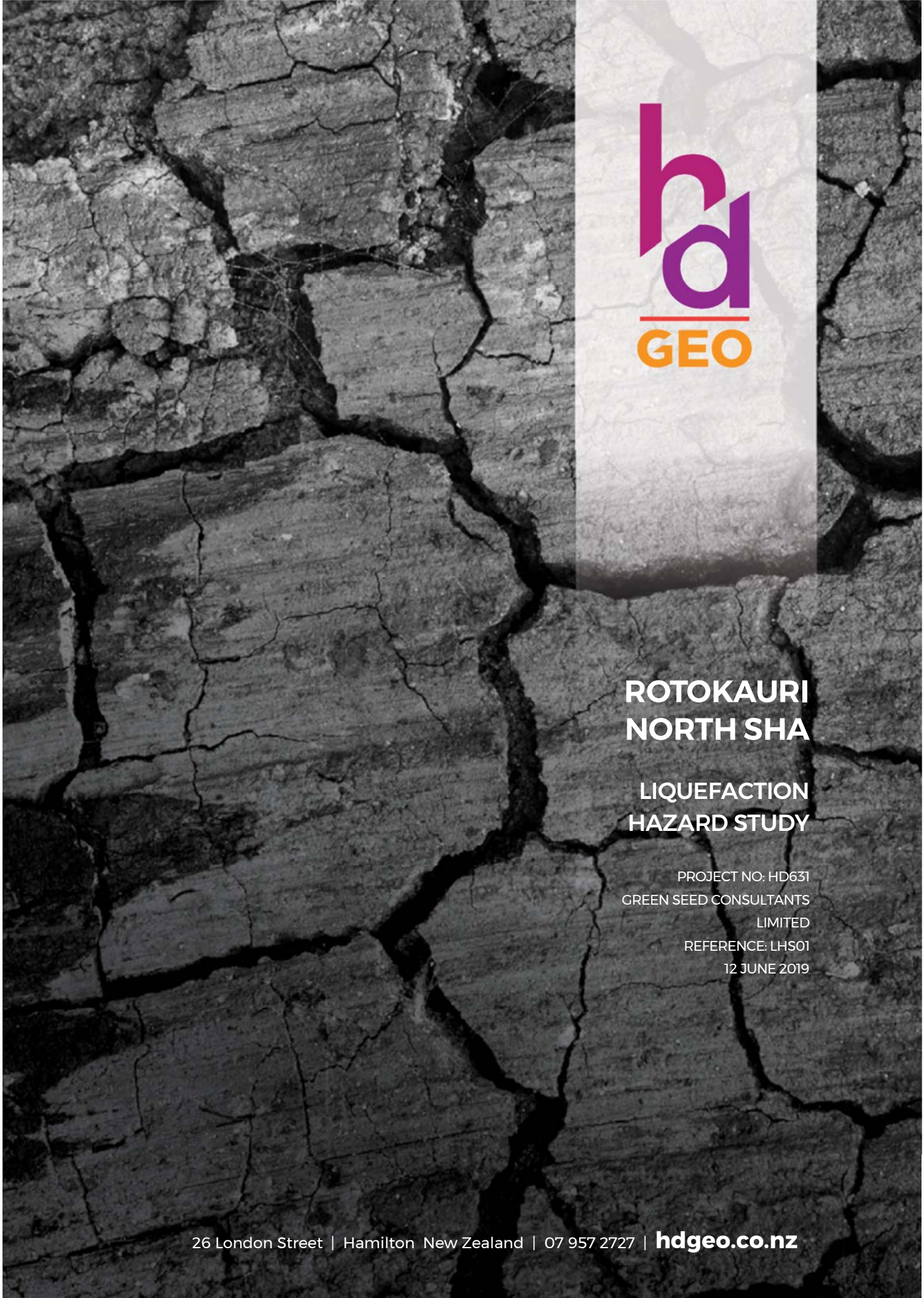

ROTOKAURI NORTH SHA

LIQUEFACTION HAZARD STUDY

PROJECT NO: HD631
GREEN SEED CONSULTANTS LIMITED
REFERENCE: LHS01
12 JUNE 2019

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Executive Summary

Green Seed Consultants Limited propose to develop the site known as the Rotokauri North Special Housing Area (SHA) into a mixture of standard and medium density residential housing, a commercial neighbourhood centre, public parks and potentially a school.

In July 2018, as part of our initial investigation of the site[1], we identified that there was a significant liquefaction hazard across the low-lying areas of the site. Since then, we have been engaged to further define the area-wide liquefaction hazard to inform the more detailed design stages.

It is intended that this assessment is used to guide the more detailed liquefaction assessments for each stage of the development.

Our scope included

- additional testing and investigation (6 seismic cone penetration tests (sCPTs) and 5 trenches
- revised analysis of the existing CPT data
- revised assessment of the area-wide liquefaction hazard
- recommendations for future assessments and design

What we found

- CPT testing is recommended as the most useful tool for estimating liquefaction susceptibility at this site
- An aging factor of 1.3 is recommended for future liquefaction assessments
- A fines correction may be warranted for future liquefaction assessments
- A site performance level of L2 (Moderate) to L3 (High) is estimated for the site, which indicates the site has a medium liquefaction vulnerability
- There is potential for lateral spreading adjacent to proposed stormwater swales

Further work

- A site specific assessment should be undertaken at suitability stage to further define the liquefaction hazard and to establish specific mitigation measures where these are required
- Further assessment should include the liquefaction induced lateral spreading risk adjacent to proposed stormwater swales

[1] HD Geo Limited. *Rotokauri North SHA Preliminary Geotechnical Report*. Project No: HD631, Ref: PGR, dated 27 July 2018.

Contents

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Introduction

Green Seed Consultants Limited propose to develop the site known as the Rotokauri North Special Housing Area (SHA) into a mixture of standard and medium density residential housing, a commercial neighbourhood centre, public parks and potentially a school.

In July 2018, as part of our initial investigation of the site[2], we identified that there was a significant liquefaction hazard across the low-lying areas of the site. Since then, we have been engaged to further define the area-wide liquefaction hazard to inform the more detailed design stages.

It is intended that this assessment is used to guide the more detailed liquefaction assessments for each stage of the development.

Liquefaction susceptibility

The susceptibility of a site to liquefaction is a combination of the expected earthquake shaking for the required design return period, the soil types and their strength/density state, and the groundwater conditions at the site. There are several measures of a sites overall susceptibility to liquefaction including liquefaction potential index (LPI), liquefaction severity number (LSN), ground surface settlement, and lateral spreading.

The liquefaction severity number (LSN) is an estimate of the anticipated expression of liquefaction at the surface and is useful for hazard screening purposes. LSN is grouped into ranges to provide guidance on the anticipated performance levels of a site in an earthquake. In general terms, increasing LSN represents increasing anticipated expression of liquefaction. A LSN of less than 10 presents insignificant anticipated expression and over 50, a severe anticipated expression.

Vertical ground settlement can occur during or immediately following an earthquake as a result of the dissipation of excess pore water pressure, loss of soil volume to sand ejecta, and consolidation of a liquefied soil. By the nature of these processes and the geological units in which liquefaction occurs, the magnitude of these settlements can vary significantly over short distances.

Lateral spreading is a phenomenon where the soil above a liquefied layer of silt or sand moves laterally towards a free face, such as a stream bank or drainage ditch.

This study aims to refine the assessment of the hazard at the site by comparing site observations to analysis results and modifying the assessment approach in line with current research.

Scope

The scope of investigation and assessment included:

- 6 seismic cone penetration tests (SCPTs) up to 20 m depth to measure the cone penetration and shear wave velocity through the soil profile and provide information for further analysis
- 5 trenches, 1 m deep and up to 10 m long to look for soil features indicative of paleoliquefaction[3]

[2] HD Geo Limited. *Rotokauri North SHA Preliminary Geotechnical Report*. Project No: HD631, Ref: PGR, dated 27 July 2018.

[3] Paleoliquefaction is any historic liquefaction features attributed to seismic events that occurred before measurements or written records were kept of earthquakes.

- revised analysis of the previously conducted cone penetration tests (CPT01 to CPT08) taking into consideration recent research publications, the latest groundwater levels, shear wave velocity results, and soil aging factors, and observed paleoliquefaction features at the site
- revised assessment of the area-wide liquefaction hazard
- recommendations for future assessments and design

Site description

The site is located at the north west extent of Hamilton City and consists of a total area of approximately 133 ha. It is bounded by the Te Kowhai Road (SH39) to the north, greenfields to the east and south and Exelby Road to the west. Burbush Road runs north to south through the eastern portion of the site. A plan showing the extent of the site, proposed development and staging is included in Appendix A.

The site lies in an area that consists of rolling hill terrain and flat-lying plains. The hill terrain (herein referred to as 'Hill Terrain') is all ground that is elevated above the flat, low-lying plains of the site (herein referred to as 'Plains'). A plan showing the site geomorphology is included in Appendix A.

The Hill Terrain is present at the western and eastern edges of the site, rising up to 18 m above the Plains. These hill areas merge south of the site, forming a south to north draining basin in which most of the site lies.

The Plains terrain makes up the majority of the west and central portions of site, while also surrounding the eastern Hill Terrain to the west, north and east. The Plains are flat with typically less than 1 m of elevation difference across the site. Numerous open drains dissect the Plains ranging from less than 0.5 m in depth and width up to 2 m width and depth. A Waikato River paleochannel, known as the Te Kowhai Channel[4] lies in the north-eastern corner of the site. The base of the paleochannel lies approximately 1.5 m below the surrounding area. Parts of the Plains are expected to be inundated by a 1 in 100 year flood event (Refer to Rotokauri ICMP Plan[5])

The site is predominantly used as pasture for grazing cattle with a dairy farm and associated buildings in the northeast of the site. There are eight rural residential dwellings and a number of sheds and barns across the remainder of the site.

Geological setting

The site is located roughly centrally within the Hamilton Basin, at the north eastern extent of Hamilton City in an area which is characterised by low rolling hills (Hamilton Hills) and plains with low terraces and gullies draining into the Waipa and Waikato Rivers (Hamilton Lowlands).

The Hamilton Hills are linear, sinuous and discontinuous hills and ridges that are a remnant of an older erosion surface. They consist of alluvial material and non-welded ignimbrites (Walton Subgroup) and are typically overlain by several metres of airfall volcanic ash (Kauroa Ash Formation and Hamilton Ash Formation). The Hamilton Lowlands are a broad, low angle alluvial fan created by the Waikato River in the Late Quaternary. The fan materials (Piako Subgroup and Hinuera Formation) are derived from rhyolitic eruptions in the central North Island and generally consist of late Pleistocene primary and secondary volcaniclastic sediments. Deposition of the fan materials stopped when the Waikato River

[4] McCraw, J., 2011. The wandering river – landforms and geological history of the Hamilton Basin. Levin, New Zealand. Geoscience Society of New Zealand.

[5] Hartland Environment Limited, June 2017. *Rotokauri – Integrated Catchment Management Plan.*

entrenched into its current course approximately 17 ka and thin airfall tephra layers accumulated on the fan surface (Hinuera Surface).

The Hill Terrain at the site is consistent with Hamilton Hills geomorphology and is mapped[6] as Walton Subgroup, a sequence of Early Pleistocene to Middle Pleistocene river and igneous river deposits dominated by primary and secondary volcaniclastic sediments.

The Plains at the site are consistent with the Hamilton Lowlands and are primarily mapped[5] as Hinuera Formation, which is described as Late Pleistocene river deposits consisting of cross-bedded pumice sand, silt and gravel with interbedded peat. A small area in the southern and south-eastern portion of the site is also mapped[5] as Piako Subgroup, which is described as Late Pleistocene river deposits consisting of locally derived mud, silt, gravel and peat.

Previous investigations and reports

In June 2018, we undertook a preliminary geotechnical investigation and assessment[7] of the site to support plan change, master planning and conceptual design for the development.

The investigation included:

- 13 hand augers up to 3 m depth
- 8 cone penetrometer tests (CPTs) up to 20 m depth
- 3 dissipation tests
- 5 temporary standpipe piezometers up to 3m depth

The key outcomes of the assessment from that study are summarised in Table 1 below.

Table 1: Summary of previous geotechnical assessment by terrain type

	Hills Terrain	Plains Terrain
Liquefaction hazard	non-liquefiable	Moderate to high liquefaction hazard
Site performance level	Level 0 (insignificant)	Level L3 (High) to Level L4 (Severe)
Lateral spreading	Not applicable since soils are non-liquefiable	Should be considered if open drains remain / stormwater swales are constructed for new development
Soft soils and static settlement	Not applicable since majority of Hill terrain is in cut	Generally low susceptibility, but static settlement should be considered if significant fill is placed above paleochannel features and close to Hill Terrain 'embayments'

[6] Edbrooke, S. W. (Compiler), 2005. Geology of the Waikato Area. Institute of Geological and Nuclear Sciences 1:250 000 geological map 4. 1 sheet + 68p. Lower Hutt, New Zealand. Institute of Geological Sciences Limited.

[7] HD Geo Limited. Rotokauri North SHA Preliminary Geotechnical Report. Project No: HD631, Ref: PGR, dated 27 July 2018.

	Hills Terrain	Plains Terrain
Earthworks	Cut materials (ie clay) may require conditioning (ie wetting/drying); materials in deep areas of cut are likely to be highly sensitive to disturbance and challenging to compact	No significant cut is proposed; earthworks are anticipated to primarily consist of fill sourced from the Hill Terrain or from swale excavations
Stability	No indications of significant instability observed; stability of any cut slopes will need to be considered at earthworks stage	Lateral spreading should be considered if stormwater swales are constructed
Pavements	Materials in deep areas of cut are likely to be highly sensitive to disturbance, natural subgrade CBR is likely to be low	High groundwater, loose or low strength materials, natural subgrade CBR is likely to be low

This report provides a revised assessment of the liquefaction hazard, site performance level, and lateral spreading; our assessment of the other items remains unchanged. Test locations are shown on the 'Geotechnical Investigation Locations' plan in Appendix A of this report. Refer to our previous report for investigation logs and further details further details regarding the above assessment.

This investigation

In order to further understand the liquefaction hazard at the site, the following additional testing has been undertaken:

- installation of 5 permanent piezometers to monitor groundwater levels (August 2018)
- 6 shear wave velocity tests by seismic cone CPTs up to 20 m depth (October 2018)
- 5 trenches, 1 m deep and up to 10 m long to look for soil features indicative of paleoliquefaction (January 2019)

Test locations are shown on the 'Geotechnical Investigation Locations' plan in Appendix A of this report. Investigation data is included in Appendix B of this report.

Ground conditions

The ground conditions at the site were typically consistent with the mapped geology. Table 2 below summarises the ground conditions encountered during the most recent and previous investigations within the Hill and Plains terrain of the site.

Table 2: Summary of typical ground conditions

Geomorphology / Description	Depth below ground level (m)	Typical CPT q_c (MPa)	Soil Description[8]
Topsoil	0.0 to 0.3		Organic Silt
Hills terrain All ground that is elevated above the flat, low-lying plains of the site	0.3 to 3.0	0.5 to 3	Stiff to very stiff clay and silty clay
	3.0 to 13.0	0.2 to 2	Stiff to very stiff clay and silty clay
	13.0 to 20.0	1 to 9	Medium dense silty sand and sandy silt
Plains terrain Areas of the site that are flat and low-lying	0.3 to 0.9	0.1 to 10	Firm to very stiff clay and silty clay
	0.9 to 16.5	0.5 to 15	Medium dense sand and silty sand and firm to very stiff clays and silty clays
	16.5 to 19.0	10 to 35	Dense sand and silty sand and very stiff to hard clays and silty clays
	19.0 to 20.0	1 to 4	Medium dense sand and silty sand and firm to very stiff clays and silty clays

Groundwater

Groundwater is currently being continuously monitored by five piezometers across the site, installed in August 2018 (refer to the 'Geotechnical Investigation Locations' plan in Appendix A for piezometer locations). Plots of the groundwater level over time for each piezometer are included in Appendix C. A summary of the groundwater levels of each piezometer is provided in Table 3 below.

Table 3: Summary of groundwater levels with each piezometer

Piezometer	Location	Starting groundwater level (2/08/18)	Highest groundwater level	Lowest groundwater level	Latest depth reading (22/05/19)
P1	north-western portion of site	0.60 m	0.17 m (3/09/18)	2.3 m (22/05/19)	2.3 m
P2	south-western portion of site	0.22 m	<0.01 m (29/08/18 & 4/12/18)	1.5 m (22/05/19)	1.5 m
P3	approximate centre of site	0.55 m	0.03 m (22/08/18)	1.8 m (12/04/19)	1.7 m
P4	north-eastern portion of site	0.42 m	0.37 m (3/09/18)	2.2 m (22/05/19)	2.2 m
P5	south-eastern portion of site	0.61 m	0.28 m (30/08/18)	1.9 m (22/05/19)	1.9 m

These levels reflect the groundwater levels during the monitoring period (August 2018 to May 2019). For the majority of the year (with the exception of a dry spell over the past 4 months), groundwater was observed to be within 0 to 1 m below the ground surface. For analysis purposes, a uniform groundwater depth of 0.5 m has been assumed for all test locations. This is considered moderately conservative and,

[8] Soil description based on material recovered in hand auger investigations or inferred from CPT data.

when the site is developed, the groundwater is likely to trend lower as infiltration is limited and storage/recharge is isolated to stormwater management areas (such as swales). Given the site is very flat and lies a considerable distance from any significant drainage networks, the depth of the water table is likely to have been relatively stable over the last 17,000 years.

Detailed area-wide liquefaction assessment

This assessment contains a detailed discussion of the liquefaction hazard for the development area. It is intended to guide development at the site and provide the basis for future assessments as the design of the site progresses.

We have undertaken a liquefaction hazard assessment of the site using data from the CPTs in accordance with the latest guidelines from the Ministry of Business Innovation and Employment (MBIE) and New Zealand Geotechnical Society (NZGS)[9]. The level of our testing and assessment would qualify as a level C, area-wide assessment in accordance with the 2017 EQC and MBIE planning guidelines[10]. The liquefaction potential of the site soils was assessed using the proprietary software CLiq[11] and LiqSVs[12], using the results of the CPTs and shear wave velocity tests, respectively.

In addition to the above, for this detailed liquefaction assessment we have:

- Reviewed recently published relevant literature relating to assessment of liquefaction hazard in Waikato soils
- Assessed the local seismic hazard using the unweighted hazard model from the NZTA Bridge manual and published information on nearby faults
- Analysed and compared the shear wave velocity liquefaction results to CPT liquefaction results
- Identified where both methods outline a high liquefaction hazard at the site in order to zone the site and identify high risk areas for trenching
- Performed trenching to look for paleoliquefaction features in areas identified as highly susceptible to liquefaction
- revised our analysis of the previously conducted cone penetration tests (CPT01 to CPT08) taking into consideration the latest groundwater levels, shear wave velocity results, and soil aging factors

Our assessment methodology and results are summarised in the sections that follow.

Literature review

Guidance documents

The Christchurch guidance documents were technical documents developed by the Ministry of Business, Innovation and Employment (MBIE) to provide guidance for repairing or rebuilding residential dwellings affected by liquefaction in the Canterbury earthquake sequence. The guidelines use estimates of vertical and lateral displacements of the upper 10 m of the soil profile to define three technical categories (TC1, TC2 and TC3) based on the expected future liquefaction performance. These

[9] Ministry of Business Innovation and Employment (MBIE)/New Zealand Geotechnical Society (NZGS). *Module 3: Identification, assessment and mitigation of liquefaction hazards.* Dated May 2016.

[10] Earthquake Commission (EQC)/Ministry of Business Innovation and Employment (MBIE). *Planning and engineering guidance for potentially liquefaction prone land.* Dated September 2017.

[11] Geologismiki. CLiq v.2.2.0.37 – CPT Liquefaction Assessment Software.

[12] Geologismiki. LiqSVs 1.2.1.1 – SPT and Shear Wave Velocity Liquefaction Assessment Software.

documents have become widely referenced across New Zealand to categorise residential sites that predict a liquefaction hazard.

Liquefaction resistance and aging factors

Research on the Waikato Basin soils has recently been carried out to determine their resistance to liquefaction[13]. Wider liquefaction research indicates that penetration based methods (eg. CPTs) can overpredict the liquefaction triggering potential in some soils, and that correction for this is needed. Clayton & Johnson (2013)[14] researched the effect that aging has on the Waikato Basin soils, with wider research by Youd & Perkins (1978)[15] and Andrus, Hayati, & Mohanan (2009)[16] indicating that there is an increase in liquefaction resistance with age, mainly due to micro cementation and secondary consolidation of settlements.

Recurrence interval/seismicity

The local seismic hazard for the site assessment is estimated using the unweighted hazard model presented in the NZTA Bridge Manual. For the 500-year recurrence interval earthquake, this gives a magnitude of 5.9 and peak ground acceleration of 0.22.

The closest known faults which contribute to the seismic hazard of the site include the Kerepehi Fault and Wairoa Fault. These faults have recurrence intervals between 3400 years and 20,000 years. Given published studies that have found paleoliquefaction features in the Waikato Basin, it can be concluded that a large earthquake has occurred in the last 12,000 to 16,000 years (the age of the Hinuera 2 surface). In the absence of other information, we have based our assessment on the hazard model presented in the NZTA Bridge Manual.

Shear wave velocity assessment

Six seismic cone penetration tests (SCPTs) were completed across the site in order to use shear wave velocity as an alternate method of estimating the soil's cyclic resistance ratio (CRR), which is an estimate of a soil's capacity to resist liquefaction. Since it can be demonstrated that shear wave velocity is more responsive to aging, the CRR calculated from shear wave velocities is generally greater than the CRR estimated from standard CPT tests. This information can be used to more accurately estimate which layers will liquefy to estimate other parameters such as aging factors.

Calculated aging factors

Using the shear wave velocity results obtained from the six SCPTs, aging factors for the soils at the site have been calculated via two methods as summarised in Table 4 below.

[13] Orense, R.P., Pender, M.J. and O'Sullivan, A, 2012. *Liquefaction Characteristics of Pumice Sands.* Final Report of EQC Project 10/589. Report date March 2012.

[14] Clayton, P.J. & Johnson, J.T., 2013. *Liquefaction resistance and possible aging effects in selected Pleistocene soils of the Upper North Island.* Proceedings of the 19th NZGS Geotechnical Symposium.

[15] Youd, T.L. & Perkins, D.M. 1978. *Cone penetrometer tests in pumice sand*. New Zealand Geomechanics News.

[16] Andrus, R., Hayati, H., & Mohanan, N. 2009. *Correcting liquefaction resistance for aged sands using Measured to Estimated Velocity Ratio (MEVR).* Journal of Geotechnical and Geoenvironmental engineering.

Table 4: Calculated aging factors for Rotokauri North

Method	Description	Aging factor
Hayati et al (2008)[17]	Factor calculated from time vs Kdr	1.5
Andrus, Hayati, & Mohanan (2009)[18]	Factor calculated from the Measured to Estimated Velocity Ratio (MEVR)	1.3

Clayton & Johnson (2013) calculated an age correction factor of 1.3 to 1.4 for the soils of the Hamilton Basin using the MEVR method proposed by Andrus, Hayati, & Mohanan (2009).

Initial assessment

To select areas for more detailed investigation and analysis, we undertook a standard assessment using the methodology in the NZGS/MBIE Module 3. That assessment neglected any aging or other modifications. The assessment classified the Plains as performance level L3 to L4 (high to severe effects from liquefaction. Where the assessment showed near-surface layers that were liquefiable, and particularly where the shear wave velocity assessment and CPT analysis agreed, we excavated trenches to look for evidence that liquefaction had occurred. Our expectation was that for areas with such high assessed surface expression, there should be widespread and significant paleoliquefaction features.

Paleoliquefaction trenches

Five trenches were completed where the CPT and shear wave velocity testing both indicated that there were liquefiable layers near the surface. The purpose of the trenching was to determine the magnitude and extent of any paleoliquefaction in order to help predict the effects of any future liquefaction. The trenches were between 6 m and 10 m in length, and up to 1.6 m depth. Trench depth was limited by the groundwater. A summary of the observations for each trench is provided in table 5 below.

Table 5: Summary of observations from paleoliquefaction trenching

Investigation	Location	Findings	Paleoliquefaction features
Trench 1	Northwest (sCPT01)	Interbedded sand and silt of the Hinuera Formation. Groundwater at 1.3 m.	None
Trench 2	North (sCPT03)	Interbedded sand and silt of the Hinuera Formation. 800 mm of peat & organic silt filling a 3 m wide paleochannel. Groundwater at 1.1 m.	None
Trench 3	Southwest (sCPT02, CPT03)	Interbedded sand and silt of the Hinuera Formation. Up to 1.5 m of peat and organic silt encountered. Groundwater at 1.5 m.	None
Trench 4	Centre (CPT06)	Interbedded sand and silt of the Hinuera Formation. Groundwater encountered at 1.2 m.	Sand injection structures. Soft sediment deformation.

[17] Hayati, H. Andrus, R., Gassman, S. Hasek, M, Camp, W. Talwani, P. 2008. *Characterizing the Liquefaction resistance of aged soils*. Geotechnical Earthquake and Engineering and Soil Dynamics IV Congress.

[18] Hayati, H. & Andrus R. 2009. *Updated Liquefaction Resistance Correction factors for Aged Sands.* Journal of Geotechnical and Geoenvironmental Engineering, Vol. 135, No. 11.

Investigation	Location	Findings	Paleoliquefaction features
Trench 5	Southeast (sCPT06, CPT08)	Interbedded sand and silt of the Hinuera Formation. Groundwater encountered at 1.5 m.	None

Paleoliquefaction features

Features which we have interpreted as paleoliquefaction structures were encountered in Trench 4. The features encountered included injection structures and soft sediment deformation. Annotated photos are included below in Figure 1 and Figure 2.

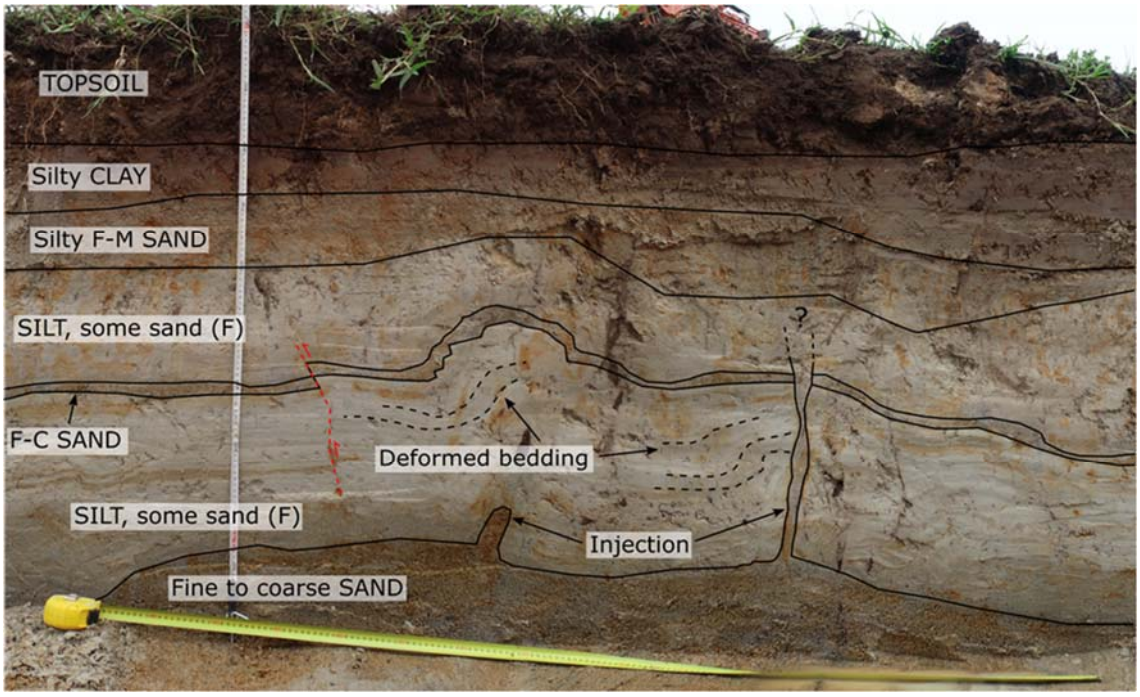


Figure 1: Annotated photo showing paleoliquefaction features encountered in TP04.

- Injection structures
  - originate from a fine to coarse sand
  - consist of fine to medium sand
  - are sub-vertical features which persist for up to 480 mm height
  - up to 30 mm wide
  - one injection displayed upwards fining
  - did not appear to reach the surface
- Soft sediment deformation
  - Included bedding deformed adjacent to, and above, injection features
  - small-scale reverse faults hosting 25 mm of offset

Discussion on paleoliquefaction findings

Our initial assessment found that an unmodified assessment using CPT data in the Plains materials reported a liquefaction hazard that should correlate with widespread surface disruption (high LSN). Our paleoliquefaction trenching found two, relatively small features, that did not appear to reach the surface. The features were only found in one location. While there are likely to be other features that

we did not find, the limited number and extent of the features we did find indicates that the unmodified analysis of the site may be conservative.

The research we reviewed supports the view that aging is likely to be a valid correction for CPT analysis in the Waikato plains soils. There is also likely to be a correction for the fines content of the soils. We did not explore this aspect of the assessment during this study.

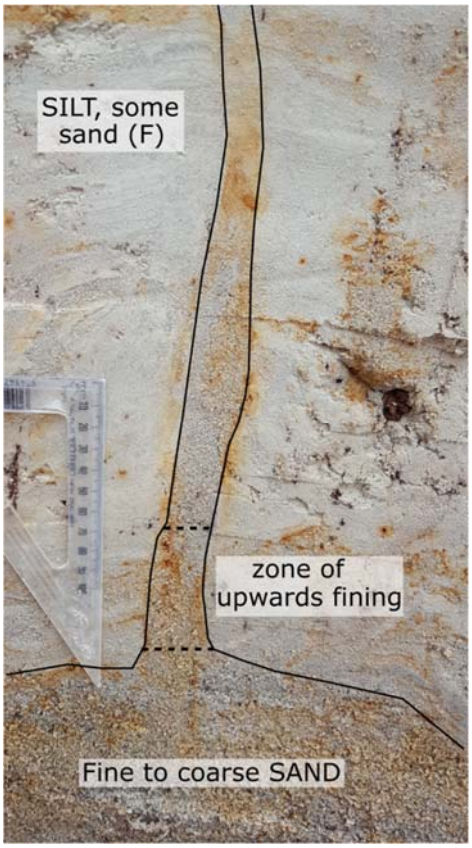


Figure 2: Paleoliquefaction injection in TP04 (annotated)

The soils in this area are also highly layered with bands of liquefiable sand often separated by non-liquefiable silt layers. Research currently being undertaken in New Zealand and internationally is showing that layered soils typically have the effect of minimising pore pressure buildup and limiting surface expression of liquefaction (J Bray, M Cubrinovski). It is likely that this effect has minimised the surface expression of liquefaction from earthquakes at this site.

Recommendations for future liquefaction assessments at the site

Refined assessment methodology

Based on the results of the liquefaction study, we recommend the following methodology for liquefaction assessment at the Rotokauri North site.

CPT assessment

CPT has proven to be the most useful tool for estimating liquefaction susceptibility at this site. The shear wave velocity testing was used to estimate the aging factor to use but proved difficult to correct in the highly layered soils on site. We recommend assessments use CPT testing.

Aging

The current research and our own correlation with the shear wave velocity indicates that a conservative aging factor based on the MEVR ratio is appropriate to use on the site. We recommend 1.3 is used.

Fines correction

Research has indicated that a fines correction is warranted in many soils. Further work could be undertaken to establish an area-wide fines correction to further refine the analysis. We do not currently have fines correlation information and so we have not used a fines correction for this area-wide study.

Assessment inputs

The design earthquake and seismic loading for the site were determined from Section 6 of the NZTA Bridge Manual[19] and NZS1170.5:2004[20] in accordance with the 2016 MBIE and NZGS guidelines[21]. Additional parameters for the liquefaction assessment were derived from testing at the site (as described above). A summary of these parameters is provided in Table 6 below.

Table 6: Seismic hazard and liquefaction assessment parameters

Site seismic classification	Class D (Deep soils)
1000 year return period PGA coefficient ($C_{0,1000}$)	0.28
Structural importance level	Level 2 for residential structures with normal importance
Structure design life	50 years
Peak ground acceleration	0.05 g for a 1 in 25-year Serviceability Limit State (SLS) event 0.22 g for a 1 in 500-year Ultimate Limit State (ULS) event
Earthquake magnitude	5.9 M
Groundwater depth[22]	0.5 m
Limit depth[23]	10 m
Aging factor for CRR[24]	1.3

Site performance level

Using the revised assessment methodology, in accordance with Table 5.1 of the NZGS guidelines[25], the site generally lies across the performance levels L2 (Moderate) to L3 (High). A summary of the

[19] New Zealand Transport Agency, 2018. *Bridge Manual, third edition, Amendment 3 (SP/M/022).*

[20] NZS 1170.5:2004. New Zealand Standard, *Structural Design Actions Part 5: Earthquake actions.* New Zealand, Standards New Zealand, Wellington.

[21] Ministry of Business, Innovation & Employment (MBIE) and New Zealand Geotechnical Society (NZGS), 2016. *Earthquake geotechnical engineering practice – Module 3: Identification, assessment and mitigation of liquefaction hazards.* Published 1 May 2016, Revision 0.

[22] Groundwater depth based on groundwater monitoring levels between August 2018 and April 2019.

[23] Tonkin and Taylor. February 2019. *Liquefaction Desktop Study (for Hamilton City Council).* Extensive studies have been undertaken showing that liquefaction triggering of soil layers more than 10m below ground level provides a negligible contribution to liquefaction damage at the surface.

[24] Calculated from shear wave velocity test results conducted at the site, comparable to current published research.

[25] Ministry of Business, Innovation & Employment and New Zealand Geotechnical Society, 2016. *Earthquake geotechnical engineering practice – Module 3: Identification, assessment and mitigation of liquefaction hazards.*

liquefaction assessment results for a range of seismic events is provided in Table 7 below. Outputs of the CPT analyses are included in Appendix D.

Table 7: Liquefaction Assessment Results

Seismic Event / Annual Exceedance Probability (AEP)	Anticipated performance	
Serviceability Limit State (SLS) (0.05 g) 1:25 AEP	• No effects expected	• No change from long term static effects
Intermediate Earthquake (0.11 g) 1:100 AEP	• Total settlements: less than 10 mm • LSN less than 2 (little to no expression of liquefaction)	• Anticipate insignificant liquefaction effects (performance level L0).
Ultimate Limit State (ULS) (0.22 g) 1:500 AEP	• Total settlements: 30 mm to 80 mm • Primarily occurring between 1.5 m and 10 m depth • LSN between 5 and 30 (minor to moderate expression of liquefaction)	• Anticipate moderate to high liquefaction effects (performance level L2 to L3). • Limited to significant liquefaction of the upper 10 m of soil with transient lateral displacements, and minor to moderate differential settlement.

In accordance with Table 4.4 of the 2017 EQC and MBIE guidelines[26], this site has a medium liquefaction vulnerability. This means that there is a probability of more than 50 percent that liquefaction-induced ground damage will be minor to moderate for a 1 in 500-year seismic event and none to minor for a 1 in 100-year seismic event.

Predicted liquefaction of this magnitude is not uncommon in the Waikato. To allow for residential and commercial construction, mitigation in the medium to high risk areas will be achievable through strengthened foundations or shallow ground improvement.

Lateral spreading

Lateral spreading is a phenomenon were liquefied material allows the soil above to move laterally towards a free face, such as a stream bank. The site currently has an isolated lateral spreading risk adjacent to the Te Kowhai Channel in the north-eastern corner of site and adjacent to stormwater drains.

Development plans show stormwater swales throughout the site which are likely to be excavated up to 2 m below current ground levels. Given the near surface soils have been identified as liquefiable in places, the formation of these swales is likely to create a lateral spreading hazard.

Specific assessment of the lateral spreading hazard will be required. Potential mitigation options for lateral spreading risk areas may include:

- dewatering of adjacent ground so liquefaction is unable to occur
- using a buttress of ground improvement along swale edges
- slope stabilisation methods

[26] Earthquake Commission (EQC)/Ministry of Business Innovation and Employment (MBIE). *Planning and engineering guidance for potentially liquefaction prone land.* Dated September 2017.

- specifying foundation types tolerant to lateral spreading in high risk areas

Future work

During development of the site, a site-specific assessment (level D) should be undertaken at suitability stage to further define the liquefaction hazard and to establish specific mitigation measures where these are required. Further assessment should include the liquefaction induced lateral spreading risk adjacent to proposed stormwater swales.

Limitations

This report has been prepared for our client, Green Seed Consultants Limited, for the purpose detailed above and may not be relied on by any other party or for any other purpose. This report contains an assessment based on a site walkover and testing at discrete locations to inform further liquefaction assessments for the proposed development.

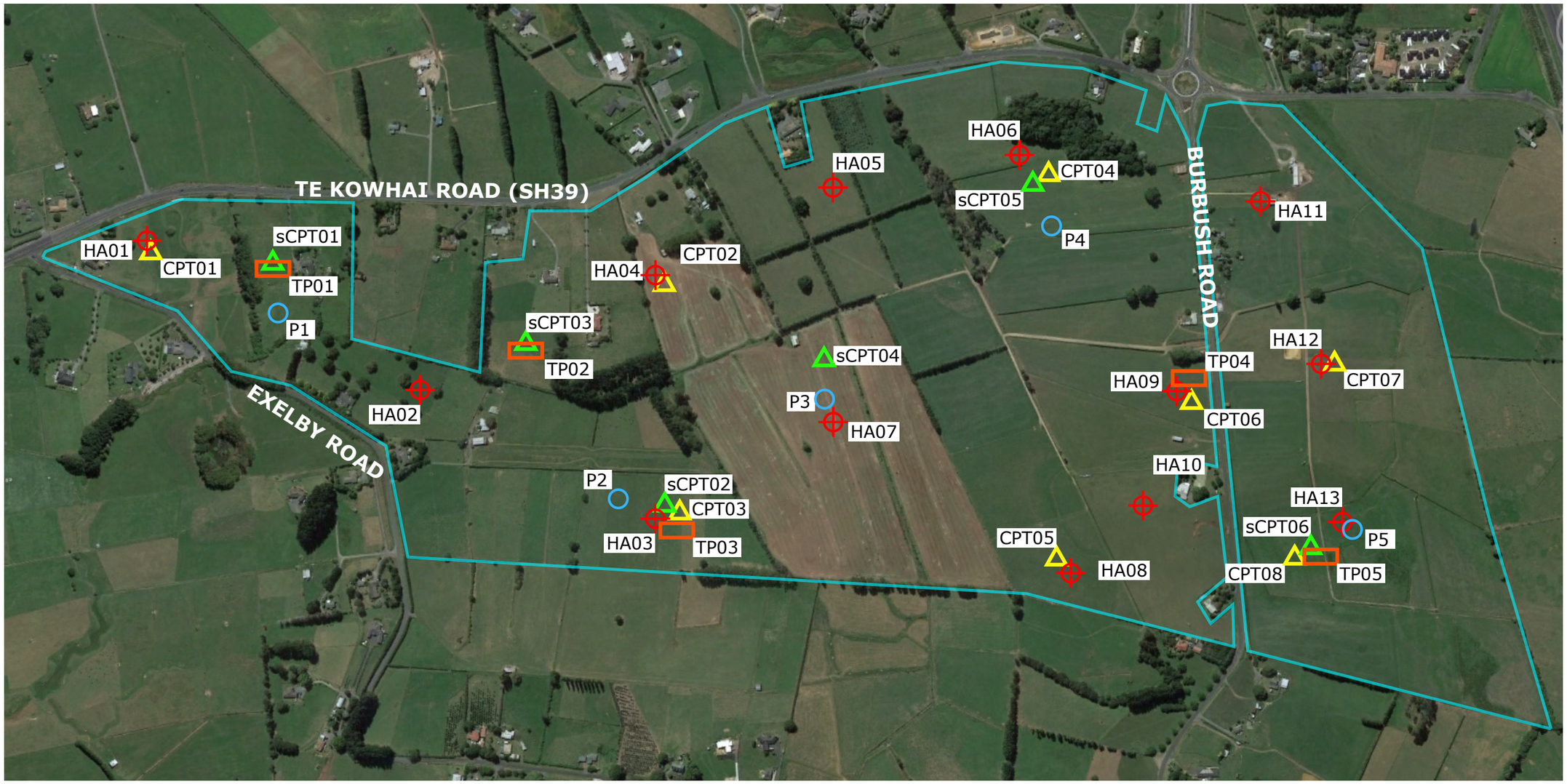
Further testing and assessment is required prior to finalising the development proposals for the site. Inferences about the conditions at the site have been made based on the testing undertaken and our understanding of the geological environment in which the site lies. The deposits in this area are by nature highly variable both vertically and laterally. We recommend that a geotechnical engineer is engaged to provide input into the design of the development and to undertake further testing, assessment and design. For continuity and to confirm ground conditions, geotechnical observation will also be required during site construction works.

