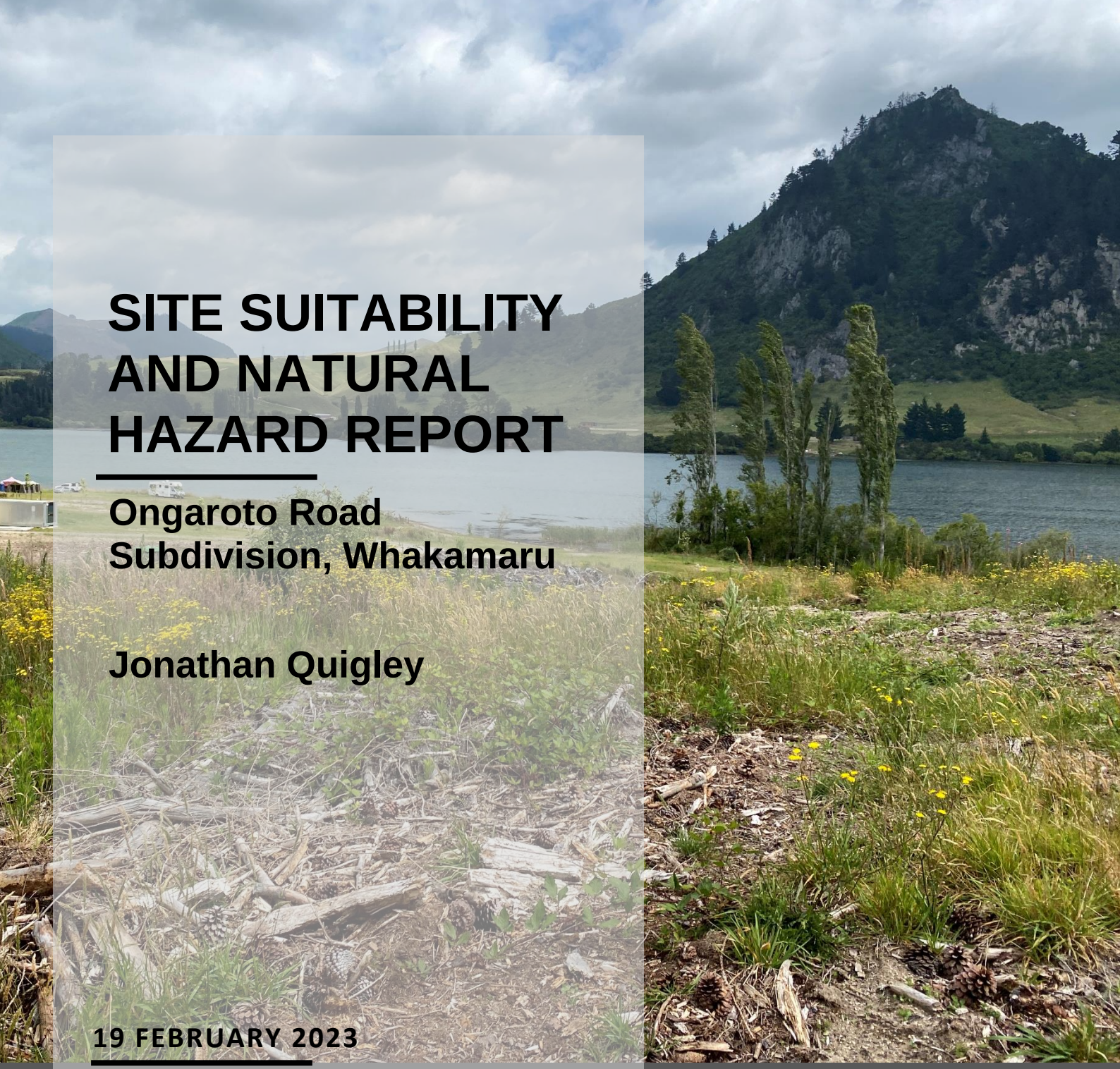

SITE SUITABILITY AND NATURAL HAZARD REPORT

Ongaroto Road Subdivision, Whakamaru

Jonathan Quigley

19 FEBRUARY 2023

PROJECT NO. C2131

TITUS

CONSULTING ENGINEERS

Approved for issue by:

X Tony Richardson

Digitally signed by Tony Richardson
DN: cn=Tony Richardson, c=NZ, o=Titus Civil Ltd, email=tonyr@tituscivil.co.nz
Reason: I have reviewed this document
Date: 2023.02.19 18:43:03 +13'00'

Anthony Richardson CPEng 1026340
Principal Project Engineer

DOCUMENT HISTORY AND STATUS

Rev.	Issued To	Date	Prepared	Reviewed	Approved
A	Jonathan Quigley	15/01/2021	MH	TR	TR
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C	Jonathan Quigley	17/11/2022	RR	TR	TR
D	Jonathan Quigley	16/02/2023	RR	JW	TR

RECORD OF REVISION CHANGES

Revision B: Updated report to assess Liquefaction.

Revision C: Updated as per Client markup

Revision D: Section 2.3 Liquefaction assessment updated to reflect Level C assessment appropriate for plan change and subdivision

Section 2.6 Flooding updated with information from Mercury Power

TITUS Consulting Engineers

Hamilton Office: Level 3, Door 3.01, 169 London St

Ph: 07 242 0017

Email: office@tituscivil.co.nz

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SUMMARY

This site has been proposed for Rural-Residential re-zoning, upon which an approximate 66 lot subdivision may occur. This report covers a high-level investigation of this site's suitability for rural-residential development. The following are the main findings of this investigation;

- As a prior forestry block, roots and stumps are present across large portions of the site and are likely to be present within proposed infrastructure and building footprints.
- Forestry workings on site have created piles of fill / spoil material across the site. This material will need to be conditioned and flattened / contoured as part of the subdivision development.
- A detailed Liquefaction assessment on this site has found that liquefaction is unlikely and site may be classed as TC1.
- Slope instability may affect the sites where slopes grades are up to 25% in some places. On these lots building restriction zones will be noted, where development within these areas will required specific engineering design.
- Earthworks required prior to the construction of foundations shall consider the removal of organic material (old roots / stumps) and reinstatement of ground to meet the requirements of NZS 4431:2022 "*Engineered fill construction for lightweight structures*".
- Standard NZS3604 foundations or engineering / "codemarked" waffle raft foundations are considered acceptable for the site, given that appropriate earthworks are carried out, and the requirements of the building code are met.
- On site soakage is considered suitable for disposal of stormwater across the development with secondary flow paths available to direct runoff to the adjacent lake reserve, proposed reserves and roading areas within the subdivision. Where secondary overland flow paths for runoff from developed lots are not available to road or reserve areas, appropriate flow paths shall be designated. In order to prevent "riling" and piping of the insitu pumice soils, soakage and swale systems may need to be lined with geotextile.
- Wastewater treatment and disposal may be achieved on lot via Primary or secondary wastewater options. Lot Specific assessments will be required at building consent stage, with particular attention being required to consider the slope on the section and the high permeability of the pumice soils on site. This may require that traditional disposal beds / trenches are avoided and dripper lines, Wisconsin mounds or ETS beds are adopted for on lot wastewater disposal.

It is considered that this site is suitable for Rural-Residential development from a geotechnical perspective.

1 INTRODUCTION

1.1 Overview

Titus Consulting Engineers has been engaged by Jonathan Quigley to perform a site assessment at the proposed Ongaroto Road Rural-Residential re-zoning for subsequent subdivision. The report includes the following;

- Section 2: Natural Hazard Assessment
- Section 3: Site Suitability Assessment

This report details findings of a preliminary geotechnical and site. Preliminary recommendations and likely requirements in relation to the proposed development and required further assessments for the site are provided. The assessment is in relation to the requirements of the local authority, South Waikato District Council, and the following technical documents;

- The Building Code
- NZS3604:2011
- District Plan
- Waikato Local Authority Shared Services (RITS)
- Waikato Regional Council Plan
- AS/NZS 1547/2012

1.2 Site Details

The site is located on the northern bank of the Waikato River near Whakamaru, above the Whakamaru Lake. The site is currently a forestry block that has been recently felled and replanted. The site is bordered by State Highway 30 to the northeast and Crown Land on the remaining side. The Waikato River encloses the Crown Land on its remaining boundaries. The site is predominantly gently to moderately sloping. Most of this slope is towards the lake with undulations from forestry earthworks near SH30. There are some steep to very steep sections of slope near the existing access way on the boundary nearest the lake. Much of the site is covered in stumps from the prior land usage. These have been removed from the eastern portion of the site.

It is noted that on a second site walkover on the 12th of October 2022 much of the site had been cleared and new pine saplings had been planted. The clearing of the site highlighted areas used as skids for forestry and showed the metal at the surface. It also showed that at the surface in some locations are boulders and rock outcrops. The lower south-eastern portion of the site directly adjacent to the lake and local reserve had shown areas of recontouring.

A general view of the site is presented in Figure 1.

Figure 1: Site Photo

1.3 Proposed Site Development

The proposed site development is in relation to the proposed rural-residential re-zoning with subsequent subdivision of an area of 31.6749 ha into approximately 66 lots with two roads within the subdivision.

A plan showing the proposed lots can be found in Appendix A. The proposed lots range in size but are each predominantly over 2500m^2. It is understood that lot sizes have the potential to change, as well as their numbers and locations.

It is proposed that access to the subdivision will be from a new road network which is to connect to SH30 at new intersection approximately halfway along the development road frontage.

1.4 Existing Water Features

There are no significant water courses or gullies on the site. However, the Waikato River (Whakamaru Lake / Reservoir) sits near the site to the south, west and east. The site is elevated from the river and has a small buffer strip of council land between them the site and the river. There was one noticeable overland flow path on the site which was dry on the day of inspection but which is expected to hold water in times of extended rain fall. This is shown in Figure 2.

Figure 2: Small overland flow path (Blue) found in the field.

1.5 Existing Services

The council maintains a toilet block in the reserve to the south of the site. A privately owned and consented wastewater system and water supply exists for the existing dwelling on site. No other services were detected during spot checks for conducting the CPT's.

1.6 Historic Land Use

Review of 'Retrolens' imagery indicates that the site was historically used for forestry. The site sits on the edge of the Waikato River above the Whakamaru Dam. Construction of the dam began in 1949 and took three years to complete. Before this date the river was at a lower level before being submerged by the lake. Historic imagery shows the site has been used for forestry since 1963. These trees were felled between 10/03/2018 and 14/1/2019.

1.7 New Zealand Geotechnical Database.

There are no relevant entries to this site on the New Zealand Geotechnical Database. However, several CPT's and Boreholes have been conducted on the opposite side of the river to the site.

1.8 Geological Setting

According to GNS Science (GNS Science, 2018), the underlying geological formation of the site is Late Pleistocene River Deposits of the Hinuera Formation, as shown in Appendix B. Expected ground conditions of this formation are cross-bedded pumice sand, silt, gravel with interbedded peat. It is considered that the underlying geology is consistent with the QMAP classification through confirmation with onsite testing.

As the site is near the source of pumice deposits seen within the Hinuera Formation it is likely more pumice is present within these samples than other places further from the source (Hamilton for example).

Boulders of the nearby Ongariti Group Rhyolite were found on site, likely from tumbling down the nearby hills. Further to the additional site testing as noted below it is shown that these boulders likely cover a majority of the site, or that this rhyolite underlies the site completely.

1.9 Soil Investigation

The site assessment conducted on 21st of December, 2020 included the following:

- General site walkover
- Hand Auger Tests: 6
- Scala Penetrometer Tests: 6
- Shear Vane Tests: 7

Test locations are shown in Appendix C and were distributed widely across the site.

Topsoil was found not found in all boreholes but in those in which it was found had a thickness of between 200mm and 500mm. Underlying soils consist predominantly of sand and silt with pumice. Overall, the boreholes generally showed a pumice rich sand with some small silt or cobble layers. In several BH's (2 and 3) some organics, pumice and sand was found between 1.1 and 1.8m. In BH's 4 and 5 two dense white pumice layers were encountered. Borehole logs are attached in Appendix D.

The ground water level was not found within 2.0m of the surface (tested late-Dec).

No soft clays were found on the site (kPa < 25).

No peat soils were found on the site.

Further testing has been conducted on site on the 12th of October 2022, which included 10 Cone Penetrometer Tests (CPTs). These were commissioned to a target depth of 20m although all refused at shallow depth. A summary of the CPTs conducted is detailed in Table 1. The CPTs identified a generally consistent profile across all locations with sand and silt identified at the surface underlain by a thick layer of clay before encountering sand and silt and then refusing. It is believed that the CPTs were refusing on the underlying rock.

Table 1: CPT Details

CPT #	Refusal Reason	Water Table Depth	Refusal Depth
1	Tip	Dry @ 5.6m	5.6
2	Tip	Dry @ 3.8m	3.9
3	Tip	Dry @ 4.4m	4.5
4	Tip	Dry @ 2.9m	3.1
5	Tip	Dry @ 2.8m	3.0
6	Tip	Dry @ 1.5m	1.8
7	Tip	Dry @ 3.6m	3.6
8	Inclination	Dry @ 1.1m	2.4
9	Inclination	Dry @ 2.6m	2.8
10	Tip	Dry @ 5.1m	5.2

2 NATURAL HAZARD ASSESSMENT

2.1 Potential Natural Hazards

Tables 2 and 3 summarise the preliminary assessment of the site for Natural Hazards in accordance with Section 106 of the Resource Management Act 1991 (RMA), including those in relation to seismic activity, liquefaction and the potential risks incurred by these events. The degree of damage incurred for each event is considered where no appropriate remedial actions are undertaken. The site risk potential for each natural hazard is interpreted by this preliminary assessment and is not necessarily conclusive.

Table 2: Natural Hazard Risk Matrix Key

DEGREE OF DAMAGE				
Negligible	Low	Medium	High	Critical

Table 3: Proposed Site Natural Hazard Risk Assessment

LIKELIHOOD	POTENTIAL CONSEQUENCES			
	None	Minor	Moderate	Severe
Almost Certain				
Likely				
Possible			• Slope instability	
Unlikely		• Flooding	• Liquefaction • Vertical settlements • Lateral spreading • Volcanic eruption/ash fall	
Very Unlikely			• Underground services uplift • Tsunami	

The risk potential for natural hazards at the site is discussed in the following sections of this report.

2.2 Seismic Hazard

According to the GNS Science New Zealand Active Faults Database, the nearest known active faults are to the east. These are approximately 17km away. These are noted as being (generally) normal faults and form an extensional rift zone within the Taupo Volcanic Zone and are displayed in Figure 3.

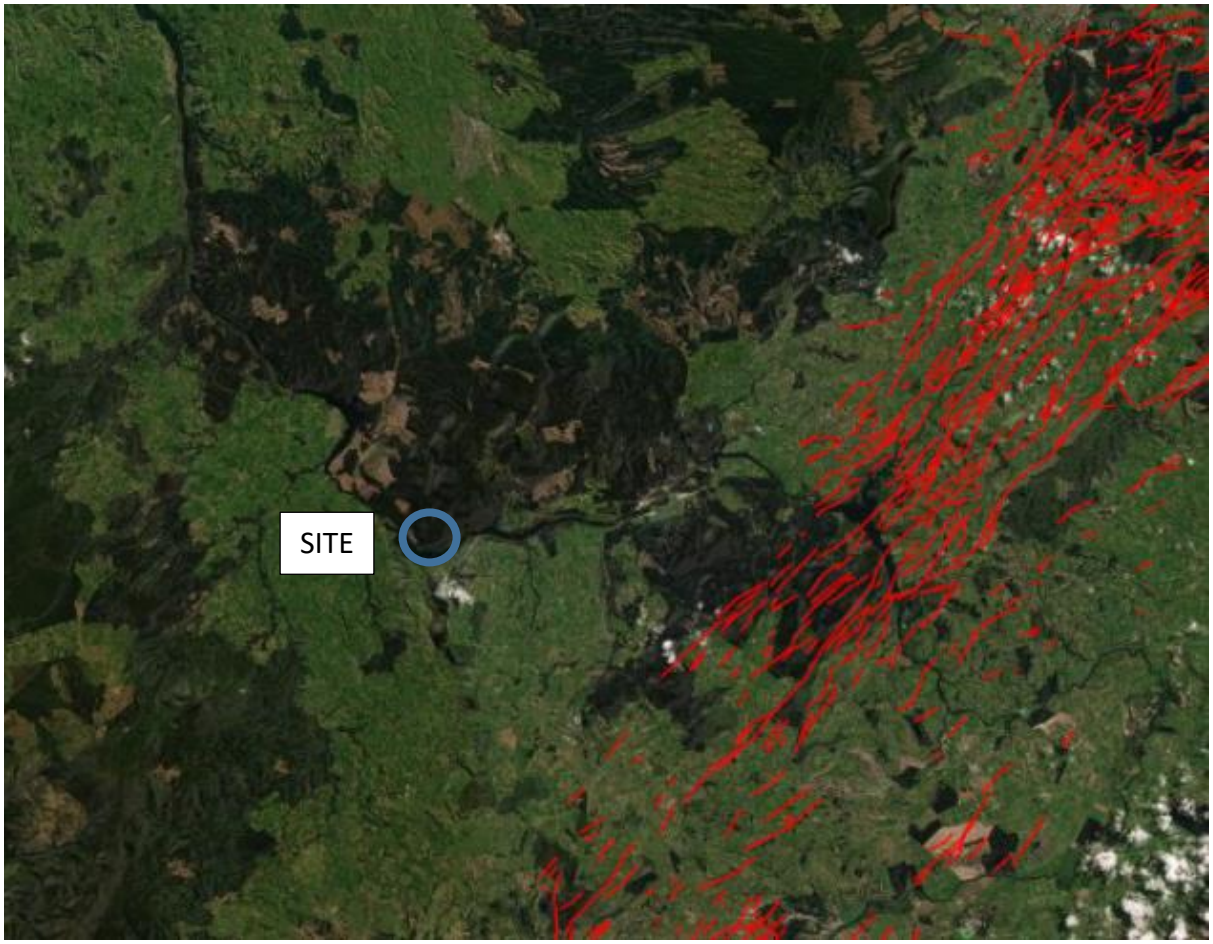


Figure 3: Active faults near the proposed subdivision (red).

Table 4 summarises the seismic parameters adopted for the site:

Table 4: Seismic parameters (Module 1, NZGS)

Module 1 MBIE/NZGS			
Importance Level 2			
Design Life:		50 Years	
Ground Acceleration (SLS)		**Ground Acceleration (ULS)**	
Mangakino		Mangakino	
Class C		Class C	
1/25		1/500	
M_{eff}	5.9	M_{eff}	5.9
PGA, a_{max} (g)	**0.08**	PGA, a_{max} (g)	**0.32**

2.3 Liquefaction

A preliminary liquefaction assessment has been undertaken for the site taking into consideration requirements of MBIE Guidance (Module 1 and 4 (2021)), Planning and engineering guidance for potentially liquefaction prone land (2017) and the "ensuring new buildings can withstand liquefaction effects" section of the Building Performance website.

Waikato Regional Council have produced a 'Level A' liquefaction map for the region (Waikato Regional Hazards Portal, 2021). A copy of the map is presented in Figure 4. This shows that liquefaction at the site is considered "possible".

Figure 4: Waikato Regional Council Regional Hazards Portal – Liquefaction (site boundary outlined in 'red')

The site is considered to be "Rural Residential" for the purpose of determining the appropriate liquefaction study detail level. In accordance with the "MBIE guidance for planning and engineering guidance on potentially liquefaction prone land", for the purpose of the assessment of "Re-zoning for Subsequent Subdivision", a "Level A – Basic Desktop Assessment" is the minimum requirement, as defined in Table 5.

