sandy silt; dark grey. Firm, wet to saturated, moderately plastic.	0.15 to 0.2	4.3 to 4.35	18, 6, 3, 4	1 to 12
3	Holocene River Deposits	Silt/clayey silt; light bluish grey. Very soft, saturated, moderately plastic.	4.5	0.8 to 1.4	0, 1	0 to 2
4	Holocene River Deposits	Fine to medium gravel and fine to coarse sand; dark grey. Very dense, rounded, well graded.	5.3 to 5.9	4.1 to 6.0	50+	10 to 35, 20+, 10 to 30
5	Holocene River Deposits	Clayey silt/silt; grey. Stiff, slightly to moderately plastic.	9.4 to 11.9	1.6 to 2.1	15, 10, 15	
6	Holocene River Deposits	Silty sandy gravel; grey. Very dense, rounded.	11+ to 14	1.35+	50+	

The ground conditions encountered during the investigation are broadly consistent with published local geological maps. Groundwater was encountered between 3.0m and 4.2m bgl in the machine boreholes during January, and groundwater was measured after each CPT in June between 0.9m and 1.9m bgl. The shallow hand auger boreholes also encountered groundwater between 0.8m and 0.9m bgl.

8.0 Geotechnical Considerations

8.1 Depth to Groundwater

Groundwater was measured between 3.0m bgl and 4.2m bgl in the machine holes during January 2019 and between 0.8m and 1.9m bgl following each CPT and hand auger borehole carried out in June 2018. Groundwater levels are likely to vary seasonally and following rainfall events. A groundwater level of 4m bgl was mapped in the GNS report for Palmerston North.

8.2 Liquefaction Potential

8.2.1 Seismic Site Classification

The seismic loading induced on a structure will depend on, amongst other factors, the stiffness of the underlying soil/rock where the structure is located. Sites with low strength deep soils can amplify ground accelerations, requiring the structures built on them to resist a higher seismic coefficient. The New Zealand Structural Design code, NZS 1170.5:2004: Earthquake Actions, contains response spectra for structural design. Sites are categorised into five classes, Classes A to E. The site classes range from rock sites, Class A and B, to very soft or deep soil sites, Class E. These categories are used in structural design analysis.

A review of the machine hole logs and CPT data indicates that depths of firm to stiff sandy silts and very dense gravels encountered in the machine holes and CPTs did not exceed the maximum depth limits for site subsoil Class C (refer Table 3.2 in NZS 1170.5:2004), however, refusal in gravels does not discount the possibility of the site being classed as subsoil Class D. Therefore, the site is conservatively identified as category **Class D** (deep soil sites) for the purposes of our liquefaction assessment.

8.2.2 Methodology

Liquefaction can occur in saturated loose to medium dense cohesionless deposits (silts and sands) in moderate to severe ground shaking. Geologically, recent materials or very weak man-made fills are the most susceptible soils. Effects on structures and subdivision infrastructure such as roads and services include; lateral spreading, settlement, loss of support, and other effects such as flotation. The steps in the liquefaction assessment are as follows:

- Review the range of soils encountered for susceptibility on a qualitative basis.
- Analytical assessment of the CPT data using GeoLogismiki v.2.1.6.7.
- The methods are based on the latest methodology from the NZGS and Ministry of Business, Innovation and Employment (MBIE) Guidelines, developed after the Canterbury earthquake sequence, with the most up to date guidance published in 2016.
- The CPT is generally regarded within the industry as the most reliable method of testing potential liquefiable materials. The ground motion parameters are based on the following:
 - 500-year return period shaking for Ultimate Limit State (ULS).
 - o Class D (deep soil).
 - Magnitude 6.9 earthquake (ULS), 6.1 Servicability Limit State (SLS).
- For the purposes of the liquefaction analyses presented in this report, a depth to groundwater of 1.0m bgl has been used.

The resulting peak ground acceleration for liquefaction analysis is 0.34g for ULS, and 0.09g for SLS using the latest MBIE guidance (2016), MBIE Module 1: Method 1, New Zealand Transport Agency Bridge Manual Addendum 6A.

8.2.3 Results

A qualitative assessment of each individual CPT investigation point has been made in terms of liquefaction susceptibility. Potentially liquefiable materials were identified within the upper 6.0m of the soil profile, comprising discrete layers of loose to medium dense sandy silt, or silty sand. The dense to very dense gravels encountered below 6m depth are not likely to liquefy. Table 2 shows the assessed thickness of any potentially liquefiable zones (i.e. saturated loose to medium dense materials) at each investigation location within alluvium and the corresponding settlement (for the SLS case of 0.09g and ULS case of 0.34g). Results from the liquefaction assessment are attached in Appendix C.

Table 2: Results of Liquefaction Assessment for ULS and SLS Event

CPT Location	CPT Depth (m)	Depth Interval of Potentially Liquefiable Soils (m)	SLS Vertical Settlement (mm)	ULS Vertical Settlement (mm)	Technical Category
1	4.8	1.0 to 1.1, 1.7 to 1.9, 2.1 to 3.4, and 3.7 to 4.5	2.5	94	TC2
2	6.1	1.0 to 2.4, 2.5 to 3.6, 3.7 to 4.3, and 4.8 to 5.7	1.5	119	TC2/3
3	5.7	1.3 to 1.5, 2.6 to 3.8, 4.2 to 4.6, and 5.5 to 5.6	2.5	80	TC2
4	4.1	1.0 to 2.2 and 2.6 to 2.9	0	39	TC2
5	5.6	1.0 to 1.2, 2.0 to 2.2, 2.6 to 3.2, 3.4 to 4.4, and 4.7 to 5.1	2.5	85	TC2
6	5.6	1.0 to 1.7, 2.0 to 2.2, 3.3 to 4.9, and 5.2 to 5.5	4	79	TC2
7	6	1.5 to 2.0, 4.2 to 4.9, and 5.2 to 6.0	2.5	71	TC2
8	5.3	3.4 to 3.7 and 4.0 to 4.4	0	24	TC2
9	5.7	2.2 to 3.7, 4.0 to 4.6, and 5.1 to 5.6	1.5	84	TC2
10	6.5	2.0 to 3.1, 4.5 to 5.2, and 5.7 to 6.5	2.5	92	TC2
11	5.7	1.0 to 1.5, 2.6 to 2.7, 3.2 to 3.3, 3.6 to 5.0, and 5.5 to 5.6	1	69	TC2
12	1.9	1.0 to 1.6 and 1.7 to 1.8	0	17	TC1

The assessed liquefied soils are within the upper Holocene River Deposits, typically described as loose to medium dense sandy silt, or silty sand. Overall, the thickness of liquefied soils for the SLS event is negligible, and several metres for the ULS event. Associated settlements are less than 15mm for the SLS event and less than 100mm (with one exception) for the ULS design seismic event. Liquefaction induced settlements in the order of 20mm to 100mm should be anticipated under the ULS event.

The liquefaction severity number (LSN) is a parameter based on investigation data, and considers the potential for liquefaction and the depth at which liquefaction occurs. This parameter has been correlated with evidence of surface ground damage in Christchurch. The LSN calculated for this site is typically between 20 and 30 (up to 45 in CPT2) and generally indicates moderate expression of liquefaction, sand boils, and minor damage to ground surface as well as minor differential settlement of structures.

The GNS Report for Palmerston North describes the low-lying materials of Holocene age, particularly saturated loose sands and silts, to be most likely to liquefy. The geological map categorises the site in the moderate to high liquefaction category for ground damage potential, however, it is noted that further subsurface information and assessment is required to determine material thicknesses and groundwater levels.

Based on the geotechnical investigation and the assessment undertaken for this site, in accordance with MBIE guidance, the site has a predicted future land performance **consistent with TC2**. We note that the MBIE guidance is for residential sites in Christchurch, however in the absence of any other available guidance, the MBIE guidelines are considered a suitable approach for this assessment.

Liquefaction presents a hazard to urban infrastructure in addition to dwellings (i.e. roads, buried services etc). This should be taken into account in infrastructure development.

8.3 Lateral Spreading

Lateral spreading may occur if a continuous horizon of liquefied soil is present. Free-face lateral spreading conditions may occur when liquefiable layers are continuous to a stream bank. The nearest free-face is adjacent to any of the streams or drainage ditches running through or close to the site. The main stream has an estimated free-face height of 2.5m located in the south-west area of the site and drainage ditches also just beyond the northern boundary (alongside Flyers Line) and in the centre of the site running approximately east to west. For conventional residential dwellings and land to be categorised as TC2 land for residential dwellings, up to 100mm of lateral stretch under the ULS event is considered acceptable and 50mm in the SLS event.

Empirical methods used to evaluate lateral spreading displacements for this site produced highly varying results with corresponding required setback distances exceeding 100m. As a comparison, MBIE have recommended various fallback setback distances from a free-face for TC3 sites in Christchurch (minor to moderate movement of less than 300mm). These distances range from 50m for typical watercourses to 100m to 200m for the Avon and Heathcote rivers. Given that the soil conditions at this site are in the TC2 category compared to the much more severe TC3 category, significantly less deformation would be expected, but this is balanced by the TC2 deformation limit of 100mm. Based on this approach, a setback distance in the order of 50m could be justified, but dwellings would need to be designed to a higher foundation standard of TC3. We note, however, such an approach may not be desirable for a new development. The options to mitigate the hazard include the following:

- 1. Ground improvement, which may be costly on a large-scale (allowing for a TC2 type foundation).
- 2. Utilise TC2 type foundations with appropriate setback i.e. without ground improvement (the setback distance requires refinement but could be considerable).
- 3. Utilise TC3 type foundations with a lesser setback than Option 2.

It should be noted that negligible liquefaction is predicted in the SLS event and the lateral spreading risk is correspondingly low. Also, there is a wide variability in seasonal groundwater levels, which also influences the lateral spreading risk. We recommend that further investigations surrounding stream banks and other free-faces are carried out to gain a more accurate prediction of lateral spreading displacements for this site and further develop options to mitigate the hazard.

9.0 Other Geotechnical Constraints

Land across the site is generally flat, therefore, the risk of slope instability is considered to be negligible.

Previously infilled streams will need to be investigated further to define the extent and nature of the material used for infilling. There may be a risk of settlement due to historic filling in these areas depending on the material used for infilling. The scale of these features is small relative to the size of the site and potentially only localised to these areas. It has been noted that none of the shallow hand augers encountered any obvious fill material.

10.0 Conclusions

From the site investigation, subsoil conditions comprise Holocene river deposits described as firm sandy and clayey silts and sands from the surface to approximately 5m bgl to 7m bgl, where very dense gravels were encountered.

An assessment of the site and subsoil conditions was carried out to determine the geotechnical risks present. These risks include liquefaction, lateral spreading, and slope instability. Since the site is generally flat, the risk of slope instability is considered to be negligible. However, the site is susceptible to liquefaction induced settlements and lateral spreading during future earthquake events.

Our liquefaction assessment predicts the upper loose river deposits to have negligible risk of liquefaction following an SLS event and 20mm to 100mm of liquefaction induced settlement under the ULS event. This corresponds to a predicted future land performance **consistent with TC2** and generally indicates moderate expression of liquefaction, sand boils, and minor damage to ground surface as well as minor differential settlement of structures. Foundations for new buildings in these areas are likely to be TC2 type foundations.

The risk of lateral spreading following an SLS event is considered to be negligible, however, under a ULS event the amount of lateral displacement varies significantly. Additional geotechnical investigations and assessments, tailored to the specific development, are recommended surrounding stream banks and other free-faces to gain a more accurate prediction of lateral spreading displacements for this site and further develop options to mitigate the hazard. In any event, we expect that with appropriate mitigation measures the site should be suitable for residential development from a geotechnical perspective, subject to the recommendations outlined in this report.

11.0 Limitation

This report has been prepared solely for the benefit of Flygers Line Investment Group Ltd as our client with respect to the brief and Palmerston North City Council in processing the plan change. The reliance by other parties on the information or opinions contained in the report shall, without our prior review and agreement in writing, be at such parties' sole risk.

Recommendations and opinions in this report are based on data from limited test positions. The nature and continuity of subsoil conditions away from the test positions are inferred, and it must be appreciated that actual conditions could vary considerably from the assumed model.

During excavation and construction, the site should be examined by an engineer or engineering geologist competent to judge whether the exposed subsoils are compatible with the inferred conditions on which the report has been based. It is possible that the nature of the exposed subsoils may require further investigation and the modification of the design based upon this report.

Riley Consultants Ltd would be pleased to provide this service to Flygers Line Investment Group Ltd and believes the project would benefit from such continuity. In any event, it is essential Riley Consultants Ltd is contacted if there is any variation in subsoil conditions from those described in the report as it may affect the design parameters recommended in the report.

APPENDIX A

CPT, MH, and HA Investigation Logs



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Auckland:

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GEOTECHNICAL AND **GEOLOGICAL INFORMATION**

SOIL TYPES AND SYMBOLS



FILL





TOPSOIL

SILT SAND

GRAVEL

CLAY

PEAT

GROUNDWATER LEVEL

10,11,10

SCALA PENETROMETER LAST 3 NUMBER OF BLOWS PER 50mm INCREMENT

ROCK TYPES AND SYMBOLS



SANDSTONE



BASALT



SILTSTONE



TUFF



MUDSTONE



IGNIMBRITE



GREYWACKE

SOIL STRENGTH CLASSIFICATION

FINE GRAINED COHESIVE SOILS

TERM	FIELD IDENTIFICATION	UNDRAINED SHEAR STRENGTH (KPa)
Very Soft (Vs)	Exudes between fingers when squeezed.	<12
Soft (S)	Easily indented by fingers.	12 – 25
Firm (F)	Indented only by strong finger pressure.	25 - 50
Stiff (St)	Indented by thumb pressure.	50 - 100
Very Stiff (VSt)	Indented by thumbnail.	100 - 200
Hard (H)	Difficult to indent by thumbnail.	200+

SPT & SCALA PENETROMETER RESULTS

TERM	SPT VALUE No. of BLOWS/300mm	SCALA PENETROMETER No. of BLOWS/100mm
very dense	>50	17+
dense	30 - 50	7 – 17
medium dense	10 - 30	3 - 7
loose	4 - 10	1 - 3
very loose	0 - 4	0 - 2

ROCK STRENGTH CLASSIFICATION

TERM	1	FIELD IDENTIFICATION	UNCONFINED UNIAXIAL COMPRESSIVE STRENGTH (MPa)
Extremely weak	(EW)	Indented by thumbnail.	< 1
Very weak	(VW)	Crumbles under firm blows wit point of geological hammer. Can be peeled with pocket kni	
Weak	(W)	Difficult to peel with pocket kr	nife. 5 – 20
Moderately strong	(MS)	Cannot be scraped or peeled with pocket knife.	20 - 50
Strong	(S)	More than one blow of geologi hammer to fracture.	ical 50 - 100
Very strong	(VS)	Many blows of geological hammer to break.	100 - 250
Extremely strong	(ES)	Can only be chipped with geological hammer.	250+

MOISTURE CONDITION

Dry (D)	Looks and feels dry; powdery and friable.
Moist (M)	Feels cool; darkened in colour; no free water when remoulded.
Wet (W)	Feels cool; darkened in colour; free water forms on hands.
Saturated (S)	Free water is present on sample.

SAMPLE TYPES

UNDISTURBED



DISTURBED

HAND AUGER DISTURBED

(solid cone)



STANDARD PENETRATION TEST



STANDARD PENETRATION TEST (hollow cone)

DRILLING METHOD

OB OPEN BARREL TT TRIPLE TUBE WB WASH BORE UNDISTURBED SH SHELBY TUBE RC ROCK CORE

STANDARD

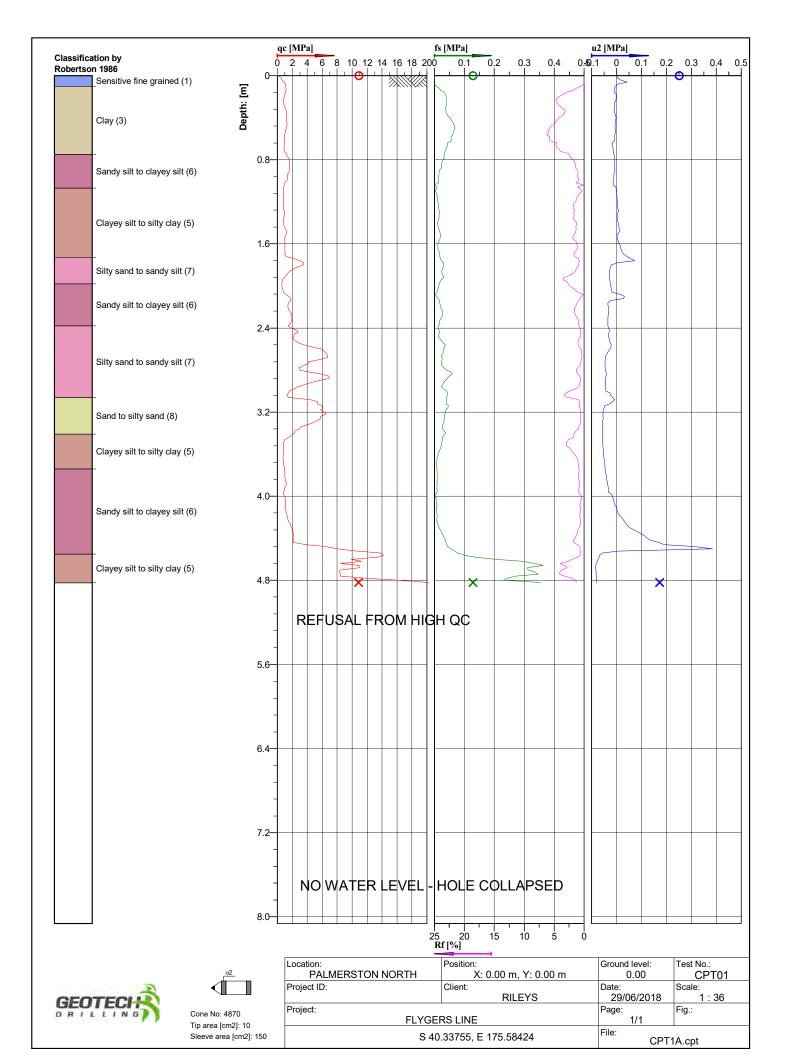
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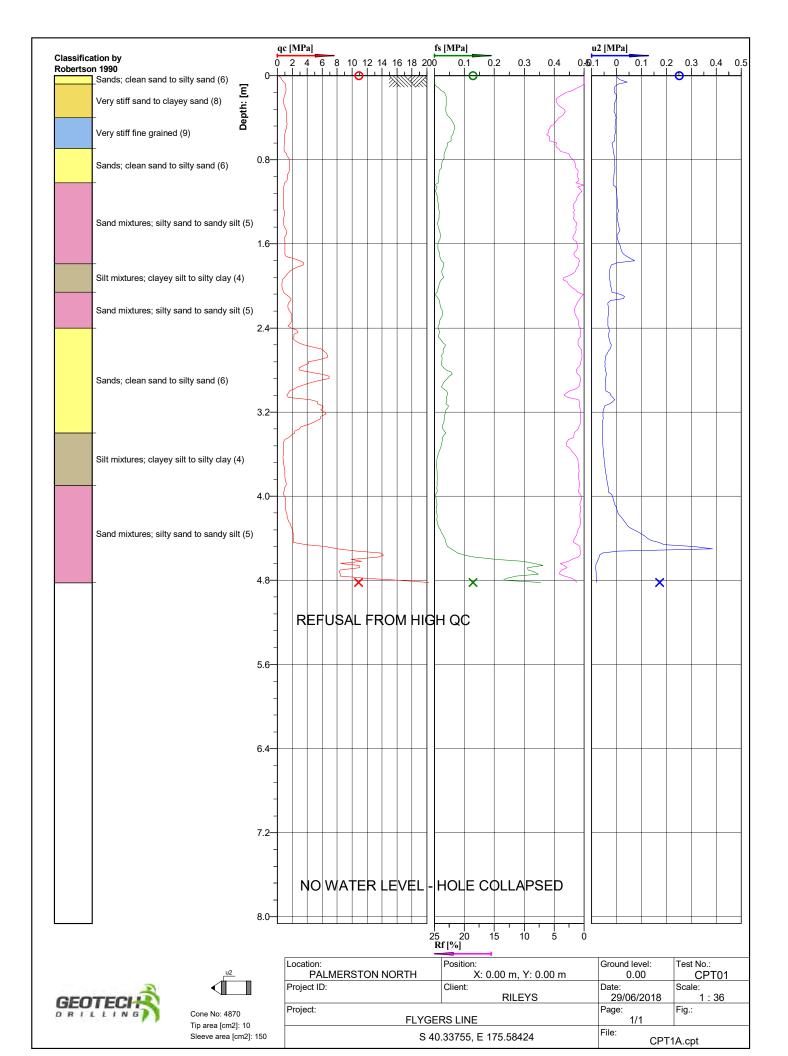
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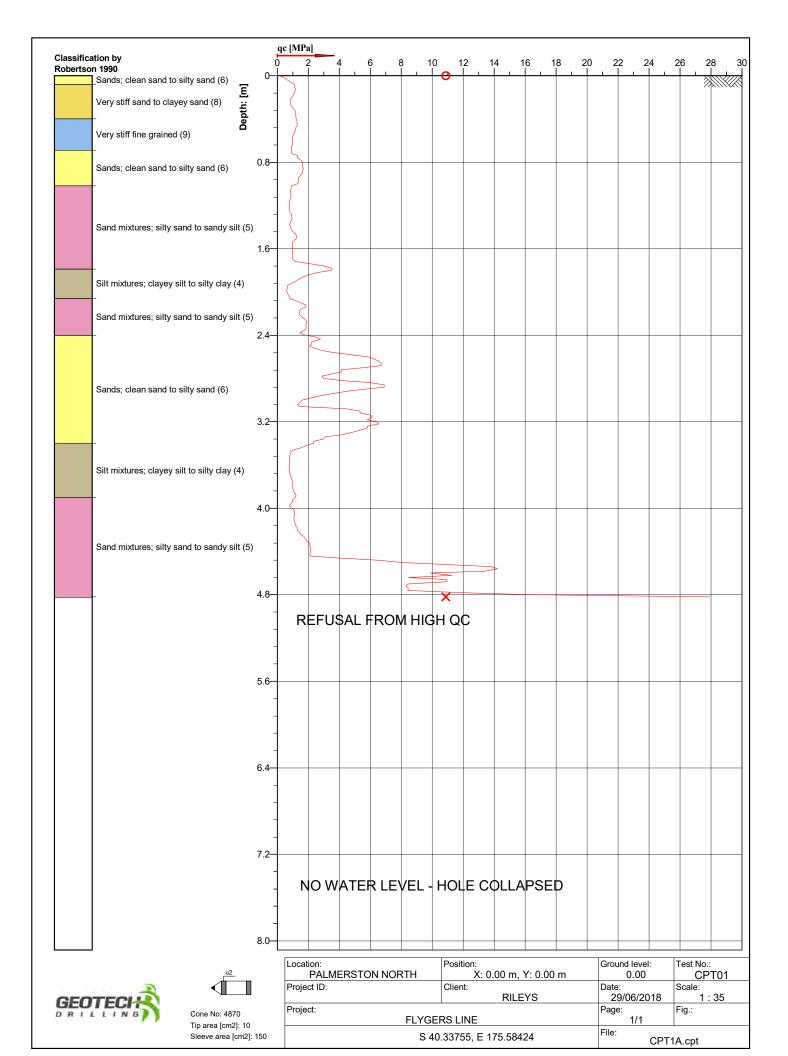
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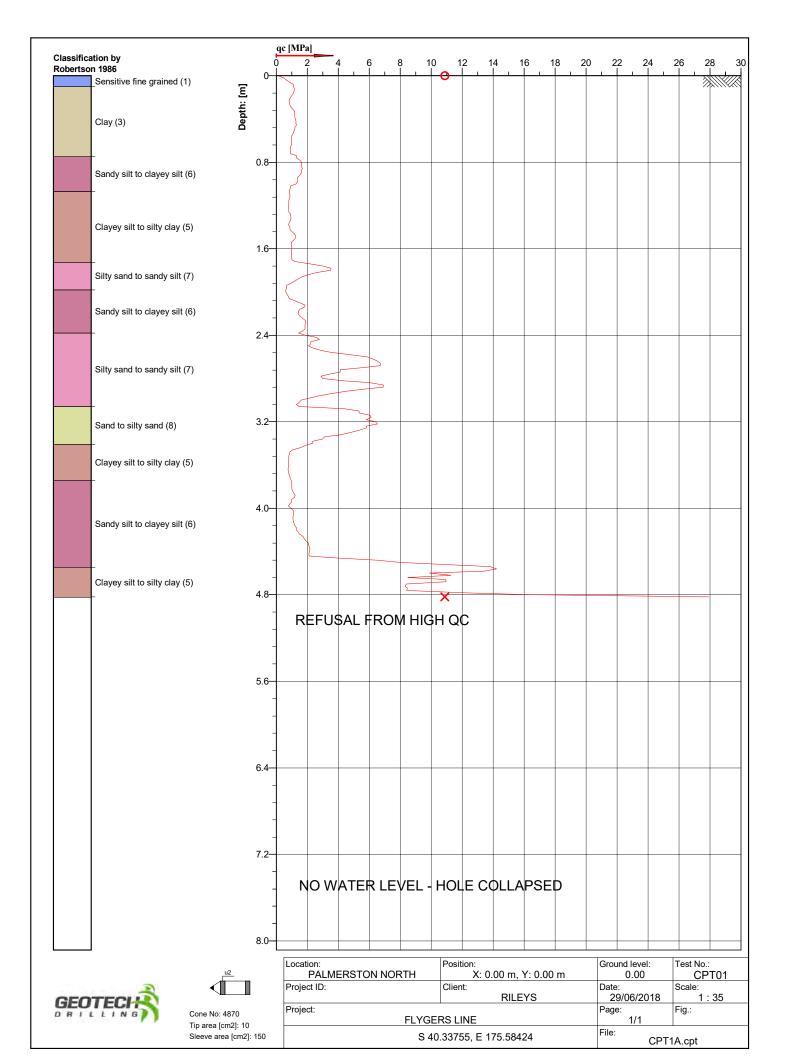
V SHEAR VANE (corrected to BS:1377) R REMOULDED STRENGTH Ρ POCKET PENETROMETER CH CLEGG HAMMER

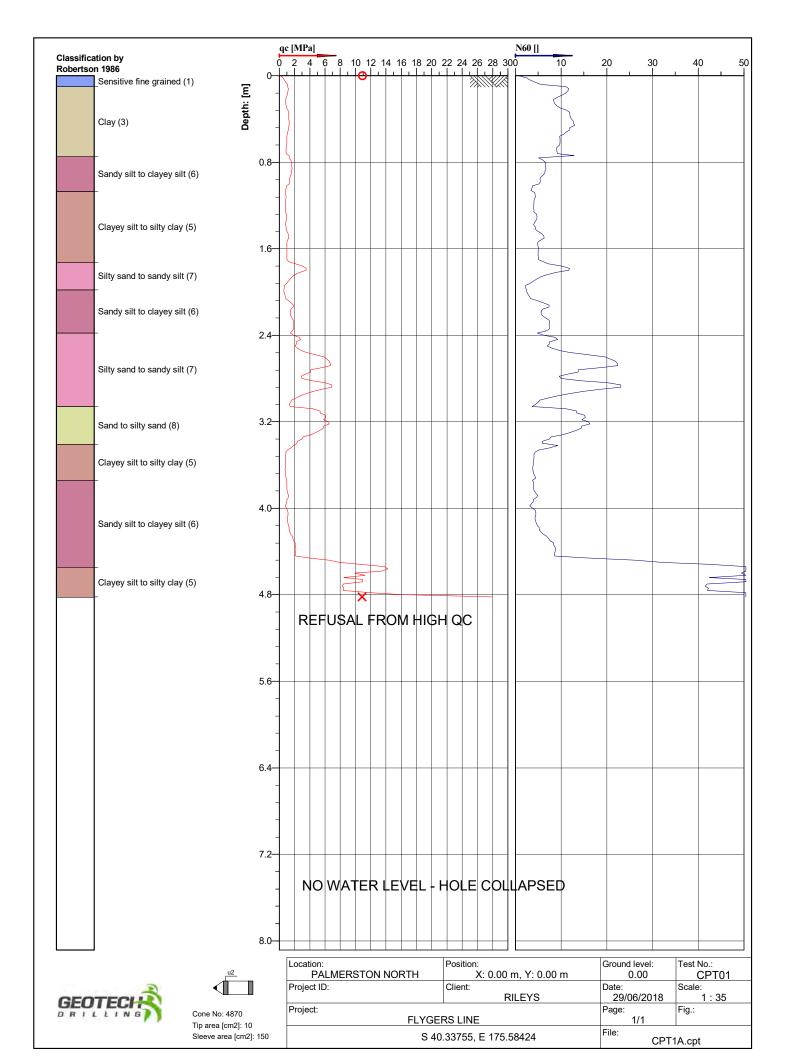
INFORMATION BASED ON THE NZ GEOTECHNICAL SOCIETY INC. GUIDELINES FOR THE CLASSIFICATION AND DESCRIPTION OF SOIL AND ROCK FOR ENGINEERING PURPOSES