APPENDIX A – SITE PLANS

Geotechnical Investigation Locations

Site Geomorphology

Proposed Development & Staging Plans



Retrieved from Google Maps 18.07.18

LEGEND

- Hand auger (HA)
- Cone penetrometer test (CPT)
- Seismic cone penetrometer test (sCPT)
- Piezometer (P)
- Test pit (TP)
- Site boundary

PROJECT:	Rotokauri North SHA
PROJECT NO:	HD631
CLIENT:	Green Seed Consultants Ltd
TITLE:	Geotechnical Investigation Locations
SCALE:	NTS
Drawing No:	HD631/01
Drawing by:	SA
Revision No:	

Plains

Hill Terrain

PROJECT: Rotokauri North SHA	
PROJECT NO: HD631	
CLIENT: Green Seed Consultants Limited	
TITLE: Site Geomorphology	
SCALE: NTS	
Drawing No: HD631/2	
Drawing by: MM	
Rev Number	
0	Initial

Rotokauri North Special Housing Area

February 2018
Green Seed Consultants Ltd

ROTOKAURI NORTH SHA AREA (Figure 1)

Map legend

- Site area
- 1 Stage 1 (53.39ha)
- 2 Stage 2 (79.72ha)

Stages 1 and 2 sought as an SHA.
Total of 133.1109ha.

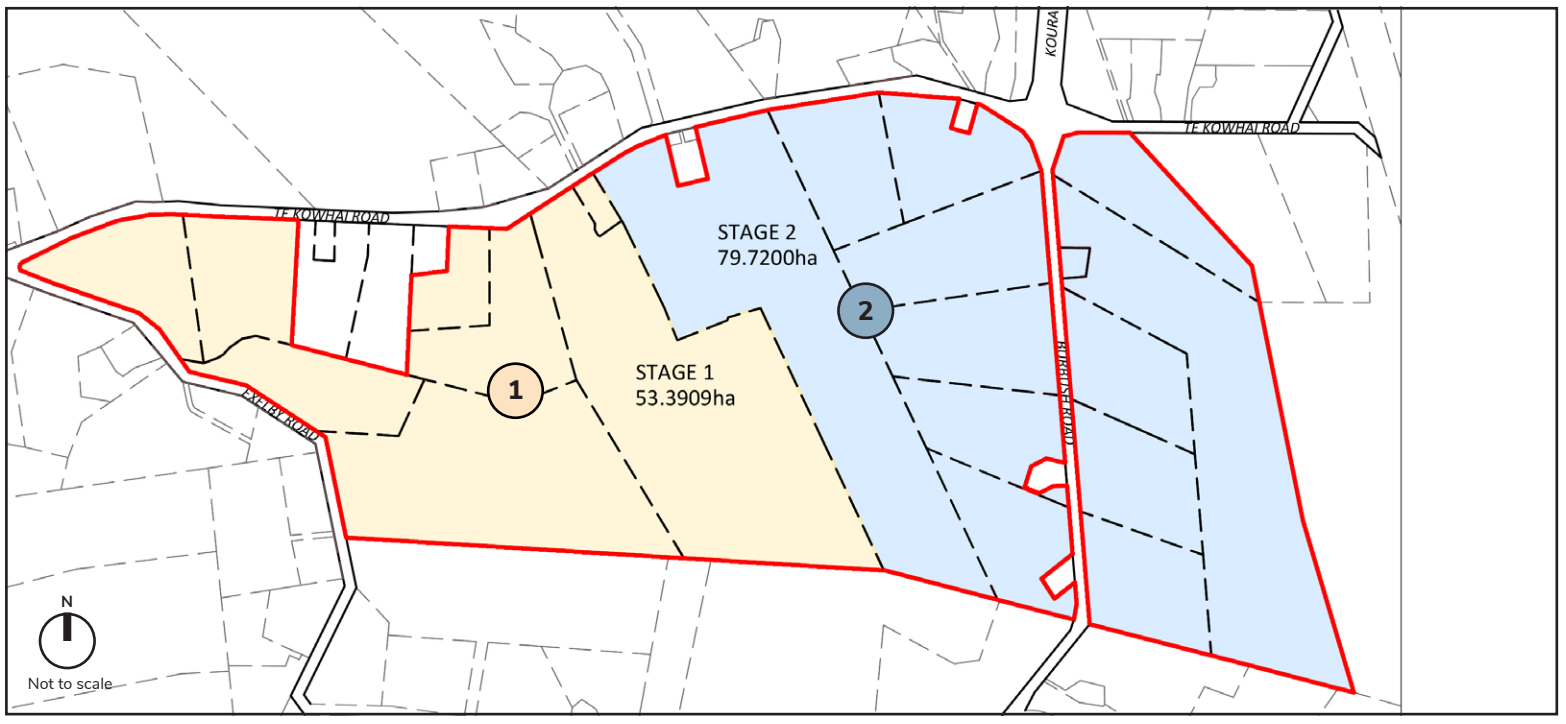


Figure 1: Rotokauri North SHA area

ROTOKAURI NORTH SHA CONCEPT (Figure 2)

Map legend

- Site area
- 1 Optimise connections to east (jobs) as well south.
- 2 Ensure each small centres is focused on its local community.
- 3 Maximise residential catchment around a small centre, and integrate movement network around the centre.
- 4 Provide for necessary stormwater conveyance and storage.
- 5 Provide district-level open space so as to maximise maximise exposure and accessibility to all. Size will be determined by Council acquisition agreement.
- 6 Ensure sensitive slopes can be appreciated as landscape features.

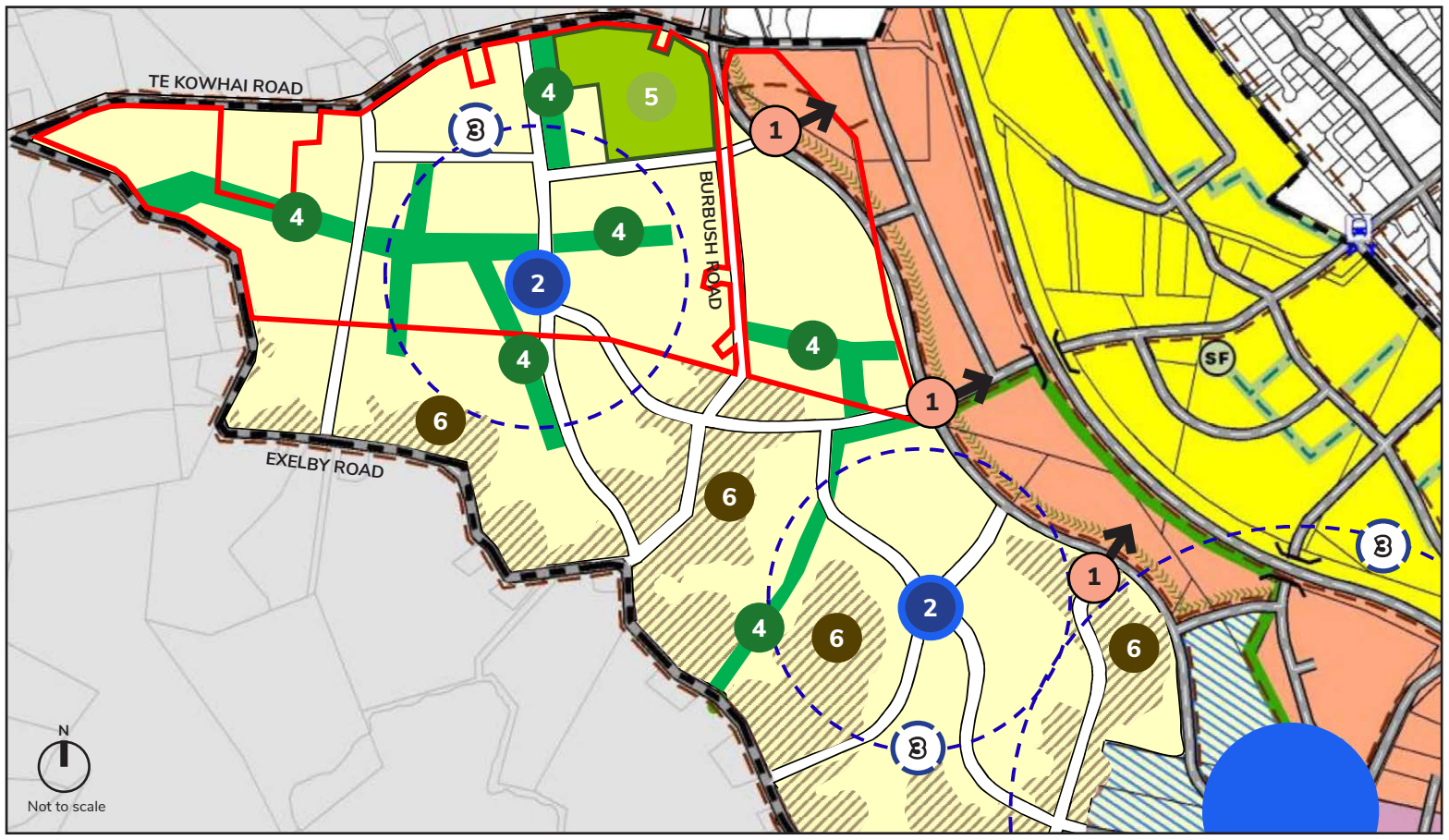


Figure 1: Key structuring elements of Rotokauri North SHA concept

ROTOKAURI NORTH SHA OPTIONS FOR STORMWATER (Figure 3)

Map legend

- Site area
- Floodway basin (conveyance and flood storage)
- Swale (conveyance only)
- Treatment wetlands
- Discharge locations

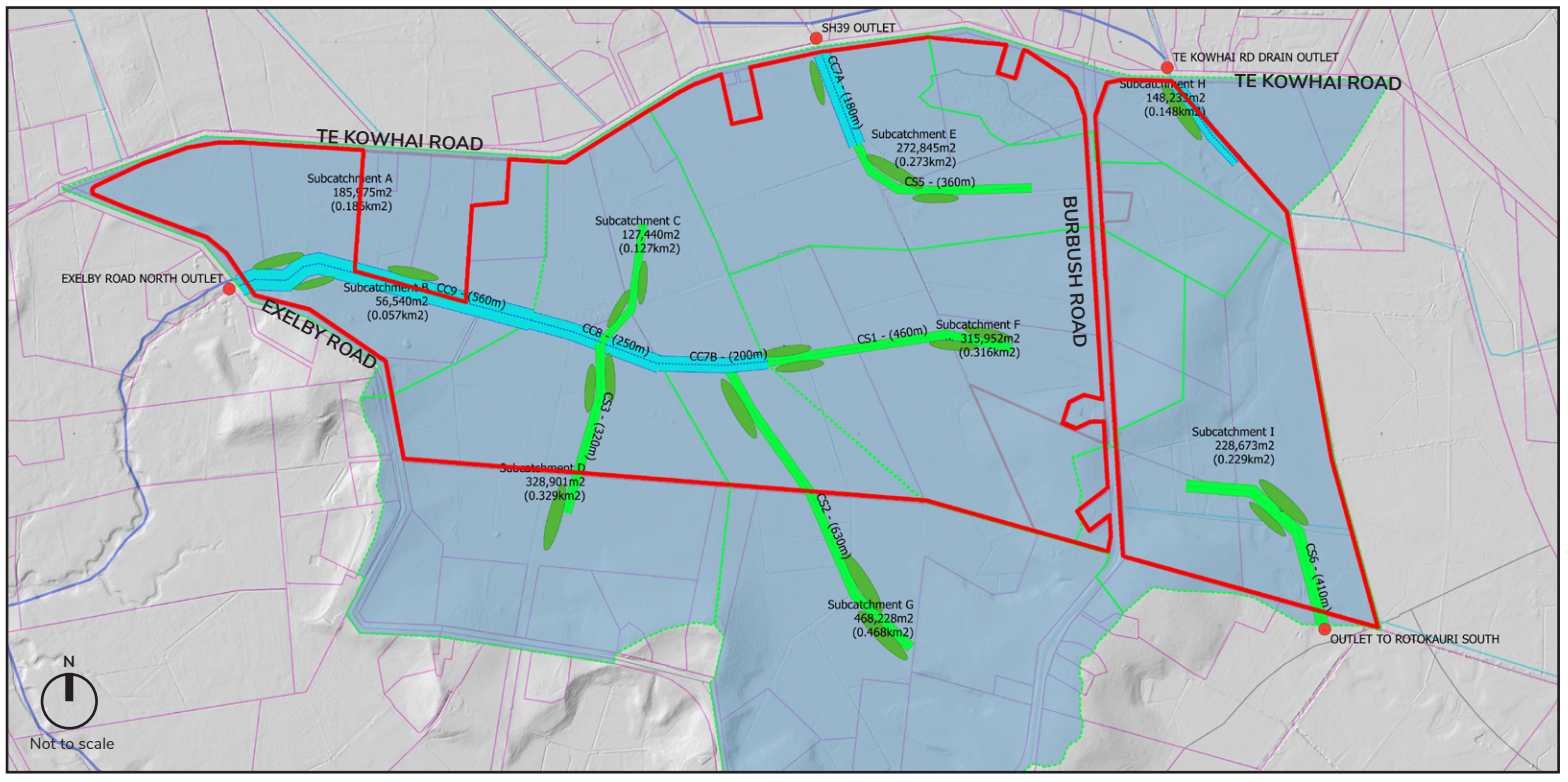


Figure 3: Rotokauri North SHA options for stormwater
Source: CKL Stormwater Solutions

Rotokauri North Special Housing Area

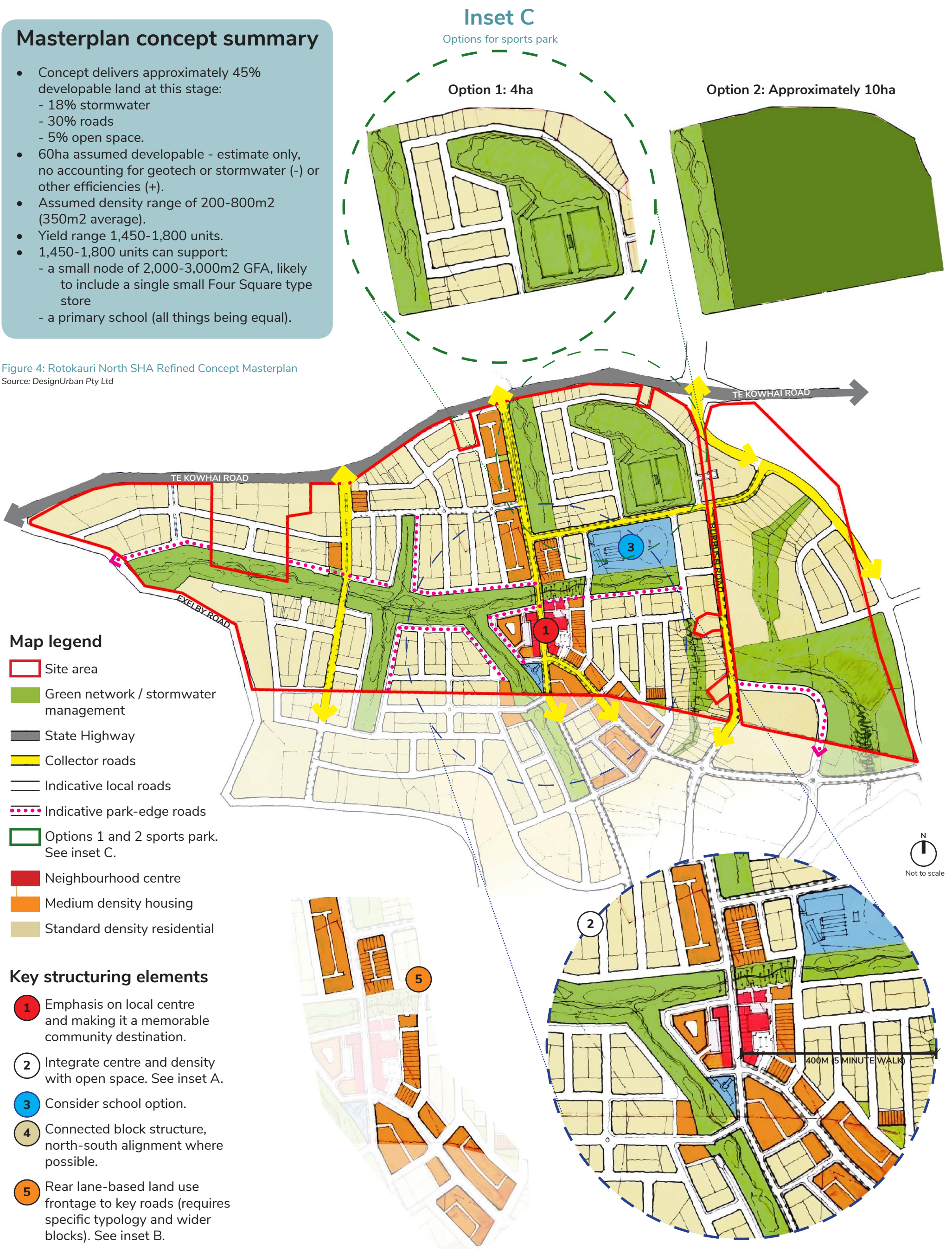
February 2018
Green Seed Consultants Ltd

ROTOKAURI NORTH SHA REFINED MASTERPLAN (Figure 4)

Masterplan concept summary

- Concept delivers approximately 45% developable land at this stage:
  - 18% stormwater
  - 30% roads
  - 5% open space.
- 60ha assumed developable - estimate only, no accounting for geotech or stormwater (-) or other efficiencies (+).
- Assumed density range of 200-800m2 (350m2 average).
- Yield range 1,450-1,800 units.
- 1,450-1,800 units can support:
  - a small node of 2,000-3,000m2 GFA, likely to include a single small Four Square type store
  - a primary school (all things being equal).

Figure 4: Rotokauri North SHA Refined Concept Masterplan
Source: DesignUrban Pty Ltd



APPENDIX B – INVESTIGATION DATA

CPT data

sCPT data

HD Geo
PO Box 9266
Waikato Mail Centre, Hamilton
www.hdgeo.co.nz

Project: **HD631 - Rotokauri North SHA Geo**
Location: **Rotokauri North**

CPT: CPT01
Total depth: 19.83 m, Date: 25/06/2018
Surface Elevation: 0.00 m
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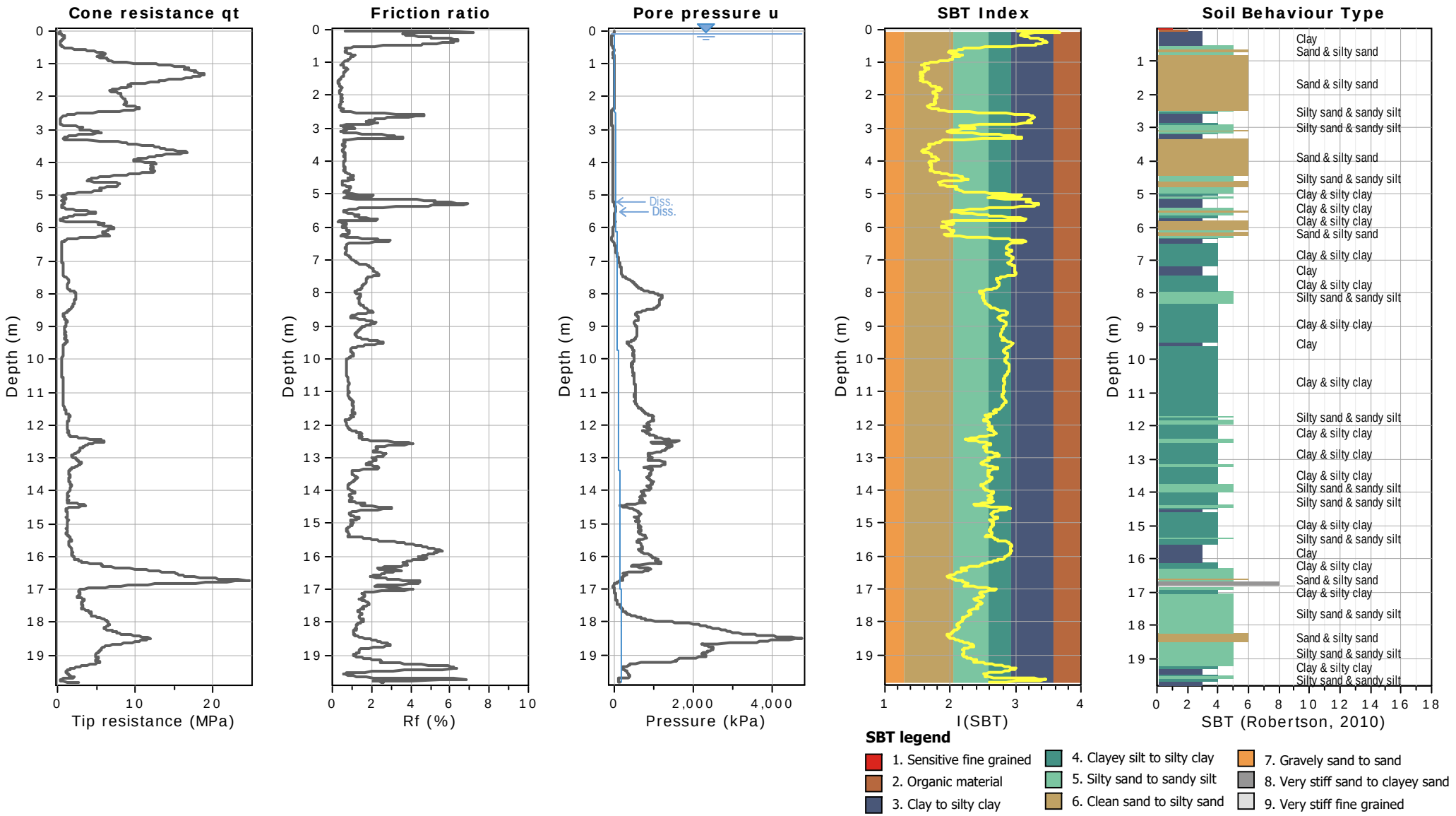
Cone Type: Uknown
Cone Operator: Uknown



HD Geo
PO Box 9266
Waikato Mail Centre, Hamilton
www.hdgeo.co.nz

Project: **HD631 - Rotokauri North SHA Geo**
Location: **Rotokauri North**

CPT: CPT02
Total depth: 18.58 m, Date: 25/06/2018
Surface Elevation: 0.00 m
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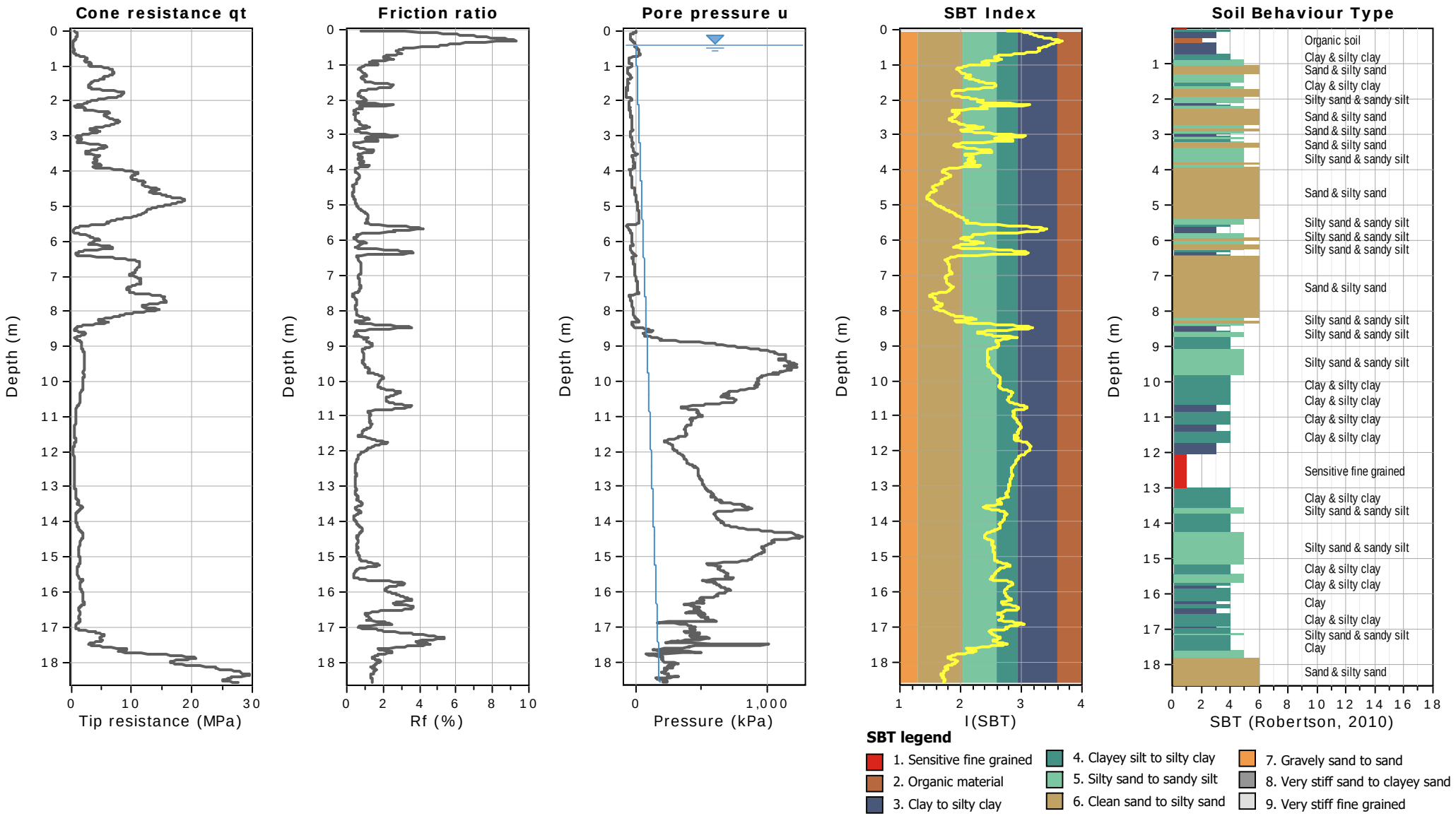

HD Geo
PO Box 9266
Waikato Mail Centre, Hamilton
www.hdgeo.co.nz

Project: **HD631 - Rotokauri North SHA Geo**
Location: **Rotokauri North**

CPT: CPT03
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Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
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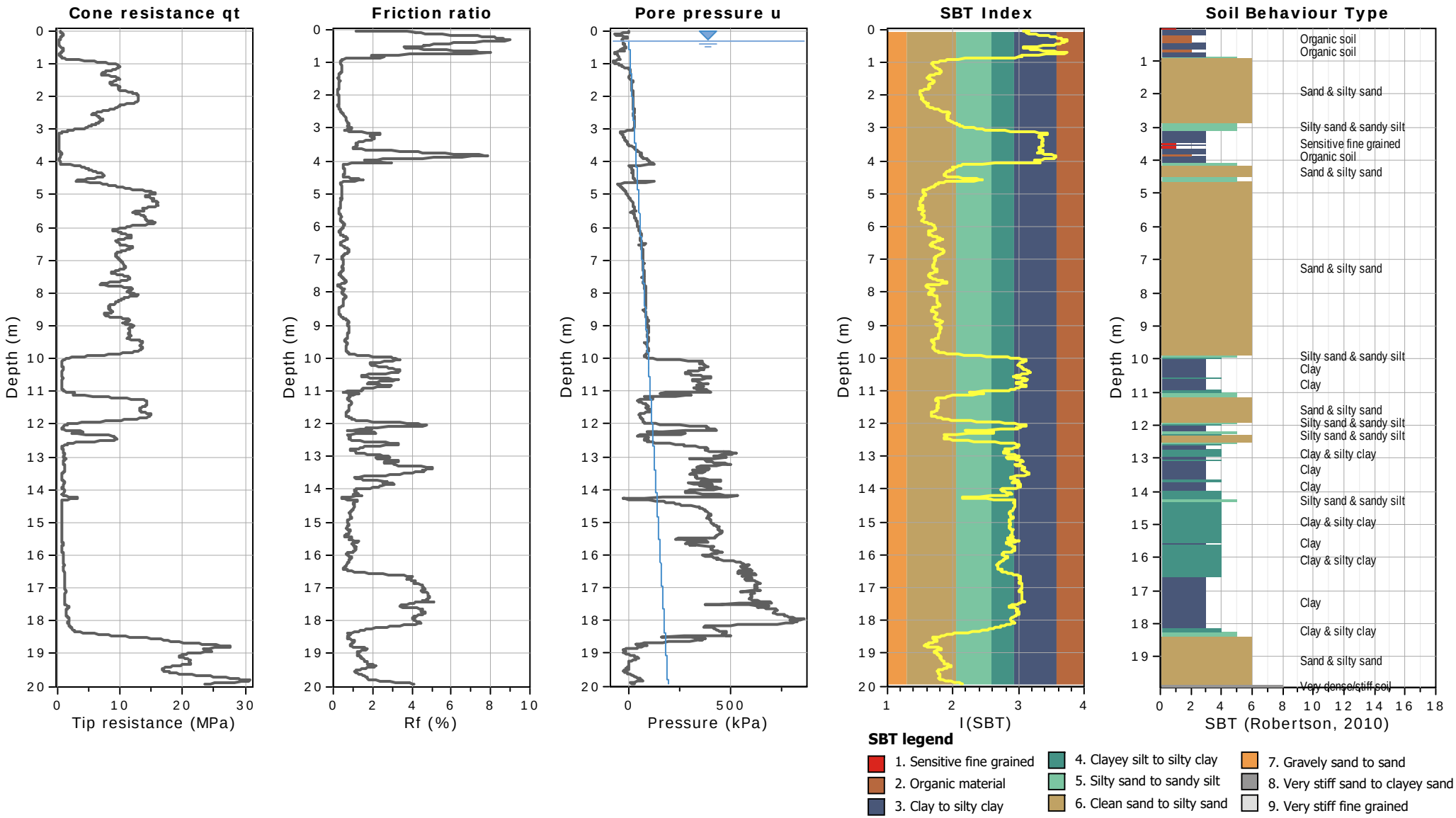
Cone Operator: Uknown



HD Geo
PO Box 9266
Waikato Mail Centre, Hamilton
www.hdgeo.co.nz

Project: **HD631 - Rotokauri North SHA Geo**
Location: **Rotokauri North**

CPT: CPT04
Total depth: 19.93 m, Date: 25/06/2018
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
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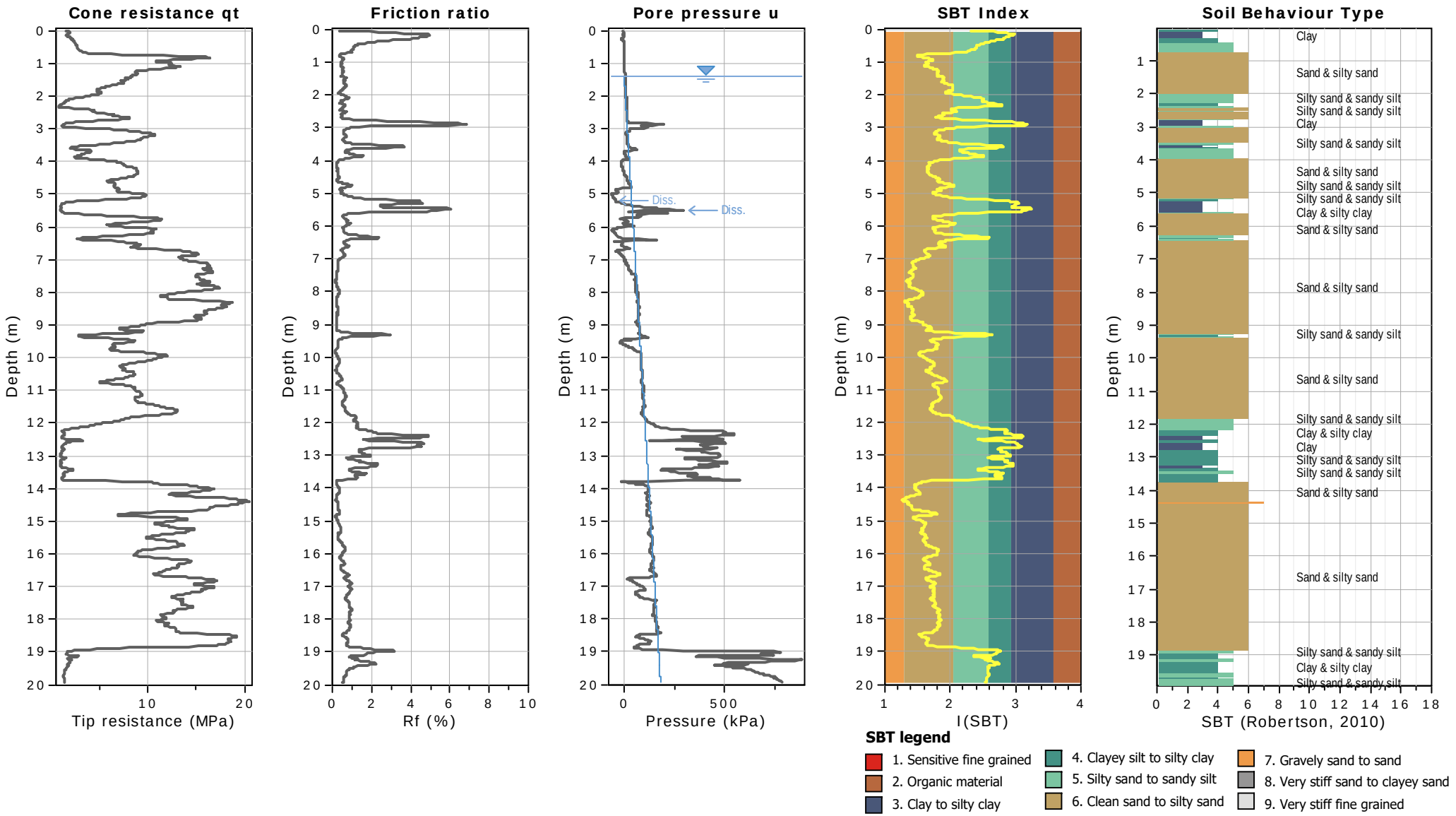
Cone Operator: Uknown



HD Geo
PO Box 9266
Waikato Mail Centre, Hamilton
www.hdgeo.co.nz

Project: **HD631 - Rotokauri North SHA Geo**
Location: **Rotokauri North**

CPT: CPT05
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Surface Elevation: 0.00 m
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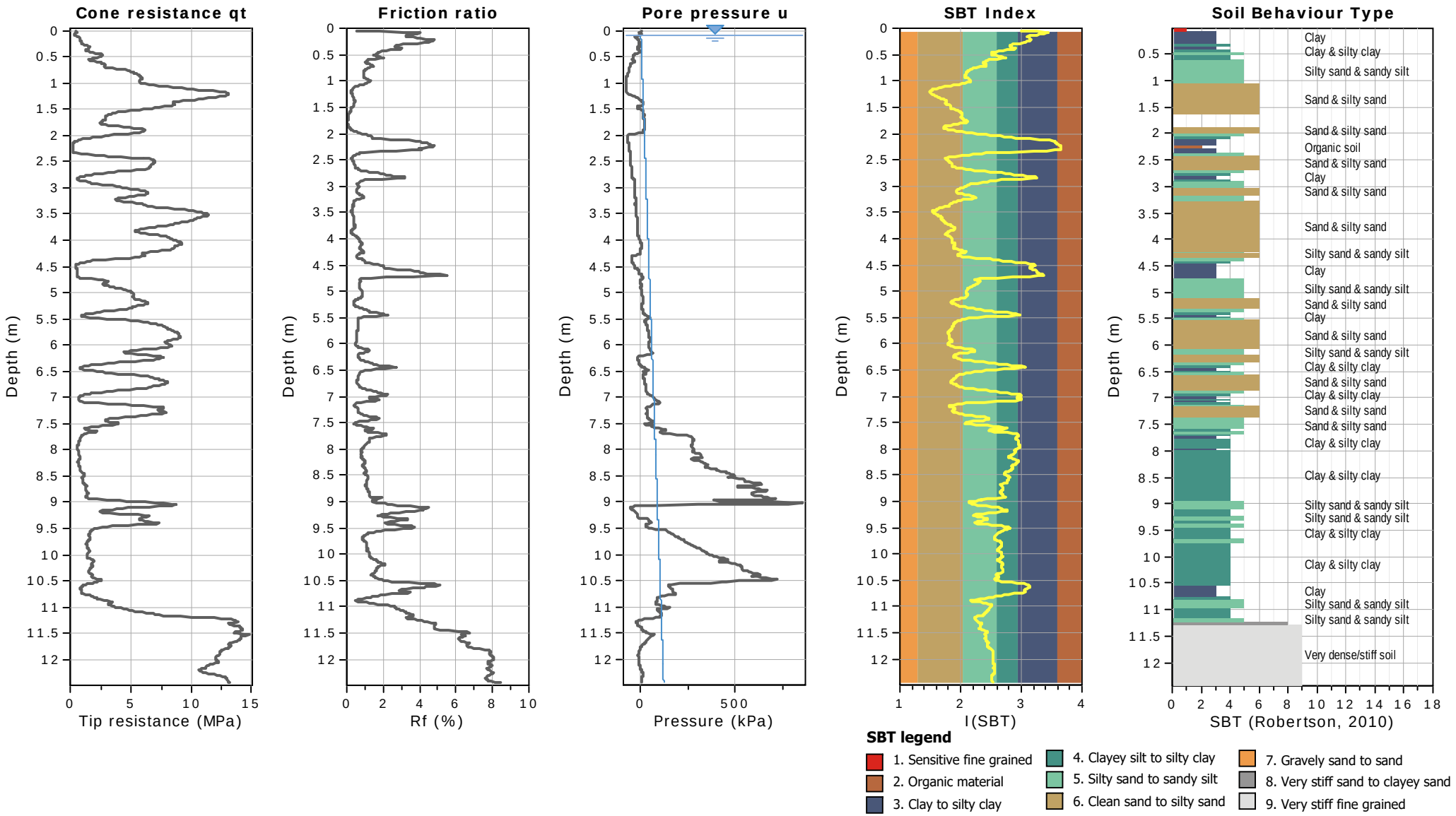