Table 5: Liquefaction Study Detail Level – Rezoning for Plan Change for Subsequent Sub-Division

Table 3.5: Example matrix for determining minimum level of detail required for plan change

Increasing likelihood andseverity of ground damage

DEVELOPMENT SCENARIO[1]	LIQUEFACTION VULNERABILITY CATEGORY[2,3]			
	LIQUEFACTION CATEGORY IS UNDETERMINED			
	LIQUEFACTION DAMAGE IS UNLIKELY		LIQUEFACTION DAMAGE IS POSSIBLE	
	Very Low	Low	Medium	High
Sparsely populated rural area (lot size more than 4 Ha) eg Change of rules to allow increasing intensity of land use, buildings and population	Level A	Level A	Level A	Level A
Rural-residential setting (lot size of 1 to 4 Ha) eg Change of rules to reduce the minimum lot size for a residential dwelling	Level A	Level A	Level A	Level A

However, it is noted that the "MBIE planning guidelines" makes provision for liquefaction assessments based on the density of deep ground investigations undertaken for sites, as detailed in Table 6. Therefore, it is considered that a higher level of liquefaction assessment may be appropriate for the proposed development at this stage which would facilitate an application for sub-division consent. The ground investigation undertaken for the site comprised 10 CPTs each extending to refusal, considered to be rock head, together with 6 hand augers. Based on a proposed development area of approximately 32Ha, the deep ground investigation undertaken equates to a spatial density of 0.3 per Ha. Consequently, in accordance with the MBIE Planning Guidance, a "Level C – Detailed area wide assessment" liquefaction assessment can be completed for the site which would be appropriate for a sub-division development.

Table 6: Liquefaction Study Detail Level – Spatial Density of Deep Ground Investigation

Table 3.3: Indicative spatial density of deep ground investigation for adequate ground characterisation for liquefaction assessments to inform planning and consenting processes

LEVEL OF DETAIL IN THE LIQUEFACTION ASSESSMENT [1,2]	AVERAGE INVESTIGATION DENSITY	AVERAGE SPACING BETWEEN	MINIMUM TOTAL NUMBER OF INVESTIGATIONS
Level A[3] Basic desktop assessment	0.01 to 1 per km²	1 to 10 km	–
Level B Calibrated desktop assessment	0.5 to 20 per km²	220 to 1400 m	3 for each geological sub-unit
Level C Detailed area-wide assessment	0.1 to 4 per Ha	50 to 320 m	5 if area > 1 Ha 3 if area 0.25 – 1 Ha 2 if area < 0.25 Ha
Level D[4] Site-specific assessment	2 to 40 per Ha	15 to 70 m	2 within or very close to the building footprint

2.3.1 Liquefaction Assessment

A 'Level C' Study is recommended for this development. A 'Level C' study consists of the information used in a 'Level B' assessment but is calibrated against subsurface investigations on site. A comparison between the conditions required for the triggering of liquefaction occurrence and conditions found beneath the proposed lots on the site is shown in Table 7.

Table 7: Conditions for liquefaction occurrence

Soil conditions considered susceptible to liquefaction occurrence	Site
Holocene to Late Pleistocene sediments	Yes*
Cohesionless	Yes*
Non-cohesive silt to medium to fine sand	Yes*
Loosely packed	Yes*
Shallow water table (<4m)	No
Thick non-liquefiable crust at the ground surface	No

**Limited layers – Or to a shallow depth*

Further to this assessment a Level C study has been completed for the development using the data from CPT's carried out on site.

2.3.2 'Level C' Assessment

The liquefaction assessment made in this report is classified as a "Level C" study (MBIE, MFE, EQC, 2017) and will evaluate liquefaction potential at this location. The scope of a "Level C" study includes:

- Basic regional-scale information
- Historic site information
- Site-Specific mapping of geology and geomorphology
- Ground investigation at sufficient density/coverage to characterise range of soil types and groundwater depths
- Detailed area wide quantitative analysis of subsurface testing data
- Simplified quantitative analysis to identify potential for lateral spreading to occur

2.3.3 Seismic Assessment

A seismic analysis was undertaken using CLiq v.3.3.2.9 CPT data, hand auger testing and onsite geology and geomorphology. The following assessment methods were adopted:

- Boulanger and Idriss (2014) calculation method;
- Boulanger and Idriss (2014) fines correction;
- Limited to 10m depth (Ministry of Business, Innovation and Employment, 2012), and;
- Ic=2.6 cutoff (MBIE, NZGS, 2016).

The water table was modelled at 4m as a conservative depth to water table as it was not found within any of the CPTs or test holes conducted on site. Sensitivity checks were conducted and are noted below.

2.3.4 Liquefaction Results

Liquefaction results are shown in Appendix E.

There is negligible liquefaction potential and negligible vertical ground settlements expected during or following the SLS earthquake event for this site.

The results of the liquefaction analysis for the ULS earthquake event show liquefaction is possible within saturated layers in the soil profile. However, with the exception of CPT01, the liquefiable layers present are less than 300mm thick with settlements due to liquefaction for the ULS event being negligible (less than 10mm). For CPT01, the assessed settlement due to liquefaction for the ULS event has been determined to be approximately 25mm. This can be considered as minor settlement with little or no impact on structures located above.

The analysis results for the ULS earthquake event are shown in Table 8 in addition to the Performance Level for liquefied deposits on the site as characterised in the MBIE Module 3.

Table 8: Liquefaction analysis results summary

Liquefaction Parameter	CPT 1	CPT 2	CPT 3	CPT 4	CPT 5	CPT 6	CPT 7	CPT 8	CPT 9	CPT 10
Liquefaction Potential Index (LPI)	2.52	0	0.29	0	0	0	0	0	0	0.10
	Low Risk									
Liquefaction Severity Number (LSN)	5.94	0	0.87	0	0	0	0	0	0	0.53
	Little to no expression of liquefaction									
Vertical Settlements (mm)	27	0	4	0	0	0	0	0	0	2
Lateral Displacements (mm)	Liquefaction is considered unlikely and as such lateral spread is also considered unlikely.									
Performance Level	Insignificant to Mild									

***Insignificant:** No significant excess pore water pressures (MBIE, NZGS, 2016).*

***Mild:** Limited excess pore water pressures; negligible deformation of the ground and small settlements (MBIE, NZGS, 2016).*

Accordingly, and in consideration of the MBIE guidelines, the site shall be classed as **TC1**.

Lateral spread/stretch can be expected where a site is located within 100m of a free face less than 2m high or within 200m of a face greater than 2m high (MBIE 2017). As liquefaction vulnerability of the site is considered low it is expected that the probability of lateral spread for the site can also be considered as low.

Due to the depth to ground water table and the notably low results and probability for liquefaction at the site a sensitivity check was completed using a water table of 2m bgl. This was also shown to have insignificant results with only CPT 1 displaying vertical settlements falling within the TC2 criteria. As such the provided TC1 recommendation is considered suitable. It is noted that CPTs were only conducted to a shallow depth, however the presence of near surface rock limited the depth of CPT analysis, and as rock is non-liquefiable these results are considered appropriate.

2.4 Slope stability

The slopes on site are generally gradual with several seemingly constructed from forestry earthworks. The largest slopes are found to the south of the site. Here slope stability analysis is likely to be required, as these sections of slope do not conform with the building code and have grades in excess of 25%. Alternatively, the site may be contoured or redesigned to have building platforms positioned away from these locations, or appropriate batters or retaining

installed, although this is not considered necessary. Based on the final proposed landform for the site, some of the proposed lots may require individual detailed slope stability assessments in order to determine appropriate building setbacks or specific design zones.

Any cut to fill earthworks required to establish a suitable building platform shall be specifically designed.

2.5 Volcanic Eruption

According to GNS Science Volcano Geology and Hazards in New Zealand the nearest active volcano is Taupo, located approximately 40km south of the site. This is at Alert Level 1. At this time no volcanic unrest is occurring at this volcano and as such no hazard is posed to the site. However, there are several other volcanic areas nearby such as Ruapehu and Rotorua. In the occurrence of small volcanic eruptions ash may gather on the dwellings proposed at this subdivision. This risk is considered unlikely.

2.6 Flooding

Council planning maps show no ponding or flooding in the area. The level of the nearby Waikato River is controlled by the Whakamaru dam and as such flooding risk is low at this site. The site is also raised above the river level giving some protection from flooding. Flooding is considered unlikely. Refer to Titus "Engineering Assessment and Infrastructure Design Report" for flooding assessments relating to secondary flows which may affect the site.

Correspondence from Mercury Power (dated 27 January 2021 (although issued on 27 January 2023))), indicates the following with respect to flood levels affecting the site and minimum FFL requirements for buildings:

> The AEE does reference natural hazards and refers to Council Planning maps, which Mercury has not reviewed for this purpose. Given the managed nature of flows and levels associated with Lake Whakamaru and the Waikato Hydro System. With no building platform for habitable structures identified, Mercury seeks a minimum freeboard for all habitable structures and dwellings is 0.5m above Probable Maximum Flood 228.67m RL, which result in a level of 229.17m RL minimum freeboard.

2.7 Tsunami

Land damage due to tsunami or coastal processes is not expected at this location. Rock collapse of the adjacent hillside into the river/lake may be enough to cause large waves to affect the site. The risk of tsunami by rock fall is considered very low.

3 SITE SUITABILITY ASSESSMENT

The following recommendations are provided to give a high-level overview of the site and its suitability. The findings of this report are provided to give indicative recommendations anticipated for the proposed development of the site, to outline further testing required and potential hazards on the site.

3.1 Foundations

Insitu soils on site were found to be well worked in places due to forestry activities with some areas of covered in loose soil and fill material. These areas should be avoided or reworked to provide stable building platforms.

As this land was once used for forestry there is also a substantial presence of many tree stumps and roots on site. These will need to be removed from large parts of the site as part of the subdivision development and prior to the siting of building platforms. These are considered organics and may be prone to settlement or may lend to the creation of voids within the soil if not removed.

Preliminary borehole and scala tests indicate varying bearing capacity. Good ground was established at variable depths. BH1 showed that good ground was not reached within 2m of the surface. BH2 had good ground at 700mm, BH3 at 500mm although had variable results at 2m, BH4 and BH5 at 1200mm and BH6 at 1500mm.

Post subdivisional earthworks, foundation options may include NZS3604 foundations and piled or concrete options.

Foundations in line with TC1 requirements are considered suitable.

3.2 Three Waters Assessment

Refer to Titus “Engineering Assessment and Infrastructure Design Report”.

3.3 Proposed Access

Refer to Titus “Engineering Assessment and Infrastructure Design Report”.

4 LIMITATIONS

This report does not assess risk of contamination of soils. This report does not provide a foundation design.

Testing portrays a limited percentage of ground conditions at Ongaroto Road Rural-Residential re-zoning with subsequent subdivision, and may not be representative of all soils present on site.

Assessment of the water table depth and moisture content is subject to seasonal variation.

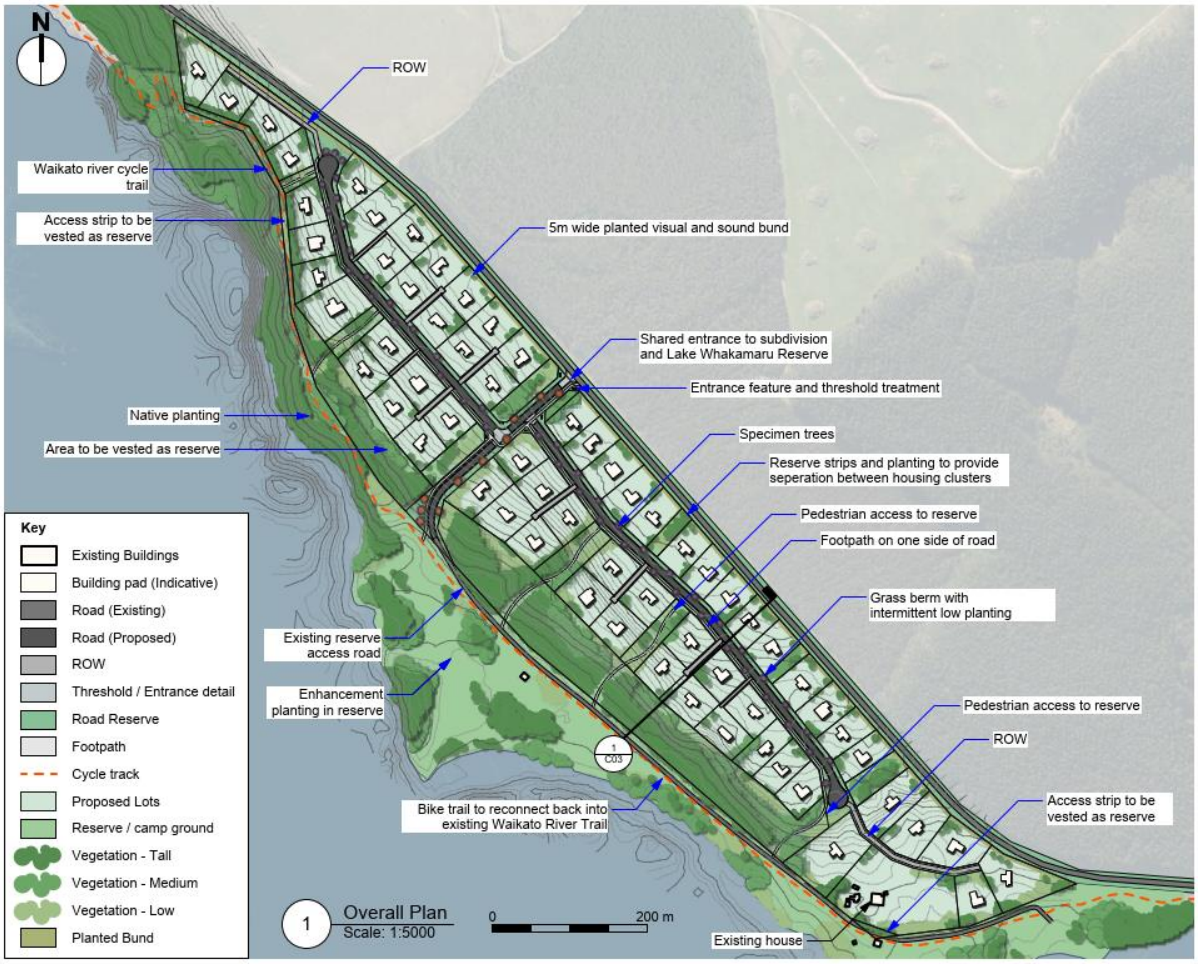
During excavation and construction, the site should be examined by a suitably qualified engineer in order to assess whether the exposed subsoils are compatible with the inferred soil conditions on which the recommendations have been based and potentially further investigation and design rationalisation may be required.

This report has been prepared solely for Jonathan Quigley, its professional advisors and local authorities in relation to Ongaroto Road Rural-Residential re-zoning with subsequent subdivision. No liability is accepted for its use for any other purpose or by any other entity. Reliance by other parties or future owners of the property on the information or opinions contained in the report shall be verified with Titus Consulting Engineers.

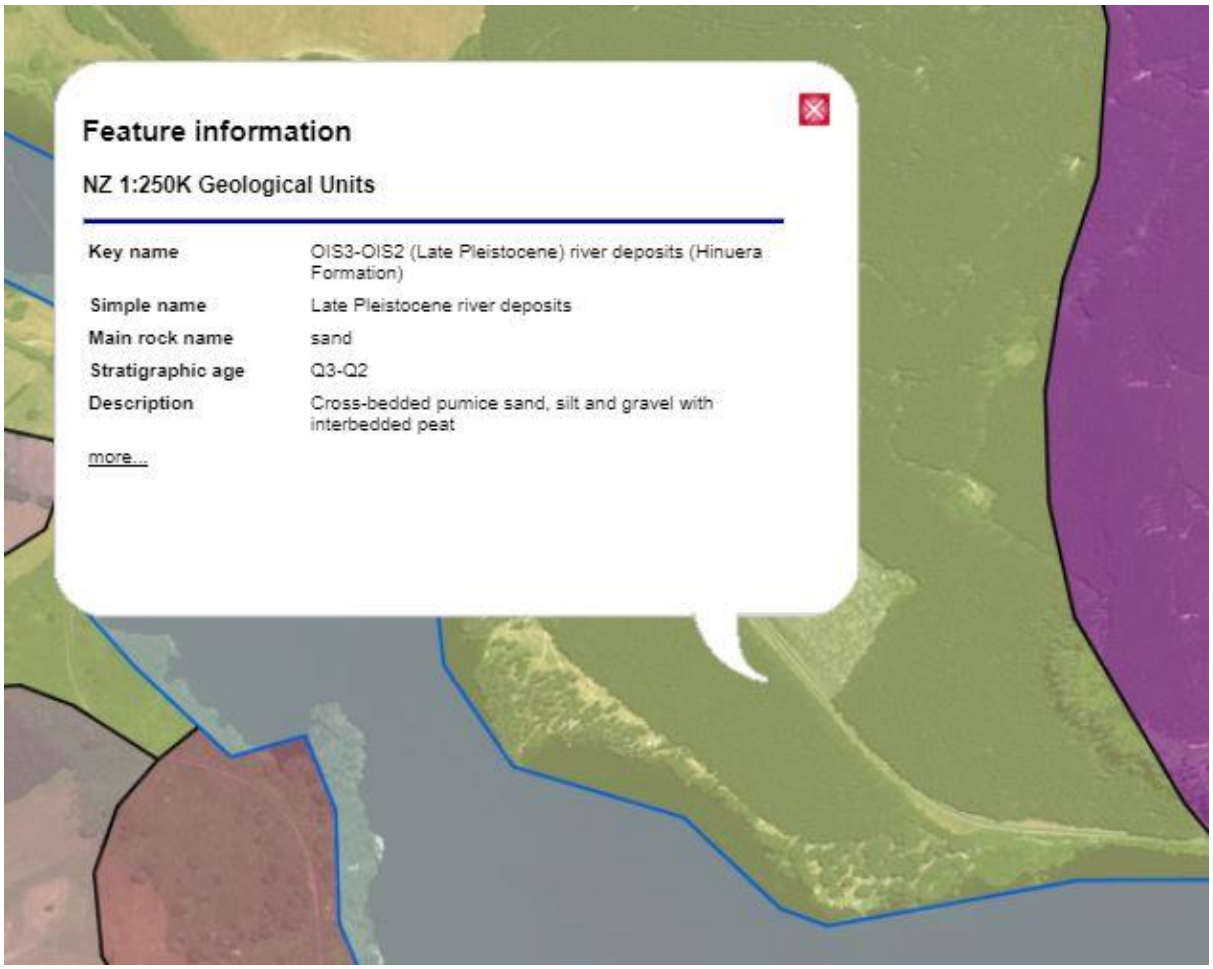
Should you be in any doubt as to the recommendations of this report it is essential that you discuss these issues with Titus Consulting Engineers prior to proceeding with any work based on this report.