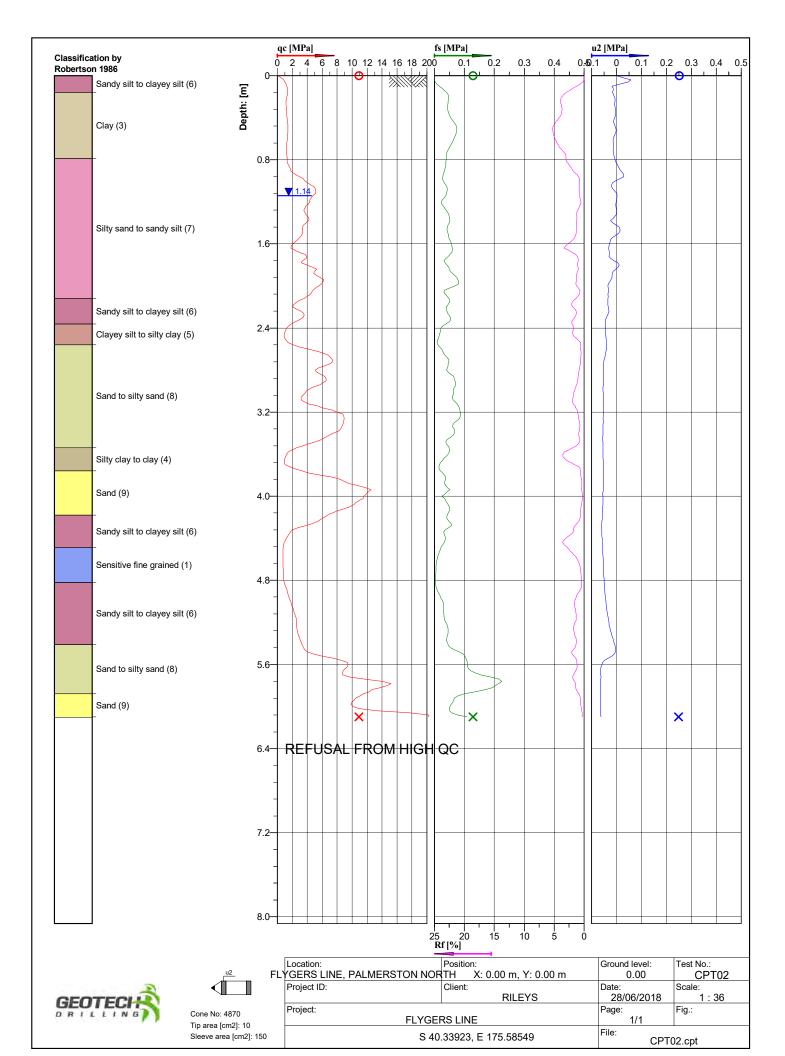


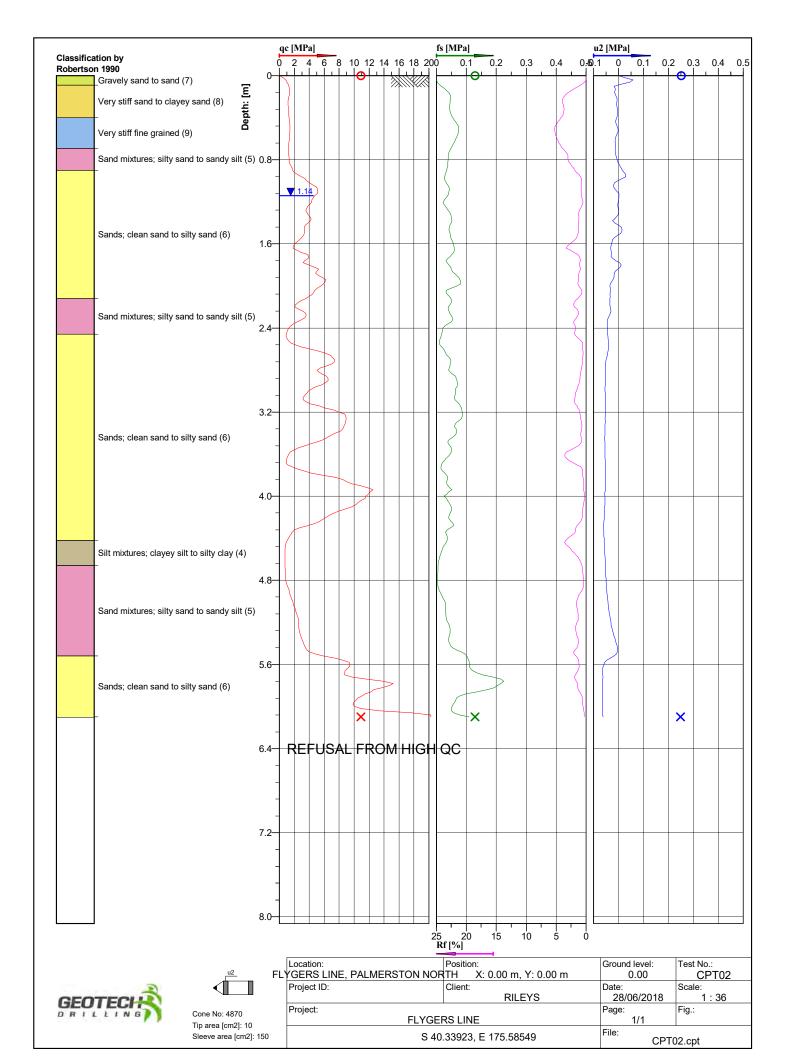


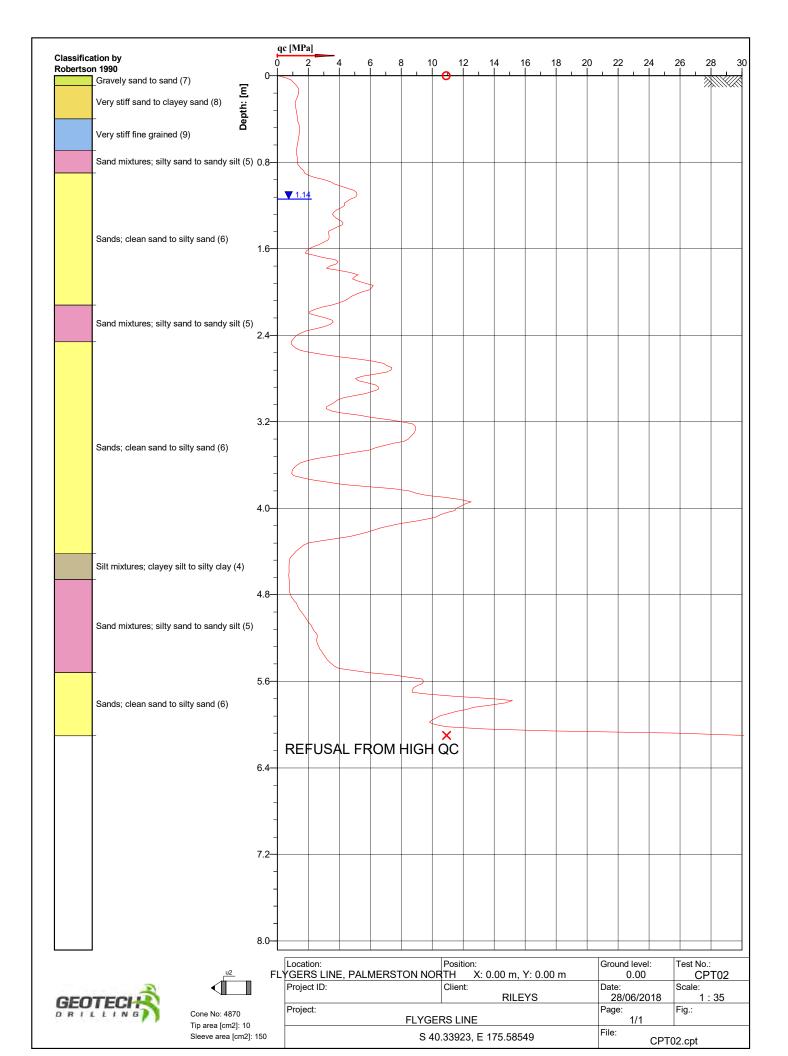


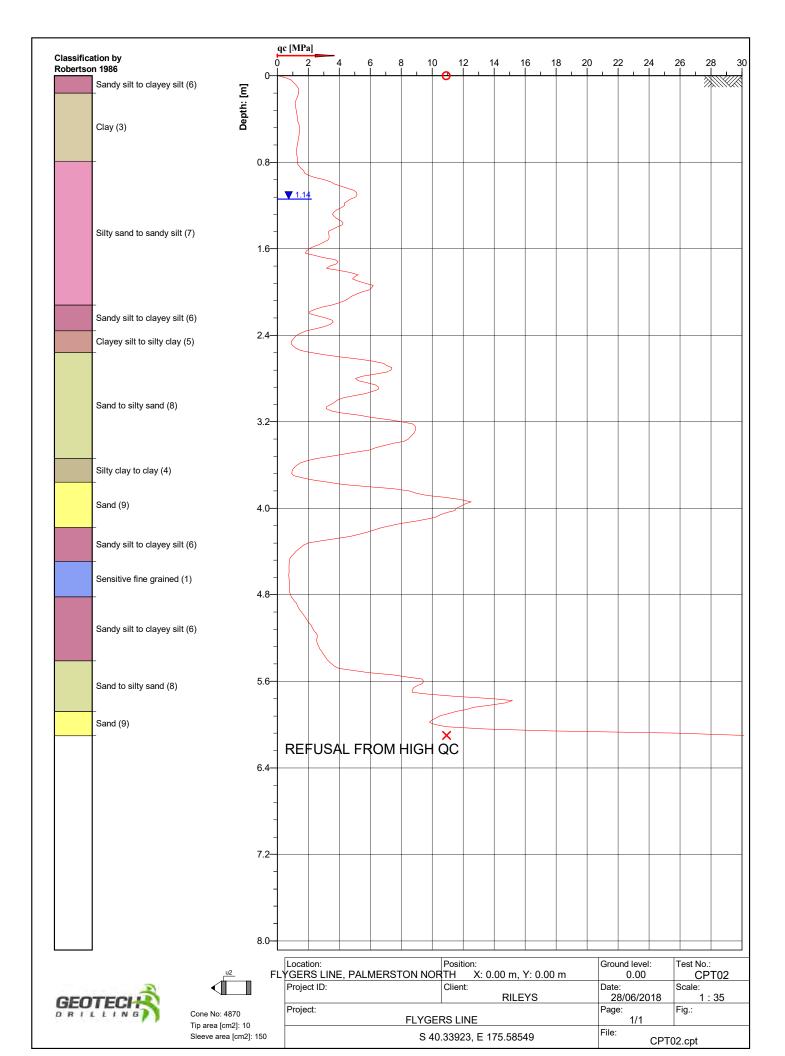


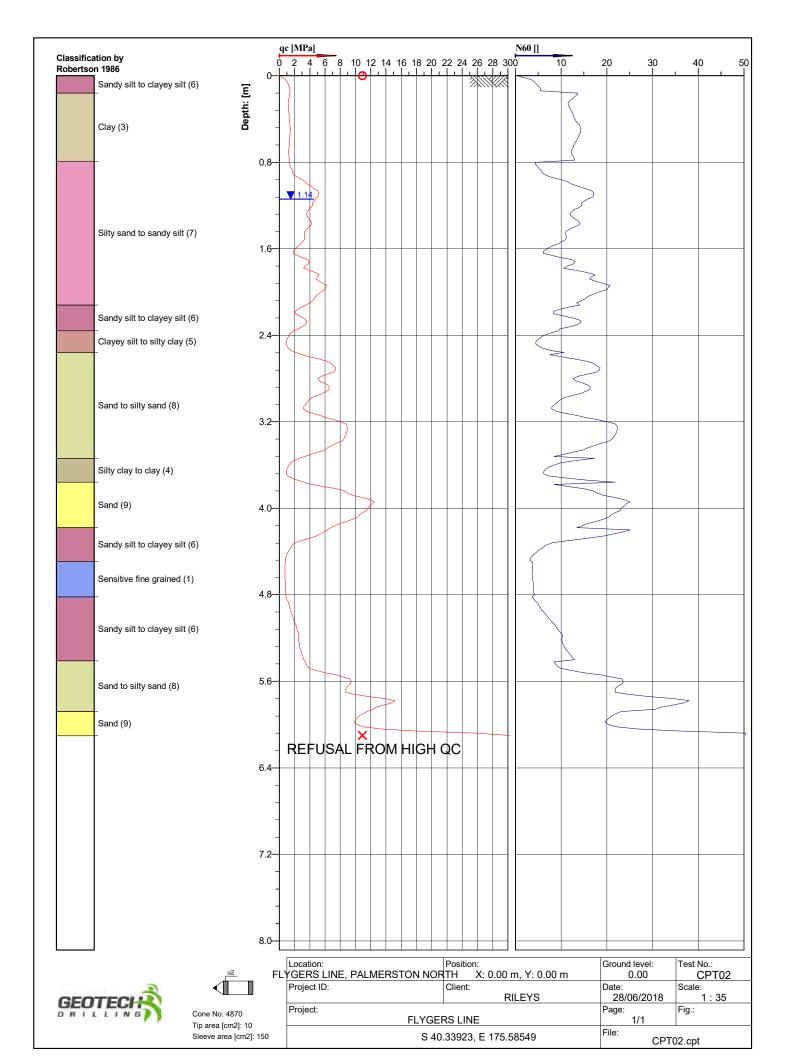


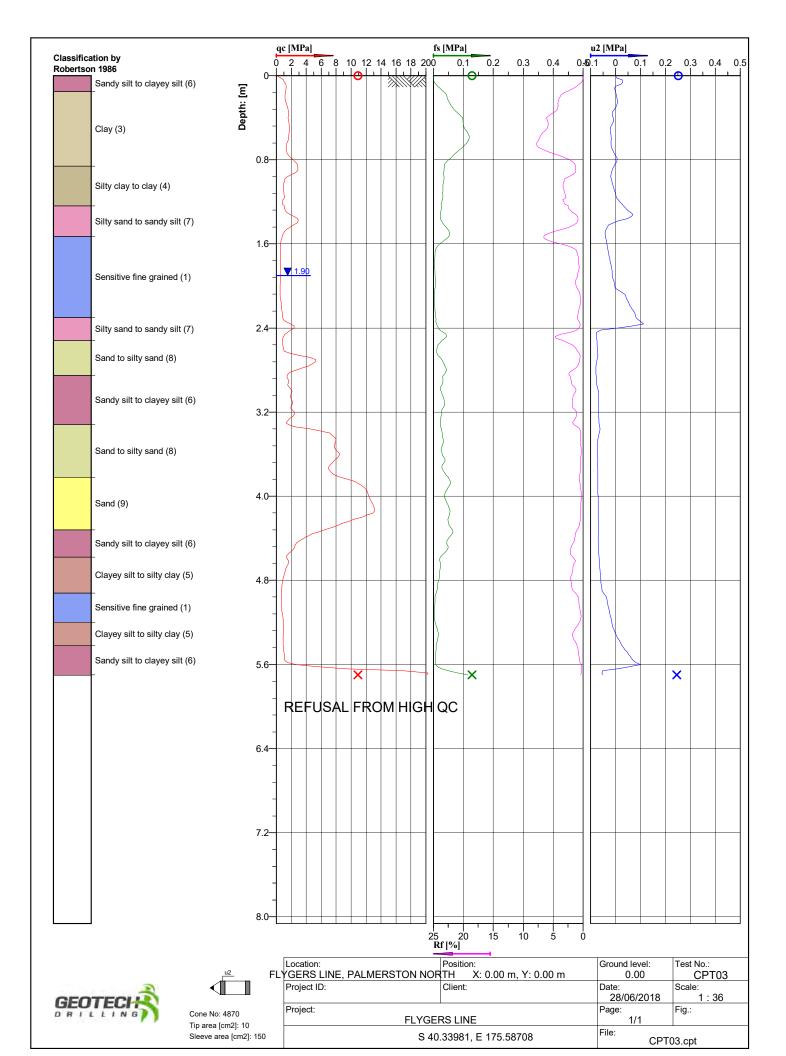


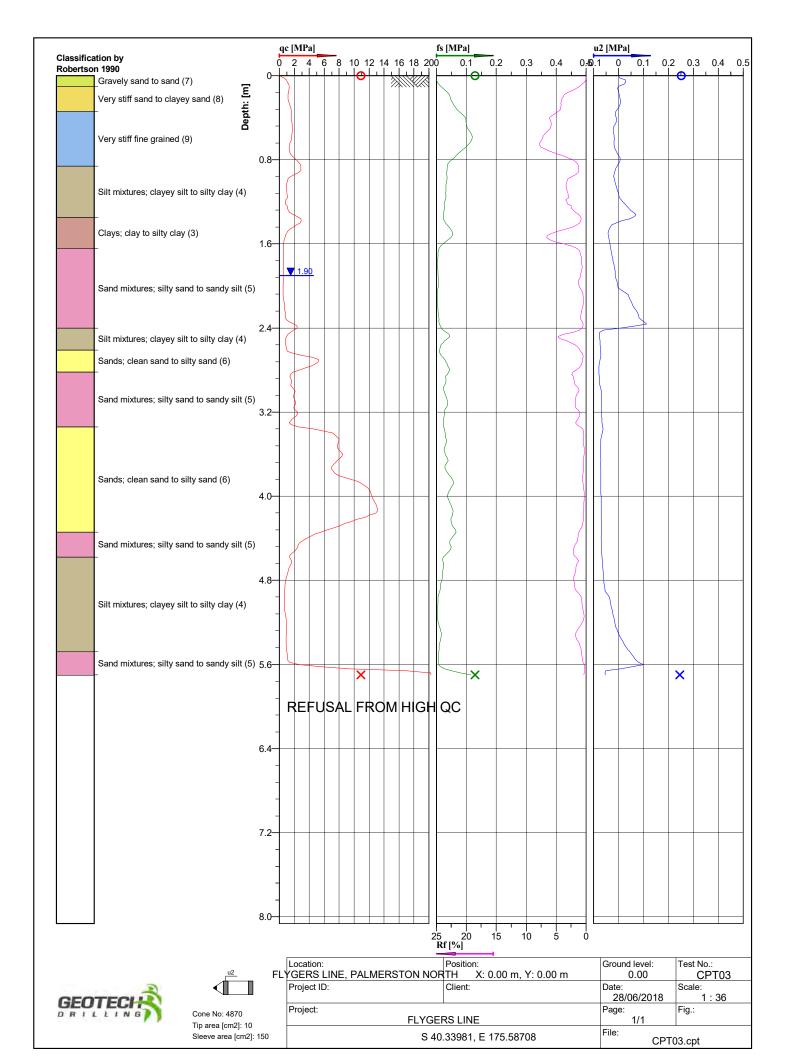


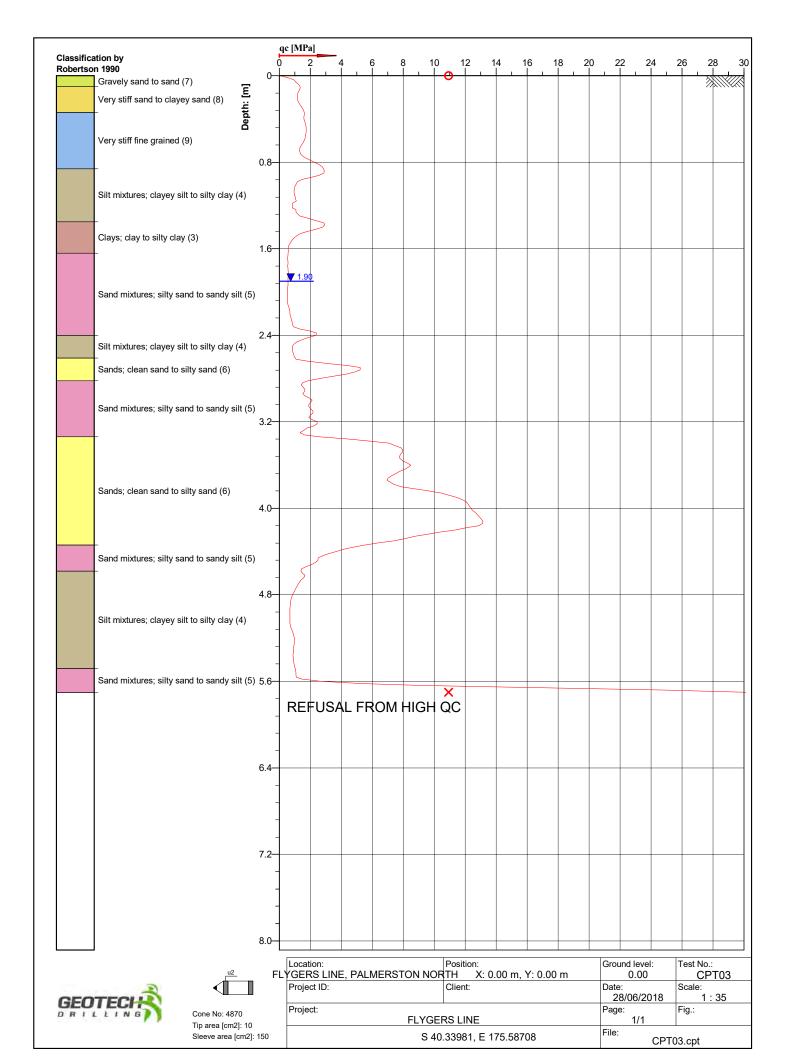


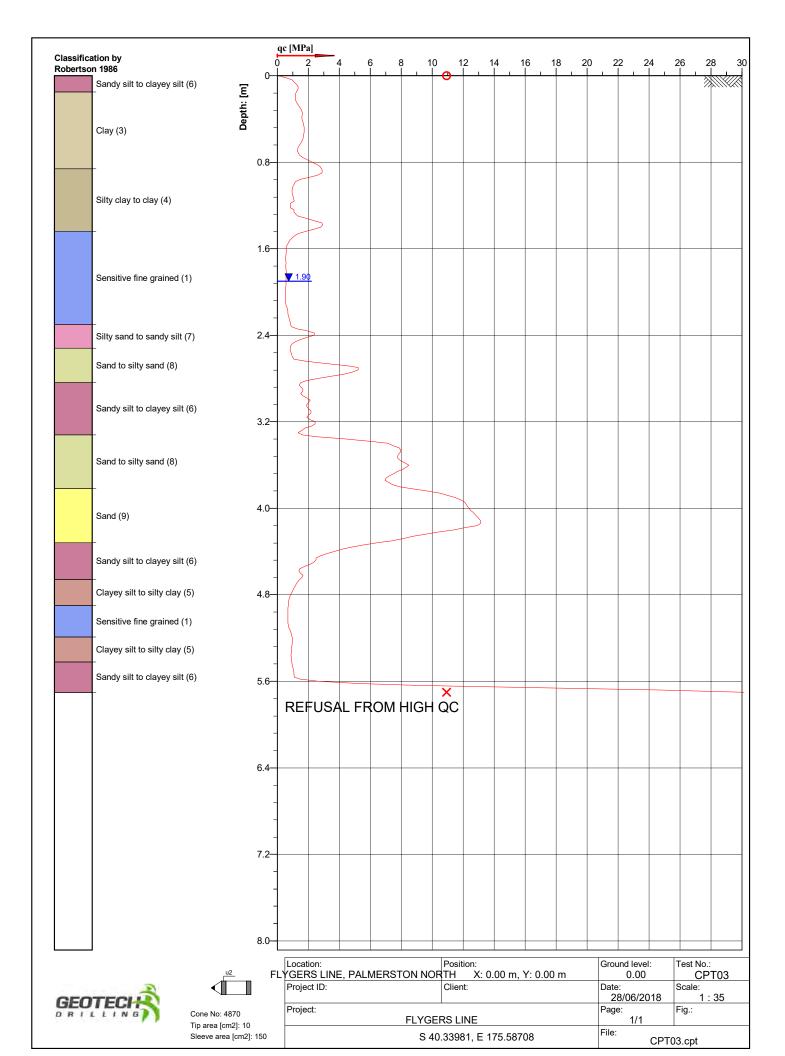


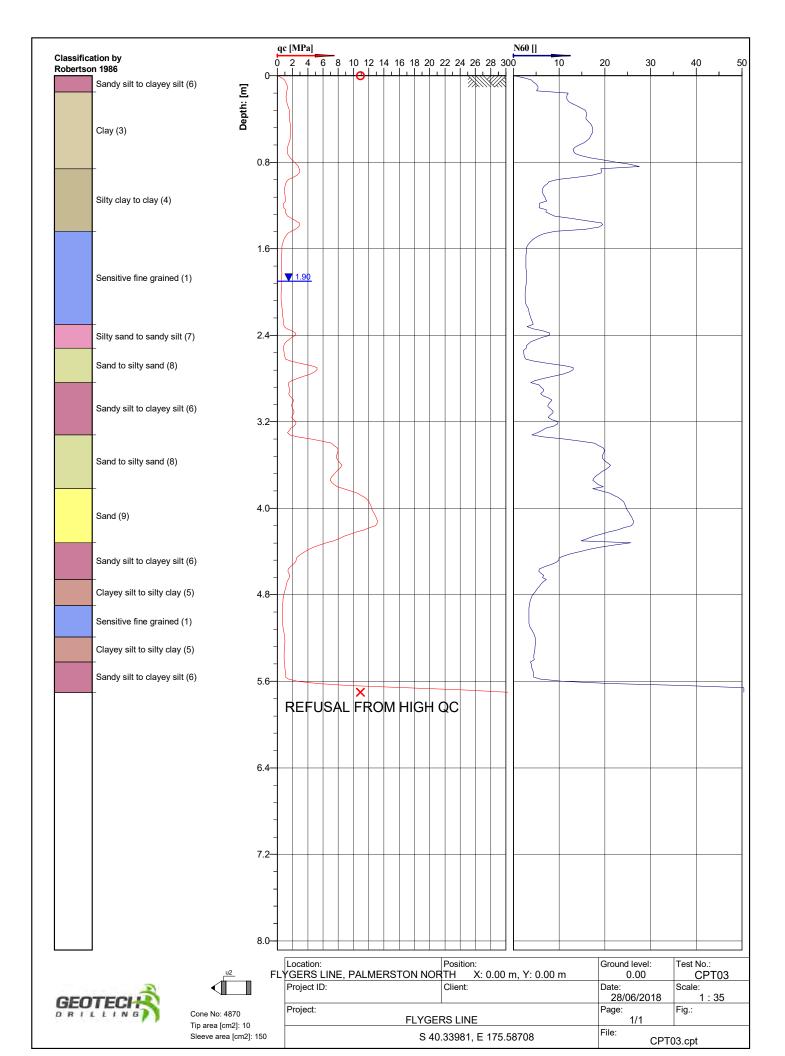


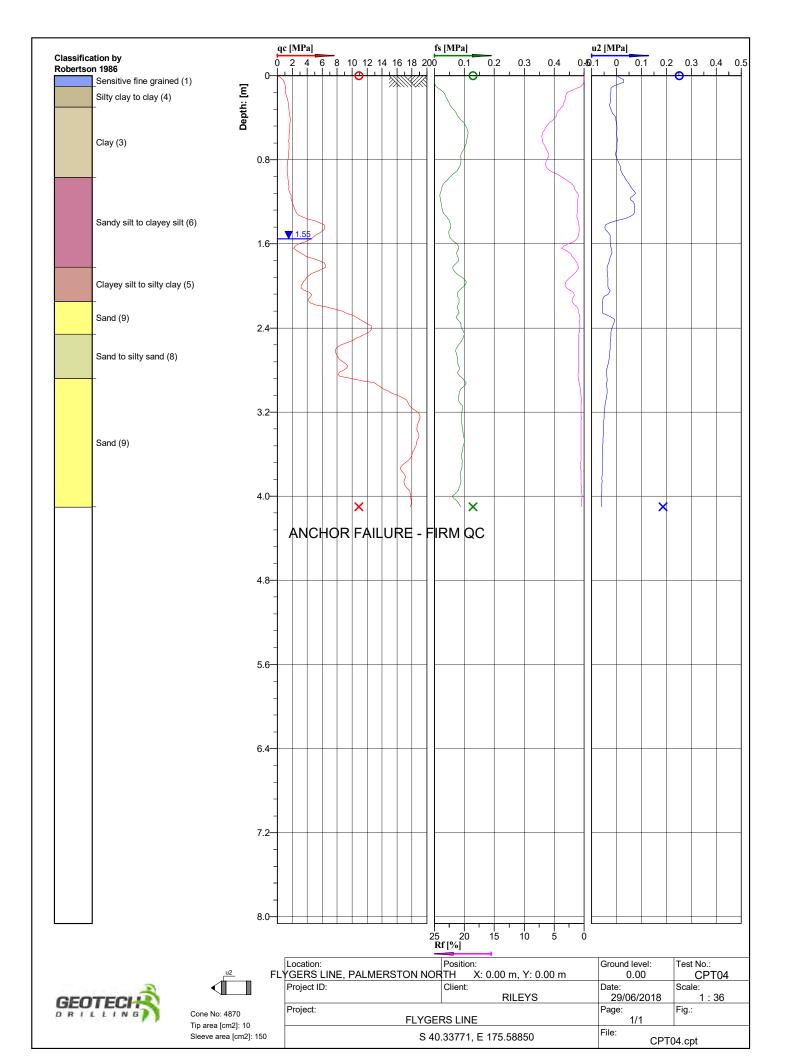


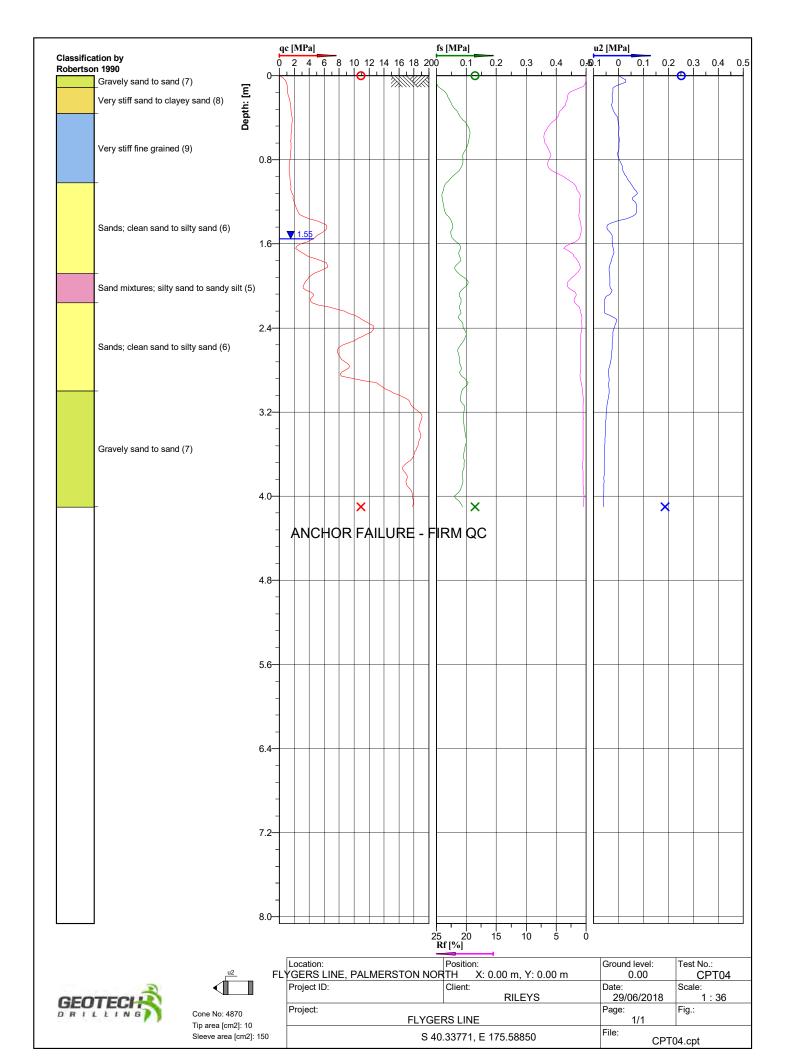


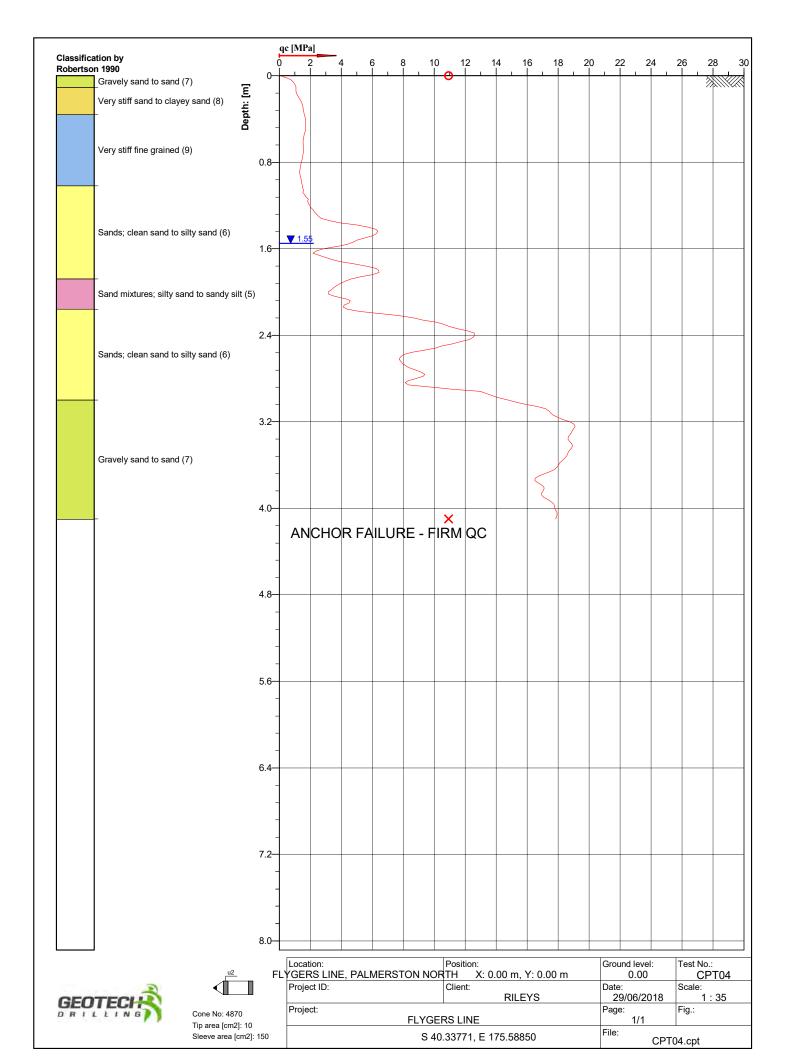


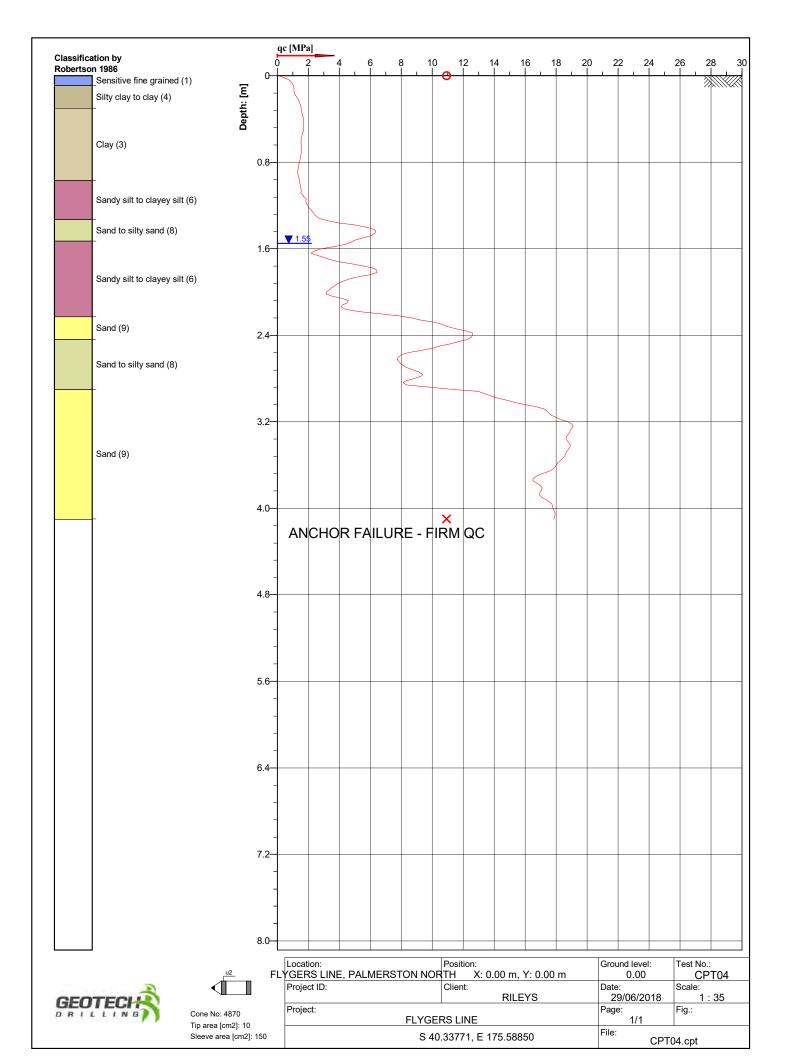


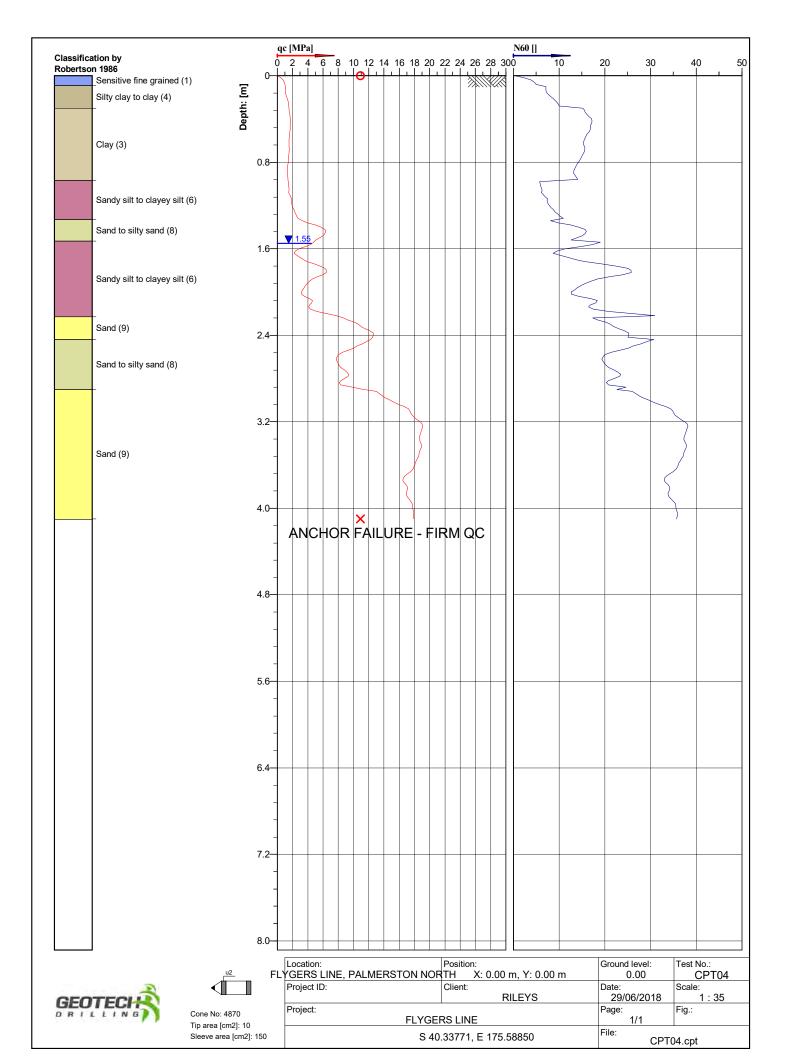


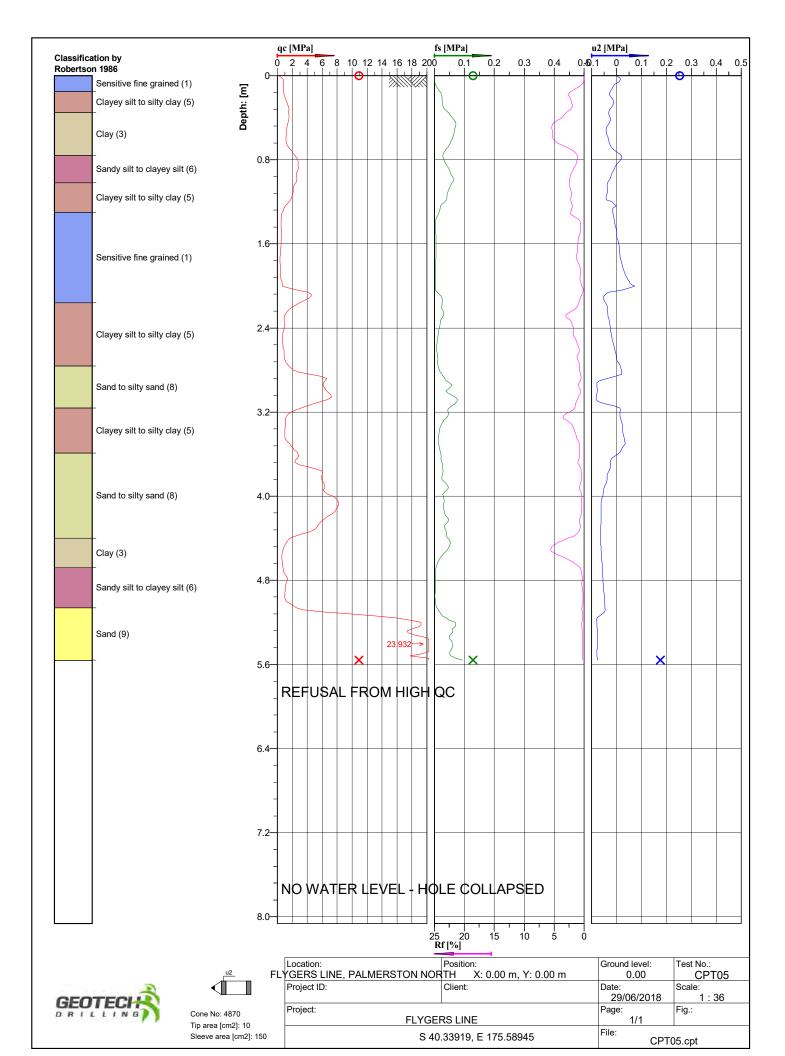


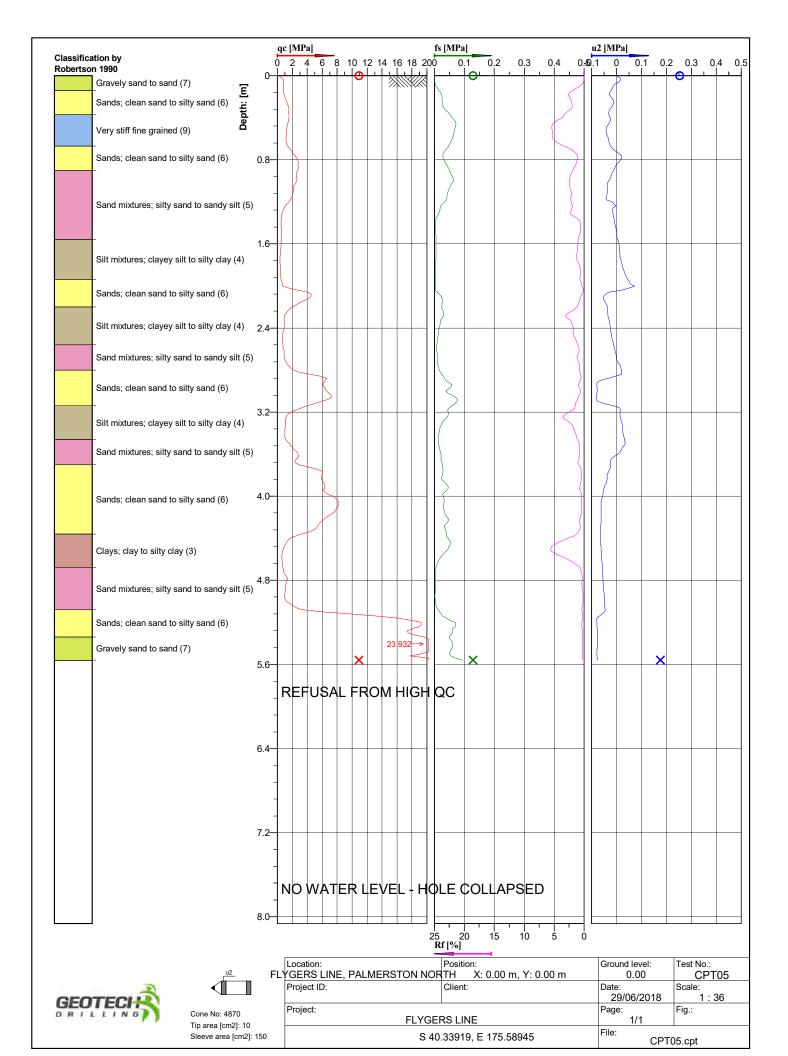


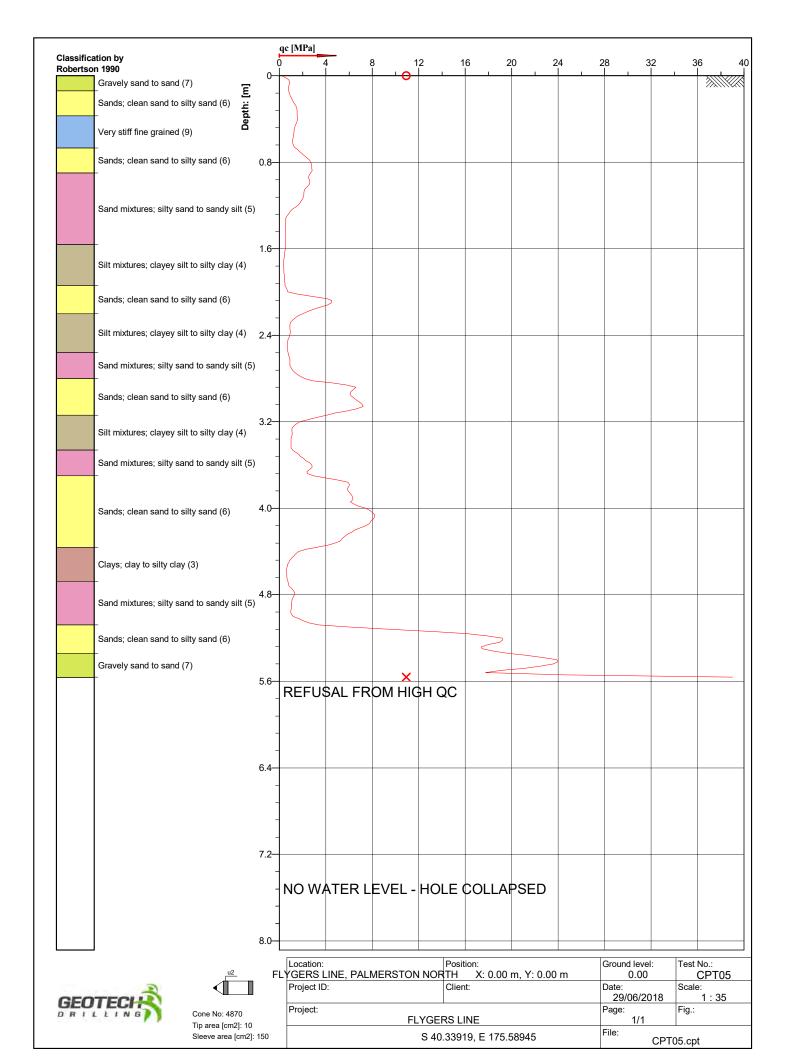


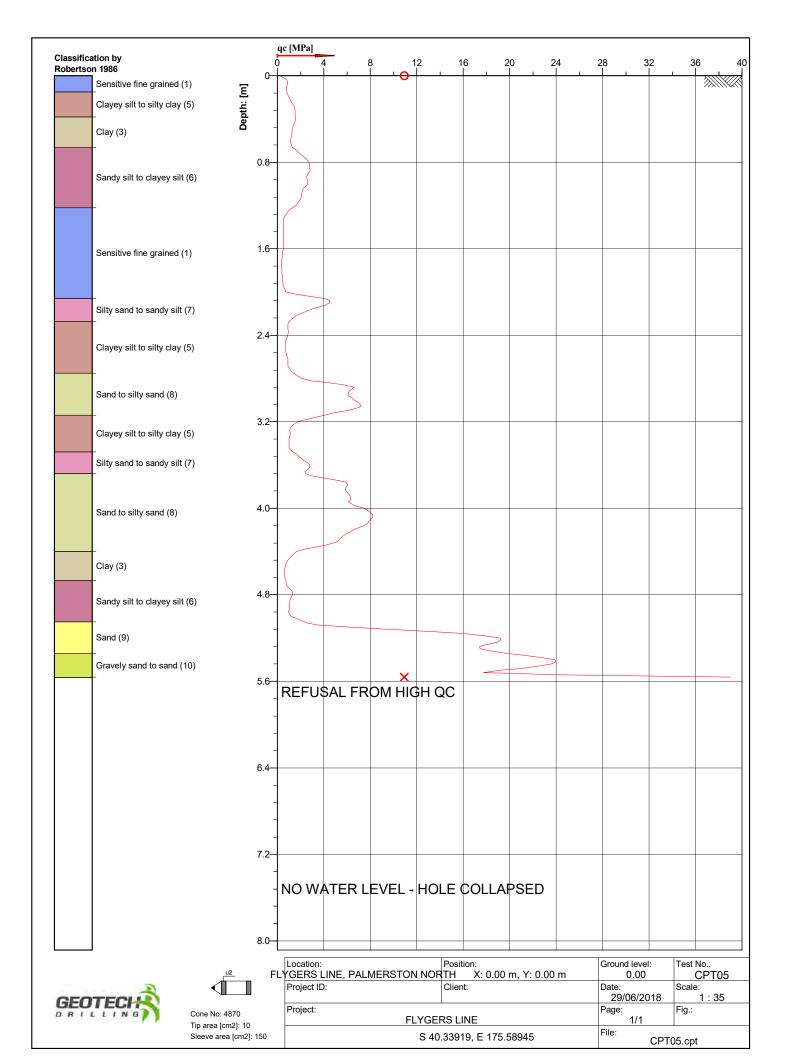