HD Geo
PO Box 9266
Waikato Mail Centre, Hamilton
www.hdgeo.co.nz

Project: **HD631 - Rotokauri North SHA Geo**
Location: **Rotokauri North**

CPT: CPT06
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Surface Elevation: 0.00 m
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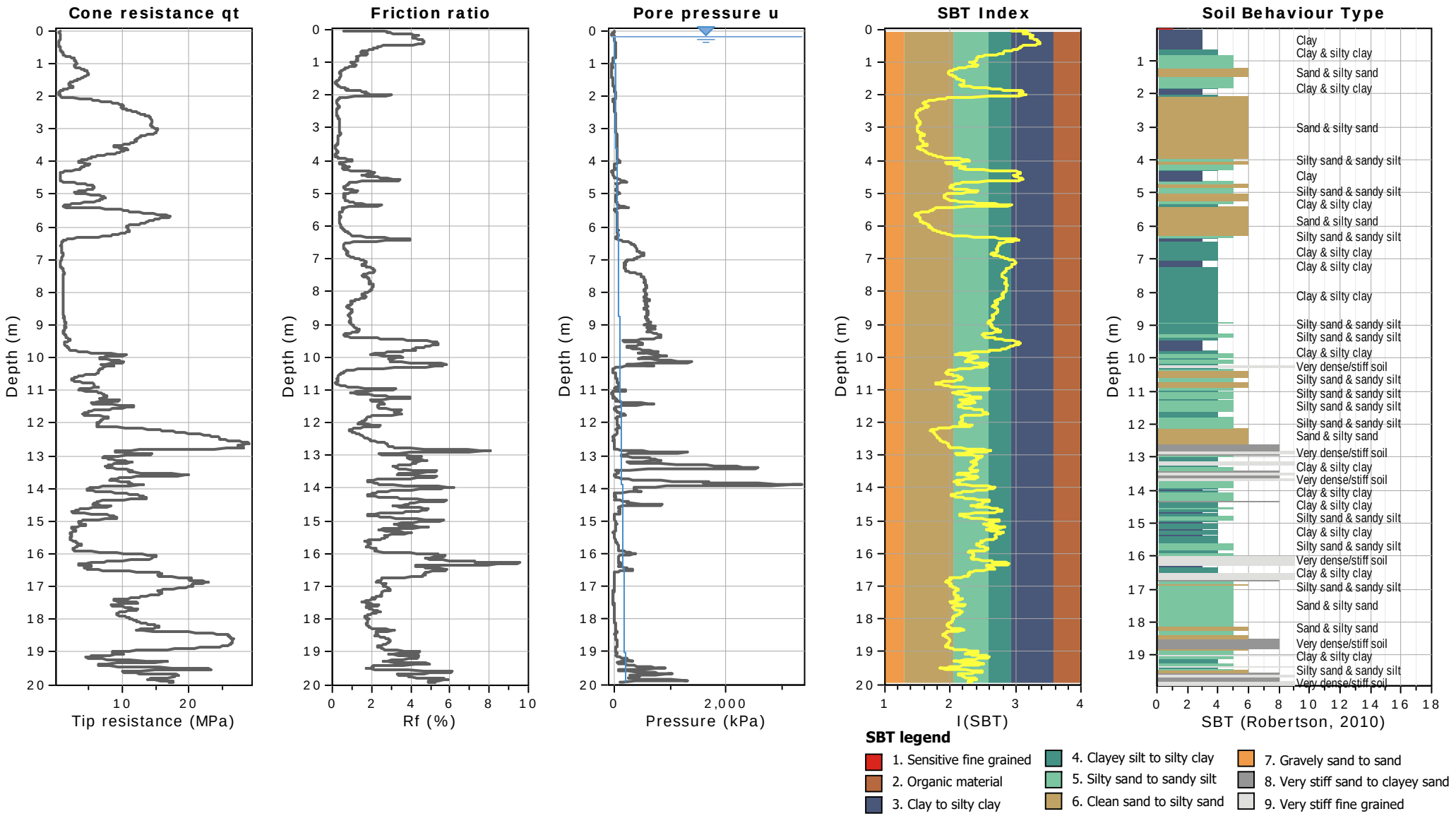

HD Geo
PO Box 9266
Waikato Mail Centre, Hamilton
www.hdgeo.co.nz

Project: **HD631 - Rotokauri North SHA Geo**
Location: **Rotokauri North**

CPT: CPT07
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Surface Elevation: 0.00 m
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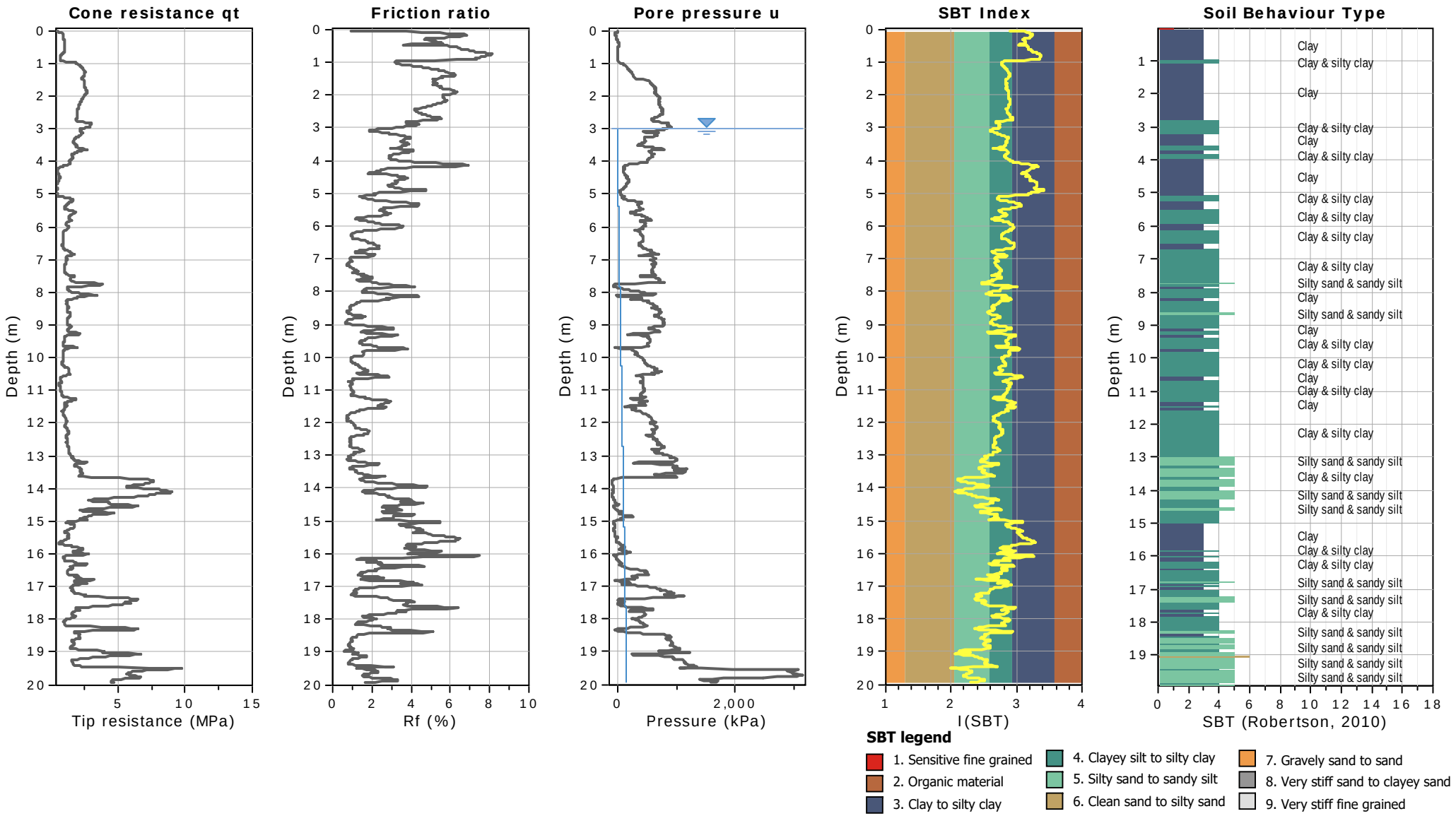

HD Geo
PO Box 9266
Waikato Mail Centre, Hamilton
www.hdgeo.co.nz

Project: **HD631 - Rotokauri North SHA Geo**
Location: **Rotokauri North**

CPT: CPT08
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Surface Elevation: 0.00 m
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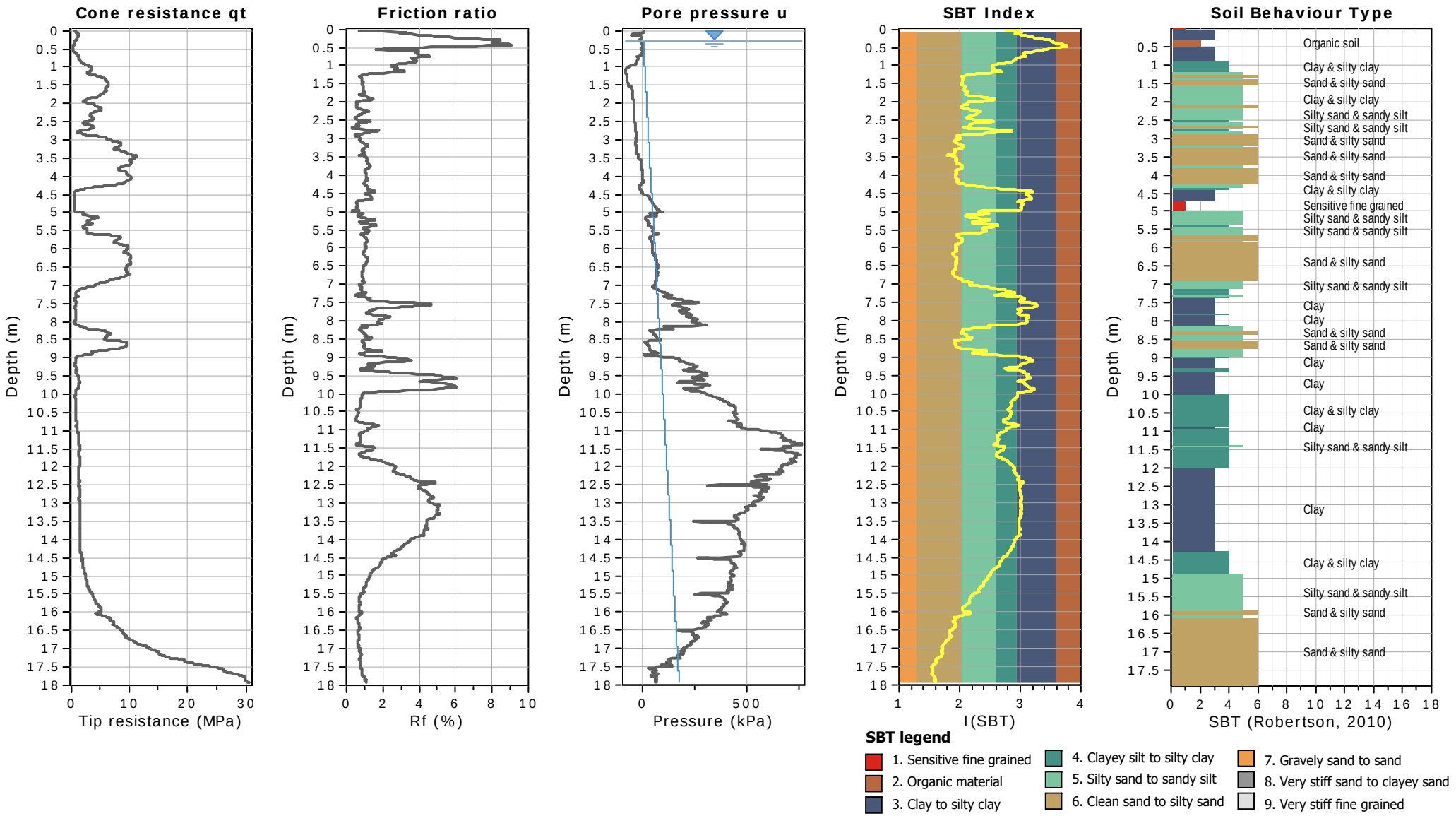

HD Geo
PO Box 9266
Waikato Mail Centre, Hamilton
www.hdgeo.co.nz

Project: **HD631 - Rotokauri North SHA Geo**
Location: **Rotokauri North**

CPT: SCPT-01
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Surface Elevation: 0.00 m
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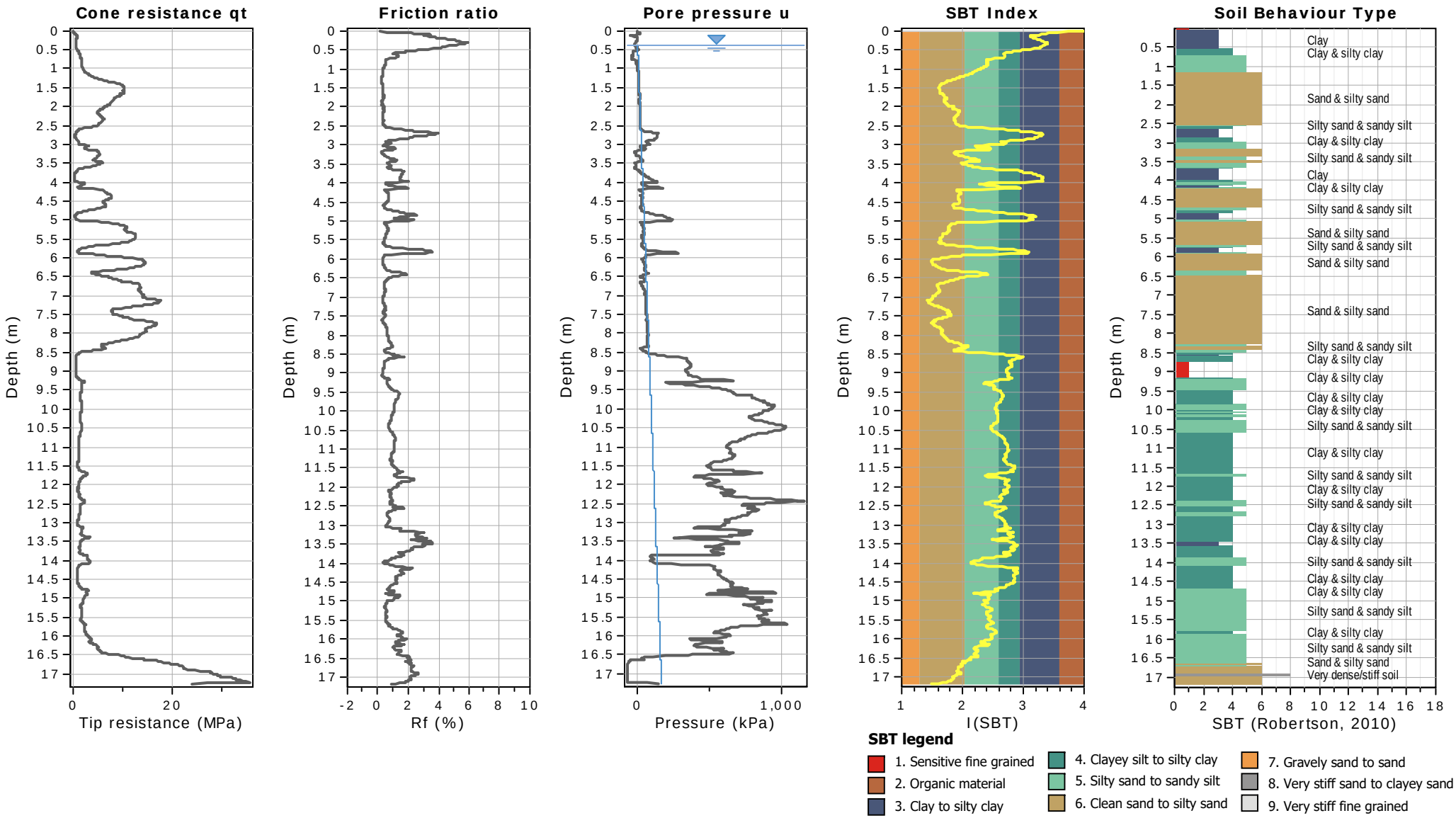

HD Geo
PO Box 9266
Waikato Mail Centre, Hamilton
www.hdgeo.co.nz

Project: **HD631 - Rotokauri North SHA Geo**
Location: **Rotokauri North**

CPT: SCPT-02
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Surface Elevation: 0.00 m
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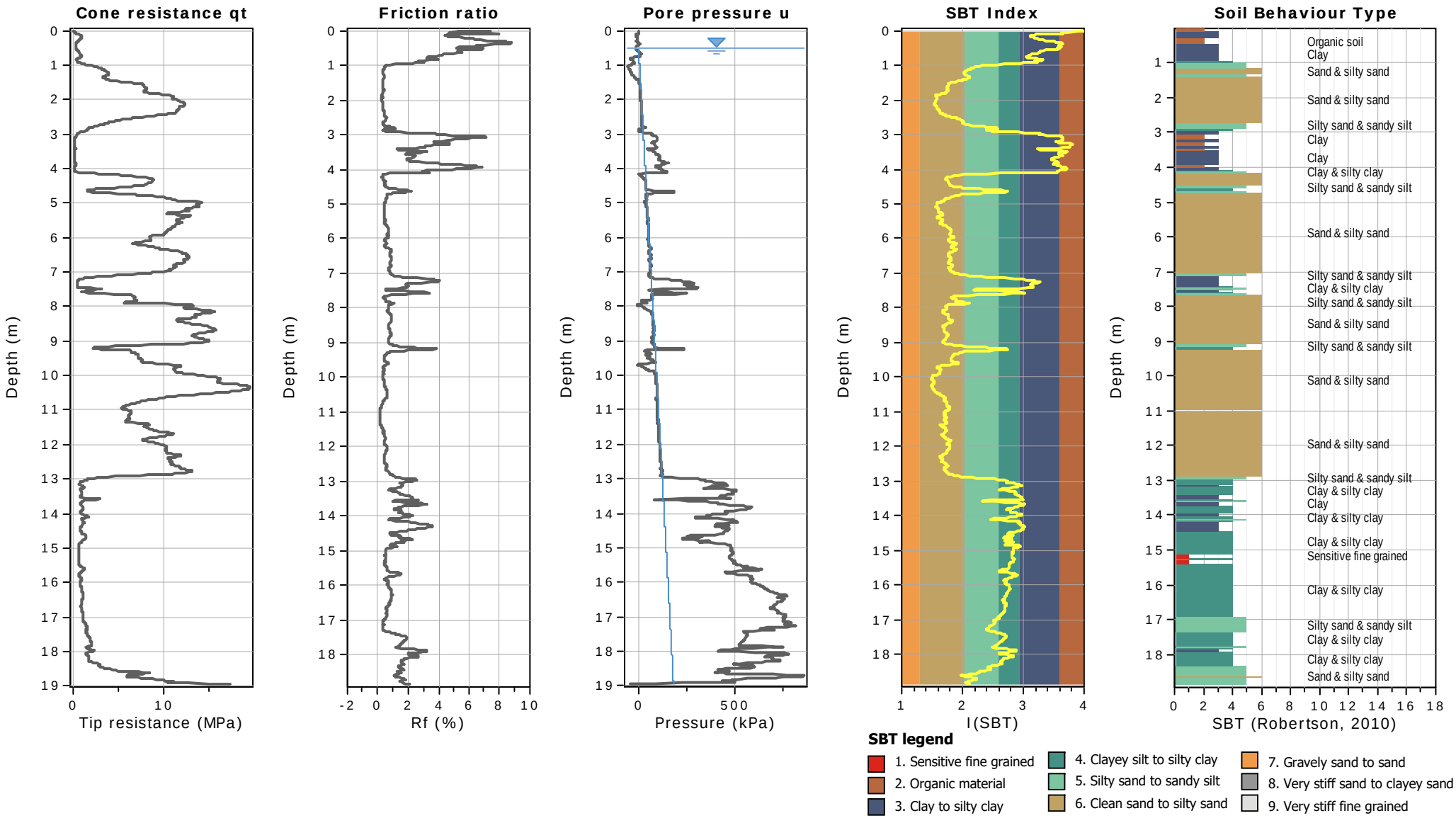

HD Geo
PO Box 9266
Waikato Mail Centre, Hamilton
www.hdgeo.co.nz

Project: **HD631 - Rotokauri North SHA Geo**
Location: **Rotokauri North**

CPT: SCPT-03
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Surface Elevation: 0.00 m
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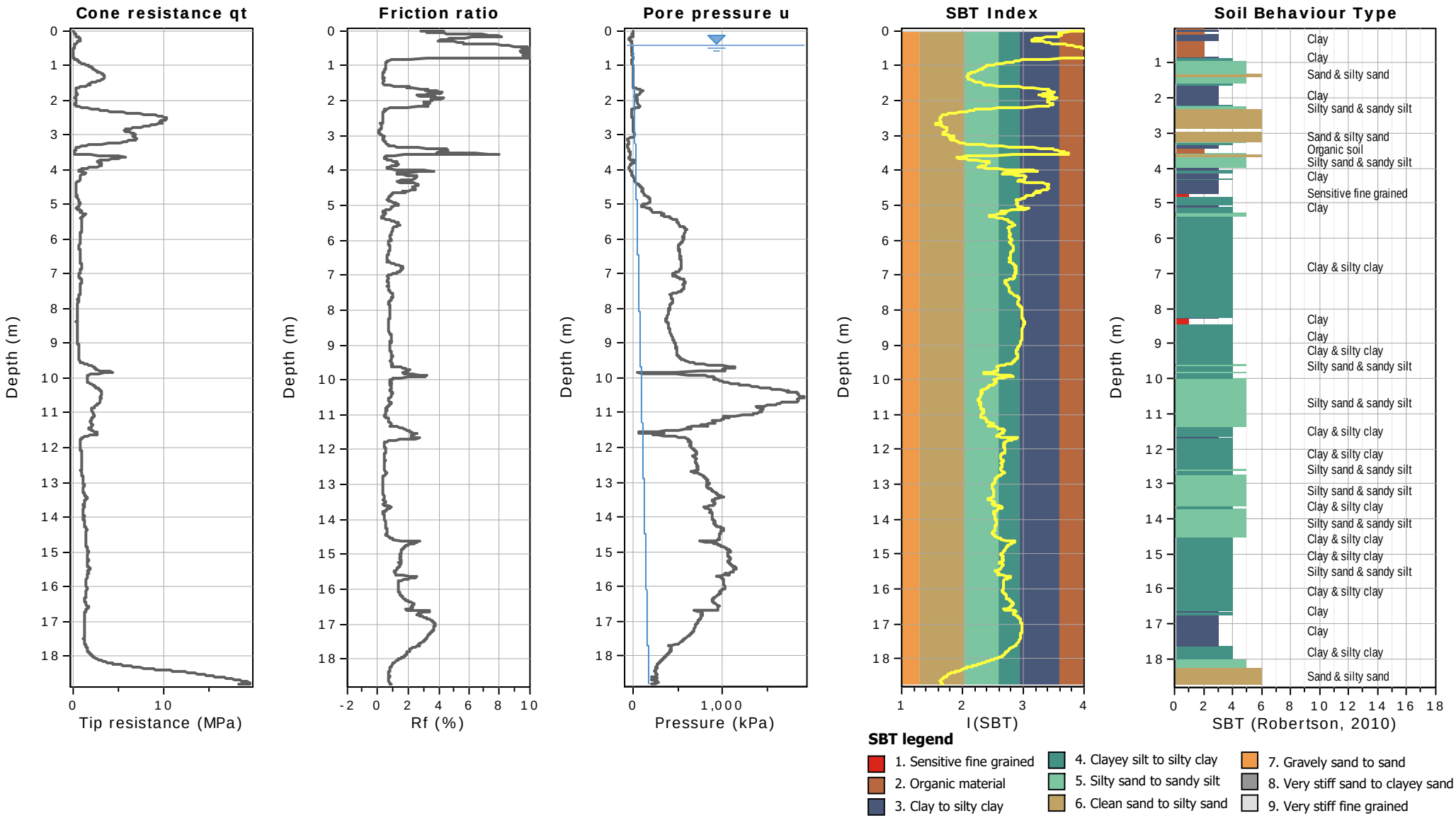

HD Geo
PO Box 9266
Waikato Mail Centre, Hamilton
www.hdgeo.co.nz

Project: **HD631 - Rotokauri North SHA Geo**
Location: **Rotokauri North**

CPT: SCPT-04
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Surface Elevation: 0.00 m
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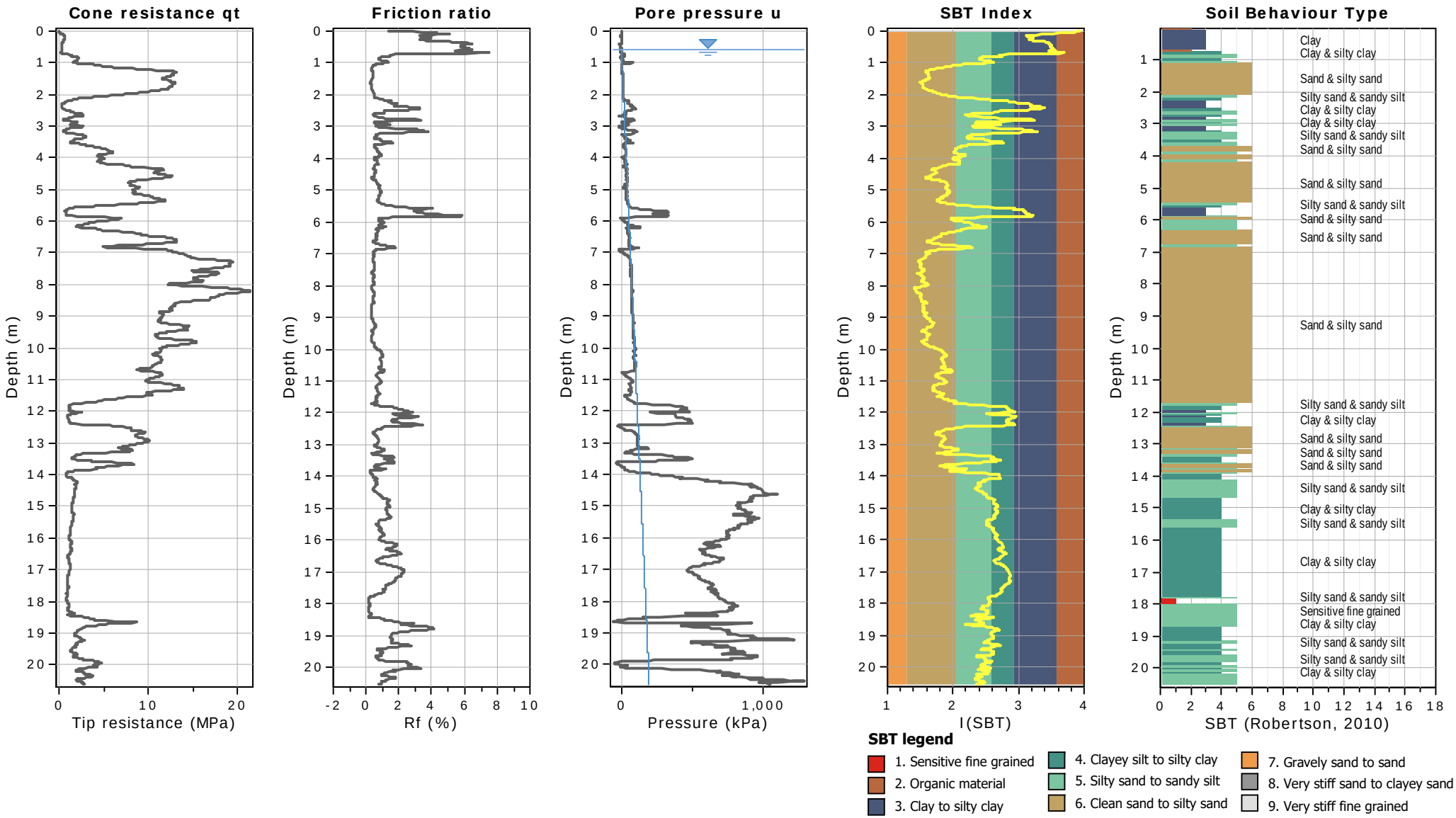

HD Geo
PO Box 9266
Waikato Mail Centre, Hamilton
www.hdgeo.co.nz

Project: **HD631 - Rotokauri North SHA Geo**
Location: **Rotokauri North**

CPT: SCPT-05
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Surface Elevation: 0.00 m
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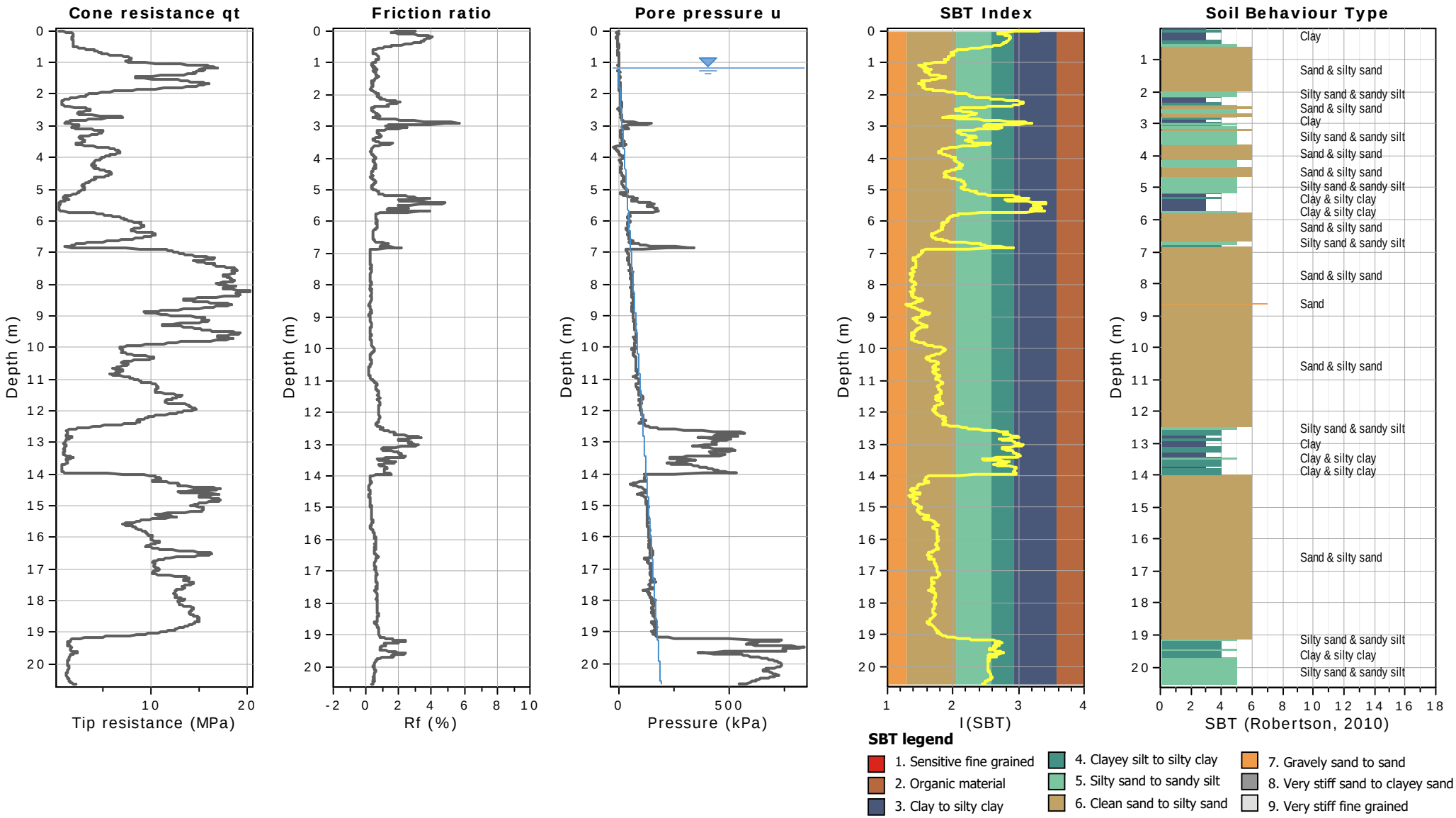

HD Geo
PO Box 9266
Waikato Mail Centre, Hamilton
www.hdgeo.co.nz

Project: **HD631 - Rotokauri North SHA Geo**
Location: **Rotokauri North**

CPT: SCPT-06
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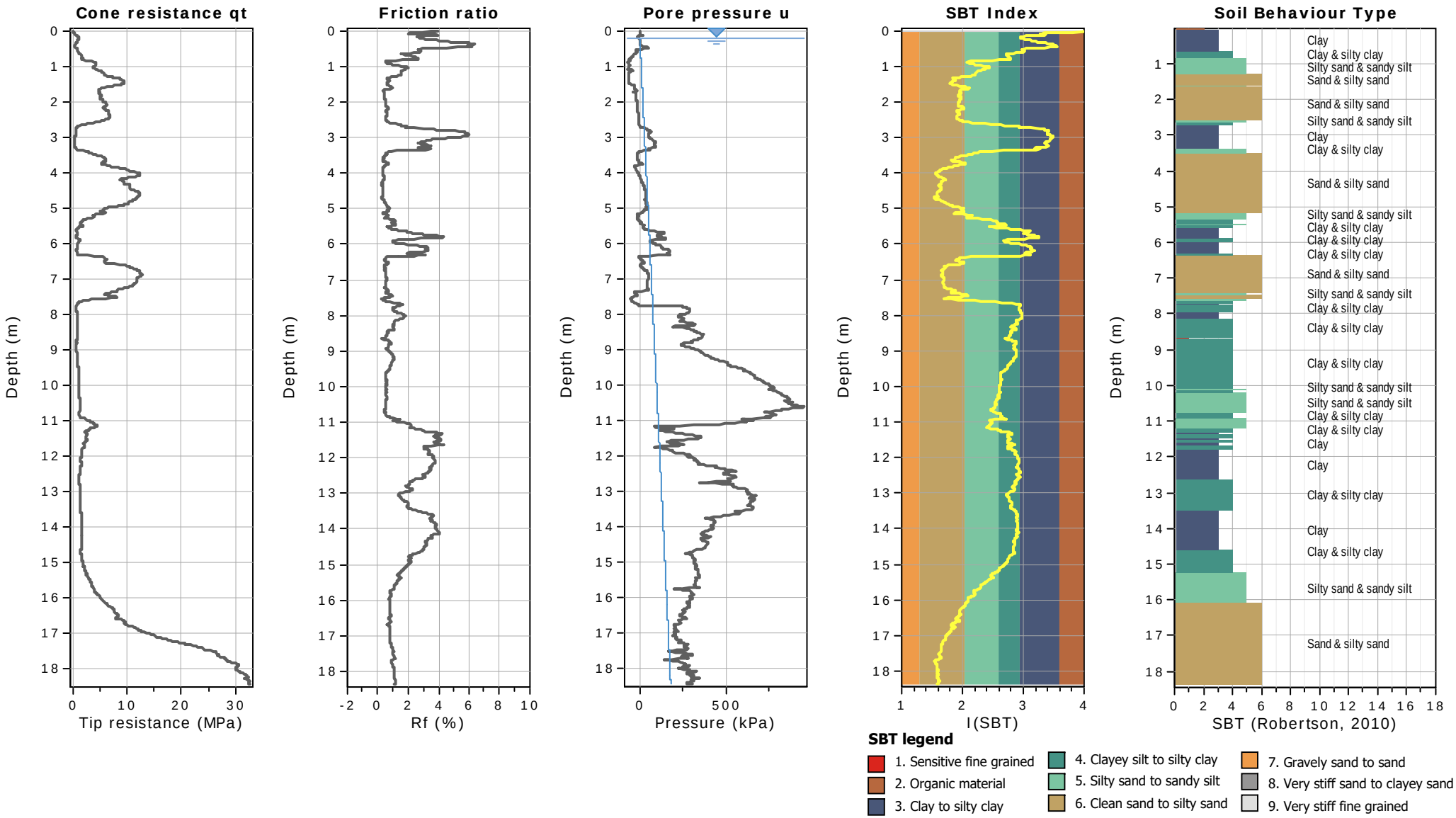
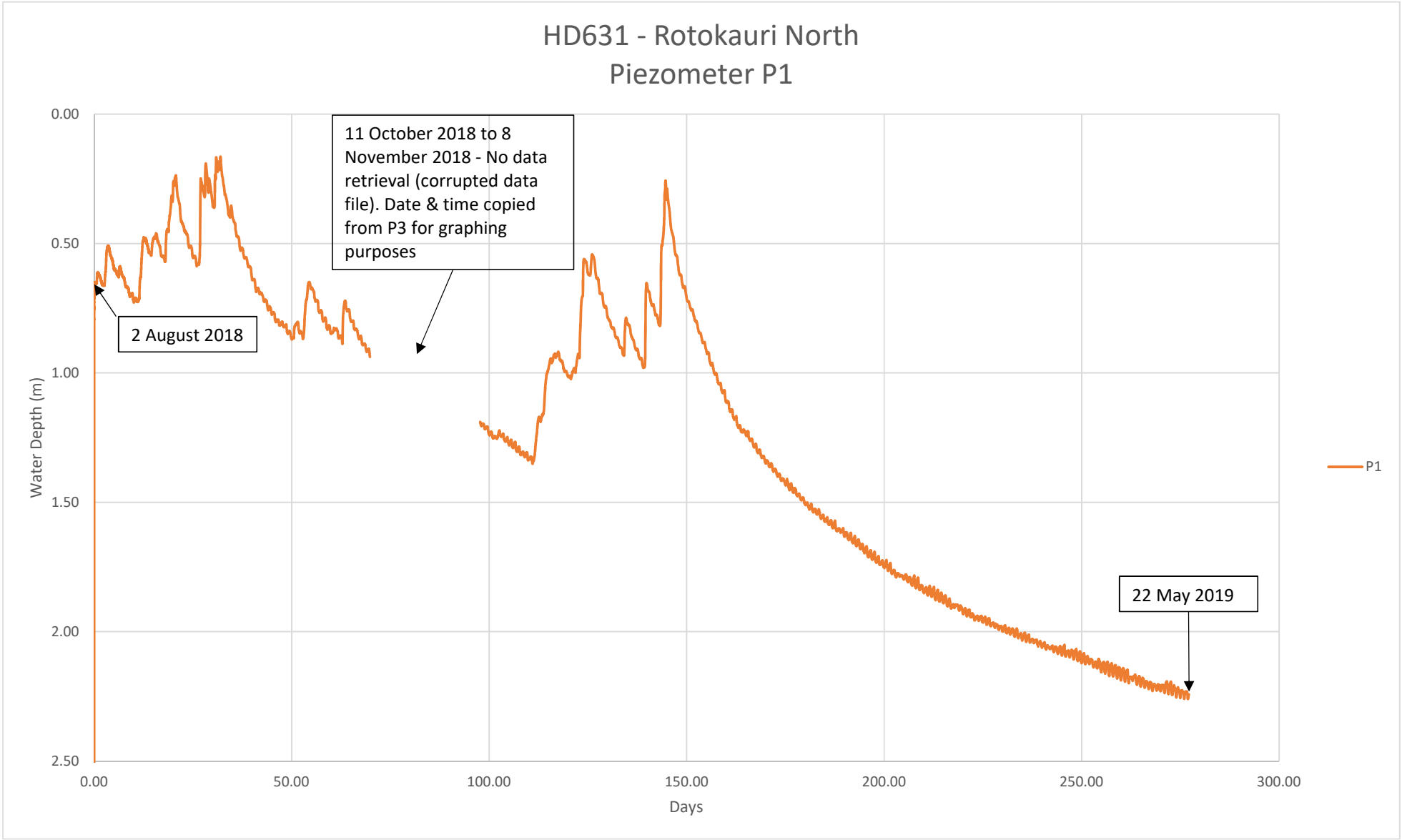
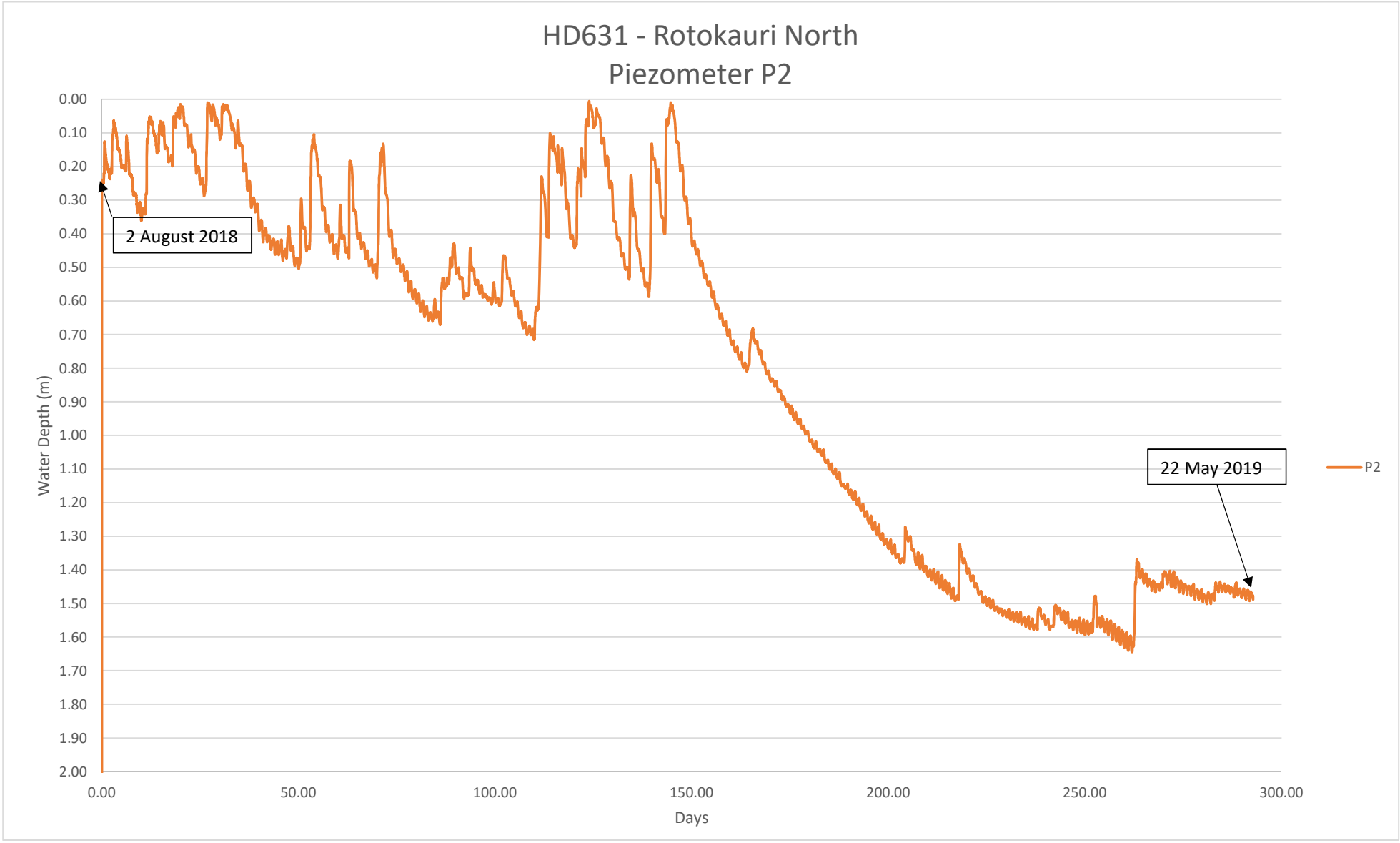