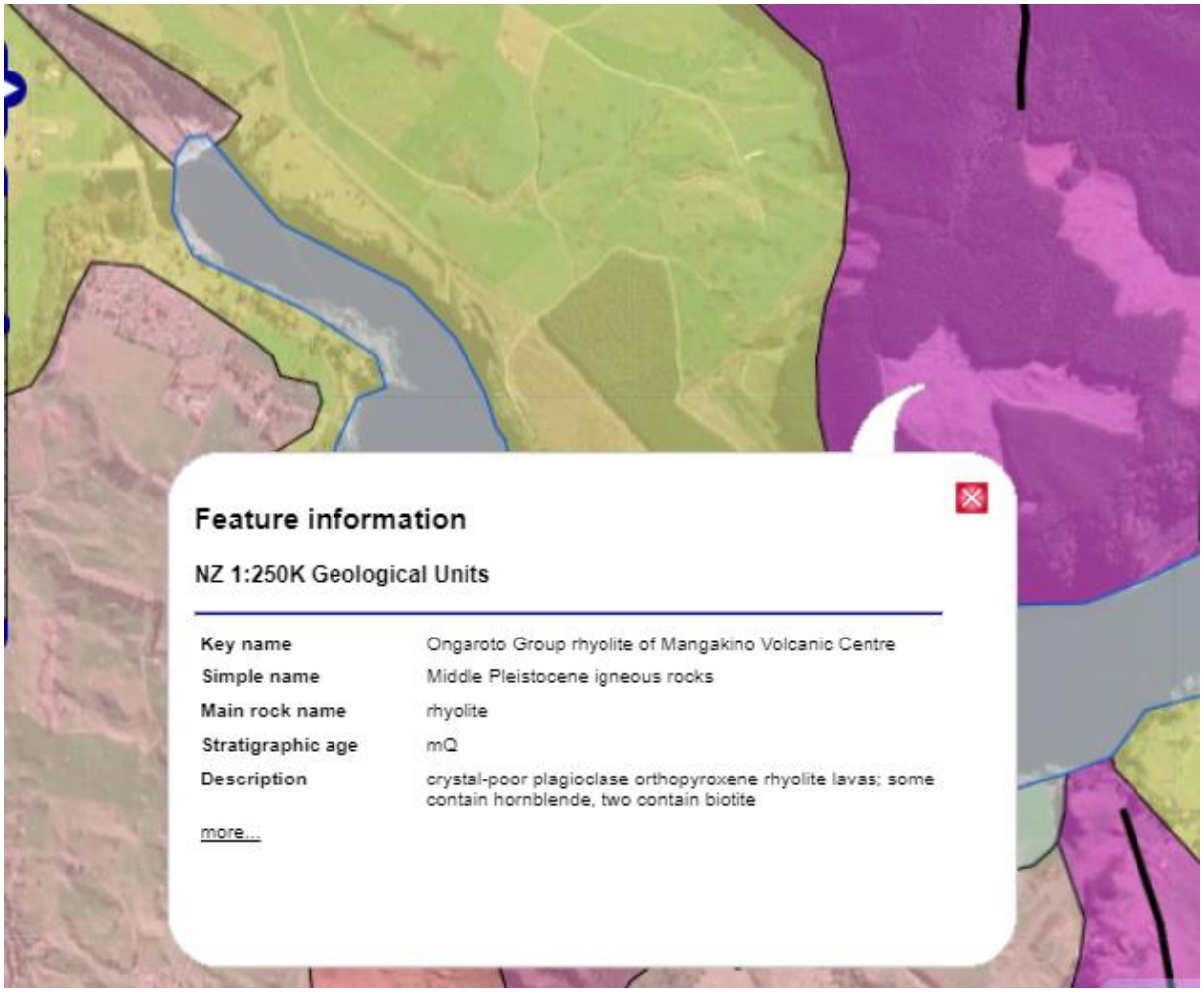
APPENDICES

Appendix A - Proposed Site Plan



Appendix B - Underlying Geology

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Ongaroto Group rhyolite of Mangakino Volcanic Centre
Simple name
Middle Pleistocene igneous rocks
Main rock name
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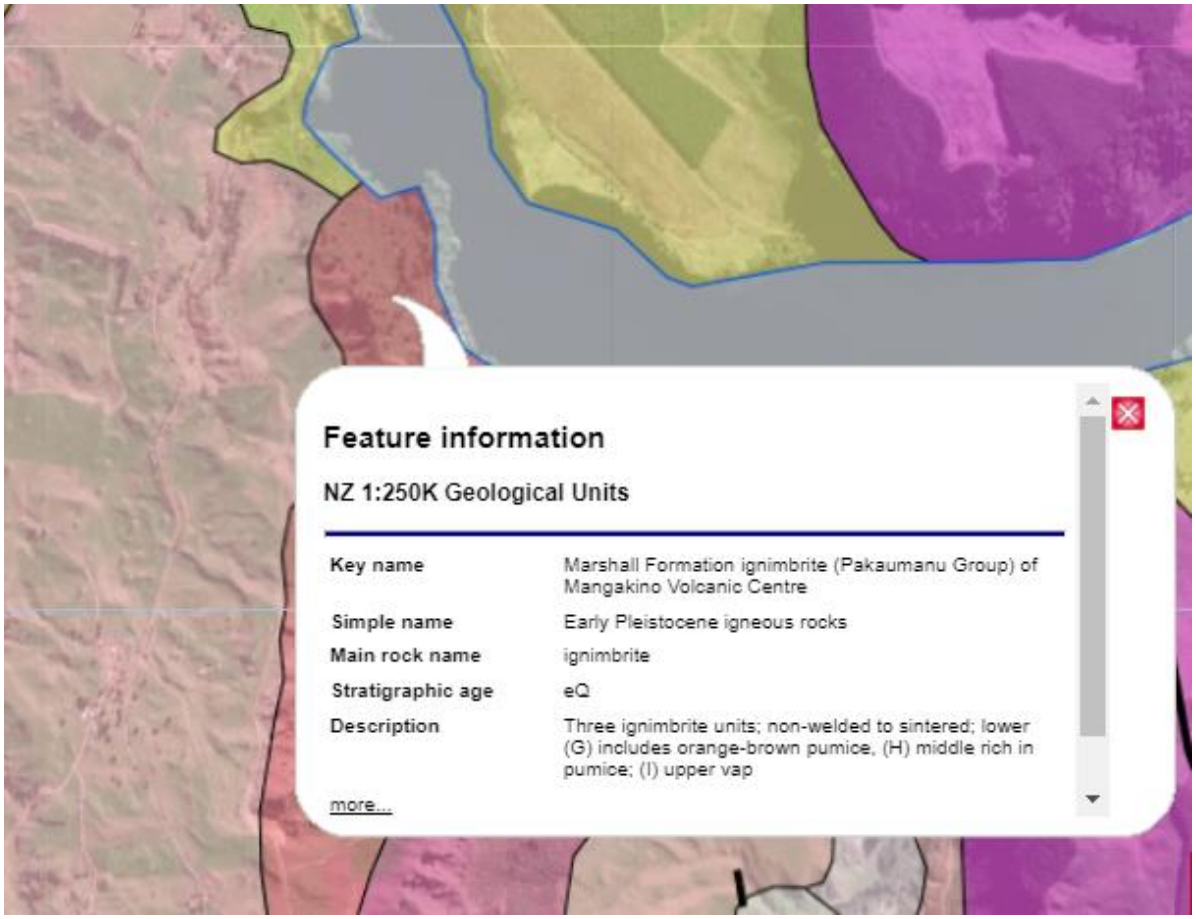
Stratigraphic age
mQ
Description
crystal-poor plagioclase orthopyroxene rhyolite lavas; some contain hornblende, two contain biotite
more...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NZ 1:250K Geological Units
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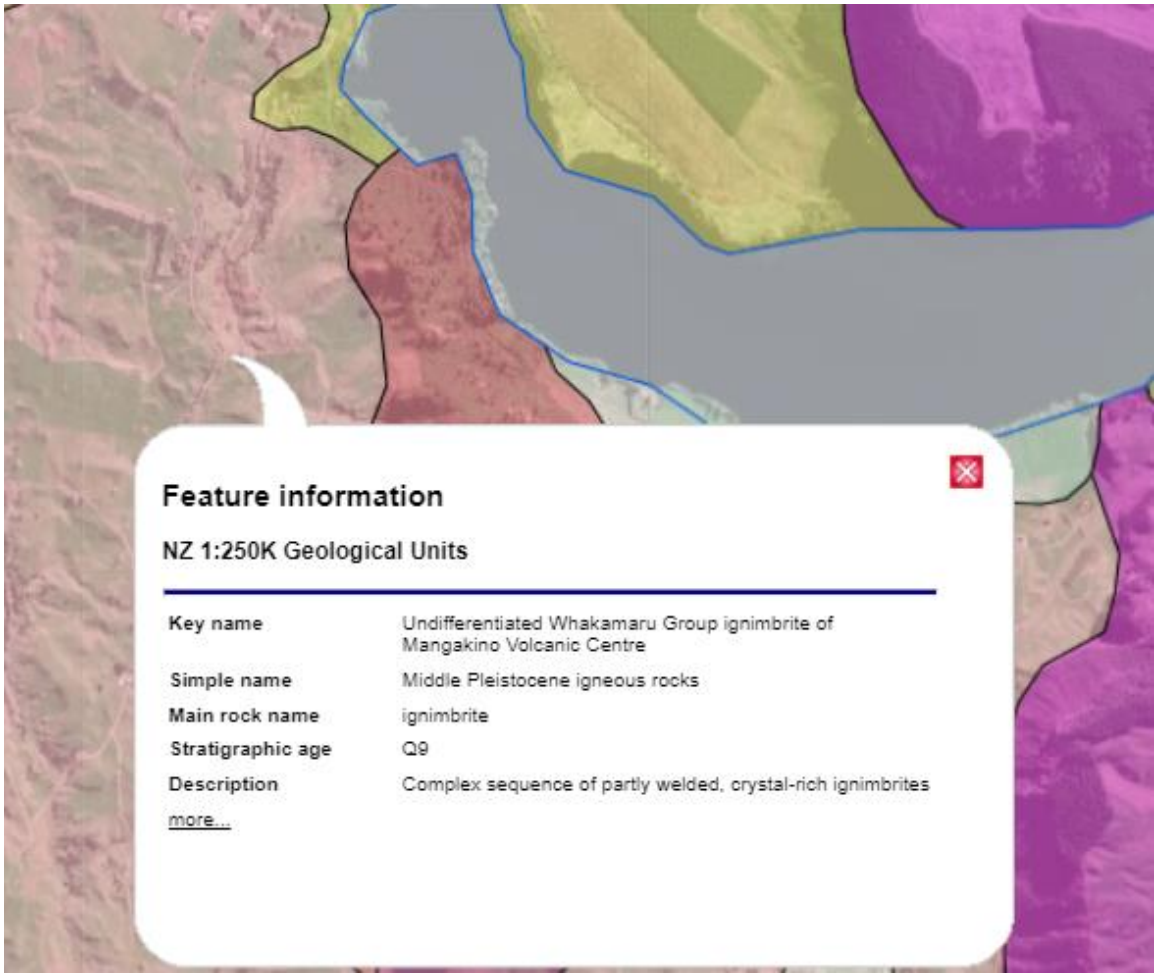
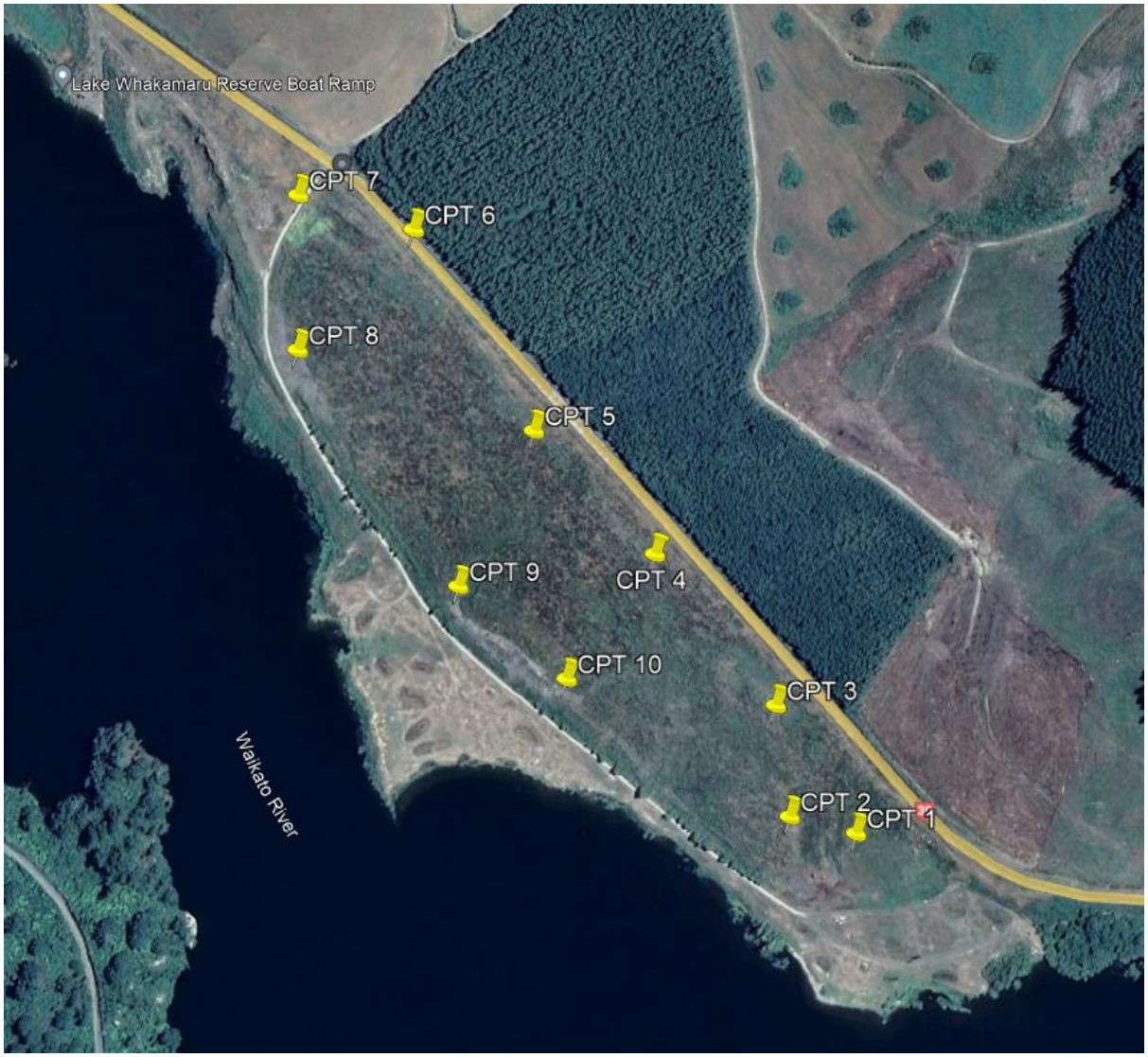
Marshall Formation ignimbrite (Pakaumanu Group) of Mangakino Volcanic Centre
Simple name
Early Pleistocene igneous rocks
Main rock name
ignimbrite
Stratigraphic age
eQ
Description
Three ignimbrite units; non-welded to sintered; lower (G) includes orange-brown pumice, (H) middle rich in pumice; (I) upper vap
more...


Feature information
NZ 1:250K Geological Units
Key name
Undifferentiated Whakamaru Group ignimbrite of Mangakino Volcanic Centre
Simple name
Middle Pleistocene igneous rocks
Main rock name
ignimbrite
Stratigraphic age
Q9
Description
Complex sequence of partly welded, crystal-rich ignimbrites
more...

Appendix C - Soil Investigation Test Locations


Lake Whakamaru Reserve Boat Ramp
CPT 7
CPT 6
CPT 8
CPT 5
CPT 9
CPT 4
CPT 10
CPT 3
CPT 2
CPT 1
Waikato River

Appendix D - Soil Investigation Logs

TITUS CONSULTING ENGINEERS

Log: **BH1**

Address: Ongaroto Rd Subdivison Whakamaru
Date: 21/12/2020
Testers: TR, MH

Project №: C2131

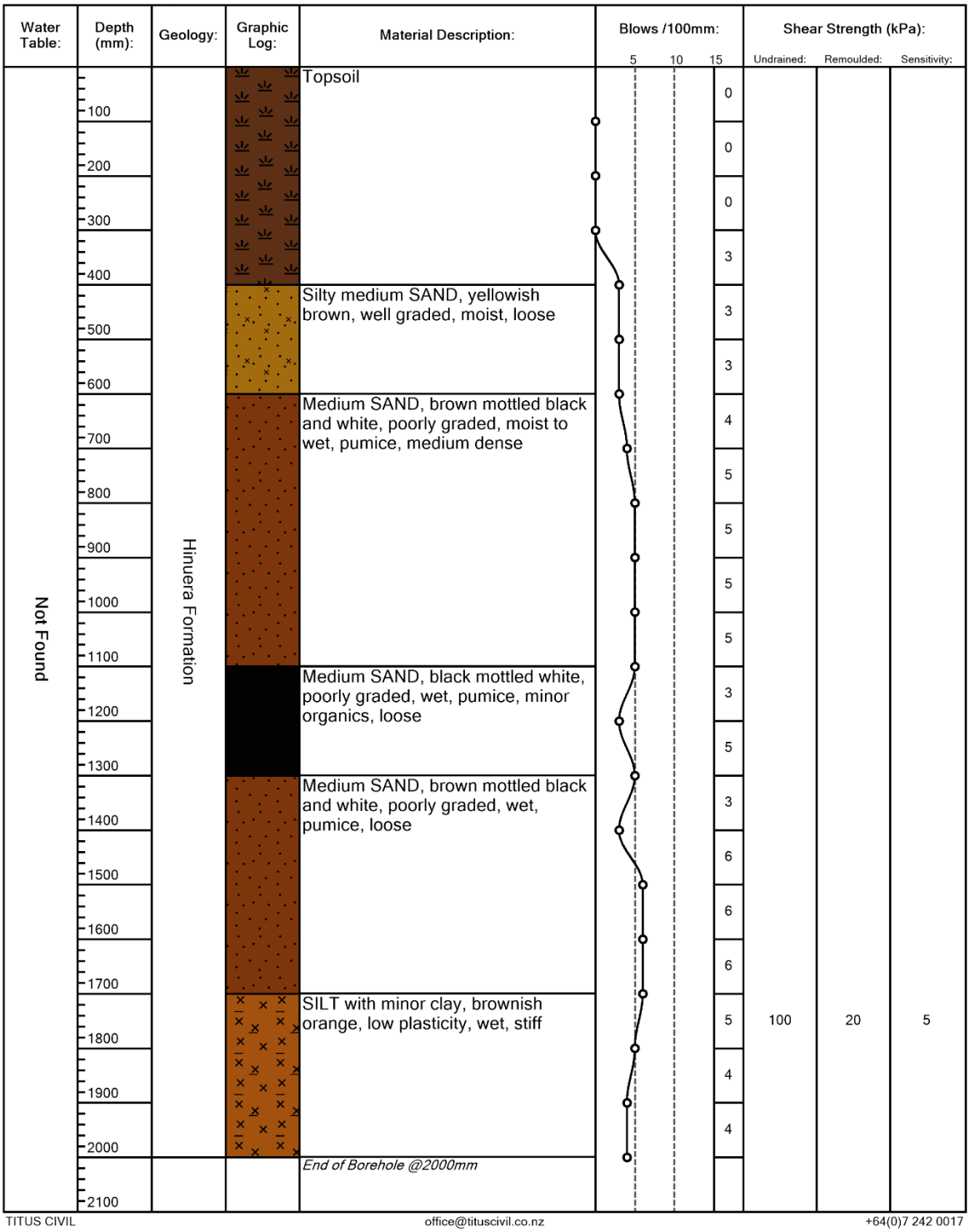
Water Table:	Depth (mm):	Geology:	Graphic Log:	Material Description:	Blows /100mm: (5 / 10 / 15)		Shear Strength (kPa): Undrained:	Remoulded:	Sensitivity:
Not Found	100	Hinuera Formation		Medium SAND, brown mottled black, poorly graded, moist, pumice, very loose to medium dense		3			
	200					3			
	300					3			
	400					3			
	500					3			
	600					3			
	700					3			
	800					1			
	900					1			
	1000					1			
	1100					3			
	1200					2			
	1300					3			
	1400					3			
	1500					2			
	1600					1			
	1700			SILT with minor clay, brownish orange, low plasticity, moist, stiff		2	69	13	5.2
	1800					2			
	1900								
	2000								
	2100			*End of Borehole @2000mm*					