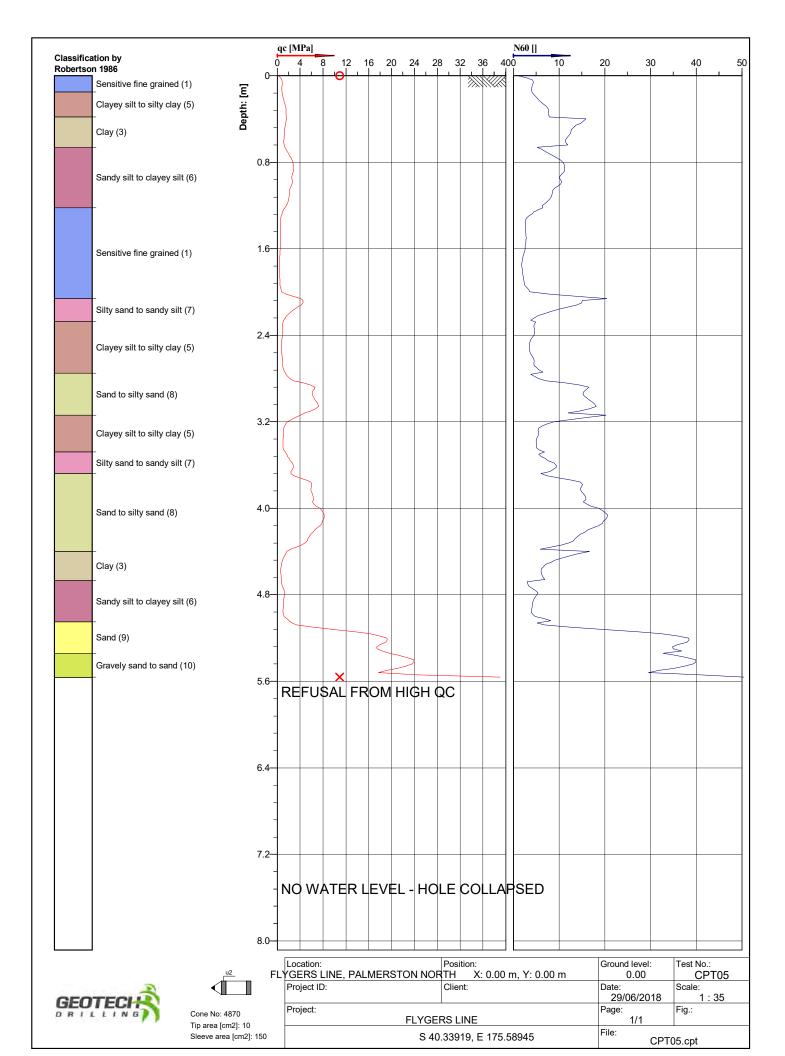


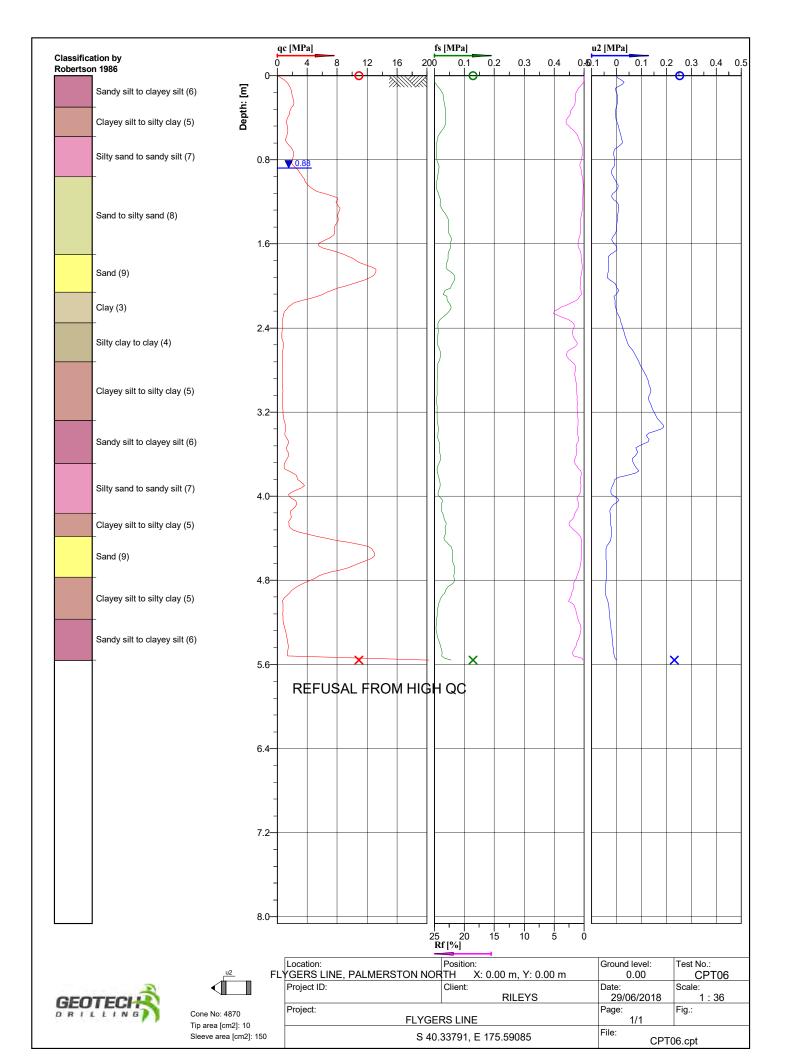


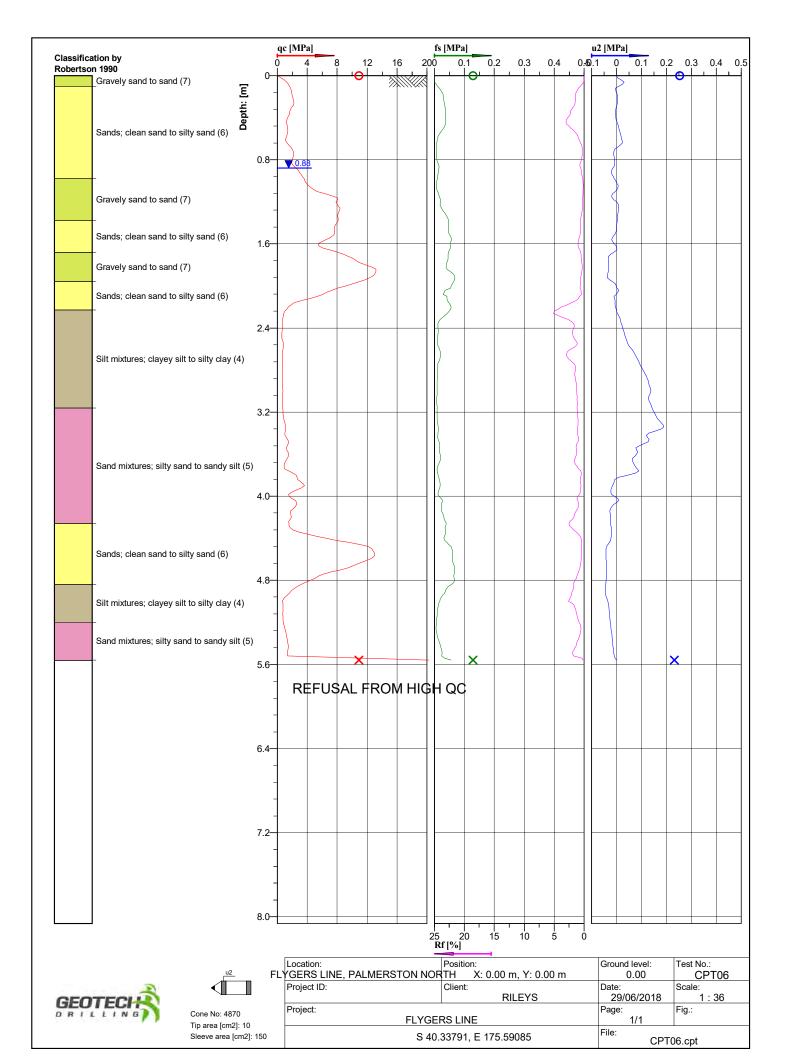


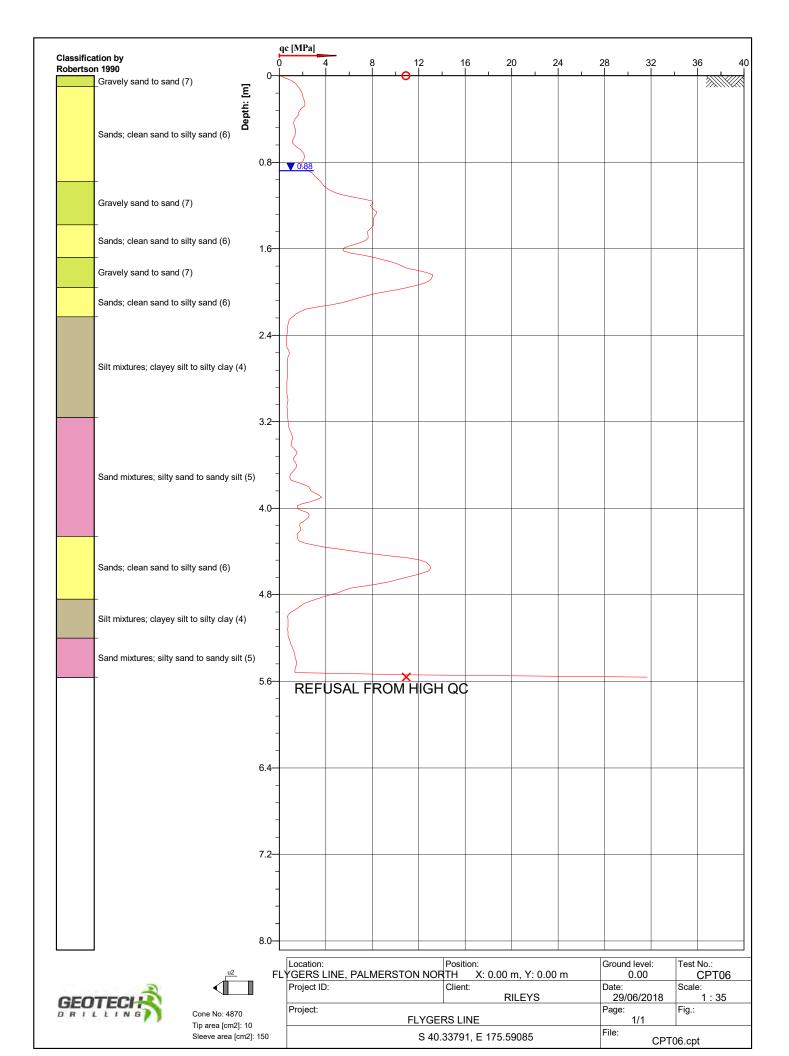


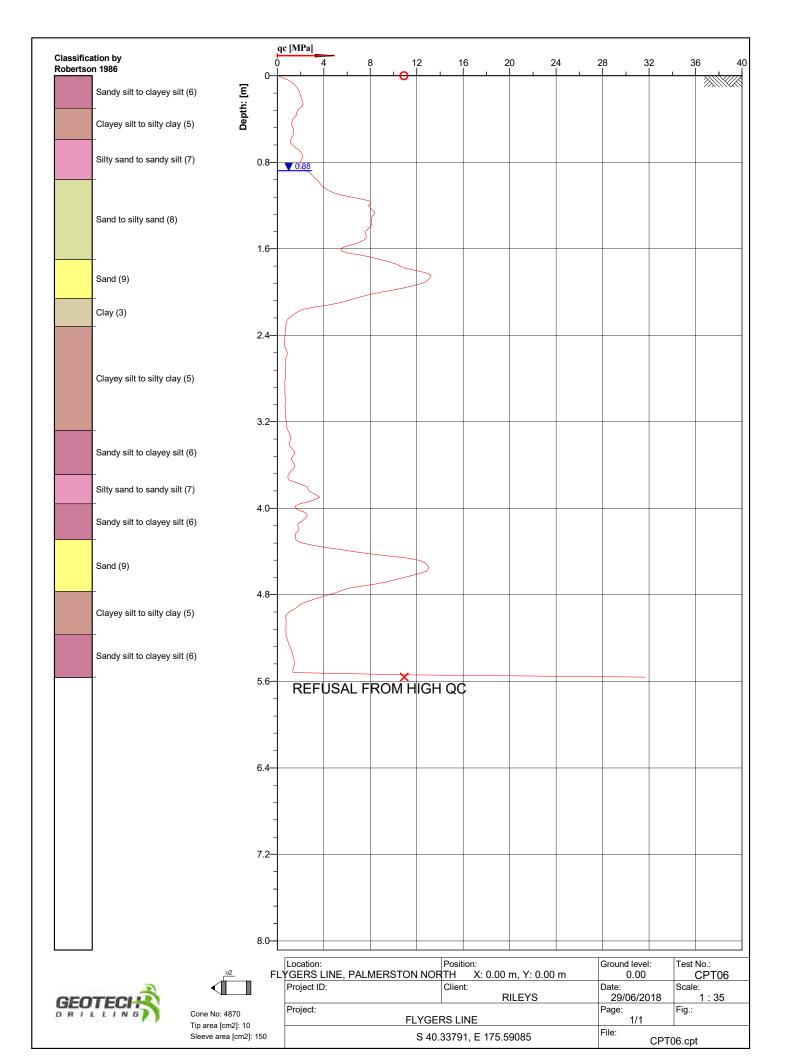


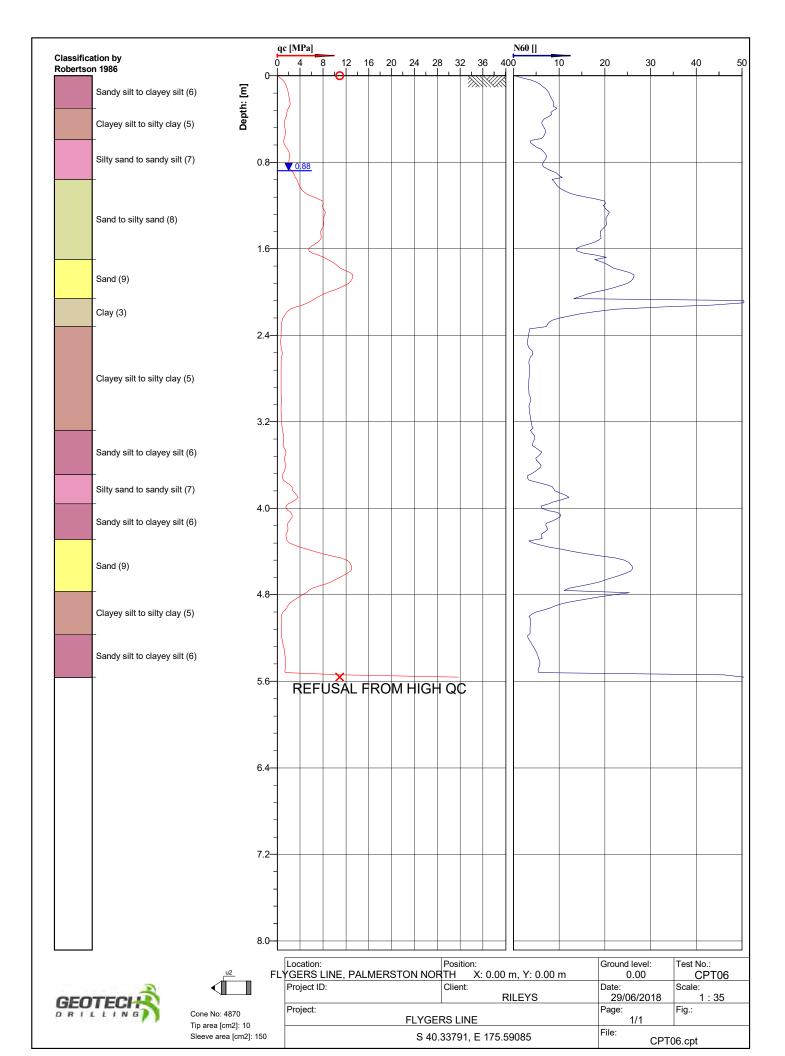


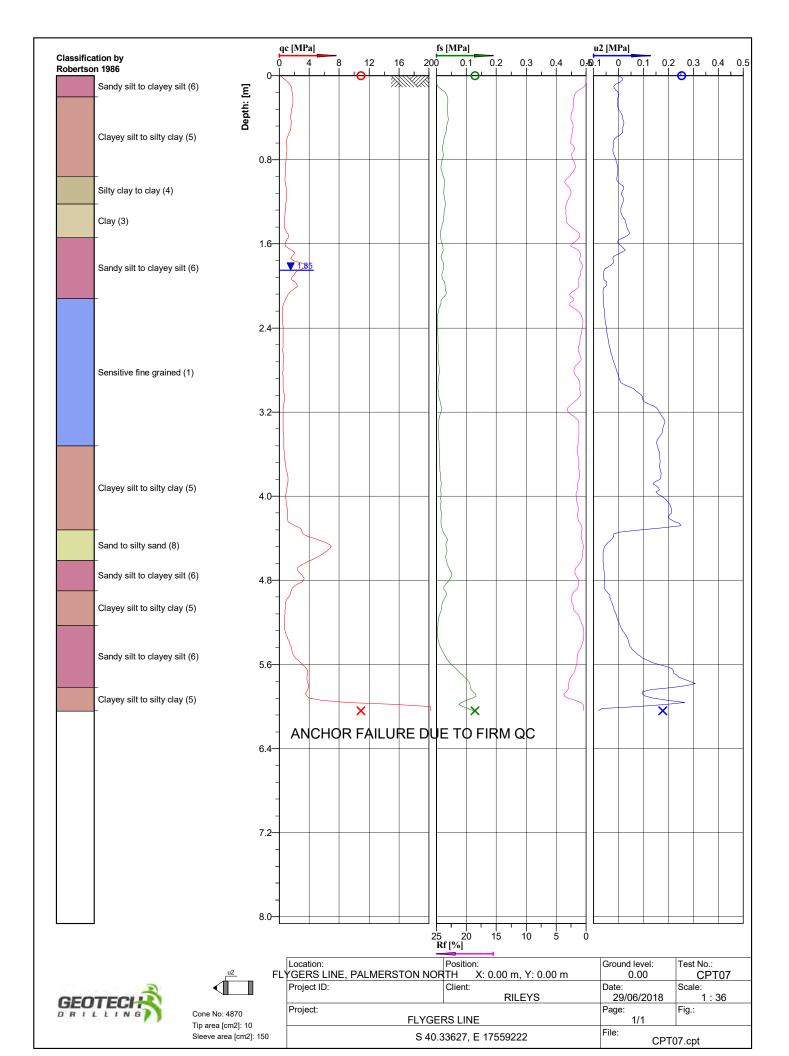


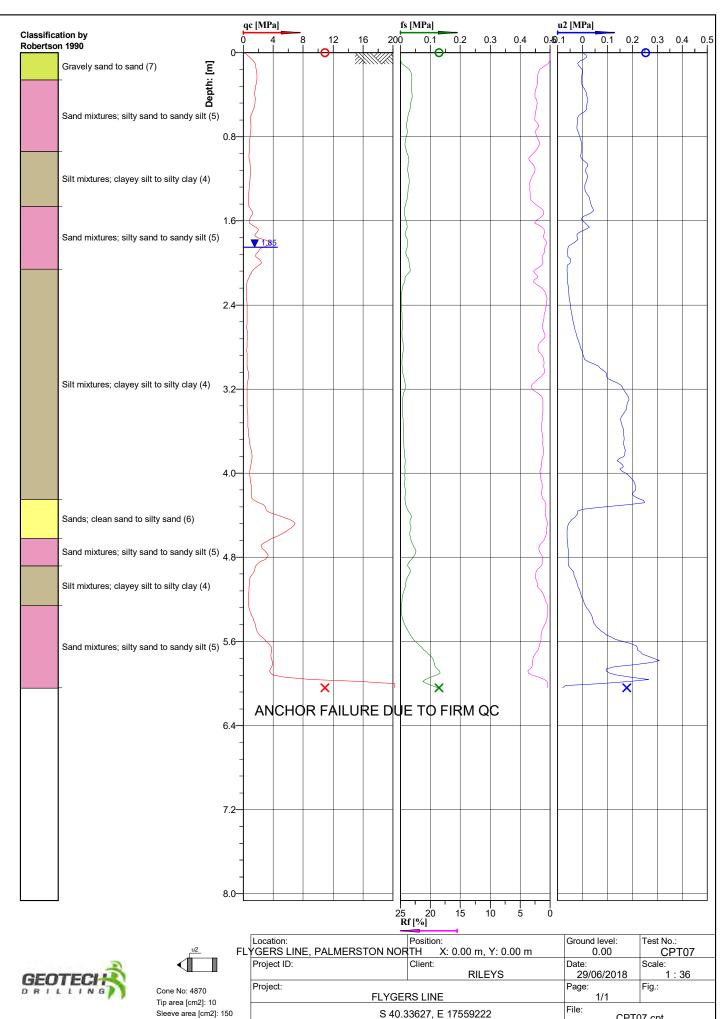




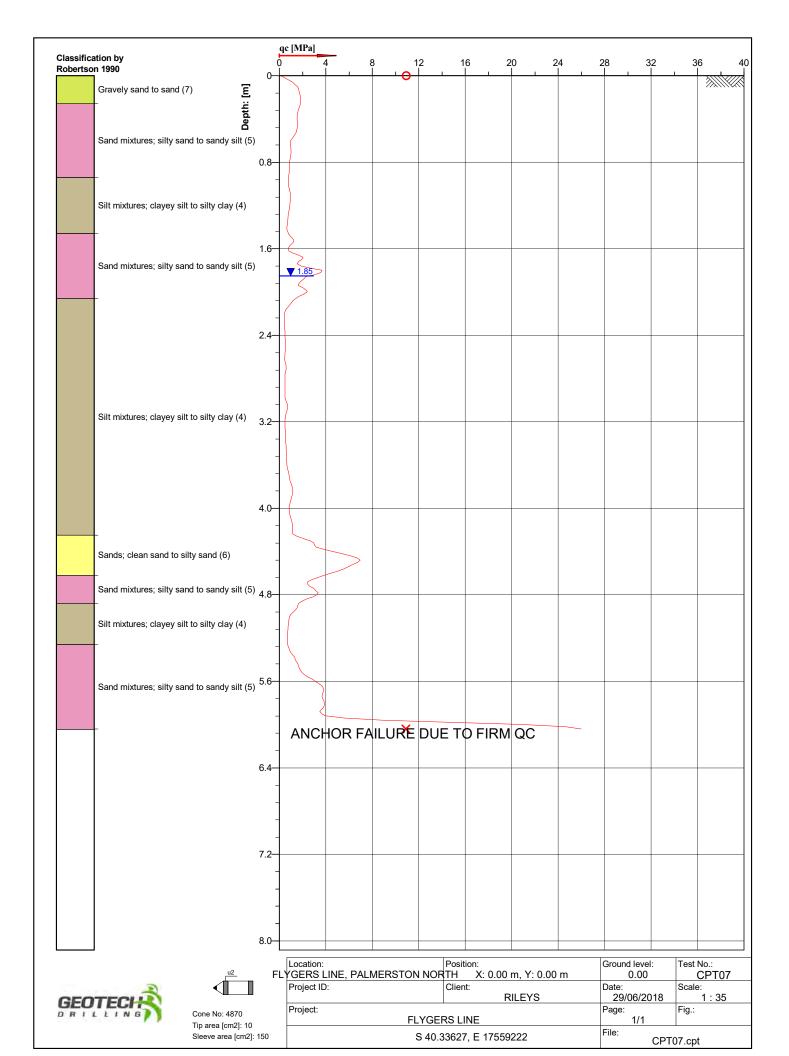


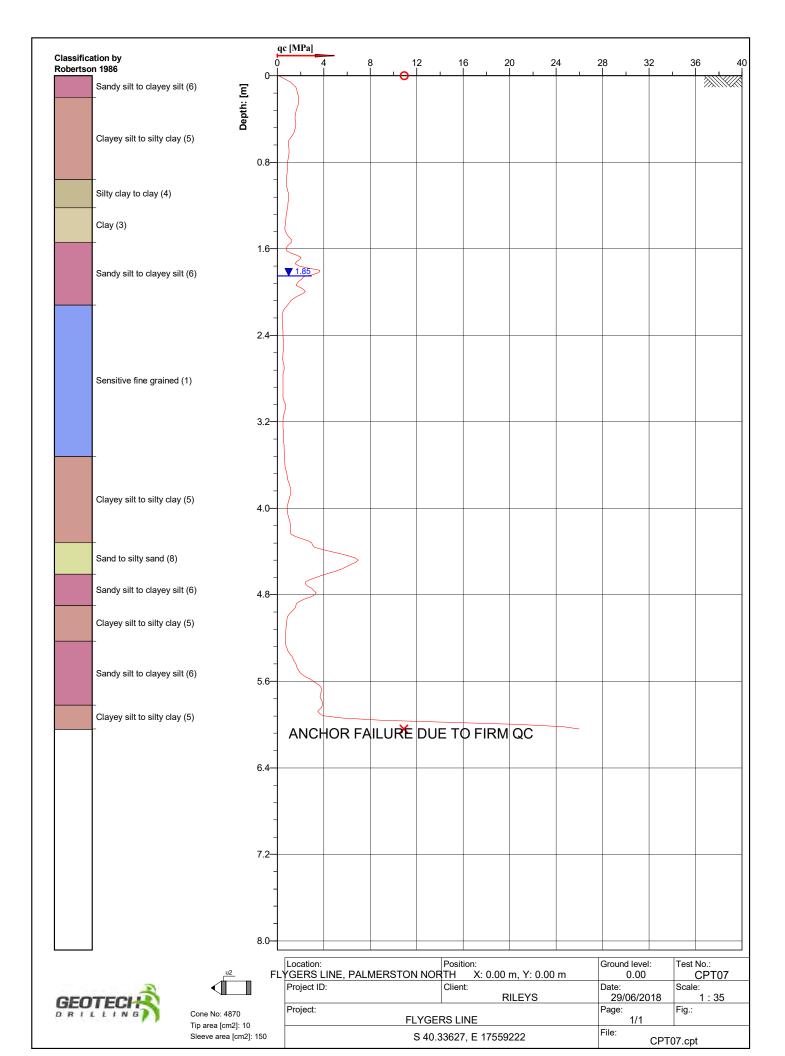


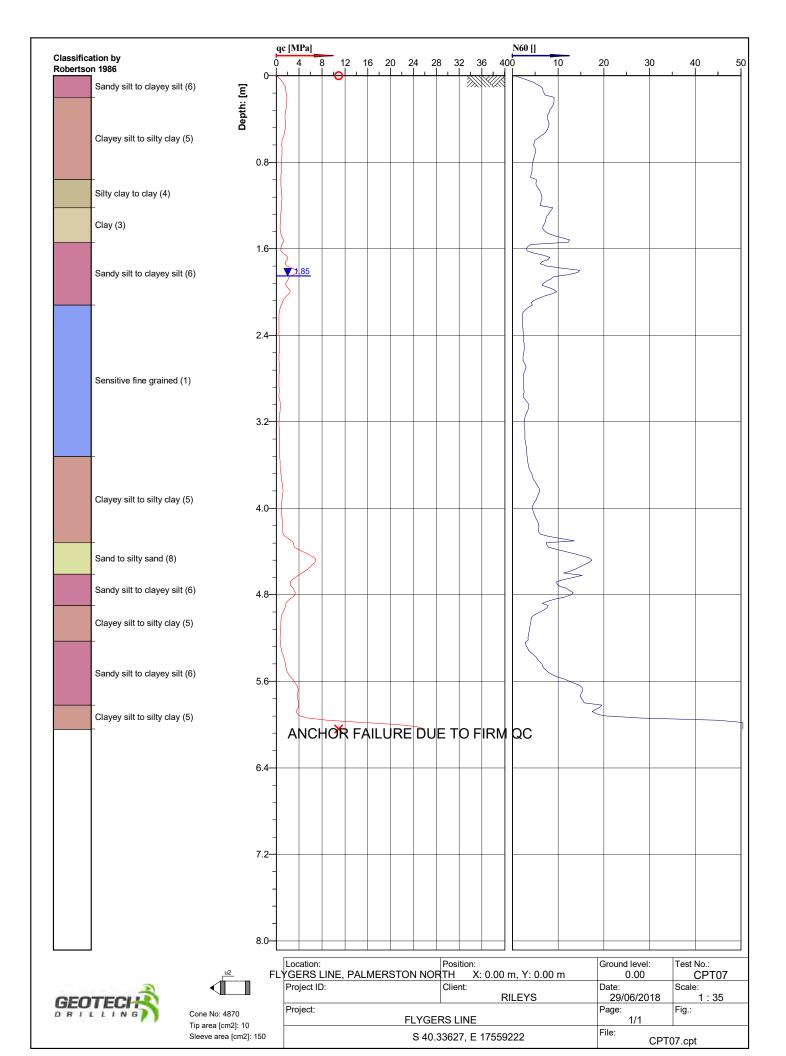


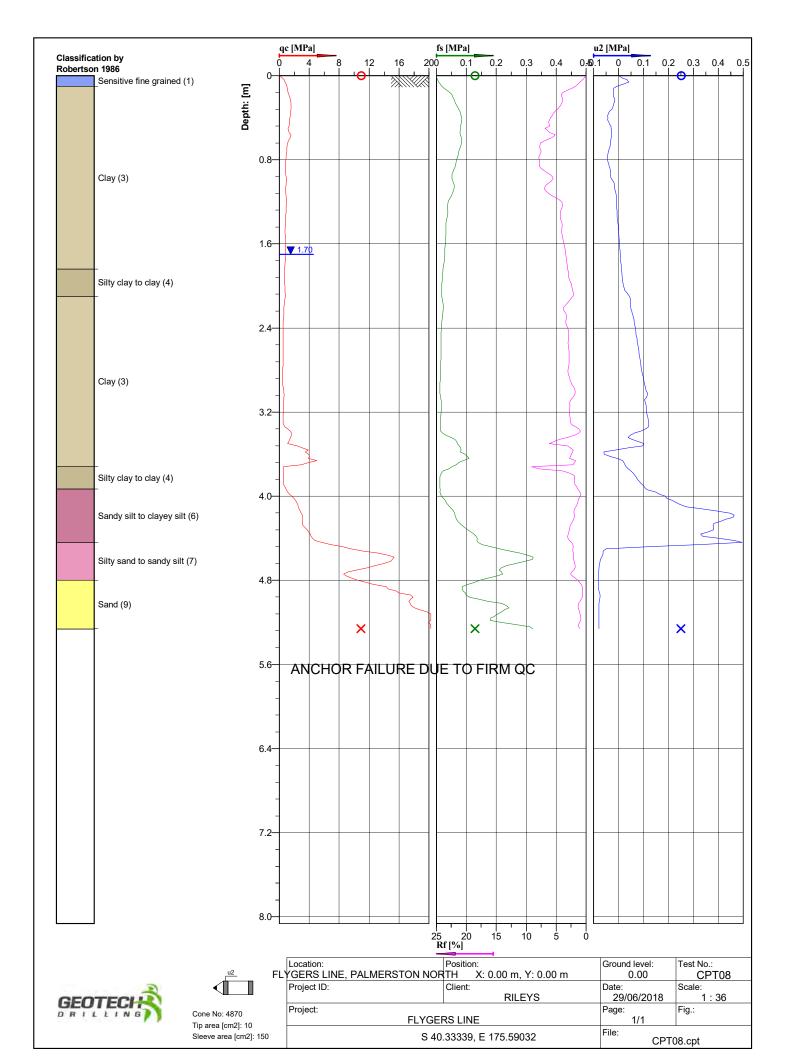


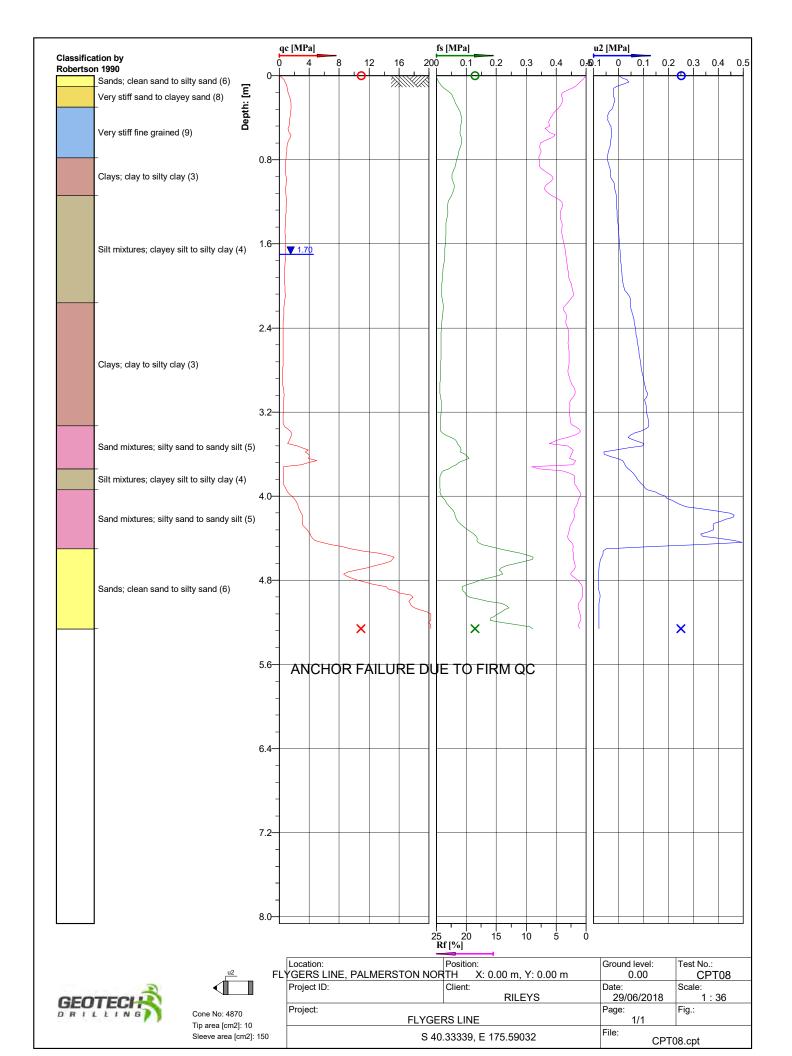
	Location:	Position:	Ground level:	Test No.:
L)	GERS LINE, PALMERSTON NOR	TH X: 0.00 m, Y: 0.00 m	0.00	CPT07
	Project ID:	Client:	Date:	Scale:
	-	RILEYS	29/06/2018	1:36
	Project:	Page:	Fig.:	
	FLYGER	1/1	_	
	S 40.33627, E 17559222		File: CPT0)7.cpt