APPENDIX C -GROUNDWATER MONITORING DATA

Piezometer plots


HD631 - Rotokauri North
Piezometer P1
11 October 2018 to 8 November 2018 - No data retrieval (corrupted data file). Date & time copied from P3 for graphing purposes
2 August 2018
22 May 2019
Water Depth (m)
0.00
0.50
1.00
1.50
2.00
2.50
0.00
50.00
100.00
150.00
200.00
250.00
300.00
Days
P1


HD631 - Rotokauri North
Piezometer P2
Water Depth (m)
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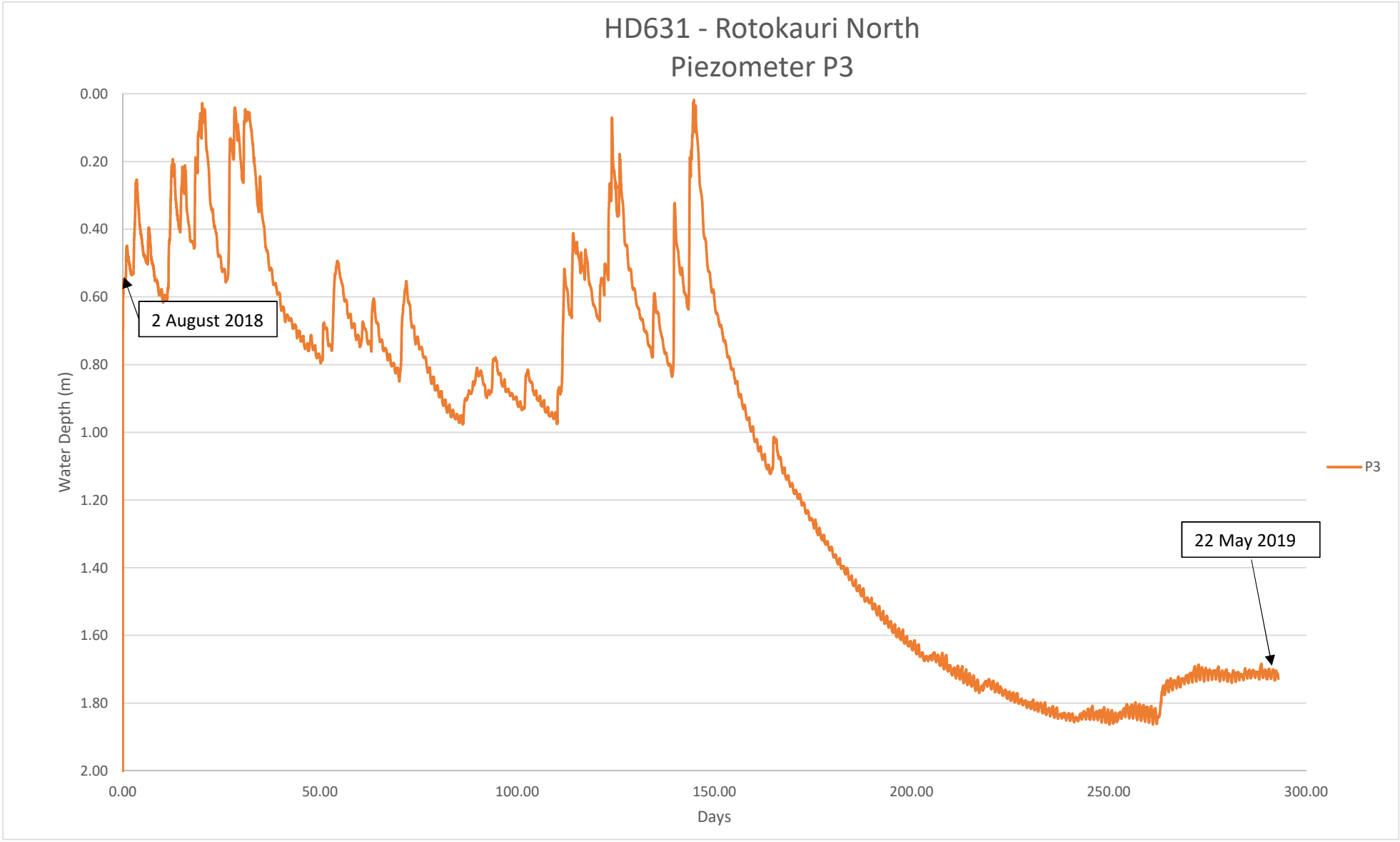
0.50
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.80
1.90
2.00
2 August 2018
22 May 2019
P2
0.00
50.00
100.00
150.00
200.00
250.00
300.00
Days


HD631 - Rotokauri North
Piezometer P3
Water Depth (m)
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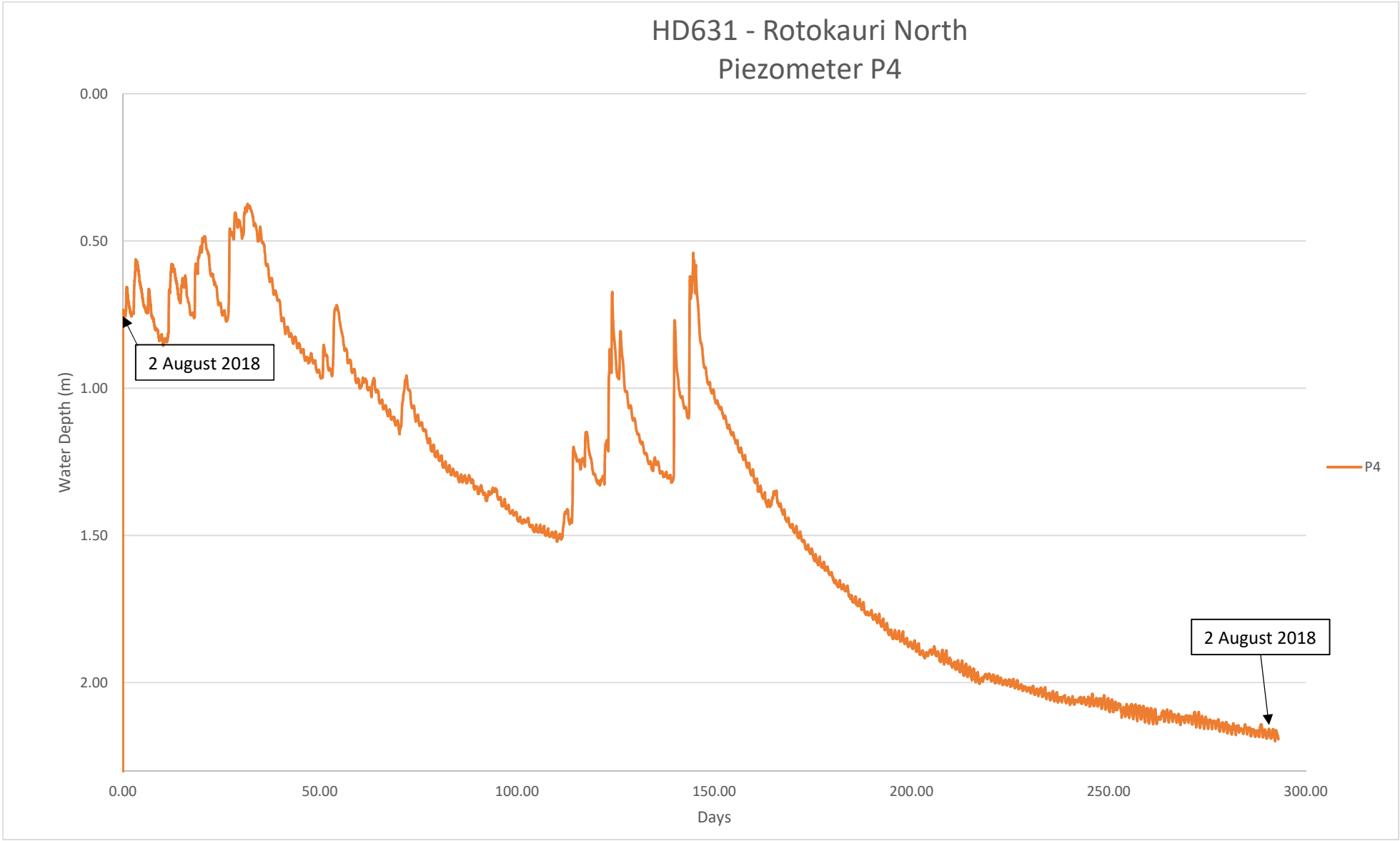
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
Days
2 August 2018
22 May 2019
P3


HD631 - Rotokauri North
Piezometer P4
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Water Depth (m)
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2 August 2018
P4
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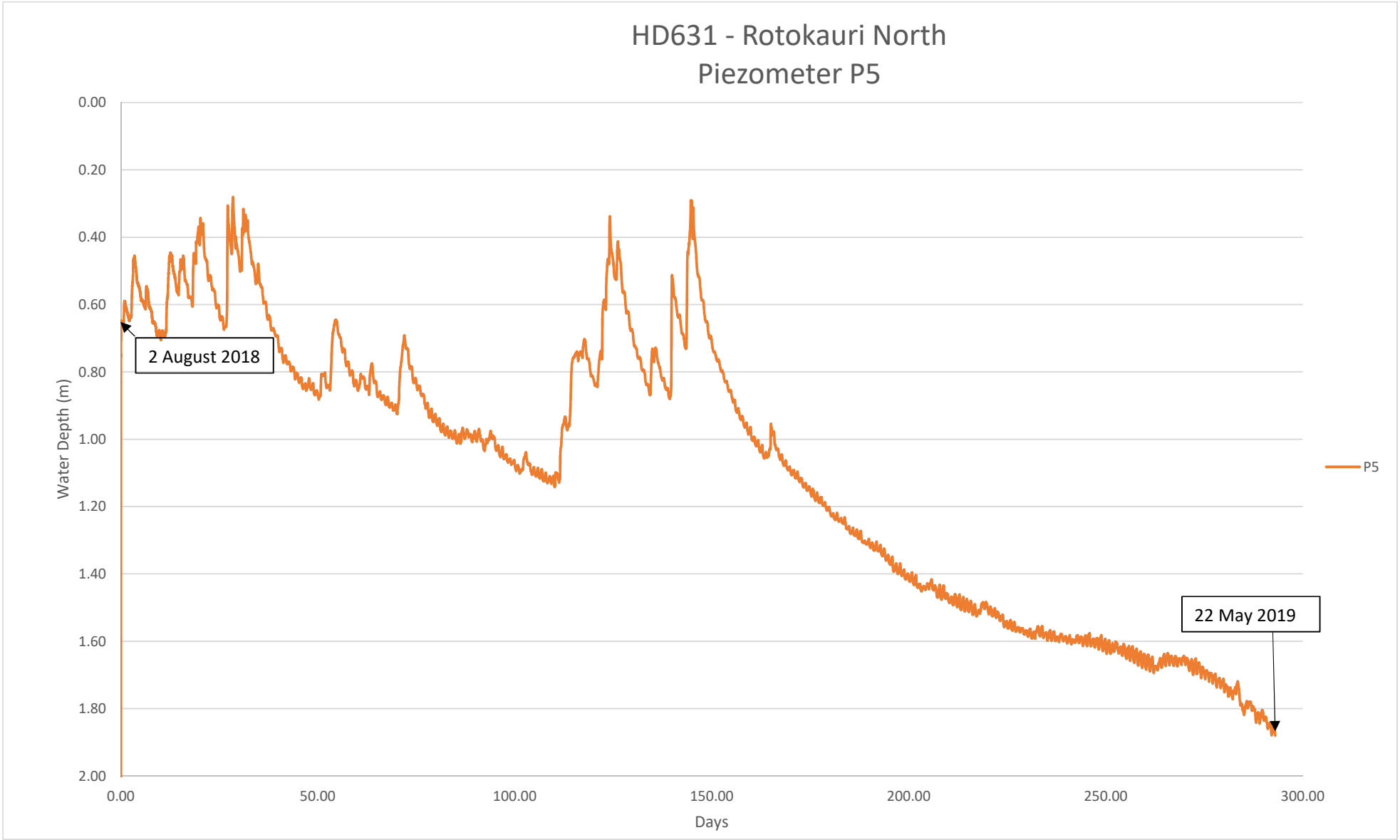
Days


HD631 - Rotokauri North
Piezometer P5
Water Depth (m)
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2 August 2018
22 May 2019
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50.00
100.00
150.00
200.00
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300.00
Days
P5

APPENDIX D – LIQUEFACTION ANALYSIS RESULTS

CPT analysis results

sCPT analysis results

HD Geo
PO Box 9266
Waikato Mail Centre, Hamilton
www.hdgeo.co.nz

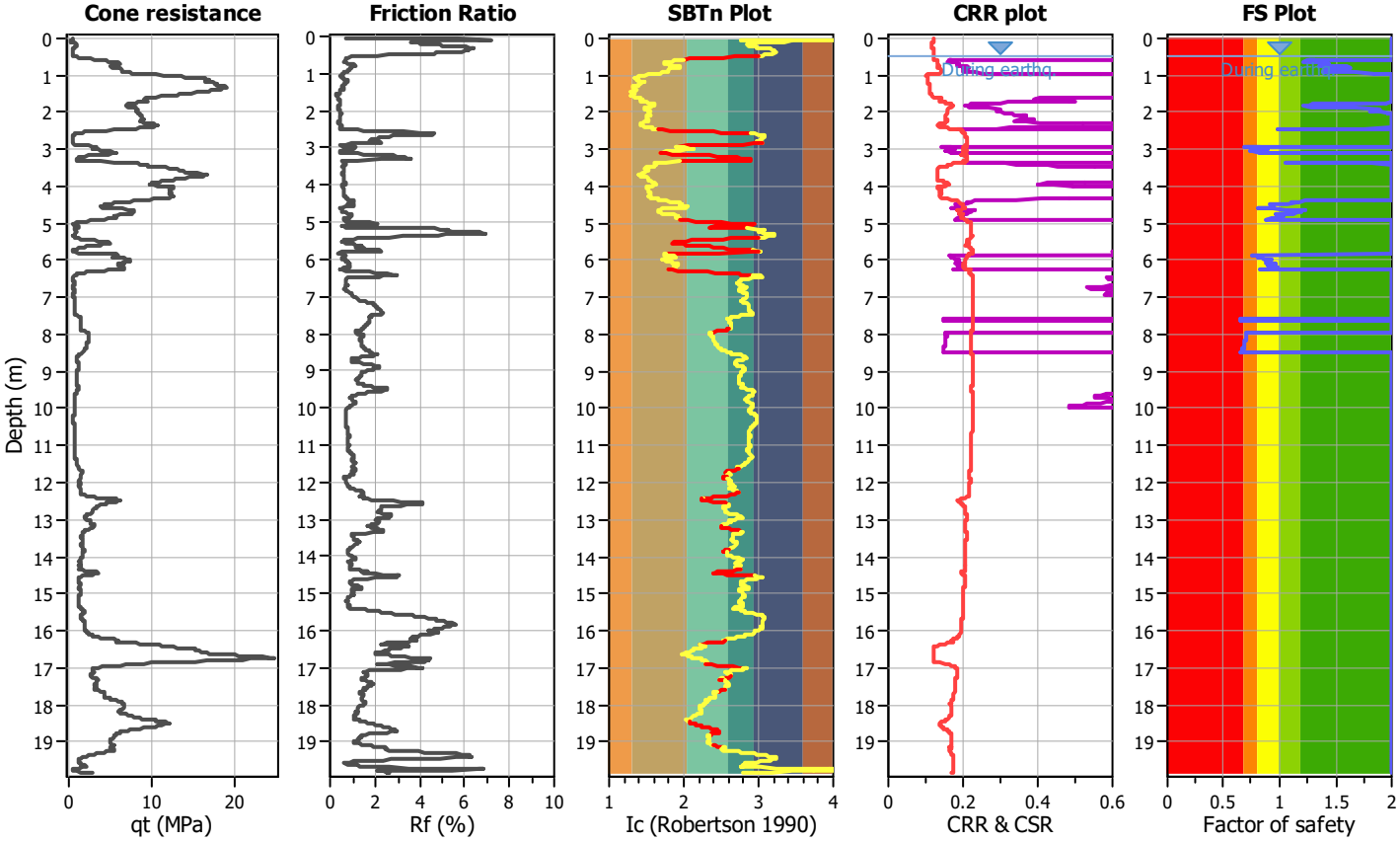
LIQUEFACTION ANALYSIS REPORT

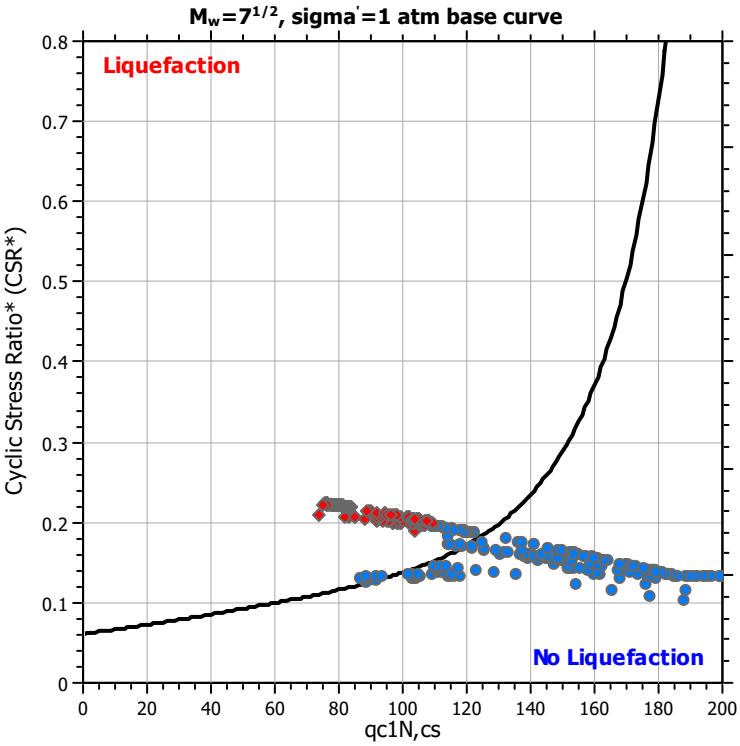
Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

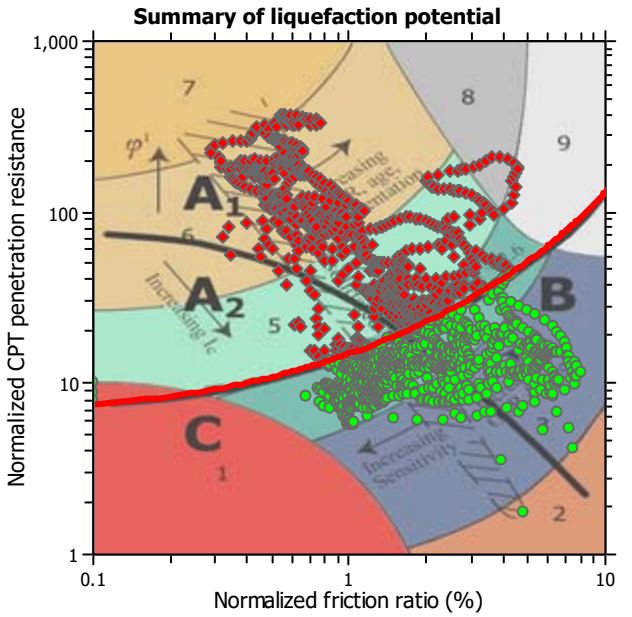
CPT file : CPT01

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.10 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

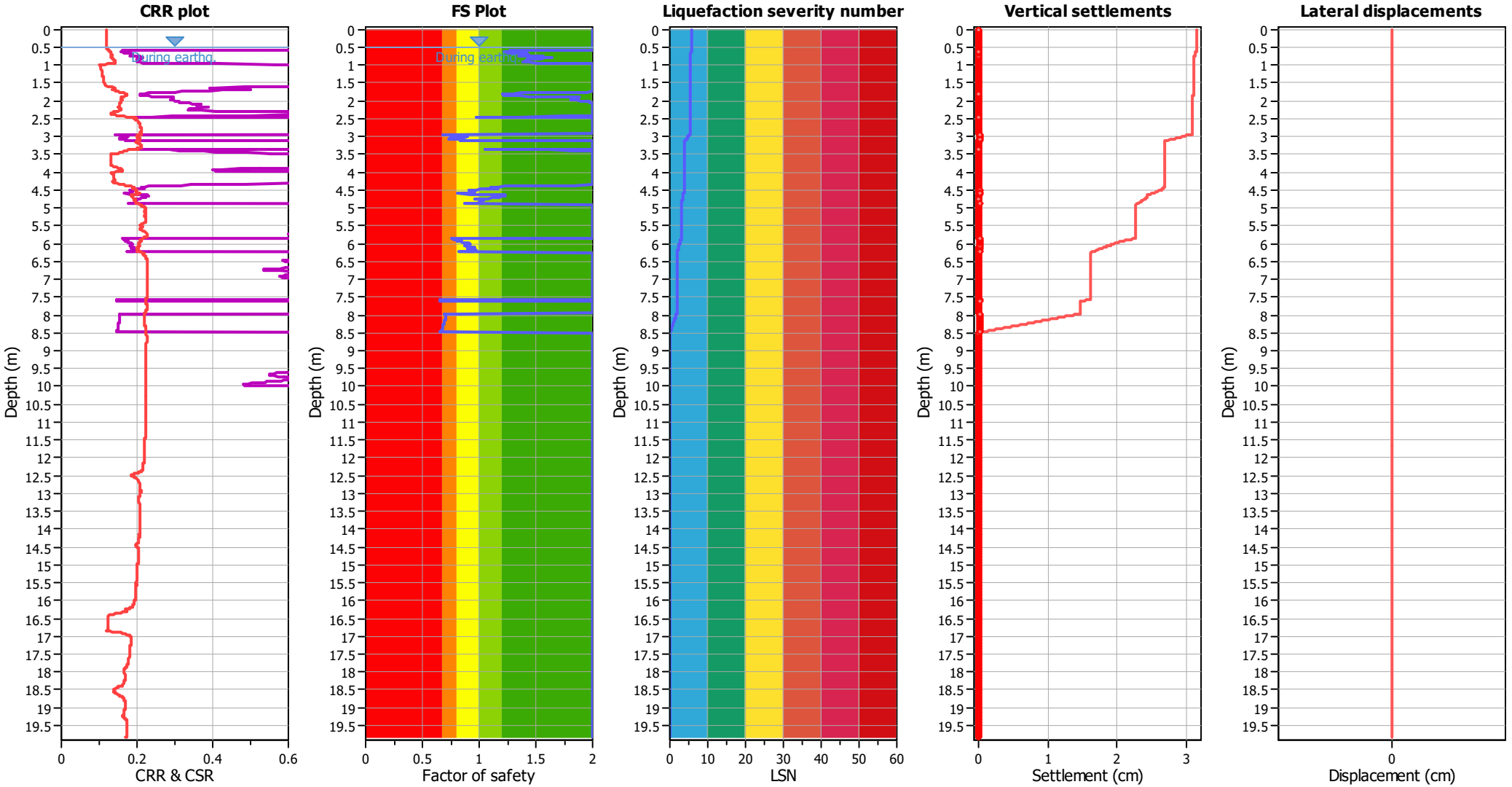






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.50 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:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.22	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	0.10 m	Fill height:	N/A	Limit depth:	10.00 m

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

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

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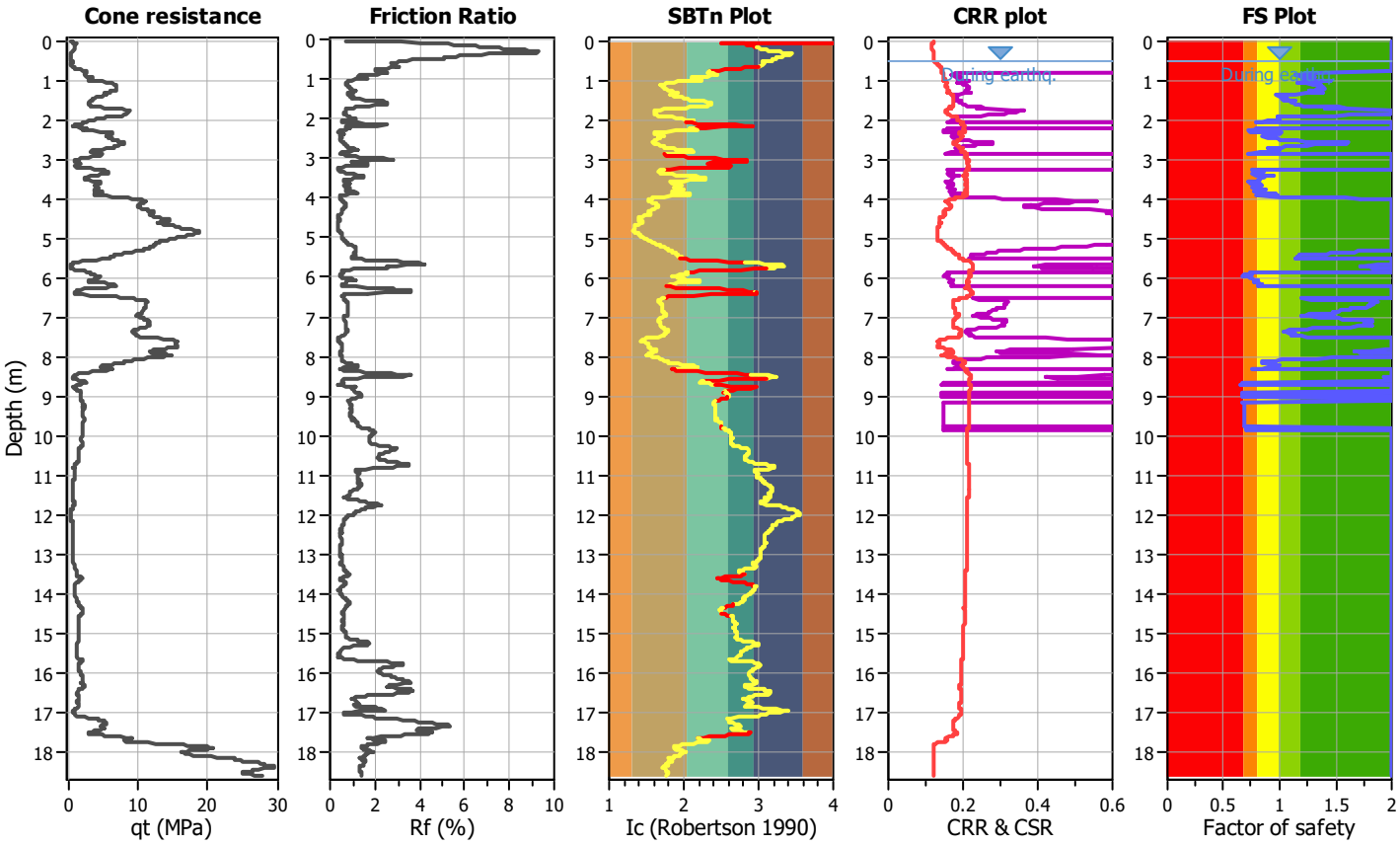
LIQUEFACTION ANALYSIS REPORT

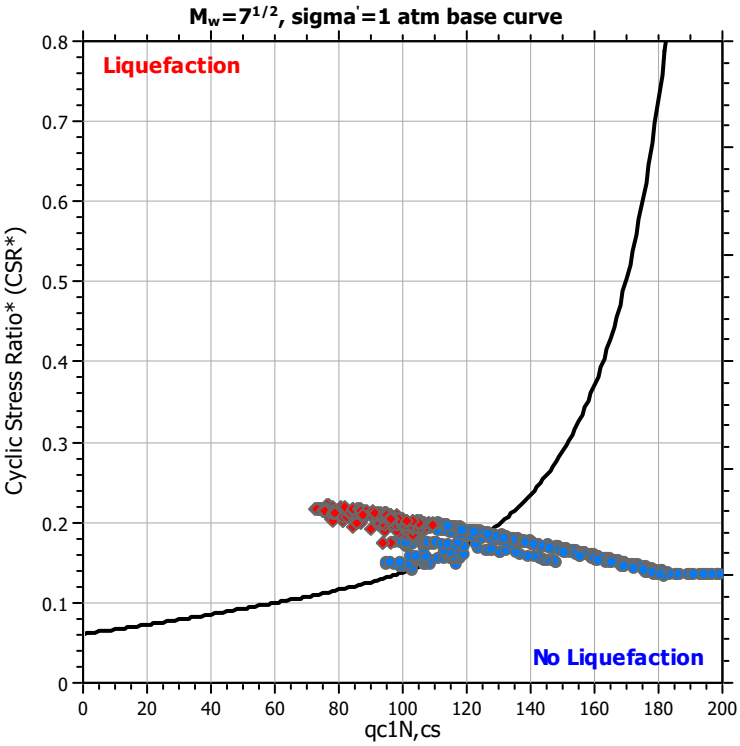
Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

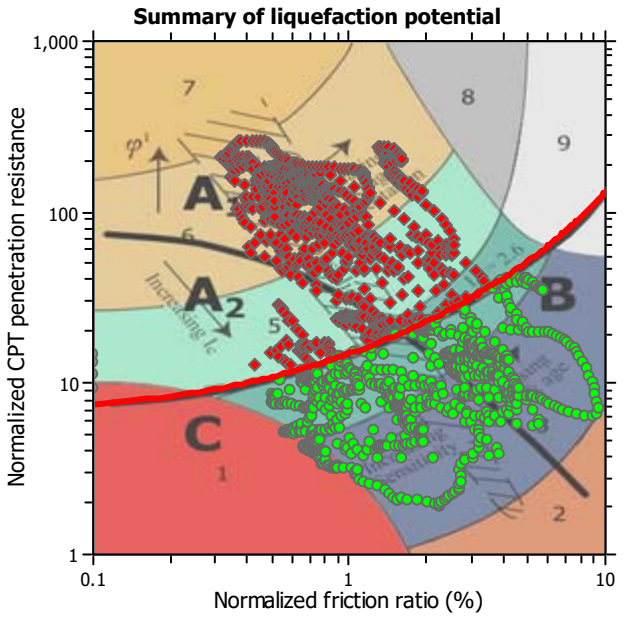
CPT file : CPT02

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.40 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

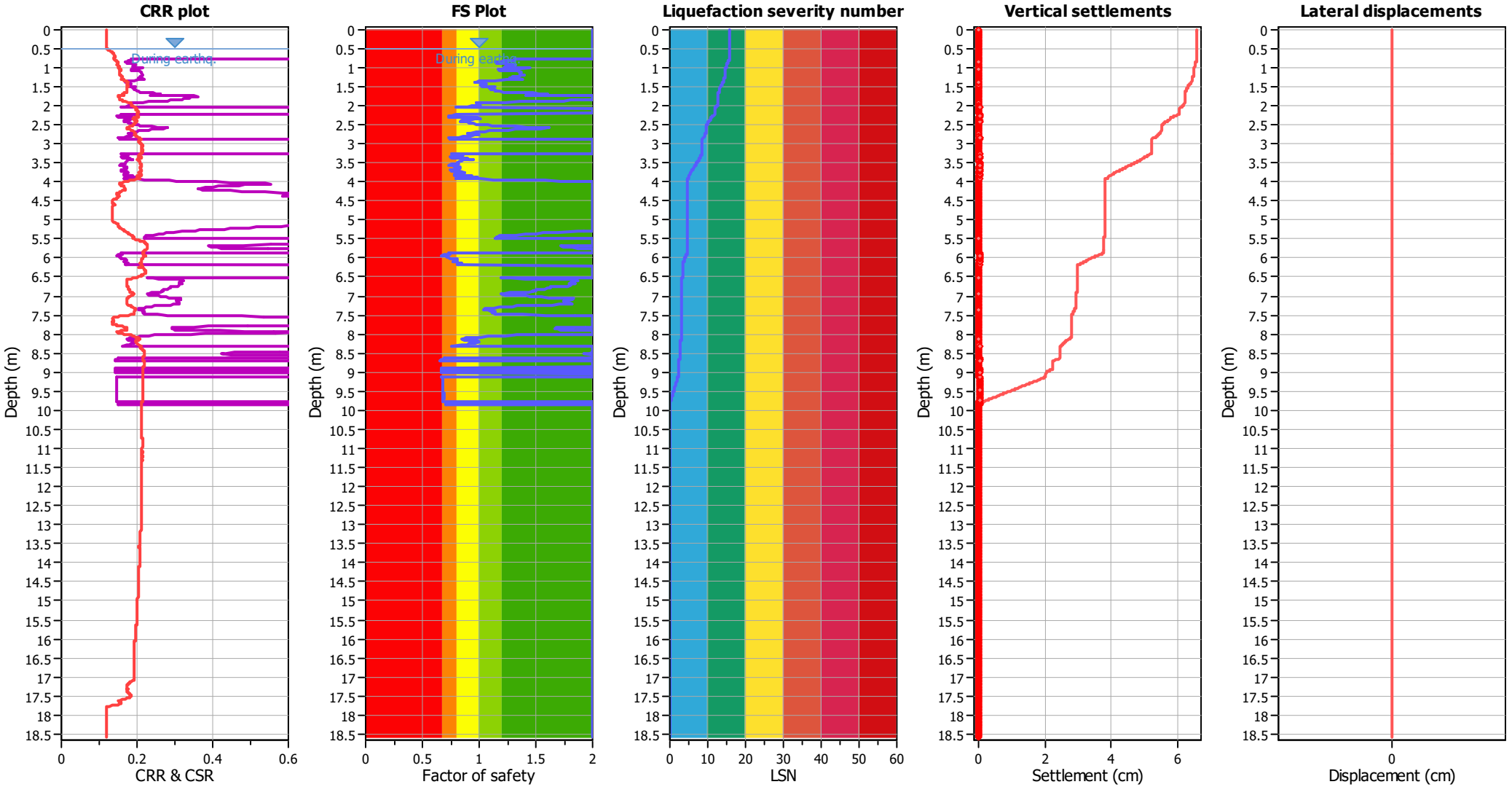






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.50 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:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.22	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	0.40 m	Fill height:	N/A	Limit depth:	10.00 m

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

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

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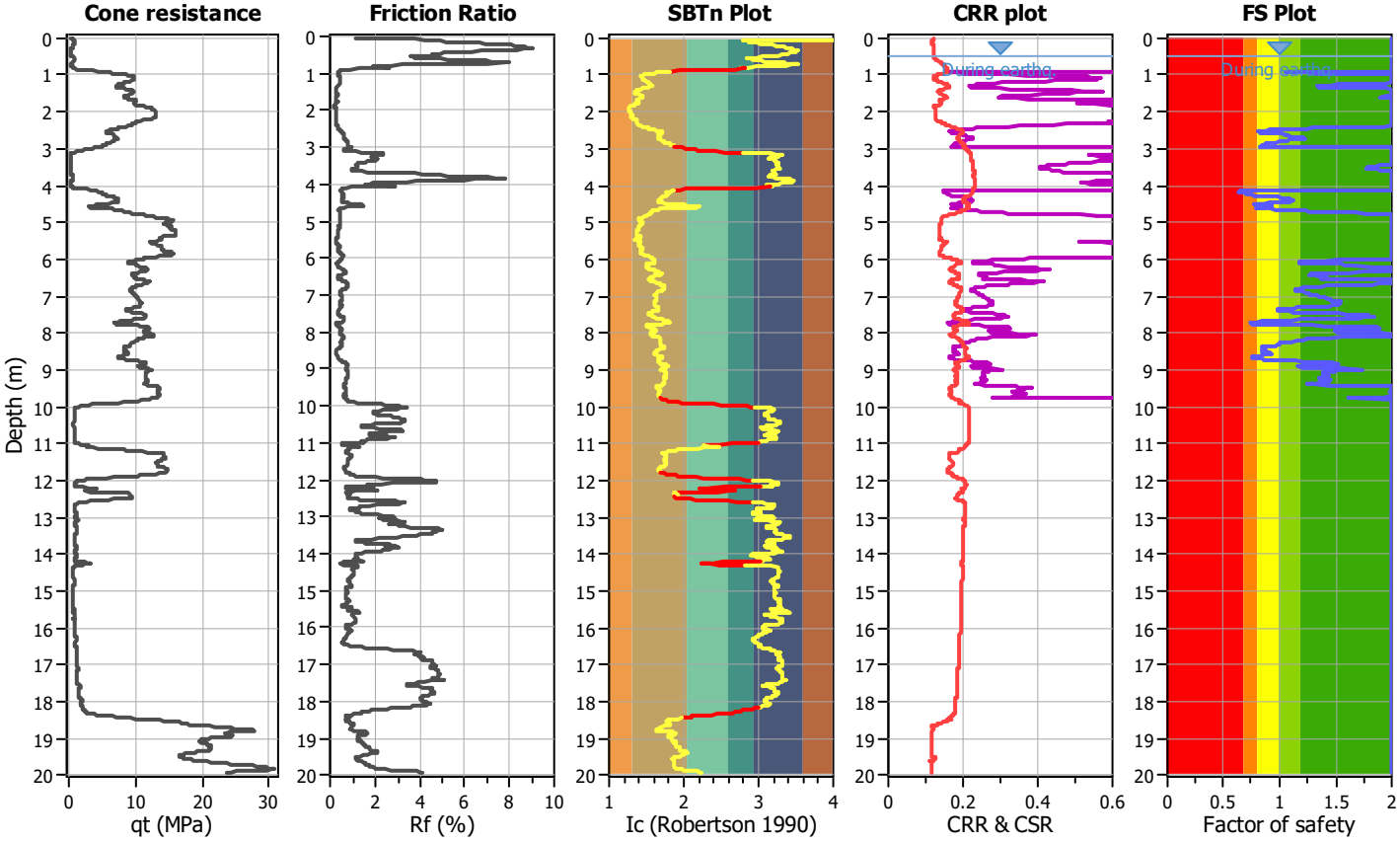
LIQUEFACTION ANALYSIS REPORT