TITUS CONSULTING ENGINEERS

Log: BH2

Address: Ongaroto Rd Subdivison Whakamaru
Date: 21/12/2020
Testers: TR, MH

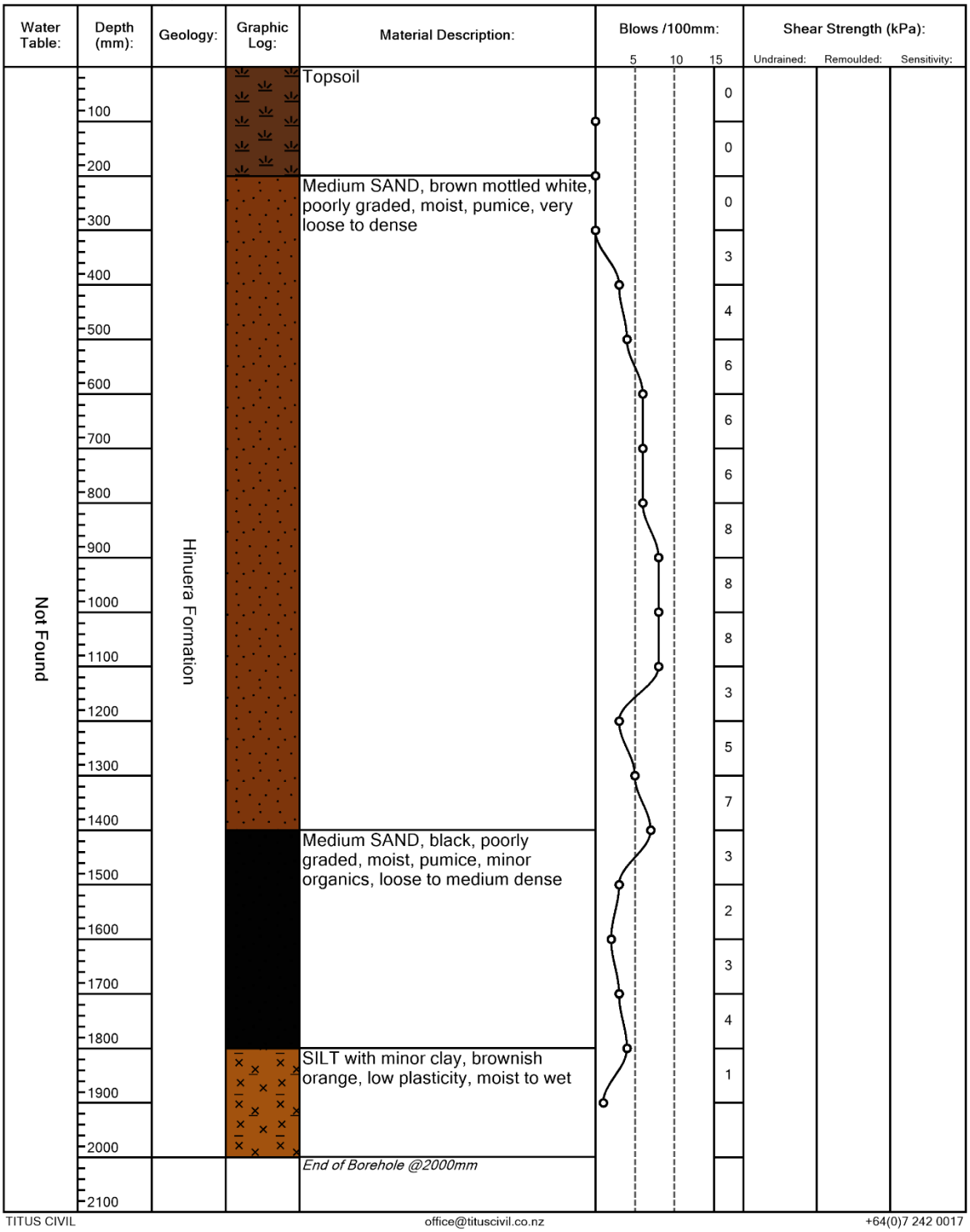
Project №: C2131



TITUS CONSULTING ENGINEERS

Log: BH3

Address: Ongaroto Rd Subdivison Whakamaru
Date: 21/12/2020
Testers: TR, MH
Project №: C2131



TITUS CONSULTING ENGINEERS

Log: BH4

Address: Ongaroto Rd Subdivison Whakamaru
Date: 21/12/2020
Testers: TR, MH

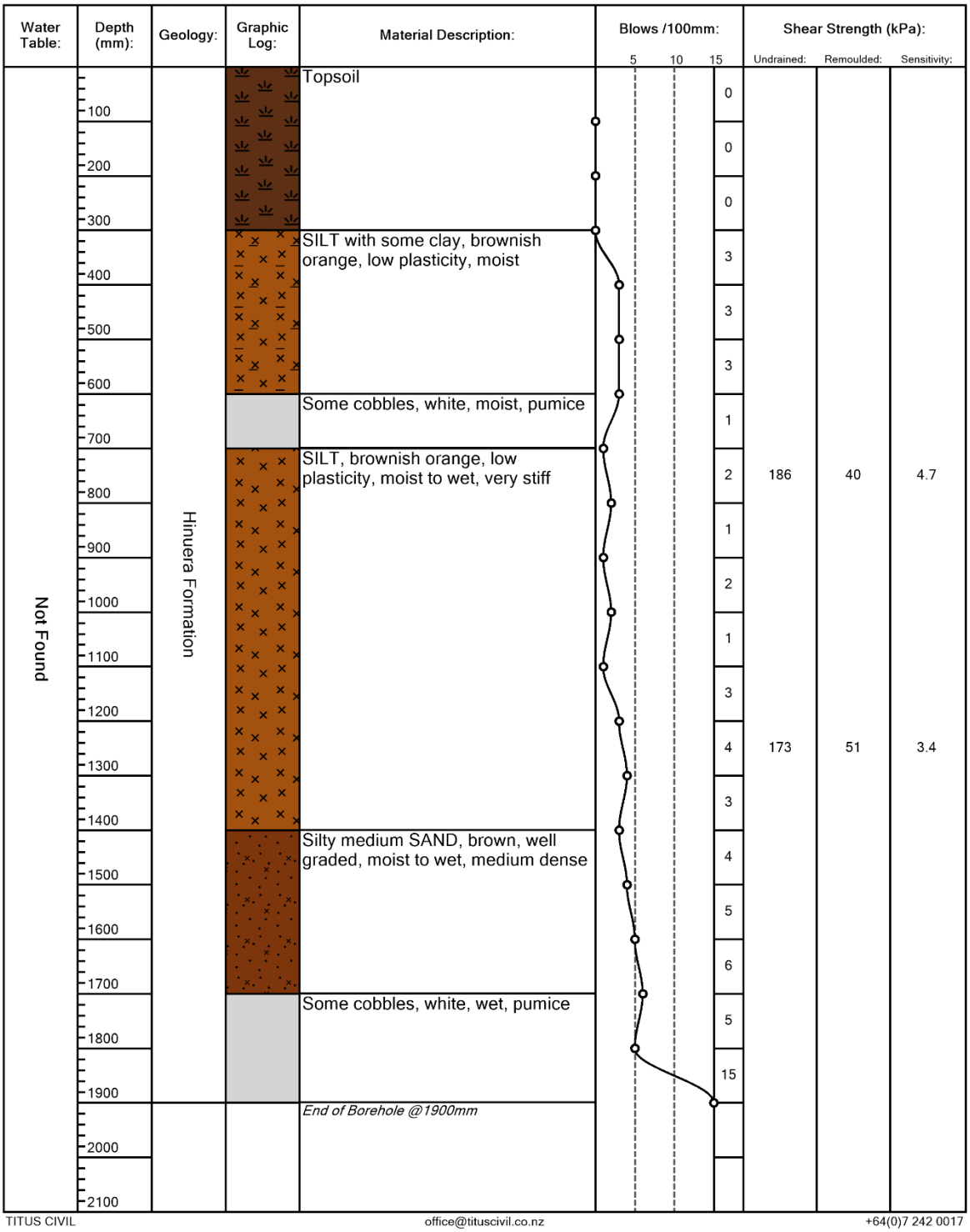
Project №: C2131

Water Table:	Depth (mm):	Geology:	Graphic Log:	Material Description:	Blows /100mm: (5 10 15)		Shear Strength (kPa): Undrained:	Remoulded:	Sensitivity:
Not Found	100	Hinuera Formation		Topsoil		0			
	200					0			
	300					0			
	400					3			
	500					6			
	600			SILT with minor clay, light yellowish brown, low plasticity, dry to moist, very stiff		7			
	700					3			
	800					2	186	100	1.9
	900					2			
	1000					2			
	1100					2			
	1200					3	173	47	3.7
	1300					4			
	1400					5			
	1500					6			
	1600			Some cobbles, white, moist, Pumice		4			
	1700			Medium SAND, brown, poorly graded, moist to wet, pumice, loose		4			
	1800					3			
	1900								
	2000								
	2100			Some cobbles, white, wet, Pumice					
	2200								
	2300			*End of Borehole @2200mm*					

TITUS CONSULTING ENGINEERS

Log: BH5

Address: Ongaroto Rd Subdivison Whakamaru
Date: 21/12/2020
Testers: TR, MH
Project №: C2131



TITUS CONSULTING ENGINEERS

Log: BH6

Address: Ongaroto Rd Subdivison Whakamaru
Date: 21/12/2020
Testers: TR, MH

Project №: C2131

Water Table:	Depth (mm):	Geology:	Graphic Log:	Material Description:	Blows /100mm:	Shear Strength (kPa): Undrained:	Remoulded:	Sensitivity:
Not Found	100	Hinuera Formation		Topsoil	0			
	200				0			
	300				0			
	400			Medium SAND, brown mottled white, poorly graded, moist to wet, pumice, very loose to medium dense	0			
	500				0			
	600				2			
	700				6			
	800				5			
	900				3			
	1000				2			
	1100				1			
	1200				2			
	1300				2			
	1400				2			
	1500				3			
	1600			SILT, brownish orange, low plasticity, moist to wet, stiff	3	107	16	6.7
	1700				3			
	1800				5			
	1900				4			
	2000							
	2100			*End of Borehole @2000mm*				

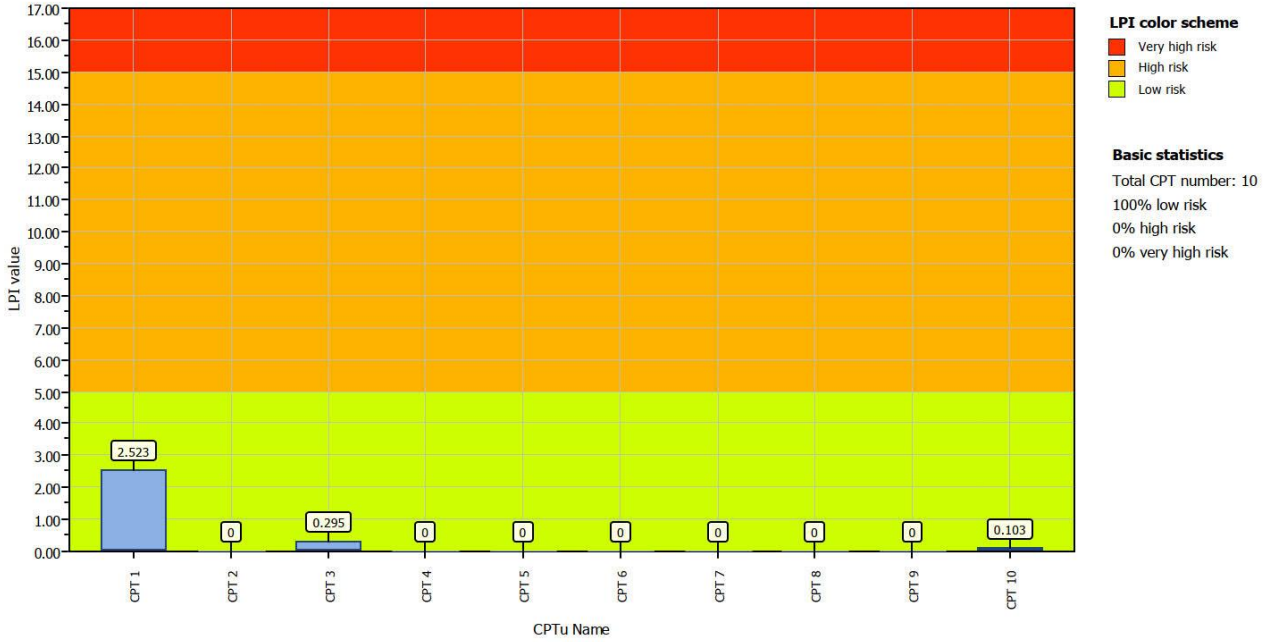
Appendix E – CPT Results and Liquefaction Assessment

TITUS CONSULTING ENGINEERS
169 London Street
Hamilton
07 242 0017

Project title :

Location :

Overall Liquefaction Potential Index report



LPI color scheme

- Very high risk
- High risk
- Low risk

Basic statistics

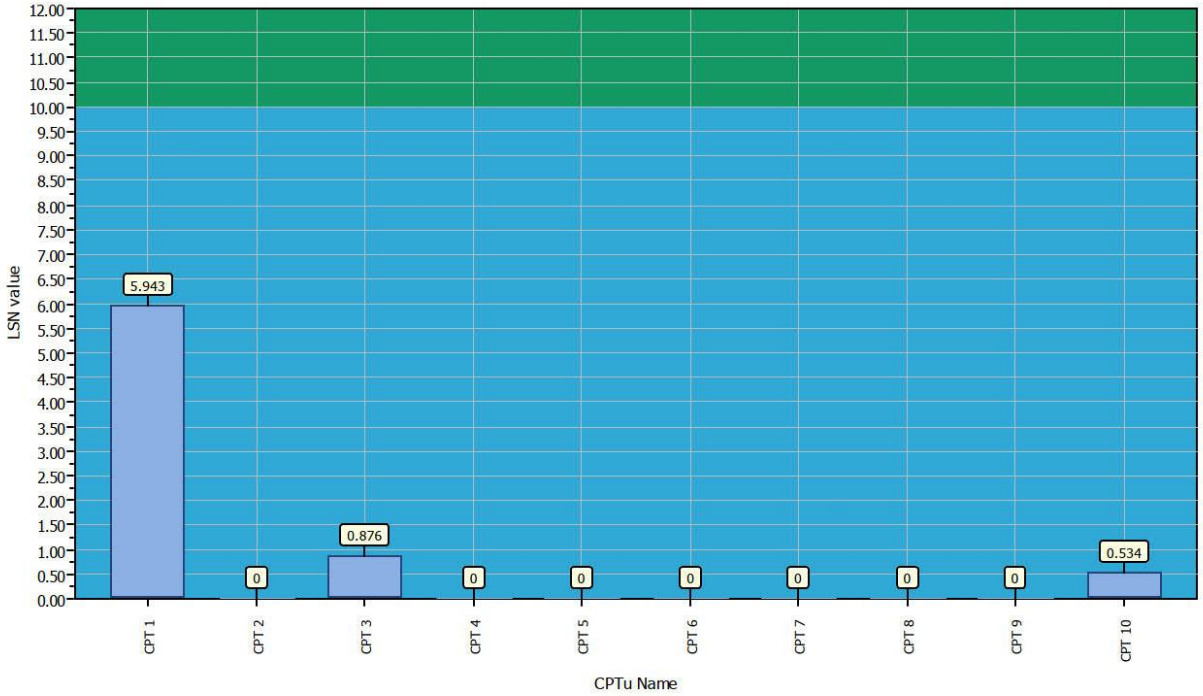
Total CPT number: 10
100% low risk
0% high risk
0% very high risk

TITUS CONSULTING ENGINEERS
169 London Street
Hamilton
07 242 0017

Project title :

Location :

Overall Liquefaction Severity Number report



LSN color scheme

- Severe damage
- Major expression of liquefaction
- Moderate to severe exp. of liquefaction
- Moderate expression of liquefaction
- Minor expression of liquefaction
- Little to no expression of liquefaction

Basic statistics

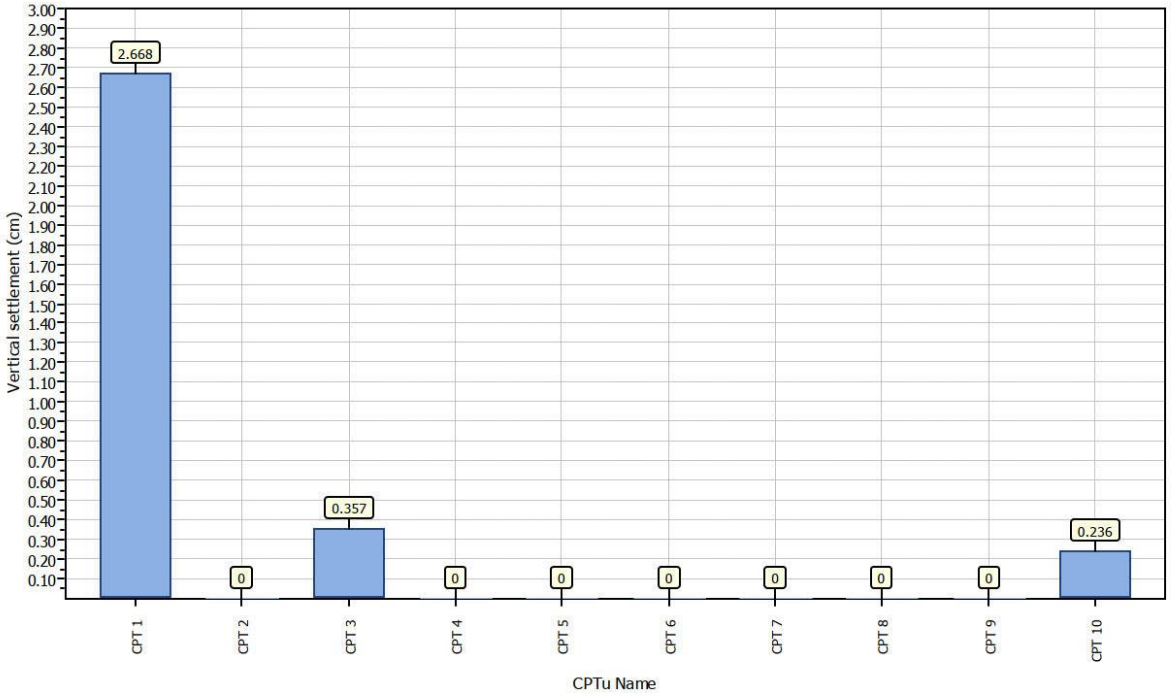
Total CPT number: 10
100% little liquefaction
0% minor liquefaction
0% moderate liquefaction
0% moderate to major liquefaction
0% major liquefaction
0% severe liquefaction