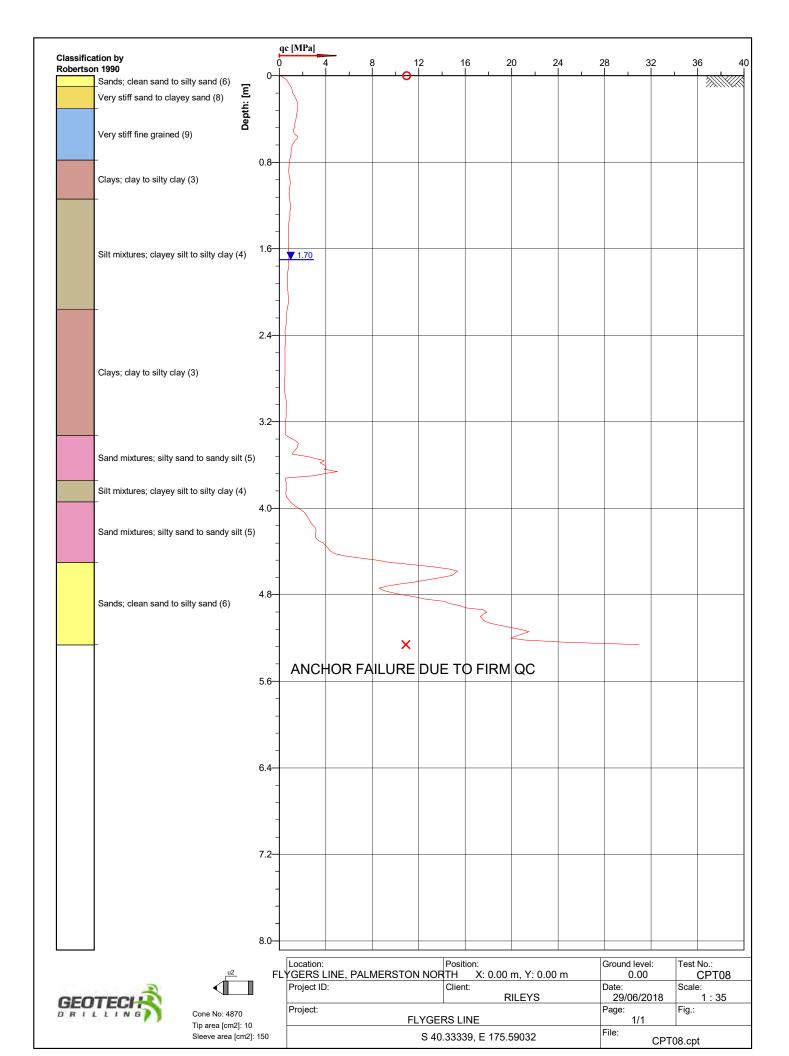


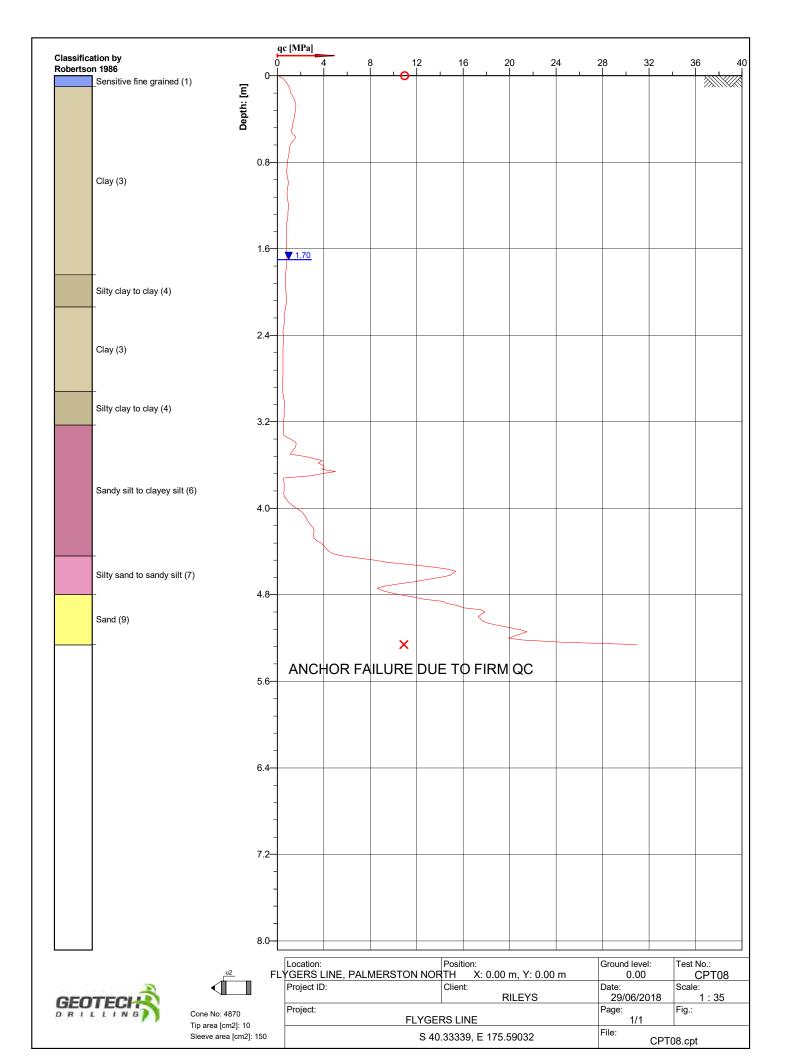


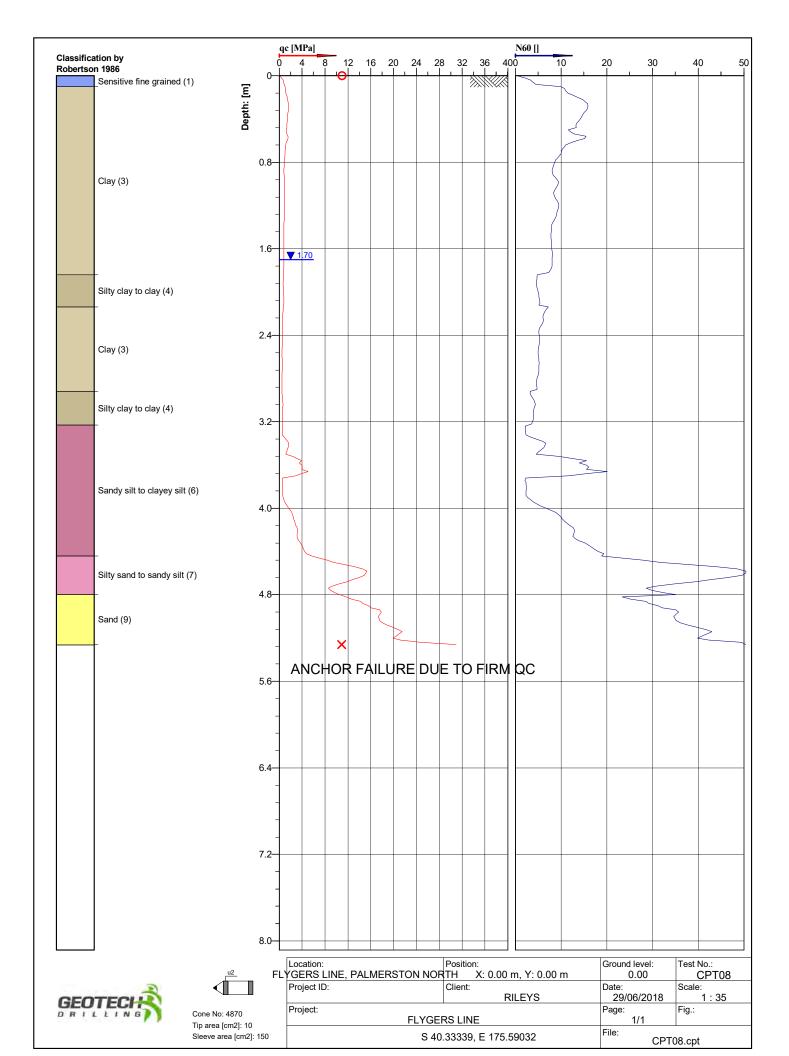


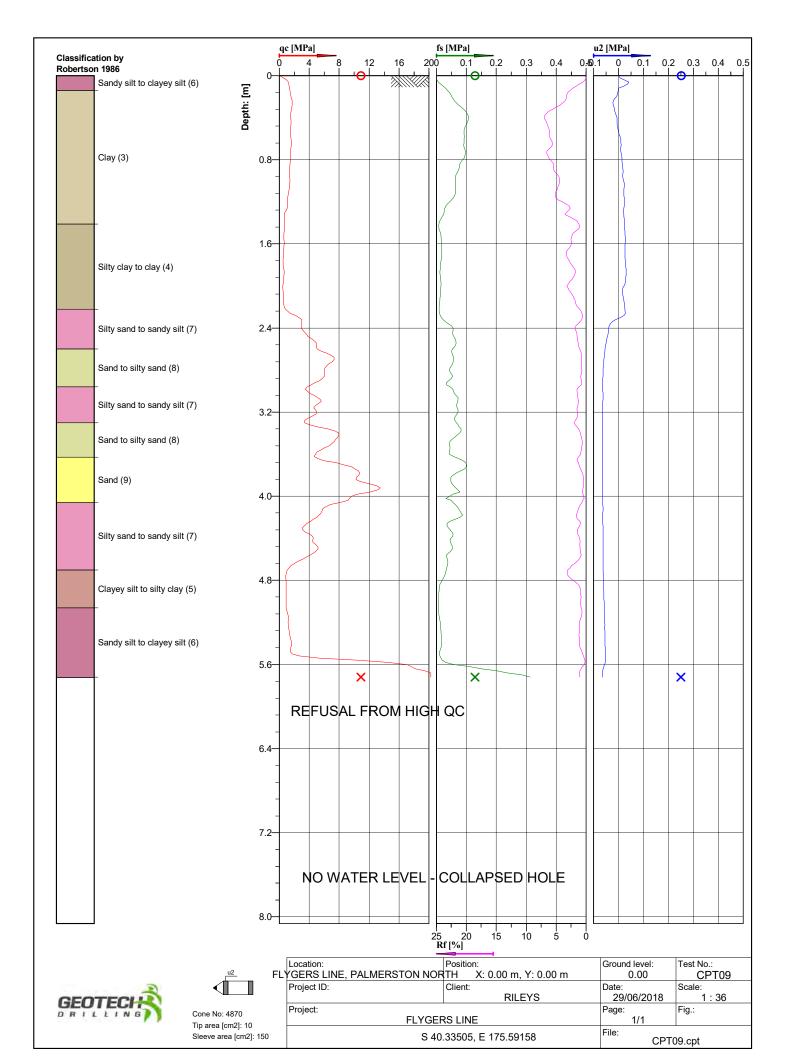


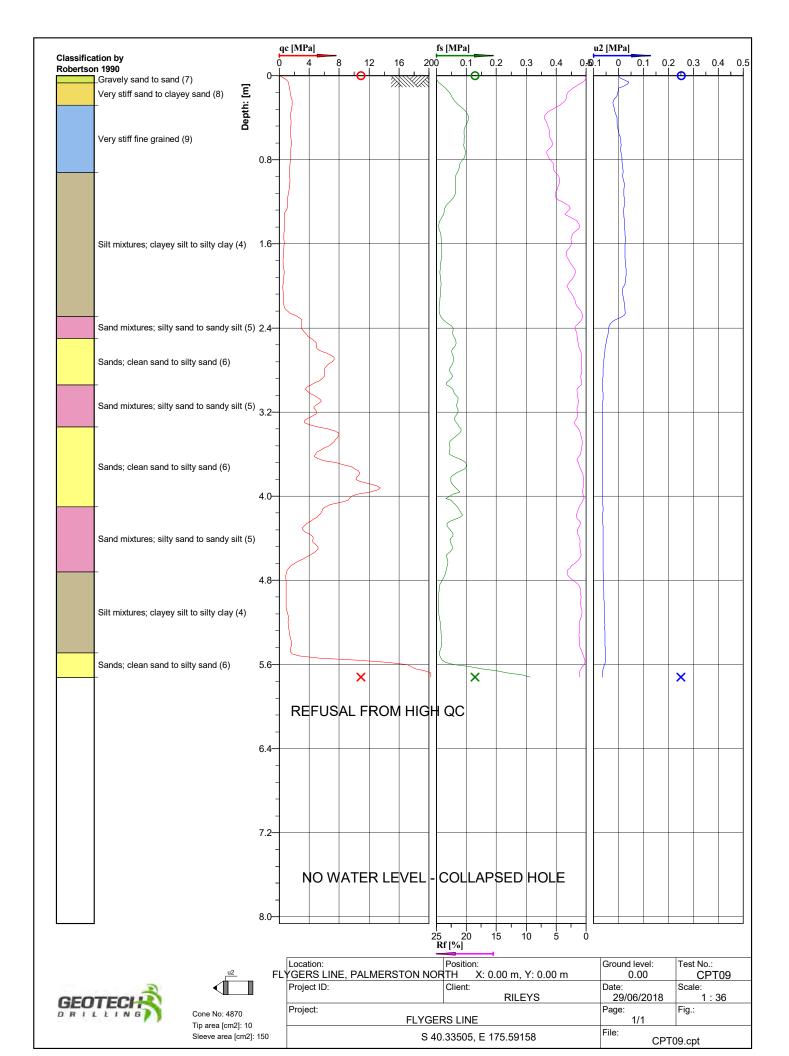


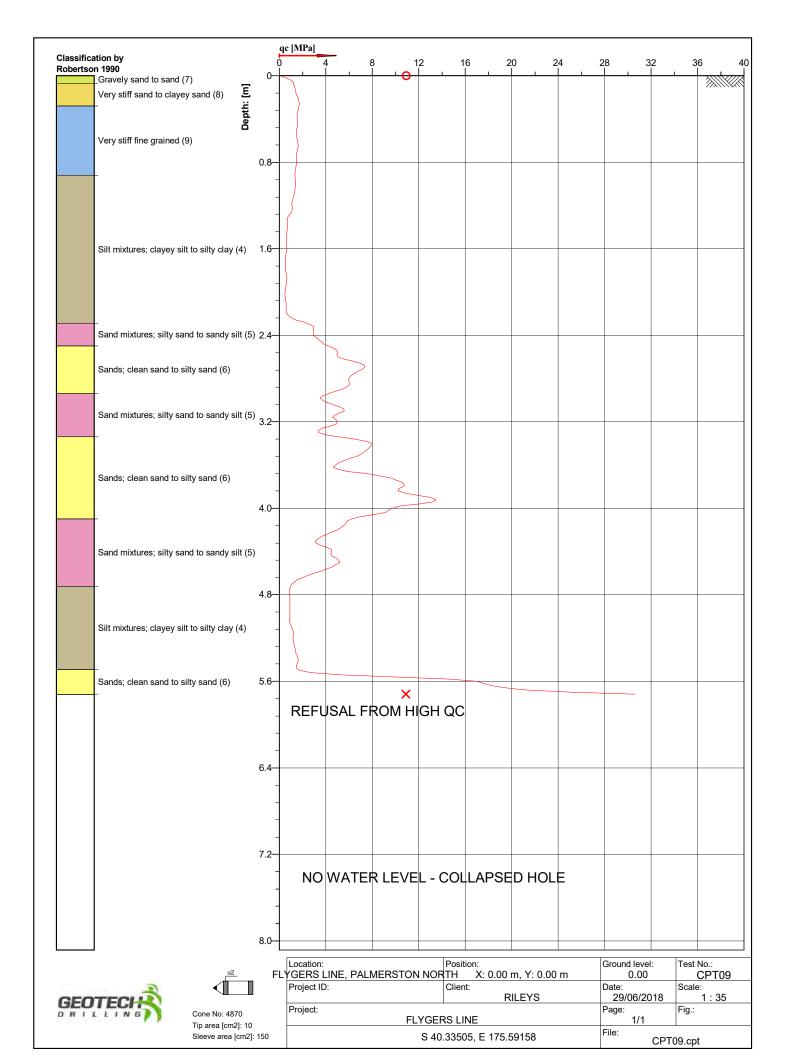


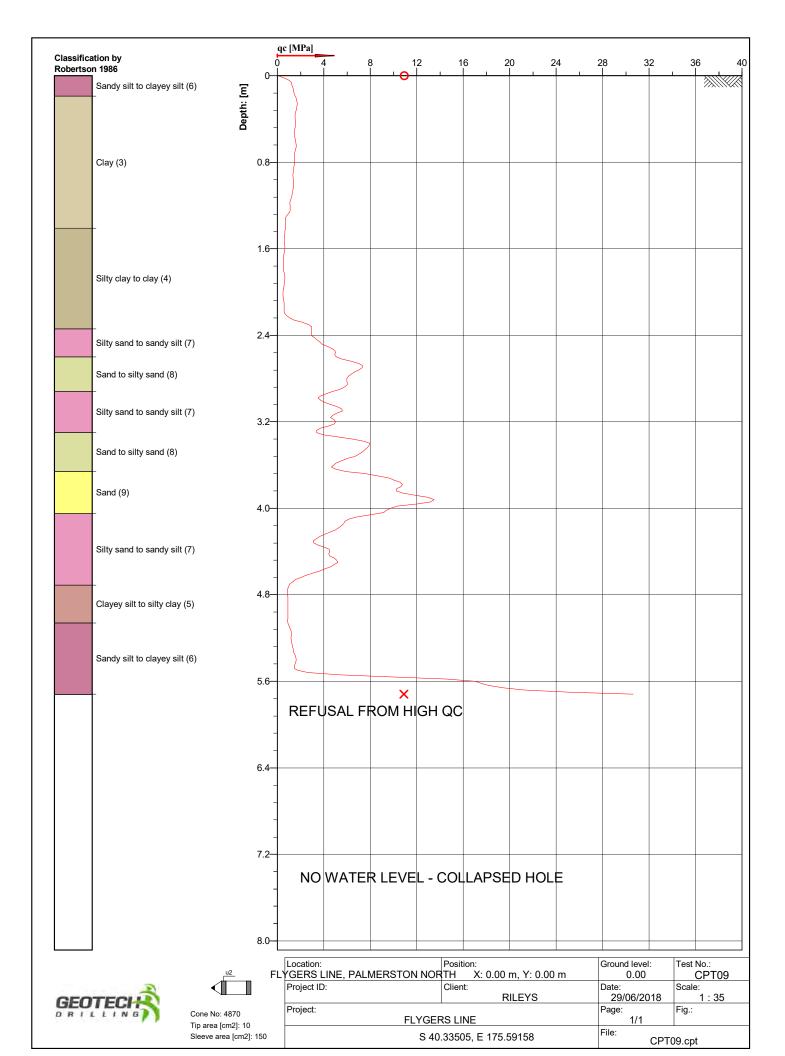


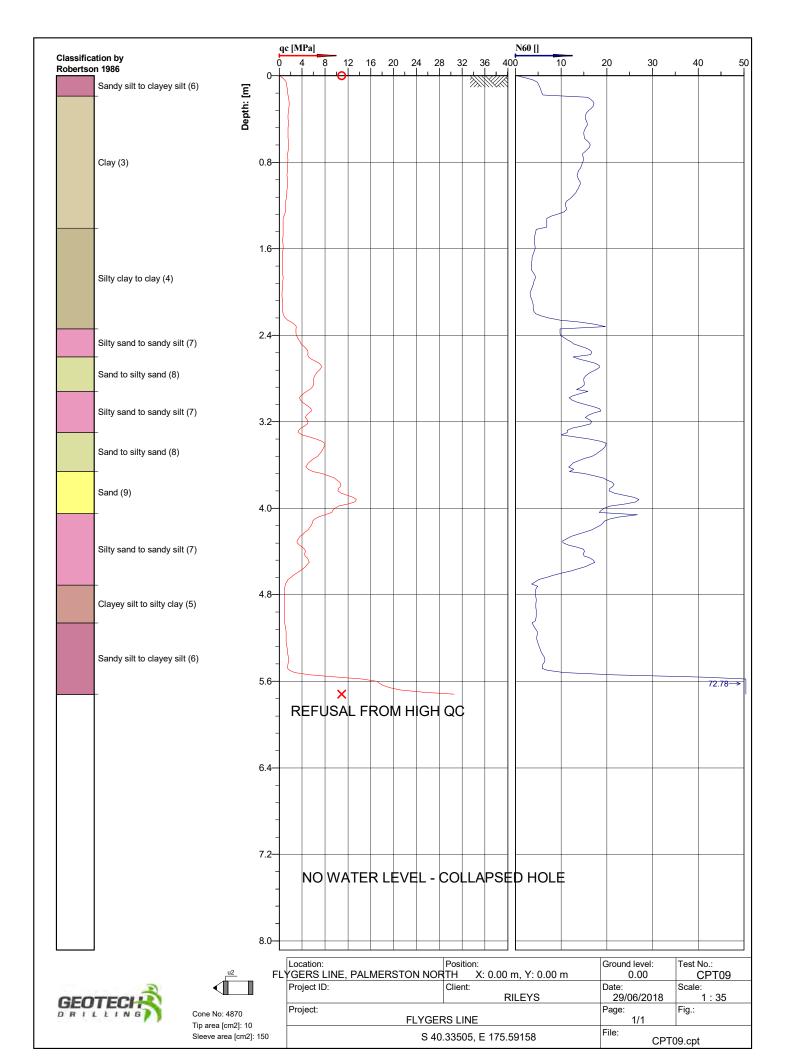


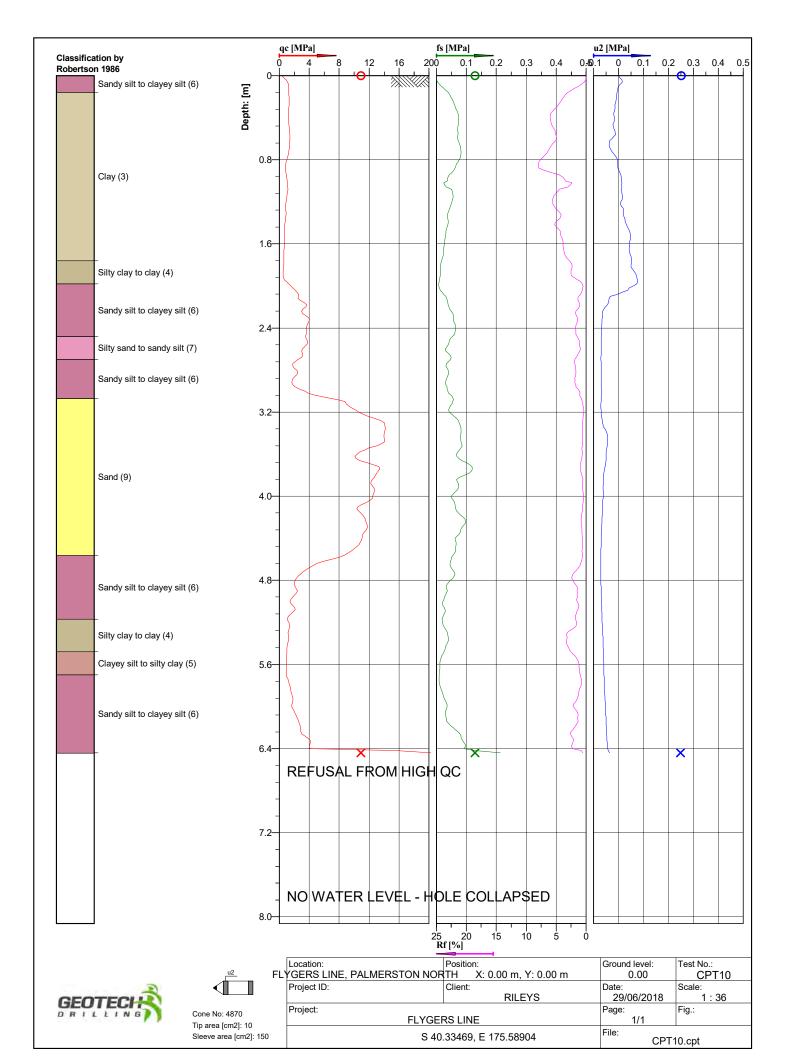


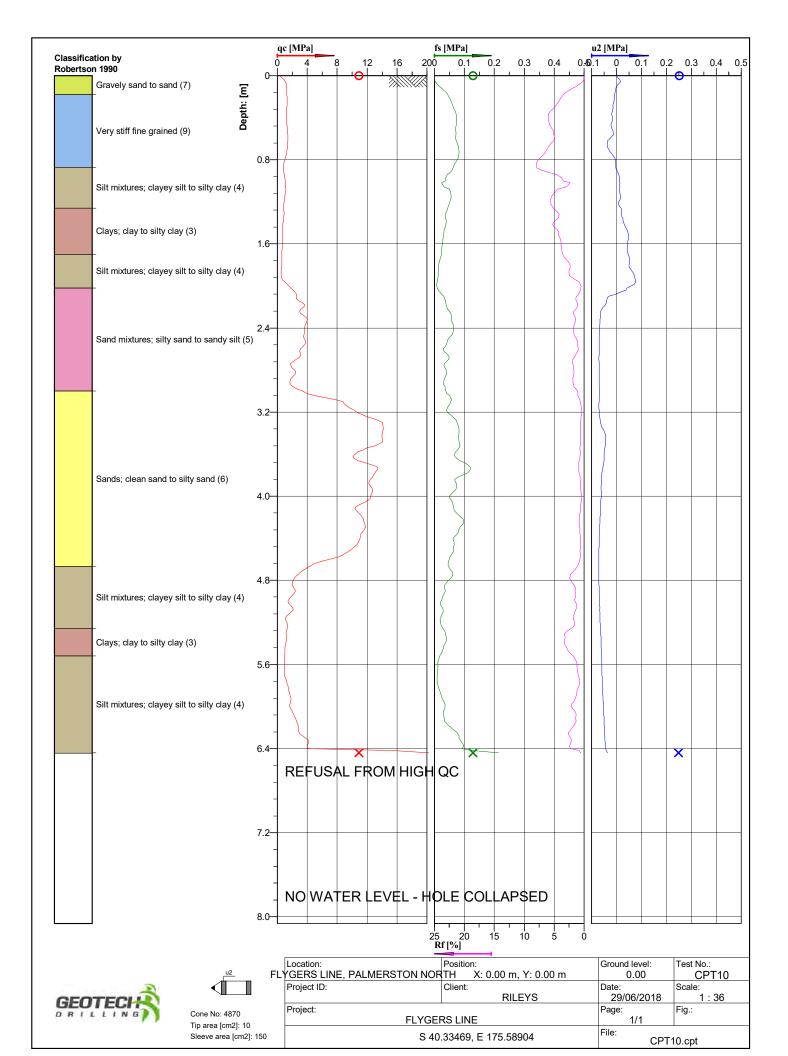


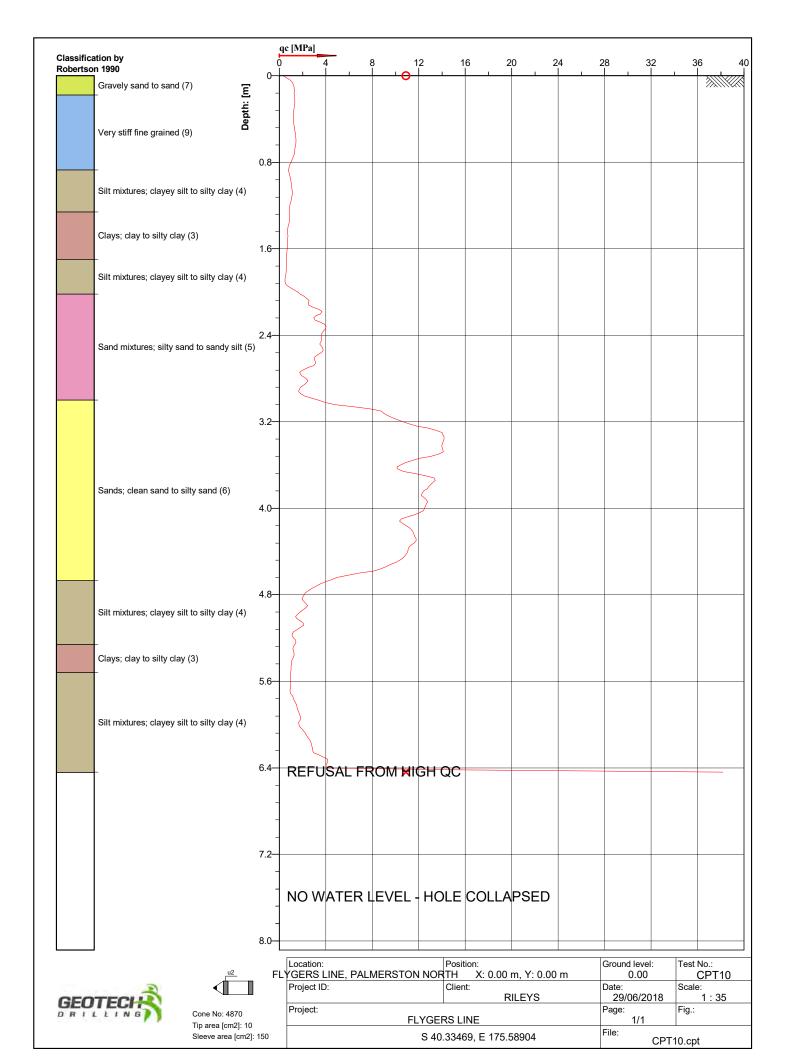


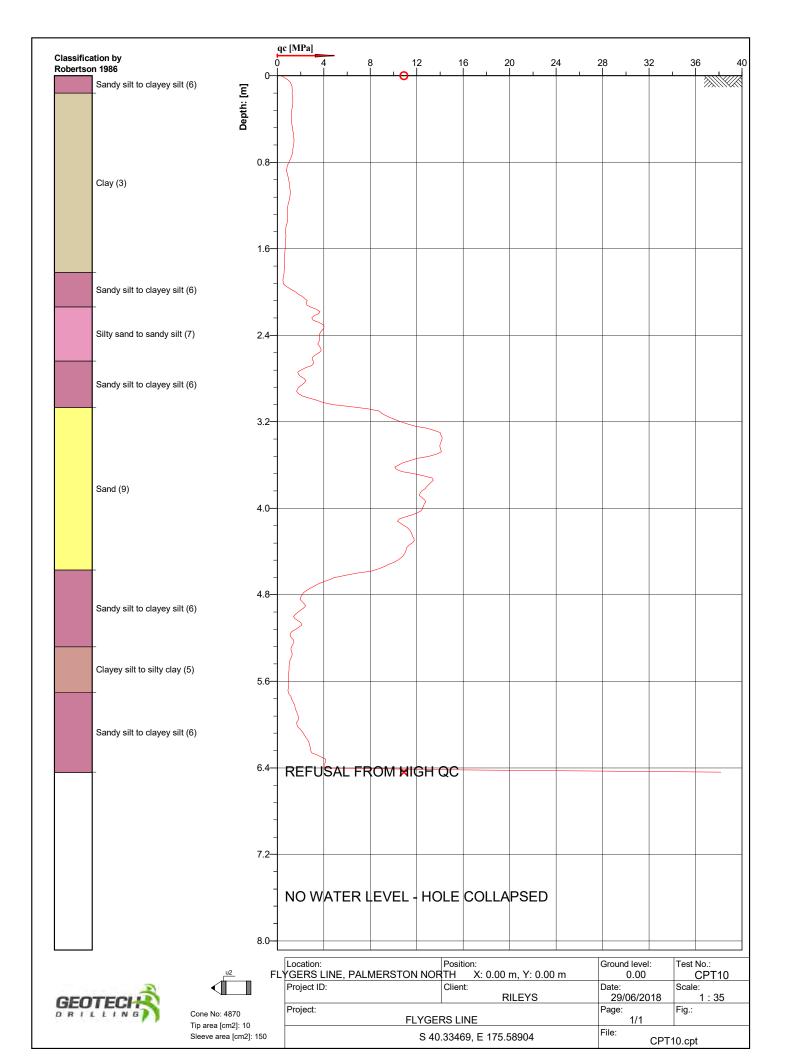


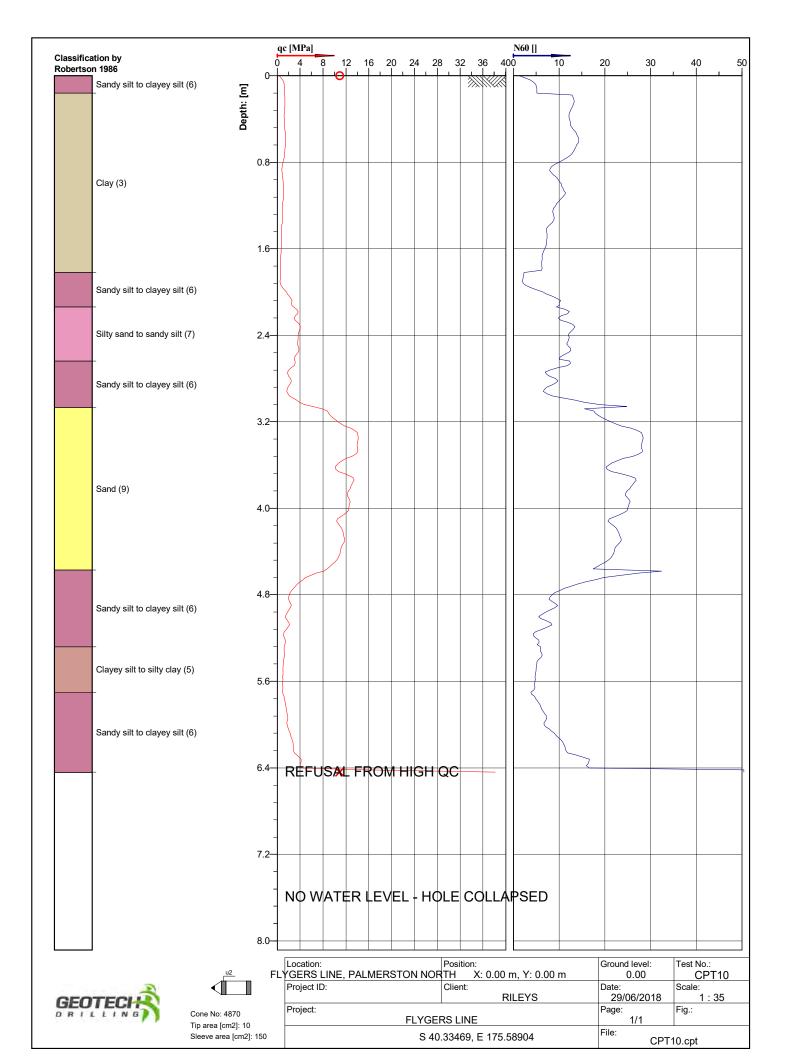


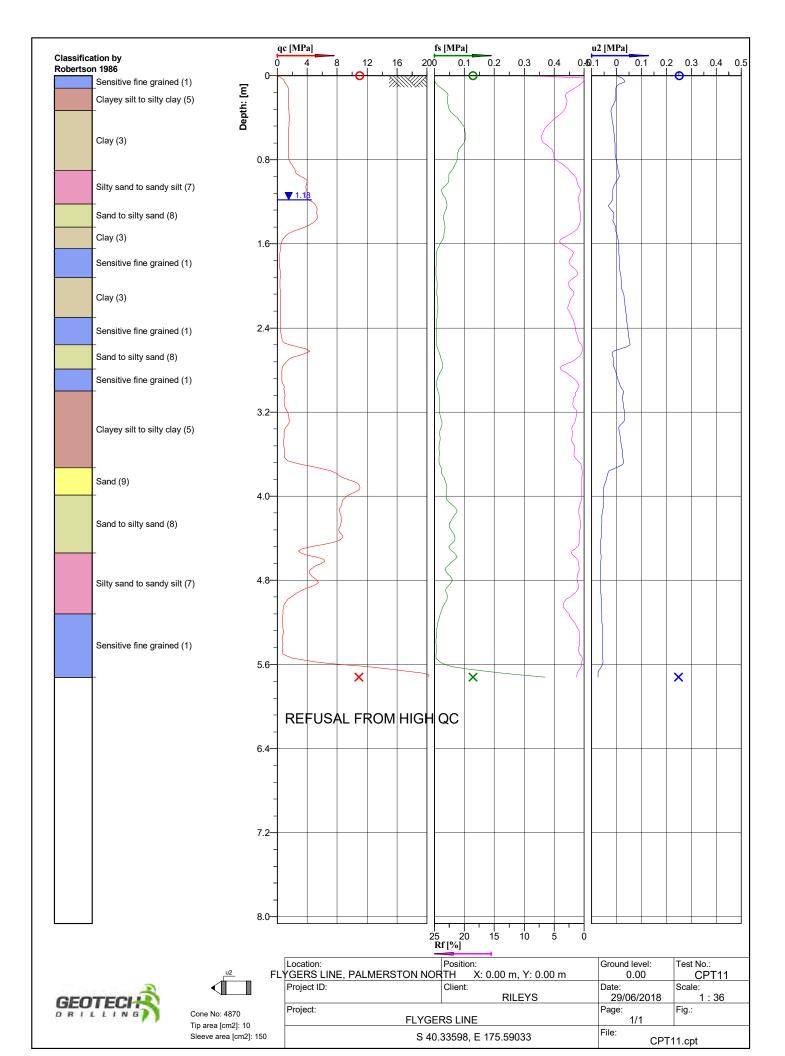


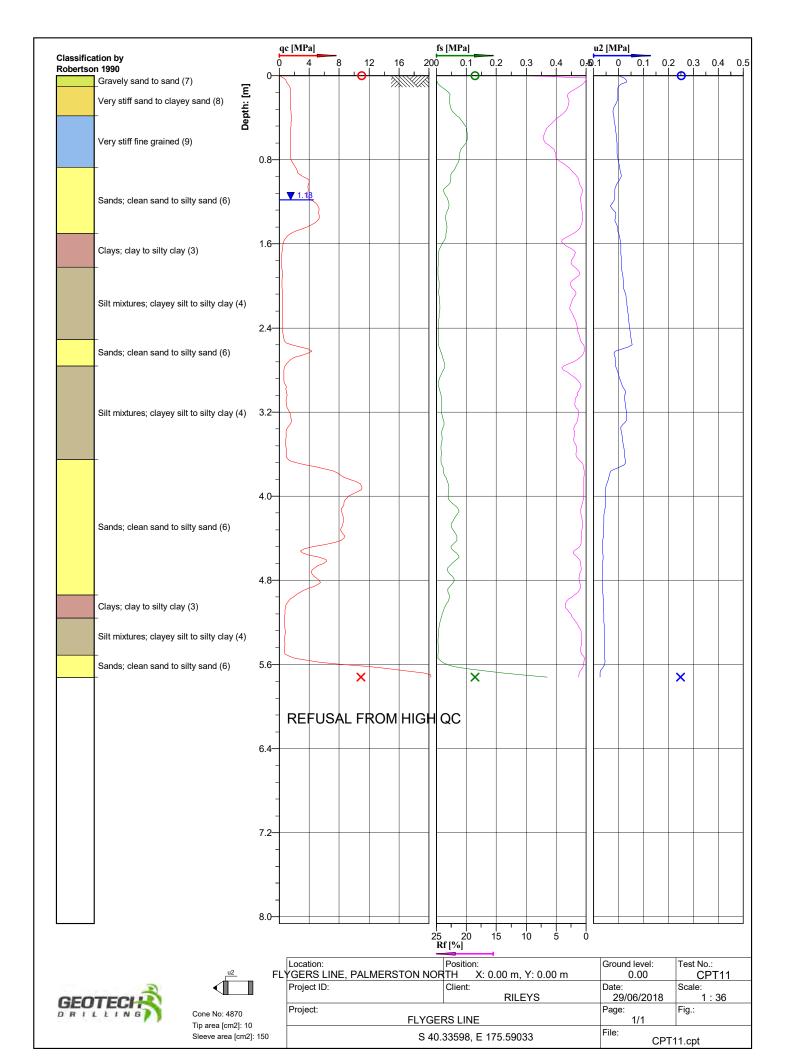


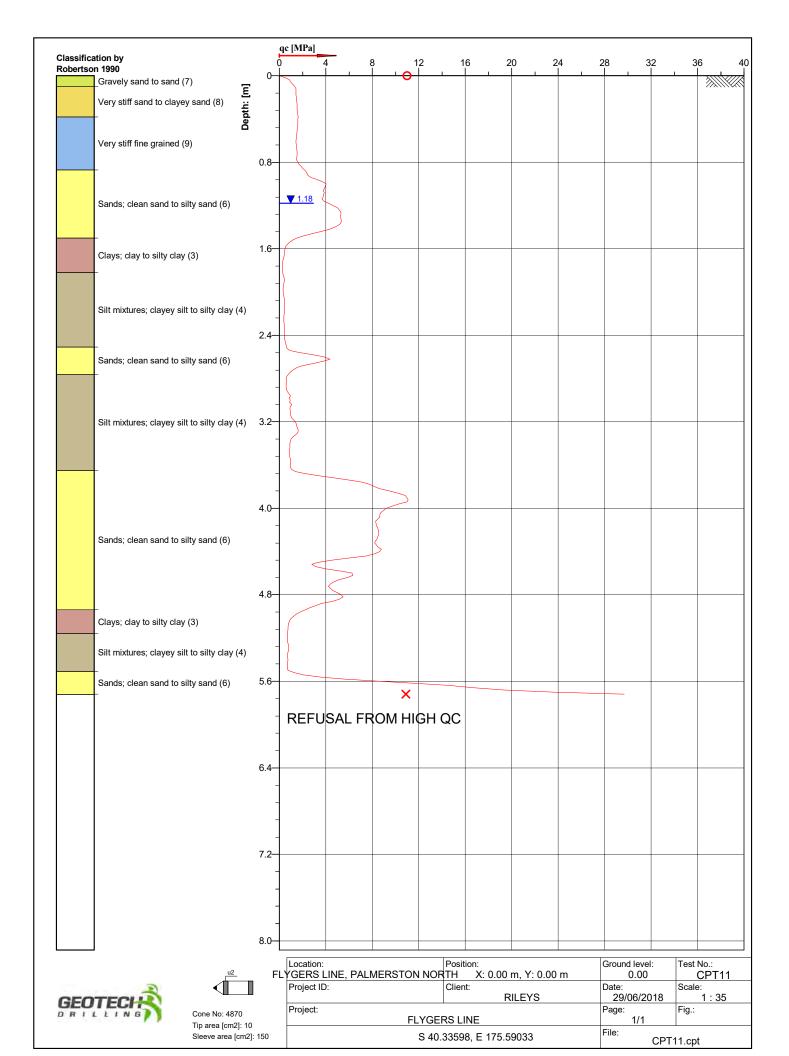


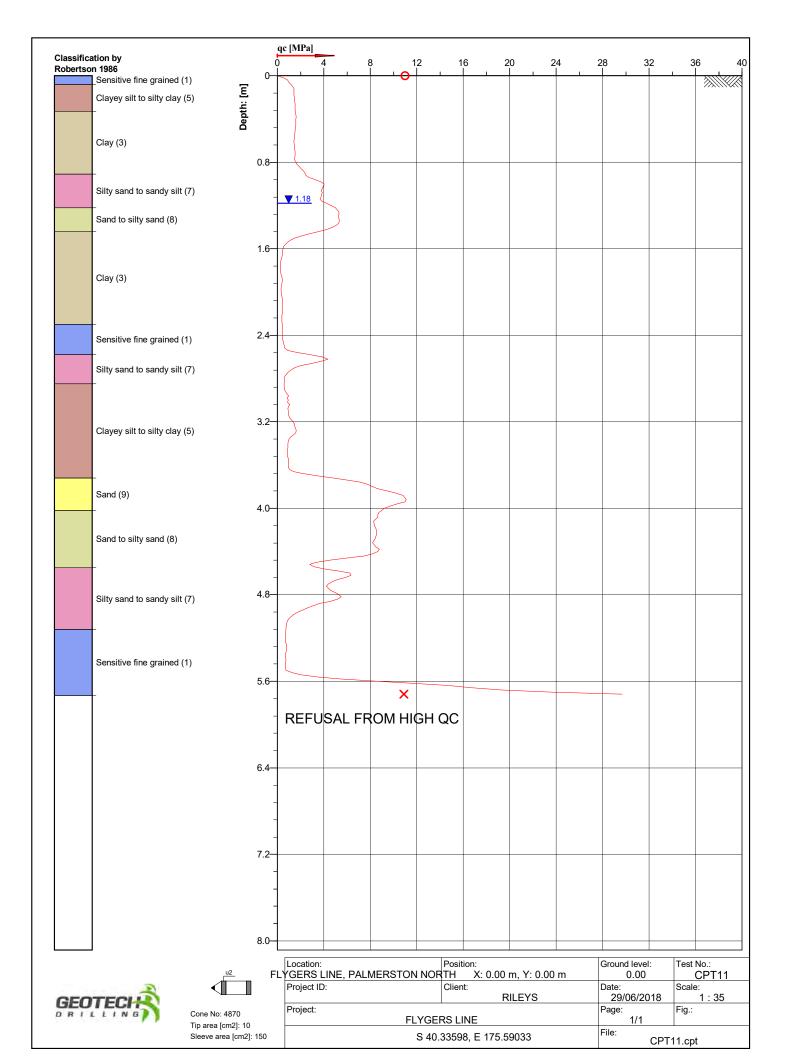


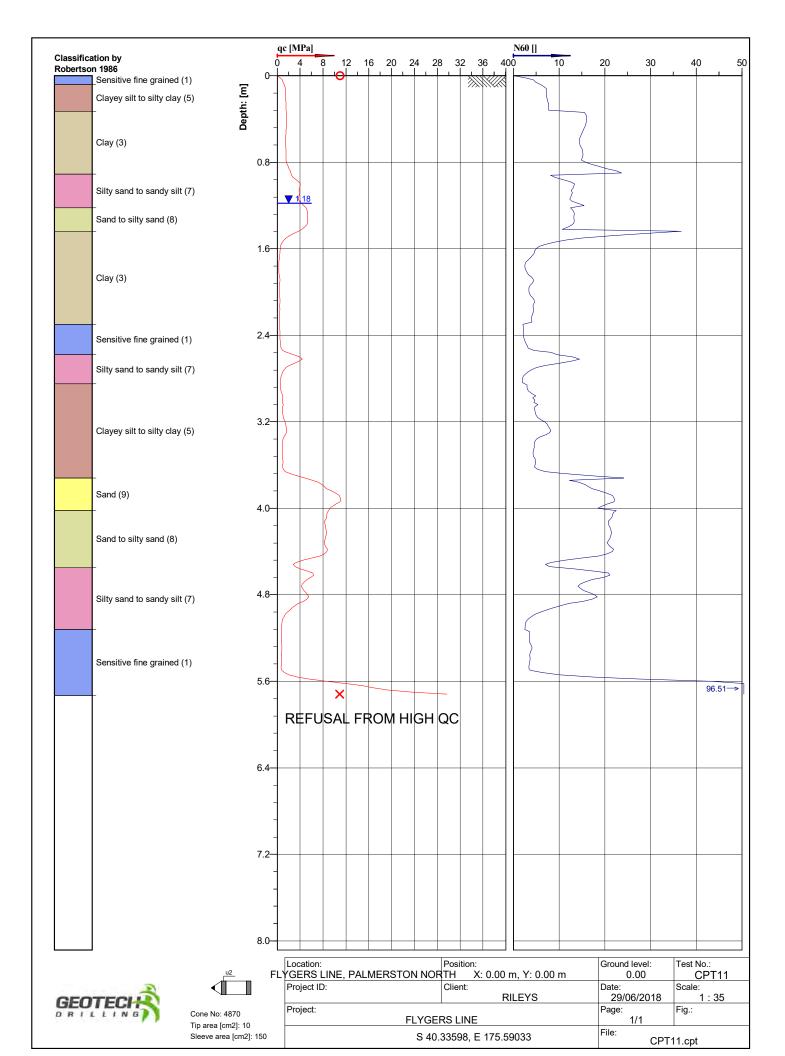


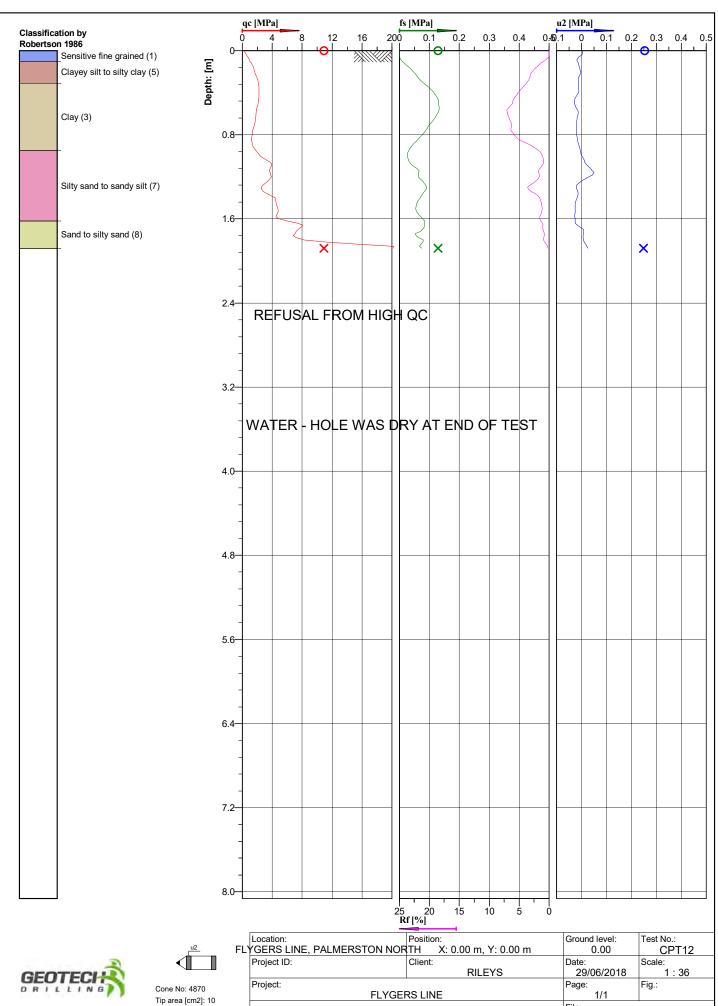






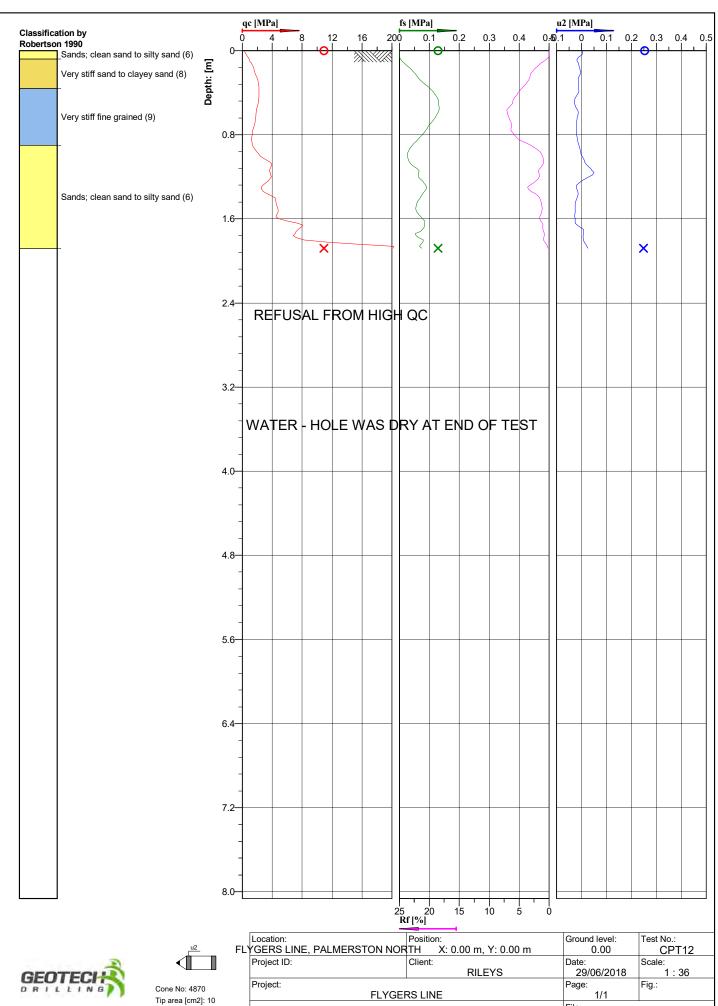






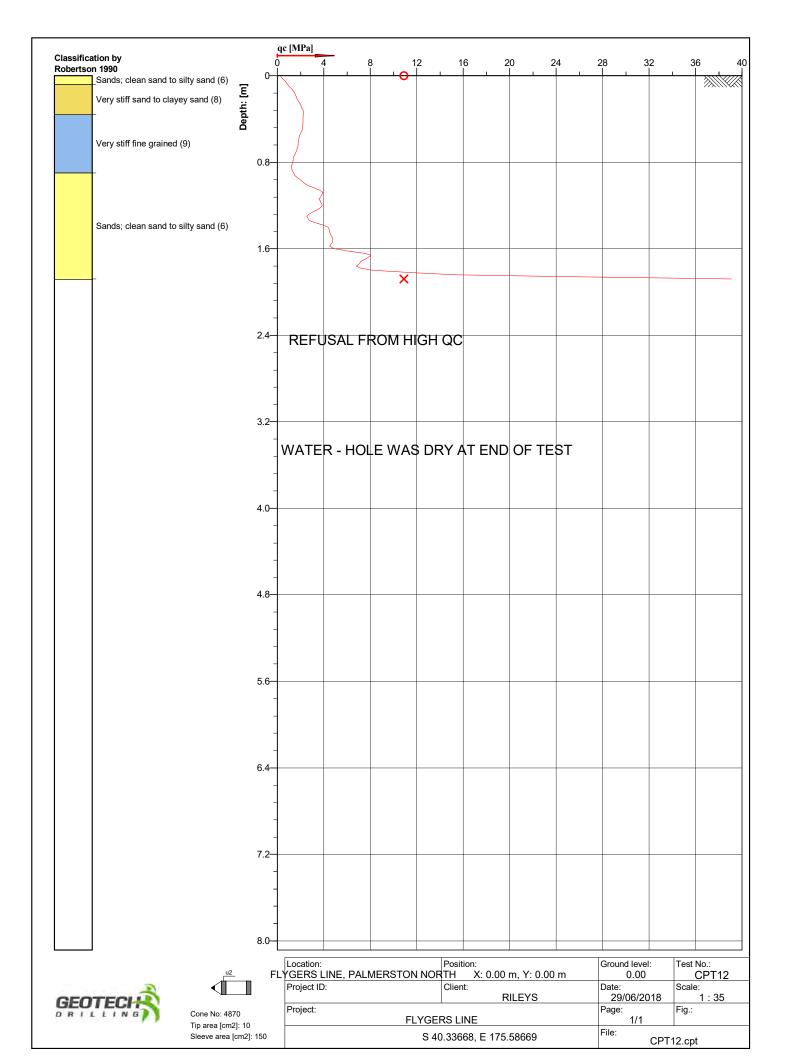
Sleeve area [cm2]: 150

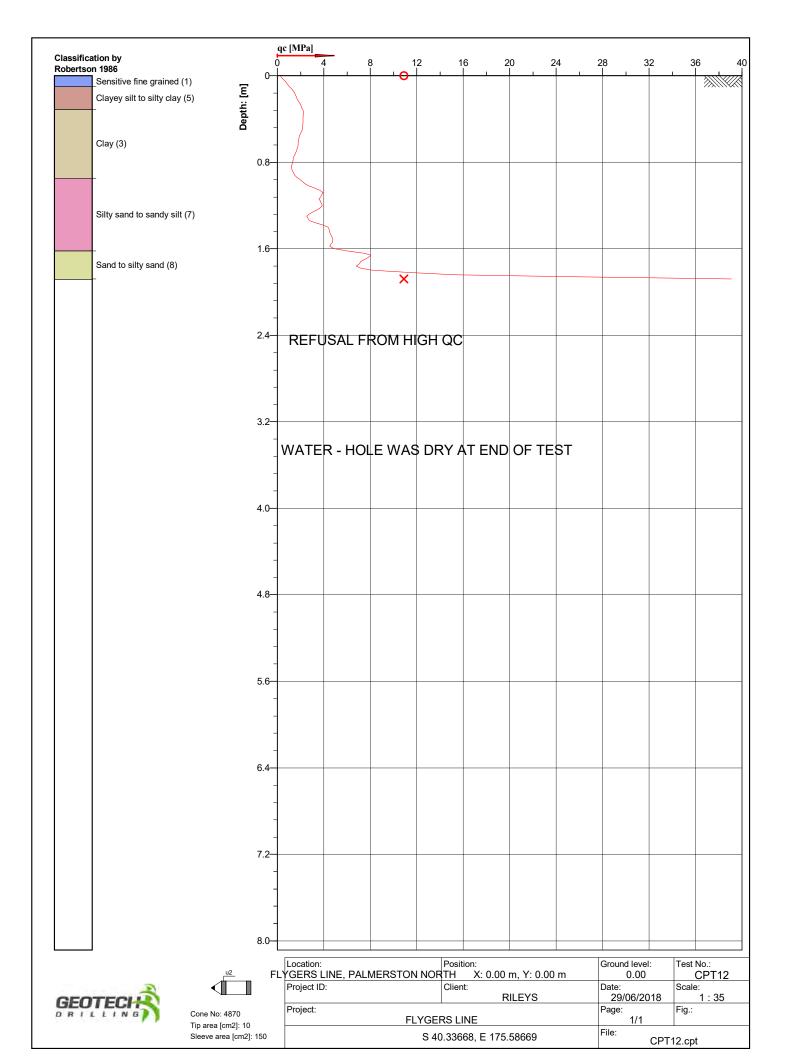
	Location:	Position:	Ground level:	Test No.:
-L\	GERS LINE, PALMERSTON NOR	TH X: 0.00 m, Y: 0.00 m	0.00	CPT12
	Project ID:	Client:	Date:	Scale:
	-	RILEYS	29/06/2018	1:36
	Project:		Page:	Fig.:
	FLYGER	1/1	_	
	S 40.33668, E 175.58669		File: CPT1	12.cpt

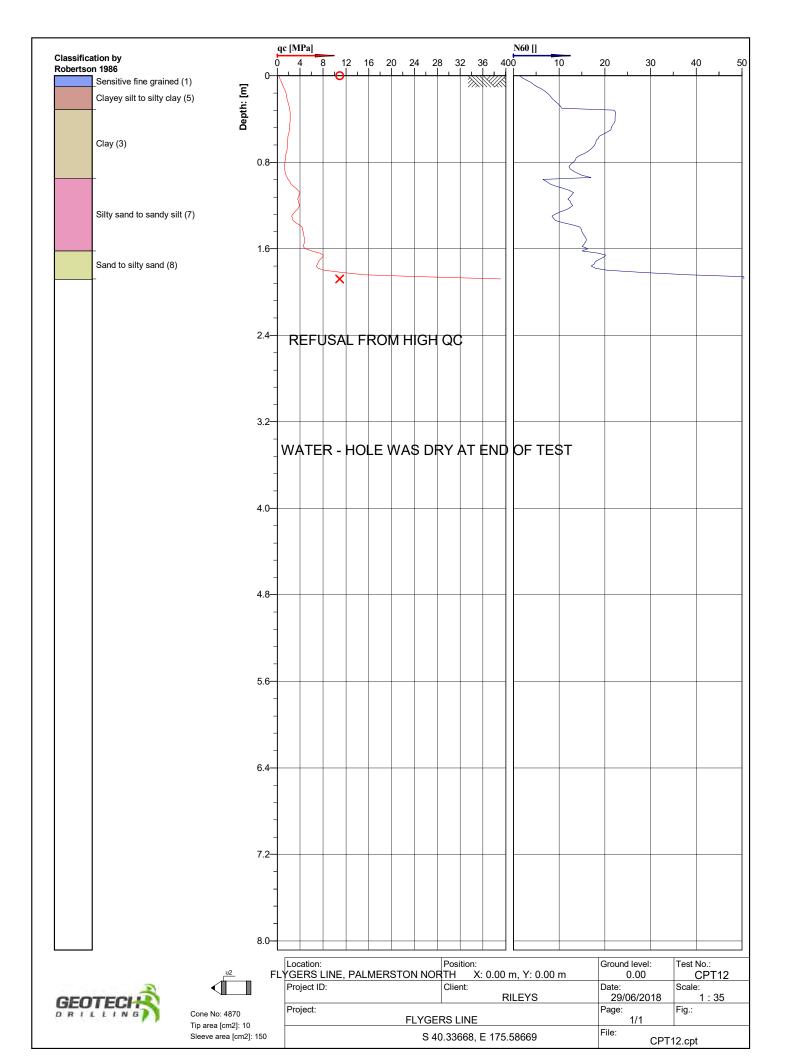


Sleeve area [cm2]: 150

	Location:	Position:	Ground level:	Test No.:
-L\	GERS LINE, PALMERSTON NOR	TH X: 0.00 m, Y: 0.00 m	0.00	CPT12
	Project ID:	Client:	Date:	Scale:
	-	RILEYS	29/06/2018	1:36
	Project:		Page:	Fig.:
	FLYGER	1/1	_	
	S 40.33668, E 175.58669		File: CPT1	12.cpt







	ect:	es and	TANTS	Tel; Fax:		1897872	2		catio							Hole position			_	_		_	111		E	No	D.:
	No.:	Lin 706	e-Flyger	S	Start		e: 16	3-01-1	19	Gro	Nor ound		el (m	ı):		Near CPT Co-Ordinate	es ():				MH)				MI	- 11
Clie	ent:		e Invest	-			ite. To	5-01-	19			ole (Dept	h;			E 1	75.6	i N	40	0.3		-	S	heet:	1 o	f 2
	riygers		e mvesu	ment	. Gro	oup	-	_		_		15.5	+ m	- -	9									Lab 3	resting		7
Elevation (m)	Depth (m)	Geological Unit		(re	efer to Geolo	o sepa	gical De arate G Informa er inform	eotech	nical :	and or			Legend	Unified Symbol	Drilling Method	Core Recove (%)		RQD (%)	Piezometer	Soil Moisture	Groundwater	Samples	Air Voids (%)	Density (Vm3)	Uniaxial Comp Strength (kPa)	· s	Field Testing
	0.20	•	TOPSOIL	; light t	browr	n; fine	rootlets	S))) × . ×		•			-1	×	M							
	-1		SILT, trac plastic.	e to m	inor c	lay; m	nixed gr	eyish o	orang	e Mois	it, sligh	ntly	× × ×														
	1.95 2		1.15 m - 1										× × × × ×						Timinininininininininininininininininini	м							SPT 1.50 m 1, 1, 1, 1, 2, 2;
			Sandy SIL slightly co	hesive							o med	ium;	× × ×			11 1	8										N=6
	3 3.70	3.45 m - 3.70 m Sandy SILT; dark grey, sand, fine.									× × × × ×								16/01/2019						SPT 3.00 m 1, 2, 2, 4, 6, 6; N=18		
	3.90 4.4.98		SILT, mine	or to so	ome o	clay; d	lark gre	y. Sligi	ht to r	modera	te plas	sticity	×			4-11	3			S							
	4.40	SILT; dark grey. Slightly plastic; trace organic inclusions							ns.		×														SPT 4.50 m		
-	4.95 -5	Silty SAND; dark grey; sand, fine to medium.									× — × —			4											0, 0, 0, 0, 0, 1; N=1		
		SAND; dark grey; medium to fine. Silty SAND; dark grey; slightly cohesive. Clayey SILT; light bluish grey. Slight to moderate plasticity.							- 10	×_ × ×	1		0.00			Timin.											
	5.90 -6											Sonic				H								SPT 6.00 m			
	6.90							ticity		000				N										2, 2, 11, 19, 20, 0/0mm; N=50+			
	-7	Ī	SILT, mind	or clay	, mino	or san	ıd; light	grey; s	sand,	fine to i	mediu	m.	°a.														14-501
			SAND; da	rk bluis	sh gre	ey. We	et; sand	, med	um to	coarse	э,	- 111	0.0			141	ij										SPT 7.50 m
	8	GRAVEL; rounded, well graded, fine to medium grain; <5 diameter. GRAVEL, some sand; rounded, well graded, fine to mediameter. GRAVEL, some sand; rounded, well graded, fine to media. 8.95 m Thin band of SILT with some clay. Silty sandy GRAVEL; gravel, fine to medium grain; <70mi							nm	000			WH											8, 10, 10, 11, 12, 17; N=50			
	9 9.45							iedium	n grair	000														SPT 9.00 m 7, 8, 11, 9, 14,			
	10		Silty sandy diameter;				i, fine to	o medi	um gr	rain; <7	'0mm		0×														13; N=47
													Q X			411	4										SPT
	-11												0 X 5 0× 5 8														10.50 m 11, 19, 20, 19, - 11/30 mm; N=50+
Ext	11.90 olanati	ons											× 4		۵,	CHAPTER.					-	71			Rem	norke	
Rock veath comp Relati veak	Mass W hered, m letely we we Rock modera	eather oders ather Streetely s	ering - unwe ately weathered, residua ngth - extre atrong, strong	ered, h ally we mely v	nighly eather weak,	weath red very	1	Small Large U100	II Dist e Dist 0 Und	netrome turbed S turbed S listurbed est - Flo	Sampl Sampl d Sam	e e ple			MAP W										Ren	idiK	
SCR RQD Attitud	R - Solid Core Recovery D - Rock Quality Designation litude of discontinuities displayed as Dip/Dip rection and Trend/Plunge Water Strike (1st, 2nd Water Rise (1st, 2nd Rise Time (minutes)								2nd				S 1:2,500 S														
All			s in metr 1:70			Oriller otech	r: n Drill	ina		Rig T	ype:								She	ear	Van	e No	.:		ged by	y: (Checked by





5		SUL	TANTS	Riley Consultants 4 Fred Thomas Drive Takapuna 0022 Tel: +649 4897872 Fax:								C	R	IL	L.	HC	DL	Εl	_C	G
Proj Rar		Lin	e-Flygers		Locati	on: erston No	orth			Hole position: Near CPT 2 (Wes	sterr	n Me	ost l	MH)				No Mi	o.: -11
Job	No.:	706	72	Start Date: 16 Finish Date: 16	-01-19 -01-19	Ground	d Level (r	n):		Co-Ordinates	(): 75.6	6 N	1 40	.3						
Clie		Lin	e Investme	ent Group		1	Hole Dep 15.34 m										SI	neet:	2 0	ıf 2
								log	po			L	ē	a			Lab T	esting		
Elevation (m)	Depth (m)	Geological Unit		Geological De (refer to separate Ge Geological Informa further inform	eotechnical ition sheet f	and for	Legend	Unified Symbol	Drilling Method	Core Recovery (%)	RQD (%)	Piezometer	Soil Moisture	Groundwater	Samples	Air Voids (%)	Density (Vm3)	Uniaxial Comp Strength (kPa)	Tests/Comments	Field Testing
	12.45		Slightly to m (continued)	, trace fine gravel and noderately plastic.			ange. ×-													SPT 12.00 m 2, 2, 2, 3, 3, 3, N=11
	-133.10	Deposits		light grey. Slightly cohe			× ,													
	14.00	Silty SAND; light grey. Slightly cohesive; sand, fine. SILT, minor clay, minor sand; light grey. Slightly plastic. Silty sandy GRAVEL; grey; gravel, well graded, rounded <10 diameter.							Sonic											SPT 13.50 m 1, 2, 3, 4, 3, 5, N=15
		Holocer																		N=15
	- 15	14.40 m Grades to light brown.																		SPT 15.00 m
	15.34 - 16		EOH @ 15.3	ЭСОН @ 15.34 m																14, 14, 20, 20, 20, 10/35mr Nc=50+
	- 17 -																			
	-18																			
	19																			
	-20																			
	-21																			
	-22																			
	- 23																			

Rock Mass Weathering - unweathered, slightly weathered, moderately weathered, highly weathered completely weathered, residually weathered Relative Rock Strength - extremely weak, very weat weak, moderately strong, strong, very strong TCR - Total Core Recovery SCR - Solld Core Recovery ROD - Rock Quality Designation Attitude of discontinuities displayed as Dip/Dip Direction and Trend/Plunge

Scala Penetrometer - blows/50mm
Small Disturbed Sample
Large Disturbed Sample
U100 Undisturbed Sample
Lugeon Test - Flow Type/Adopted Value
Water Strike (1st, 2nd ...)
Water Rise (1st, 2nd ...)
Rise Time (minutes)

Remarks

All	dimensions in metres
	Scale 1:70

RILEYAKL GLB Log RILEY MH (REV2) - NO SOIL STRENG



	RILEY CONSULTANTS Engineers and Geologists
	Project: Rangitikei Line-Flyge
	Job No.: 170672
	Client: Flygers Line Inves
1	

170672 - MACHINE HOLE LOGS GPJ <<DrawingFile>>

(REV2)-NO

Riley Consultants Limited

DRILL HOLE LOG

Takapuna 0622 Tel: +649 4897872 Location: Hole position: No.: ers Line Palmerston North Near CPT 4 MH2 Ground Level (m): Co-Ordinates (): Start Date: 15-01-19 Finish Date: 15-01-19 E 175.6 N 40.3 Hole Depth: Sheet: tment Group 10.64 m 1 of 1 Unified Symbol **Drilling Method** Lab Testing Geological Uni Soil Moisture Groundwater Depth (m) Piezometer Legend RQD (%) Samples Geological Description Core Recovery Comp (kPa) Field Testing (%) Voids (%) (refer to separate Geotechnical and Geological Information sheet for further information) Density 25 50 0.20 ĴĴ TOPSOIL, light grey, slightly plastic, dry DM SILT with some clay; mixed grey and orange. Dry to moist, moderately plastic. 1.70 1.50 m 0, 2, 2, 1, 1, 2; N=6 M 1.95 Sandy SILT, grey with trace brownish orange staining. Moist, non-plastic. MW Silty fine SAND; dark grey. Moist to wet. 3 SPT 3.00 m 2, 4, 4, 4, 8, 6; N=22 SAND with some silt; dark grey. 3.45 Medium SAND; dark grey. V 4.50 m 3, 6, 9, 9, 12, 15; 5 5 00 Holocene Alluvial Sonic SILT; dark grey. Non to slightly plastic. N=45 20/02/2019 14:52 Produced by gINT Professional 5.60 × Clayey SILT, dark grey. Moderately to highly pistic. 6 × SPT 6.00 m 0, 2, 5, 13, 18, 14/70m N=50+ S Ox 6.50 Gravelly SILT/silty GRAVEL with minor clay; dark greenish grey. Very dense; saturated. Well graded, rounded <50mm dia. Ox X 4 % % % % % % Silty GRAVEL with minor sand. Rounded, <70mm dia. SPT 7.50 m 9, 12, 15, 16, 7/40mn N=50+ 7.90 000 GRAVEL with some sand, minor silt. Well graded, rounded 8.45 000 Sandy fine GRAVEL; bluish grey. Sand, medium to coarse. 00 9 SPT 9.00 m 19, 19, 16, 19, GRAVEL with some sand and silt; greenish grey. Rounded grave 0 000 N=50+ 10 000 SPT 10.50 m 22, 26/70mr N=50+ 10.64 EOH @ 10.64 m -11 Explanations: MAP Remarks Rock Mass Weathering - unweathered, slightly weathered, moderately weathered, highly weathered completely weathered, residually weathered Relative Rock Strength - extremely weak, very weak moderately strong, strong, strong TCR - Total Core Recovery SCR - Solid Core Recovery SCR - Solid Core Recovery RQD - Rock Quality Designation Attitude of discontinuities displayed as Dip/Dip Direction and Trend/Plunge Scala Penetrometer - blows/50mm Small Disturbed Sample Large Disturbed Sample U100 Undisturbed Sample Lugeon Test - Flow Type/Adopted Value Water Strike (1st, 2nd ...) Water Rise (1st, 2nd ...) and Rise Time (minutes) Driller: Rig Type: Shear Vane No .: Checked by All dimensions in metres Logged by: Scale 1:70 Garry - Geotech Drilling Sonic GJ

Scale 1:70

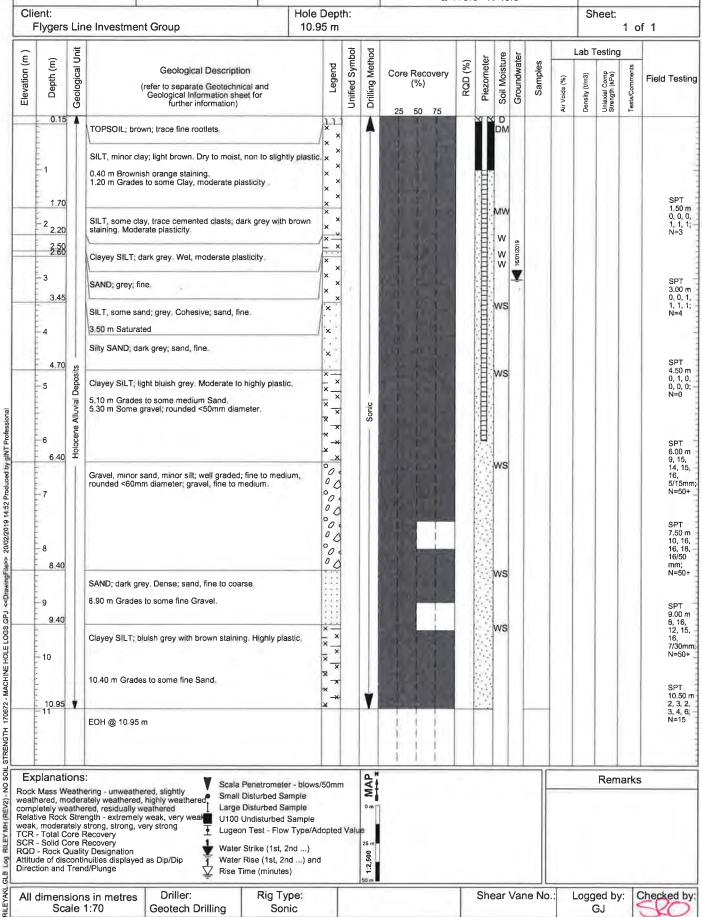
Geotech Drilling

Sonic

Riley Consultants Limited 4 Fred Thomas Drive Takapuna 0622 Tel: +649 4897872

DRILL HOLE LOG

Engineers and Geologists	Fax:						
Project: Rangitikei Line-Flygers	Line	Locatio Palmer		Vorth	Hole posit Near CP		No.: MH3
Job No.: 170672	Start Date: 16- Finish Date: 16-		Grou	nd Level (m):	Co-Ordina	ntes (): E 175.6 N 40.3	
Client: Flygers Line Investm	ent Group			Hole Depth: 10.95 m			Sheet: 1 of 1



		CONS			Takap Tel: +	d Thomas L ouna 0622 +649 48978 +649 4897	72													H	14	NE) /	٩L	JG	EF	R L	OG	
	Project Rang		ine-l	- - lygers			010		ocatic alme	n: rston N	lorth						posit	ion: stern	corn	er of	site						١	lo.:	
	Job N	0.:	0672		S	tart Dat inish Da		-06-	18	Grour		evel ((m):		_			ates (Н	A 1	
	Client Fly		ine I	nvestm	ent G	Group						e De														She		of 1	