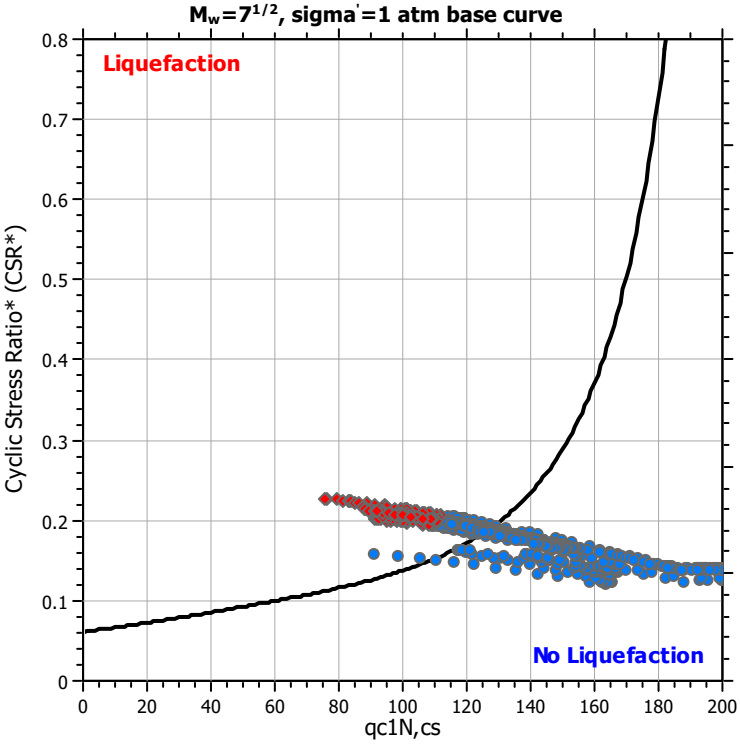
Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

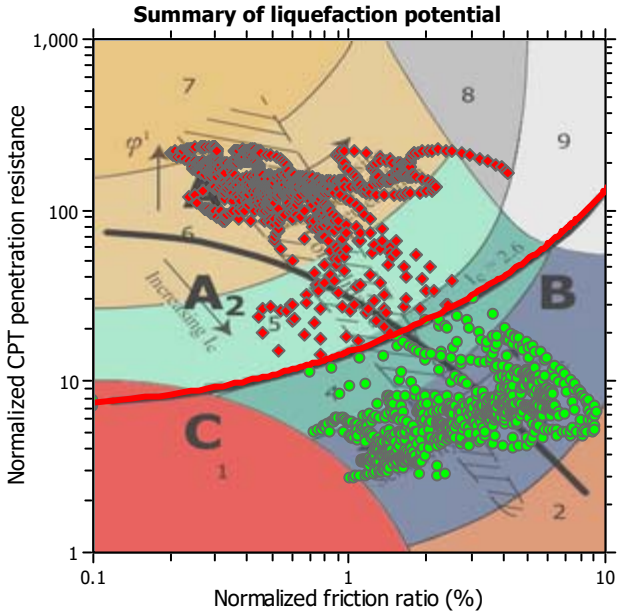
CPT file : CPT03

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.30 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

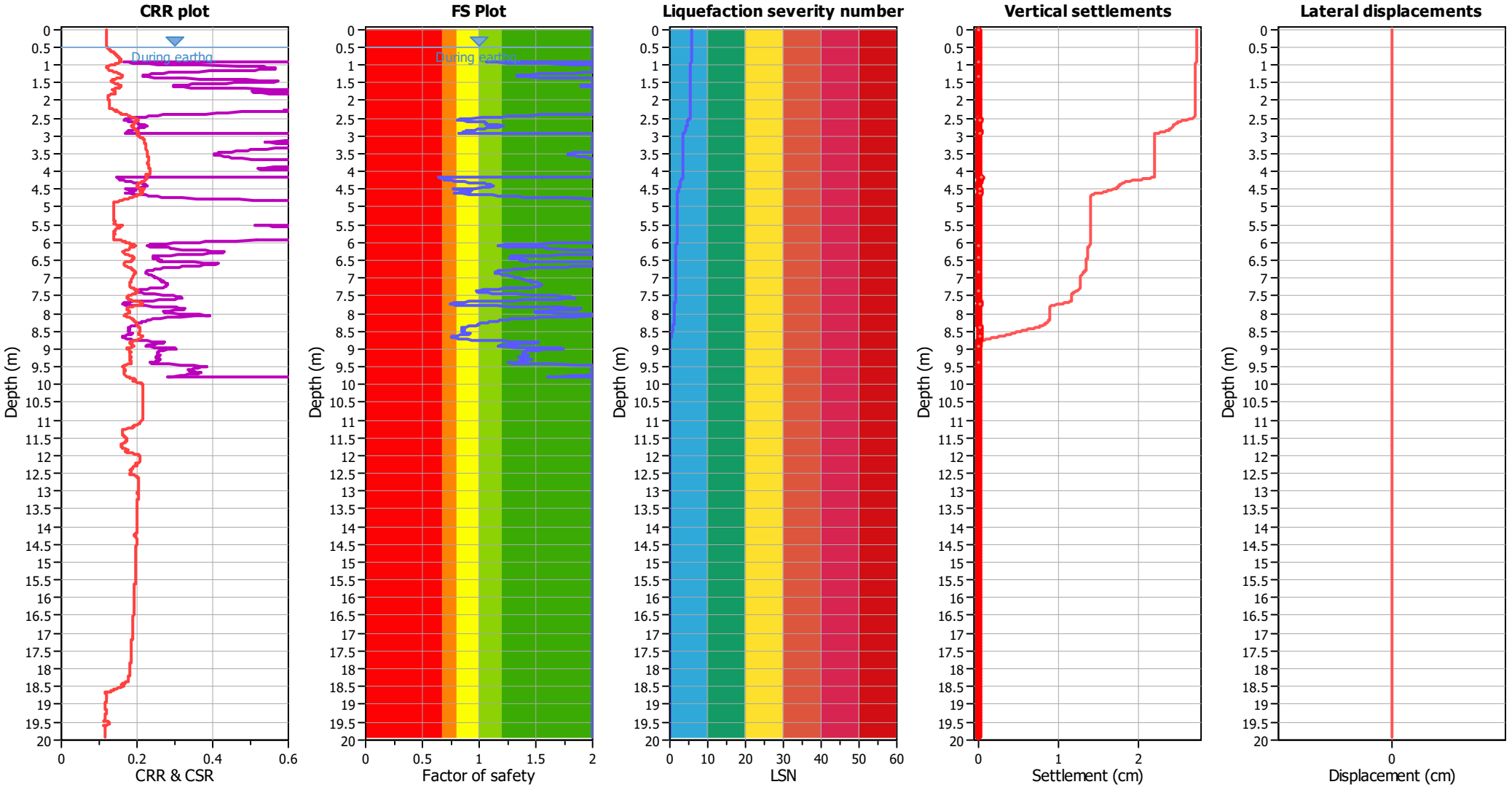






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.50 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:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.22	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	0.30 m	Fill height:	N/A	Limit depth:	10.00 m

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

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

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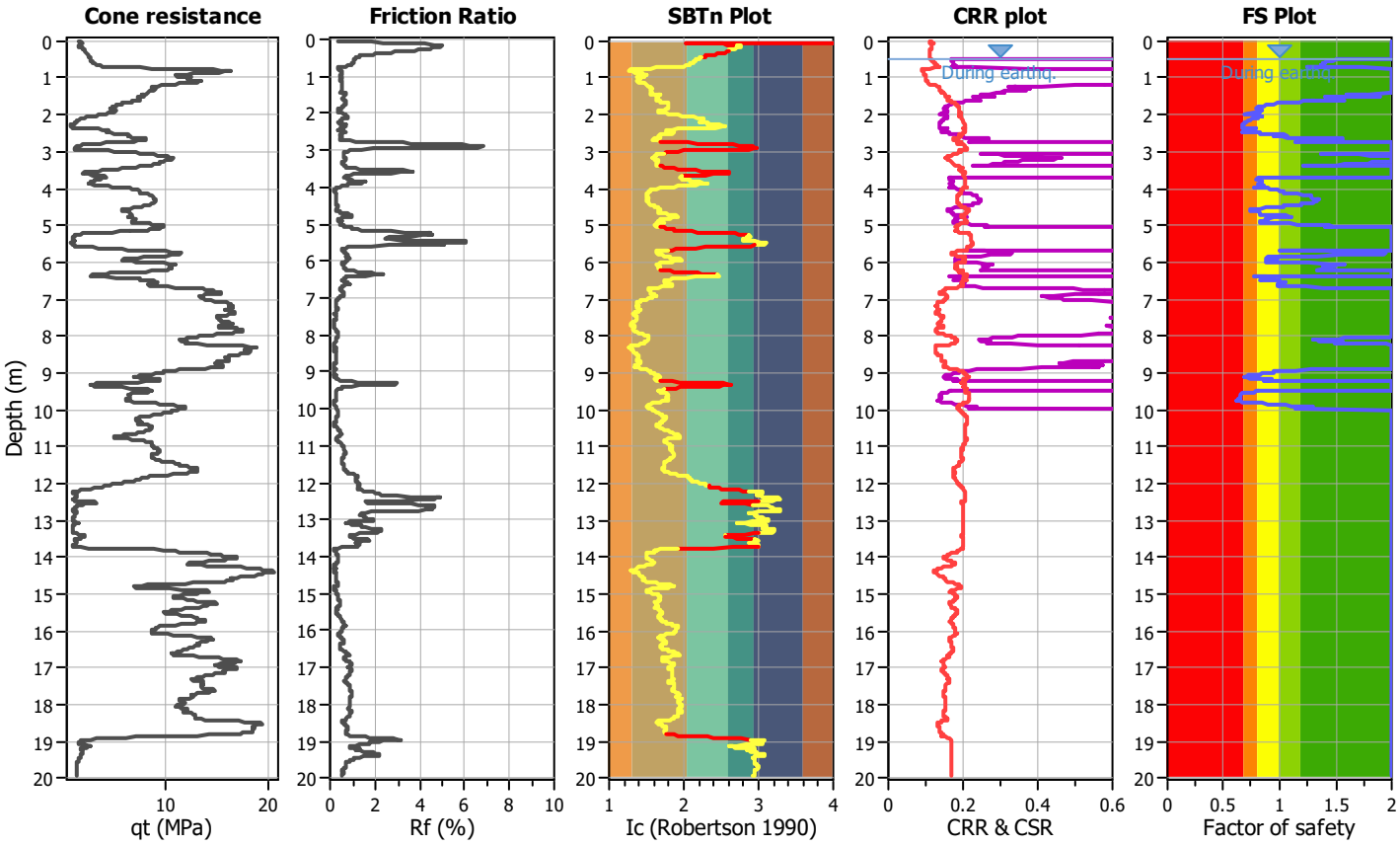
LIQUEFACTION ANALYSIS REPORT

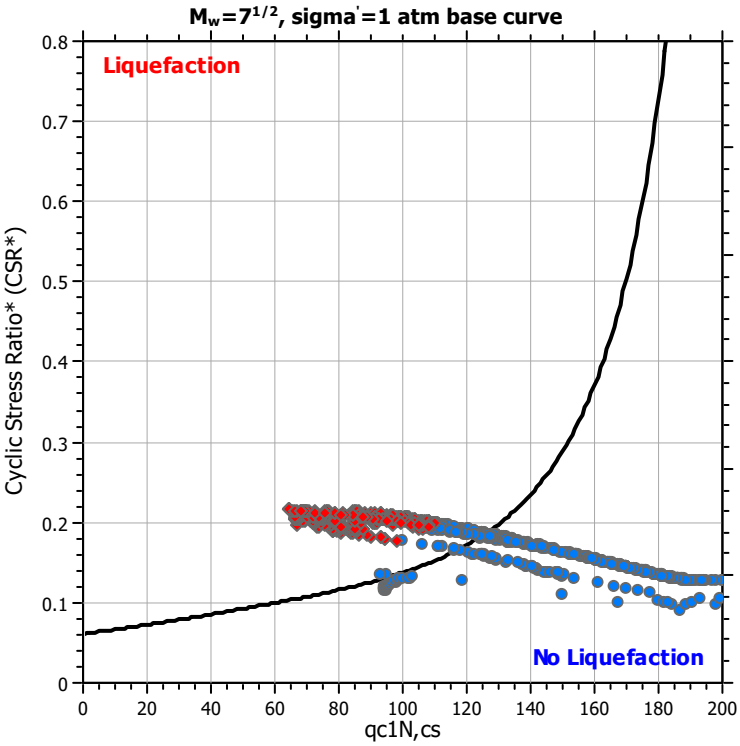
Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

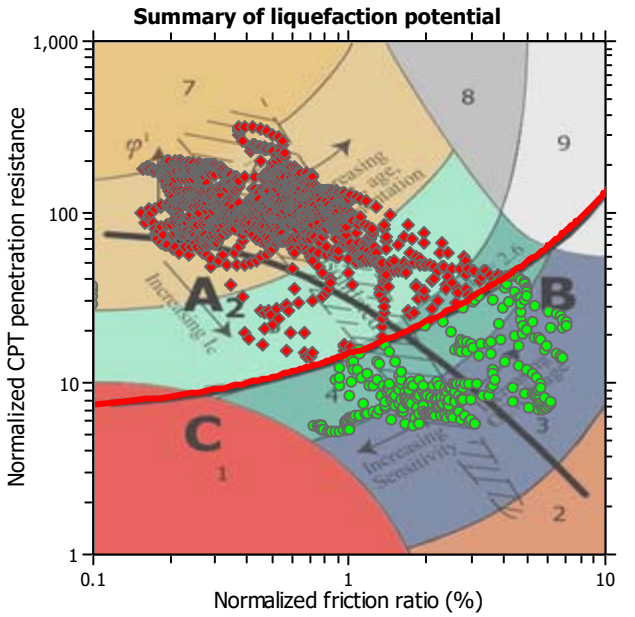
CPT file : CPT04

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.10 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

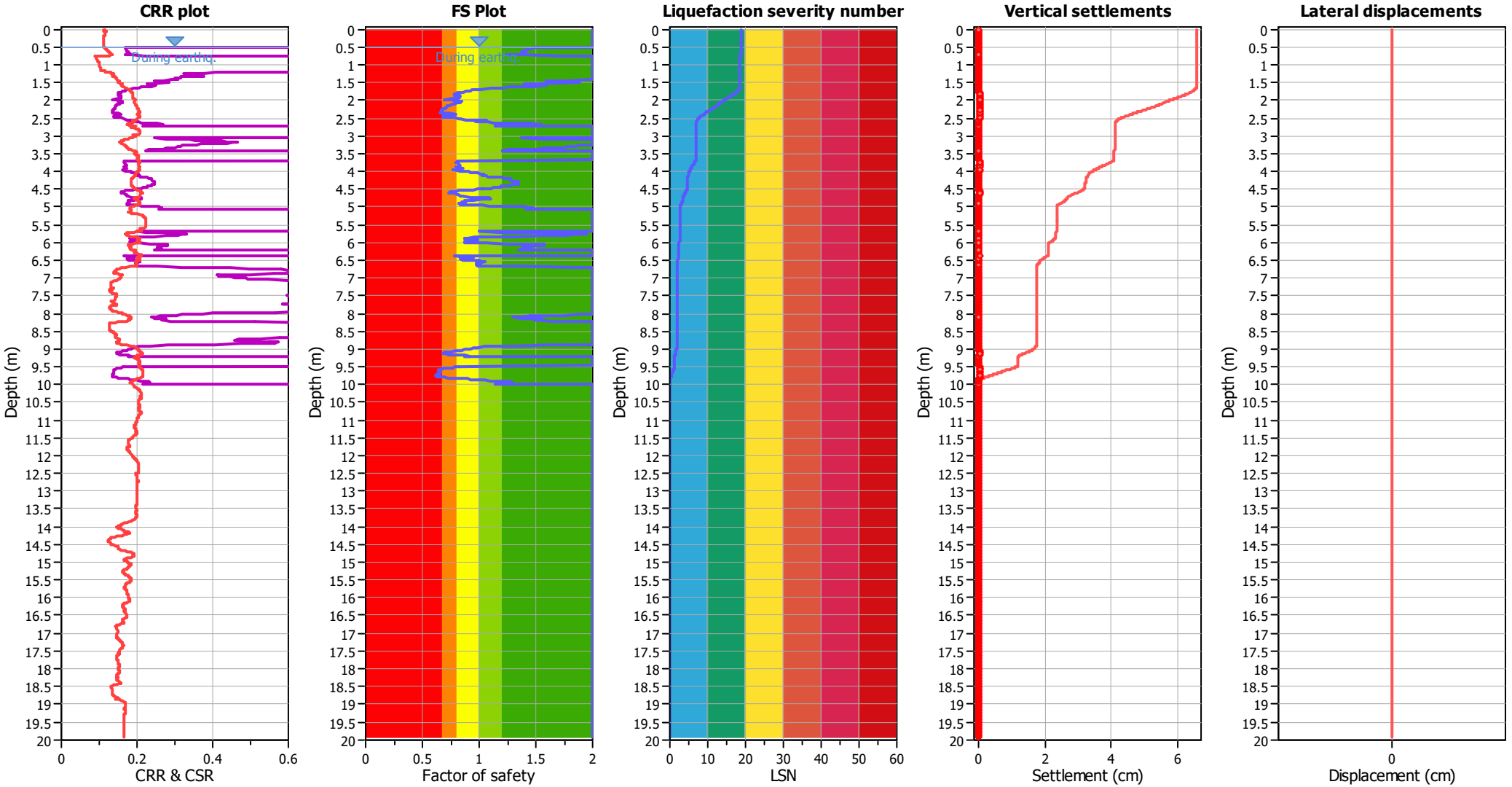






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.50 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:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.22	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.10 m	Fill height:	N/A	Limit depth:	10.00 m

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

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

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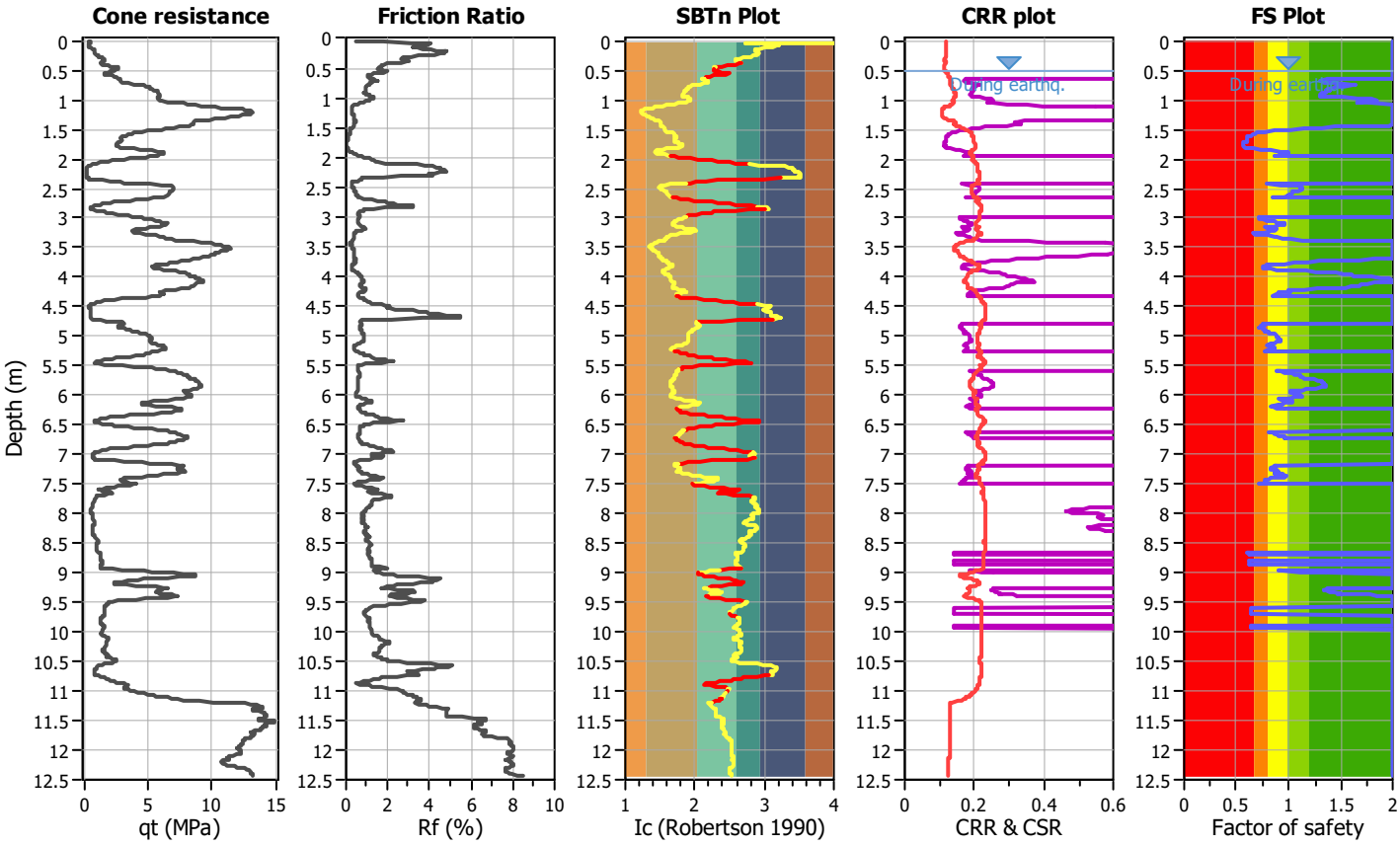
LIQUEFACTION ANALYSIS REPORT

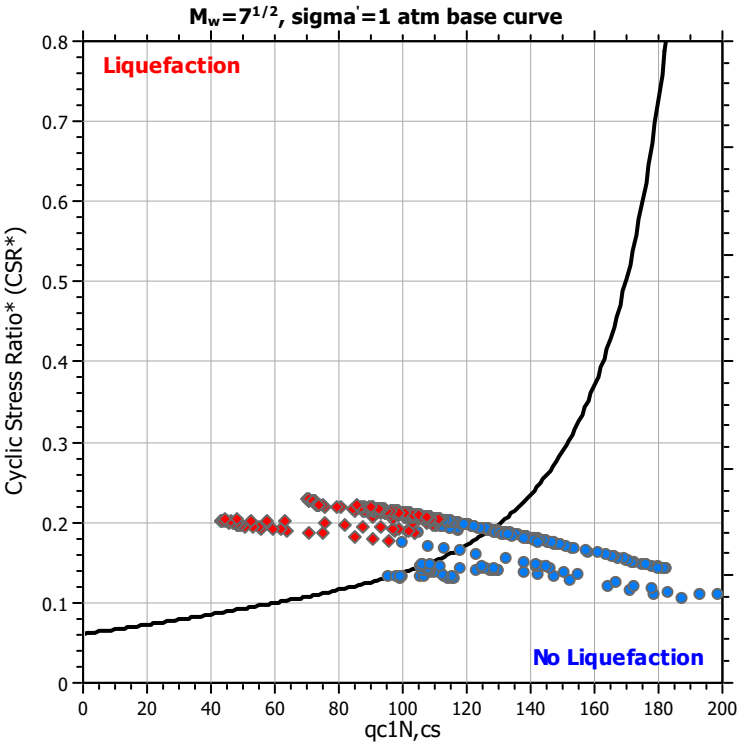
Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

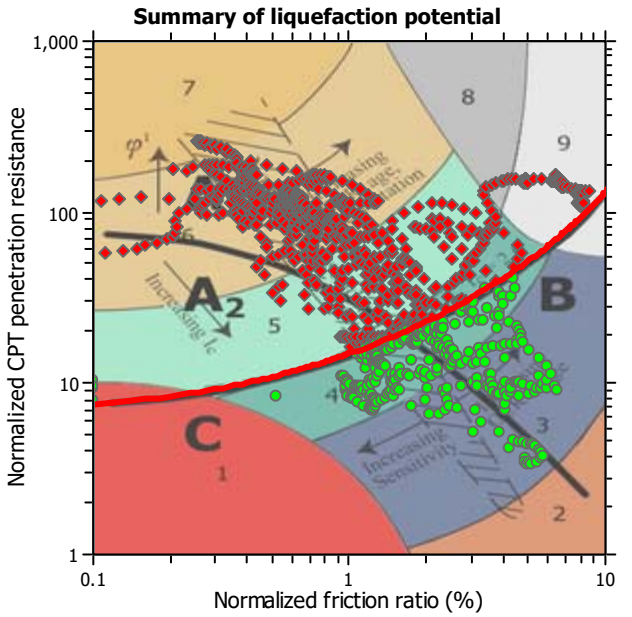
CPT file : CPT05

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.10 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

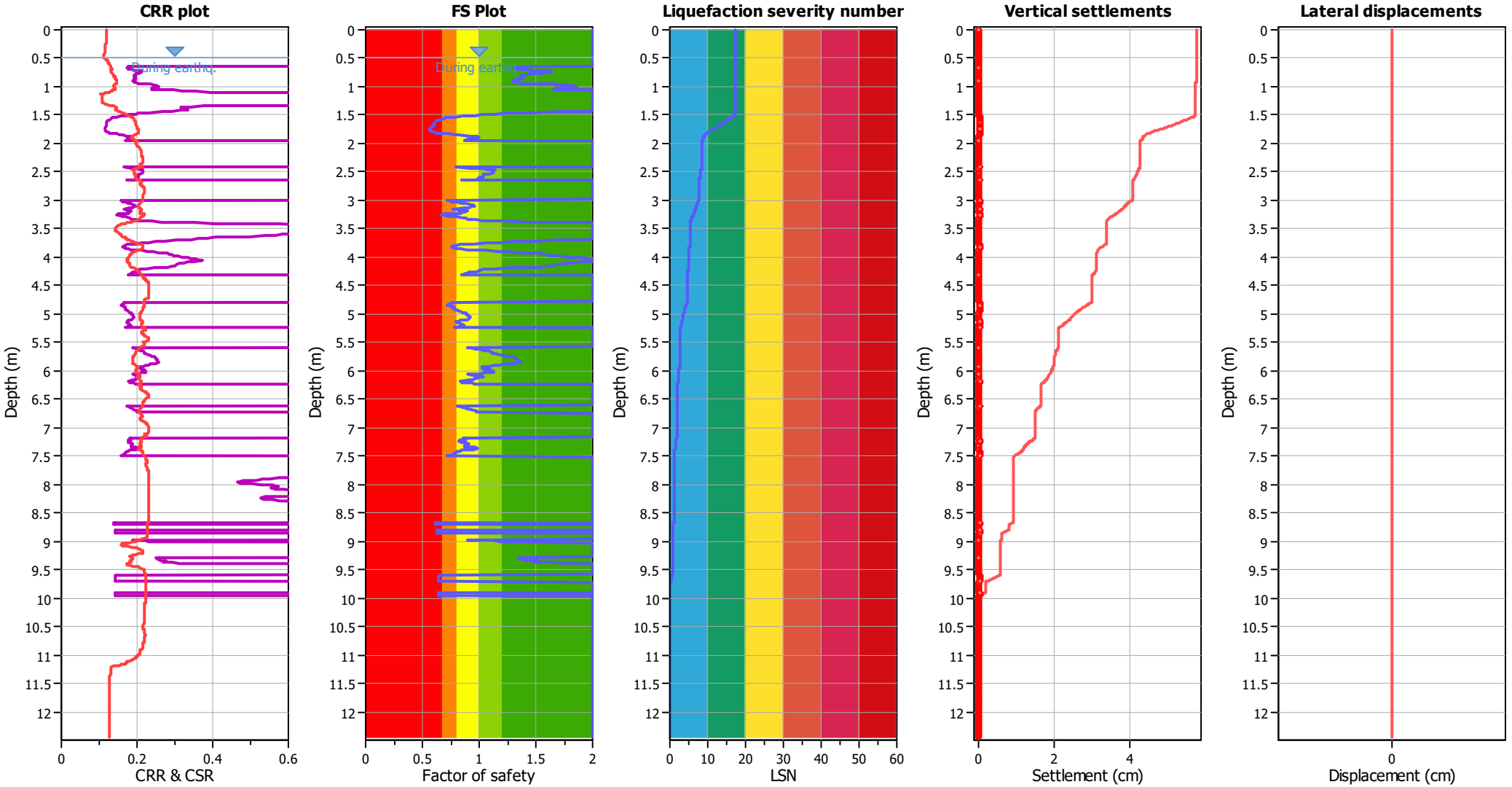






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.50 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:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.22	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	0.10 m	Fill height:	N/A	Limit depth:	10.00 m

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

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

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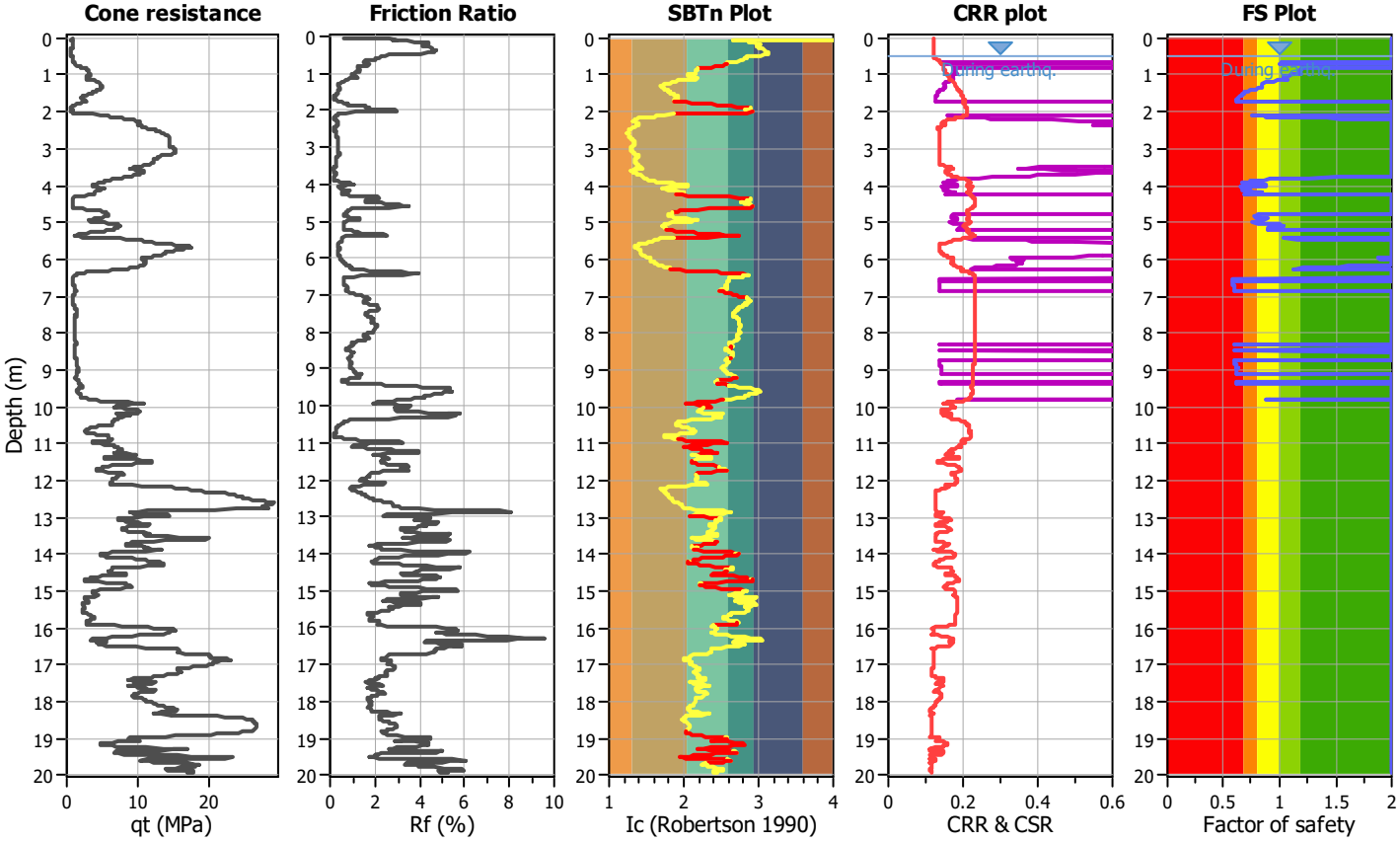
LIQUEFACTION ANALYSIS REPORT

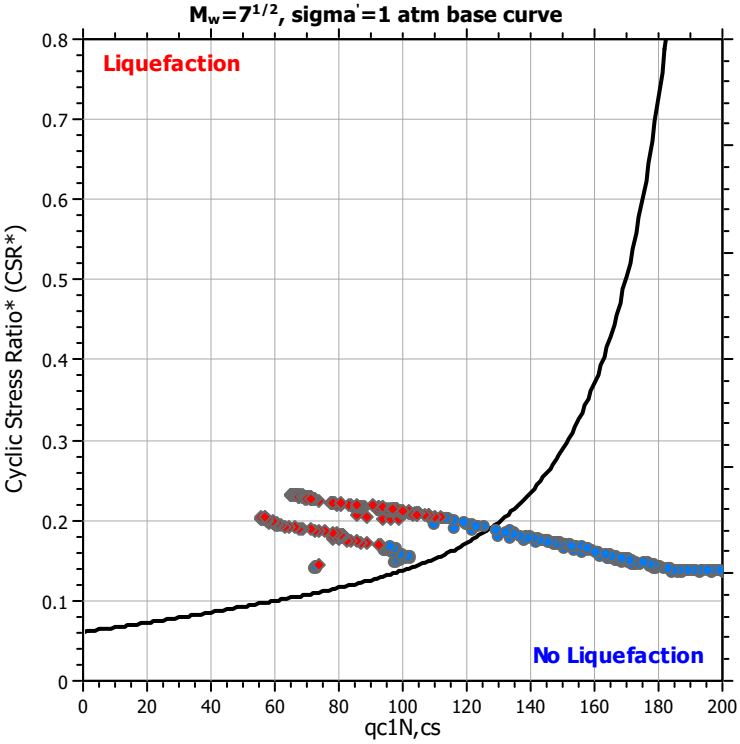
Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

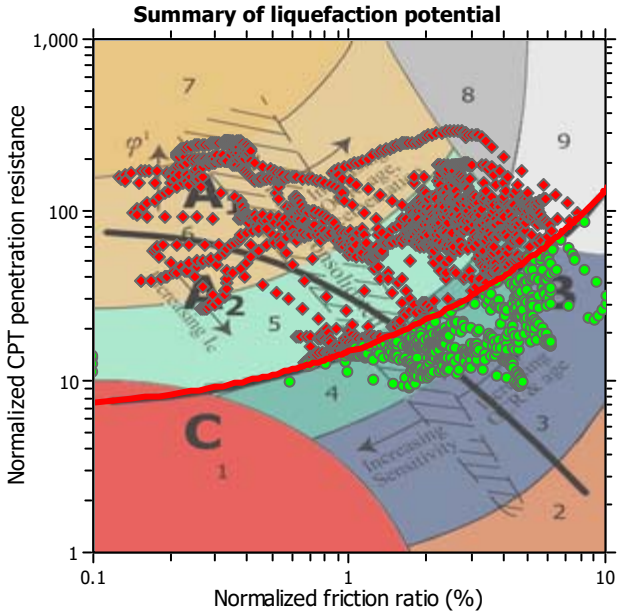
CPT file : CPT06

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.20 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

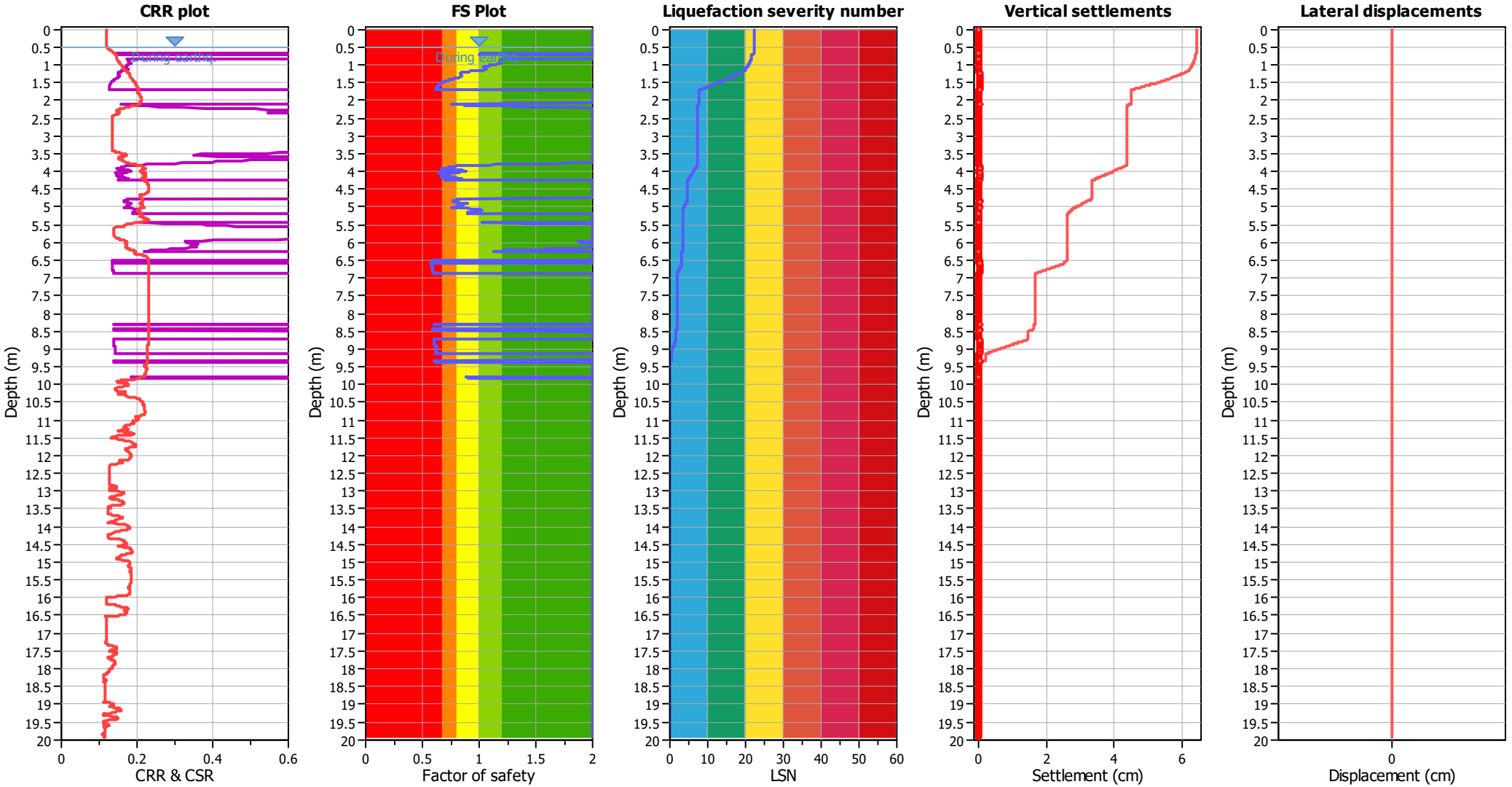






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.50 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:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.22	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	0.20 m	Fill height:	N/A	Limit depth:	10.00 m