TITUS CONSULTING ENGINEERS
169 London Street
Hamilton
07 242 0017

Project title :

Location :

Overall vertical settlements report



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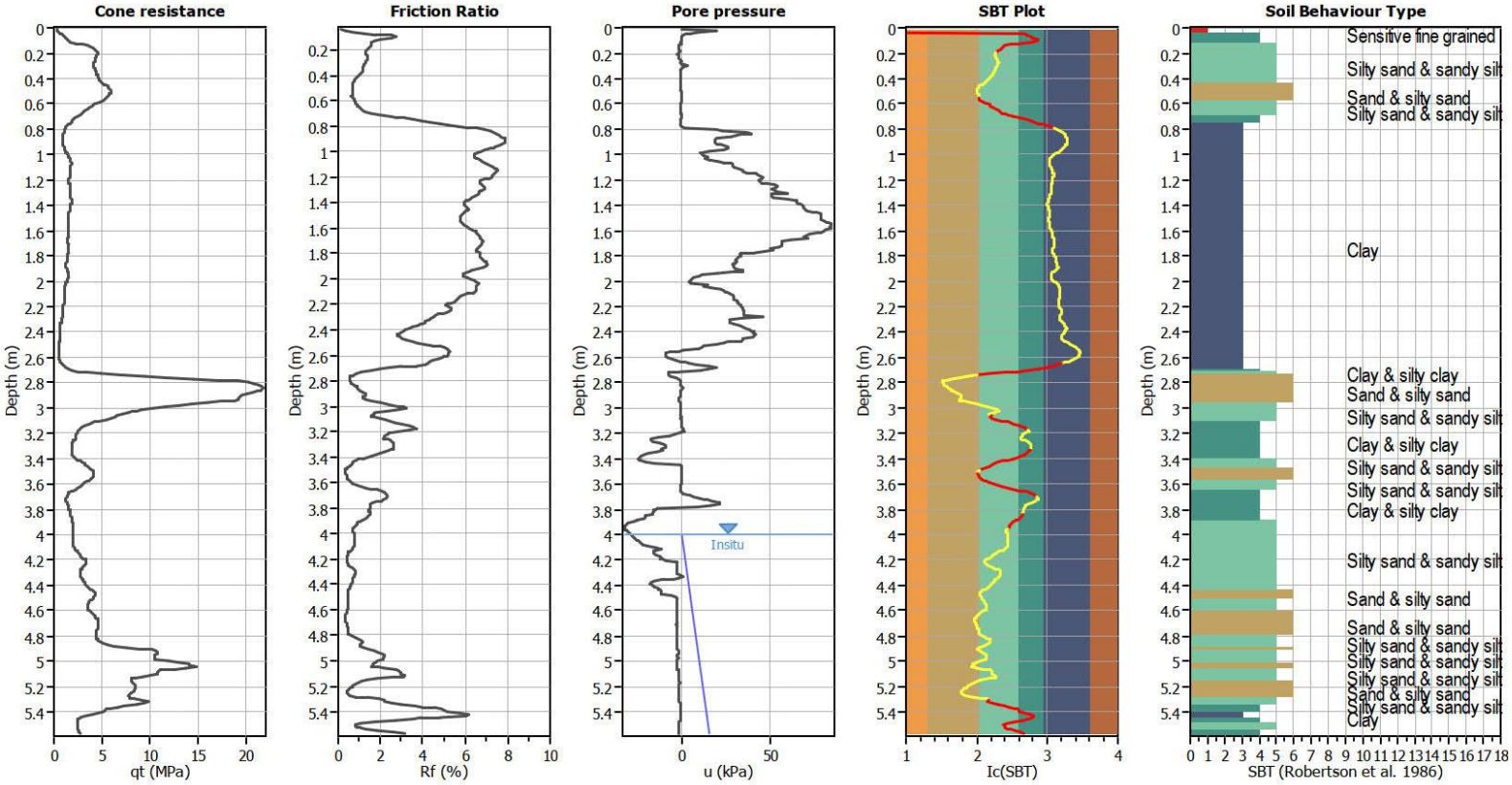
CPT name: CPT 1

CPT basic interpretation plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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

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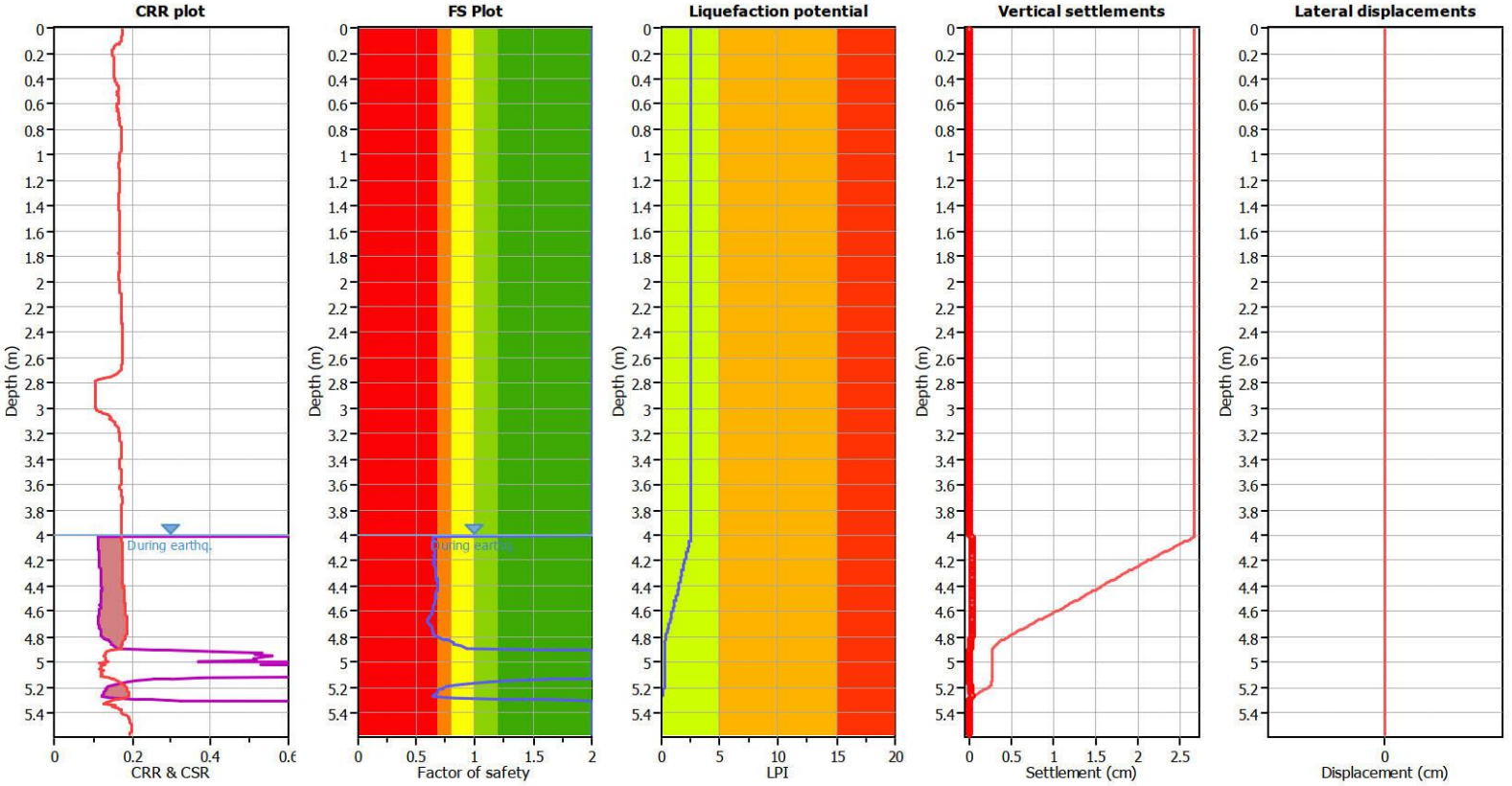
CPT name: CPT 1

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

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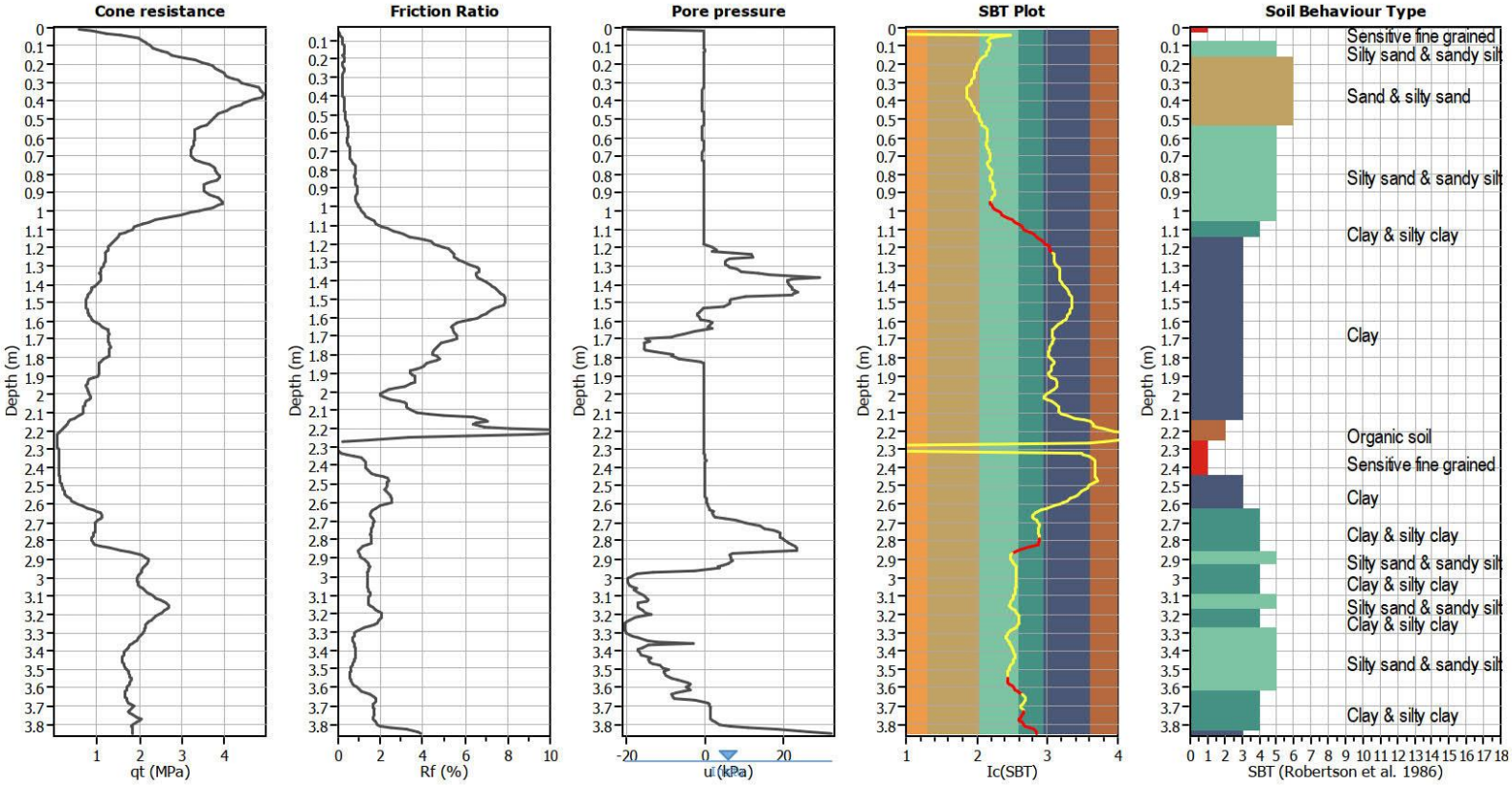
CPT name: CPT 2

CPT basic interpretation plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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

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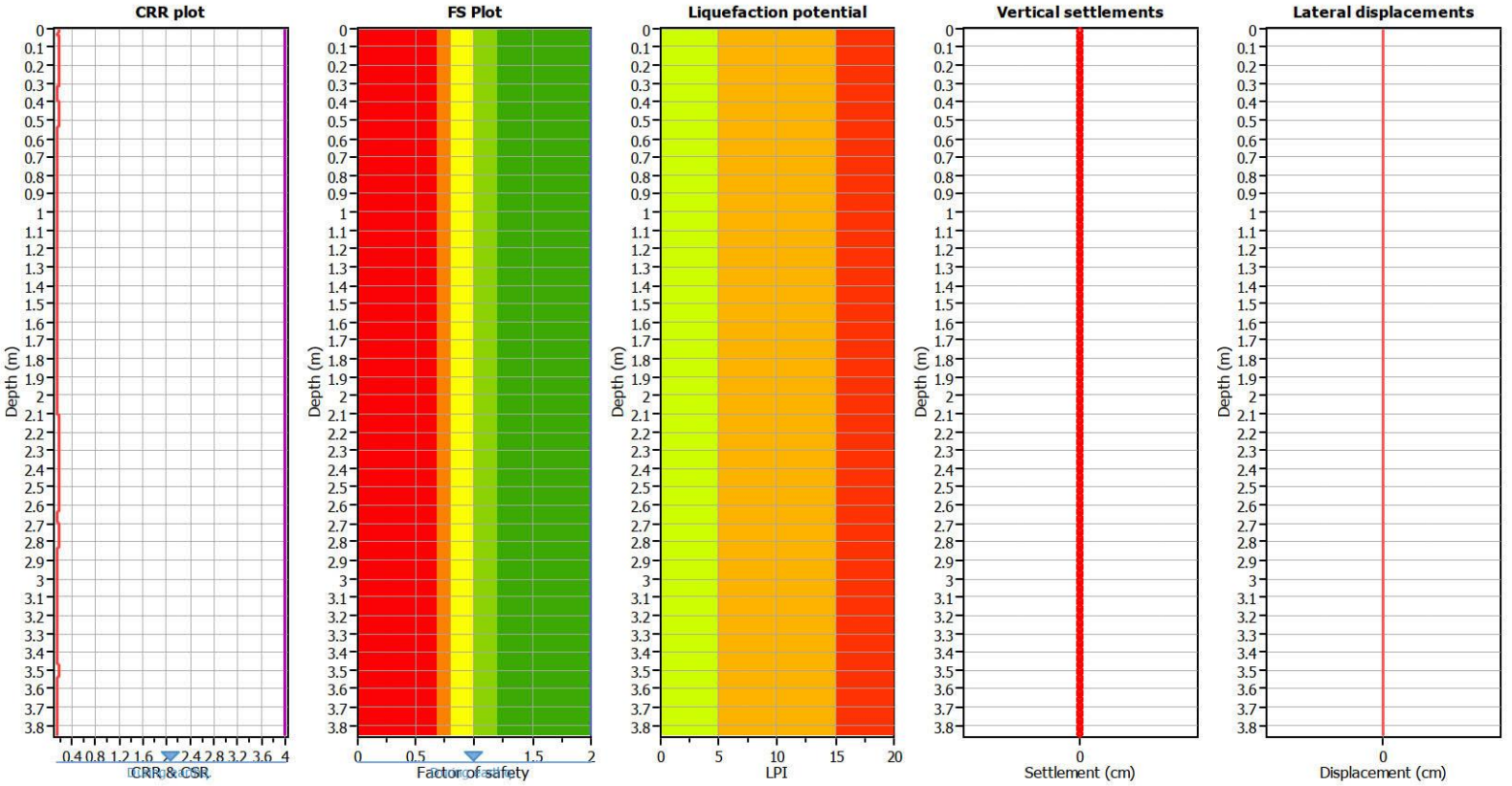
CPT name: CPT 2

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

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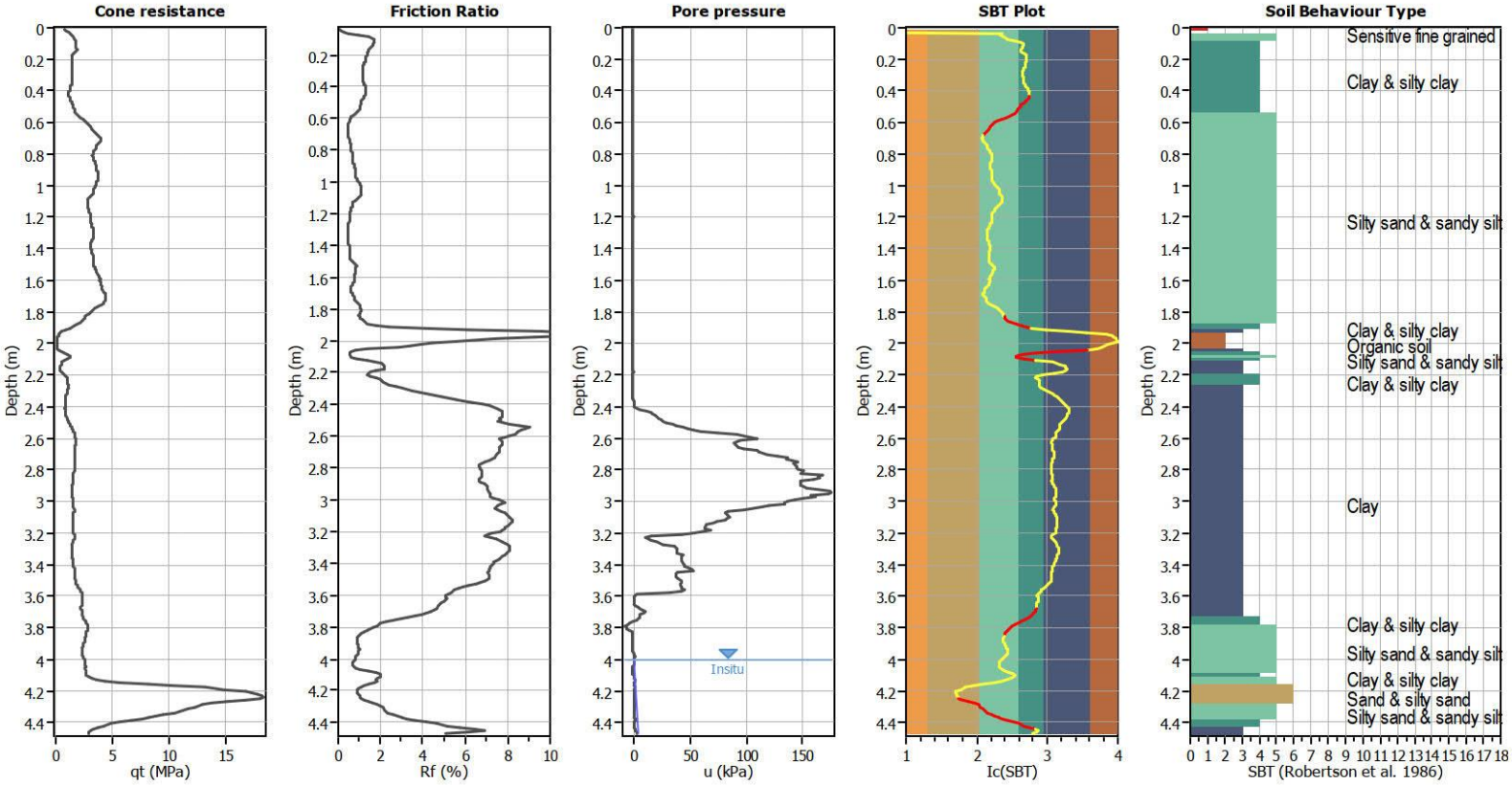
CPT name: CPT 3