	Elevation (m)	Depth (m)	Geological Unit	(re		Geologic separate (nation she				ological tion)		Legend	Unified Symbol			(kPa	•			ala Pe olows				Groundwater	Soil Moisture	Samples		Tests	
			Holocene Alluvial Deposits Geo	TOPSO	DIL; Silt	t; grey; ro	ots; NVO						Unif		50 1		50 20	00	3		9		P 11:	ນ້ອ	w W	1 2			-
duced by gINT Professional		0.80	SILT, minor clay; light grey and orange mixed. Wet, slightly plastic. Silty SAND; grey. Saturated, non plastic; NVO.								- 	× × ×	-											<u>*</u>	w	3			-
GLB Log RILEY HA (AKL) NO MAP 170672 - MACHINE HOLE LOGS.GPJ < <drawingfile>> 22/02/2019 12:44 Produced by</drawingfile>		1.00 FOH @ 1.00 m										(.12	y																-
GLB Log RILEY HA (AKL) NO MAP 1706	Explanations: Rock Mass Weathering - unweathered, slightly weathered, moderately weathered, highly weathered, completely weathered, residually weathered Relative soil Strength - very soft/very loose, small Disturbed Sample firm/medium dense, stiff/dense, very stiff/very dense U100 Undisturbed Sample U100 Undisturbed Sample All dimensions in metres								s/50mm neability 1 nidt Ham I Vane Sł eak, R=R Lonke (Fest mer hear St esidua toggepe st, 2nd	itreng al, etrate d) a	ĵ	Pa)	X] No] Slov] Rap LE T	ne w See	ATER ep (deflow (depth	ı)					ntam	No Visu ination	Remar al or Olf was ob	actory served.		
RILEYAKL	All di	Il dimensions in metres Scale 1:9																		She	ear \	Van	e No).	L	ogged. G		Checked GJ	by:

٤	CONSI		NTS Tal	red Thomas Drive kapuna 0622 : +649 4897872 k: +649 4897873										ŀ	łΑ	ND	A	U(SEF	R L	OG
Proje Rang		ne-l	-lygers Lin			ation: nerston N						wes	tern b	oounda	ary						lo.:
Job N		672		Start Date: 28 Finish Date: 28	8-06-18 8-06-18		d Leve	l (m):	(Co-O	rdina	ates ()	:						Н	A2
Clien Fly		ne I	nvestment	Group			Hole D		h:										Shee		of 1
Elevation (m)	Depth (m)	Geological Unit	(refer to Info	Geological Des separate Geotech rmation sheet for fu	nical and	Geological	Legend	lodenyo bogial	S S		ear S (kPa)				romete 0 mm)	r atemporious	Soil Moisture	Samples		Tests
	-		TOPSOIL; S	Silt; grey. Moist, nor	n plastic; N	NVO.								 				D	4		
	0.35	vial Deposits	SILT, trace Moist to we	to minor clay; grey i t, slightly plastic; N'	with oranç VO.	ge staining.	× ×	\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \										MW	/ 5		
	-	Holocene Alluvial	SILT with m slightly plas	ninor clay; greyish o stic; NVO.	oist to wet,	× × × × × × × × × × × × × × × × × × ×	× × × × × ×										MM				
	0.80		SILT with tr plastic; NV	 ace fine sand; greyi).	— — — — e. Wet, non	×	× × ×										w				
	0.95	v	Silty SAND	; grey. Saturated, no	on plastic;	; NVO.	× :		 			 			 			S	6		
	-		EOH @ 1.0	0 m																	
	-																				
										 	 	ı 		 		 					
Rock weath weath Relat soft/le firm/	lanation Mass W hered, me hered co hered tive soil S mail Dis medium c arge Dis	cala Penetro ows/50mm ermeability T chmidt Hamr situ Vane Sh =Peak, R=Re Peak, R=Re /Ater Rise (1:	est ner lear Strer esidual, pspepara	ate;		НО	Rap	ne v See id Infl ERMI	ep (de low (d NATE	pth) lepth)		 			F No Visua nination		actory				
		ons	in metres		(/							S	hear	Vane	No.		Logged		Checked by	

4 Fred Thorras Drive Takapuna 0622 Tel: +649 4897872 Fax: +649 4897873	HAND AUGER LOG
Project: Location: Hole	e position: No.:
	Ordinates ():
Client: Hole Depth: Flygers Line Investment Group 1.00 m	Sheet: 1 of 1
Geological Description (refer to separate Geotechnical and Geological Information sheet for further information) Geological Description (kF	Pa) (blows / 50 mm) H E E Tests
TOPSOIL; grey. Silt, rootlets. Moist, non plastic; NVO.	150 200
Rock Mass Weathering - unweathered, slightly weathered, moderately weathered, highly weathered, completely weathered, residually weathered Relative soil Strength - very soft/very loose, soft/loose, Small Disturbed Sample firm/[radio Disturbed Sample Sample Water Rise (1st. 2nd) and HOLE	INDWATER Jone Own Seep (depth) Appid Inflow (depth) TERMINATED DUE TO: Get Depth Remarks NVO - No Visual or Olfactory Contamination was observed. Shear Vane No. Logged by: Checked by:

		RII CONSU Engineers a		NTS Te	Fred Thomas Drive kapuna 0622 l: +649 4897872 x: +649 4897873	Limito								ŀ	ΗA	ND	Αl	JC	SER	LC	OG
ŀ	Projec						cation:						sition:							N	0.:
	Job N	0.:		-lygers Lir	Start Date: 28	 3-06-18	Imerston Nort B Ground I		(m):		_		i portio	n of sit	e					Н	A 4
	Client		672		Finish Date: 28	3-06-18		ole De	enth:										Sheet	t-	
ļ	Fly			nvestmen	t Group			1.00 m											-		of 1
	Elevation (m)	Depth (m)	Geological Unit	(refer t	Geological Des o separate Geotechr rmation sheet for fur	nical and	d Geological	Legend	Unified Symbol		•	ar Str (Pa)			a Penet ows / 50	trometer 0 mm) 9 12	Groundwater		Samples		Tests
	-	- 0.25 -	Holocene Alluvial Deposits	SILT, trace	clay; light grey with ntly plastic; NVO.		staining. Moist,	\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\										М			
gINT Professional	-	0.60	Holo	SILT, mino Moist, sligh	v and orange.	× × × × × × × × × × × × × × × × × × ×										M			-		
Produced by		1.00	<u>,</u>	SILT, mino slightly pla	r fine sand, trace cla stic; NVO.	y; grey.	Wet, non to					 			 	 					-
GLB Log RILEY HA (AKL) NO MAP 170672 - MACHINE HOLE LOGS.GPJ < <drawningfile>> 22/02/2019 12:45 Produced by gINT Professional</drawningfile>	Rock weath weath weath	nered, mo nered, co nered	ering - unweately weather	Scala Penetrome blows/50mm Permeability Test Schmidt Hammer Insitu Vane Sheai	r Streng	th (kF			None Slow S	VATER	lepth)					Re No Visual nination w		ctory			
GLB Log RILEY	soft/lo	ose mall Dis redium d arge Dis	turbe lense turbe	th - very soft d Sample stiff/dense, d Sample bed Sample	/very loose, very stiff/very dense	V=Peak, R=Resid WRTel-banke (ose, Water Rise (1st, 2 Rise Time (minute	e net rate 2nd) a			HOL	-	MINAT	(depth								
RILEYAKL.	All di	imensio Sca		in metres :9										Shear	· Vane	No.	L	ogged GJ	by:	Checked by: GJ	

Polymeristic Poly	CONSU	JLTA and Ge	NTS Taka	ed Thomas Drive ipuna 0622 +649 4897872 +649 4897873										H	łΑ	NE) /	٩L	JG	ER	L	OG
September Sept		ine_F					North	`						f site							N	lo.:
Topic Figure Fi	Job No.:			Start Date: 2	28-06-1	18 Gro			(m):	_				Joice							Н	A5
TOPSOIL: grey, roces. Most NVO. 1		ine I	nvestment	Group		· · · · · · · · · · · · · · · · · · ·														Shee		of 1
TOPSOIL, grey, note. Moist, NVO. Sit. T minor day, trace send, light grey with orange and admiring. Motes, displikely plants. TNOS Sit. T minor day, trace send, light grey with orange and admiring. Motes, displikely plants. TNOS X X X X X X X X X X X X X X X X X X X	Elevation (m) Depth (m)	Geological Unit					I	Legend	Unified Symbol	(kPa)		ין י					Groundwater		Samples		Tests
weathered, completely weathered, residually weathered Schmidt Hammer Insitu Vane Shear Strength (kPa)	- 0.30 - 11.00 - 1 1.00 - 1 weathered, moweathered, conweathered, con	Seather and the seather and th	SILT, minor of staining. Moi	clay, trace sand; st, slightly plastic	light grey; NVO.	Scala Penet blows/50mn Permeability Schmidt Har	rromete 1 7 Test mmer	× × × × × × × × × × × × × × × × × × ×		 				3 					M O - N	lo Visua	l or Olfa	actory
Relative soil Strength - very soft/very loose, Soft/loose Small Disturbed Sample firm/Lingdium dense Stiff/dense, very stiff/very dense U100 Undisturbed Sample U100 Undisturbed Sample V=Peak, R=Residual, WREL Sorte (1st, 2nd) and WREL Sorte (1st, 2nd) and Rapid Inflow (depth) HOLE TERMINATED DUE TO: Target Depth Target Depth	soft/loose Small Dist firm/medium d Large Dist	turbe lense turbe	d Sample stiff/dense, v d Sample	V=Peak, R= Water Rise	Residu ફ (tost e,e, (1st, 2i	ual, zvetr ate nd))		E TE	RMINA		,	TO:									
											S	hear	Vane	e No	D.	L		by:	Checked by GJ			

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Job No.:				Start Date: 2	9-06-18	Ground		(m):			Ordinate		riyge	#15 LII	ie				Н	A 7
Client:	1700 rs Lir		nvestment	Finish Date: 2 Group	29-06-18		Hole De											Shee		of 1
Elevation (m)	Depth (m)	Geological Unit	(refer to Info	Geological De o separate Geotech rmation sheet for fu	nnical and	Geological mation)	Legend	Unified Symbol	Soil	(kP	Strengtha)	า ร	Scala P (blows	enetro s / 50 r	nm)	Groundwater		Samples		Tests
_		A	TOPSOIL; s	silt; grey. Moist, no	n plastic; N	IVO.	\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\			 							М			
-	0.25	vial Deposits ——————	SILT, trace NVO.	clay, trace sand; g	rey. Moist,	non plastic;	× × × × × × × × × × × × × × × × × × ×	<u>L</u>									М			
-	O.50 O.50 Image: Sign of the control of the contr																MW			
	1.00	•	EOH @ 1.0	0 m		×××														
weathere weathere weathere Relative s soft/loose firm/medi Large	ss Wed, mo ed, cor ed soil St all Dist ium de e Dist	eathe derainplet rengt urbec ense urbec	tely weathered ely weathered th - very soft/	ed, residually	cala Penetrom ows/50mm ermeability Te chmidt Hamm situ Vane She =Peak, R=Res Rel Sanke (N 'ater Rise (1st se Time (mine	st er ear Streng sidual, spenetrate , 2nd)	9	Pa) [No Slo Ra HOLE 1	NDWATE one w Seep pid Inflow ERMINA	(dept	pth)	ГО:				Ro No Visua nination v		actory	
	ensio Scal		n metres 9		Se T W								Sh	iear V	/ane N	lo.	L	ogged.	by:	Checked by: GJ

Riley Consultants Limited 4 Fred Thomas Drive **HAND AUGER LOG** Takapuna 0622 Tel: +649 4897872 Fax: +649 4897873 No.: Proiect: Location: Hole position: Rangitikei Line-Flygers Line Palmerston North Central site HA8 Job No.: Start Date: 29-06-18 Co-Ordinates (): Ground Level (m): 170672 Finish Date: 29-06-18 Sheet: Client: Hole Depth: Flygers Line Investment Group 1.00 m 1 of 1 Elevation (m) Geological Unit Unified Symbol Soil Moisture Groundwater Depth (m) Legend Samples Geological Description Soil Shear Strength Scala Penetrometer Tests (blows / 50 mm) (refer to separate Geotechnical and Geological Information sheet for further information) (kPa) 100 150 200 TOPSOIL; grey. Moist; NVO. ()10 lll)))lll 111 0.25 М SILT, minor clay; light grey with light orange. Moist, slightly plastic; NVO. × × 11 × × Holocene Alluvial Deposits × × 0.60 MW SILT, minor to some clay; greyish orange mixed. Moist to wet, slightly plastic. 170672 - MACHINE HOLE LOGS.GPJ <<DrawingFile>> 22/02/2019 12:45 Produced by gINT Professional 0.85 W SILT, minor sand, trace clay; light greyish orange. Wet; NVO. 12 1.00 EOH @ 1.00 m

Explanations:

GLB Log RILEY HA (AKL) NO MAP

Rock Mass Weathering - unweathered, slightly weathered, moderately weathered, highly weathered, completely weathered, residually weathered

Relative soil Strength - very soft/very loose,

soft/loose Small Disturbed Sample firm/medium dense, stiff/dense, very stiff/very dense Large Disturbed Sample

V	Scala Penetrometer -
Ť	blows/50mm
₹	Permeability Test
V	Schmidt Hammer
	Insitu Vane Shear Strength (kPa)

	V=Peak, R=Residual,
<u></u>	Water Usuatale (ose, experience
	Water Rise (1st, 2nd) and
<u>Z</u>	Rise Time (minutes)

GROUNDWA	ΙEΚ
□ N	

Slow Seep	(depth)

Target Depth

	Rapid Inflow (depth)
но	LE TERMINATED DUE TO:

Remarks

NVO - No Visual or Olfactory Contamination was observed.