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

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

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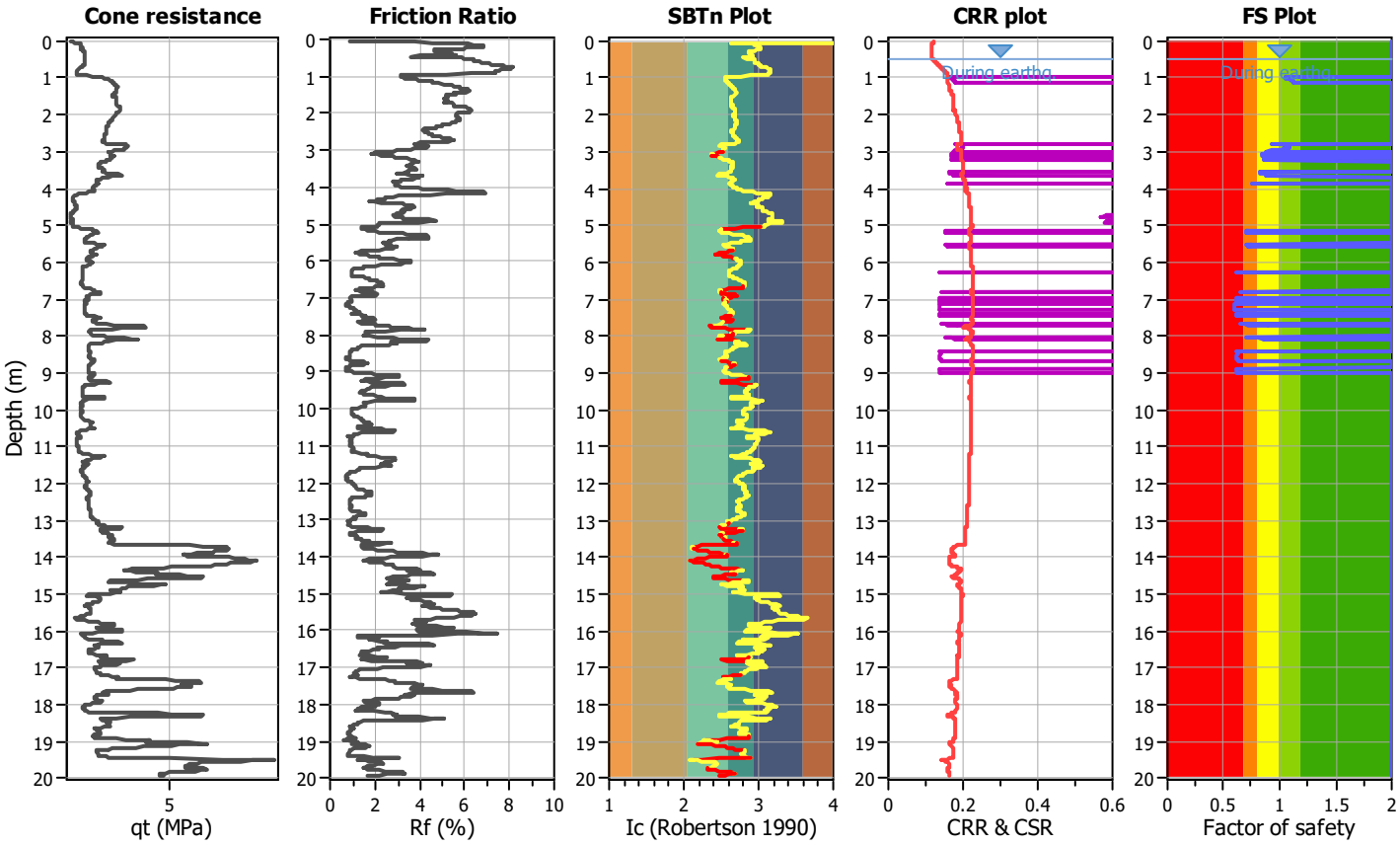
LIQUEFACTION ANALYSIS REPORT

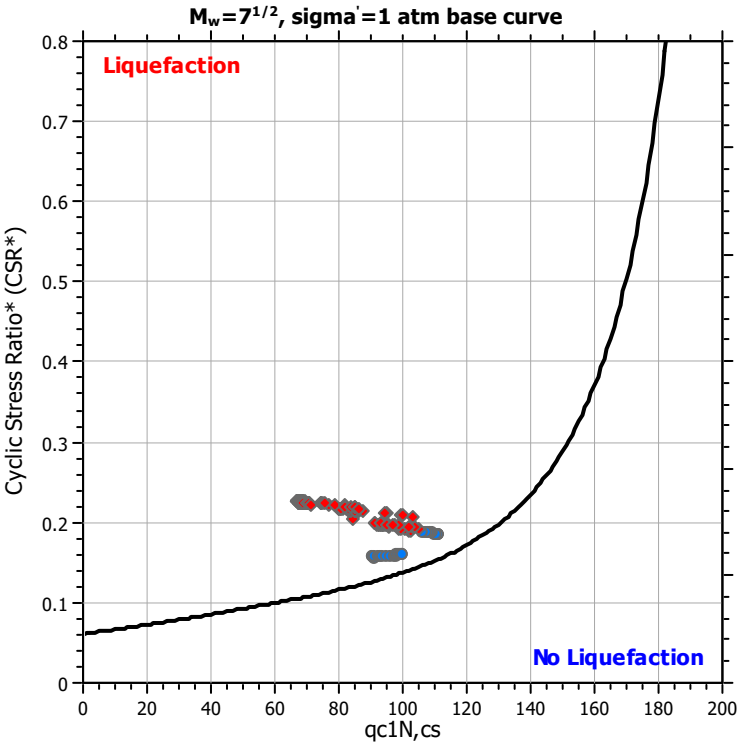
Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

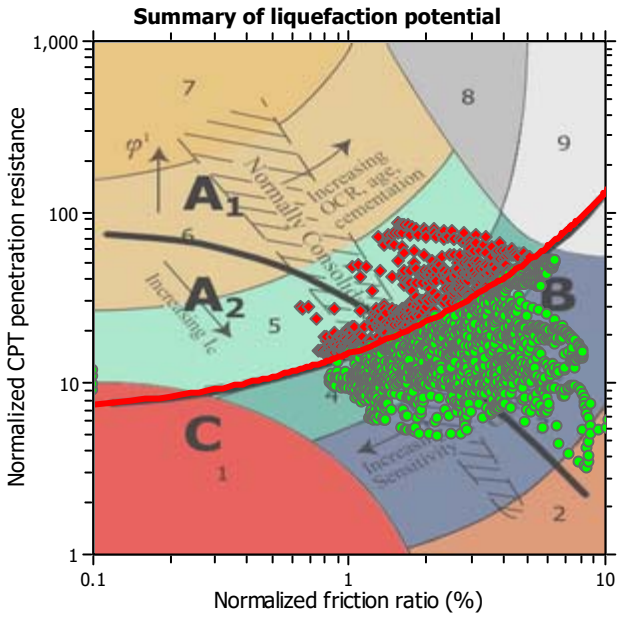
CPT file : CPT07

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.00 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

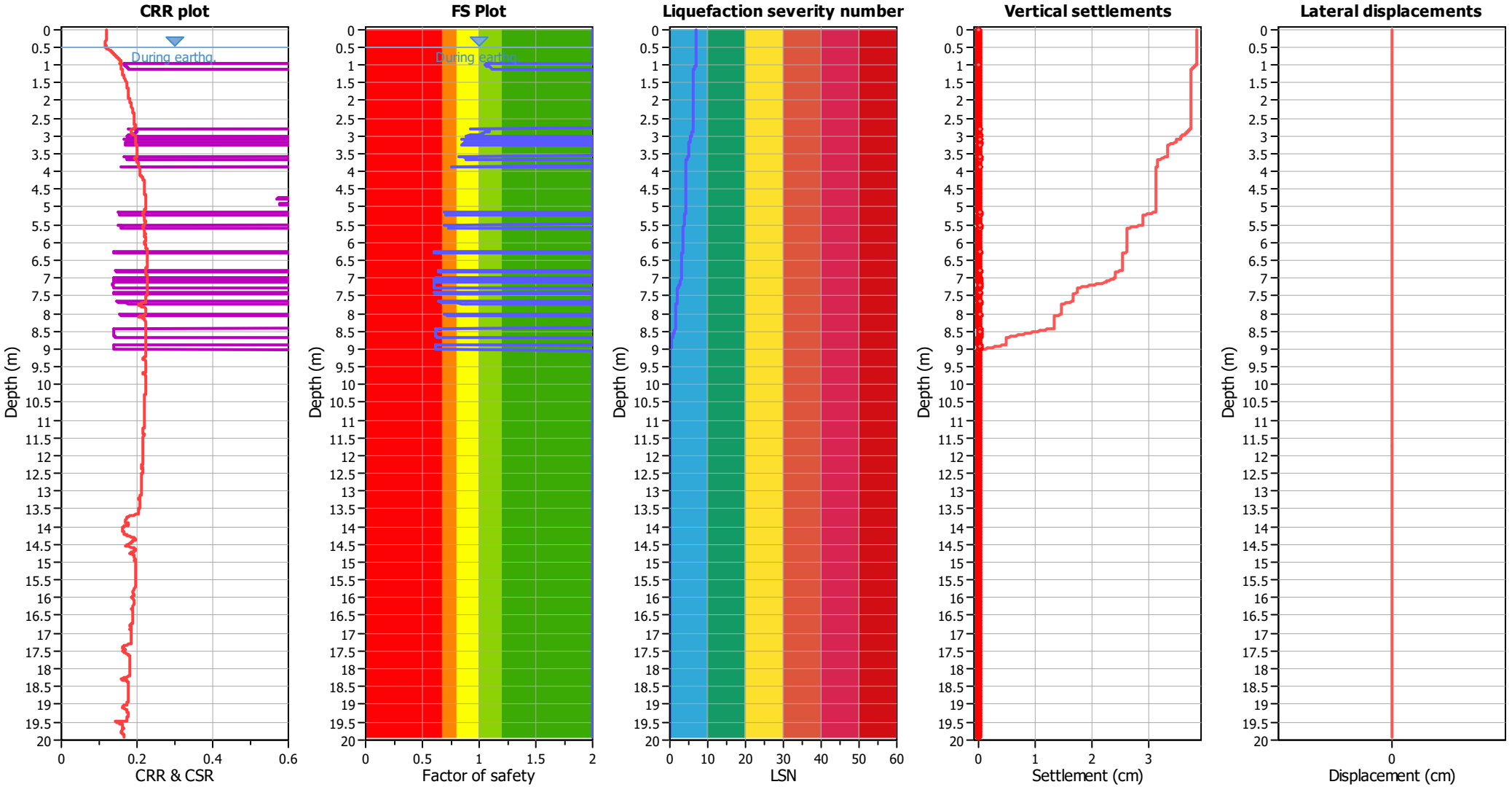






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.50 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:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.22	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	0.00 m	Fill height:	N/A	Limit depth:	10.00 m

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

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

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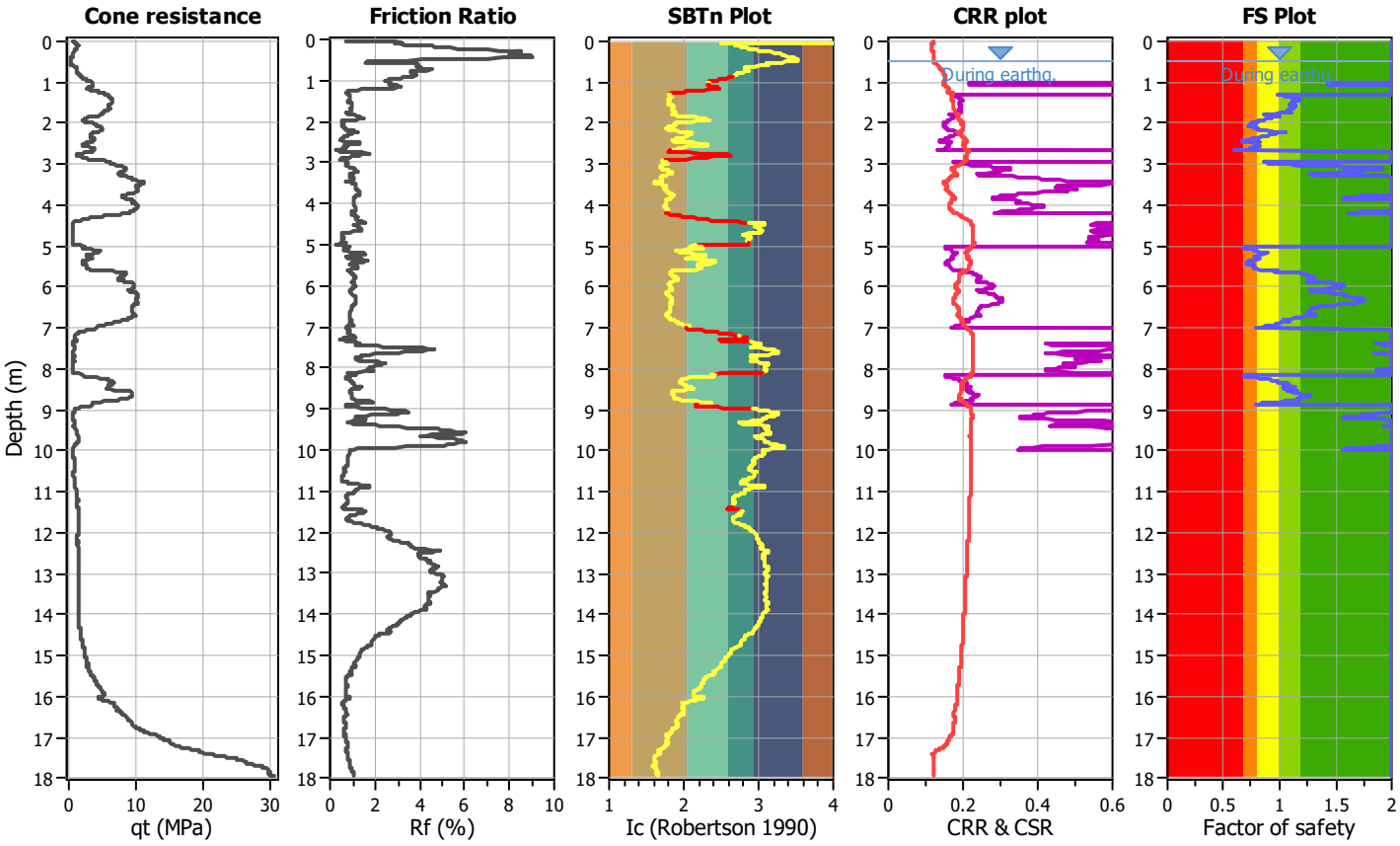
LIQUEFACTION ANALYSIS REPORT

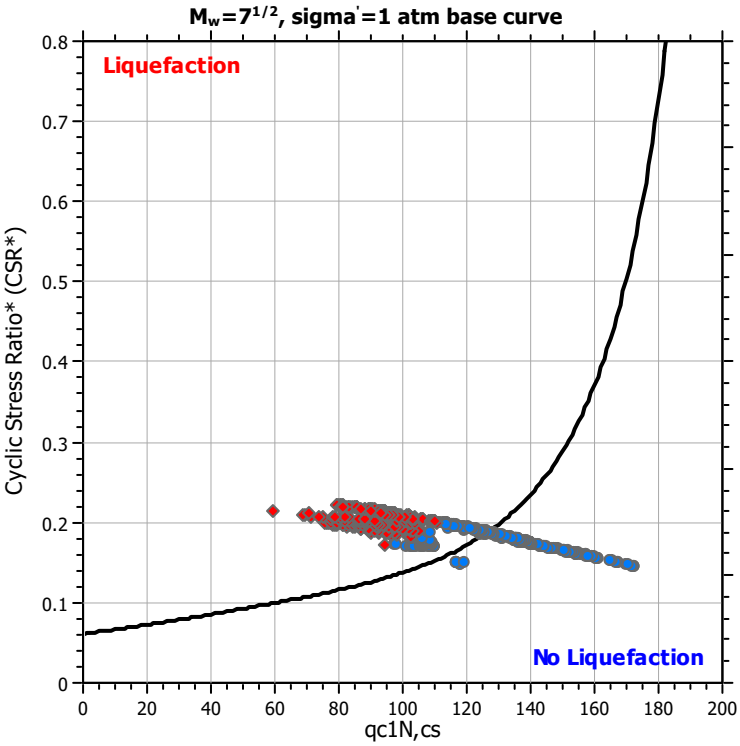
Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

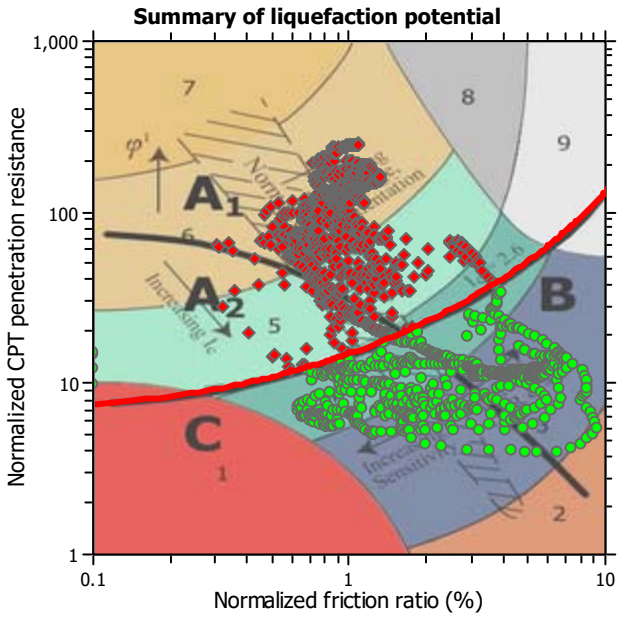
CPT file : CPT08

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.30 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

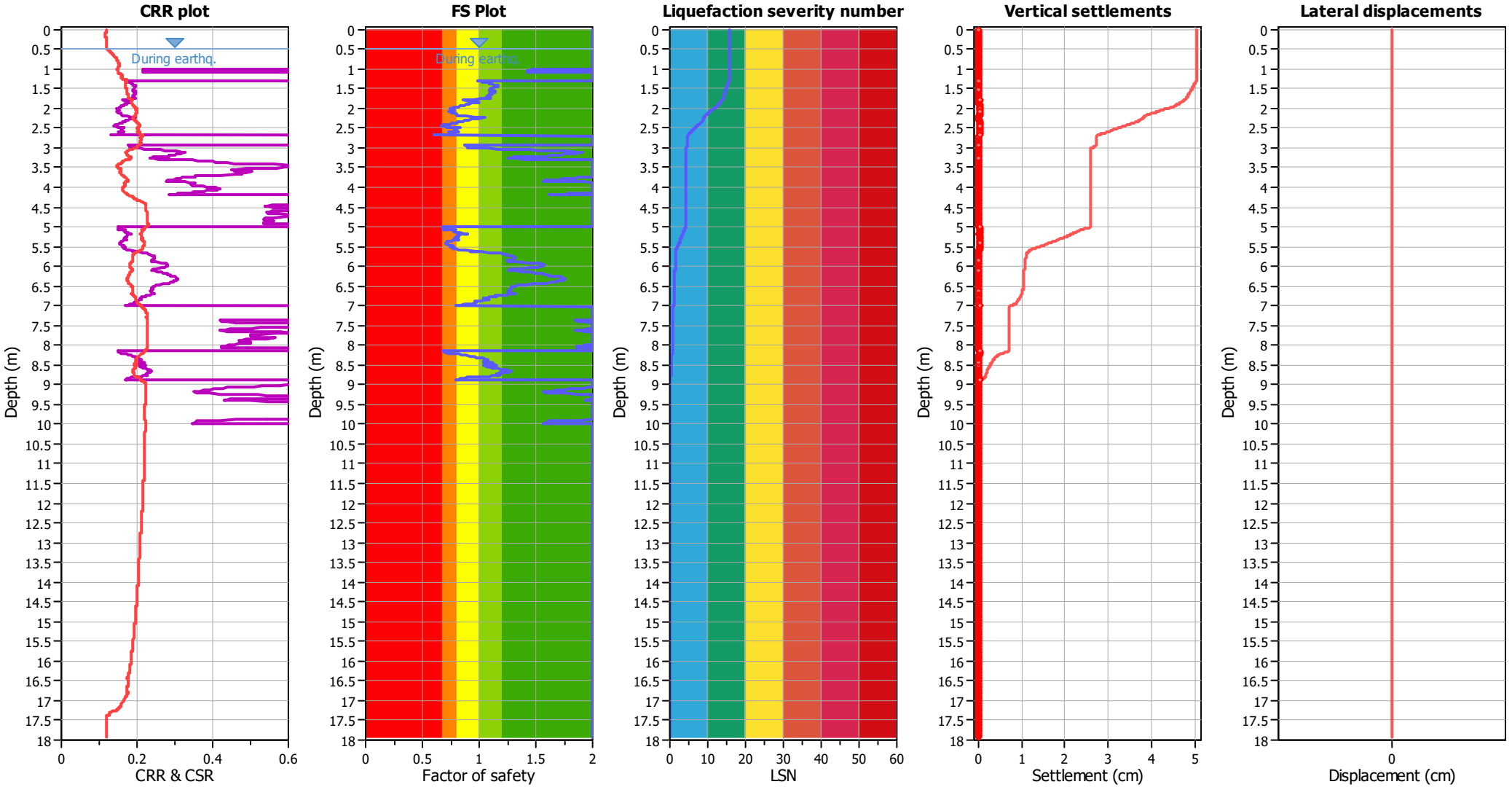






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.50 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:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.22	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	0.30 m	Fill height:	N/A	Limit depth:	10.00 m

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

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

HD Geo
PO Box 9266
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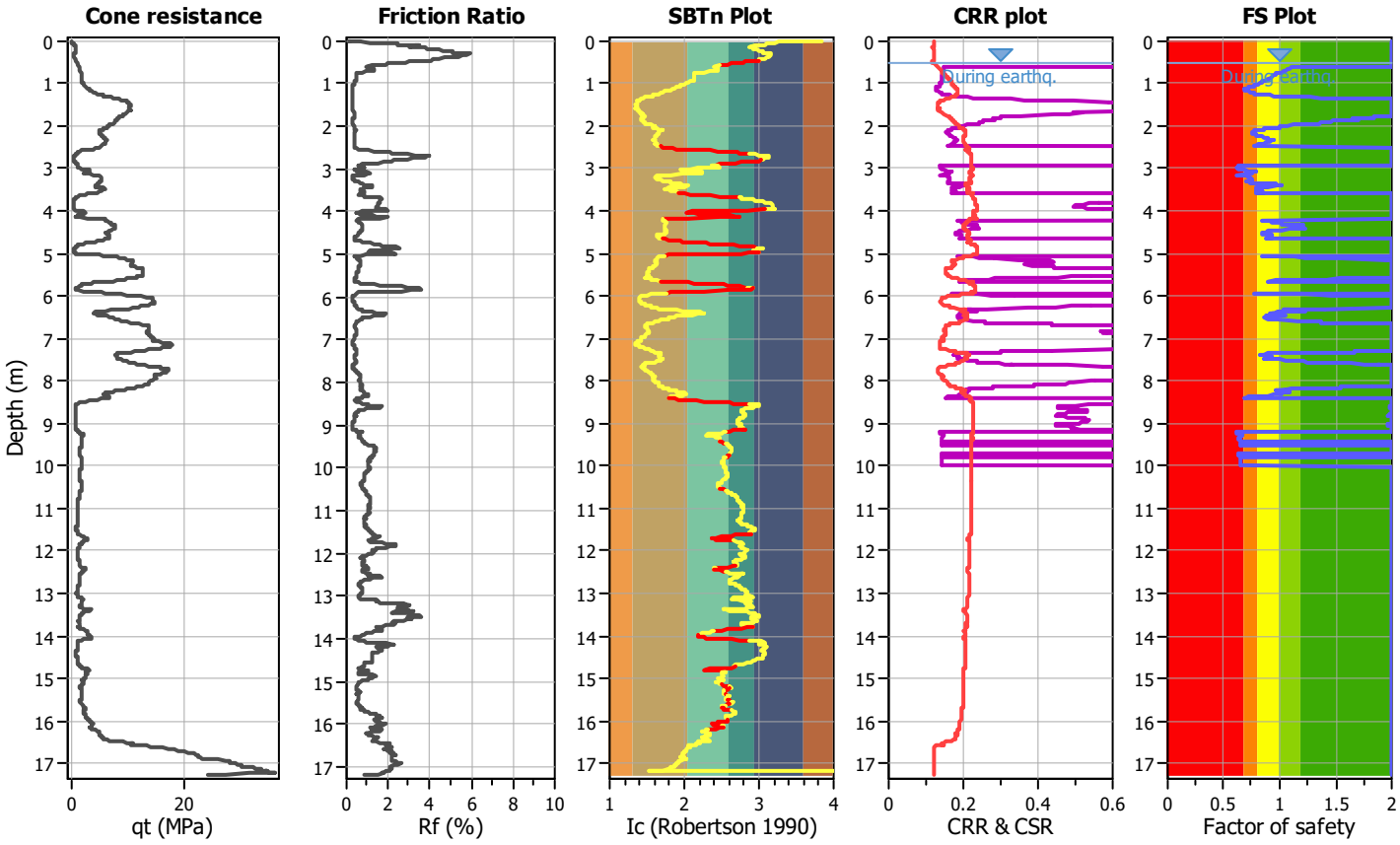
LIQUEFACTION ANALYSIS REPORT

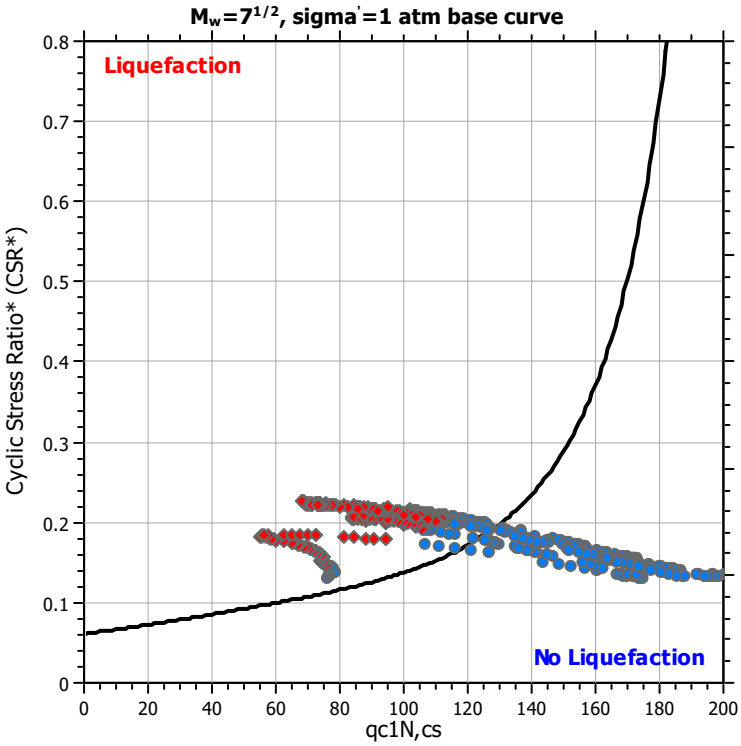
Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

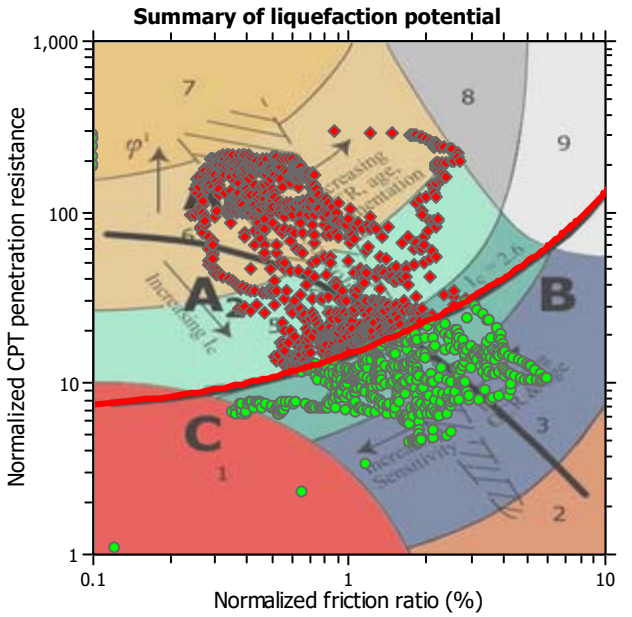
CPT file : SCPT-01

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.40 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

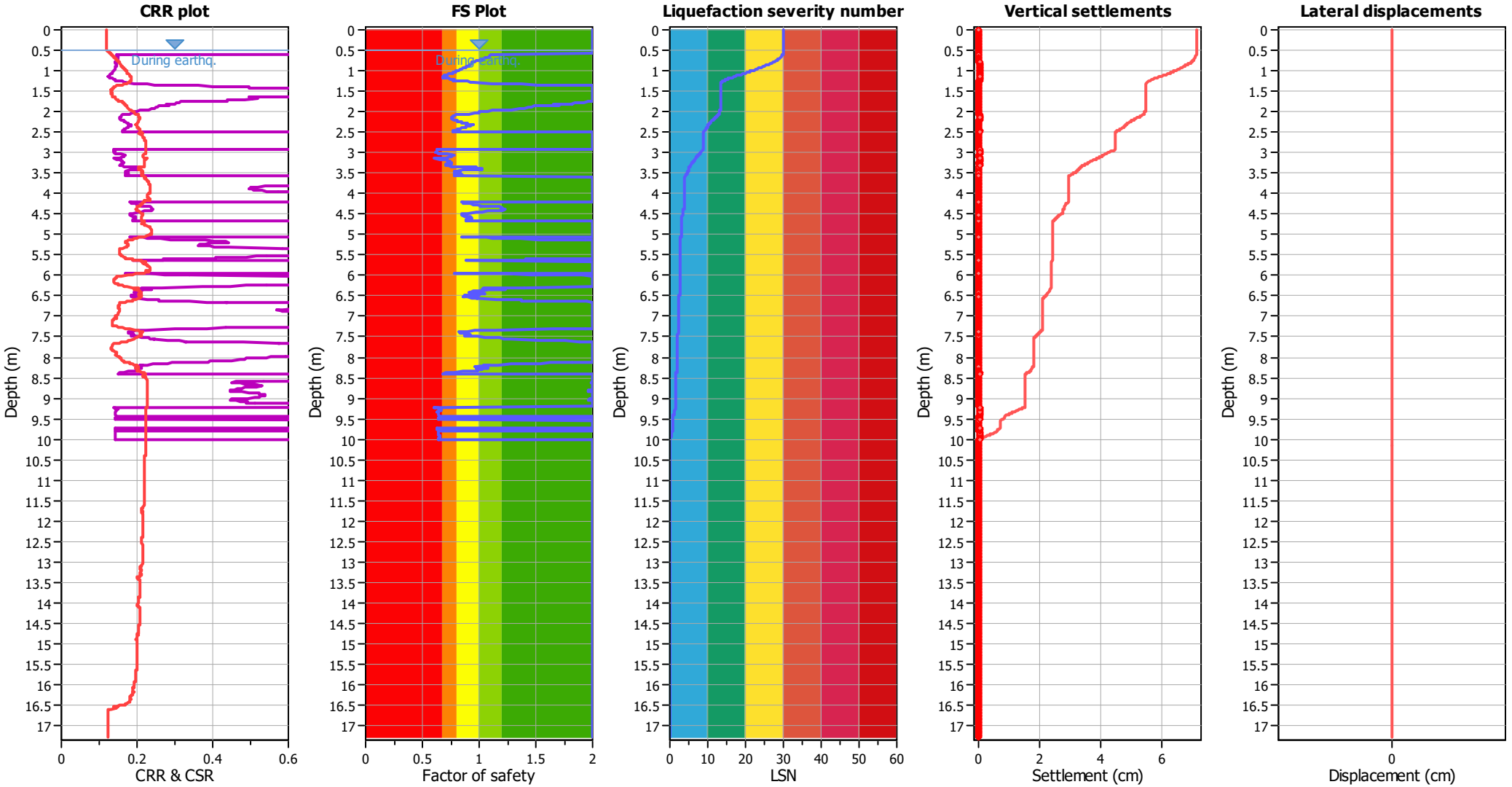






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.50 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:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.22	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	0.40 m	Fill height:	N/A	Limit depth:	10.00 m

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

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

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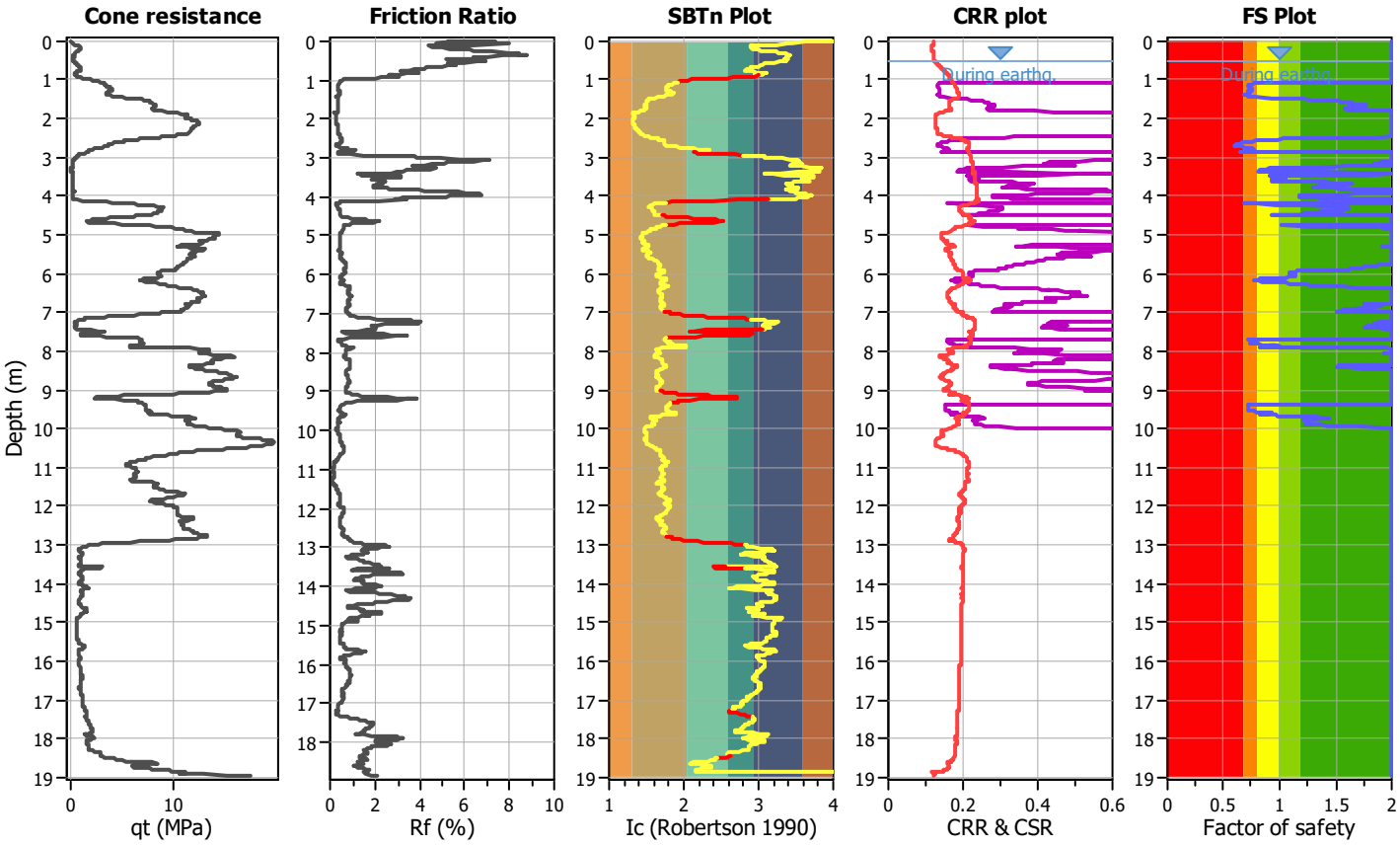
LIQUEFACTION ANALYSIS REPORT

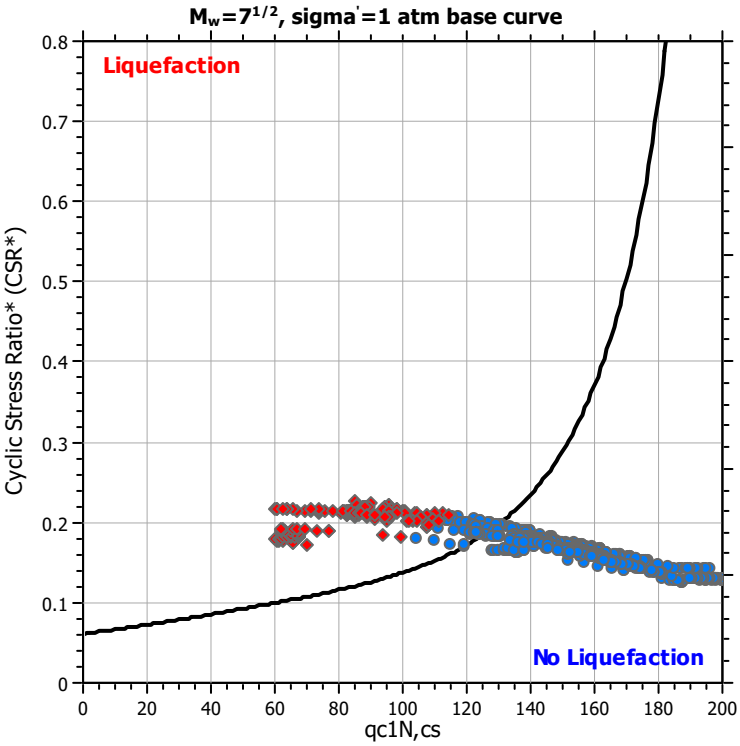
Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

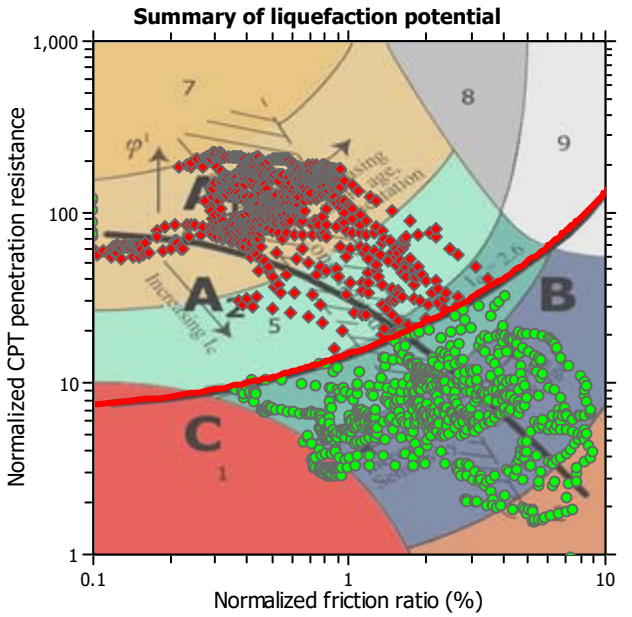
CPT file : SCPT-02

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

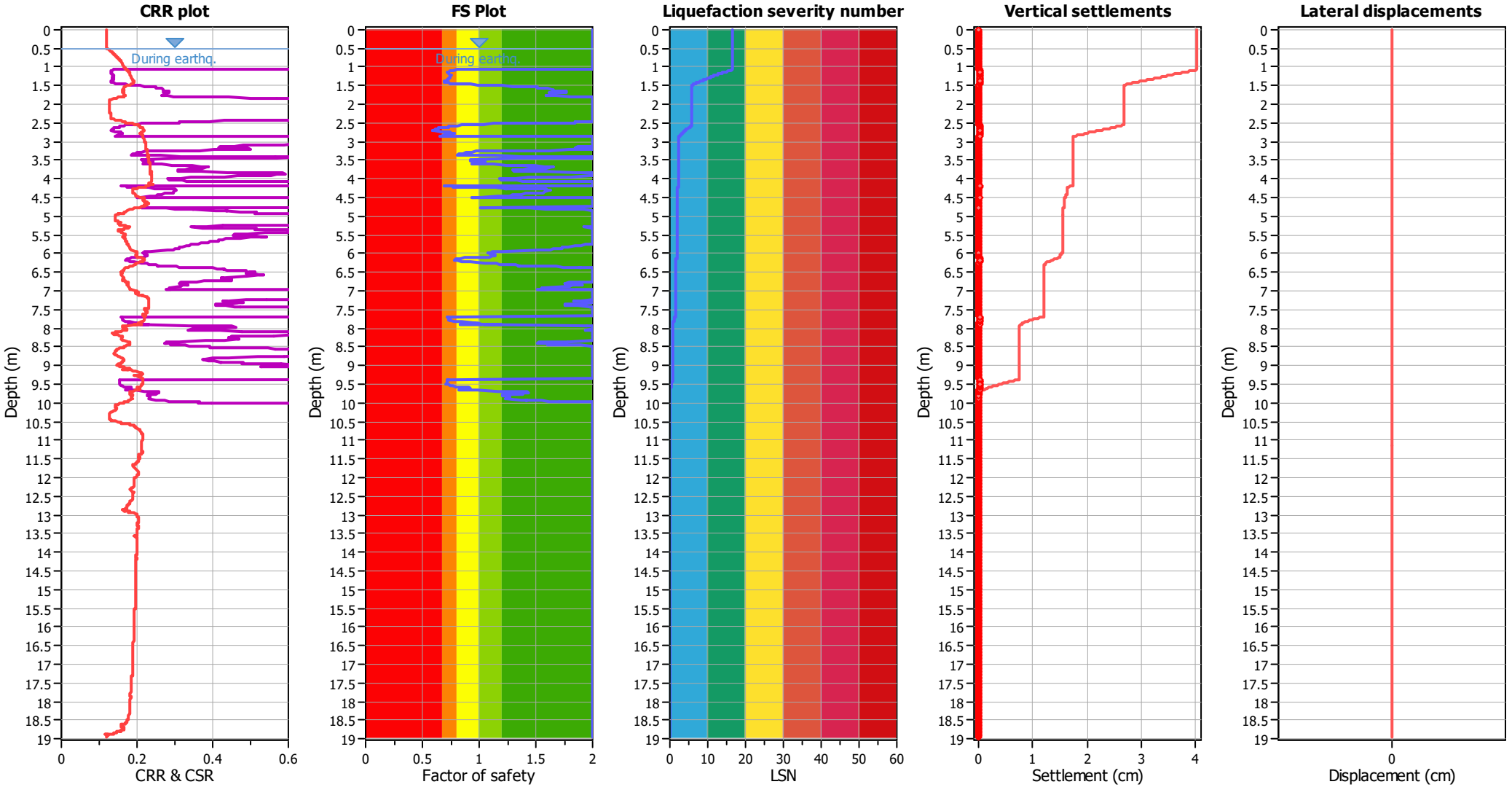






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.50 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:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.22	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	0.50 m	Fill height:	N/A	Limit depth:	10.00 m