CPT basic interpretation plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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

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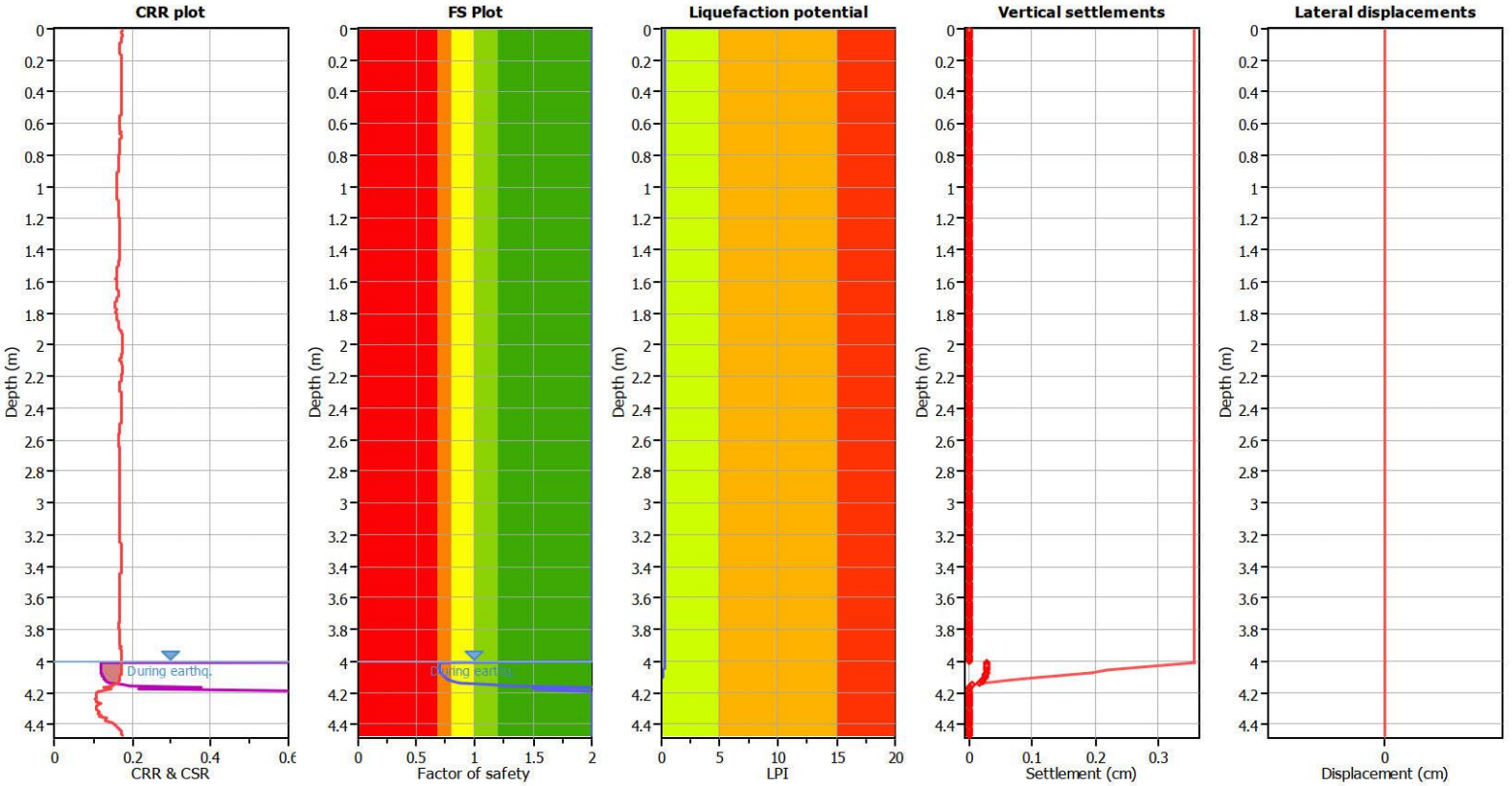
CPT name: CPT 3

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

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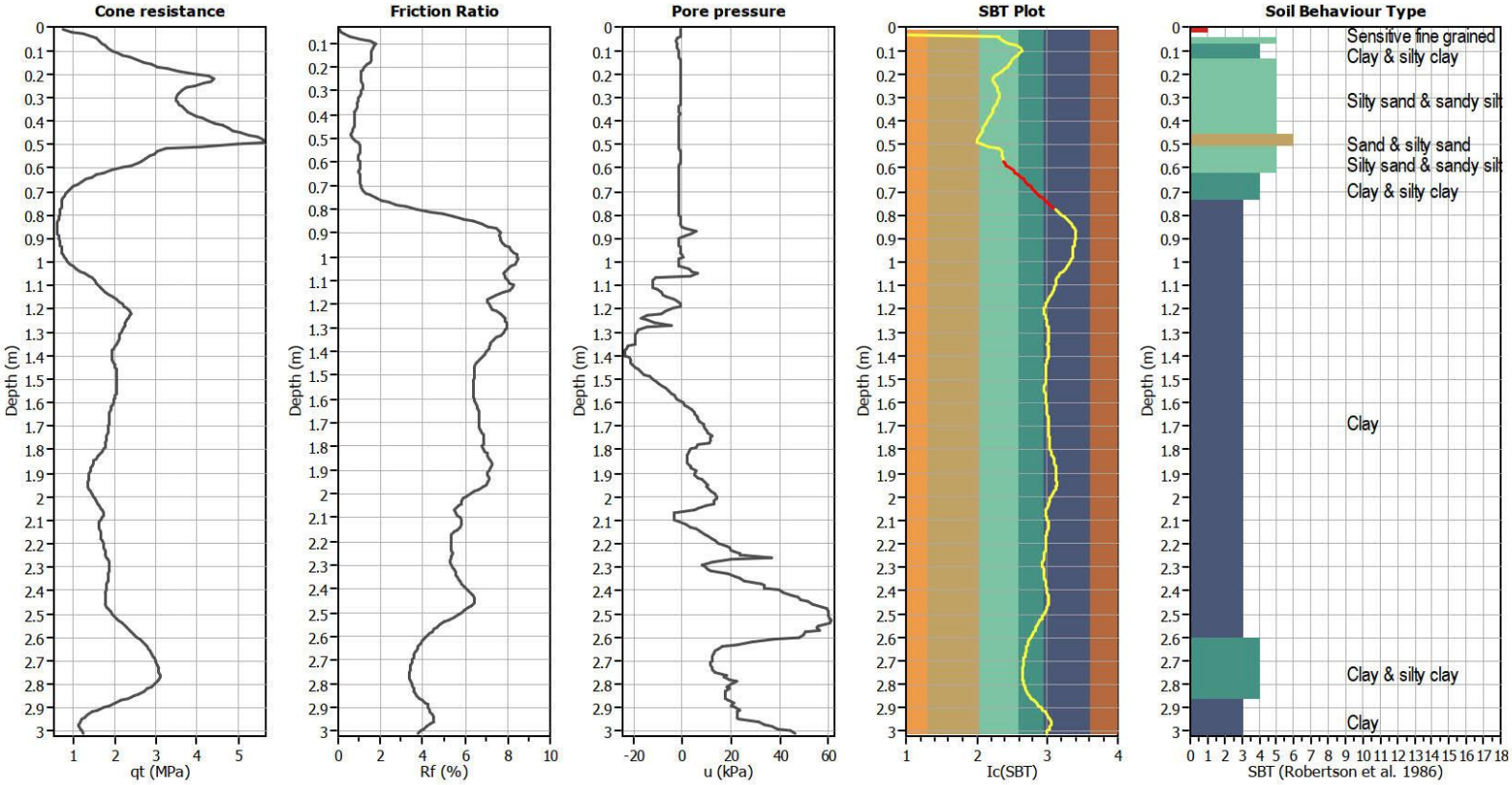
CPT name: CPT 4

CPT basic interpretation plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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

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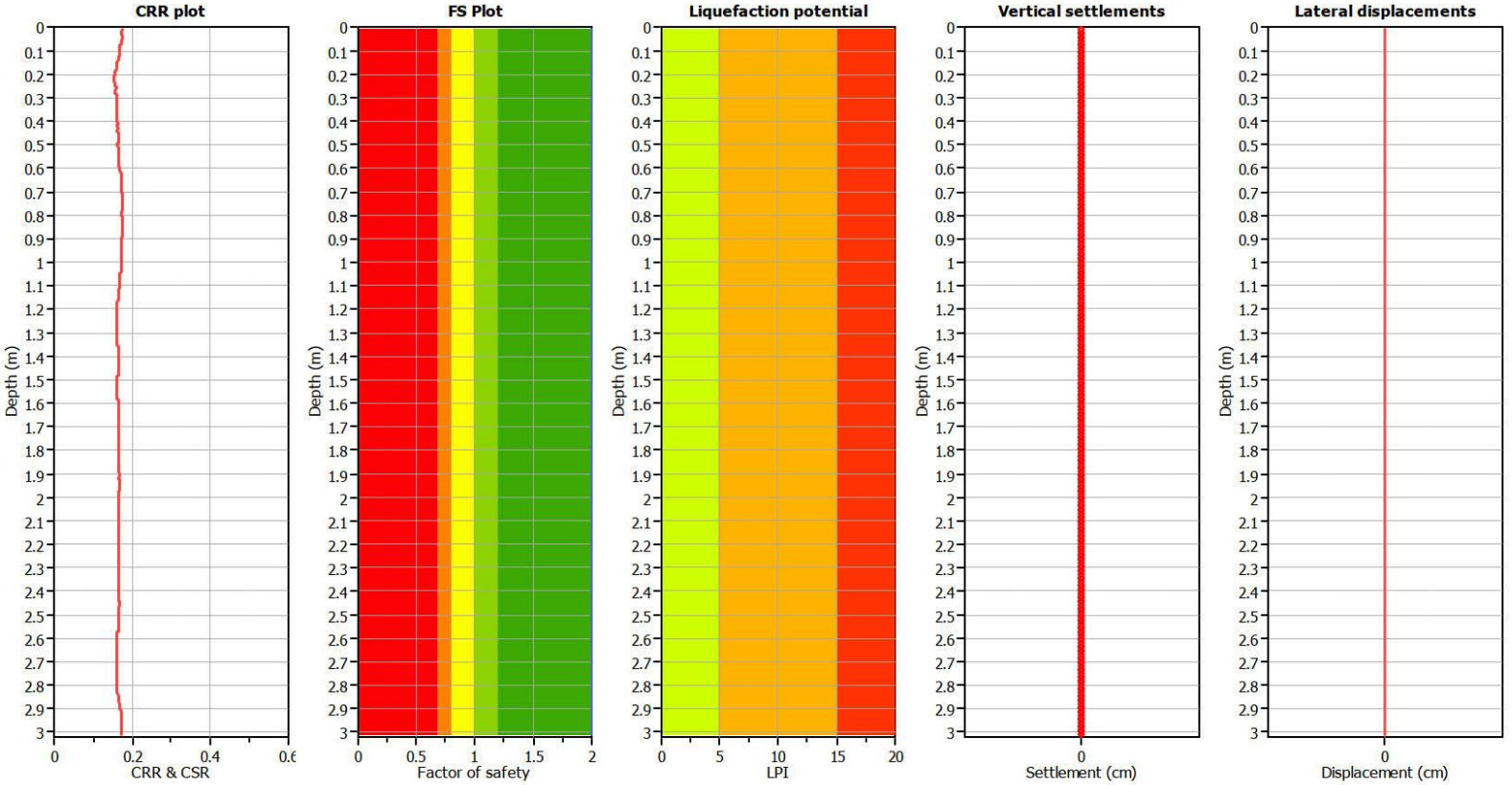
CPT name: CPT 4

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

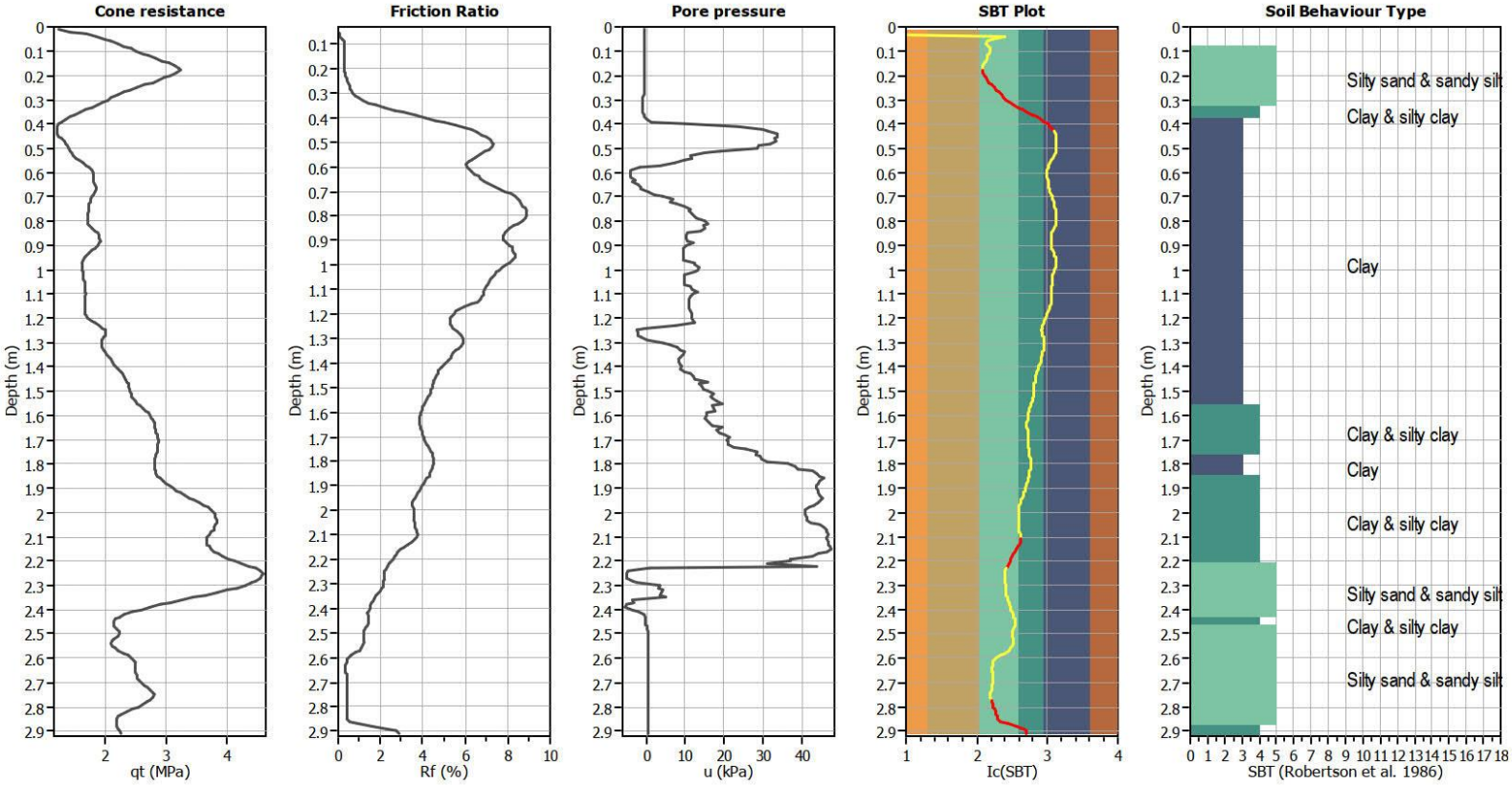
LPI color scheme

- Very high risk
- High risk
- Low risk

This software is licensed to: Titus Civil Consulting Engineers

CPT name: CPT 5

CPT basic interpretation plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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

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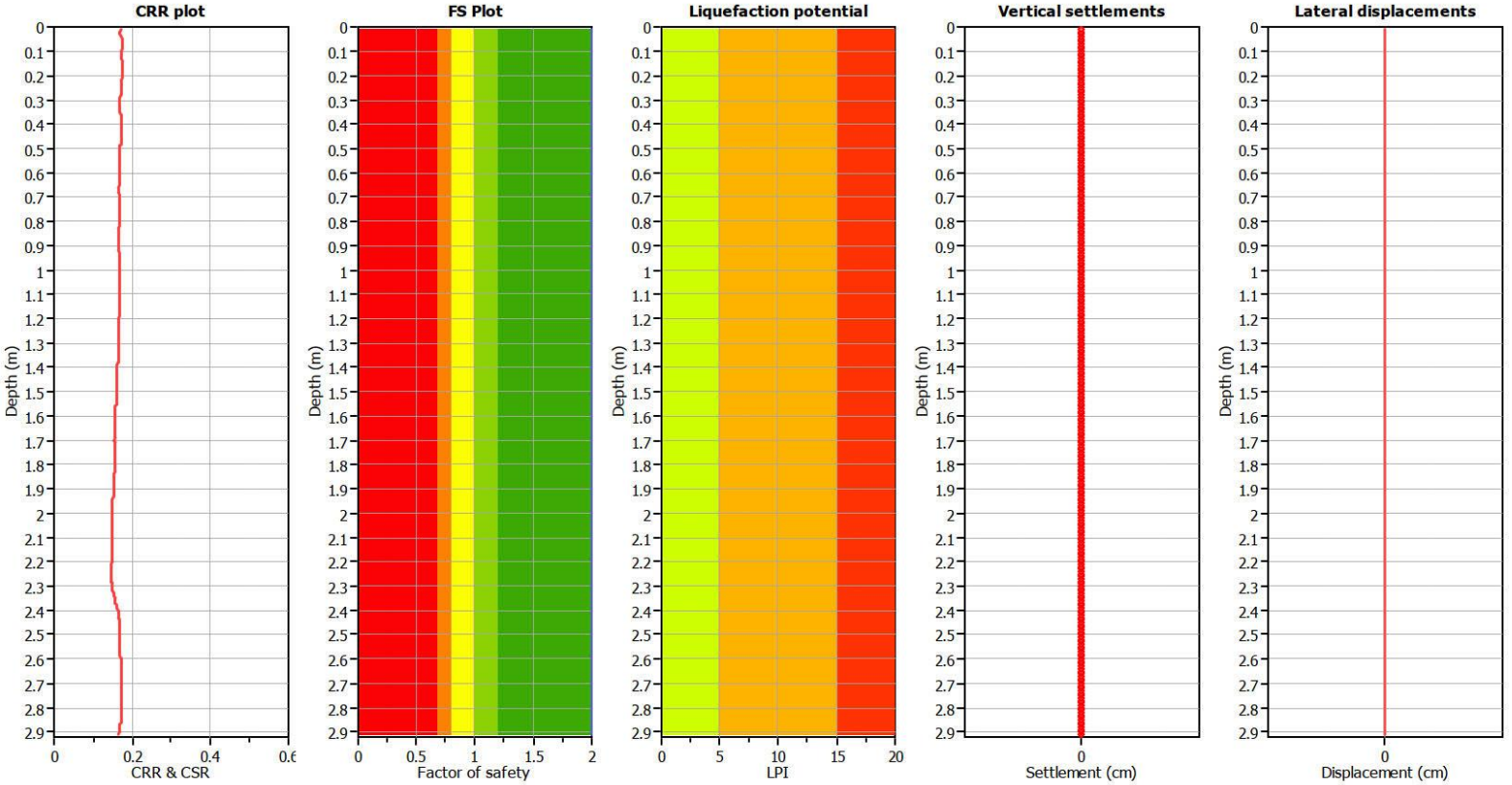
CPT name: CPT 5