U100 Undisturbed Sample	
I dimoneione in motroe	

Scale 1:9

٤	CONS		NTS TO	Fred Thomas Drive akapuna 0622 el: +649 4897872 ax: +649 4897873											HA	ND	Αl	JC	SER	L	OG
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Job N	lo.: 170	672		Start Date: Finish Date:	29-06- 29-06-	18 18	Ground	Level	(m):		C	o-Ord	inates	():						H	A9
			nvestmen	it Group				ole De 1.00 n											Shee		of 1
Elevation (m)	Depth (m)	Geological Unit	Geological Description (refer to separate Geotechnical and Geolog Information sheet for further information					Legend	Unified Symbol		(I	ar Str (Pa)	ength	Scal (bl	a Pene ows / 5	trometer 0 mm)	51 Groundwater	1	Samples		Tests
	-		TOPSOIL;	grey. Moist, non	plastic. N	VO.												М	13		
	- 0.25	-	SILT, trace	e sand; light grey c; NVO.	with orang	ge stainii	ng. Moist,	\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \										М	14		
	-	rial Deposits						× × × × × × × × × × × × × × × × × × ×						 							
	-	Holocene Alluvial Deposits						× × × × × × × ×													
	0.70		Silty SANI	D; grey. Saturated	d, non plas	tic; NVC).	× × · · · · · · · · · · · · · · · · · ·	- > >									S			
	- 1 ^{1.00}	•						× · · · · · · · · · · · · · · · · · · ·	>										15		
	-		EOH @ 1.	00 m									. — — — —								
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Explanations: Rock Mass Weathering - unweathered, slightly weathered, moderately weathered, highly weathered, completely weathered, residually weathered Relative soil Strength - very soft/very loose, soft/loose, Small Disturbed Sample firm/medium. dense, stiff/dense, very stiff/very dense lugge Disturbed Sample U100 Undisturbed Sample Rise Time (min						50mm ability Test It Hammer Vane Sheal k, R=Resid SPIRE (1981) Rise (1st, 2	r Streng dual, e <u>p</u> retrate 2nd)	}	Pa)	X :	None Slow S Rapid	Inflow MINAT	depth 0. (depth)				Remarks 7 - No Visual or Olfactory amination was observed.			
EXPlanations: Rock Mass Weathering - unweathered, slightly weathered, moderately weathered, highly weathered, completely weathered, residually weathered Relative soil Strength - very soft/very loose, spft/loose, Small Disturbed Sample firm/redum dense stiff/dense, very stiff/very dense firm/redum dense stiff/dense, very stiff/very dense 1 U100 Undisturbed Sample All dimensions in metres Scale 1:9						es)			Shear Vane No. Logged by: Chec						Checked by GJ						

ځ	CONSI			4 Fred Thor Takapuna 0 Tel: +649 4 Fax: +649	1622 1897872													Н	A	NI) /	4	JG	EF	R L	OG
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Job N		672		Start Finish	Date: 2 n Date: 2	29-06- 29-06-	18 18	Grour	nd Le	evel ((m):		C	Co-O	rdina	ates	():								H	A10
Fly	Client: Flygers Line Investment Group								Hole 1.0	e De 00 m														Shee		of 1
Elevation (m)	Depth (m)	Geological Unit	(refe		ological Description parate Geotechnical and Geological ion sheet for further information)													(blows / 50 mm)								Tests
	- 0.20	A	TOPSOI	L; grey. Mo	oist, non pl	lastic; N	VO.						 	 		 	 						М			
	-	Holocene Alluvial Deposits	SILT, tra	ice clay; M	loist, slightl	ly plastio	c; NVC	Э.	× × × × × × × × × × × × × × × × × × ×	· × × × × × × × × ×				 									M			
	0.60	Holocene Holocene	SILT, mi mix. Moi	nor clay, tr	race grit; gi	- — — rey and c; NVO.	— — brown	— — —	e	× × × × × × × × × × × × × × × × × × ×													M			
	11.00	•	EOH @	1.00 m					×	×				 					 							
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Rock weath weath weath Relati soft/lg firm/n	nered, monered, conered ive soil Soose mall Disnedium carge Di	eathe odera mple treng turbe turbe turbe	itely weath tely weath th - very s	veathered, hered, high hered, resid soft/very loc se, very sti	nly dually	▼ ▼ × × se	Pern Schr Insite V=P Wate Wate	la Penetro vs/50mm neability 1 midt Ham u Vane Sh eak, R=R eak, R=R er Rise (1 er Rise (1	Γest mer near St esidua (Φs₽,eΣγε st, 2nd	trengi al, etrate d) a		²a)	HOL	Nor Slow Rap E TI	ne v See id Inf	flow (lepth (depti	h)	ГО:					F No Visua nination		actory
		ons	in metre			=		(1111		•								Sh	near	Var	ne No	D.	L	oggeo. GJ		Checked by GJ

2	CONSI Engineers		4 Fr Take Tel:	red Thomas Drive apuna 0622 +649 4897872 :: +649 4897873	Liiiilou								H	IAN	ID /	Δl	JG	ER	LC	OG
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Job N	lo.:			Start Date: 29	-06-18	Ground I		(m):				ates ():		Dounda	ar y				HA	\11
Clien	170 t:	6/2		Finish Date: 29	-06-18	 	ole De	epth:										Sheet	•	
	/gers Li		nvestment	Group			1.00 m												1 0	of 1
Elevation (m)	Depth (m)	Geological Unit		Geological Desc separate Geotechn mation sheet for furt		ological tion)	Legend	Unified Symbol		il Shear (kP				Penetron vs / 50 m		Groundwater	Soil Moisture	Samples		Tests
AP 70672 - MACHINE HOLE LOGS GPJ < <drawingfile>> 22/02/2019 12.44 Produced by gINT Professional </drawingfile>	- 0.25 - 0.70 - 11.00	∵ Holocene Alluvial Deposits — — — Holocene Alluvial Deposits — — — — — — — — — — — — — — — — — — —	SILT, trace of plastic; NVC	clay; light grey and co.	orange. Mois	st, slightly ist to wet,		Unit					3			5	M	Re	emark or Olfo	
Weath soft/kg firm/[nered, monered, conered ive soil Soose Brall Disagge D	mple treng turbe	tely weathere tely weathere th - very soft/v	ed, highly d, residually	Perm Schn Insitu V=Pe WRR Wate	s/50mm neability Test nidt Hammer u Vane Sheai eak, R=Resid to Sarke (1981) er Rise (1st, 2 Time (minute	· r Streng dual, epetrate 2nd) a	; }	'a)	Slo Ra HOLE	pid Inf		epth)	TO:				No Visual nination w		
All d		ons	in metres		_ 7800	(-/						S	hear Va	ane No	0.	L	ogged b	oy:	Checked by: GJ

2	CONSU Engineers	JLTA ind Ge	4 F Tak Tel	red Thomas Drive apuna 0622 : +649 4897872 :: +649 4897873	Limitod								H	IAN	D /	Αl	JG	BER	LC	OG	
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Job N					9-06-18	Ground		(m):				ates ()		o near s	ilicus				HΑ	12	
Clien	ıt:		nvestment		9-00-10		lole De 1.00 m											Sheet	: 1 c	of 1	
Elevation (m)	Depth (m)	Geological Unit	(refer to	Geological Des separate Geotech mation sheet for fu	I Description otechnical and Geological for further information) Puer Burger Scil Shear Streng (kPa)								(blows / 50 mm) S E S O O O O O O O O O								
	0.20			lark grey. Moist, not clay, trace sand; lig).					 								М			-	
	- 0.50	Holocene Alluvial Deposits ————	Condu SII T	: light groy Wet new	n plastic: NV	1 0	× × × × × × × × × × × × × × × × × × ×										w			_	
	-	Holocene	Sandy SIL I	; light grey. Wet, no	on piastic; NV	O.	× .× . × .× . × .× . × .× . × .× .													-	
Produced by gINT Professional	0.90		SILT, some plastic; NV0	clay; light grey. Sal).	turated, mode	erately	× × × × × × × × × × × × × × × × × × ×										S			-	
OrawingFile>> 22/02/2019 12:44	_		EOH @ 1.0	0 m																-	
RILEYAKL. GLB. Log. RILEY HA (AKL) NO MAP 170672 - MACHINE HOLE LOGS. GPJ < <drawingfile>> 22/02/2019 12:44 Produced by gINT Professional professiona</drawingfile>	-																			-	
Expl	anation				▼ Scala	a Penetrome	eter -		 	GROL	JNDW	ATER	<u> </u>	- i -				Re	marks	S	
Rock weath weath weath weath weath weath weath weath weath soft/lg firm/[hered, mo hered, co hered tive soil S oose Small Dis medium c arge Dis	mple treng turbe	ately weathers tely weathers ath - very soft/ atd Sample e stiff/dense, d Sample	ed, residually	blows Perm Schn Insitu V=Pe Wate Wate	s/50mm neability Test nidt Hamme I Vane Shea eak, R=Resid I SMRE (PSR er Rise (1st, 1	t r r Streng dual, pe net rate 2nd) a	;	'a)	S R HOLE	None low Se apid In	ep (de flow (d	epth) depth) ED DUE	TO:				No Visual ination w	or Olfa	ctory	
All d		ons	in metres			Time (minut	.es)					· 	S	hear Va	ane No	0.	L	ogged k	by:	Checked by: GJ	

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Job No.	.:			Start Date:	29-06-	18 Grou	ind Lev	vel (m):				ates ()		OII OI	Site				HA	\13
Client: Flyge			nvestmen	Finish Date: t Group	29-06-	18	Hole 1.0	De _l											Sheet		of 1
Elevation (m)	Depth (m)	Geological Unit	(refer t Info	Geological E o separate Geote ormation sheet fo	echnical a	nd Geological		Legend	Unified Symbol		(kl	r Stre			Penetr vs / 50	•	Groundwater	Soil Moisture	Samples		Tests
-		A	TOPSOIL;	grey. Moist; NVC).					50) 100 	150 2 		3 (66 99	12	15 	М	16		
-	0.30	Holocene Alluvial Deposits	SILT, mino Moist, sligh	r clay, trace sand tly plastic; NVO.	d; grey and	d orange mixed	×	× × × × × × × × × × × × × × × × × × ×										M	17		-
Journal by Birk Fridessicial	4.00		0.80 m Gra brownish c	ades to minor to s range mixed. Mo	some clay pist, slightl	, trace grit; gre y plastic; NVO	× × × × × × × ×	× × × ×											18		
Explan Kanapana Little 1977/97/ Authority of	1 1.00		EOH @ 1.0	00 m			X														
Explar Rock M weather	lass We red, mo red, col e soil Si se nall Dist edium d rge Dist	eathe odera mple treng turbe ense urbe	tely weather tely weather th - very soft	ed, residually	ense $\frac{1}{2}$	Scala Penetri blows/50mm Permeability Schmidt Ham Insitu Vane S V=Peak, R=F WRFe Sanke Water Rise (* Rise Time (m	Test nmer Shear Sti Residual (Pst;e214 1st, 2nd	rengt I, etrate I) a		a) [S R HOLE	apid In	ep (de flow (c		TO:	1			Re No Visual nination w		actory
,	nensio Scal		in metres 9											S	hear '	Vane N	lo.	L	ogged.	by:	Checked by: GJ

Riley Consultants Limited 4 Fred Thomas Drive **HAND AUGER LOG** Takapuna 0622 Tel: +649 4897872 Fax: +649 4897873 No.: Proiect: Location: Hole position: Rangitikei Line-Flygers Line Central site Palmerston North **HA14** Job No.: Start Date: 29-06-18 Co-Ordinates (): Ground Level (m): 170672 Finish Date: 29-06-18 Sheet: Client: Hole Depth: Flygers Line Investment Group 1.00 m 1 of 1 Elevation (m) Geological Unit Unified Symbol Soil Moisture Groundwater Depth (m) Legend Samples Geological Description Soil Shear Strength Scala Penetrometer Tests (refer to separate Geotechnical and Geological Information sheet for further information) (blows / 50 mm) (kPa) 100 150 200 TOPSOIL; NVO. ()19 lll)))111 0.20 М × SILT, trace clay; light grey and orange. Moist, non plastic; NVO. $\label{eq:silter} % \begin{subarray}{ll} \end{subarray} % \begin{subarray}{ll$ × 20 × × × × Holocene Alluvial Deposits 170672 - MACHINE HOLE LOGS.GPJ << DrawingFile>> 22/02/2019 12:44 Produced by gINT Professional 0.90 Silty SAND; brownish orange grey. Wet to saturated; NVO. WS 21 1.00 EOH @ 1.00 m

Explanations:

Log RILEY HA (AKL) NO MAP

Rock Mass Weathering - unweathered, slightly weathered, moderately weathered, highly weathered, completely weathered, residually weathered

Relative soil Strength - very soft/very loose,

soft/loses
Small Disturbed Sample
firm/medium dense stiff/dense, very stiff/very dense
Large Disturbed Sample
U100 Undisturbed Sample

	1	Insitu Vane Shear Strength (kPa) V=Peak, R=Residual,
9	¥	With the top of the state of th
-	1	Water Rise (1st, 2nd) and
	\vee	Rise Time (minutes)

Scala Penetrometer -

blows/50mm

Permeability Test

Schmidt Hammer

GROUNDWATER	
	None

Slow	Seep	(depth

	spui)
HOLE TERMINATED	DUE TO:
Target Depth	

Remarks

NVO - No Visual or Olfactory Contamination was observed.

All dimensions in metres	
Scale 1.0	

APPENDIX B

Laboratory Test Results

PLASTICITY INDEX TEST REPORT



Project:

Rangitikie Line

Location:

Rangitikie Line

Client:

Riley Consultants Ltd

Contractor:

Not Stated

Sampled by:

Not Stated

Sampling method:

Not Stated

Sample description:

Brownish Grey; silty CLAY

Sample condition:

brownish Grey, siny CL

Sample reference:

As Received

Sample depth:

MH3 2.1m

Project number:

1-LA014.00

Lab ref number:

Date sampled: Not Stated

AL3490/1

Client ref number:

170672

Folder number:

45.0

Test Results

As rec'd water content:

45.0%

Liquid limit:

69

Plastic limit:

27

Plasticity Index:

42

Test methods		Notes	
Water Content:	NZS 4402 : 1986, Test 2.1	Test performed on: Fraction passing 0.425mm test sieve	
Liquid Limit:	NZS 4402: 1986, Test 2.2	Sample descriptions are not covered by IANZ accreditation.	
Plastic Limit:	NZS 4402: 1986, Test 2.3		
Plasticity Index:	NZS 4402: 1986, Test 2.4		

Date tested:

05/02/19

Sampling is not covered by IANZ Accreditation. Results apply only to sample tested.

Date reported:

08/02/2019

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IANZ Approved Signatory

Thirushen Pillay

Designation:

Senior Civil Engineering Technician

Date:

08/02/2019

Mey



LAF-103 (06/18)

Page 1 of 1

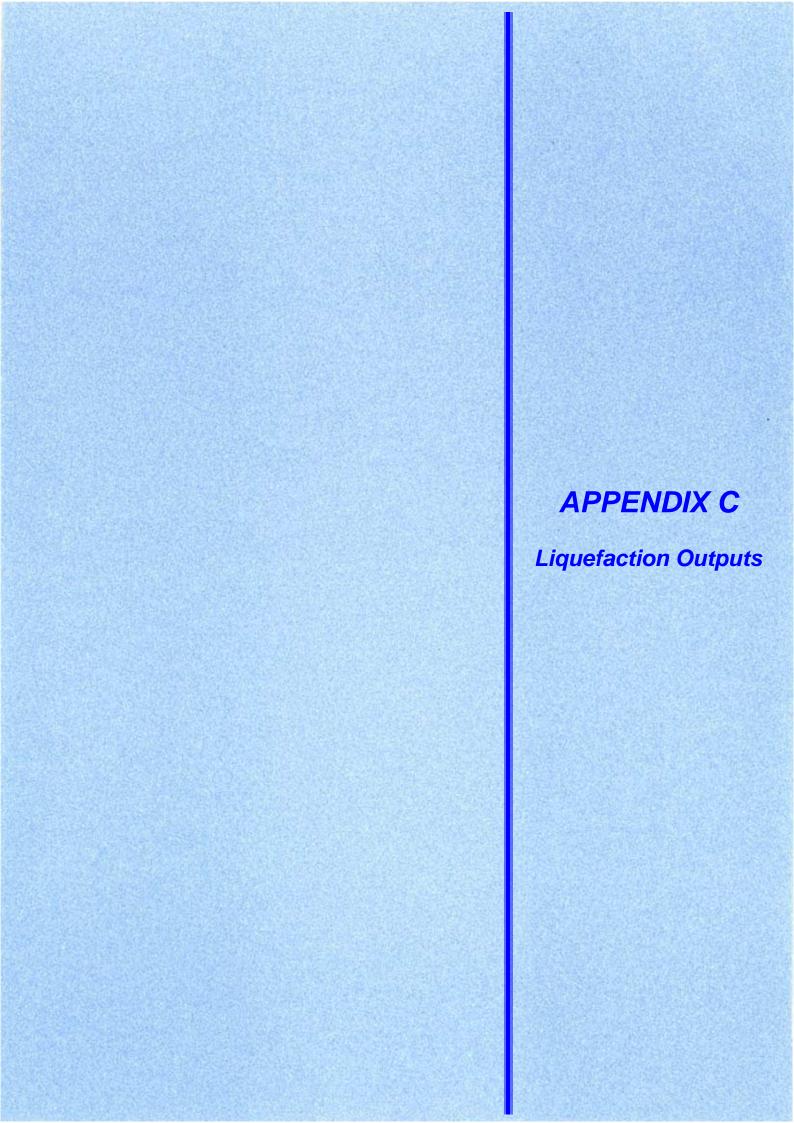


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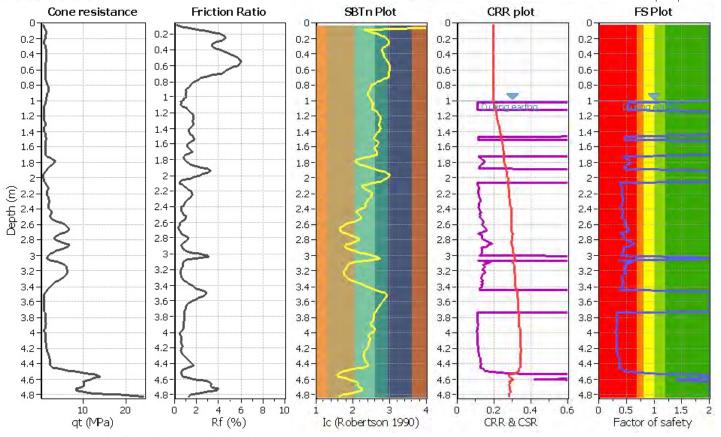
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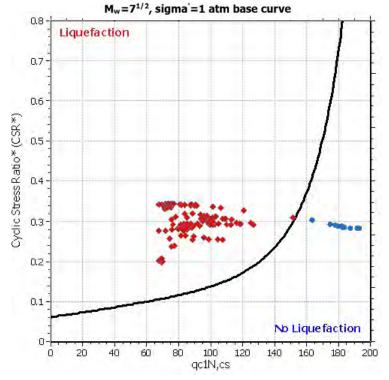
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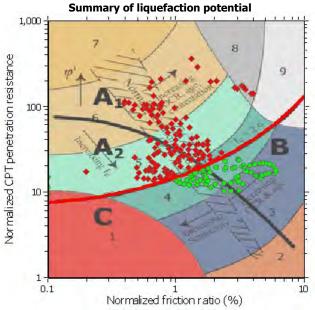
CPT file: CPT01

Input parameters and analysis data

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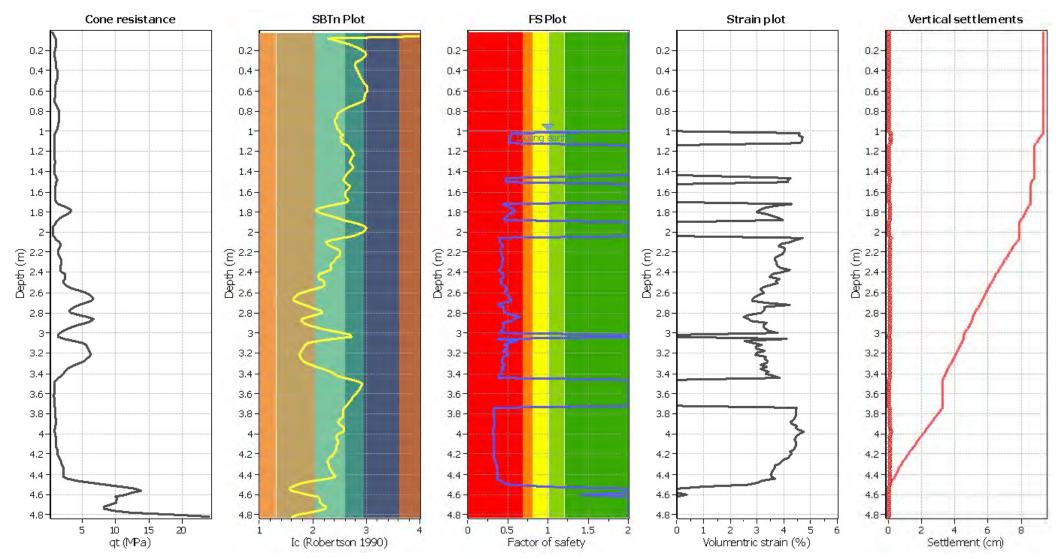




Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry.

Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Estimation of post-earthquake settlements



Abbreviations

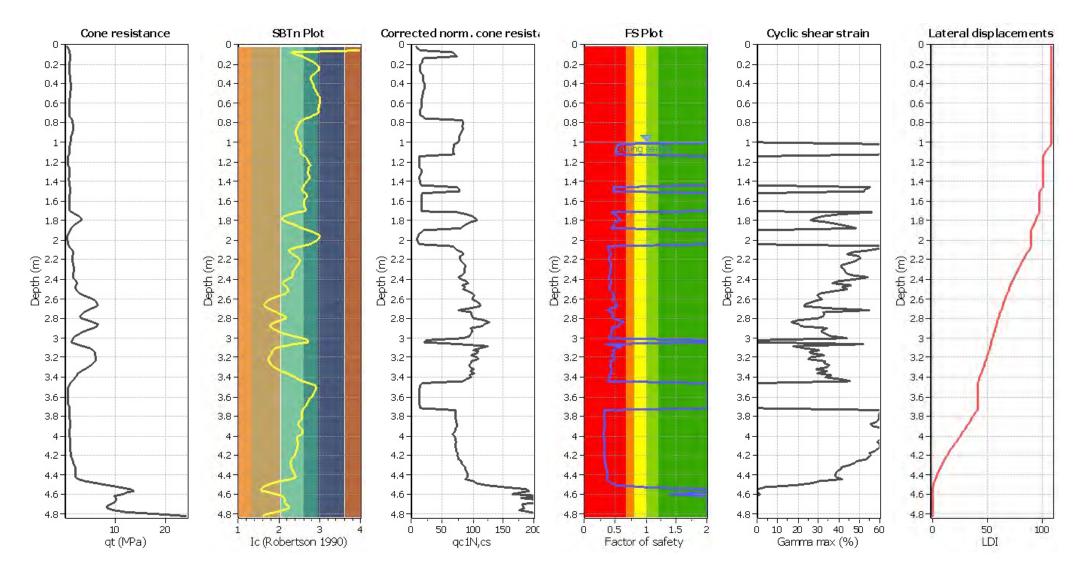
qt: Total cone resistance (cone resistance qc corrected for pore water effects)

Ic: Soil Behaviour Type Index

FS: Calculated Factor of Safety against liquefaction

Volumentric strain: Post-liquefaction volumentric strain

Estimation of post-earthquake lateral Displacements



Abbreviations

 $q_{\text{t}}\text{:}$ Total cone resistance (cone resistance q_{c} corrected for pore water effects)

Ic: Soil Behaviour Type Index

q_{c1N,cs}: Equivalent clean sand normalized CPT total cone resistance

F.S.: Factor of safety

γ_{max}: Maximum cyclic shear strain LDI: Lateral displacement index



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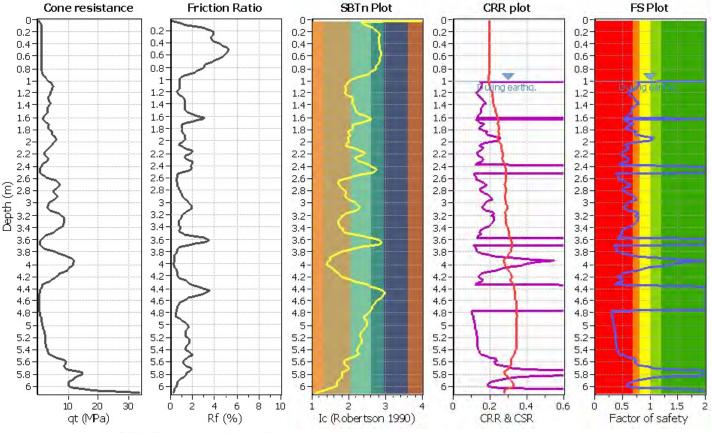
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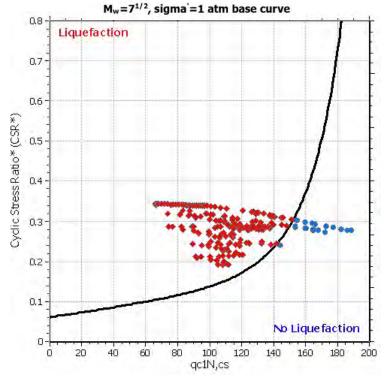
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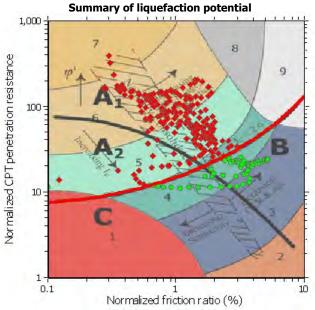
CPT file: CPT02

Input parameters and analysis data

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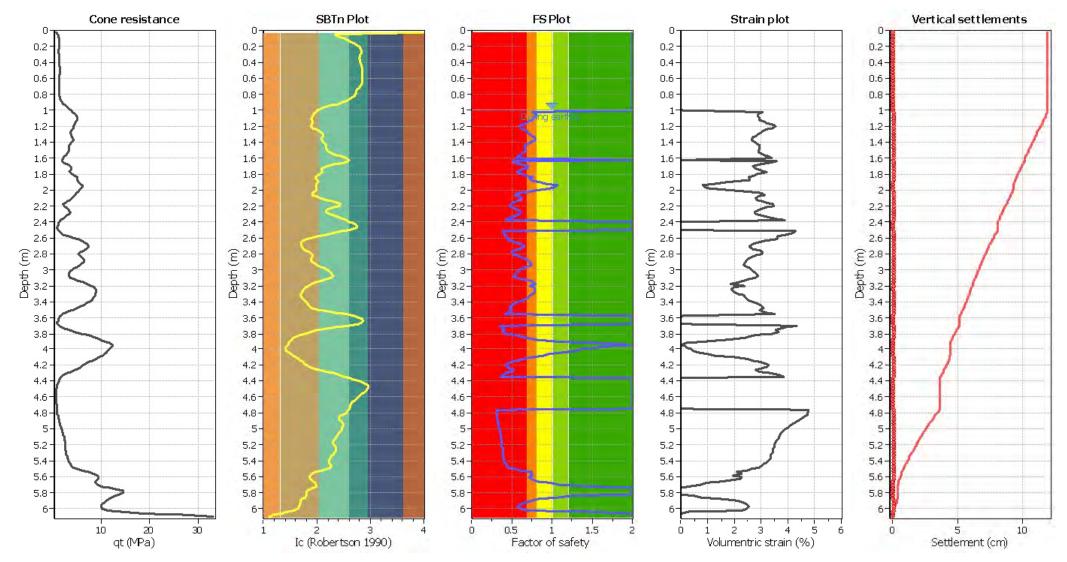




Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry.

Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Estimation of post-earthquake settlements



Abbreviations

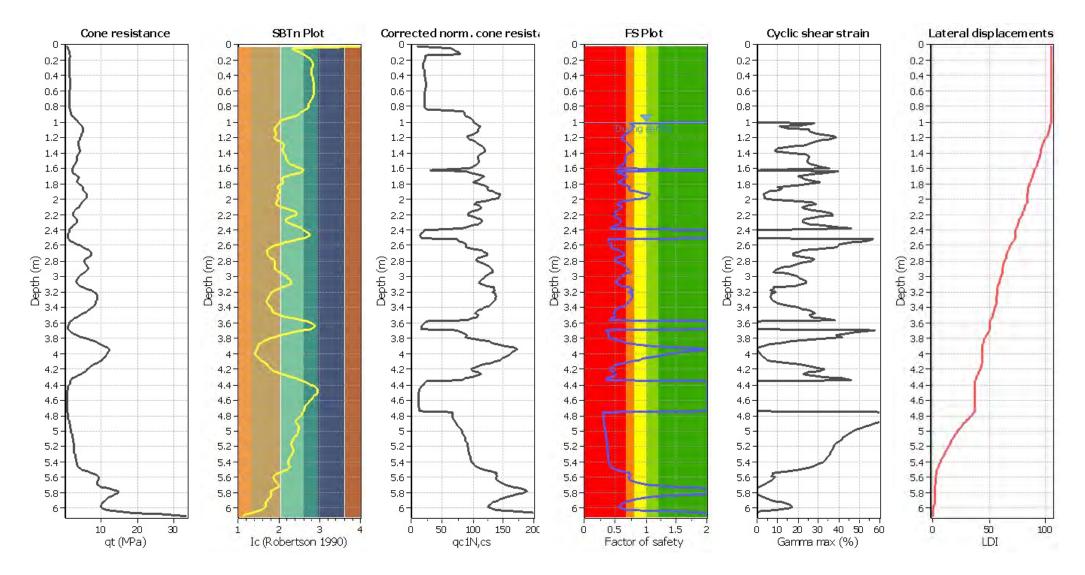
 q_t : Total cone resistance (cone resistance q_c corrected for pore water effects)

Ic: Soil Behaviour Type Index

FS: Calculated Factor of Safety against liquefaction

Volumentric strain: Post-liquefaction volumentric strain

Estimation of post-earthquake lateral Displacements



Abbreviations

 $q_{\text{t}} :$ Total cone resistance (cone resistance q_{c} corrected for pore water effects)

Ic: Soil Behaviour Type Index

qc1N.cs: Equivalent clean sand normalized CPT total cone resistance

F.S.: Factor of safety

γ_{max}: Maximum cyclic shear strain LDI: Lateral displacement index



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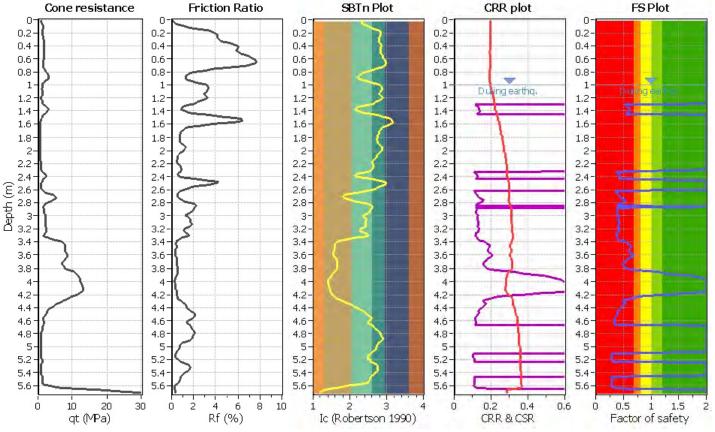
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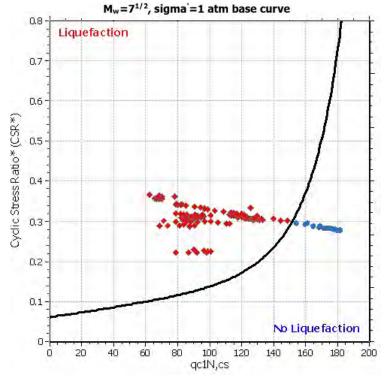
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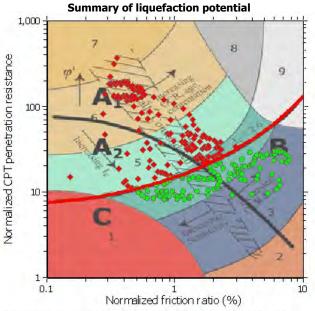
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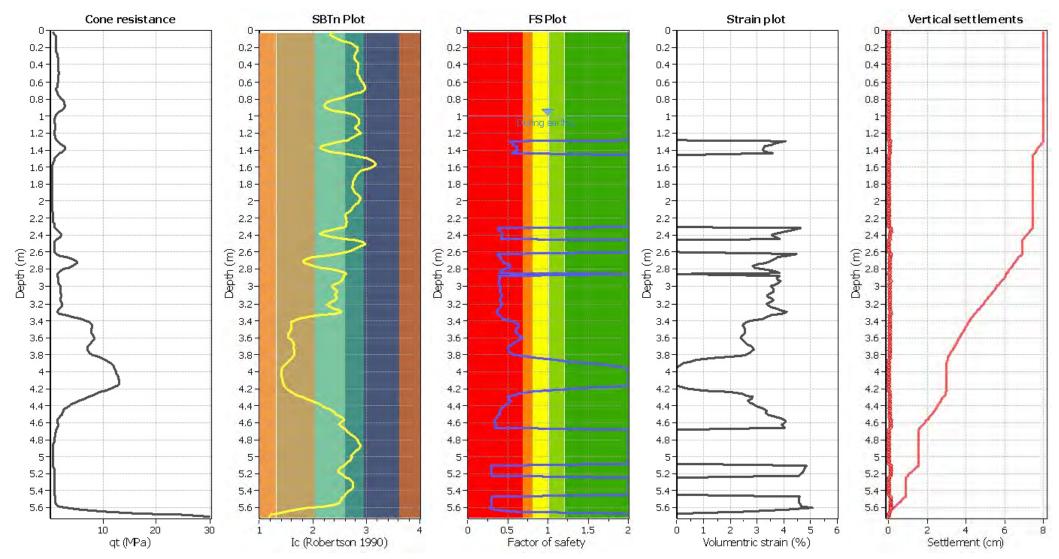




Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry.

Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Estimation of post-earthquake settlements



Abbreviations

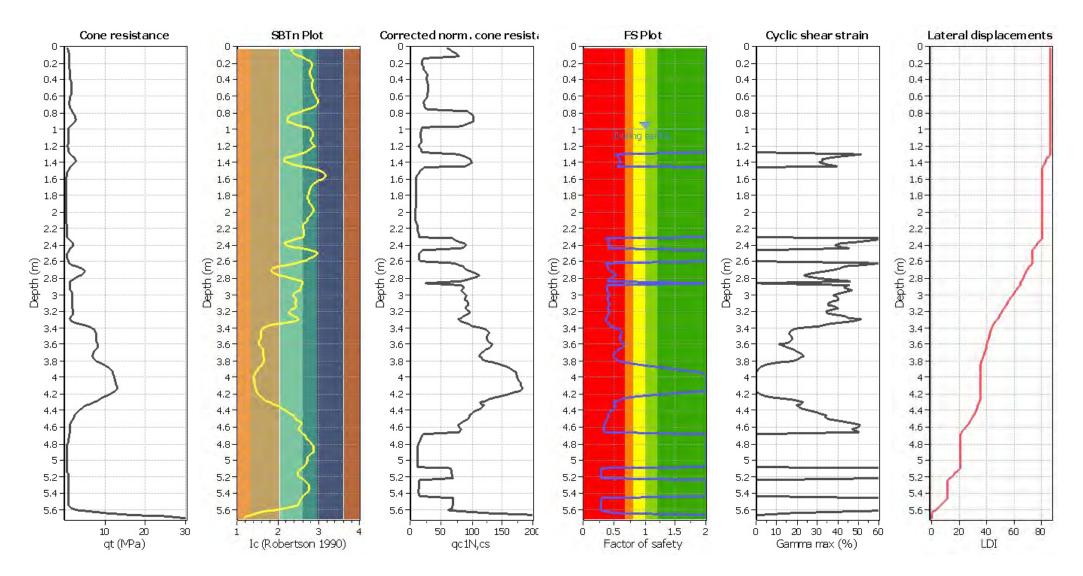
 q_t : Total cone resistance (cone resistance q_c corrected for pore water effects)

Ic: Soil Behaviour Type Index

FS: Calculated Factor of Safety against liquefaction

Volumentric strain: Post-liquefaction volumentric strain

Estimation of post-earthquake lateral Displacements



Abbreviations

 $q_{\text{t}}.$ Total cone resistance (cone resistance q_{c} corrected for pore water effects)

Ic: Soil Behaviour Type Index

q_{c1N,cs}: Equivalent clean sand normalized CPT total cone resistance

F.S.: Factor of safety

γ_{max}: Maximum cyclic shear strain LDI: Lateral displacement index



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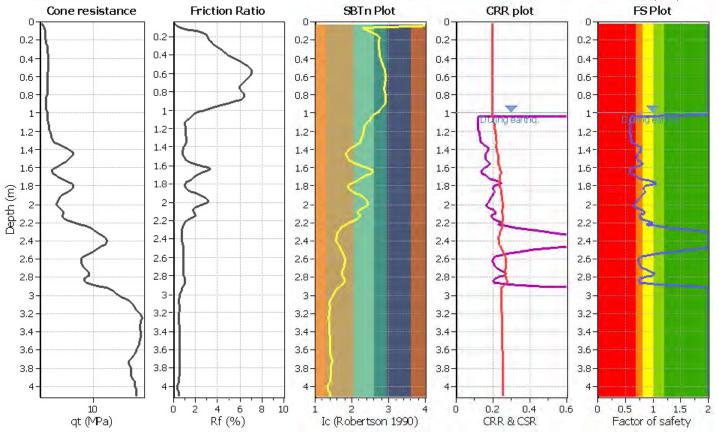
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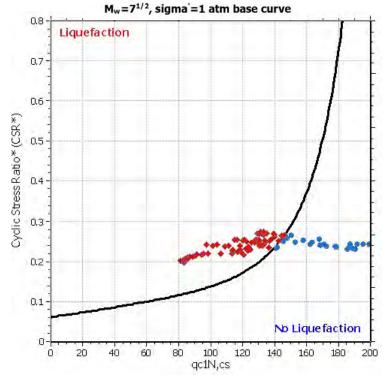
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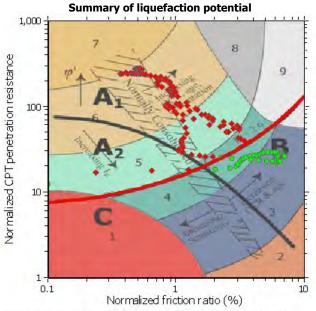
CPT file: CPT04

Input parameters and analysis data

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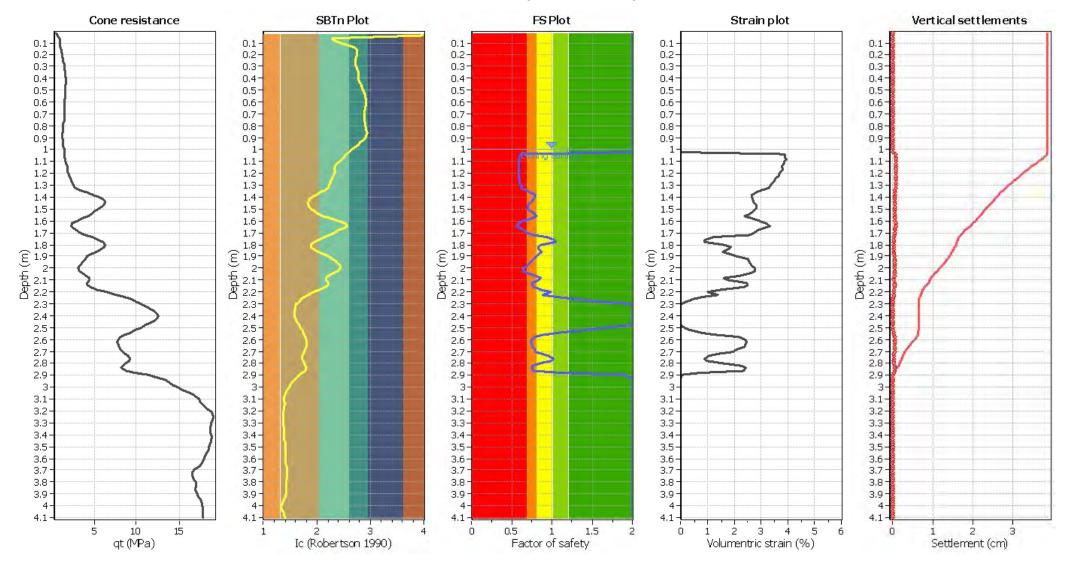




Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry.

Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Estimation of post-earthquake settlements



Abbreviations

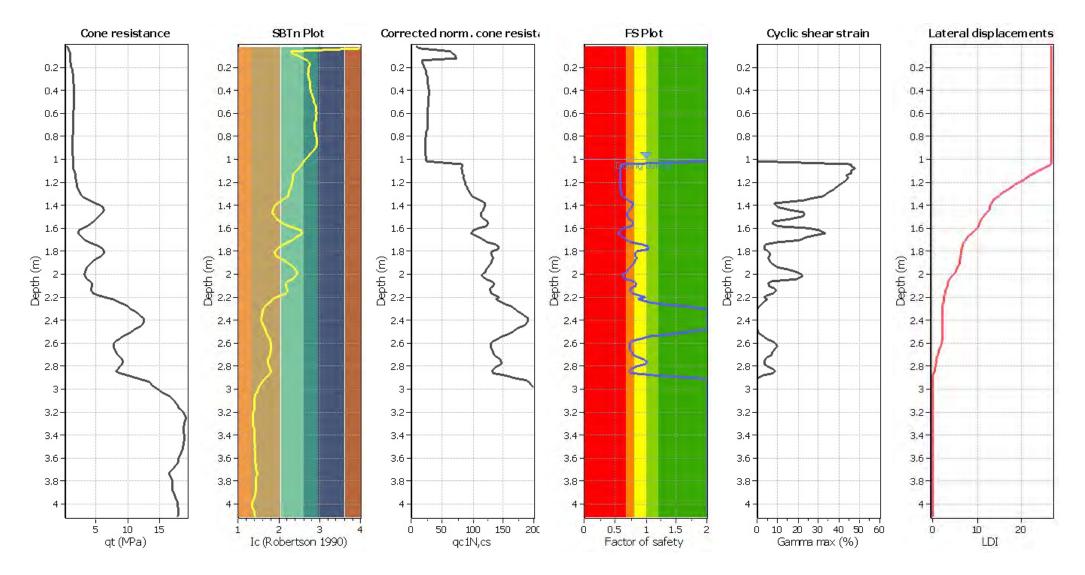
 q_t : Total cone resistance (cone resistance q_c corrected for pore water effects)

Ic: Soil Behaviour Type Index

FS: Calculated Factor of Safety against liquefaction

Volumentric strain: Post-liquefaction volumentric strain

Estimation of post-earthquake lateral Displacements



Abbreviations

 $q_{\text{t}}\text{:}$ Total cone resistance (cone resistance q_{c} corrected for pore water effects)

Ic: Soil Behaviour Type Index

q_{c1N,cs}: Equivalent clean sand normalized CPT total cone resistance

F.S.: Factor of safety

γ_{max}: Maximum cyclic shear strain LDI: Lateral displacement index



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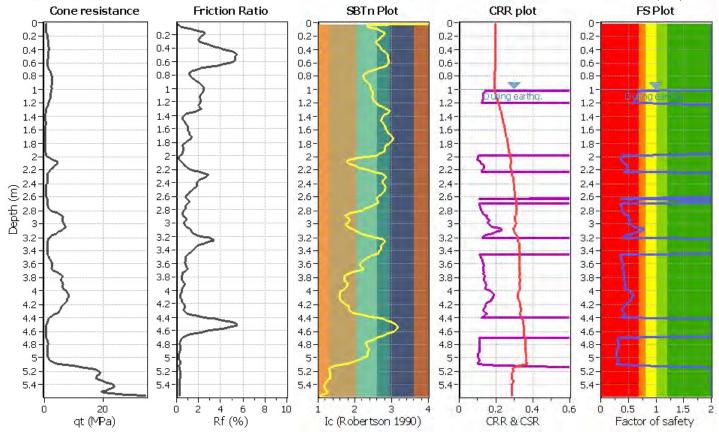
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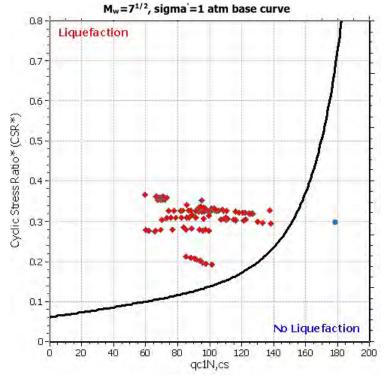
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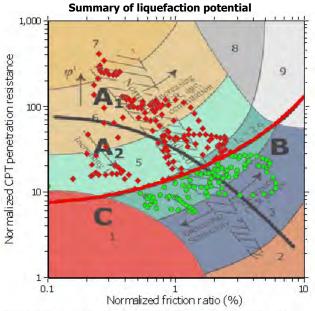
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Input parameters and analysis data

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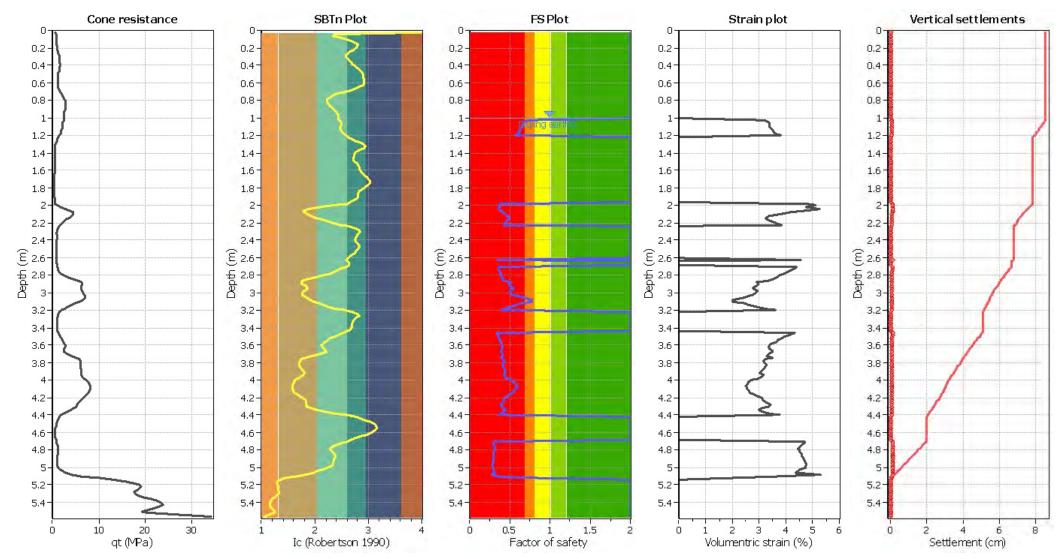




Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry.

Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Estimation of post-earthquake settlements



Abbreviations

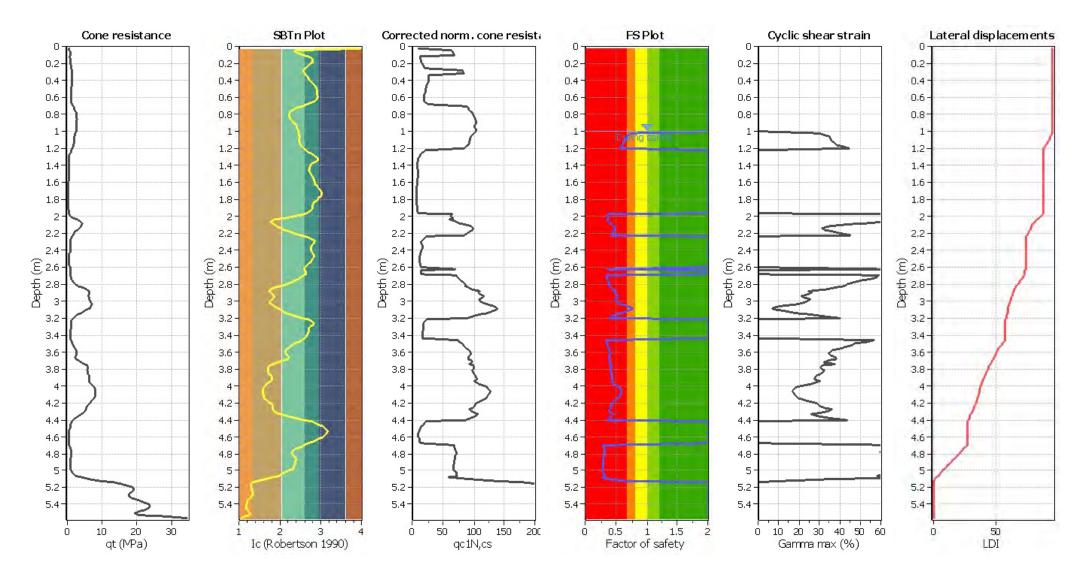
 q_t : Total cone resistance (cone resistance q_c corrected for pore water effects)

Ic: Soil Behaviour Type Index

FS: Calculated Factor of Safety against liquefaction

Volumentric strain: Post-liquefaction volumentric strain

Estimation of post-earthquake lateral Displacements



Abbreviations

 $q_{\text{t}}\text{:}$ Total cone resistance (cone resistance q_{c} corrected for pore water effects)

Ic: Soil Behaviour Type Index

q_{c1N,cs}: Equivalent clean sand normalized CPT total cone resistance

F.S.: Factor of safety

γ_{max}: Maximum cyclic shear strain LDI: Lateral displacement index



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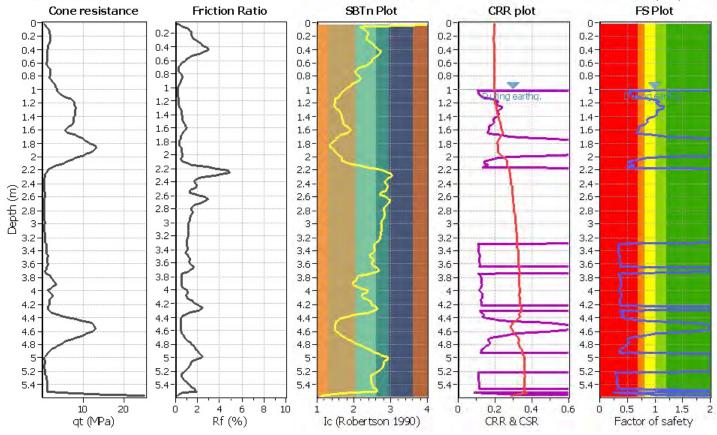
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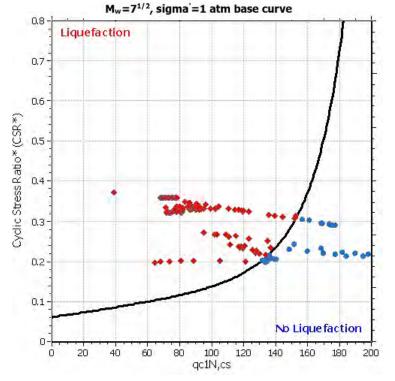
Project title: 170672 Location: Flygers Line

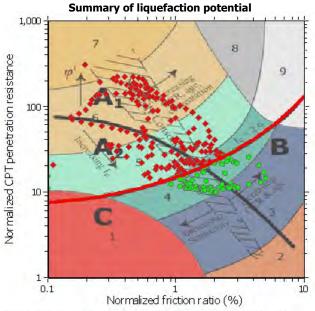
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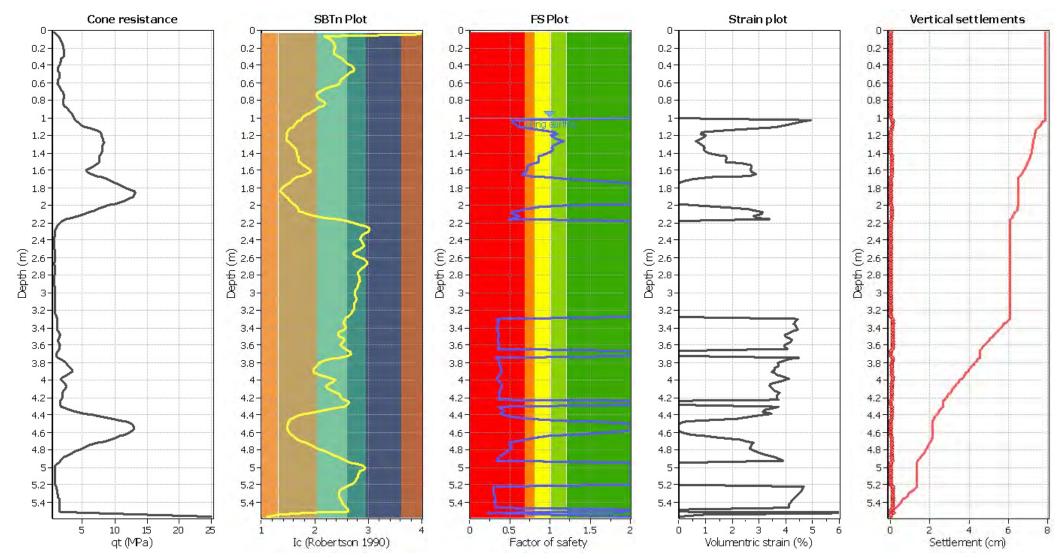
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Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry.

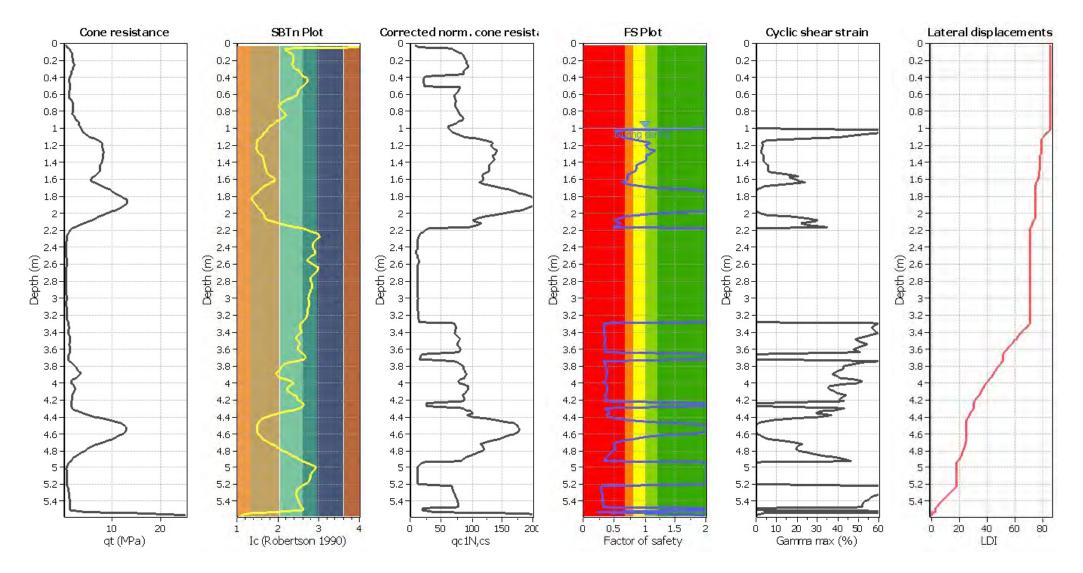


Abbreviations

 q_t : Total cone resistance (cone resistance q_c corrected for pore water effects)

Ic: Soil Behaviour Type Index

FS: Calculated Factor of Safety against liquefaction



Abbreviations

 $q_{\text{t}}.$ Total cone resistance (cone resistance q_{c} corrected for pore water effects)

Ic: Soil Behaviour Type Index

q_{c1N,cs}: Equivalent clean sand normalized CPT total cone resistance

F.S.: Factor of safety

γ_{max}: Maximum cyclic shear strain LDI: Lateral displacement index



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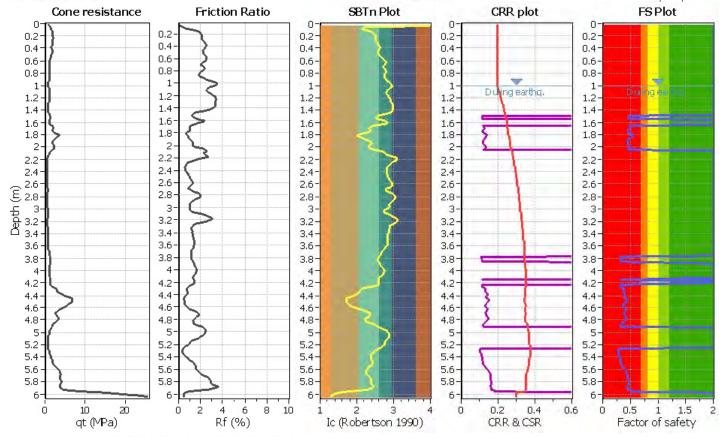
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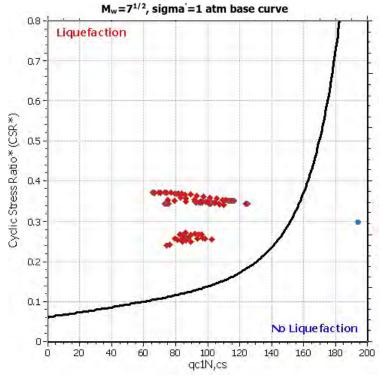
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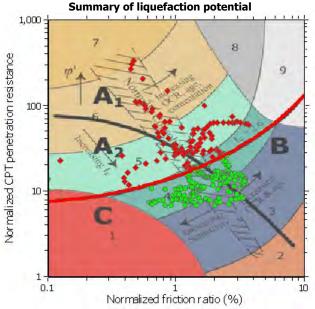
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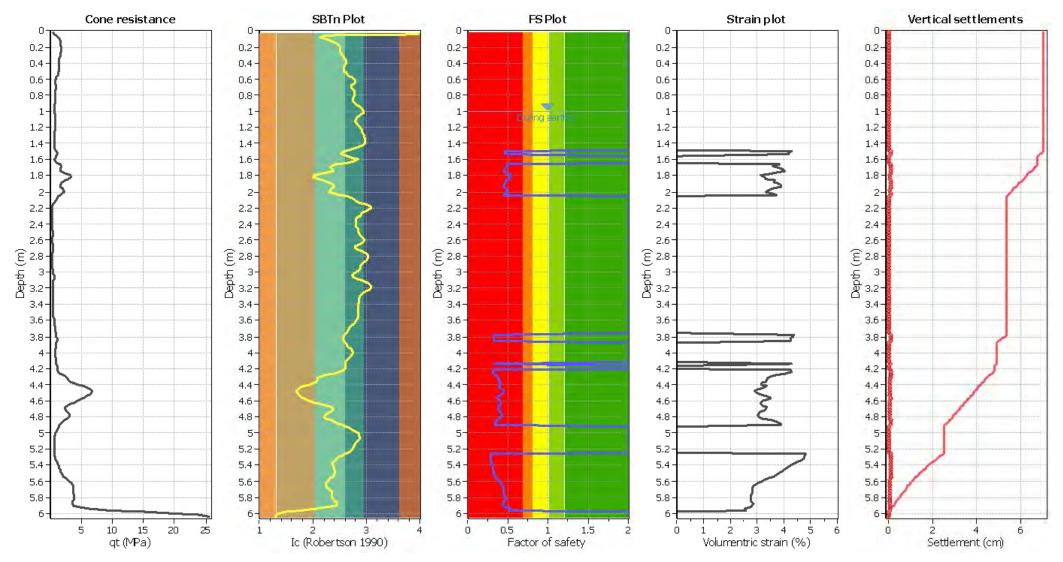
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Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry.

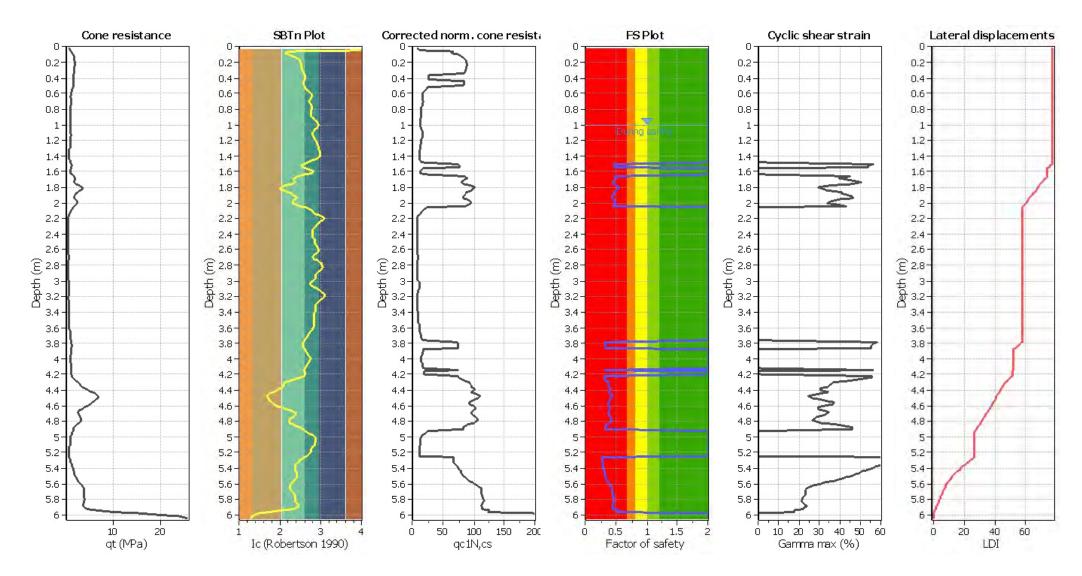


Abbreviations

 q_t : Total cone resistance (cone resistance q_c corrected for pore water effects)

Ic: Soil Behaviour Type Index

FS: Calculated Factor of Safety against liquefaction



Abbreviations

 $q_{\text{t}} :$ Total cone resistance (cone resistance q_{c} corrected for pore water effects)

Ic: Soil Behaviour Type Index

q_{c1N,cs}: Equivalent clean sand normalized CPT total cone resistance

F.S.: Factor of safety

γ_{max}: Maximum cyclic shear strain LDI: Lateral displacement index



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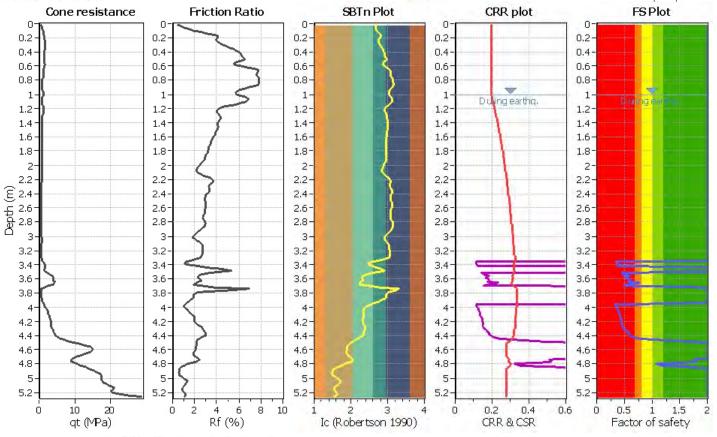
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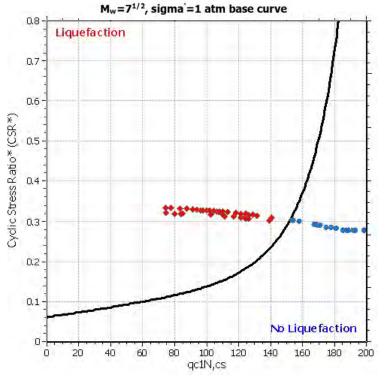
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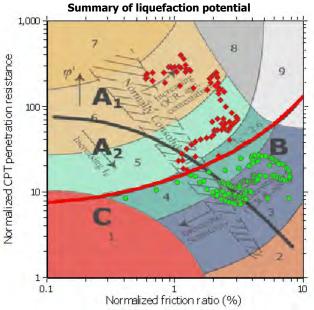
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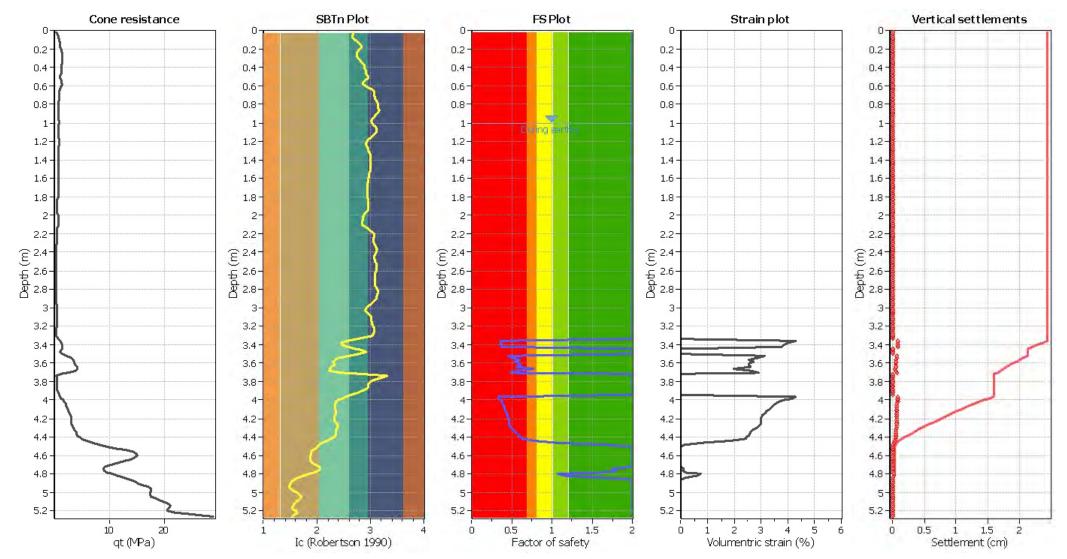
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Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry

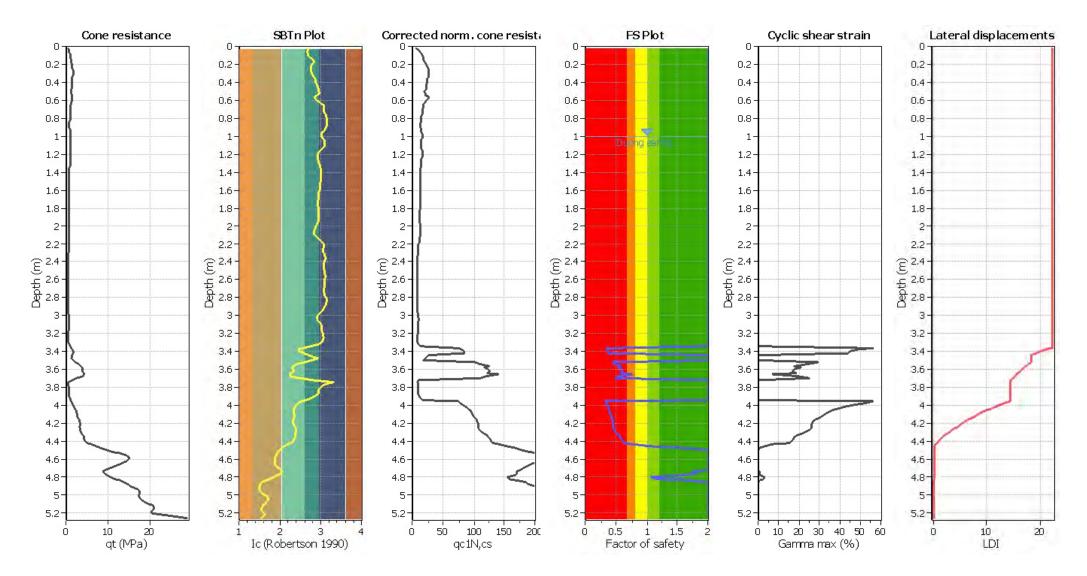


Abbreviations

 q_t : Total cone resistance (cone resistance q_c corrected for pore water effects)

Ic: Soil Behaviour Type Index

FS: Calculated Factor of Safety against liquefaction



Abbreviations

 $q_{\text{t}}.$ Total cone resistance (cone resistance q_{c} corrected for pore water effects)

Ic: Soil Behaviour Type Index

q_{c1N,cs}: Equivalent clean sand normalized CPT total cone resistance

F.S.: Factor of safety

γ_{max}: Maximum cyclic shear strain LDI: Lateral displacement index



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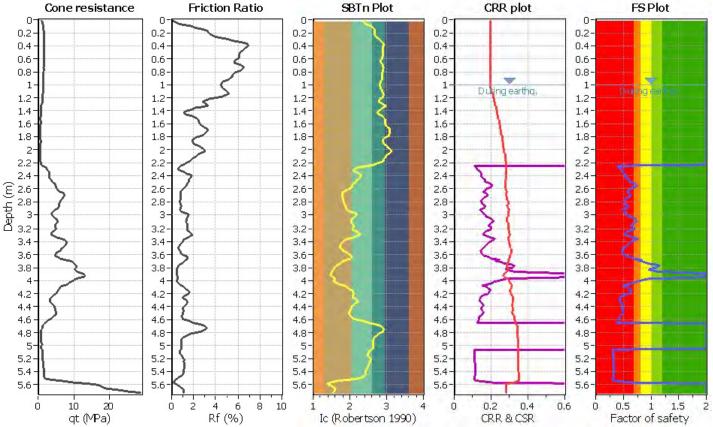
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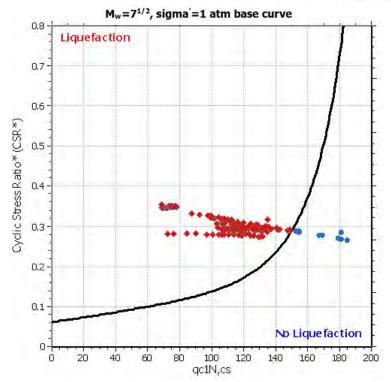
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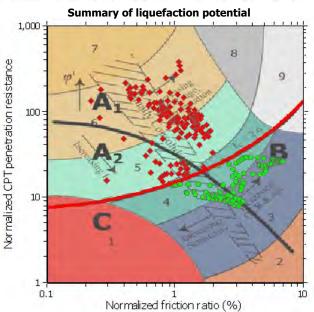
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Input parameters and analysis data

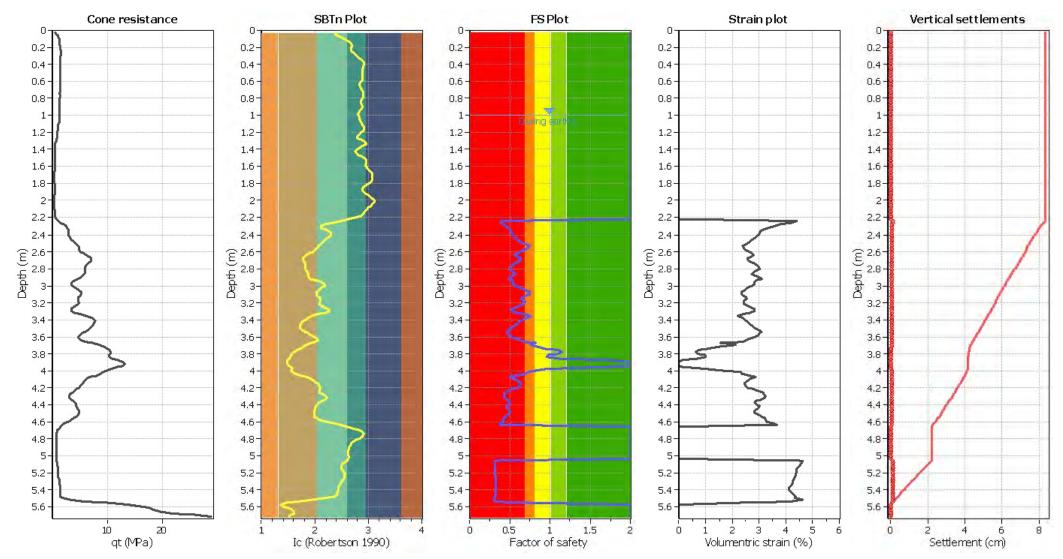
B&I (2014) 1.00 m G.W.T. (in-situ): Use fill: Nο Clay like behavior Analysis method: Fines correction method: B&I (2014) G.W.T. (earthq.): 1.00 m Fill height: N/A applied: Sands only Points to test: Based on Ic value Average results interval: 3 Fill weight: N/A Limit depth applied: No Earthquake magnitude M_w: Ic cut-off value: 2.60 Trans. detect. applied: No Limit depth: N/A Based on SBT Peak ground acceleration: 0.34 Unit weight calculation: K_σ applied: Yes MSF method: Method







Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry.

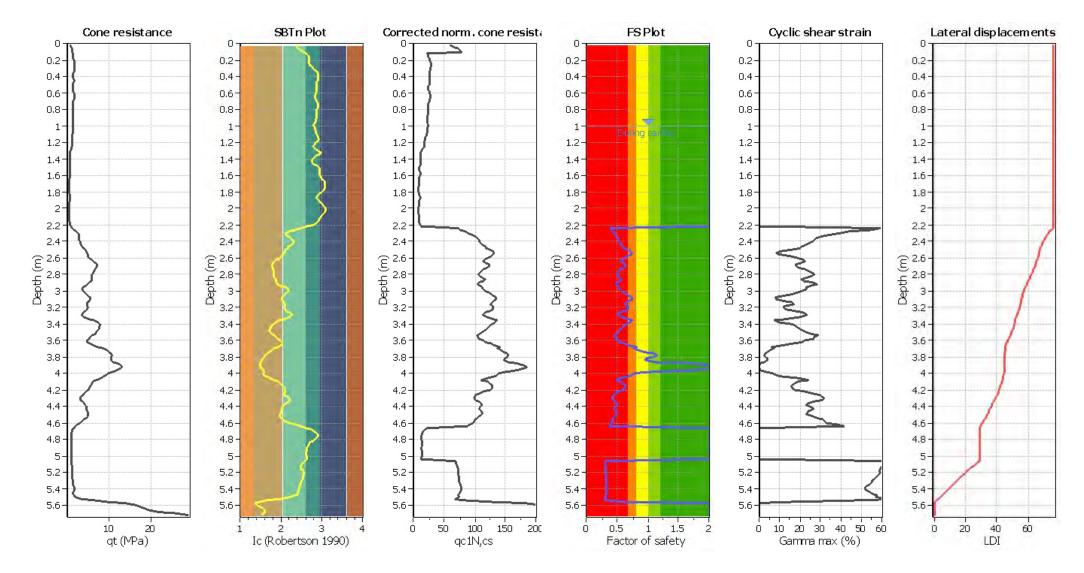


Abbreviations

 q_t : Total cone resistance (cone resistance q_c corrected for pore water effects)

Ic: Soil Behaviour Type Index

FS: Calculated Factor of Safety against liquefaction



Abbreviations

 $q_{\text{t}} :$ Total cone resistance (cone resistance q_{c} corrected for pore water effects)

Ic: Soil Behaviour Type Index

q_{c1N,cs}: Equivalent clean sand normalized CPT total cone resistance

F.S.: Factor of safety

γ_{max}: Maximum cyclic shear strain LDI: Lateral displacement index



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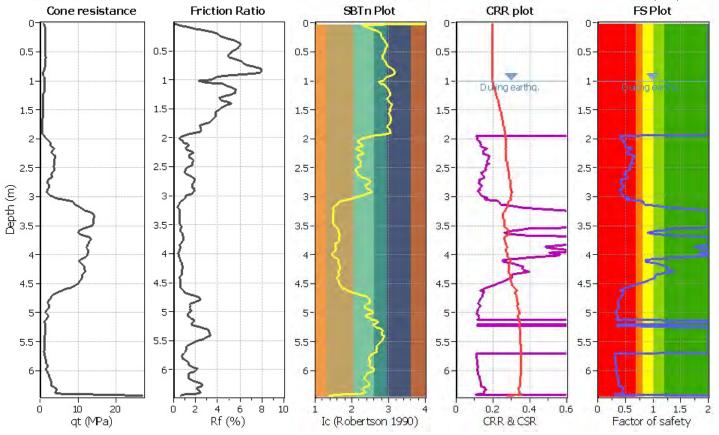
LIQUEFACTION ANALYSIS REPORT

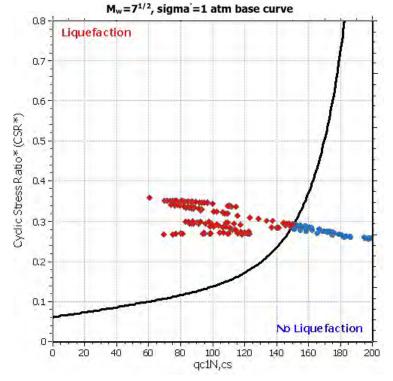
Project title: 170672 Location: Flygers Line

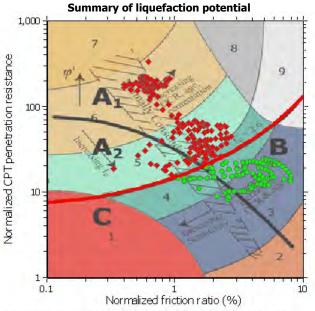
CPT file: CPT10

Input parameters and analysis data

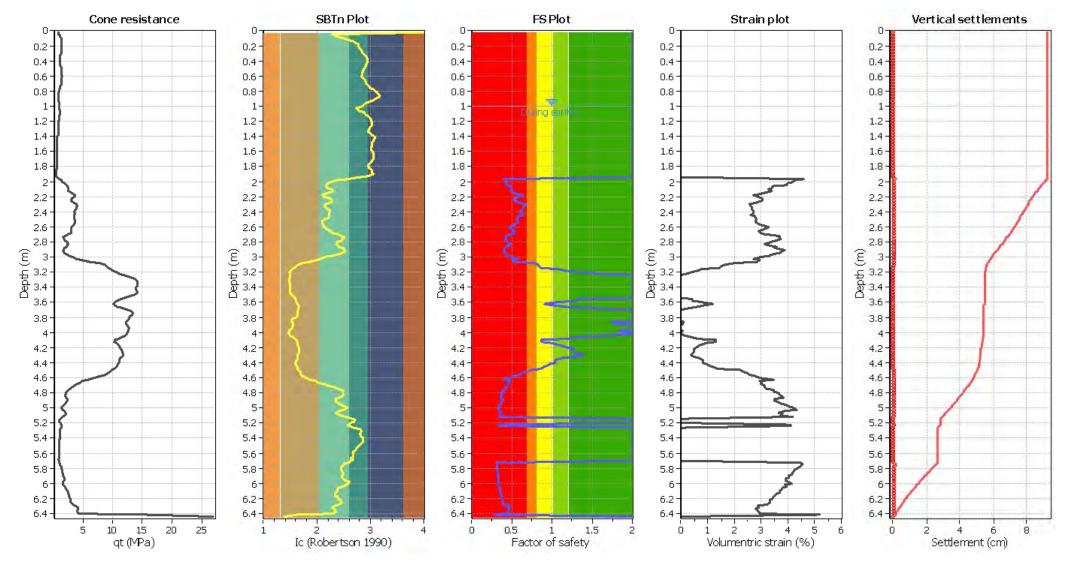
Clay like behavior B&I (2014) 1.00 m G.W.T. (in-situ): Use fill: Nο Analysis method: Fines correction method: B&I (2014) G.W.T. (earthq.): 1.00 m Fill height: N/A applied: Sands only Points to test: Based on Ic value Average results interval: 3 Fill weight: N/A Limit depth applied: No Earthquake magnitude M_w: Ic cut-off value: 2.60 Trans. detect. applied: No Limit depth: N/A Based on SBT Peak ground acceleration: 0.34 Unit weight calculation: K_σ applied: Yes MSF method: Method







Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry.

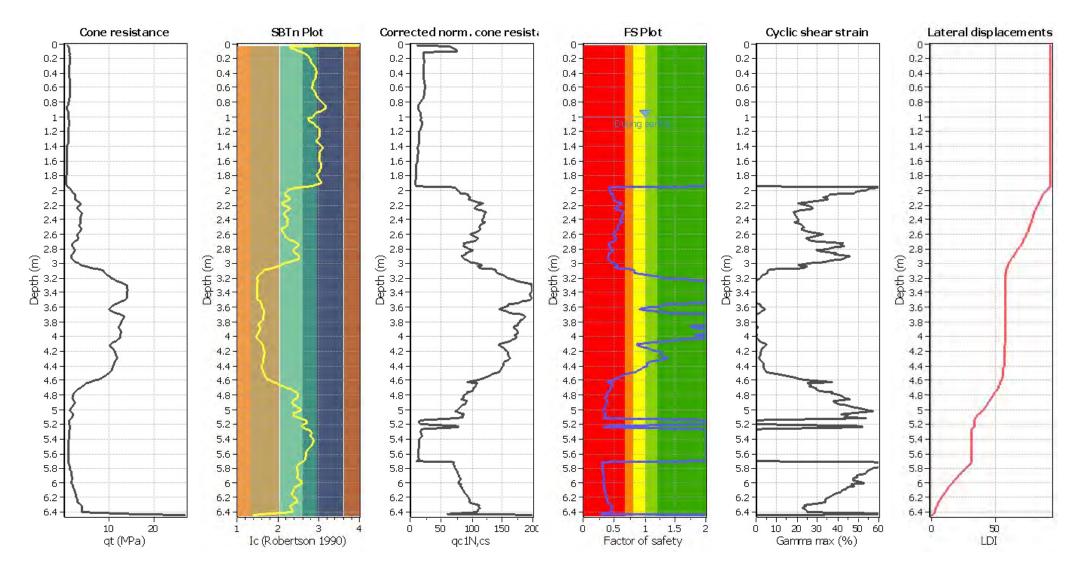


Abbreviations

 q_t : Total cone resistance (cone resistance q_c corrected for pore water effects)

Ic: Soil Behaviour Type Index

FS: Calculated Factor of Safety against liquefaction



Abbreviations

qt: Total cone resistance (cone resistance qc corrected for pore water effects)

Ic: Soil Behaviour Type Index

q_{c1N,cs}: Equivalent clean sand normalized CPT total cone resistance

F.S.: Factor of safety

ymax: Maximum cyclic shear strain LDI: Lateral displacement index



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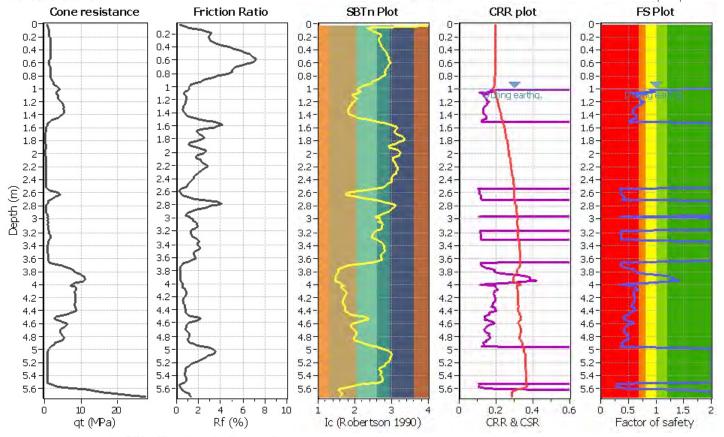
LIQUEFACTION ANALYSIS REPORT

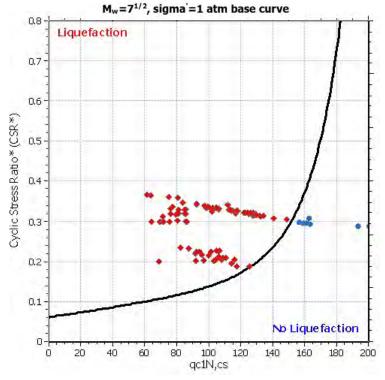
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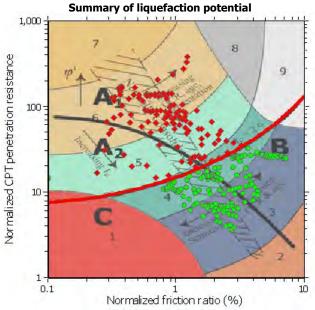
CPT file: CPT11

Input parameters and analysis data

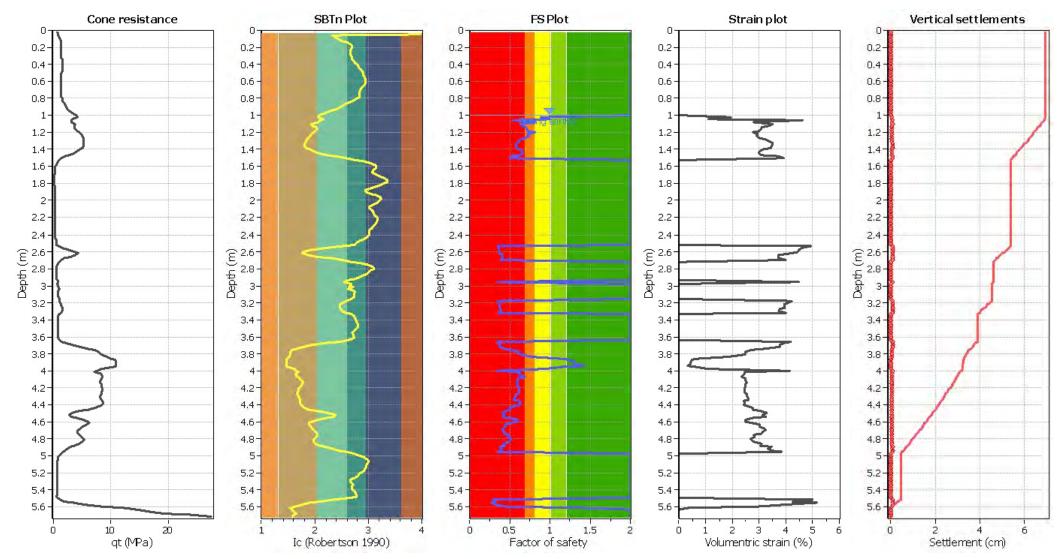
B&I (2014) 1.00 m G.W.T. (in-situ): Use fill: Nο Clay like behavior Analysis method: B&I (2014) G.W.T. (earthq.): 1.00 m Fill height: N/A applied: Sands only Fines correction method: Points to test: Based on Ic value Average results interval: 3 Fill weight: N/A Limit depth applied: No Earthquake magnitude M_w: Ic cut-off value: 2.60 Trans. detect. applied: No Limit depth: N/A Based on SBT Peak ground acceleration: 0.34 Unit weight calculation: K_σ applied: Yes MSF method: Method







Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry.

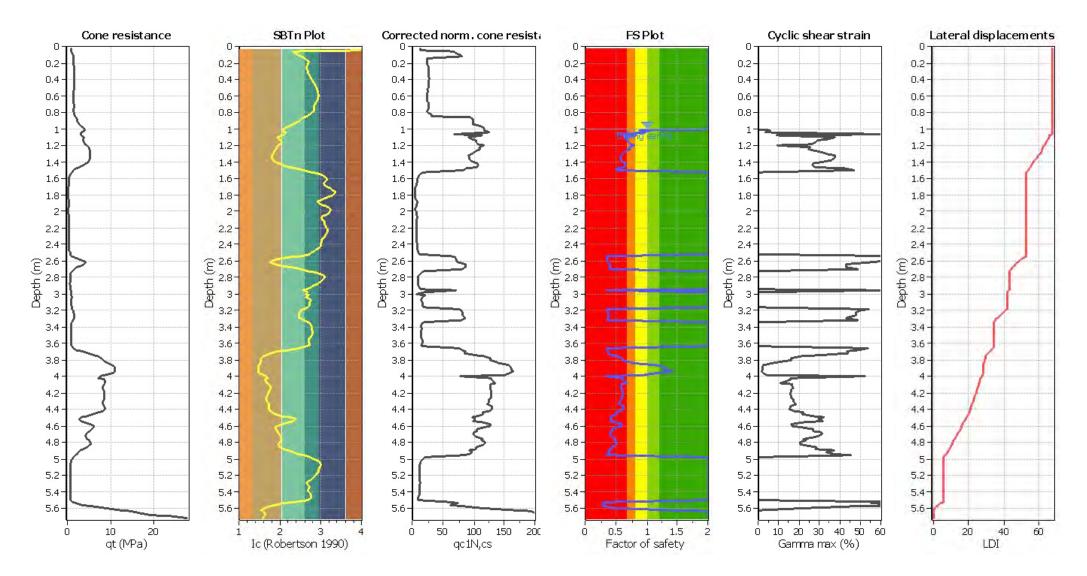


Abbreviations

 q_t : Total cone resistance (cone resistance q_c corrected for pore water effects)

Ic: Soil Behaviour Type Index

FS: Calculated Factor of Safety against liquefaction



Abbreviations

 $q_{\text{t}}\text{:}$ Total cone resistance (cone resistance q_{c} corrected for pore water effects)

Ic: Soil Behaviour Type Index

q_{c1N,cs}: Equivalent clean sand normalized CPT total cone resistance

F.S.: Factor of safety

γ_{max}: Maximum cyclic shear strain

LDI: Lateral displacement index



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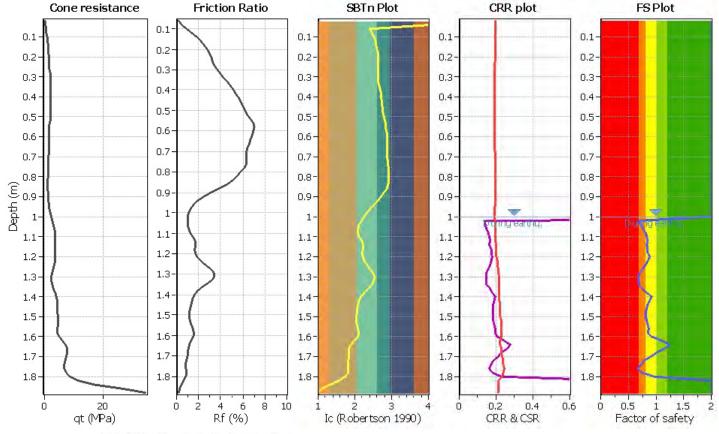
LIQUEFACTION ANALYSIS REPORT

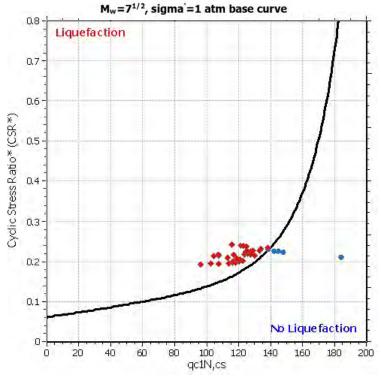
Project title: 170672 Location: Flygers Line

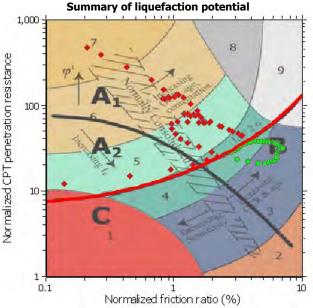
CPT file: CPT12

Input parameters and analysis data

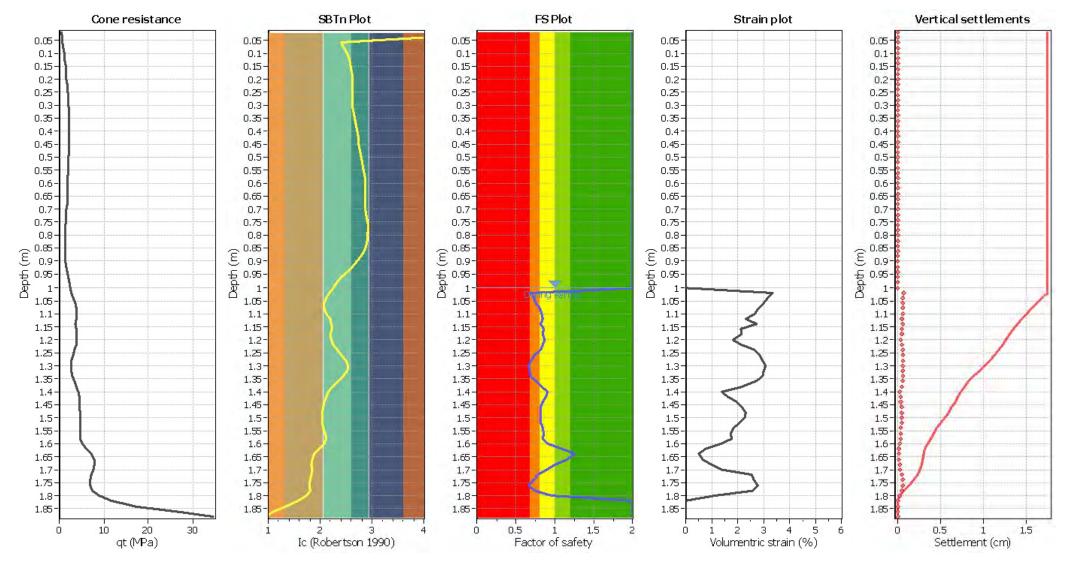
B&I (2014) 1.00 m G.W.T. (in-situ): Use fill: Nο Clay like behavior Analysis method: Fines correction method: B&I (2014) G.W.T. (earthq.): 1.00 m Fill height: N/A applied: Sands only Points to test: Based on Ic value Average results interval: 3 Fill weight: N/A Limit depth applied: No Earthquake magnitude M_w: Ic cut-off value: 2.60 Trans. detect. applied: No Limit depth: N/A Peak ground acceleration: 0.34 Unit weight calculation: Based on SBT K_σ applied: Yes MSF method: Method







Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry.

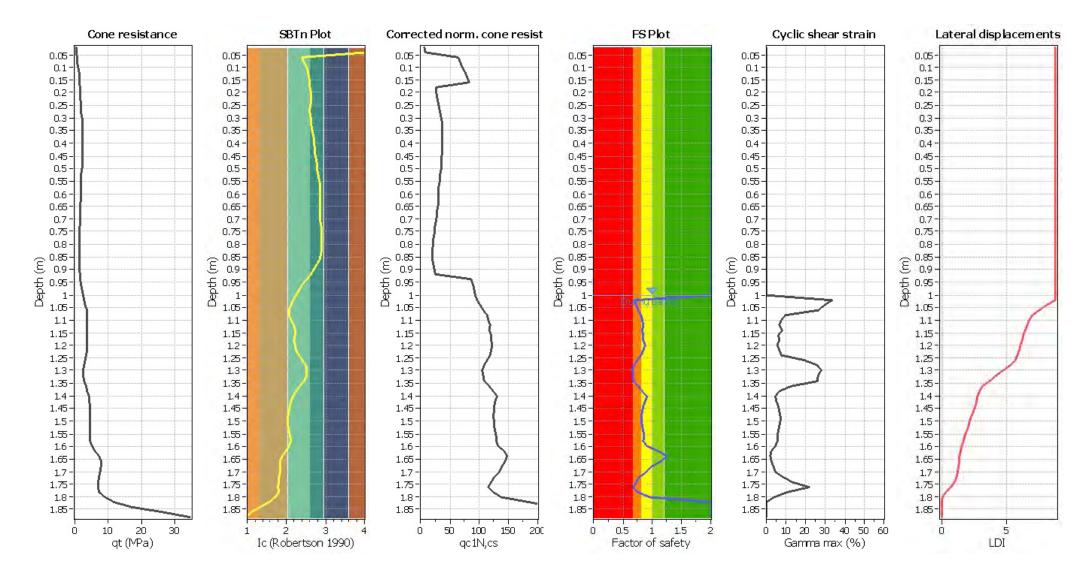


Abbreviations

qt: Total cone resistance (cone resistance qc corrected for pore water effects)

Ic: Soil Behaviour Type Index

FS: Calculated Factor of Safety against liquefaction



Abbreviations

 $q_{\text{t}}.$ Total cone resistance (cone resistance q_{c} corrected for pore water effects)

Ic: Soil Behaviour Type Index

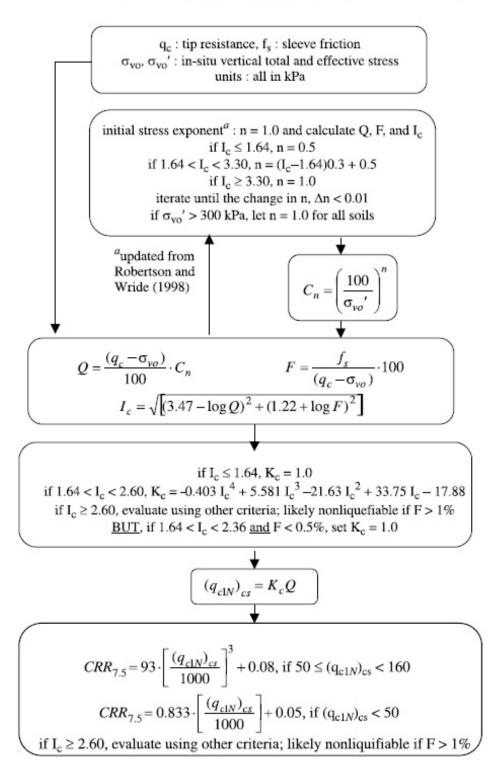
q_{c1N,cs}: Equivalent clean sand normalized CPT total cone resistance

F.S.: Factor of safety

γ_{max}: Maximum cyclic shear strain LDI: Lateral displacement index

Procedure for the evaluation of soil liquefaction resistance, NCEER (1998)

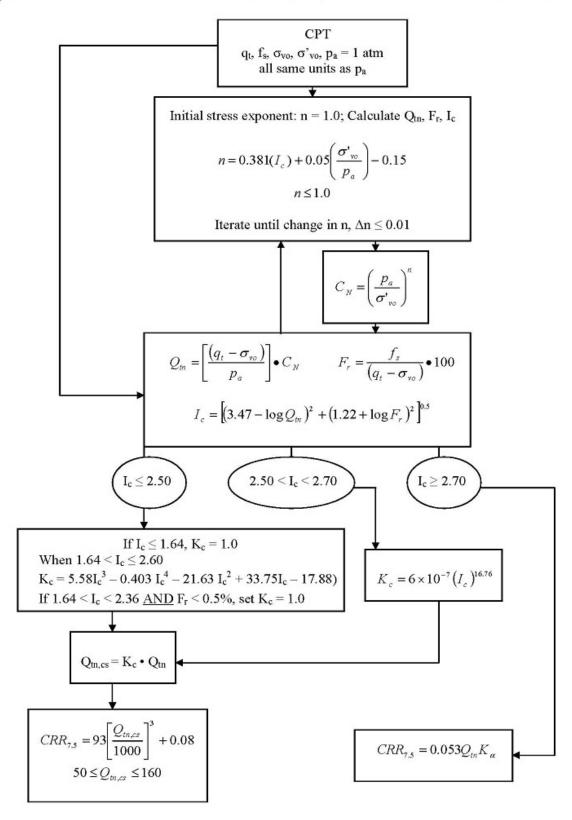
Calculation of soil resistance against liquefaction is performed according to the Robertson & Wride (1998) procedure. The procedure used in the software, slightly differs from the one originally published in NCEER-97-0022 (Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils). The revised procedure is presented below in the form of a flowchart¹:



¹ "Estimating liquefaction-induced ground settlements from CPT for level ground", G. Zhang, P.K. Robertson, and R.W.I. Brachman

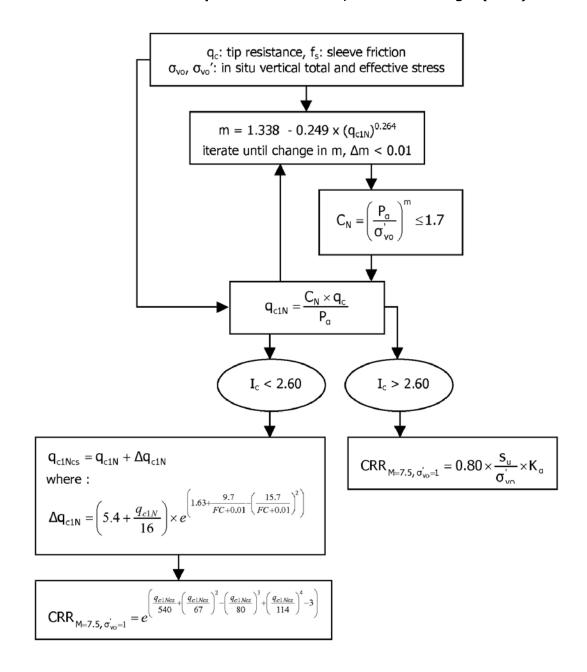
Procedure for the evaluation of soil liquefaction resistance (all soils), Robertson (2010)

Calculation of soil resistance against liquefaction is performed according to the Robertson & Wride (1998) procedure. This procedure used in the software, slightly differs from the one originally published in NCEER-97-0022 (Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils). The revised procedure is presented below in the form of a flowchart¹:

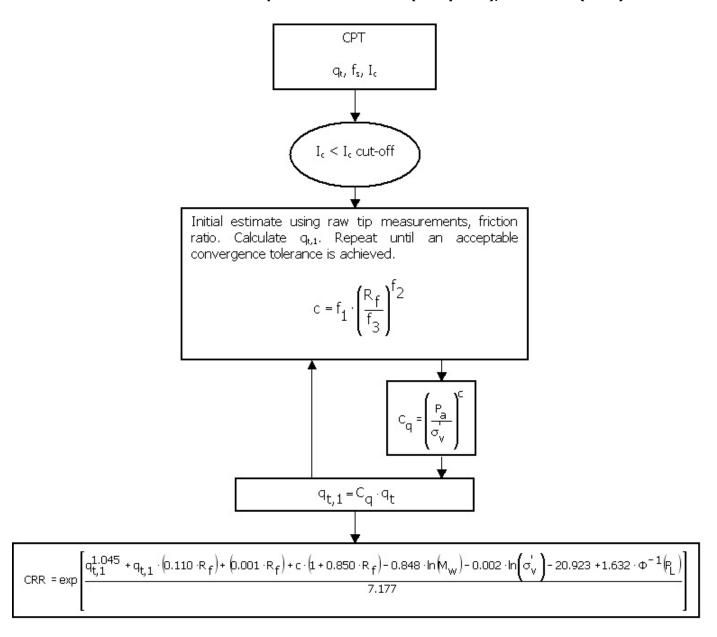


¹ P.K. Robertson, 2009. "Performance based earthquake design using the CPT", Keynote Lecture, International Conference on Performance-based Design in Earthquake Geotechnical Engineering – from case history to practice, IS-Tokyo, June 2009

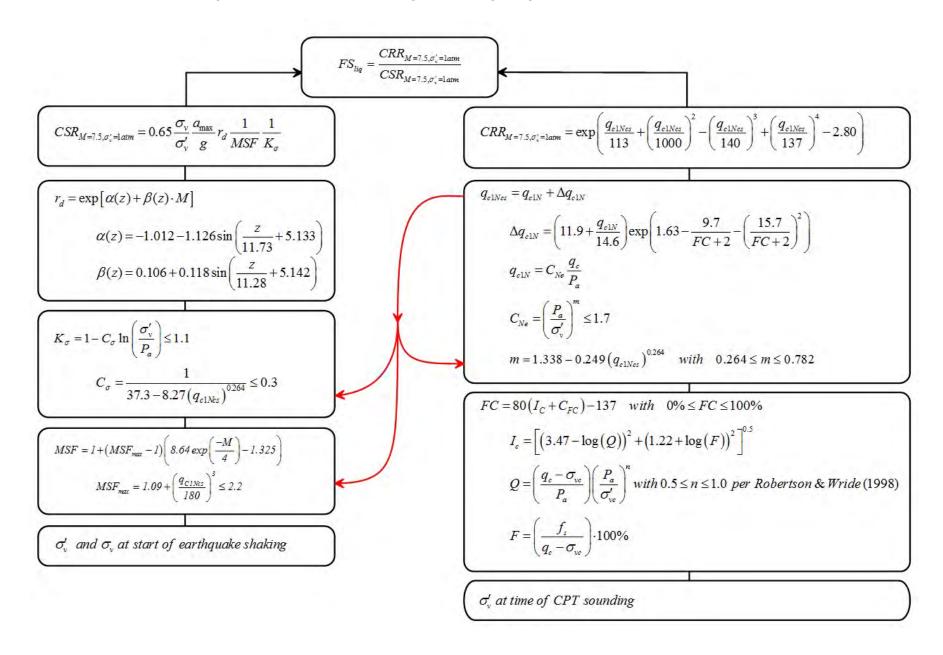
Procedure for the evaluation of soil liquefaction resistance, Idriss & Boulanger (2008)



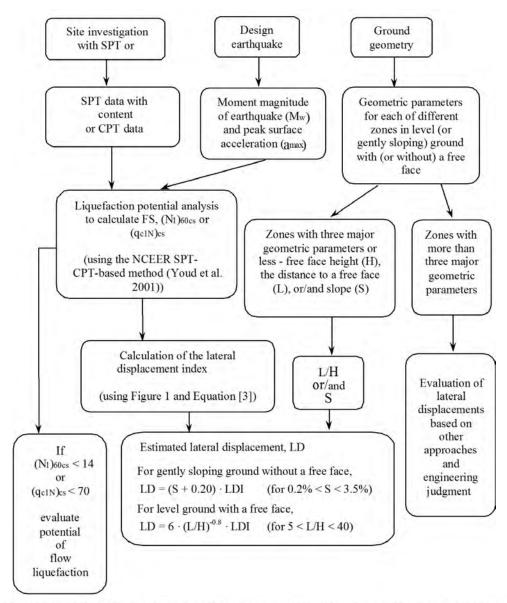
Procedure for the evaluation of soil liquefaction resistance (sandy soils), Moss et al. (2006)



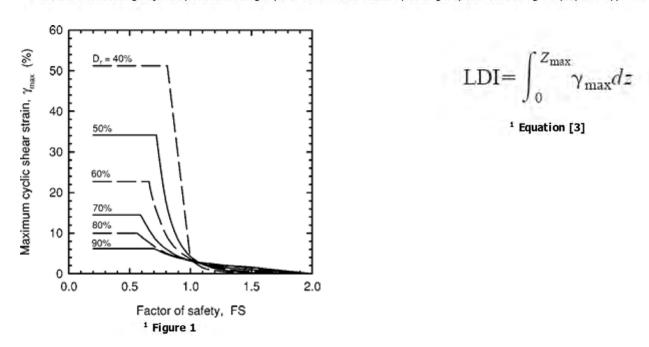
Procedure for the evaluation of soil liquefaction resistance, Boulanger & Idriss(2014)



Procedure for the evaluation of liquefaction-induced lateral spreading displacements

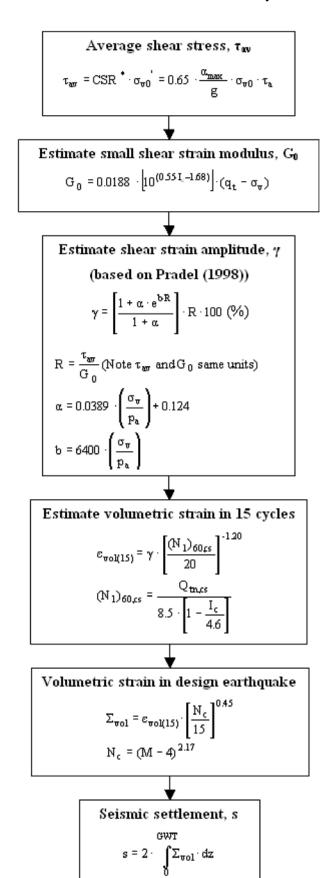


¹ Row chart illustrating major steps in estimating liquefaction-induced lateral spreading displacements using the proposed approach



¹ "Estimating liquefaction-induced ground settlements from CPT for level ground", G. Zhang, P.K. Robertson, and R.W.I. Brachman

Procedure for the estimation of seismic induced settlements in dry sands



Robertson, P.K. and Lisheng, S., 2010, "Estimation of seismic compression in dry soils using the CPT" FIFTH INTERNATIONAL CONFERENCE ON RECENT ADVANCES IN GEOTECHNICAL EARTHQUAKE ENGINEERING AND SOIL DYNAMICS, Symposium in honor of professor I. M. Idriss, San Diego, CA

Liquefaction Potential Index (LPI) calculation procedure

Calculation of the Liquefaction Potential Index (LPI) is used to interpret the liquefaction assessment calculations in terms of severity over depth. The calculation procedure is based on the methology developed by Iwasaki (1982) and is adopted by AFPS.

To estimate the severity of liquefaction extent at a given site, LPI is calculated based on the following equation:

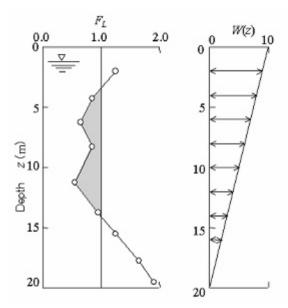
$$\mathbf{LPI} = \int_{0}^{20} (10 - 0.5_{Z}) \times F_{L} \times d_{z}$$

where:

 $F_L = 1$ - F.S. when F.S. less than 1 $F_L = 0$ when F.S. greater than 1 z depth of measurment in meters

Values of LPI range between zero (0) when no test point is characterized as liquefiable and 100 when all points are characterized as susceptible to liquefaction. Iwasaki proposed four (4) discrete categories based on the numeric value of LPI:

LPI = 0 : Liquefaction risk is very low
0 < LPI <= 5 : Liquefaction risk is low
5 < LPI <= 15 : Liquefaction risk is high
LPI > 15 : Liquefaction risk is very high



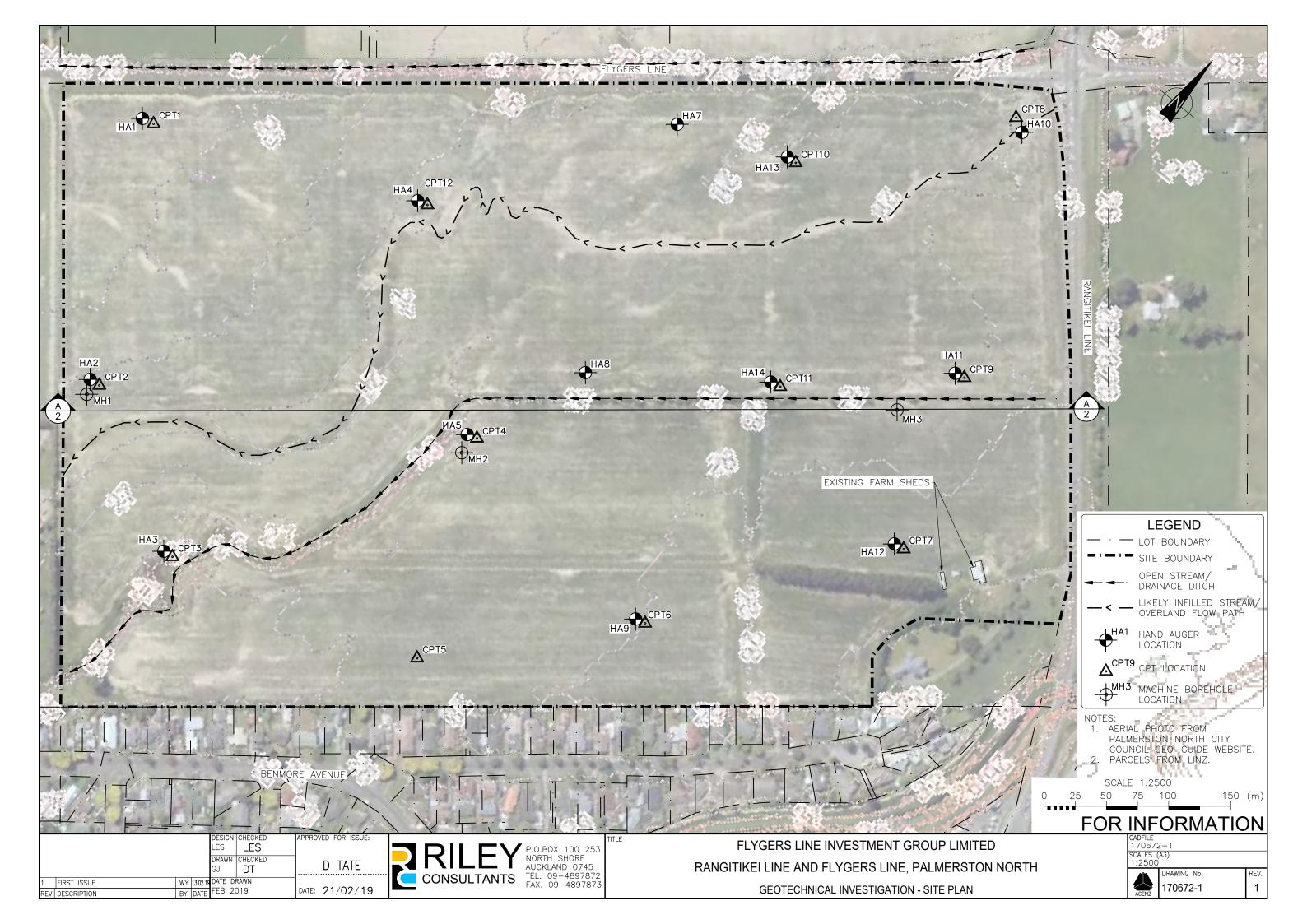
Graphical presentation of the LPI calculation procedure

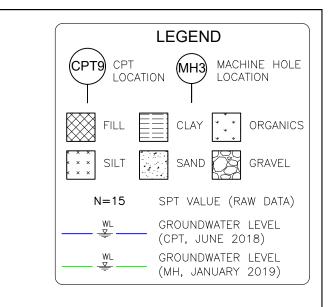
References

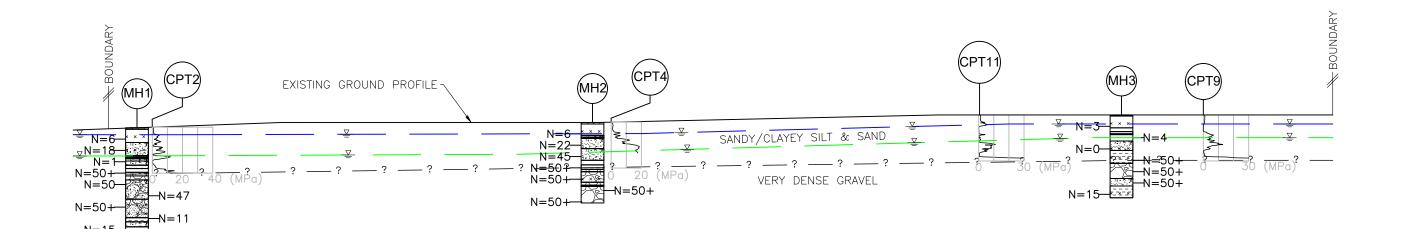
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APPENDIX D

RILEY Dwgs: 170672-1 and -2

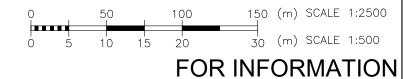






CROSS SECTION

HORIZONTAL SCALE 1:2500
VERTICAL SCALE 1:500



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DRAWN CHECKED GJ JM	D TATE	NORTH SHORE AUCKLAND 0745 CONCULTANTS TEL 09-4897872	RANGITIKEI LINE AND FLYGERS LINE, PALMERSTON NORTH
1 FIRST ISSUE WY 13.02.15 DATE DRAWN REV DESCRIPTION BY DATE FEB 2019	DATE: 21/02/19	CONSULTANTS TEL. 09-4897872 FAX. 09-4897873	GEOTECHNICAL INVESTIGATION - CROSS SECTION A

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	CADFILE 170672	2-2			
	SCALES (A3) AS SHOWN				
	Alb.	DRAWING No.	REV.		
	ACENZ	170672-2	1		