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

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

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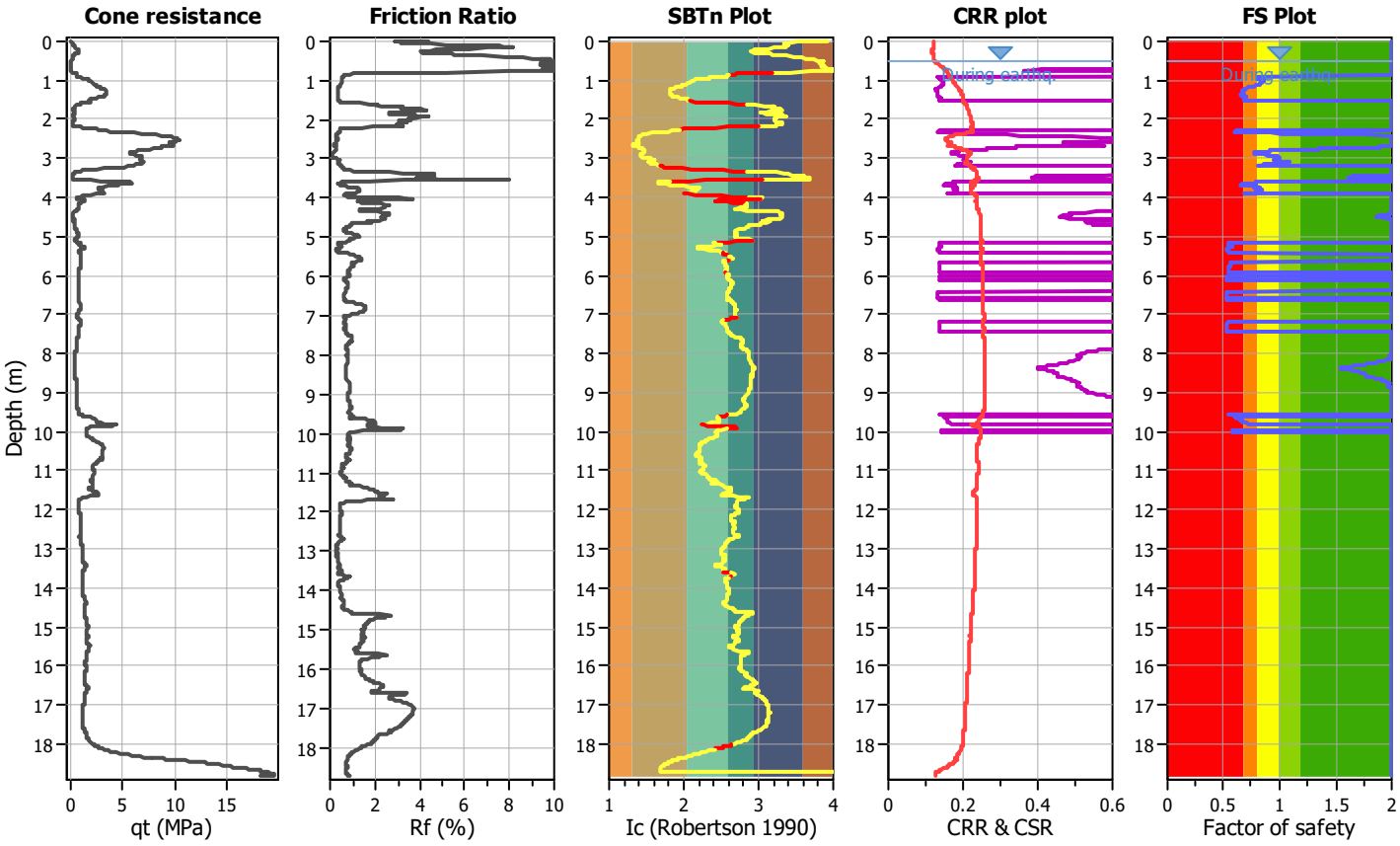
LIQUEFACTION ANALYSIS REPORT

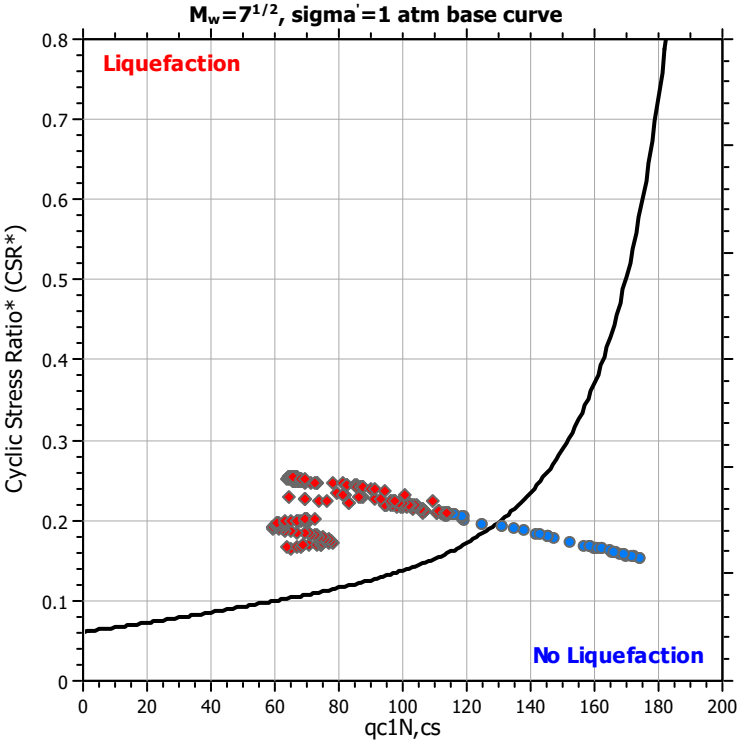
Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

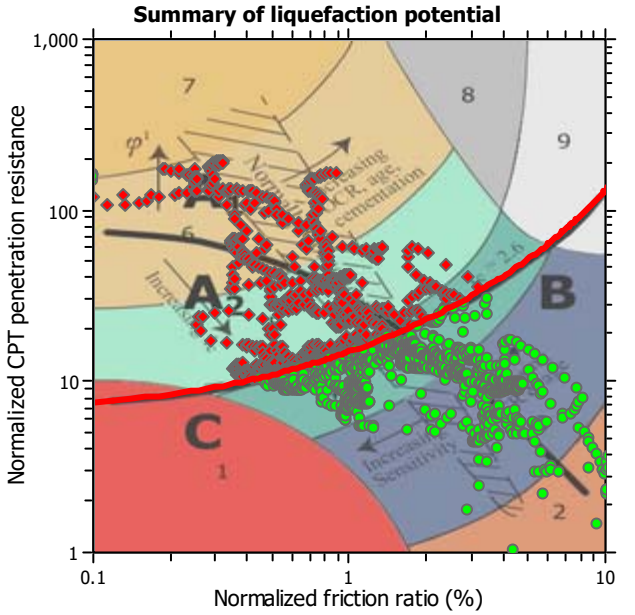
CPT file : SCPT-03

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.40 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

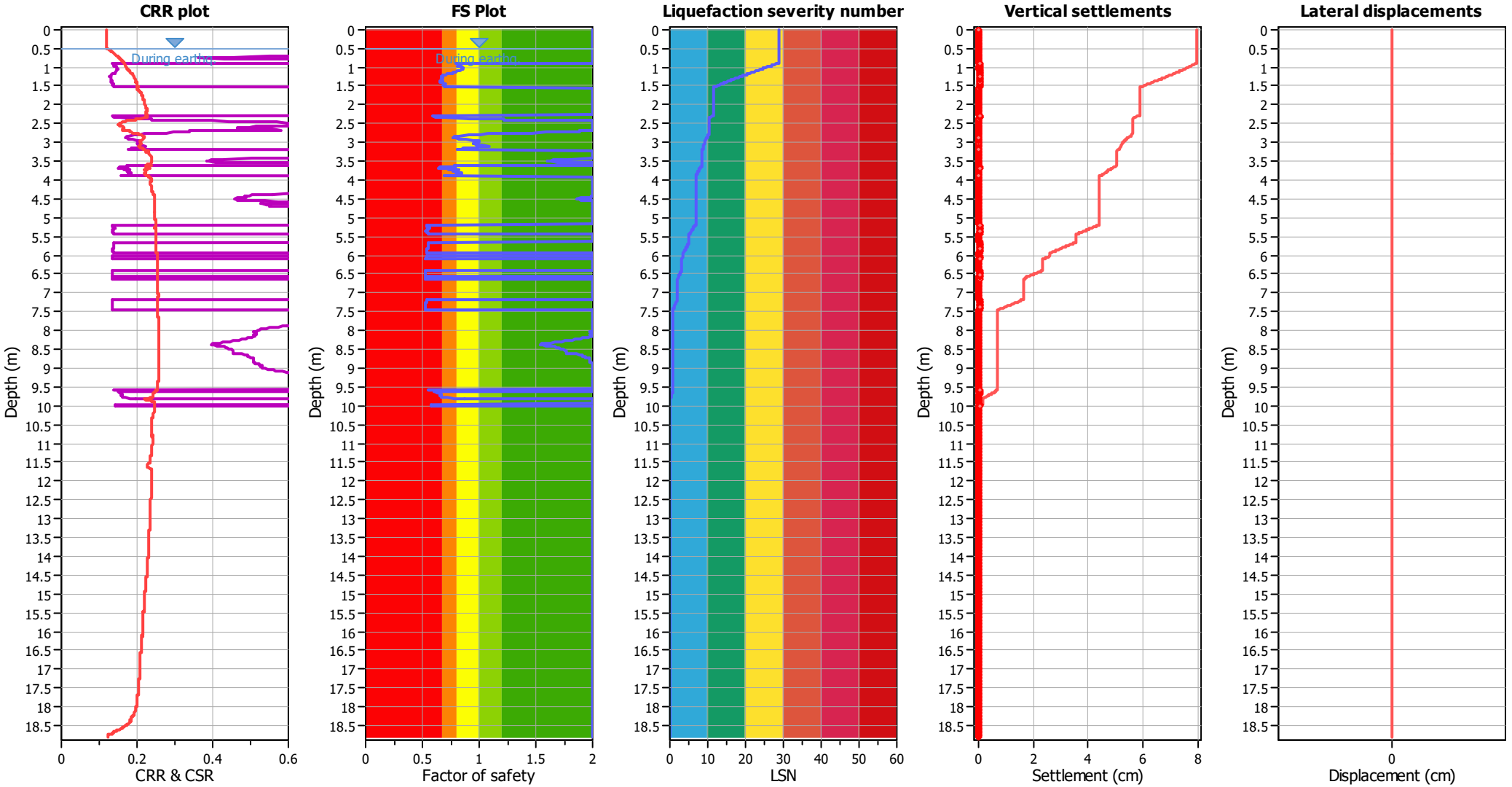






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.50 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:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.22	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	0.40 m	Fill height:	N/A	Limit depth:	10.00 m

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

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

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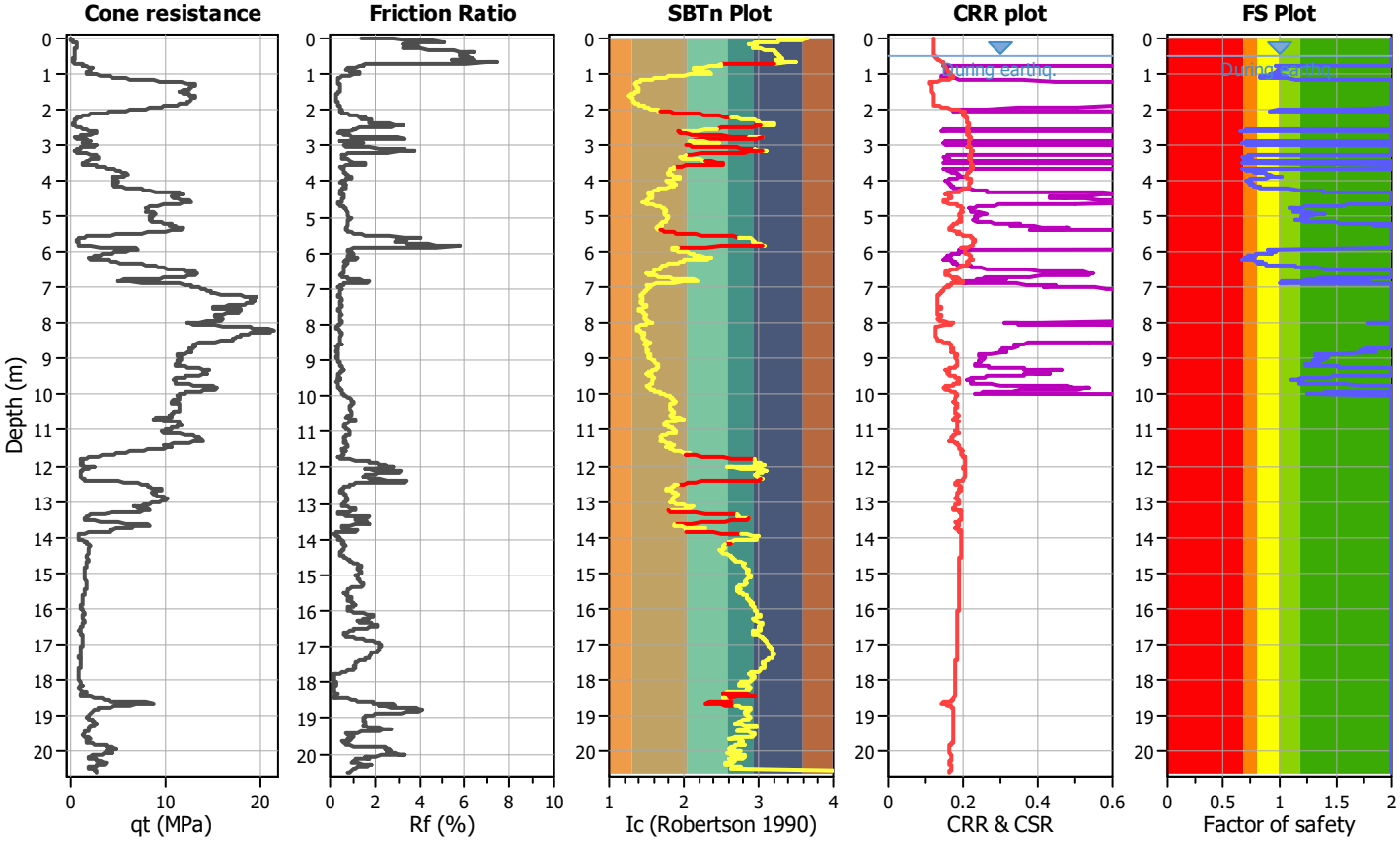
LIQUEFACTION ANALYSIS REPORT

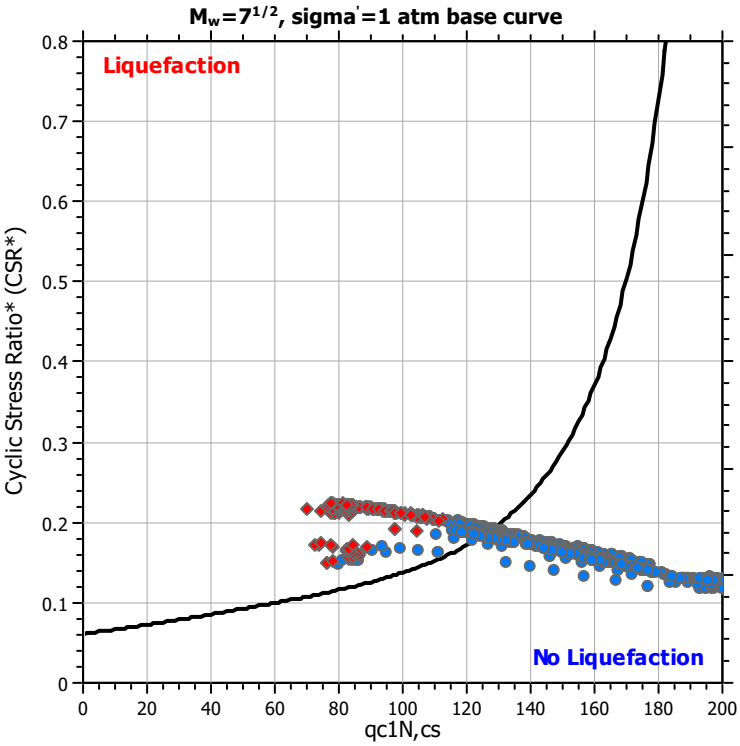
Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

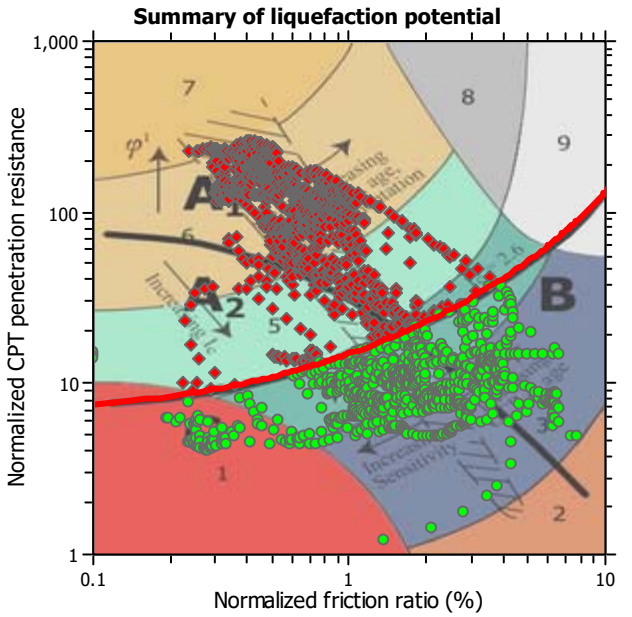
CPT file : SCPT-04

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.60 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

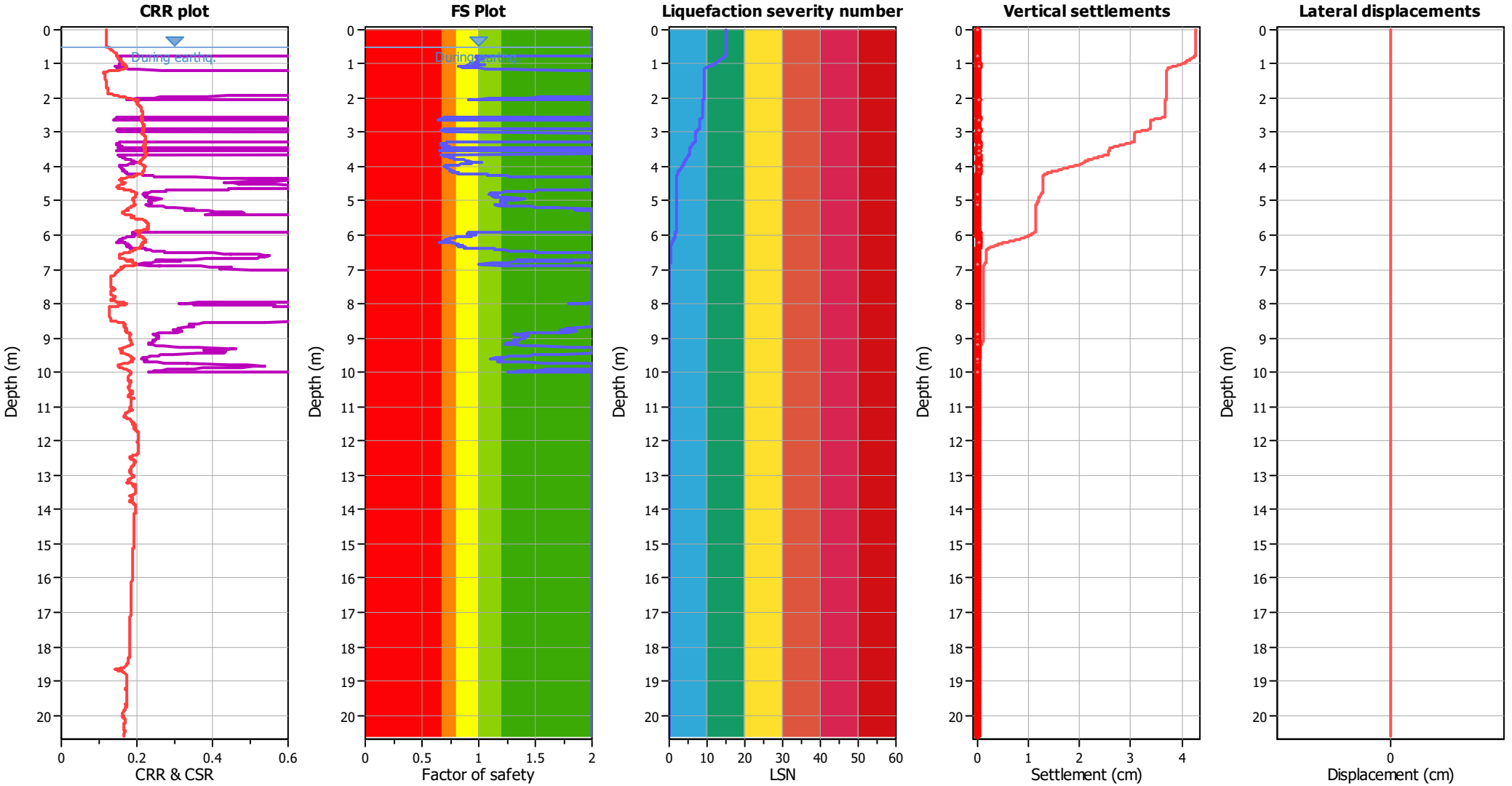






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.50 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:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.22	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	0.60 m	Fill height:	N/A	Limit depth:	10.00 m

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

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

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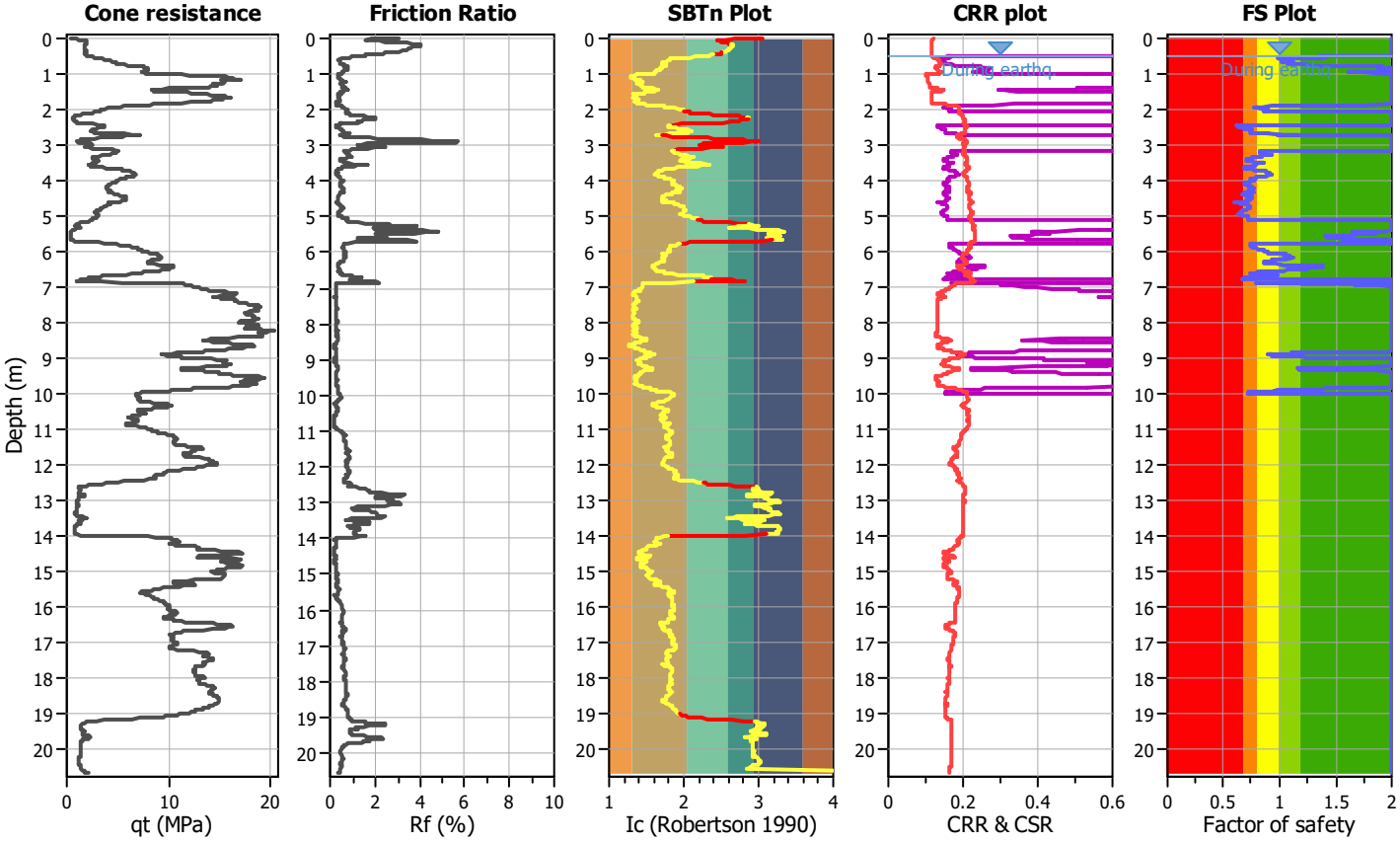
LIQUEFACTION ANALYSIS REPORT

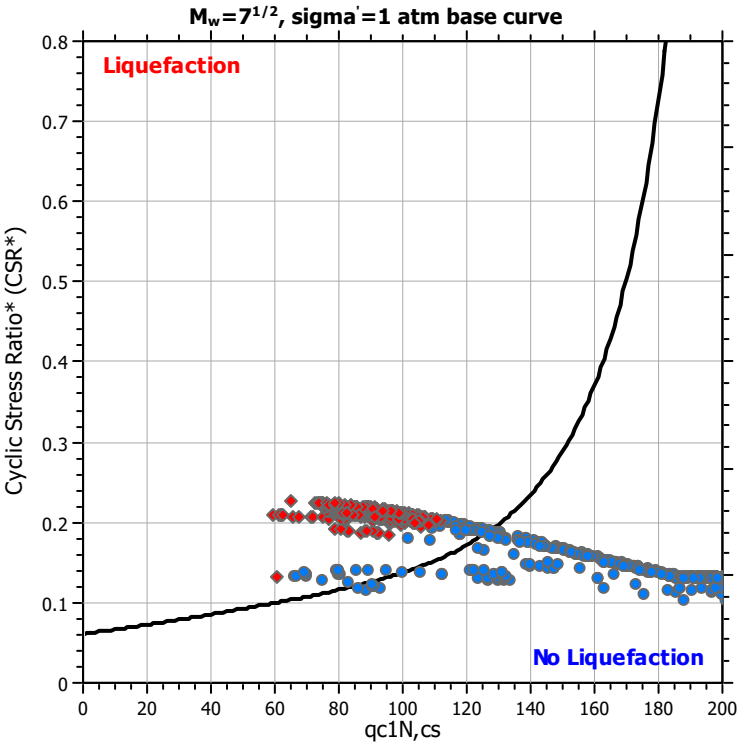
Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

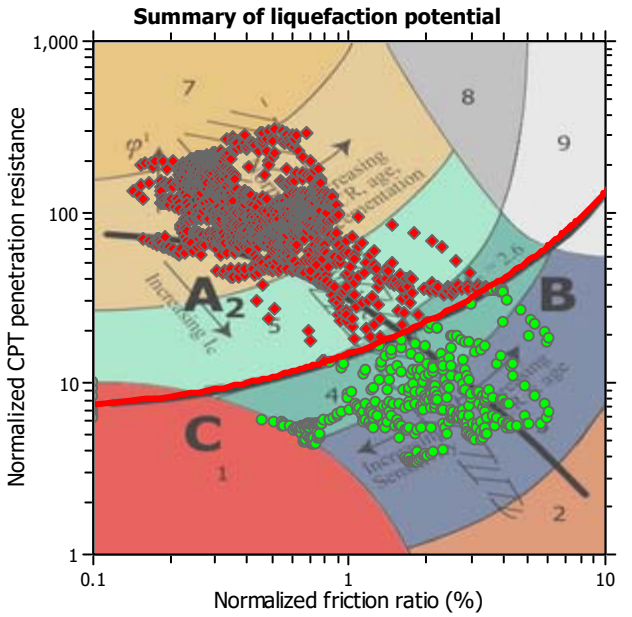
CPT file : SCPT-05

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.16 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

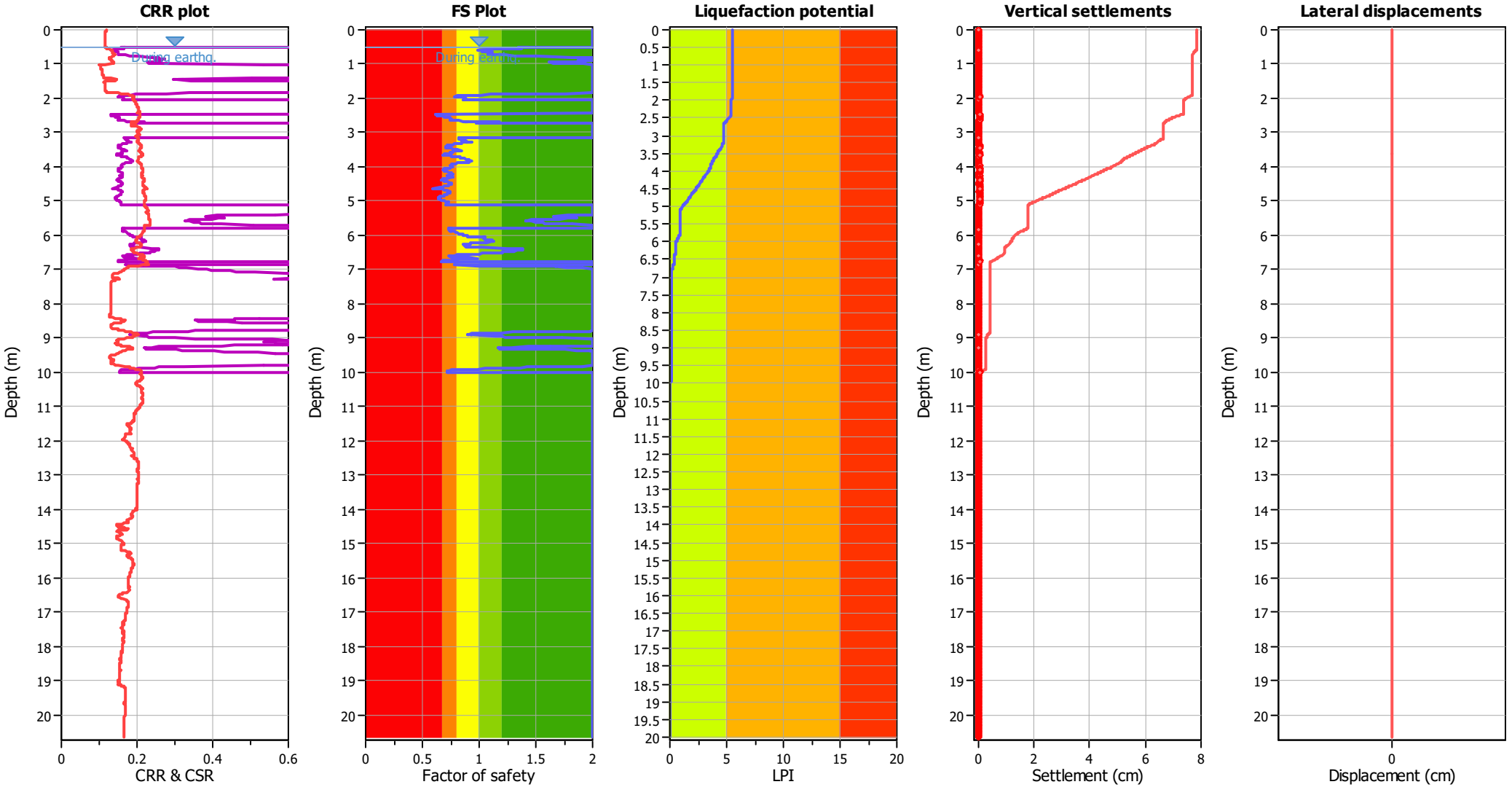






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.50 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:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.22	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	1.16 m	Fill height:	N/A	Limit depth:	10.00 m

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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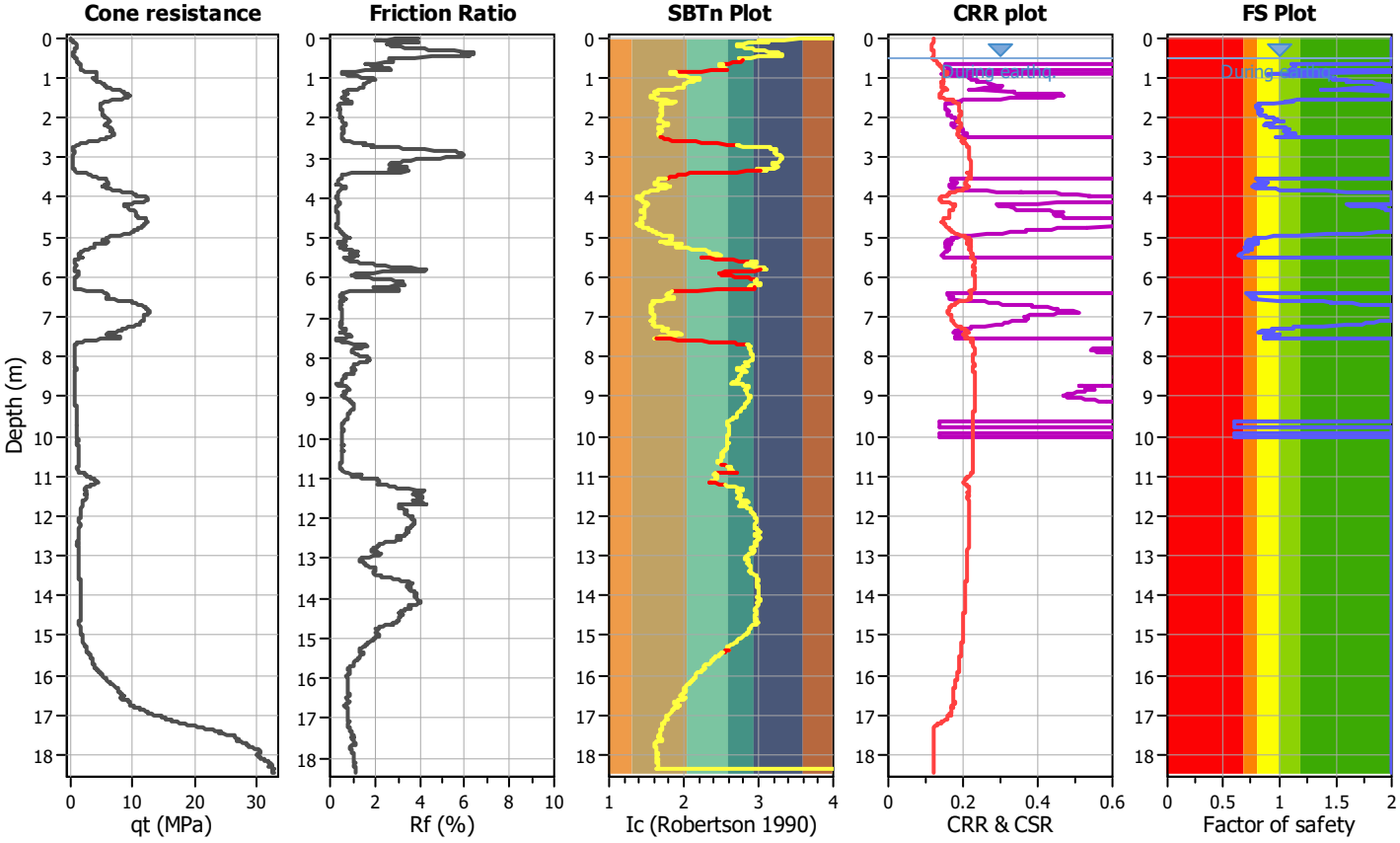
LIQUEFACTION ANALYSIS REPORT

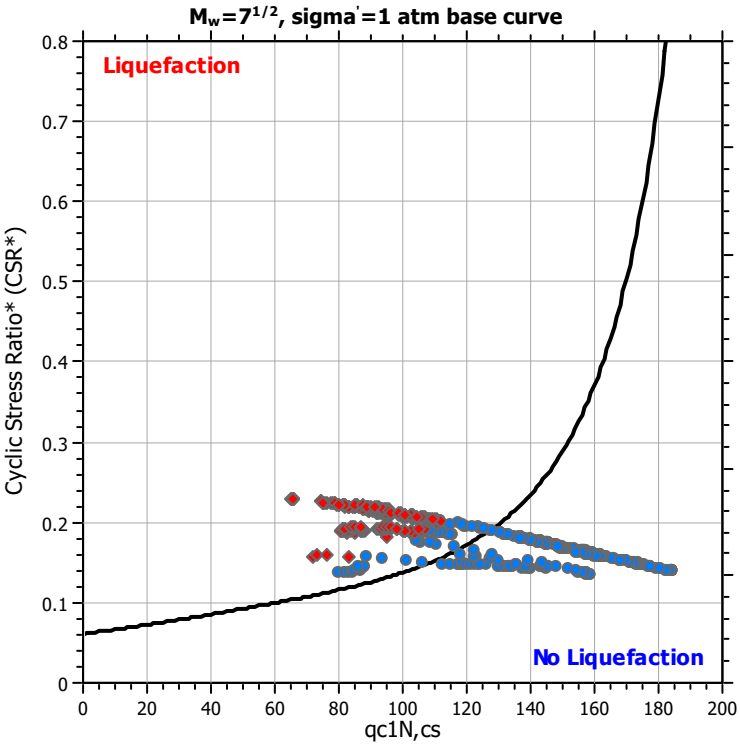
Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