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

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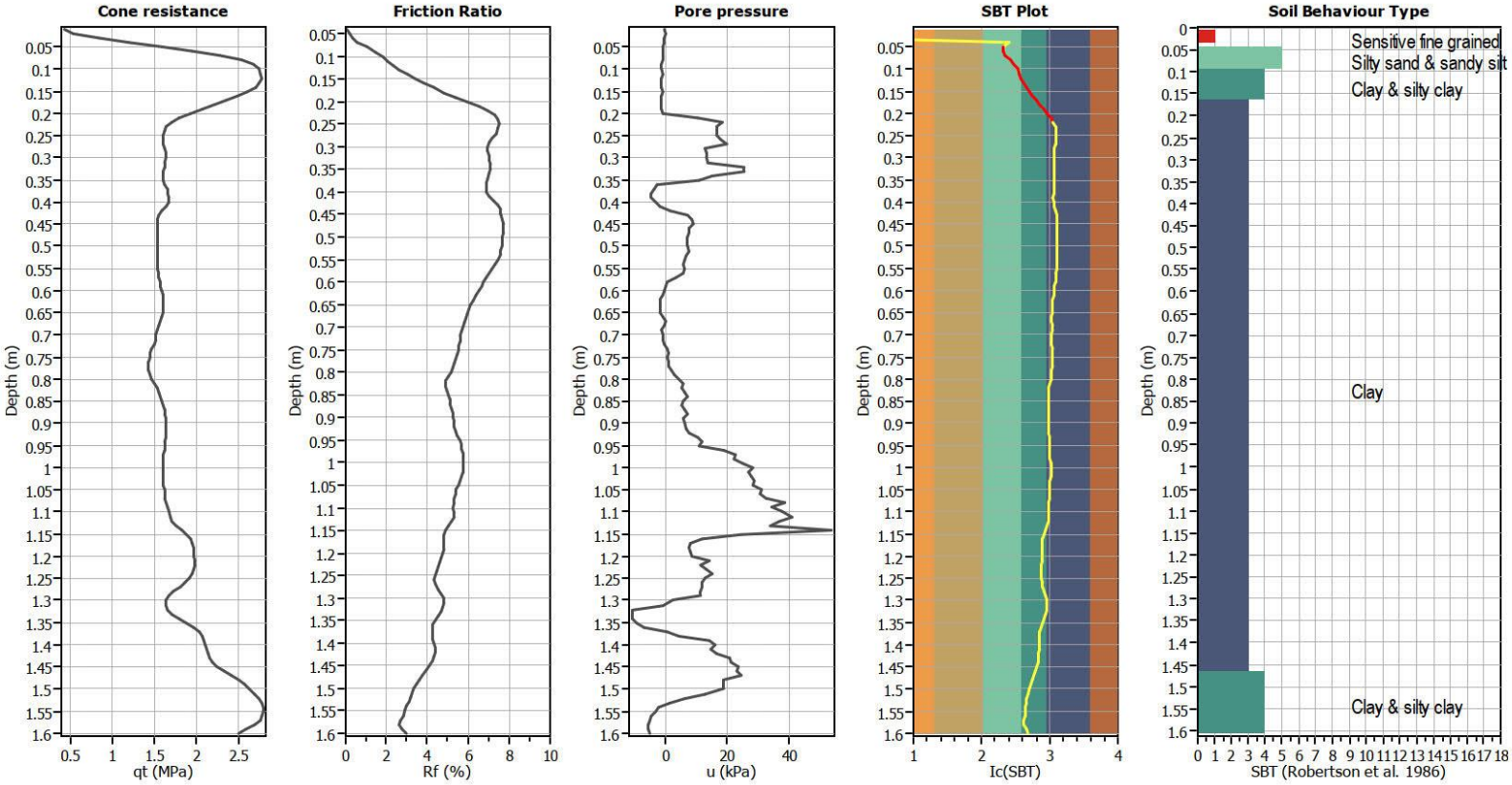
CPT name: CPT 6

CPT basic interpretation plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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

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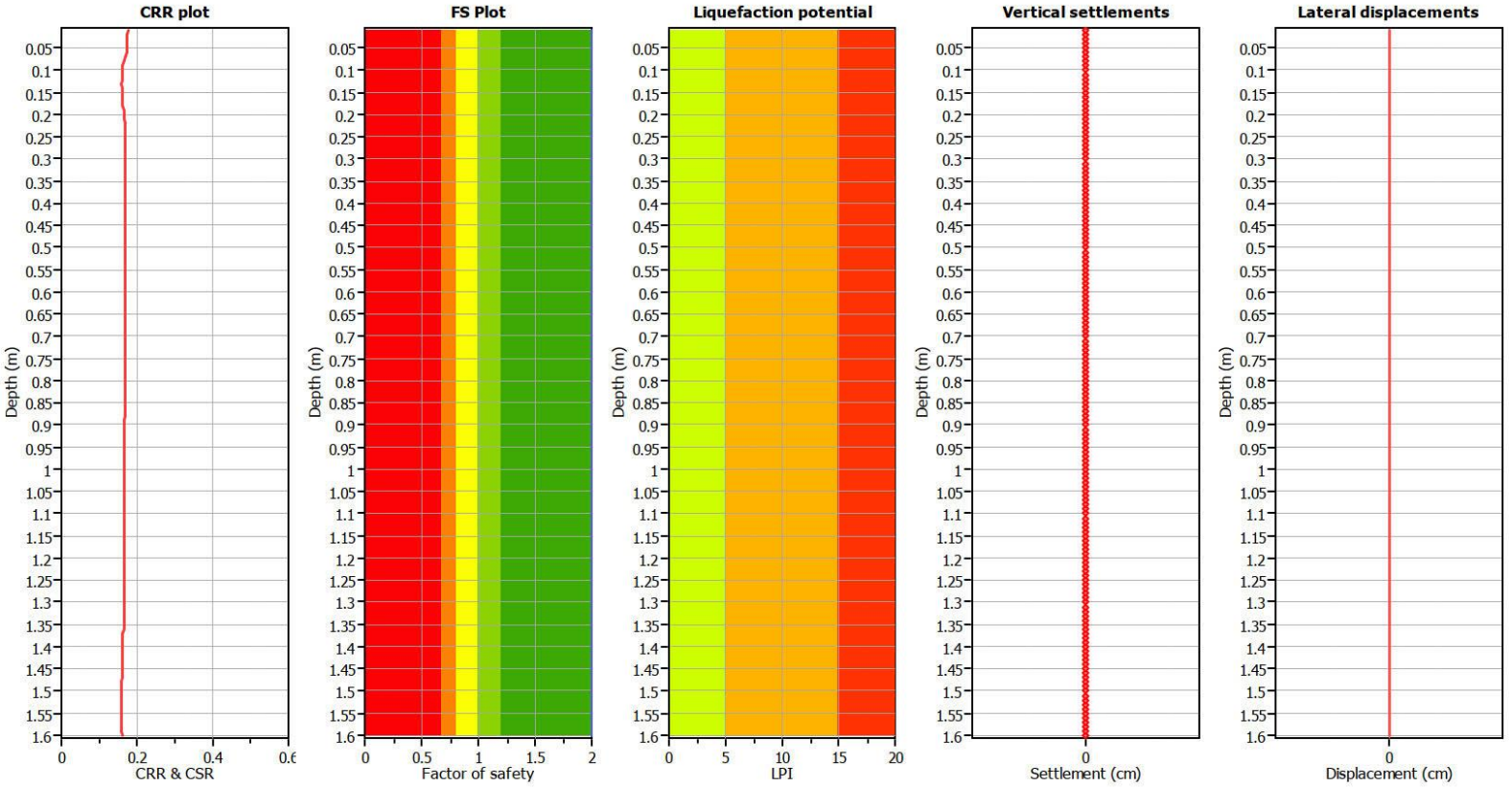
CPT name: CPT 6

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

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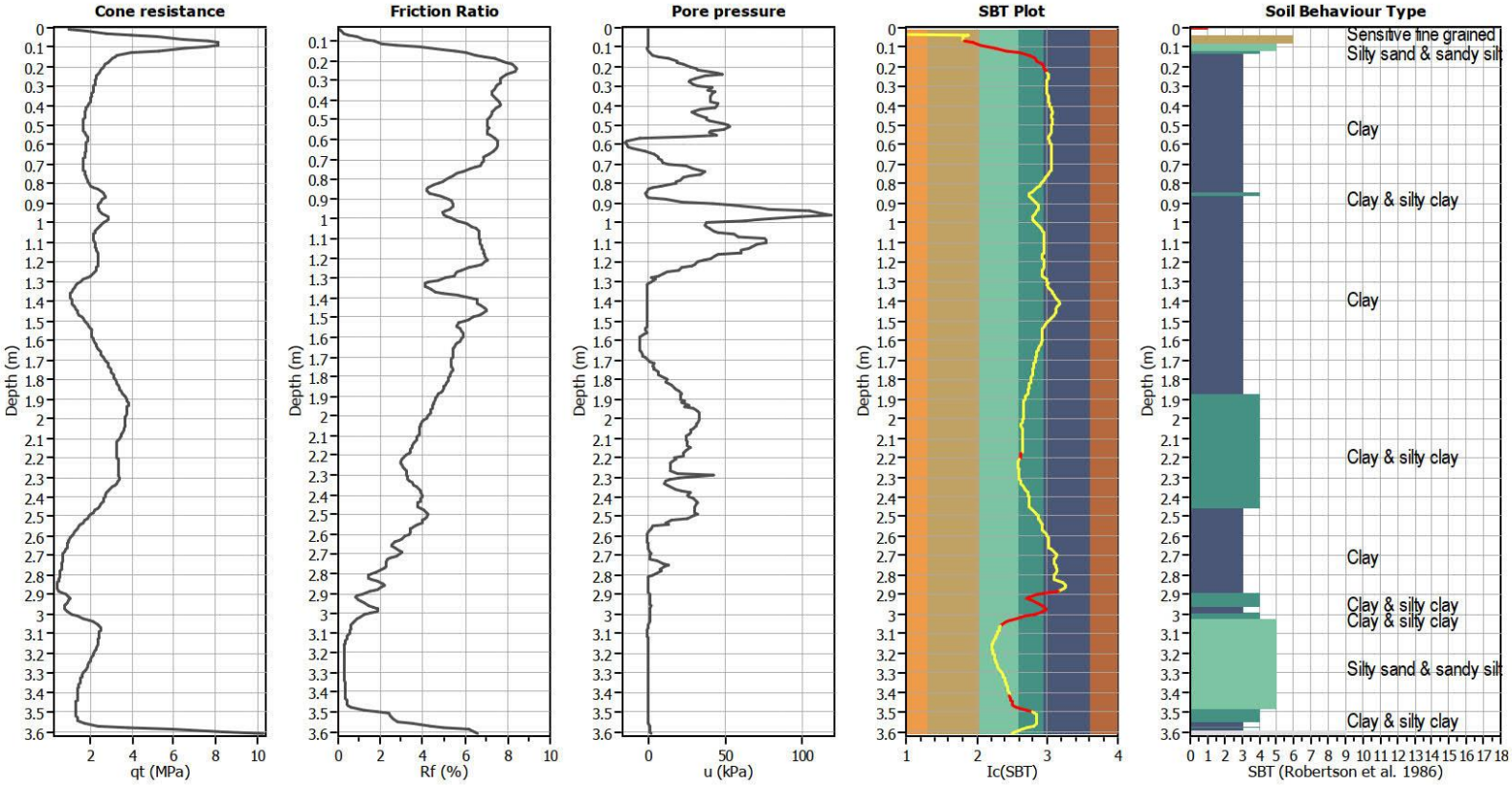
CPT name: CPT 7

CPT basic interpretation plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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

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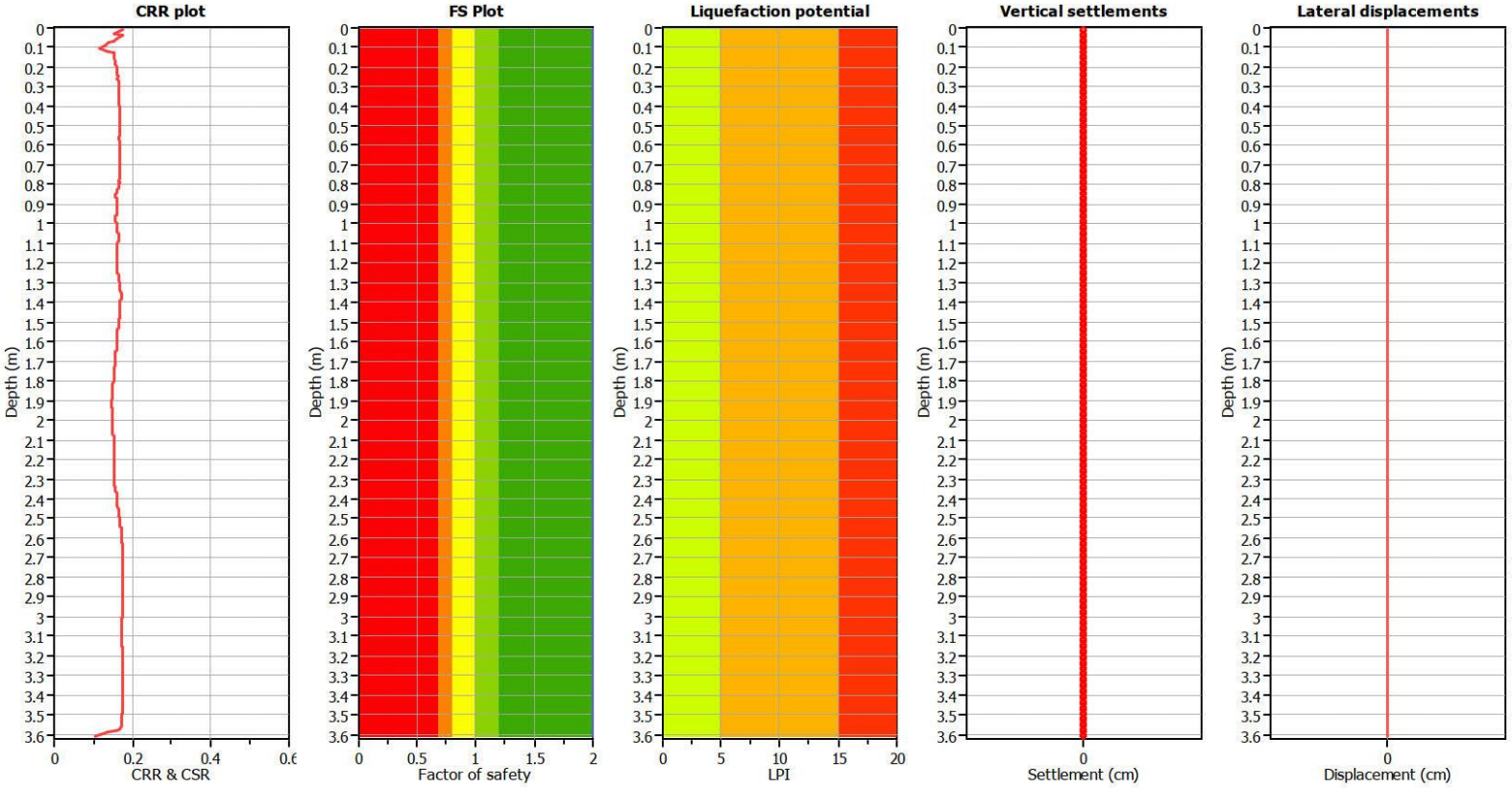
CPT name: CPT 7

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

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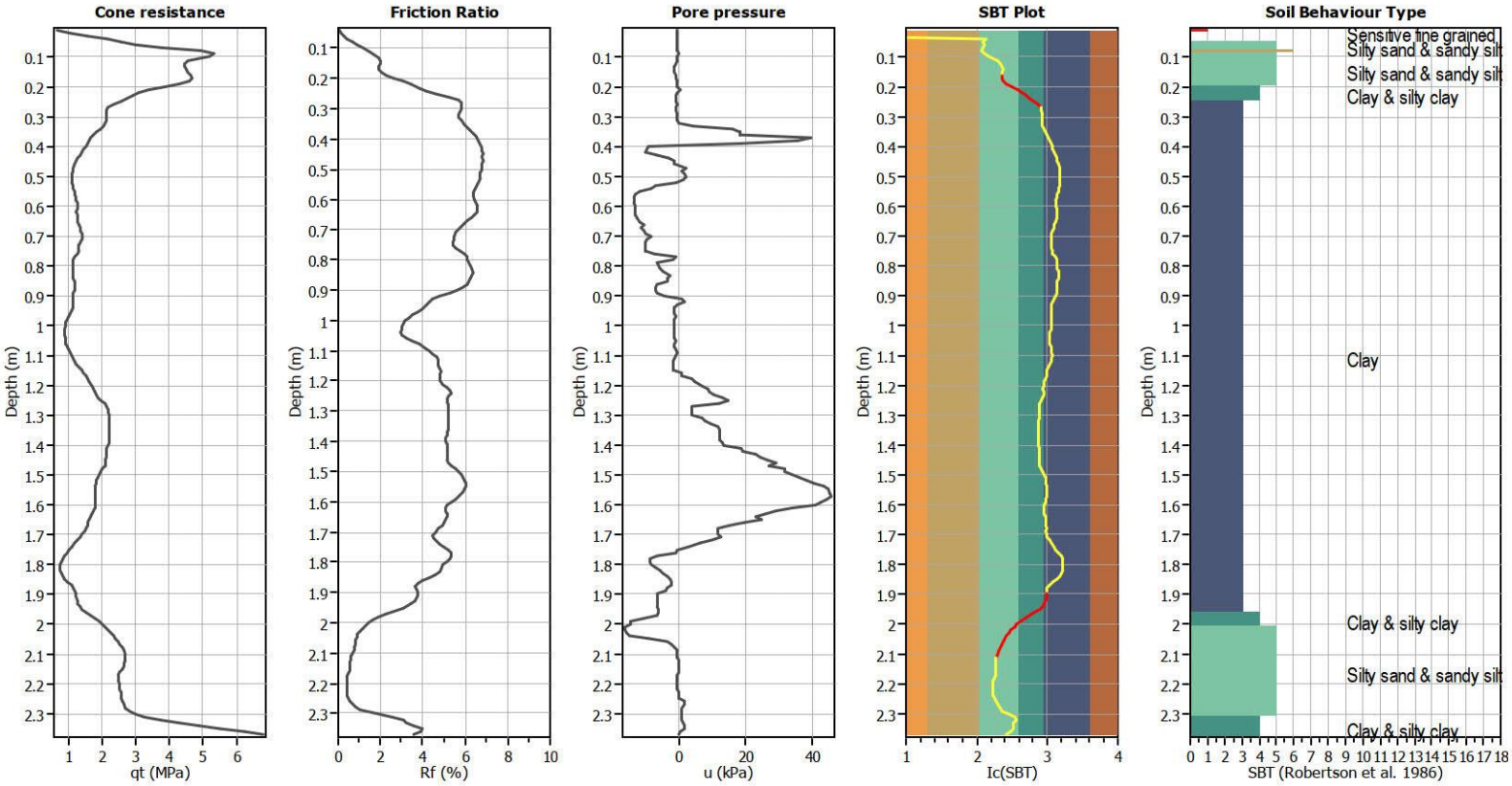
CPT name: CPT 8