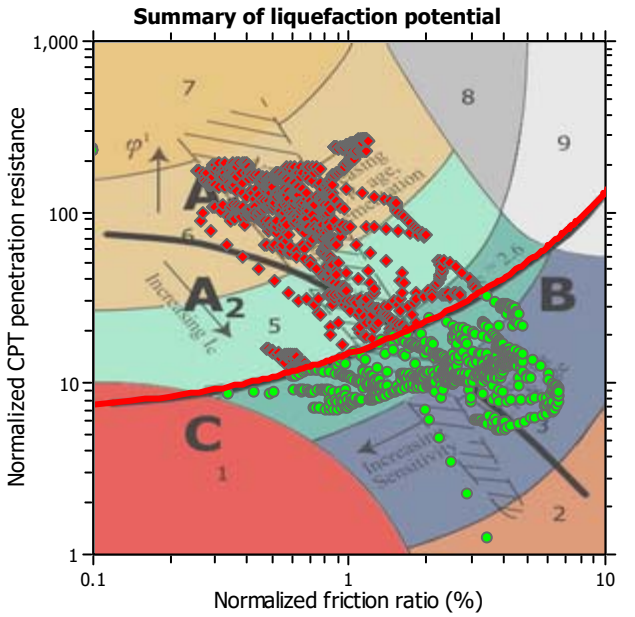
CPT file : SCPT-06

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	0.20 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	Yes
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	10.00 m
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

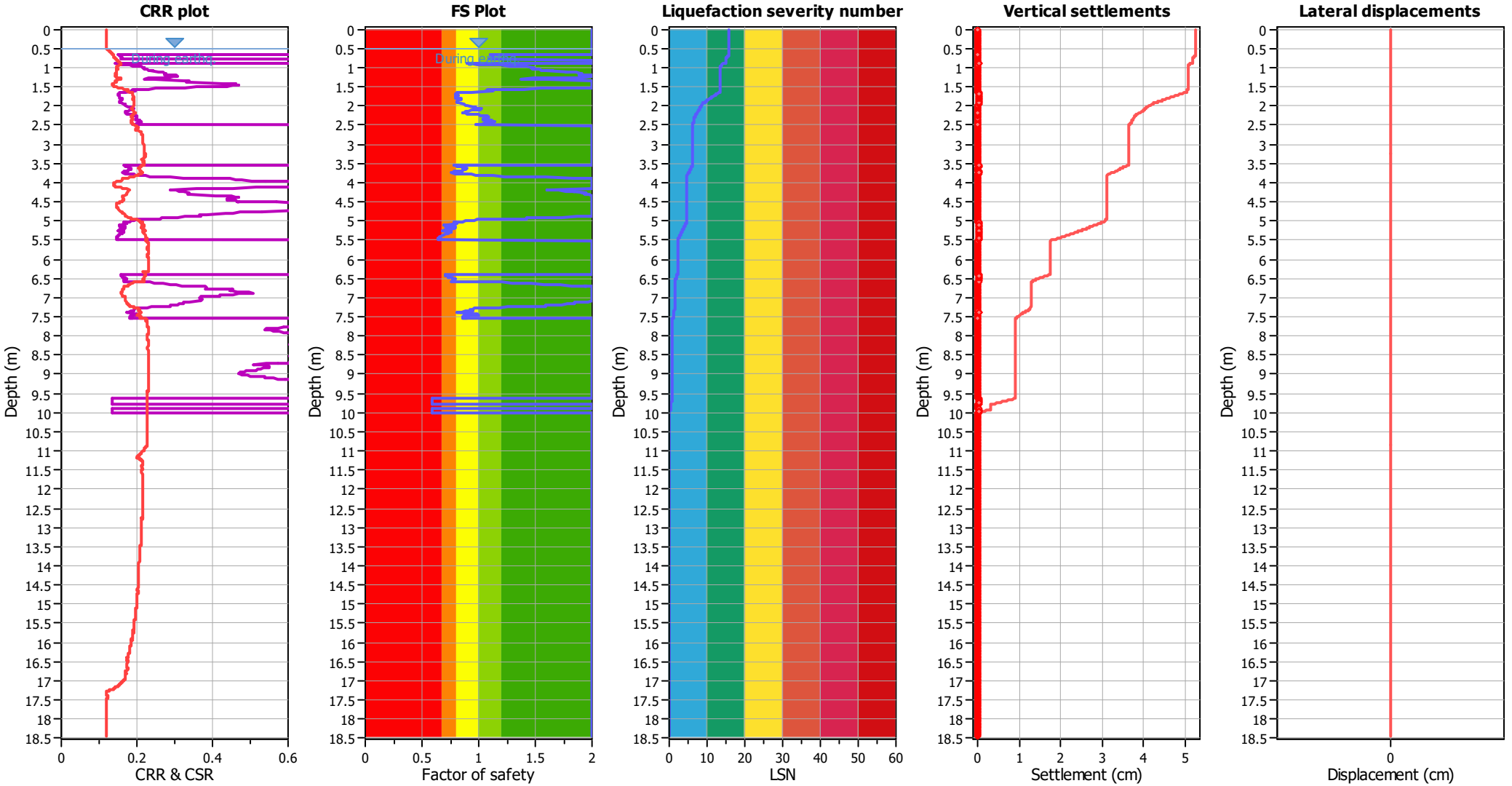






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.50 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:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sand & Clay
Peak ground acceleration:	0.22	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	0.20 m	Fill height:	N/A	Limit depth:	10.00 m

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

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

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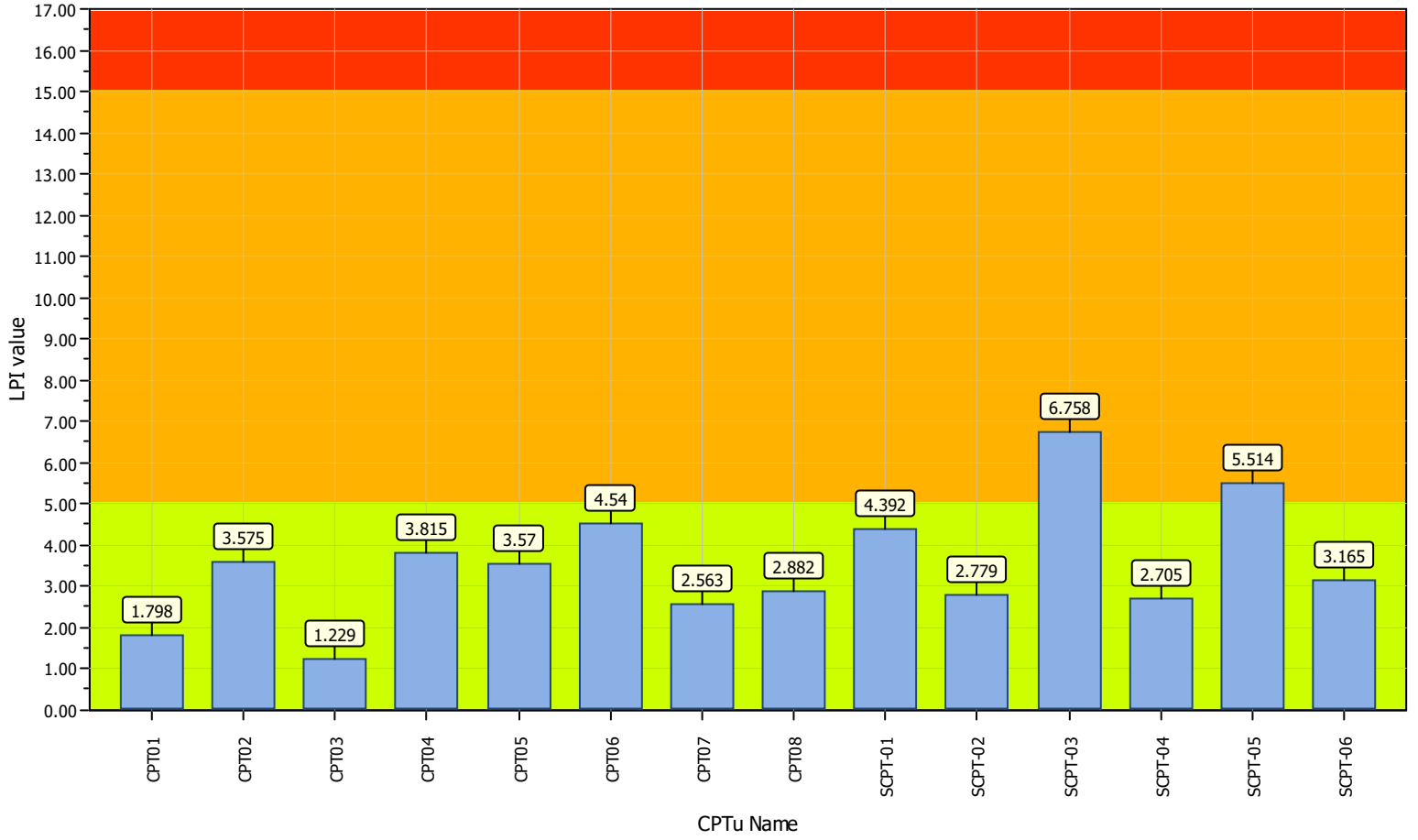
Project title : HD631 - Rotokauri North SHA Geo

Location : Rotokauri North

Overall Liquefaction Potential Index report



LPI color scheme

- Very high risk
- High risk
- Low risk

Basic statistics

Total CPT number: 14
86% low risk
14% high risk
0% very high risk

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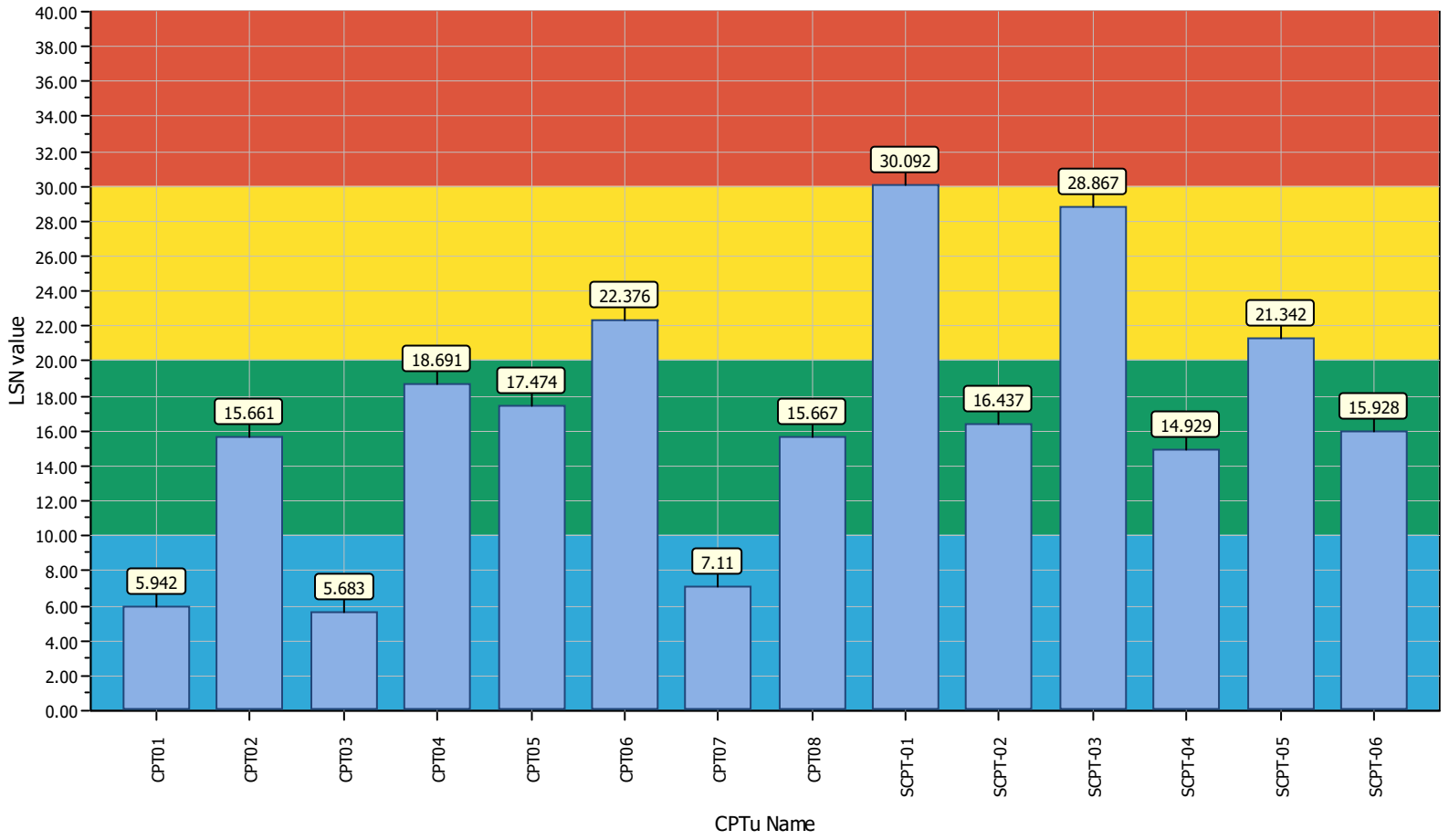
Project title : HD631 - Rotokauri North SHA Geo

Location : Rotokauri North

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: 14

21% little liquefaction

50% minor liquefaction

21% moderate liquefaction

7% moderate to major liquefaction

0% major liquefaction

0% severe liquefaction

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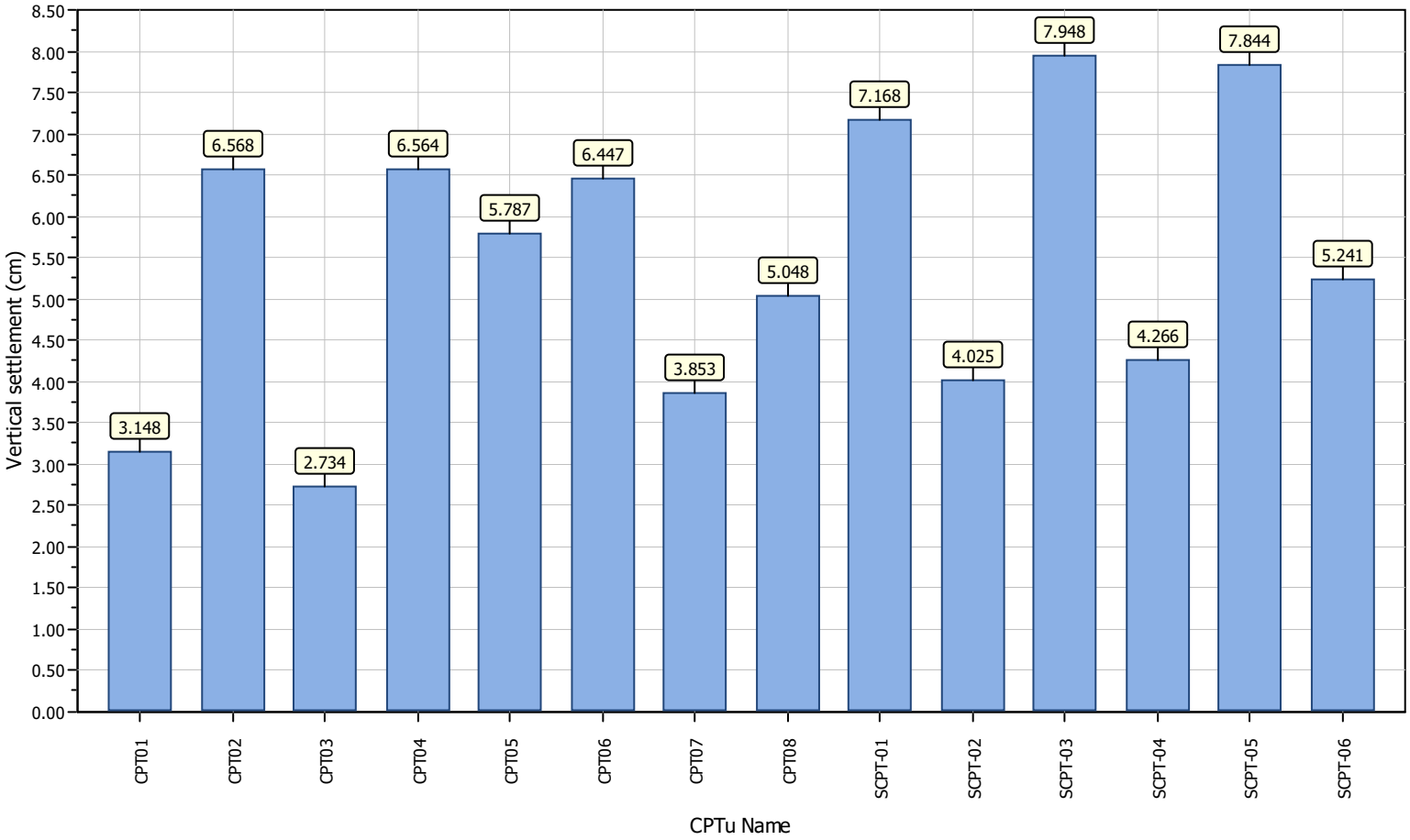
Project title : HD631 - Rotokauri North SHA Geo

Location : Rotokauri North

Overall vertical settlements report



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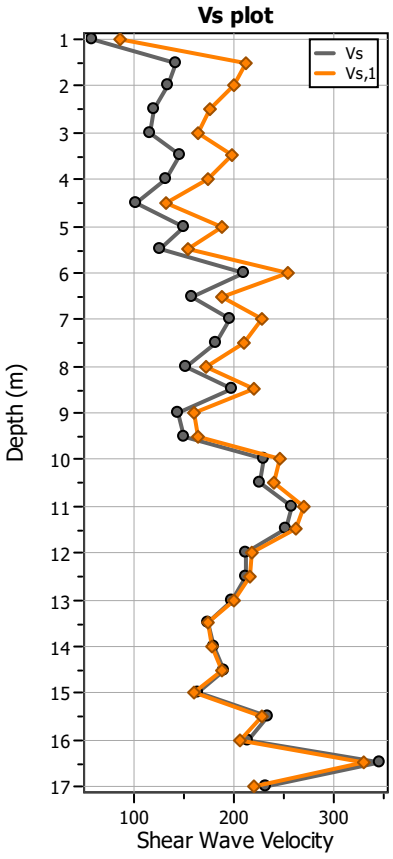
Vs BASED LIQUEFACTION ANALYSIS REPORT (Kayen et al. 2013)

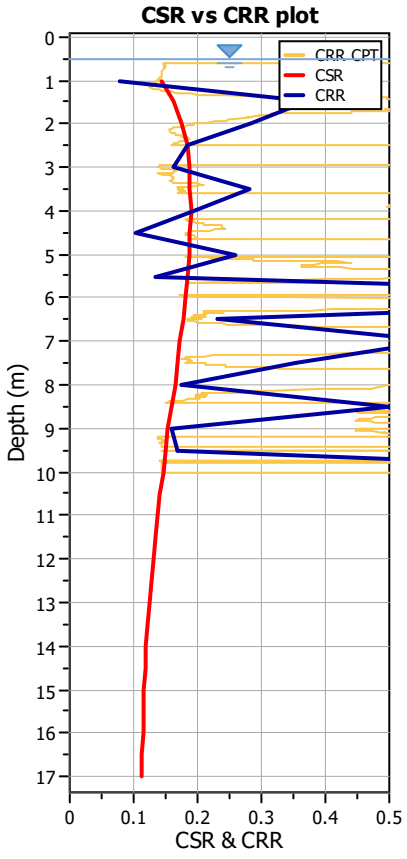
Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

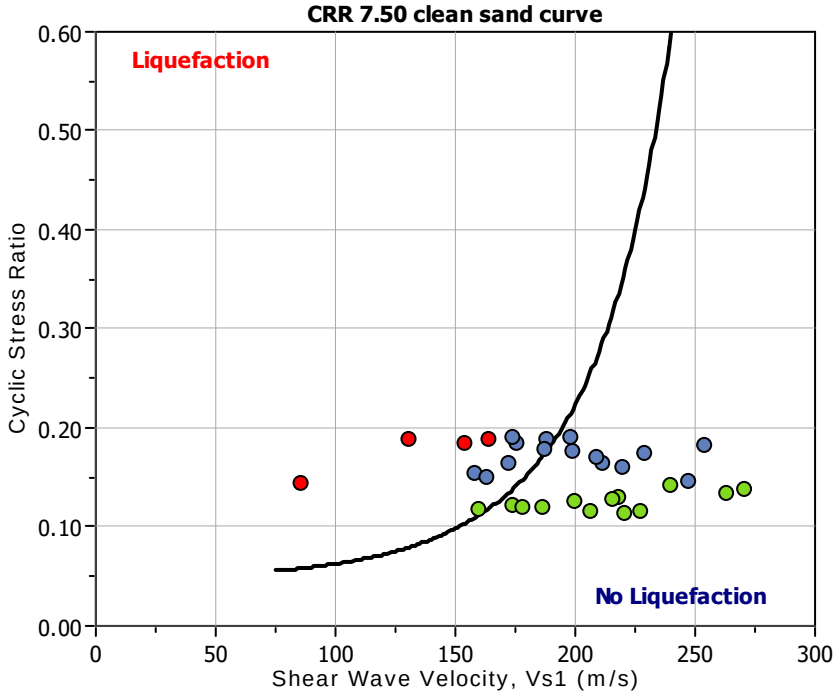
CPT file : SCPT-01

:: Input parameters and analysis properties ::

Calculation method:	Kayen et. al (2013)
G.W.T. (in-situ):	0.40 m
G.W.T. (earthq.):	0.50 m
Earthquake magnitude M_w:	5.90
Peak ground acceleration:	0.22g







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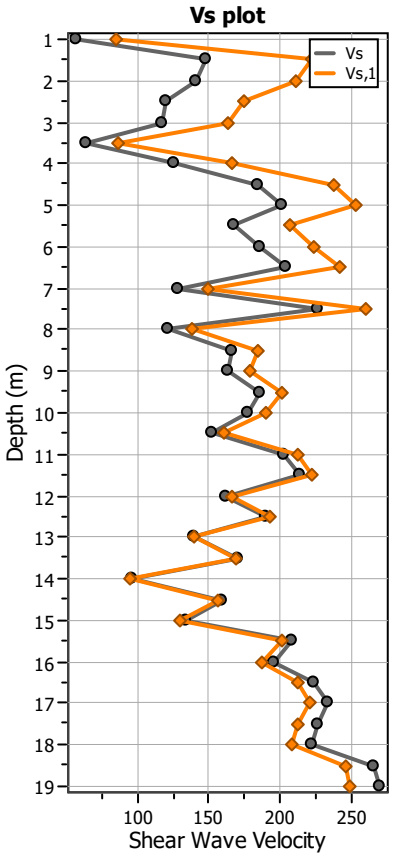
Vs BASED LIQUEFACTION ANALYSIS REPORT (Kayen et al. 2013)

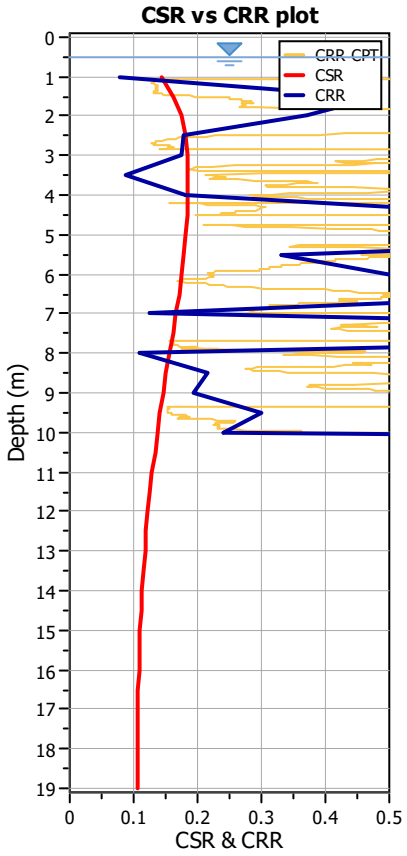
Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

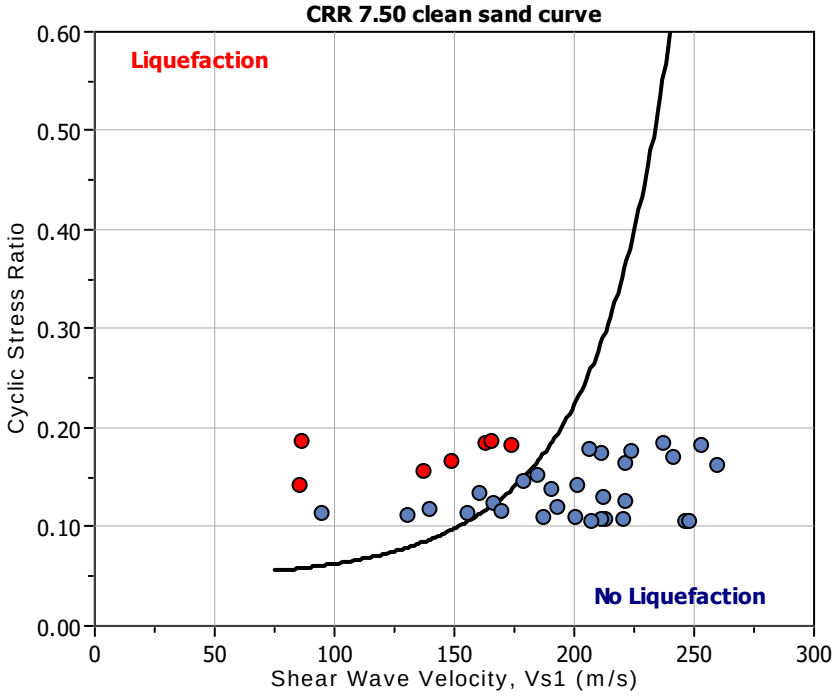
CPT file : SCPT-02

:: Input parameters and analysis properties ::

Calculation method:	Kayen et. al (2013)
G.W.T. (in-situ):	0.50 m
G.W.T. (earthq.):	0.50 m
Earthquake magnitude M_w:	5.90
Peak ground acceleration:	0.22g







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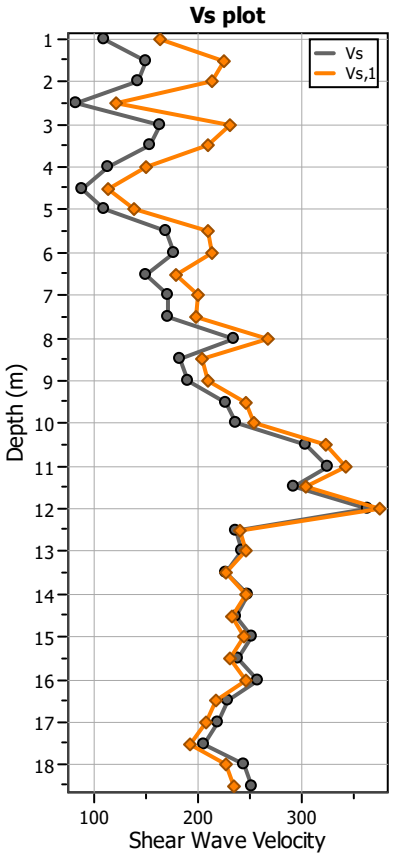
Vs BASED LIQUEFACTION ANALYSIS REPORT (Kayen et al. 2013)

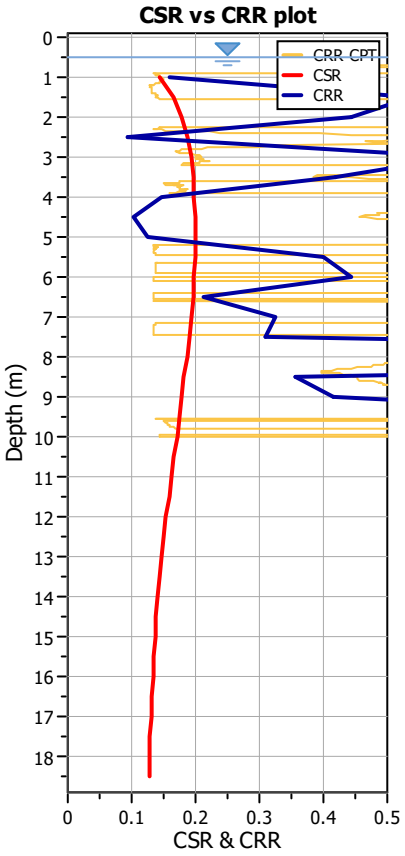
Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

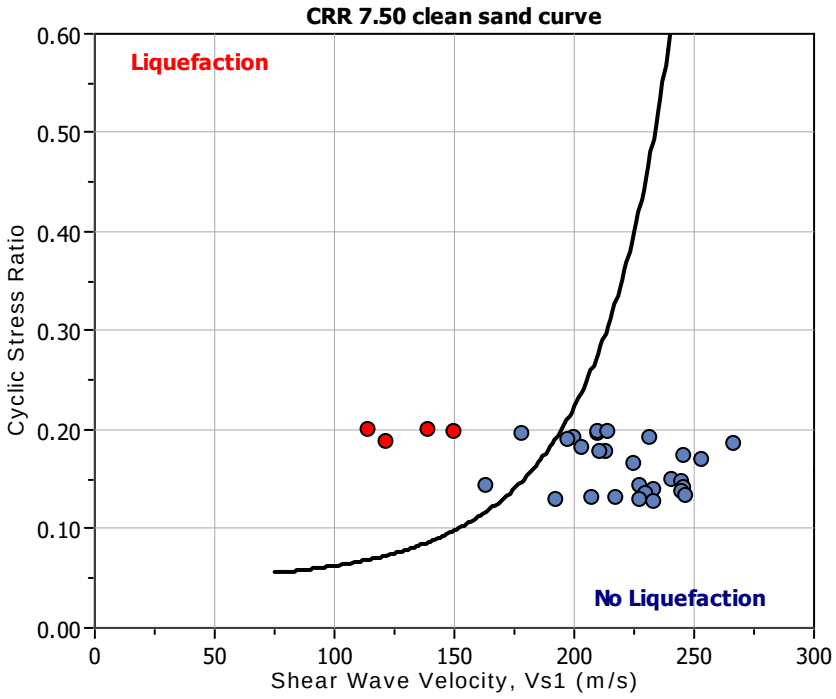
CPT file : SCPT-03

:: Input parameters and analysis properties ::

Calculation method:	Kayen et. al (2013)
G.W.T. (in-situ):	0.40 m
G.W.T. (earthq.):	0.50 m
Earthquake magnitude M_w:	5.90
Peak ground acceleration:	0.22g







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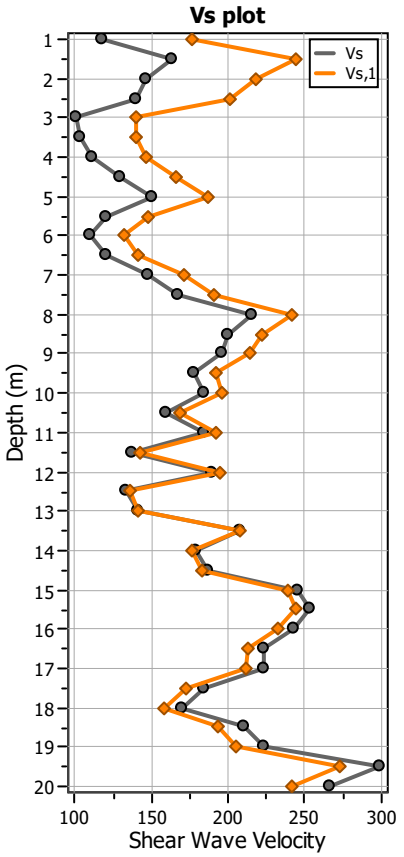
Vs BASED LIQUEFACTION ANALYSIS REPORT (Kayen et al. 2013)

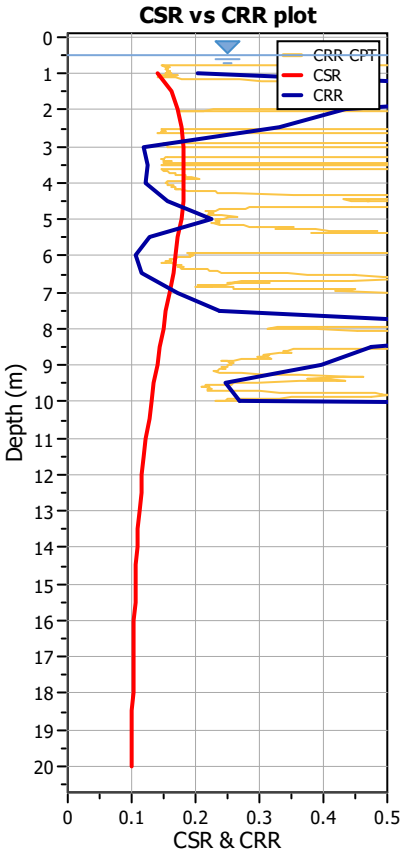
Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

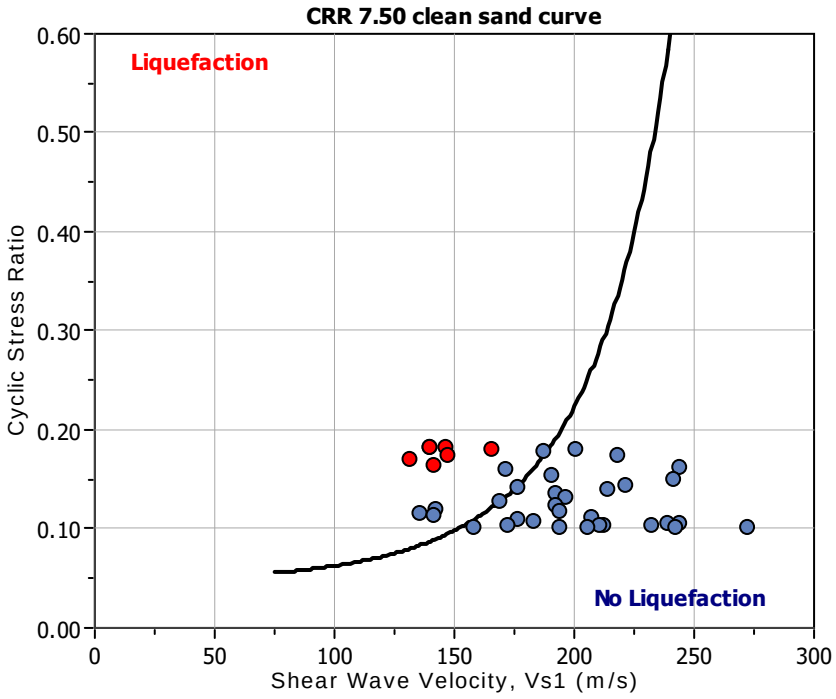
CPT file : SCPT-04

:: Input parameters and analysis properties ::

Calculation method:	Kayen et. al (2013)
G.W.T. (in-situ):	0.60 m
G.W.T. (earthq.):	0.50 m
Earthquake magnitude M_w:	5.90
Peak ground acceleration:	0.22g







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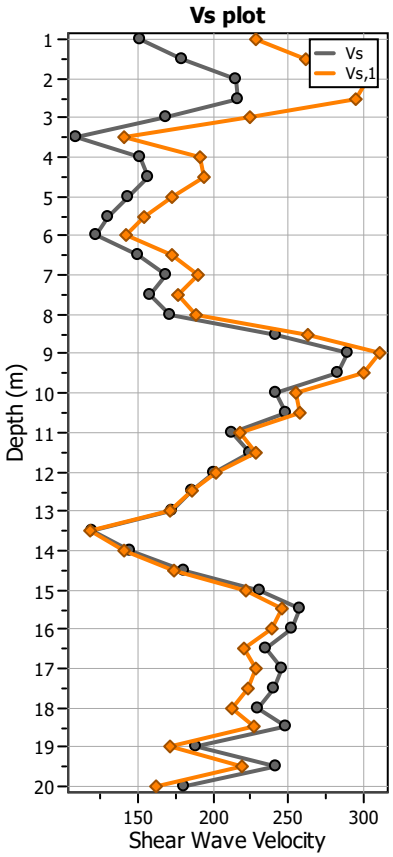
Vs BASED LIQUEFACTION ANALYSIS REPORT (Kayen et al. 2013)

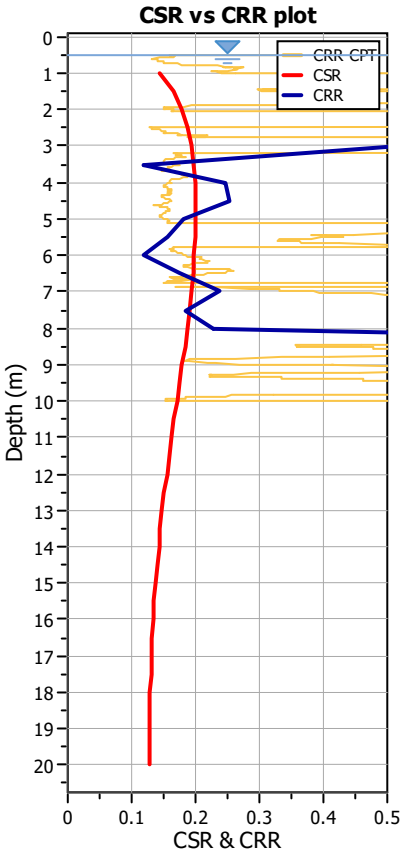
Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

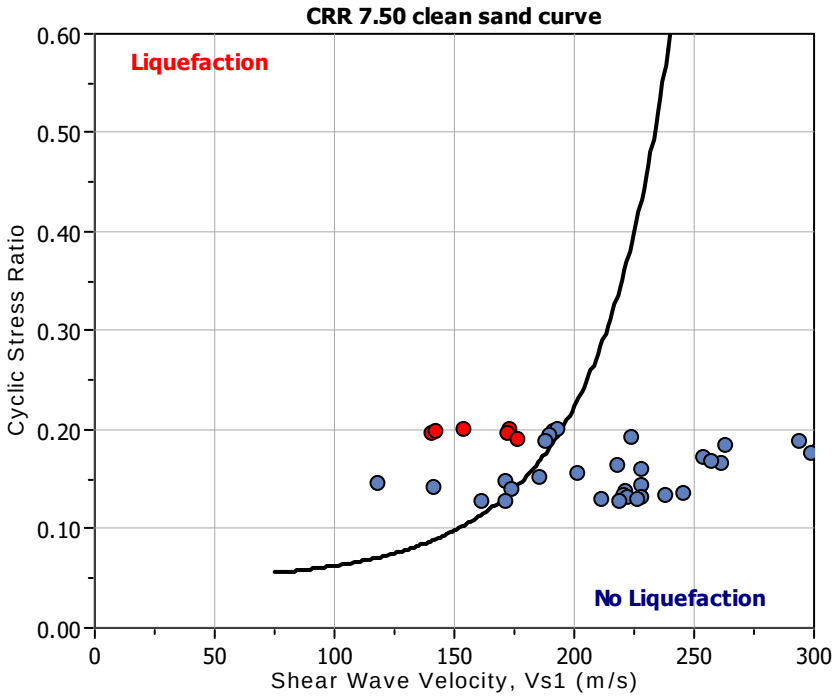
CPT file : SCPT-05

:: Input parameters and analysis properties ::

Calculation method:	Kayen et. al (2013)
G.W.T. (in-situ):	1.16 m
G.W.T. (earthq.):	0.50 m
Earthquake magnitude M_w:	5.90
Peak ground acceleration:	0.22g







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Vs BASED LIQUEFACTION ANALYSIS REPORT (Kayen et al. 2013)

Project title : HD631 - Rotokauri North SHA Geo **Location : Rotokauri North**

CPT file : SCPT-06

:: Input parameters and analysis properties ::

Calculation method:	Kayen et. al (2013)
G.W.T. (in-situ):	0.20 m
G.W.T. (earthq.):	0.50 m
Earthquake magnitude M_w:	5.90
Peak ground acceleration:	0.22g