CPT basic interpretation plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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

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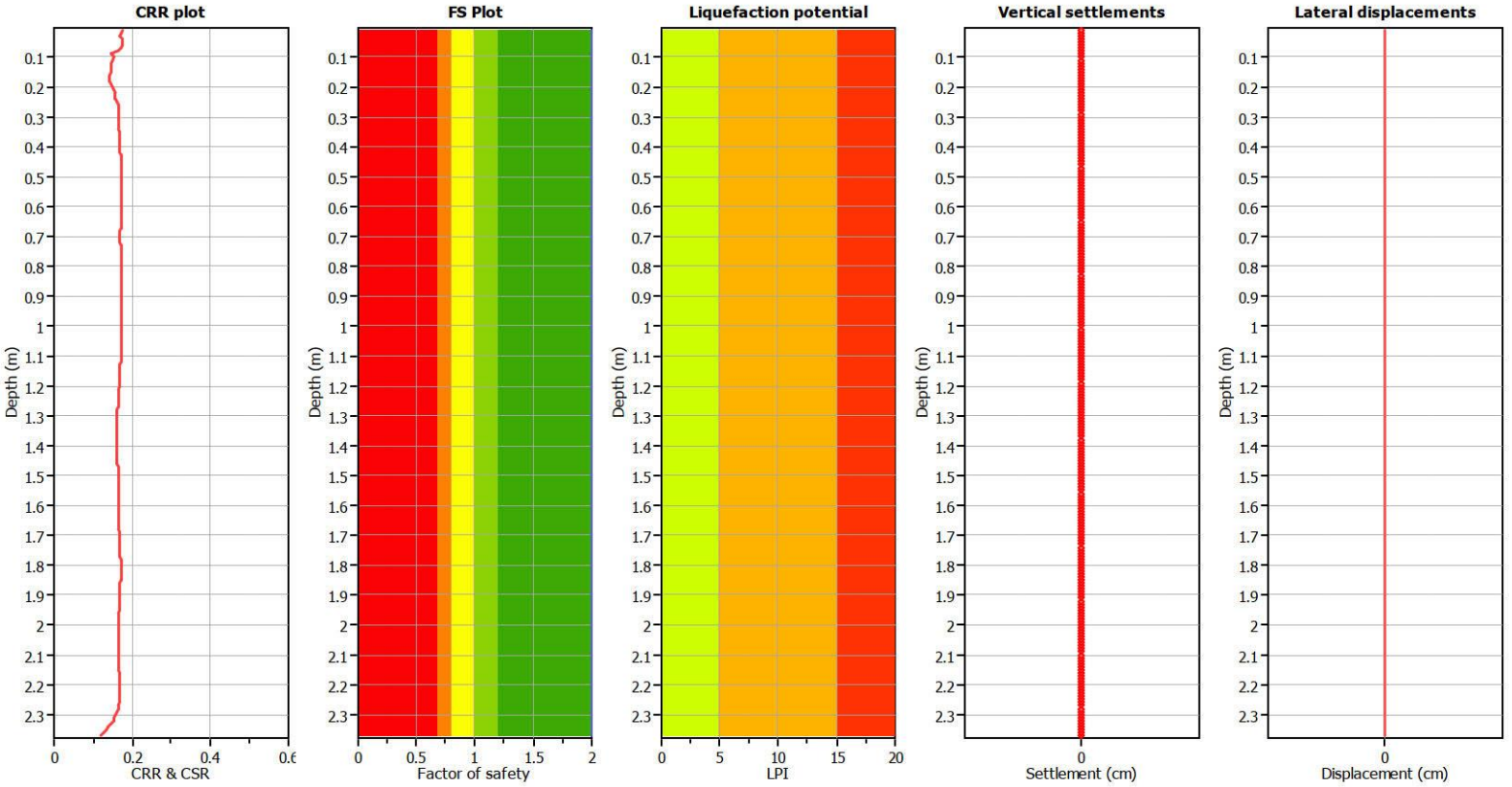
CPT name: CPT 8

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

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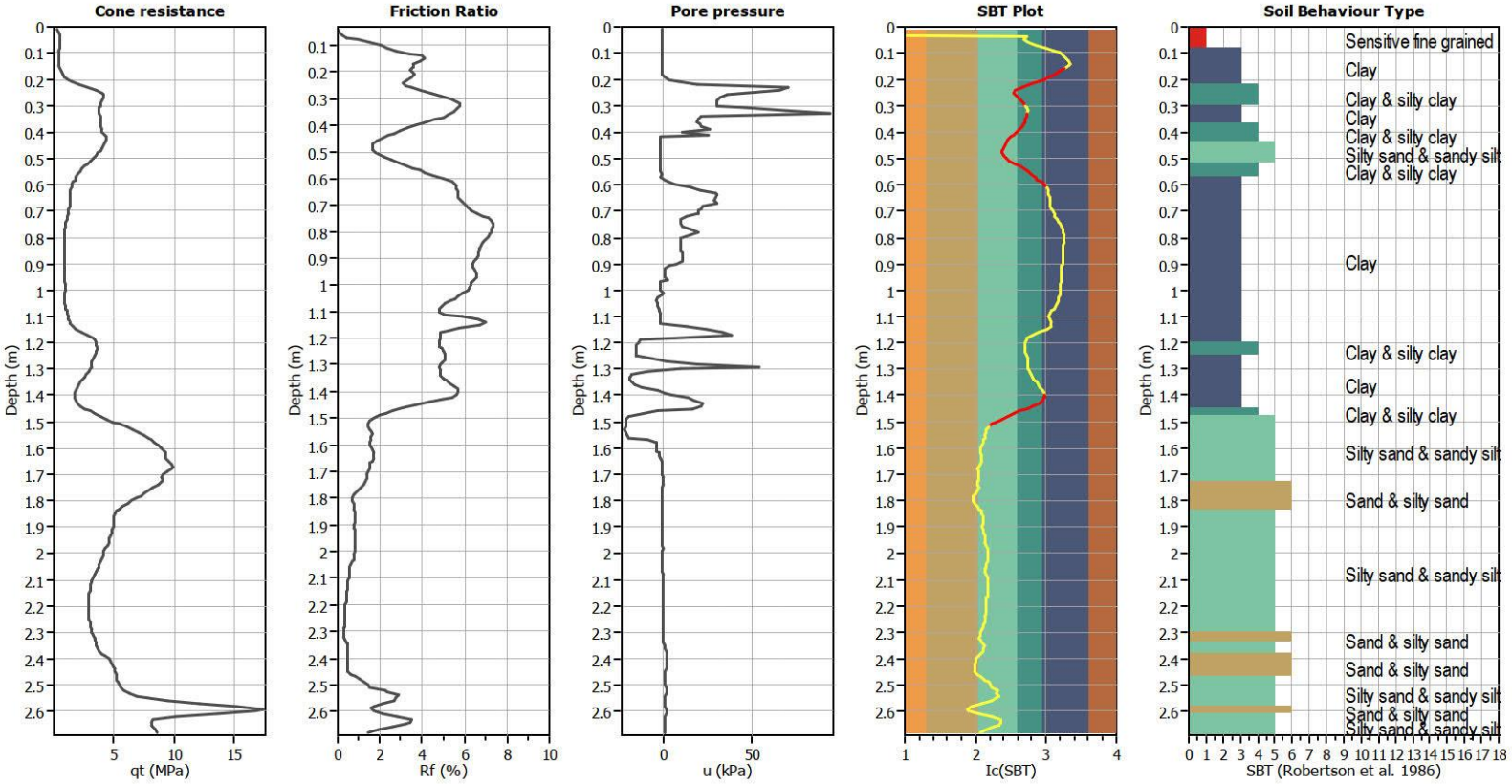
CPT name: CPT 9

CPT basic interpretation plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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

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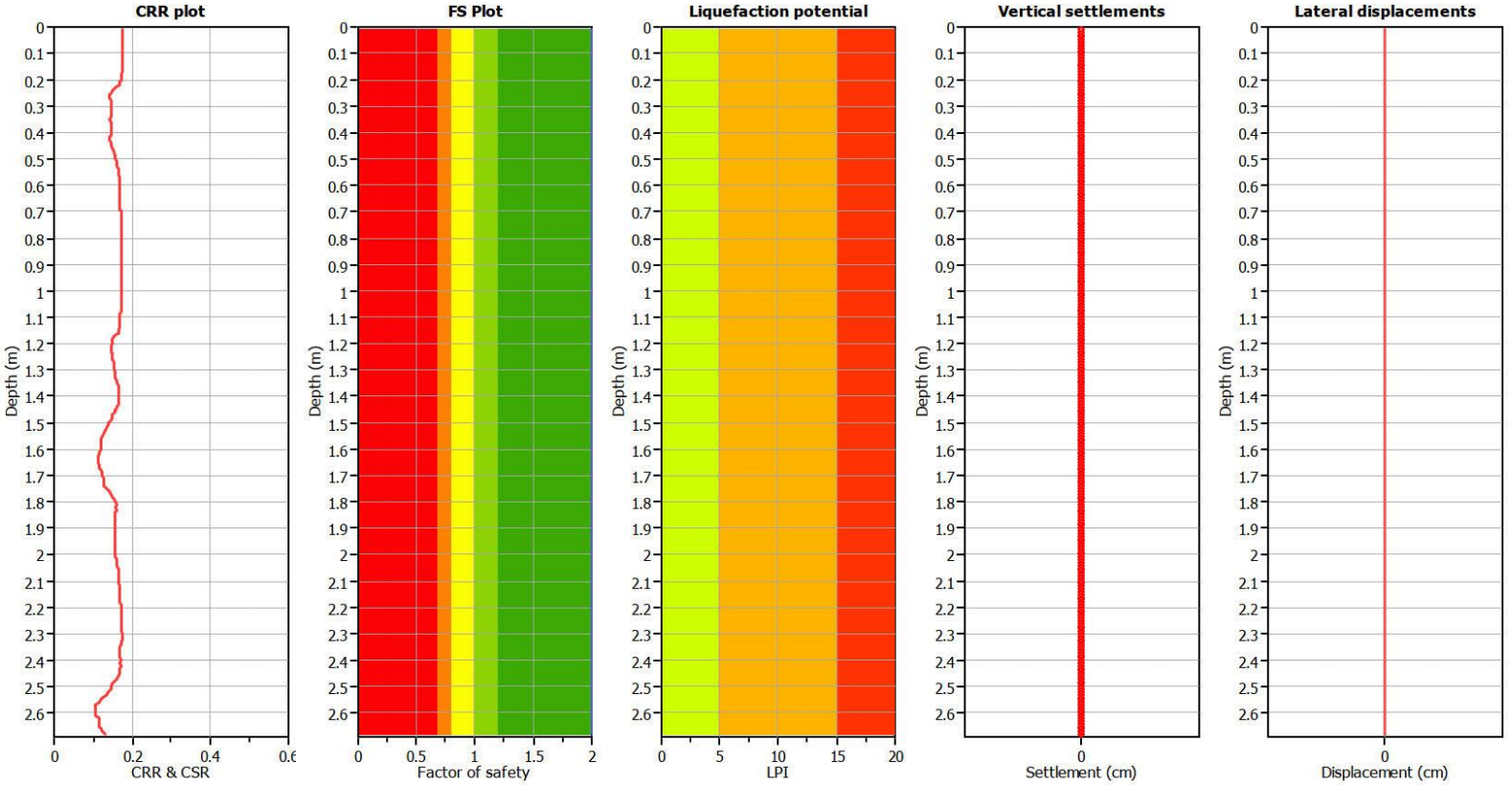
CPT name: CPT 9

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

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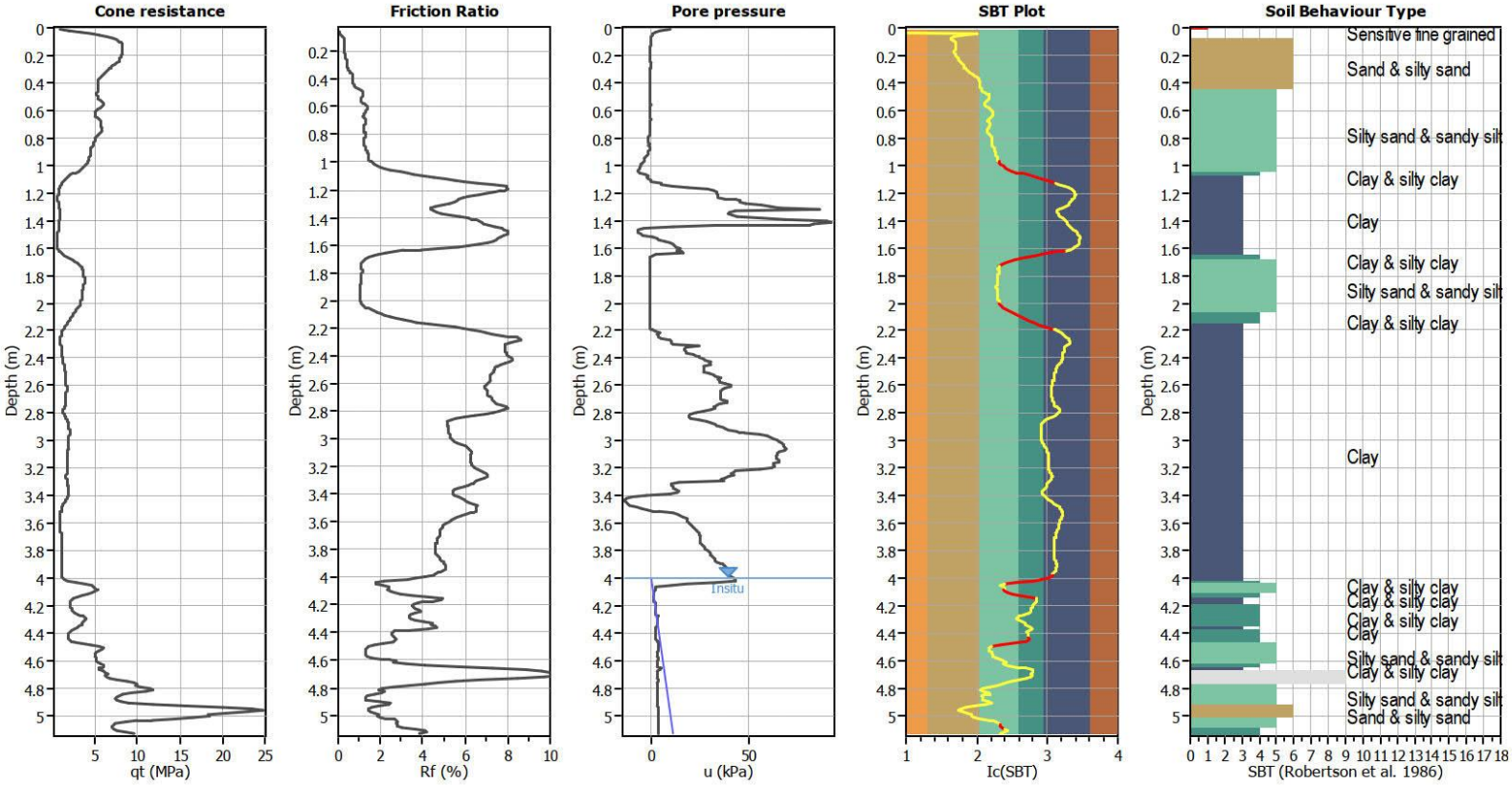
CPT name: CPT 10

CPT basic interpretation plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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

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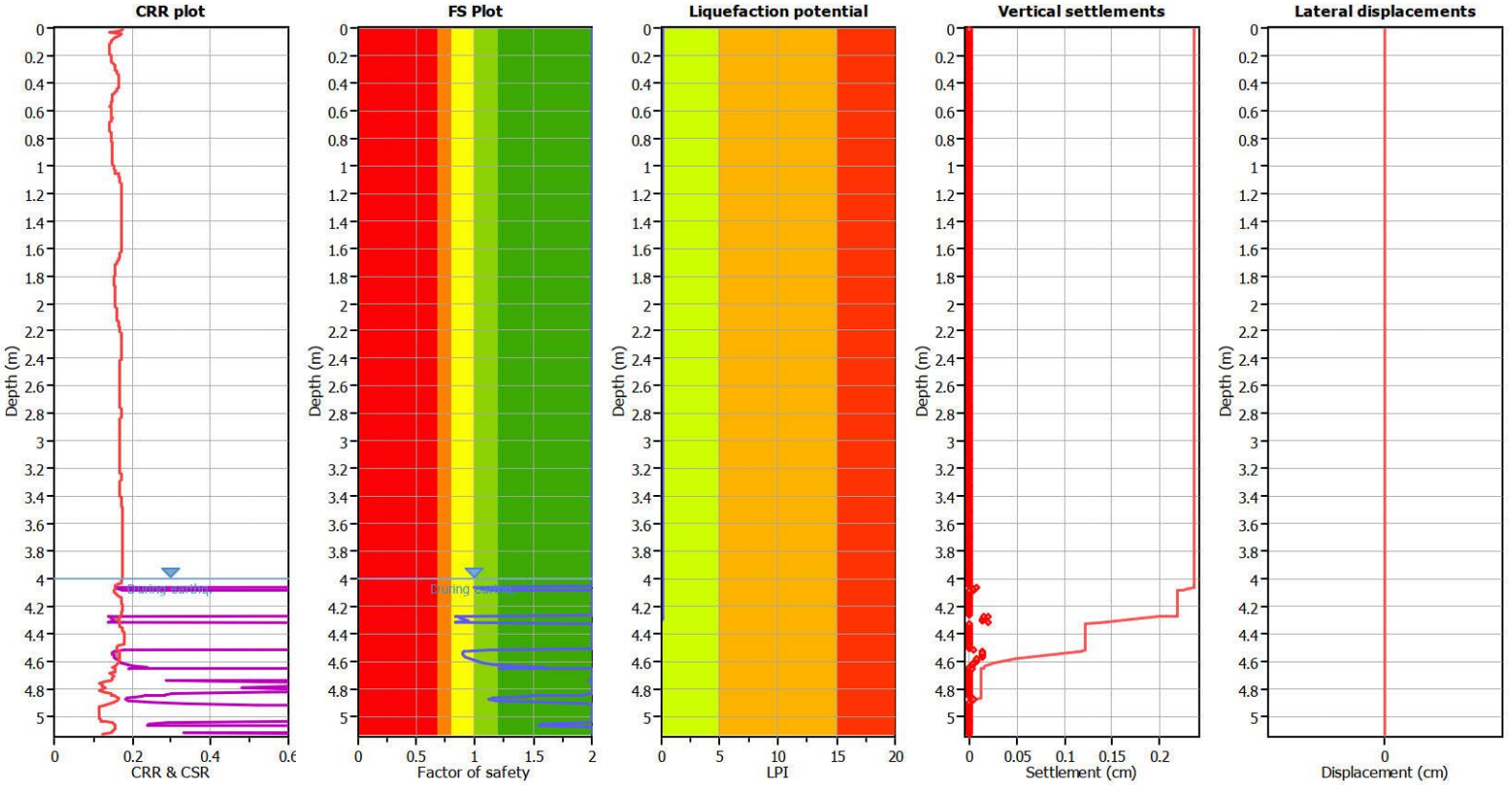
CPT name: CPT 10

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	4.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	6.00	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.32	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	4.00 m	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

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- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk