



ROTOKAURI NORTH SHA

PRELIMINARY GEOTECHNICAL REPORT

PROJECT NO: HD631
GREEN SEED CONSULTANTS
LIMITED
REFERENCE: PCR
27 JULY 2018

Executive Summary

HD Geo have been engaged by Green Seed Consultants Limited to conduct a preliminary geotechnical assessment for the Rotokauri North Special Housing Area (SHA) to support master planning and conceptual design for the development. The SHA is located at the northwest extent of Hamilton City and is comprised of approximately 133 ha. It is proposed to develop the site into a mixture of standard and medium density residential housing, a commercial neighbourhood centre, public parks and potentially a school.

The site predominantly consists of flat-lying plains (referred to as the 'Plains') with rounded hill terrain (referred to as the 'Hill Terrain') in the western and eastern portions of the site rising up to 18 m above the plains. The Hill Terrain is mapped as alluvial and non-welded ignimbrite deposits (Walton Subgroup) which are typically covered in volcanic ash. The Plains are mapped as primary and secondary volcanoclastic sediments with a wide variety of grain sizes (Piako Subgroup and Hinuera Formation).

The investigation included 13 hand augers, 8 cone penetrometer tests (CPTs), 3 dissipation tests and 5 temporary standpipe piezometers which were monitored over a one-week period. The ground conditions encountered in the investigation were typically consistent with the mapped geology. Volcanic ash deposits were encountered in the Hill Terrain to the termination depth of the hand augers (3.0 m), with the CPTs interpreting predominantly clay to 20 m. On the Plains, a thin layer of volcanic ash was encountered at the surface (up to 0.9 m) with layered deposits of alluvial silt, sand and clay to 20 m. Groundwater levels measured from the temporary piezometers and dissipation testing showed groundwater levels were typically very shallow across the site, ranging between less than 0.1m to 1.2 m below the ground surface.

Given the presence of sandy soils and a high groundwater table at the site, a screening analysis was completed on all CPTs to assess the liquefaction risk at the site. The results showed that the Hill Terrain has no liquefaction hazard and the Plains typically have a high to severe liquefaction hazard. The analysis showed that the material on the Plains may encounter moderate to excessive differential settlements and total vertical settlements on the order of 100 mm to 200 mm (under ULS conditions). The liquefaction hazard in the low-lying areas of the site appears to be considerable and significant mitigation measures would likely be required to allow for residential construction.

This preliminary assessment also indicates that the risk of ground settlement under loading from fill is low and the materials likely to be cut from the hill terrain are likely to be suitable as an earthworks material. There are currently no significant concerns regarding the stability of the slopes at the site. However, given the liquefaction risk in the near surface and the plan to excavate the stormwater swales below the current ground level, the construction of this network may create a liquefaction induced lateral spreading hazard at the site.

Based on the results of this preliminary investigation, large areas of the site have a high liquefaction hazard which will need to be further defined and incorporated into the master planning and conceptual design as the development proposals are further progressed. Recommendations for further work include further investigation and assessment to further understand the liquefaction hazard at the site, a more detailed investigation of the risk of settlement in areas where significant fill is likely, establish the groundwater regime for detailed liquefaction analysis through dissipation testing or piezometers and to investigate cut areas of site to determine fill properties.

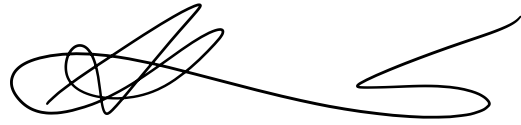
Contents

Executive Summary	i
Introduction	1
Scope.....	1
Site Description	1
Desk Study.....	2
Aerial Imagery	2
Geological Setting	2
Proposed development.....	3
Ground Conditions	3
Hill Terrain.....	3
Plains	4
Groundwater.....	4
Geotechnical Assessment	5
Liquefaction	5
Assessment inputs	5
Liquefaction susceptibility	6
Site performance level	6
Lateral Spreading	7
Soft soils and Settlement	7
Earthworks	7
Stability	7
Pavements.....	8
Recommendations	8
Liquefaction	8
Settlement	8
Groundwater.....	8
Limitation	9
Appendix A – Site Plan	A
Appendix B – Development Concepts and Staging.....	B
Appendix C – Investigation Data	C
Appendix D – Liquefaction Analysis	D
Appendix E – Historic Aerial Imagery.....	E



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Introduction

HD Geo have been engaged by Green Seed Consultants Limited to undertake a preliminary geotechnical assessment of the site known as the Rotokauri North Special Housing Area (SHA). It is proposed to develop the site into a mixture of standard and medium density residential housing, a commercial neighbourhood centre, public parks and potentially a school.

This report is intended to provide a 'high level' site-wide preliminary geotechnical assessment to support master planning and conceptual design for the proposed development. Further geotechnical investigation, assessment and design will be required as the development proposals are further progressed.

Scope

The scope of this assessment included investigation of the ground conditions to broadly characterise the geology at the site, to identify major geotechnical constraints and to input into planning of the development. The scope of investigation and assessment included:

- Desk study and detailed site walkover to identify key constraints;
- A total of eight cone penetration test (CPT) probes (CPT01 to CPT08) to determine deeper ground conditions and provide information for analysis.
- 13 hand augers (HA01 to HA13) to determine shallow ground conditions across the site;
- Five piezometers (ST01 to ST05) installed and monitored over a one-week period to record groundwater levels;
- Three dissipation tests were undertaken in the CPTs to assess the groundwater levels;
- Development of a ground model for the site to inform the assessment; and,
- Assessment of the geology, geo-hazards and requirements for further work.

The locations of the investigations undertaken are shown on Figure 1 in Appendix A. Logs of the investigations are included in Appendix C.

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. There are two rural-residential properties on Burbush Road and six on Te Kowhai Road which are not included in the site. A plan showing the extent of the site 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'). The western edge of the site abuts an area of Hill Terrain which rises up to 18 m in height above the Plains. The area of Hill Terrain within the site rises to approximately 10 m above the Plains. The eastern portion of site is dominated by Hill Terrain which rises up to 18 m above the Plains. The Hill Terrain in the west of site runs northwest to southeast and the hill terrain in the east runs north-northeast to south-southwest. These hill areas merge south of the site. This topographical feature forms a south to north draining basin in which the majority of the site lies. The Hill Terrain typically has gentle crests with sides that slope gently to moderately. The exception

within the site is the eastern slopes of the eastern Hill Terrain in the east of site which reach gradients up to 1V:3H.

The Plains make 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 much of the site. Numerous open drains dissect the Plains, with the west and central portions of site draining south to north to larger channels which direct flows west to Ohote Stream and eventually, the Waipa River. The northeast portion of site drains north to a Waikato River paleochannel known as the Te Kowhai channel¹ which also outlets to the Waipa River. The southeast of site drains through man-made drainage channels to the south, through a gap between low hills to Lake Rotokauri. A second paleochannel is present in this area of site. It is a shallow channel (less than 0.5 m deep), that prior to the formation of the drainage network directing flows to Rotokauri Lake, likely had a south to north paleocurrent direction to the Te Kowhai Channel.

The open drains across the site range from less than 0.5 m in depth and width up to 2 m width and depth. Parts of the low-lying areas of site are located in areas that are expected to be inundated by a 1 in 100 year flood event (Refer to Rotokauri ICMP Plan²).

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

Desk Study

A desktop study was completed prior to the site investigation to identify areas of interest. The desktop study consisted of a review of historical aerial imagery³ and relevant geological maps⁴.

Aerial Imagery

The earliest available aerial imagery, from 1943, shows that the Hill Terrain and Plains in much of the site are predominantly pasture, with the central portion of the low-lying southern boundary covered in patches of low scrub (possible wetland). Imagery through to 1963 show decreasing levels of shrub cover and by 1974, all shrub cover has been cleared from site to form pasture. Since 1974, the site has largely remained unchanged. Relevant photographs are included in Appendix D.

There were no signs of instability at the site, however there were features of small to medium scale instability present in gully heads to the south of site from 1943. Later imagery shows little or change to these features.

Geological Setting

The site is located roughly centrally within the Hamilton Basin 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).

¹ McCraw, J. (2011) *The Wandering River, Landforms and geological history of the Hamilton Basin*. Levin, Geoscience Society of New Zealand.

² Hartland Environment Limited (June, 2017) *Rotokauri – Integrated Catchment Management Plan*.

³ Sourced from <http://retrolens.nz> and licensed by LINZ CC-BY 3.0.

⁴ GNS Science, *New Zealand Geology Web Map*, <http://data.gns.cri.nz/geology>.

The Hamilton Hills are linear, sinuous and discontinuous hills and ridges that are remnant of an older erosion surface. They consist of alluvial material and non-welded ignimbrites (Walton Subgroup) and are typically overlain by a number of metres of airfall volcanic ash (Kauroa Ash and Hamilton Ash). 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 volcanoclastic sediments with a wide variety of grain sizes. Deposition of the fan materials ceased when the Waikato River entrenched into its current course approximately 17 ka and thin airfall tephra layers accumulated on the fan surface (Hinuera Surface).

The New Zealand Geological map (QMap) for the Waikato Region shows that Walton Subgroup, Hinuera Formation and Piako Subgroup materials are mapped at the site. The Walton Subgroup is mapped in the Hill Terrain and is described as Early Pleistocene to Middle Pleistocene alluvium dominated by primary and re-worked non-welded ignimbrite. The Hinuera Formation and Piako Subgroup are mapped on the Plains. The Hinuera Formation is mapped in the majority of the flat-lying areas of site with small areas in the south and southeast of the site described as the Piako Subgroup. The Hinuera Formation is described as Late Pleistocene cross-bedded pumice sand, silt and gravel with interbedded peat and the Piako Subgroup is described as Late Pleistocene locally derived mud, silt, gravel and peat.

Proposed development

We understand from the drawings supplied outlining the proposed works that the development will comprise a mixture of standard and medium density residential housing, a commercial neighbourhood centre, public parks and potentially a school. The development will contain numerous new local roads and five collector roads linking internal areas with Te Kowhai Road, Exelby Road, Burbush Road and yet to be constructed roads to the south.

The proposed development consists of two stages, Stage 1 in the western portion of site covering an area of approximately 53 ha and Stage 2 in the eastern portion of site which is approximately 80 ha. The proposed development concept and staging plans are included in Appendix B.

Ground Conditions

The ground conditions at the site were typically consistent with the mapped geology. The ground conditions have been grouped into areas based on their geomorphology and the conditions encountered in the investigation. All references to soil types and strength/density states from the CPTs are based on the soil behaviour types as interpreted by the CPT results.

Hill Terrain

The Hill Terrain is all ground that is elevated above the flat, low-lying plains of the site. The hand auger boreholes HA10, HA12 and the CPT CPT07 were completed in the Hill Terrain and encountered the following ground conditions:

- Topsoil up to depths of 0.3 m
- Clay and silt to the base of the augers (3.0 m) consistent with Hamilton Ash deposits. Peak shear vane strengths in these materials range from 104 kPa to greater than 203 kPa showing the material to be very stiff to hard.

- CPT07 encountered 13 m of clay, underlain by layered clay, silt and sand deposits to the termination depth of the CPT (19.9m). These materials are consistent with Walton Subgroup deposits. The clay materials were very stiff in the upper 4.0 m of the deposit, then stiff to 13 m, then stiff to very stiff in the remainder of the deposit. The sand layers were typically medium dense.

Plains

The Plains are areas of site that are flat and low-lying. The hand auger boreholes HA01 to HA09, HA11 and HA13, and the CPT investigations CPT01 to CPT06 and CPT08 were completed on the Plains and encountered the following ground conditions:

- Topsoil up to depths of 0.3 m
- Silt and clay between 0.4 m and 0.9 m depth consistent with volcanic ash deposits. Peak shear vane strengths in these materials range from 45 kPa to greater than 131 kPa showing the material to be firm to hard.
- Predominantly sand deposits from the base of the silt and clay to the termination depth of the augers (maximum of 1.8 m depth). Occasional silt layers were present up to 0.9 m thick however these layers were typically less than 300 mm thick. Dynamic cone penetrometer (DCP) testing in the sand deposits recorded between 2 blows/100mm and 15 blows/100mm showing the material to be loose to dense. The sand deposits typically showed an increase of density with depth with all locations being at least medium dense by 1 m depth.
- The CPTs encountered layered sand, silt and clay deposits to the termination depth of the CPTs (typically 20 m). The deposits are predominantly sand dominated in the upper 8 m to 10 m, becoming more clay dominated with depth. The lithologies have varying thicknesses with uniform sand layers reaching a maximum thickness of 6.5 m and uniform clay layers reaching a maximum thickness of 6 m. The sand layers are typically medium dense and the clay and silt layers range from firm to very stiff however are commonly firm.
- CPT05 terminated at 12.4 m as the CPT reached its maximum penetrative force upon a layer described as a very dense/stiff soil.

Groundwater

Testing to determine the groundwater levels at the site comprised of dissipation in the CPTs and temporary piezometers. Three dissipation tests were completed in three CPTs between 5.21 m and 5.5 m depth across the site. Five temporary standpipe piezometers were installed and monitored over a 1 week period. During the monitoring period, the nearest weather station (less than 0.5km to the west of site) recorded 35.2mm of rainfall over a two day period, resulting in elevated groundwater levels for much of the monitoring period. The groundwater monitoring showed a clear response to rainfall. The results of these groundwater investigations are included in Table 1 and Table 2 below.

Table 1. Dissipation testing groundwater results.

Dissipation Test	Area of site	Depth of groundwater (BGL)
CPT01	Northwest corner	<0.1m
CPT03	Southwest corner	0.30m
CPT04	Northeast corner	1.2m

Table 2. Temporary standpipe piezometer groundwater results.

Piezometer	Area of site	Depth of groundwater (BGL)
ST01	Northwest corner	0.25m to <0.1m
ST02	Southwest corner	0.30m to <0.1m
ST03	Approximate centre	0.50m to <0.1m
ST04	Northeast corner	1.10m to 0.80m
ST05	Southeast corner	0.50m to 0.15m

These levels reflect the groundwater levels during the monitoring period. Higher or lower levels are likely during other periods and further monitoring to determine the variation in groundwater levels is recommended.

Geotechnical Assessment

This assessment is a collection of general information and advice to assist planning the site for residential development. It is intended to be a high-level assessment to guide the master planning and concept development of the site. Further work will be required as the planning progresses.

Liquefaction

A liquefaction assessment has been undertaken using data from the CPT testing. The assessment has been undertaken in accordance with the 2016 MBIE and NZGS⁵ guidelines in order to estimate the liquefaction hazard across the site. This study would qualify as a Level C, 'detailed area-wide assessment' in accordance with the 2017 EQC and MBIE planning guidelines⁶. Outputs from the liquefaction analysis are included in Appendix D.

Assessment inputs

A screening analysis was completed on the 8 CPTs undertaken at the site for 1 in 500-year (ULS) and 1 in 25-year (SLS) design events. The soil behaviour index (Ic) for the CPT located in the hill terrain was lowered from 2.6 to 2.2 based upon the results of the most recent research on Hamilton Ash deposits in the Waikato⁷. The test results were analysed using the proprietary software CLIQ (Geologismiki) and engineering calculations in accordance with the most recent NZGS guidelines³.

The design earthquake for analysis of the liquefaction susceptibility has been assessed from Section 6 of the NZTA Bridge Manual⁸. Input parameters are provided below:

- Site seismic classification: Class D (Deep soils)
- Structure Importance Level: Level 2 (Normal importance, residential structures)

⁵ Ministry of Business, Innovation & Employment and New Zealand Geotechnical Society, 2016. *Earthquake geotechnical engineering practice – Module 3: Identification, assessment and mitigation of liquefaction hazards*.

⁶ Earthquake Commission (EQC) & Ministry of Innovation and Employment (MBIE), 2017. *Planning and engineering guidance for potentially liquefaction prone land*.

⁷ Clayton, P. & Wong, I., 2017. *Application of soil specific correction factors for liquefaction assessment: case study in Waikato soils for the Hamilton section of the Waikato expressway*.

⁸ New Zealand Transport Agency (2016) *Bridge Manual (SP/M/022), Third edition*.

- Peak ground acceleration: 0.05g (SLS) for a 1 in 25-year event
0.22g (ULS) for a 1 in 500 year event
- Earthquake magnitude: 5.9
- Groundwater depth: Between 0.1 m and 1.1 m below ground level (as measured during the investigation)

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 ground surface settlement, liquefaction potential index (LPI) and liquefaction severity number (LSN). The CPTs have been assessed under ULS conditions with the analysis limited to 15 m depth for the screening assessment accordance with the guidelines.

LPI

The potential damage that liquefaction can cause can be estimated using the liquefaction potential index (LPI). LPI is a combination of the thickness of liquefying layers and the depth below the ground surface at which the layers lie. An LPI of below 5 indicates a low risk, between 5 and 15 a high risk and over 15, a very high risk. The CPTs on the Plains typically have LPI values between 6 and 11 indicating a high risk of liquefaction. The analysis for CPT03 (located on the Plains in the southwest of site) had an LPI value of 4, indicating a low risk of liquefaction. The analysis for the CPT located in the Hill Terrain (CPT07) had an LPI of 0, indicating there is no risk of liquefaction.

LSN

The liquefaction severity number (LSN) provides 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. An LSN of less than 10 presents insignificant anticipated expression and over 50, a severe anticipated expression. The CPTs on the Plains typically have LSN values between 25 and 45 indicating moderate to severe anticipated expressions of liquefaction. The analysis for CPT03 had an LSN value of 18, indicating a minor anticipated expression of liquefaction. The analysis for the CPT located in the Hill Terrain (CPT07) had an LSN of 0, indicating there is no anticipated expression of liquefaction.

Site performance level

In accordance with the NZGS guidelines³ the Hill Terrain lies in the Performance Level L0 (Insignificant), showing there is no liquefaction hazard. The Plains (with the exception of CPT03) lie across the Performance Levels L3 (High) to L4 (Severe). These performance levels are broadly defined as the following:

- Liquefaction occurring in a significant portion, to complete liquefaction of the deposit;
- Moderate to excessive differential settlements;
- Total settlements from 100mm to over 200mm (under ULS conditions).

At the level of this assessment, the liquefaction hazard on the Plains appears to be considerable and significant mitigation measures would likely be required to allow for residential and infrastructure construction. We recommend a more detailed assessment of the site is undertaken to refine the assessment of the site. Further investigation should include other test methods to refine the assessment of the liquefaction potential.

Lateral Spreading

Lateral spreading is a phenomenon where liquefied material allows the soil above to move laterally towards a free face, such as a stream bank. Currently, the areas of site that have a liquefaction hazard are flat and so there is no lateral spreading risk. The development plans however show stormwater swales throughout the site which are likely to be excavated up to 2.0 m depth below current ground levels. The liquefaction assessment of the site showed that the soils in the near surface were liquefiable, and as such, the formation of these swales may create free faces that could mean a lateral spreading hazard for the site. Further assessment of this hazard will be required as part of the detailed assessment.

Soft soils and Settlement

Given the likelihood of fill being required on the Plains to raise site levels above flooding levels, a screening analysis was completed on the 7 CPTs that were located on the Plains to determine the susceptibility of the ground to static settlements when loaded. The preliminary analysis indicates that the site generally has a low susceptibility to static settlement as most of the soils are sandy.

While not encountered during this investigation, our experience in the area has shown that organic and soft soils are commonly (but not exclusively) found in paleochannel features and close to the Hill Terrain in 'embayments'. In order to ease grades from the steep Hill Terrain to the Plains it is likely that fill placed will be at its greatest depths closest to the hills, where these organic or soft soils are commonly encountered. As the risk of consolidation settlements is often greatest in these areas they should be a target area for future investigations.

Earthworks

Earthworks at the site are likely to consist of cut and fill operations in order to ease grades on the site, create level building platforms, fill open drains, form stormwater storage and conveyance, and to raise the Plains above flood levels.

The investigations completed in the elevated areas of site encountered Hamilton Ash materials which are typically suitable as an earthwork material. Some moisture conditioning may be required to ensure that soils are placed and compacted near their optimum moisture content, as it is likely that materials will be wet of optimum. Beneath the ash, the Puketoka Formation is often encountered. The Puketoka Formation soils are highly sensitive and break down on working. Laboratory testing of the materials and an earthworks specification will be required for the site for any significant cut or fill proposals.

Stability

There are no indications of any recent, large scale instability having occurred at the site, or in the immediate surrounding area. Features that may be indicative of small to medium-scale instability were observed to the south of site however historic aerial imagery indicate these failures have not changed significantly in at least the last 70 years. Active observed instability in the area tends to be shallow creep on steeper slopes and is often associated with springs, saturated soils or stock movement.

Earthworks on the site are likely to reduce the overall stability risk by reducing both the heights and grades of current slopes. Cuts up to 3 m height at 1V:3H sloped batters are expected to be stable, however shallower grades may be required for other purposes (eg. Landscaping). Where cut slopes are steeper or higher than this, specific assessment and design will be required. Earthworks on the

Hill Terrain may demand grades that will require retaining. Specific design will be required for retaining walls.

As mentioned above, the formation of the stormwater swales at the site may create a liquefaction induced lateral spreading hazard at the site. Reducing the slope grade of the swales may reduce this hazard or slope stabilisation methods may be required. Further assessment of the lateral spreading risk will be required.

Instability is often driven by, or significantly influenced by, surface water or groundwater. Control of water from the development will be necessary to ensure that there is no adverse effect on the slopes. Water should be collected and directed away from slopes. Any collected water will need to be discharged in a controlled manner to a protected outlet.

Pavements

A number of roads are proposed for the development and although the road grading design has not been completed (so subgrade levels are not known), it is likely road pavement subgrades will be based on Piako Subgroup materials, Hinuera Formation materials, Hamilton Ash materials and, depending on cut depths in the hill terrain, the sensitive materials of the Puketoka Formation.

Based on these anticipated ground conditions and the testing completed during the investigation, it is likely that natural subgrade CBR will be low. Improvement of the subgrade will likely be required by either compaction of the insitu material or by undercutting and replacement with a hardfill subgrade improvement layer. Where organic material is encountered, removal and replacement with suitable backfill will be required.

Specific testing and design will be required to determine the final pavement requirements.

Recommendations

Based on the results of this preliminary investigation, large areas of the site have a high liquefaction hazard which will need to be further defined and incorporated into the master planning and conceptual design of the site. This assessment encountered ground conditions that will require further investigation and assessment as the development proposals are further progressed. Further investigations should include the below.

Liquefaction

- Further investigation and assessment to further understand the liquefaction hazard at the site and outline mitigation measures where necessary. These investigations should include shear wave velocity testing and laboratory testing of onsite soils.
- Investigation of the liquefaction induced lateral spreading risk adjacent to proposed stormwater swales.

Settlement

- Investigation of the risk of settlement in areas where significant fill is likely; focusing close to the Hill Terrain/Plains boundary and paleochannels.

Groundwater

- Establish the groundwater regime for detailed liquefaction analysis through dissipation testing or piezometers;

Earthworks

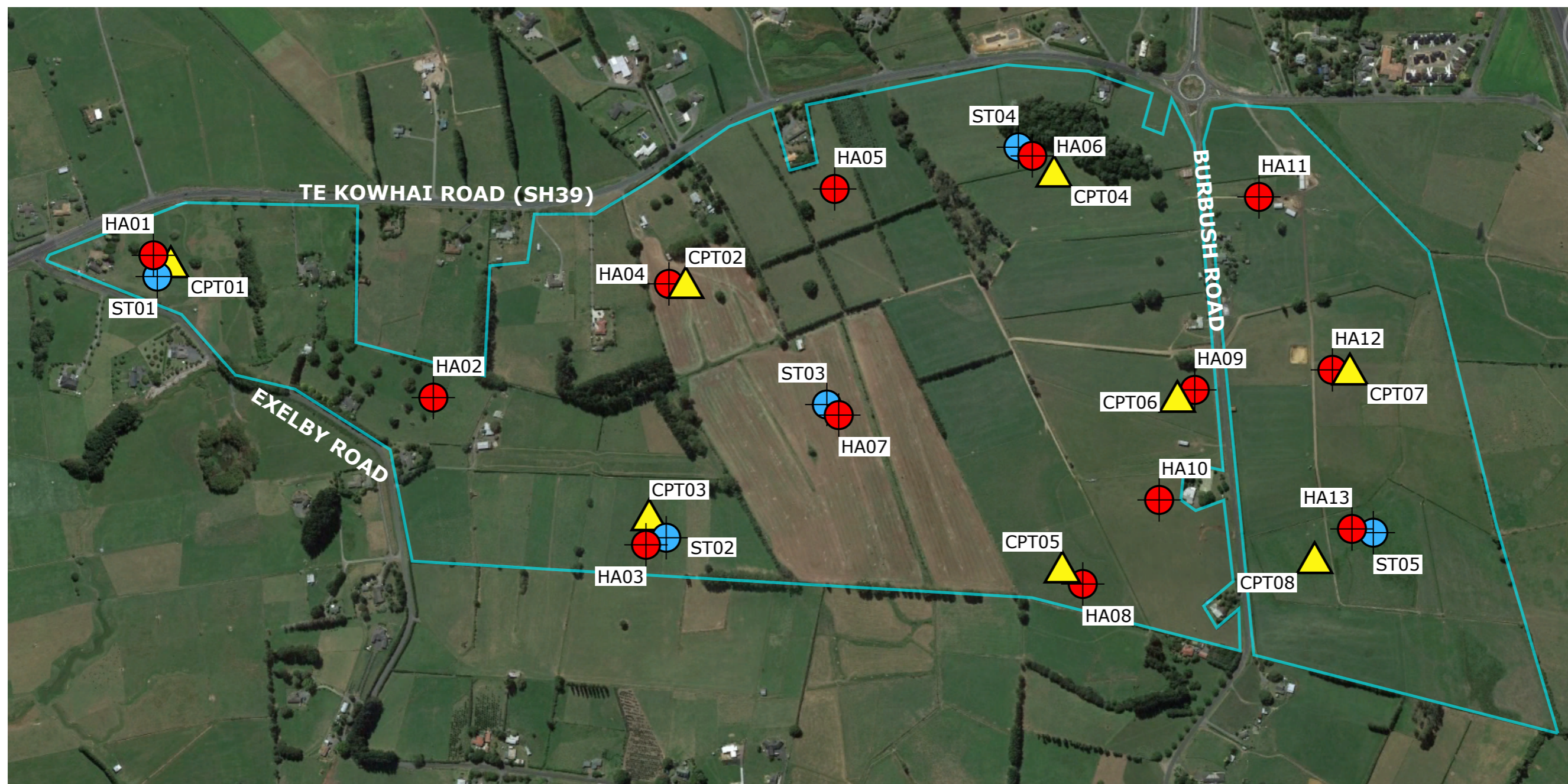
- Investigation of cut areas to determine fill properties.

Limitation






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 support master planning and conceptual design 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 PLAN





LEGEND

-  Hand Auger
-  Cone Penetrometer Test
-  Temporary Piezometer
-  Site boundary
-  WRC 5m contours

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:	

Retrieved from Google Maps 18.07.18



-  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

APPENDIX B – DEVELOPMENT CONCEPTS AND STAGING

ROKOKAURI 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.

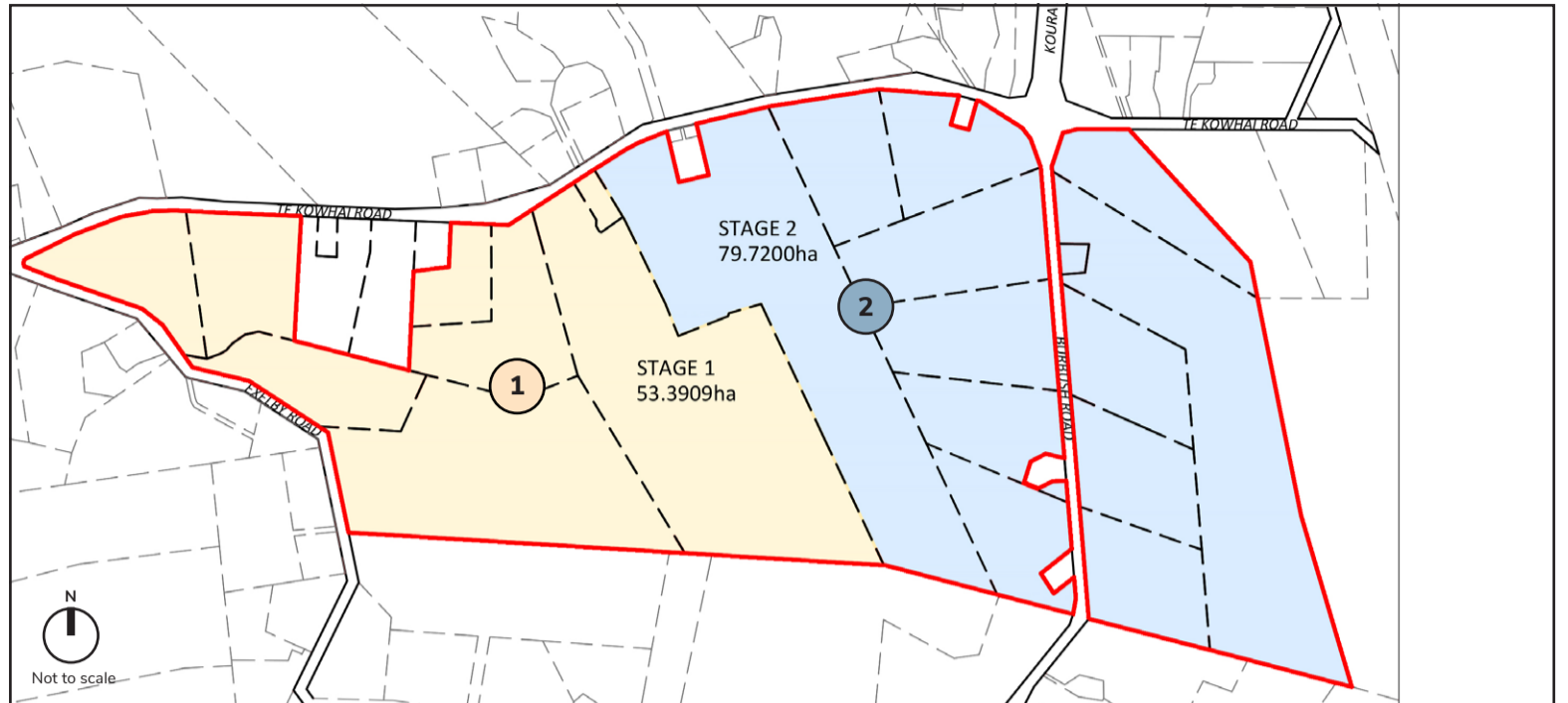


Figure 1: Rotokauri North SHA area

ROKOKAURI 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 exposure and accessibility to all. Size will be determined by Council acquisition agreement.
- 6 Ensure sensitive slopes can be appreciated as landscape features.

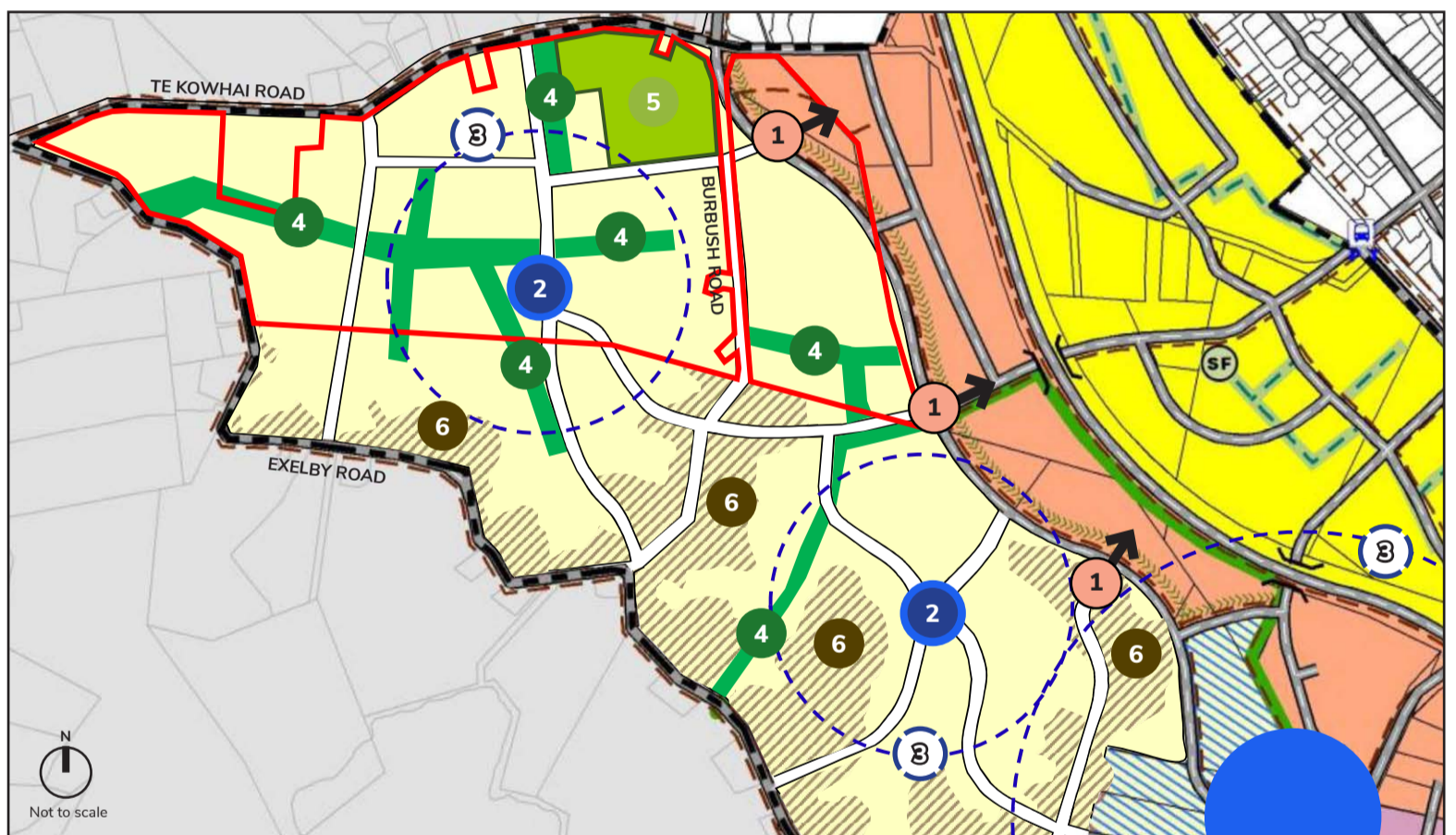


Figure 1: Key structuring elements of Rotokauri North SHA concept

ROKOKAURI NORTH SHA OPTIONS FOR STORMWATER (Figure 3)

Map legend

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

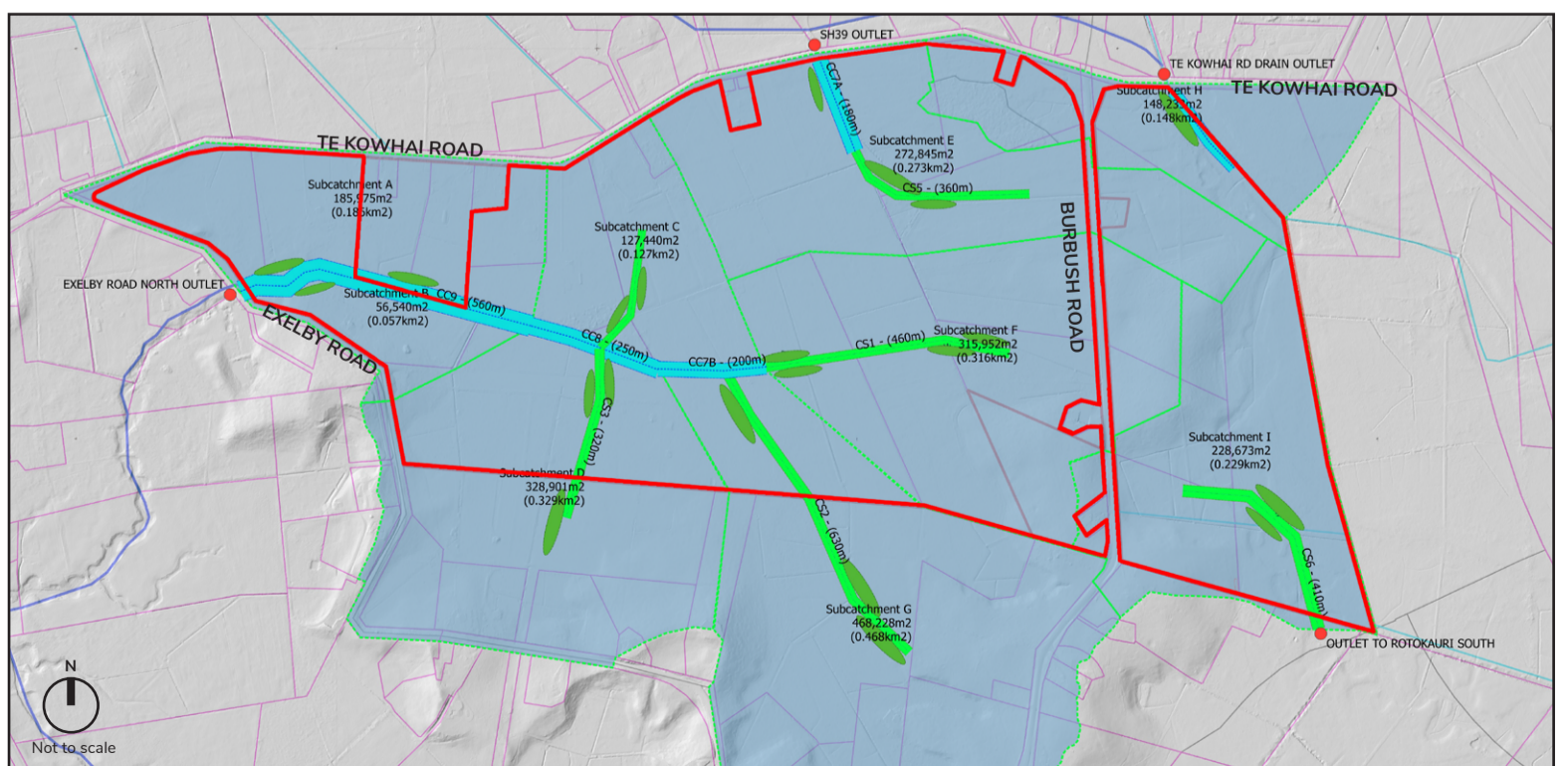


Figure 3: Rotokauri North SHA options for stormwater

Source: CKL Stormwater Solutions

Rotokauri North Special Housing Area

February 2018
Green Seed Consultants Ltd

ROKOKAURI 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).

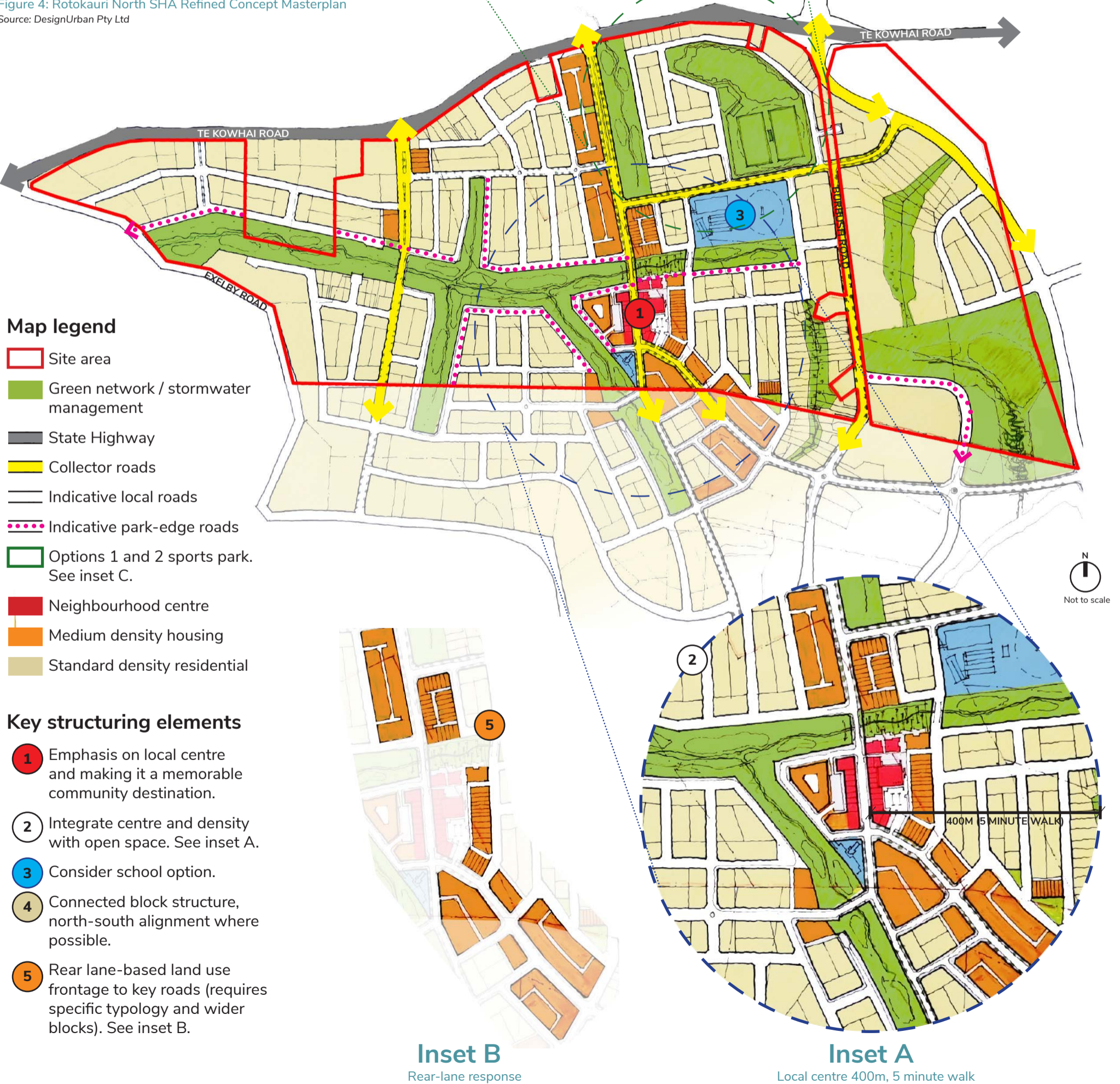
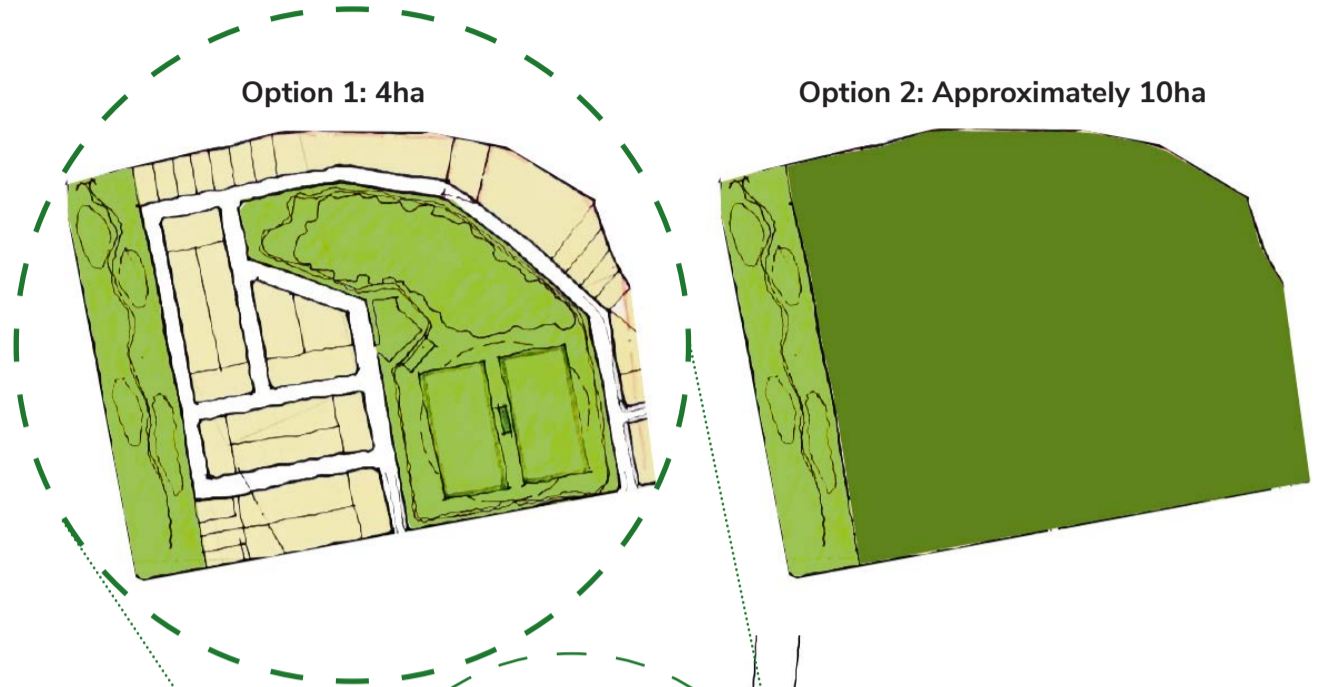
Figure 4: Rotokauri North SHA Refined Concept Masterplan
Source: DesignUrban Pty Ltd

Inset C

Options for sports park

Option 1: 4ha

Option 2: Approximately 10ha



Map legend

- Site area
- Green network / stormwater management
- State Highway
- Collector roads
- Indicative local roads
- Indicative park-edge roads
- Options 1 and 2 sports park. See inset C.
- Neighbourhood centre
- Medium density housing
- Standard density residential

Key structuring elements

- 1 Emphasis on local centre and making it a memorable community destination.
- 2 Integrate centre and density with open space. See inset A.
- 3 Consider school option.
- 4 Connected block structure, north-south alignment where possible.
- 5 Rear lane-based land use frontage to key roads (requires specific typology and wider blocks). See inset B.

Inset B

Rear-lane response

Inset A

Local centre 400m, 5 minute walk

APPENDIX C – INVESTIGATION DATA



Test Record

Test Type: Hand Auger

Test Results

Date: 22/06/2018

Project: HD631 - Rotokauri North SHA Geo

Test Number: HA01/ST01

Location: Plains, northwest corner of site

Land Parcel: Sec 23, SO 495676

Tested by: MM

Checked by: SA

Depth	Geology	DCP (blows/ 100mm)	Shear Vane (kPa)	Material Description	Detailed Description
0.0	Topsoil	1		Topsoil.	0.0m: SILT; dark brownish black. Moist; trace rootlets. 0.1m: saturated.
0.1		1			
0.2	Volcanic Ash	1	93/3	Undifferentiated airfall tephra.	0.2m: SILT, some clay, minor sand; light grey, streaked orange. Stiff; wet; moderate plasticity; quick; sand, fine to medium.
0.3		1			
0.4		1			
0.5		2			
0.6	Hinuera Formation	2		Cross bedded pumice sand and silt.	0.6m: SAND, minor silt; light brownish grey. Medium dense; saturated; well graded; sand, fine to coarse, lithics. 1.0m: dense. 1.2m: SAND, minor silt; brownish grey. Dense; saturated; well graded; sand, medium to coarse, lithics, quartz.
0.7		3			
0.8		6			
0.9		5			
1.0		7			
1.1		9			
1.2		9			
1.3		12			
1.4		11			
1.5		9			
1.6	5			1.5m: End of borehole Unable to Advance. 1.6m: medium dense to dense. 2.6m: loose to medium dense.	
1.7	5				
1.8	5				
1.9	5				
2.0	7				
2.1	7				
2.2	3				
2.3	5				
2.4	9				
2.5	10				
2.6	4				
2.7	2				
2.8	3				
2.9	2				
3.0		7			3.0m: End of Strength Testing Target Depth.

<p>Groundwater observations: Groundwater at 0.1m at time of testing.</p> <p>Shear Vane: SV 534</p>	<p>Comments: Unable to advance past 1.5m due to hole collapse.</p>
--	---



Test Record

Test Type: Hand Auger

Test Results

Date: 22/06/2018

Project: HD631 - Rotokauri North SHA Geo

Test Number: HA02

Location: Plains, west of site

Land Parcel: Lot 5 DPS 15123

Tested by: SA

Checked by: MM

Depth	Geology	DCP (blows/ 100mm)	Shear Vane (kPa)	Material Description	Detailed Description
0.0	Topsoil	1		Topsoil.	0.0m: SILT; dark brownish black. Moist; trace rootlets.
0.1		2			
0.2		1			
0.3	Volcanic Ash	1	64/9	Undifferentiated airfall tephra.	0.3m: SILT, minor sand; brown. Stiff; moist; low plasticity; sensitive; sand, fine, poorly graded.
0.4		2			
0.5		1			
0.6		1	73/36		
0.7	Hinuera Formation	2		Cross bedded pumice sand and silt.	0.7m: SILT; some sand; brown. Stiff; wet; low plasticity; moderate sensitivity; sand, fine. 0.9m: SAND, some silt; brown. Loose to medium dense; saturated; sand, fine to medium, pumice, quartz, lithic fragments.
0.8		2			
0.9		2			
1.0		4			1.0m: End of Borehole Unable to Advance. 1.2m: medium dense.
1.1		4			
1.2		4			
1.3		4			
1.4		4			
1.5		4			
1.6		5			
1.7		6			
1.8		5			
1.9		5			
2.0		5			
2.1		5			
2.2		6			
2.3		7			
2.4		3			
2.5		3			
2.6		5			
2.7		5			
2.8		4			
2.9		3			
3.0		3			3.0m: End of Strength Testing Target Depth.

<p>Groundwater observations: Groundwater at 1.0m at time of testing.</p> <p>Shear Vane: SV 1710</p>	<p>Comments: Unable to advance past 1.0m due to hole collapse.</p>
---	---



Test Record

Test Type: Hand Auger

Test Results

Date: 22/06/2018

Project: HD631 - Rotokauri North SHA Geo

Test Number: HA03/ST02

Location: Plains, southwest of site

Land Parcel: Lot 5 DPS 15123

Tested by: SA

Checked by: MM

Depth	Geology	DCP (blows/ 100mm)	Shear Vane (kPa)	Material Description	Detailed Description	
0.0	Topsoil	1		Topsoil.	0.0m: SILT; dark brownish black. Moist; trace rootlets.	
0.1		1				
0.2	Volcanic Ash	1	87/15	Undifferentiated airfall tephra.	0.2m: SILT; dark brown. Stiff; moist to wet; sensitive; high plasticity.	
0.3		2				
0.4	Hinuera Formation	1	90/20	Cross bedded pumice sand and silt.	0.4m: Sandy SILT; greyish brown. Stiff; moist to wet; low plasticity; sand, fine, uniformly graded. 0.6m: saturated. 0.7m: SAND, some silt; greyish brown. Loose; saturated; dense; sand, fine to medium; well graded.	
0.5		2				
0.6		2				
0.7		2				
0.8		5				
0.9		8				
1.0		10				
1.1		8				
1.2		7				
1.3		8				
1.4	14					
1.5		15			1.5m: End of Borehole Unable to Advance.	
1.6		11				
1.7		Refusal			1.7m: End of Strength Testing Unable to Advance.	
1.8						
1.9						
2.0						
2.1						
2.2						
2.3						
2.4						
2.5						
2.6						
2.7						
2.8						
2.9						
3.0						

<p>Groundwater observations: Groundwater at 0.6m at time of testing.</p> <p>Shear Vane: SV 1710</p>	<p>Comments: Unable to advance past 1.5m due to hole collapse. Unable to advance past 1.7m due to refusal.</p>
---	---



Test Record

Test Type: Hand Auger

Test Results

Date: 21/06/2018

Project: HD631 - Rotokauri North SHA Geo

Test Number: HA04

Location: Plains, northern centre of site

Land Parcel: Lot 2 DP 485743

Tested by: SA

Checked by: MM

Depth	Geology	DCP (blows/ 100mm)	Shear Vane (kPa)	Material Description	Detailed Description
0.0	Topsoil	1		Topsoil	0.0m: SILT; dark brownish black. Moist; trace rootlets.
0.1		2			
0.2		1			
0.3	Volcanic Ash	1	75/29	Undifferentiated airfall tephra.	0.3m: Clayey SILT; brown. Stiff; moist to wet; high plasticity. 0.6m: saturated.
0.4		1			
0.5		1	55/29		
0.6		2			
0.7		2			
0.8		3			
0.9	Hinuera Formation	5	87/15	Cross bedded pumice sand and silt.	0.9m: Silty SAND; brownish grey. Medium dense; saturated; sand, fine, uniformly graded. 1.5m: SILT, minor organics; grey. Stiff; saturated; low plasticity; sensitive.
1.0		4			
1.1		5			
1.2		4			
1.3		5			
1.4		5	87/35		
1.5		6			
1.6		4			
1.7		3			
1.8		6			
1.9		6			
2.0		4			
2.1		5			
2.2		6			
2.3		15			
2.4	14				
2.5	8				
2.6	14				
2.7	14				
2.8	14				
2.9					
3.0					

<p>Groundwater observations: Groundwater at 0.5m at time of testing.</p> <p>Shear Vane: SV 1710</p>	<p>Comments: Unable to advance past 2.6m due to hole collapse. Unable to advance past 2.9m due to refusal.</p>
---	---



Test Record

Test Type: Hand Auger

Test Results

Date: 21/06/2018

Project: HD631 - Rotokauri North SHA Geo

Test Number: HA05

Location: Plains, northern centre of site

Land Parcel: Lot 2 DP 485743

Tested by: SA

Checked by: MM

Depth	Geology	DCP (blows/ 100mm)	Shear Vane (kPa)	Material Description	Detailed Description
0.0	Topsoil	2		Topsoil	0.0m: SILT; dark brownish black. Moist; trace rootlets.
0.1		2			
0.2		2			
0.3	Hinuera Formation	2		Cross bedded pumice sand and silt.	0.3m: Silty SAND, some gravel; dark brown. Loose; moist to wet; sand, fine to coarse, well graded; gravel, fine, subrounded, lithic fragments. 0.6m: brownish orange. 1.3m: SAND, some gravel, minor silt; brownish orange. Medium dense, saturated; sand, fine to coarse, well graded, quartz, pumice, lithic fragments; gravel, fine, subrounded, lithic fragments. 1.8m: grey.
0.4		1			
0.5		2			
0.6		2			
0.7		2			
0.8		2			
0.9		2			
1.0		2			
1.1		2			
1.2		3			
1.3		5			
1.4		4			
1.5		3			
1.6		5			
1.7		3			
1.8	6				
1.9	6				
2.0	4				
2.1	3			2.1m: End of Borehole Unable to Advance.	
2.2	7				
2.3	7				
2.4	5				
2.5	4				
2.6	4				
2.7	5				
2.8	5				
2.9	6				
3.0	2				3.0m: End of Strength Testing Target Depth

<p>Groundwater observations: Groundwater at 0.8m at time of testing.</p> <p>Shear Vane: SV 1710</p>	<p>Comments: Unable to advance past 2.1m due to hole collapse.</p>
---	---



Test Record

Test Type: Hand Auger

Test Results

Date: 22/06/2018

Project: HD631 - Rotokauri North SHA Geo

Test Number: HA06/ST04

Location: Plains, northeast of site

Land Parcel: Lot 1 DPS 15254

Tested by: SA

Checked by: MM

Depth	Geology	DCP (blows/ 100mm)	Shear Vane (kPa)	Material Description	Detailed Description
0.0	Topsoil	1		Topsoil.	0.0m: SILT; dark brownish black. Moist; trace rootlets.
0.1		2			
0.2	Volcanic Ash	2	131/20	Undifferentiated airfall tephra.	0.2m: Clayey SILT; brownish orange. Very stiff; moist; low plasticity; sensitive.
0.3		2			
0.4		3			
0.5		3			
0.6	Hinuera Formation	5		Cross bedded pumice sand and silt.	0.6m: Gravely SAND; dark brownish orange. Moist; medium dense; sand, fine to coarse, well graded, quartz, pumice, lithic fragement; gravel, subrounded, lithic fragments. 0.9m: grey. 1.1m: dense.
0.7		9			
0.8		5			
0.9		4			
1.0		3			
1.1		12			
1.2		10			
1.3		12			
1.4		12			
1.5		11			
1.6		12			
1.7	9				
1.8	8			1.8m: End of Borehole Unable to Advance	
1.9	5				
2.0	3				
2.1	2				
2.2	1				
2.3	1				
2.4	3				
2.5	4				
2.6	6				
2.7	5				
2.8	3				
2.9	6				
3.0				3.0m: End of Strength Testing Target Depth.	

<p>Groundwater observations: Groundwater at 1.5m at time of testing.</p> <p>Shear Vane: SV 1710</p>	<p>Comments: Unable to advance past 1.8m due to hole collapse.</p>
---	---



Test Record

Test Type: Hand Auger

Test Results

Date: 22/06/2018

Project: HD631 - Rotokauri North SHA Geo

Test Number: HA07/ST03

Location: Plains, approximate centre of site

Land Parcel: Lot 2 DP485743

Tested by: MM

Checked by: SA

Depth	Geology	DCP (blows/ 100mm)	Shear Vane (kPa)	Material Description	Detailed Description
0.0	Topsoil	2		Topsoil.	0.0m: SILT; dark brownish black. Moist; trace rootlets.
0.1		1			
0.2		0.5			
0.3	Volcanic Ash	0.5	45/16	Undifferentiated airfall tephra.	0.3m: SILT, minor sand; dark reddish brown. Firm; wet; low dilatency; moderate sensitivity; sand, fine.
0.4		1			
0.5		1			
0.6	Hinuera Formation	2		Cross bedded pumice sand and silt.	0.6m: SAND, some silt; reddish brown. Loose to medium dense; saturated; uniformly graded; sand, medium, lithics. 0.9m: SAND, minor silt; dark reddish brown. Dense; saturated; well graded; sand, fine to medium, lithics. 1.1m: SAND, minor silt; dark reddish brown. Dense; saturated; well graded; sand, fine to coarse, lithics, quartz.
0.7		3			
0.8		4			
0.9		7			
1.0		8			
1.1		6			
1.2		7			
1.3		10		1.3m: End of Log Unable to Advance.	
1.4		10			
1.5		8			
1.6		8			
1.7		12			
1.8		11			
1.9		9			
2.0		13			
2.1		12			
2.2		13			
2.3		13			
2.4		refusal		2.4m: End of Log Unable to Advance.	
2.5					
2.6					
2.7					
2.8					
2.9					
3.0					

<p>Groundwater observations: Groundwater at 0.6m at time of testing.</p> <p>Shear Vane: SV 534</p>	<p>Comments: Unable to advance from 1.3m due to hole collapse. Unable to advance from 2.4m due to refusal.</p>
--	---



Test Record

Test Type: Hand Auger

Test Results

Date: 21/06/2018

Project: HD631 - Rotokauri North SHA Geo

Test Number: HA08

Location: Plains, southern boundary of site

Land Parcel: SEC 53 SO 495676

Tested by: SA

Checked by: MM

Depth	Geology	DCP (blows/ 100mm)	Shear Vane (kPa)	Material Description	Detailed Description
0.0	Topsoil	1		Topsoil	0.0m: SILT; dark brownish black. Moist; trace rootlets.
0.1		1			
0.2		0.5			
0.3	Volcanic Ash	0.5		Undifferentiated airfall tephra.	0.3m: Silty CLAY, minor sand. Light brownish grey. Moist; high plasticity; sand, fine.
0.4		1			
0.5	Hinuera Formation	2		Cross-bedded pumice sand and silt.	0.5m: SAND, light brownish grey. Moist to wet; uniformly graded; sand, fine. 0.8m: grey, saturated. 1.0m: SAND; grey. Saturated; well graded; sand, fine to medium.
0.6		4			
0.7		4			
0.8		4			
0.9		5			
1.0		5			
1.1		7			
1.2		6			
1.3		6			
1.4		6			
1.5		5			
1.6	6				
1.7	6				
1.8	7				
1.9	2				
2.0	2				
2.1	4				
2.2	8				
2.3	10				
2.4	7				
2.5	4				
2.6	6				
2.7	10				
2.8	6				
2.9	10				
3.0					3.0m: End of strength testing Target Depth.

<p>Groundwater observations: Groundwater at 1.2m at time of testing.</p> <p>Shear Vane: SV 1710</p>	<p>Comments: Unable to advance past 1.5m due to hole collapse.</p>
---	---



Test Record

Test Type: Hand Auger

Test Results

Date: 22/06/2018

Project: HD631 - Rotokauri North SHA Geo

Test Number: HA09

Location: Plains, northeast of site

Land Parcel: Lot 4 DP 359488

Tested by: SA

Checked by: MM

Depth	Geology	DCP (blows/ 100mm)	Shear Vane (kPa)	Material Description	Detailed Description
0.0	Topsoil	1		Topsoil.	0.0m: SILT; dark brownish black. Moist; trace rootlets.
0.1		1			
0.2	Volcanic Ash	2	75/12	Undifferentiated airfall tephra.	0.2m: Clayey SILT; dark grey. Stiff; moist to wet; high plasticity; sensitive.
0.3		2			
0.4	Hinuera Formation	3		Cross bedded pumice sand and silt.	0.4m: SAND, some silt; light grey. Loose to medium dense; wet; sand, fine, poorly graded. 0.6m: saturated 0.8m: sand, fine to medium, pumiceous.
0.5		2			
0.6		4			
0.7		5			
0.8		6			
0.9		8			
1.0		7			
1.1		6			1.1m: End of Borehole Unable to Advance.
1.2		7			
1.3		6			
1.4		7			
1.5		6			
1.6		4			
1.7		2			
1.8		2			
1.9		3			
2.0		7			
2.1	8				
2.2	13				
2.3	13				
2.4	13				
2.5	15				
2.6	14				
2.7	Ref				2.7m: End of Strength Testing Unable to Advance.
2.8					
2.9					
3.0					

<p>Groundwater observations: Groundwater at 0.6m at time of testing.</p> <p>Shear Vane: SV 1710</p>	<p>Comments: Unable to advance past 1.1m due to hole collapse. Unable to advance past 2.7m due to refusal.</p>
---	---



Test Record

Test Type: Hand Auger

Test Results

Date: 22/06/2018

Project: HD631 - Rotokauri North SHA Geo

Test Number: HA10

Location: Hill terrain, southeast corner of site

Land Parcel: Lot 2 DP 359488

Tested by: SA

Checked by: MM

Depth	Geology	DCP (blows/ 100mm)	Shear Vane (kPa)	Material Description	Detailed Description	
0.0	Topsoil			Topsoil.	0.0m: SILT; dark brownish black. Moist; trace rootlets.	
0.1						
0.2						
0.3	Hamilton Ash			Undifferentiated airfall tephra.	0.3m: Silty CLAY, dark brownish orange. Very stiff; moist; moderate plasticity; moderate sensitivity.	
0.4						
0.5						
0.6			151/78			0.7m: brownish orange, insensitive.
0.7						
0.8						
0.9			203+			
1.0						
1.1						1.1m: Clayey SILT; light brown. Hard; moist; low plasticity; sensitive.
1.2			191/44			
1.3						
1.4						
1.5			203+			1.5m: Silty CLAY; light brown. Hard; moist; moderate plasticity; moderate sensitivity.
1.6						
1.7						
1.8			160/70			
1.9						
2.0						
2.1		148/58				
2.2						
2.3						
2.4		116/58				
2.5						
2.6						
2.7		165/78				
2.8						
2.9				2.9m: flakes of mica.		
3.0			203+		3.0m: End of Log Target Depth.	

<p>Groundwater observations: No groundwater at time of testing.</p> <p>Shear Vane: SV 1710</p>	<p>Comments:</p>
--	-------------------------



Test Record

Test Type: Hand Auger

Test Results

Date: 22/06/2018

Project: HD631 - Rotokauri North SHA Geo

Test Number: HA11

Location: Plains, northeast corner of site

Land Parcel: Lot 6 DP 359488

Tested by: SA

Checked by: MM

Depth	Geology	DCP (blows/ 100mm)	Shear Vane (kPa)	Material Description	Detailed Description
0.0	Topsoil	1		Topsoil.	0.0m: SILT; dark brownish black. Moist; trace rootlets.
0.1		3			
0.2	Volcanic Ash	2	116/58	Undifferentiated airfall tephra.	0.25m: Silty CLAY, some sand; dark brown, mottled black. Stiff; moist; high plasticity; sensitive; sand, fine to coarse. 0.5m: Clayey SILT; dark brown. Very stiff; moist; high plasticity; moderate sensitivity.
0.3		2			
0.4		2			
0.5		3			
0.6		3			
0.7		4			
0.8	Hinuera Formation	3	174/26	Cross bedded pumice sand and silt.	0.8m: Silty SAND; grey, mottled brownish orange. Medium dense; moist to wet; sand, fine to medium. 1.3m: SAND; greyish white. Medium dense; saturated; sand, fine to medium. 2.1m: SILT; greyish white. Very stiff; moist to wet; sensitive. 2.3m: 50mm fine to medium SAND; greyish white; moderate sensitivity. 2.8m: SAND; greyish white. Dense; saturated; sand, fine to medium. 2.9m: bluish grey; sand, fine to coarse, well graded, pumiceous.
0.9		4			
1.0		6			
1.1		5			
1.2		5			
1.3		6			
1.4		3			
1.5		3			
1.6		5			
1.7		5			
1.8		3			
1.9		3			
2.0		6			
2.1		8			
2.2	6				
2.3	6				
2.4	8	148/55			
2.5	9				
2.6	12				
2.7	12				
2.8	11				
2.9	11				
3.0					3.0m: End of Log Target Depth.

<p>Groundwater observations: Groundwater at 1.2m at time of testing.</p> <p>Shear Vane: SV 1710</p>	<p>Comments:</p>
---	-------------------------



Test Record

Test Type: Hand Auger

Test Results

Date: 22/06/2018

Project: HD631 - Rotokauri North SHA Geo

Test Number: HA12

Location: Hill terrain, eastern area of site

Land Parcel: Lot 9 DPS 15255

Tested by: SA

Checked by: MM

Depth	Geology	DCP (blows/ 100mm)	Shear Vane (kPa)	Material Description	Detailed Description
0.0	Topsoil			Topsoil.	0.0m: SILT; dark brownish black. Moist; trace rootlets.
0.1					
0.2	Hamilton Ash			Undifferentiated airfall tephra.	0.2m: Silty CLAY; dark brownish orange. Hard; moist; moderate plasticity. 0.7m: brownish orange; insensitive. 1.3m: light brownish orange. 2.8m: trace of mica. 2.9m: Sandy SILT, some clay. Hard; moist; moderate plasticity; sand, fine to medium, mica.
0.3					
0.4					
0.5					
0.6					
0.7					
0.8					
0.9					
1.0					
1.1					
1.2					
1.3					
1.4					
1.5					
1.6					
1.7					
1.8					
1.9					
2.0					
2.1					
2.2					
2.3					
2.4					
2.5					
2.6					
2.7					
2.8					
2.9					
3.0			203+		3.0m: End of Log Target Depth.

<p>Groundwater observations: No groundwater at time of testing.</p> <p>Shear Vane: SV 1710</p>	<p>Comments:</p>
--	-------------------------



Test Record

Test Type: Hand Auger

Test Results

Date: 22/06/2018

Project: HD631 - Rotokauri North SHA Geo

Test Number: HA13/ST05

Location: Plains, southeast corner of site

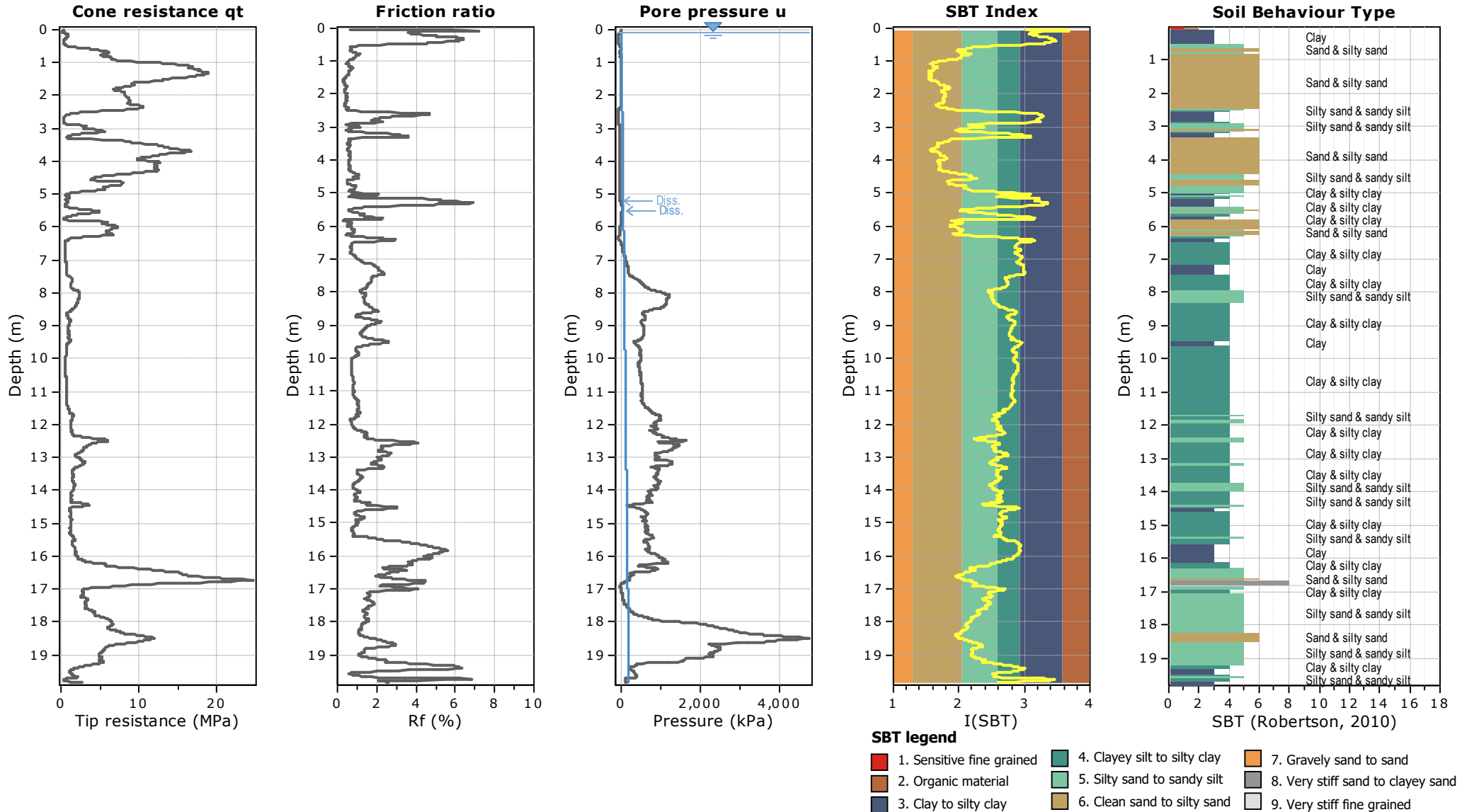
Land Parcel: Lot 2 DP 359488

Tested by: MM

Checked by: SA

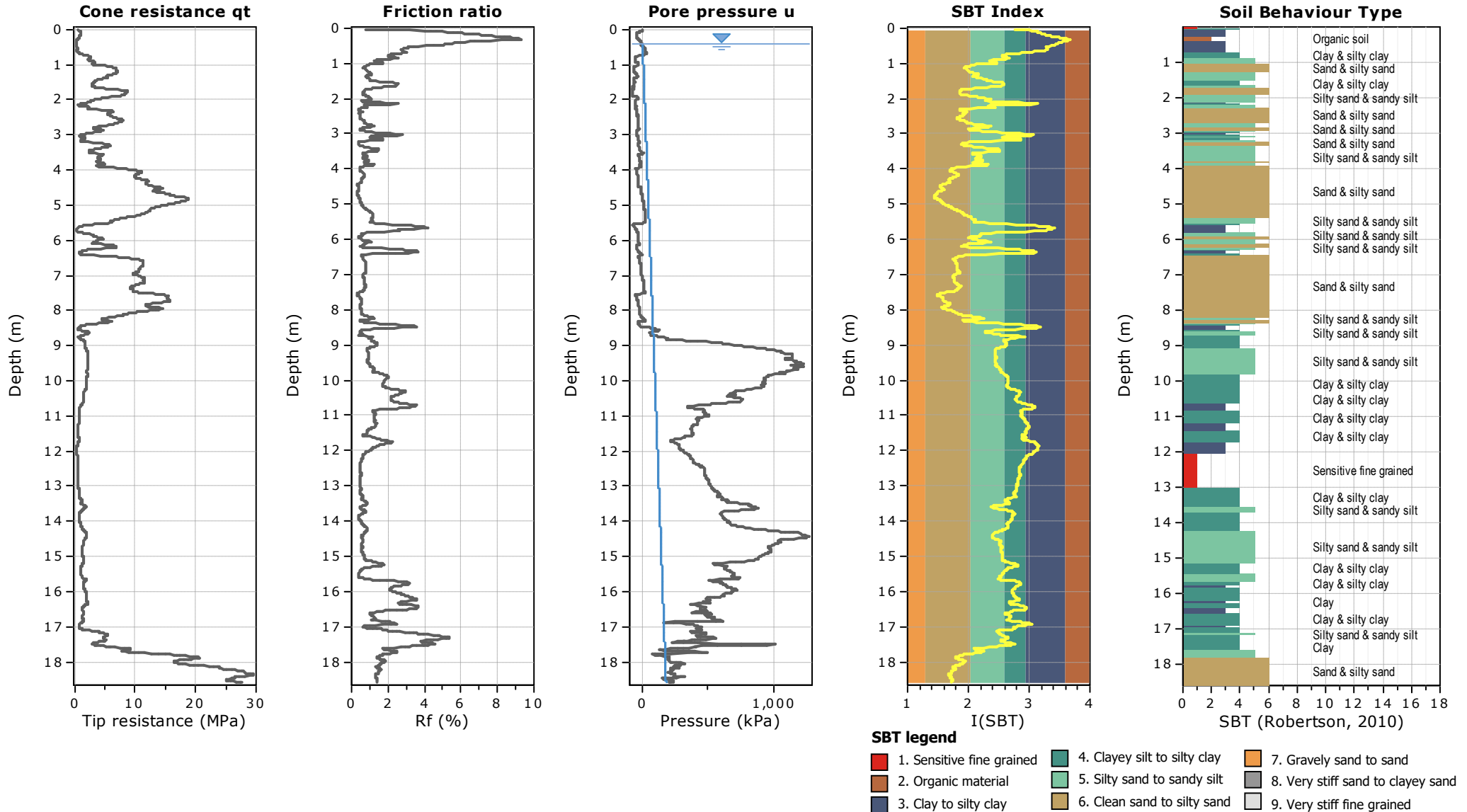
Depth	Geology	DCP (blows/ 100mm)	Shear Vane (kPa)	Material Description	Detailed Description
0.0	Topsoil	3		Topsoil.	0.0m: SILT; dark brownish black. Moist; trace rootlets.
0.1		1			
0.2		1			
0.3	Volcanic Ash	1	38/13	Undifferentiated airfall tephra.	0.3m: Clayey SILT; brownish orange. Firm; moist; moderate plasticity; moderate sensitivity.
0.4		2			
0.5	Hinuera Formation	2		Cross bedded pumice sand and silt.	0.5m: SILT, some clay, minor sand; light grey. Firm; moist; moderate dilatency; moderate sensitivity; sand, fine. 0.8m: saturated. ----- 0.9m: SAND, some silt; light grey. Medium dense; saturated; well graded; sand, fine to medium lithics. ----- 1.2m: SAND, minor silt; light grey. Medium dense; saturated; uniformly graded; sand, medium, lithics. ----- 1.6m: Silty SAND; light grey. Medium dense; saturated; poorly graded; sand, fine to medium, lithics. ----- 1.9m: SILT, some sand; greyish blue. Medium dense to dense; wet; moderate dilatency; sand, fine. ----- 2.1m: Sandy SILT; light brownish grey. Medium dense to dense; wet; moderate dilatency; sand, fine.
0.6		2			
0.7		2			
0.8		4			
0.9		3			
1.0		5			
1.1		5			
1.2		4			
1.3		4			
1.4		5			
1.5		6			
1.6		6			
1.7		4			
1.8		3			
1.9	4				
2.0	9				
2.1	5				
2.2	7				
2.3	6			2.3m: End of Borehole Unable to Advance.	
2.4	5			2.4m: medium dense.	
2.5	4				
2.6	3				
2.7	5				
2.8	5				
2.9	9				
3.0	5			3.0m: End of Strength Testing Target Depth.	

<p>Groundwater observations: Groundwater at 0.8m at time of testing.</p> <p>Shear Vane: SV 534</p>	<p>Comments: Unable to advance past 2.3m due to hole collapse.</p>
--	---





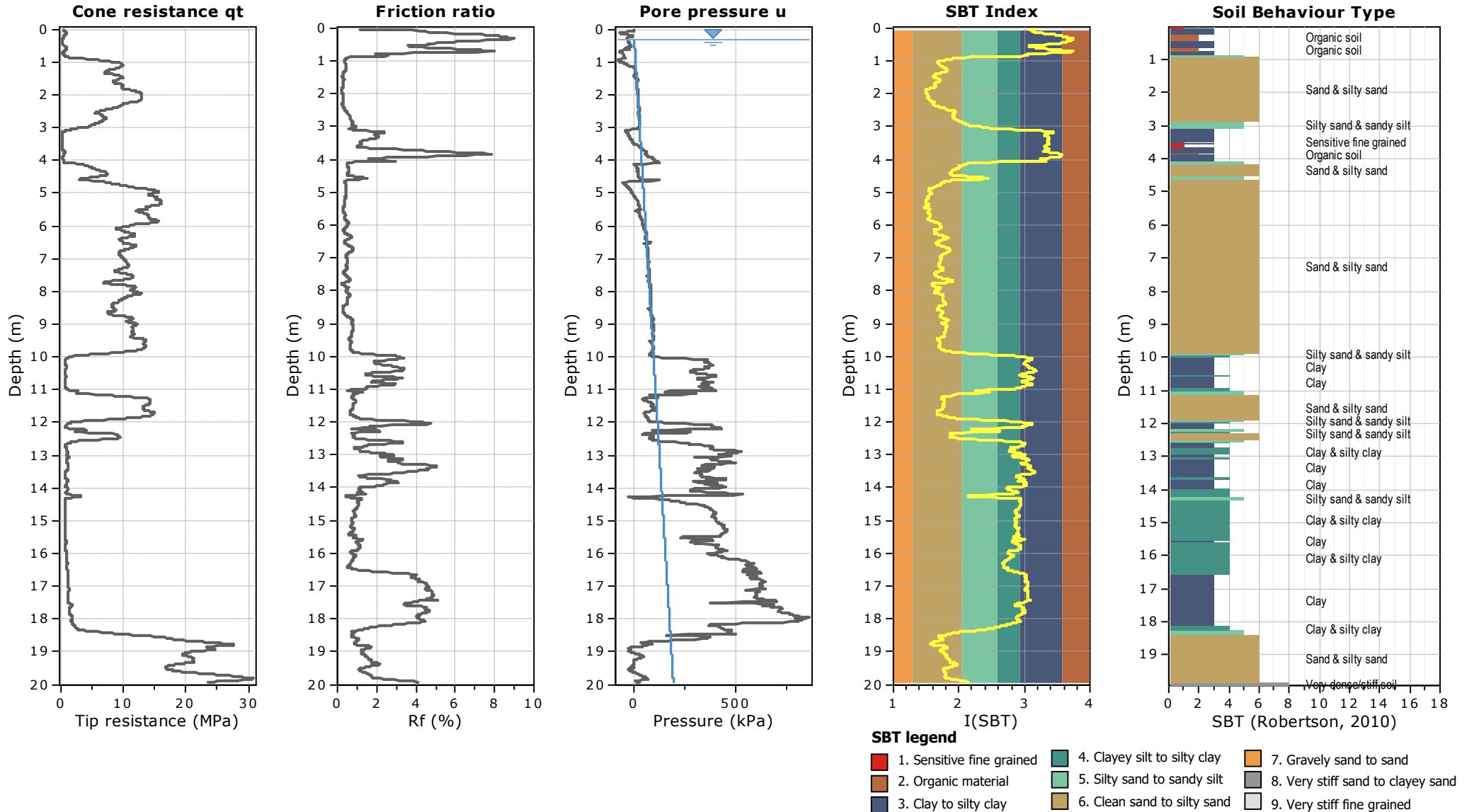
Project: HD631 - Rotokauri North SHA Geo
Location: Rotokauri North

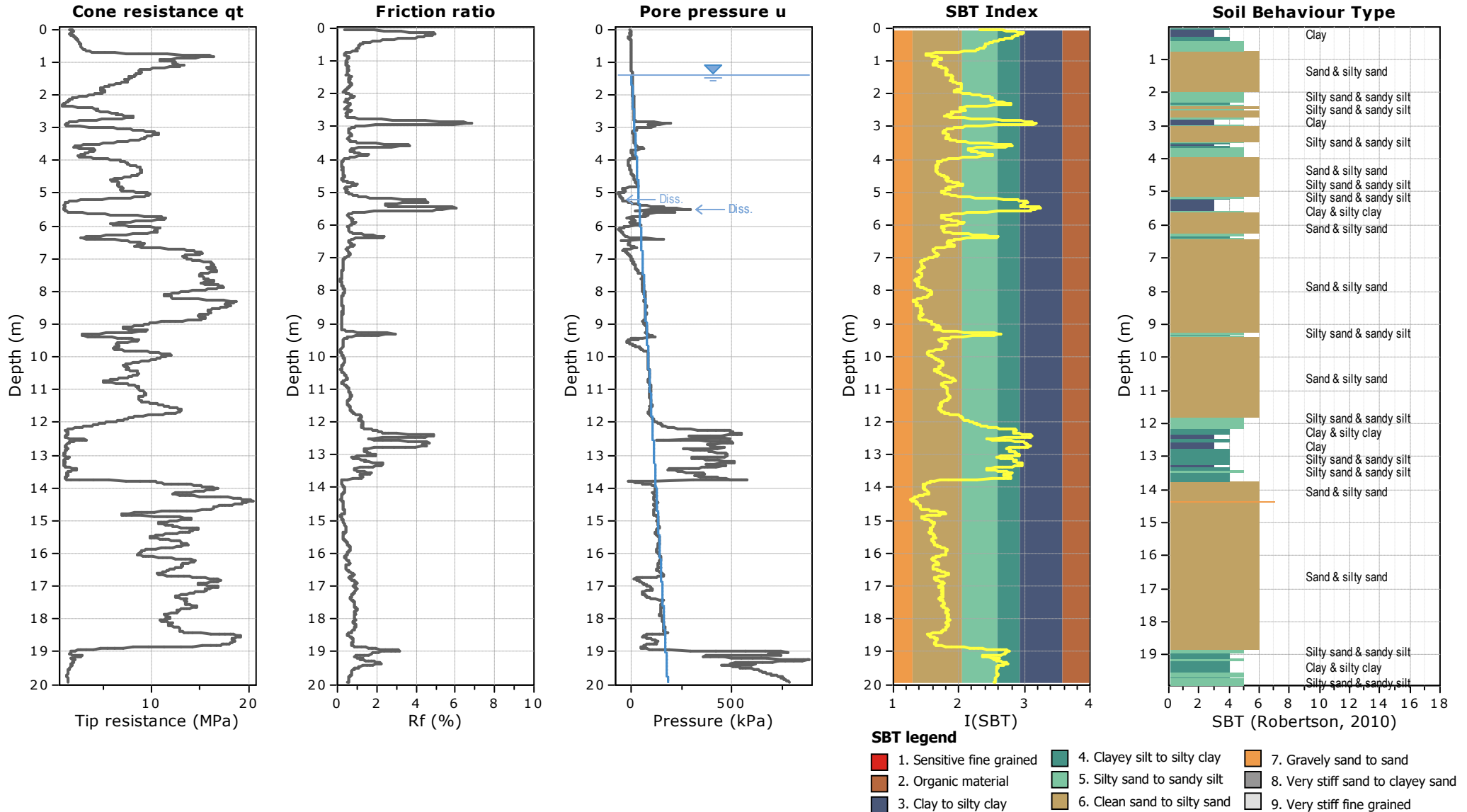




Project: HD631 - Rotokauri North SHA Geo

Location: Rotokauri North

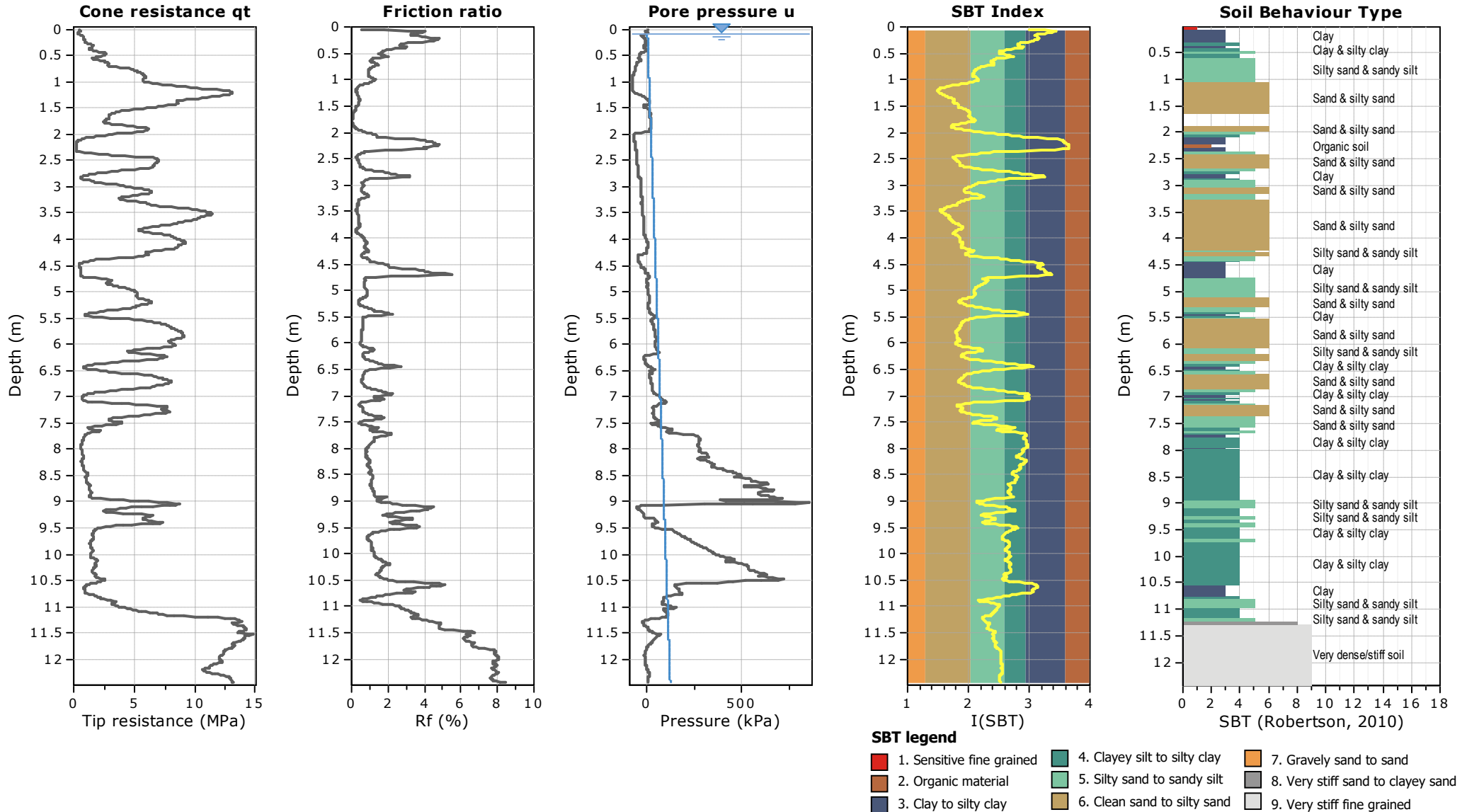


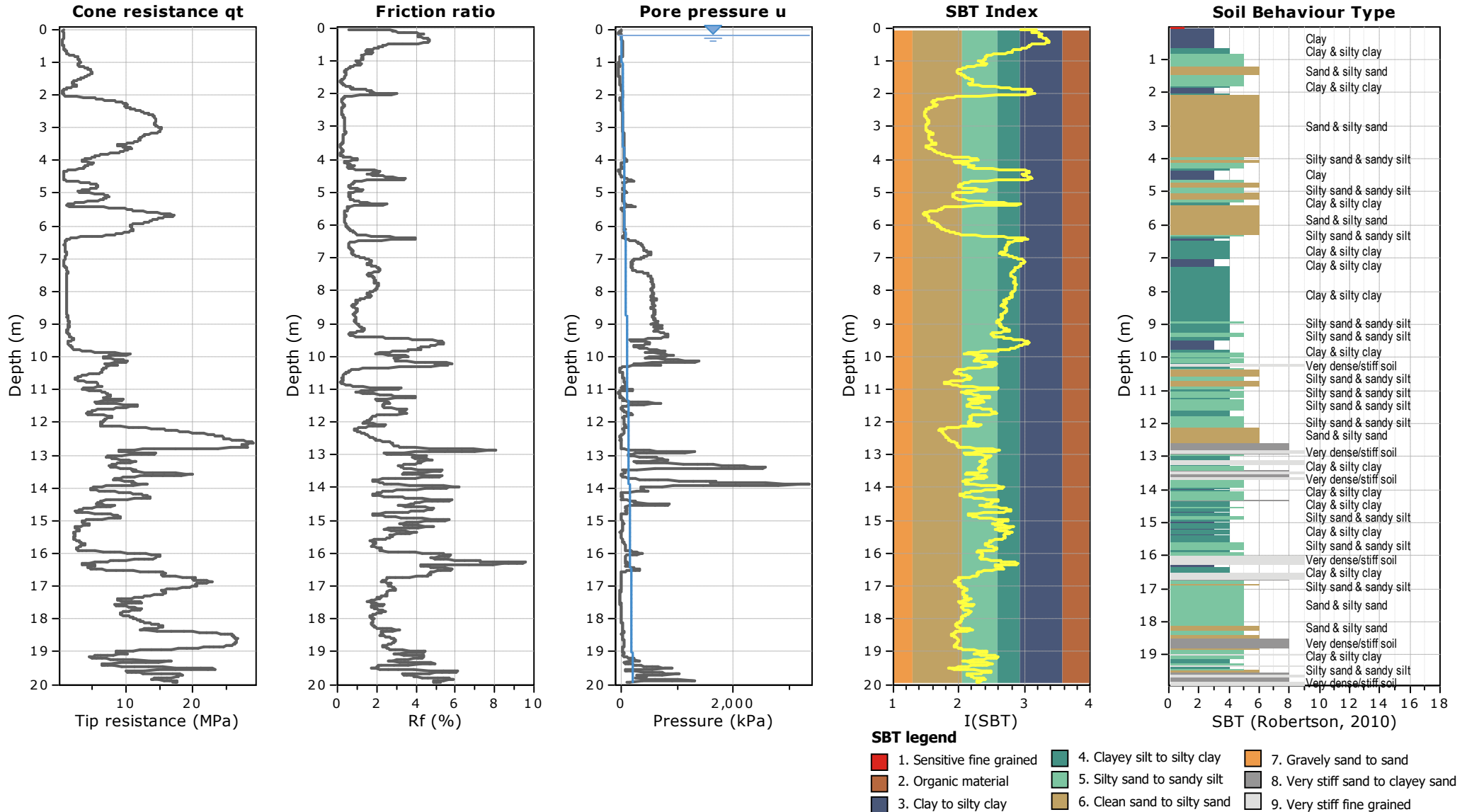




Project: HD631 - Rotokauri North SHA Geo

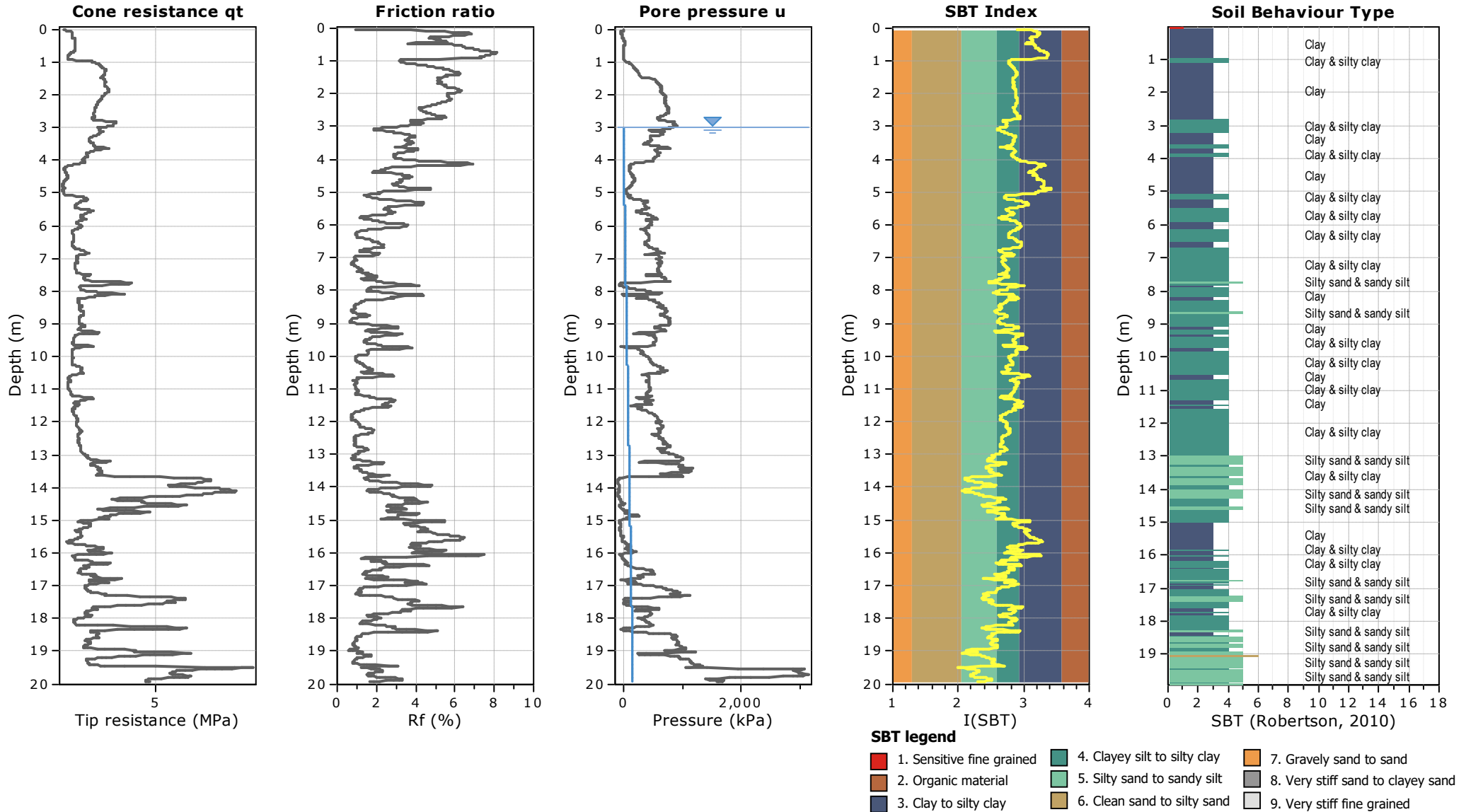
Location: Rotokauri North







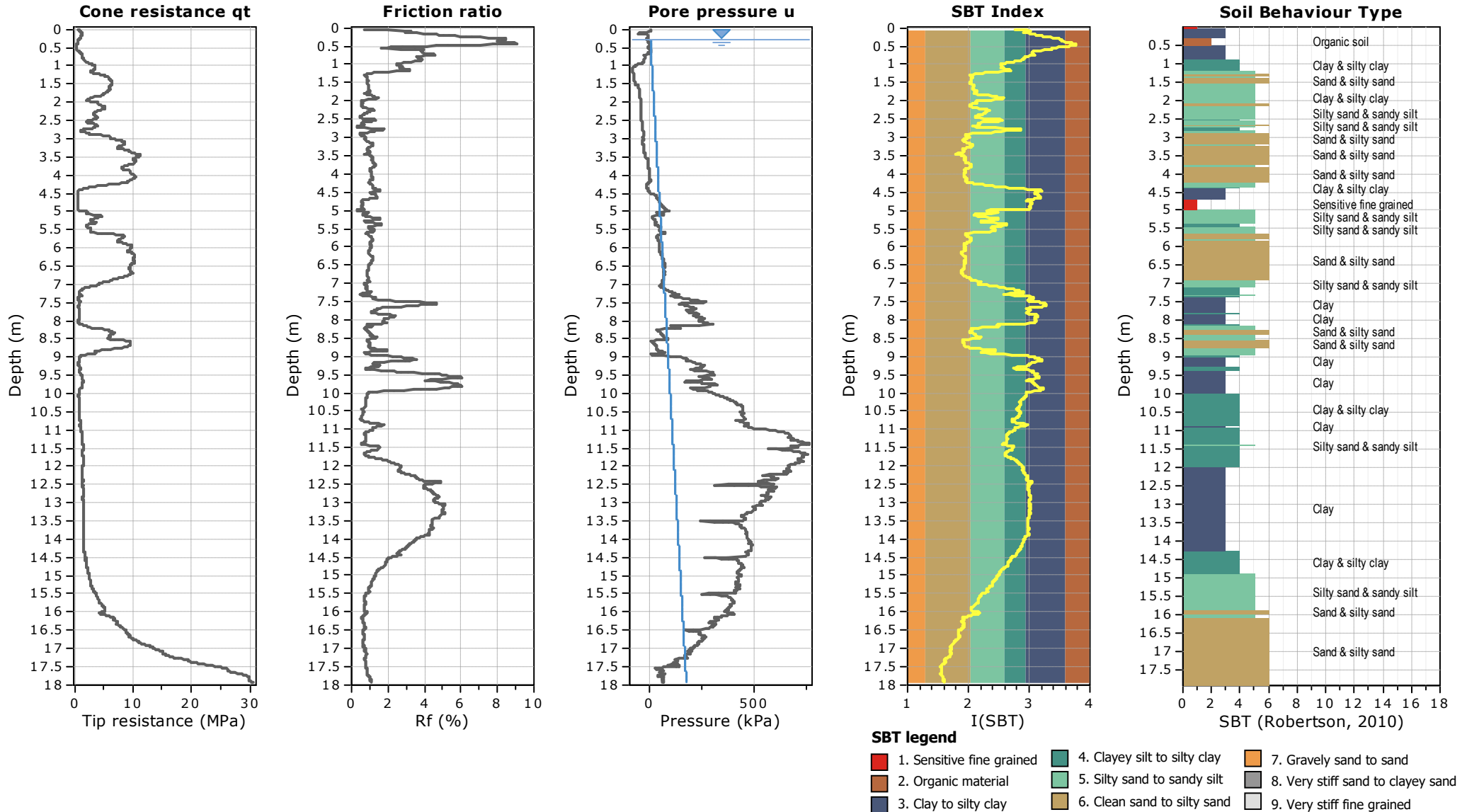
Project: HD631 - Rotokauri North SHA Geo
Location: Rotokauri North





Project: HD631 - Rotokauri North SHA Geo

Location: Rotokauri North



APPENDIX D – LIQUEFACTION ANALYSIS

LIQUEFACTION ANALYSIS REPORT

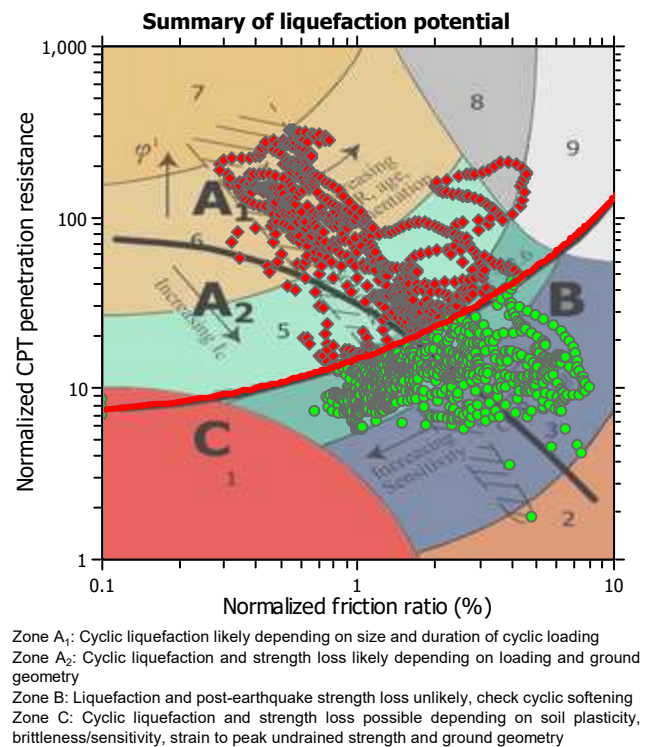
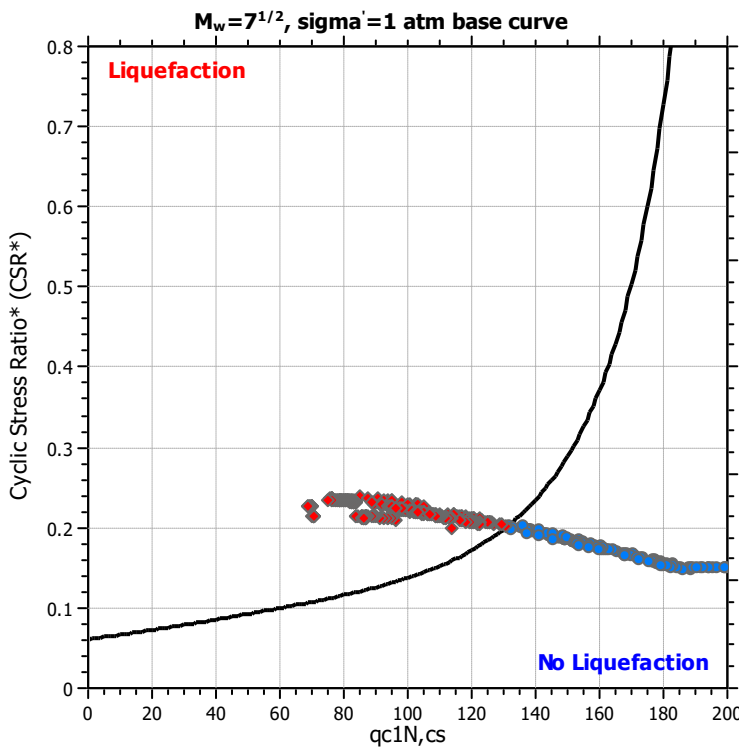
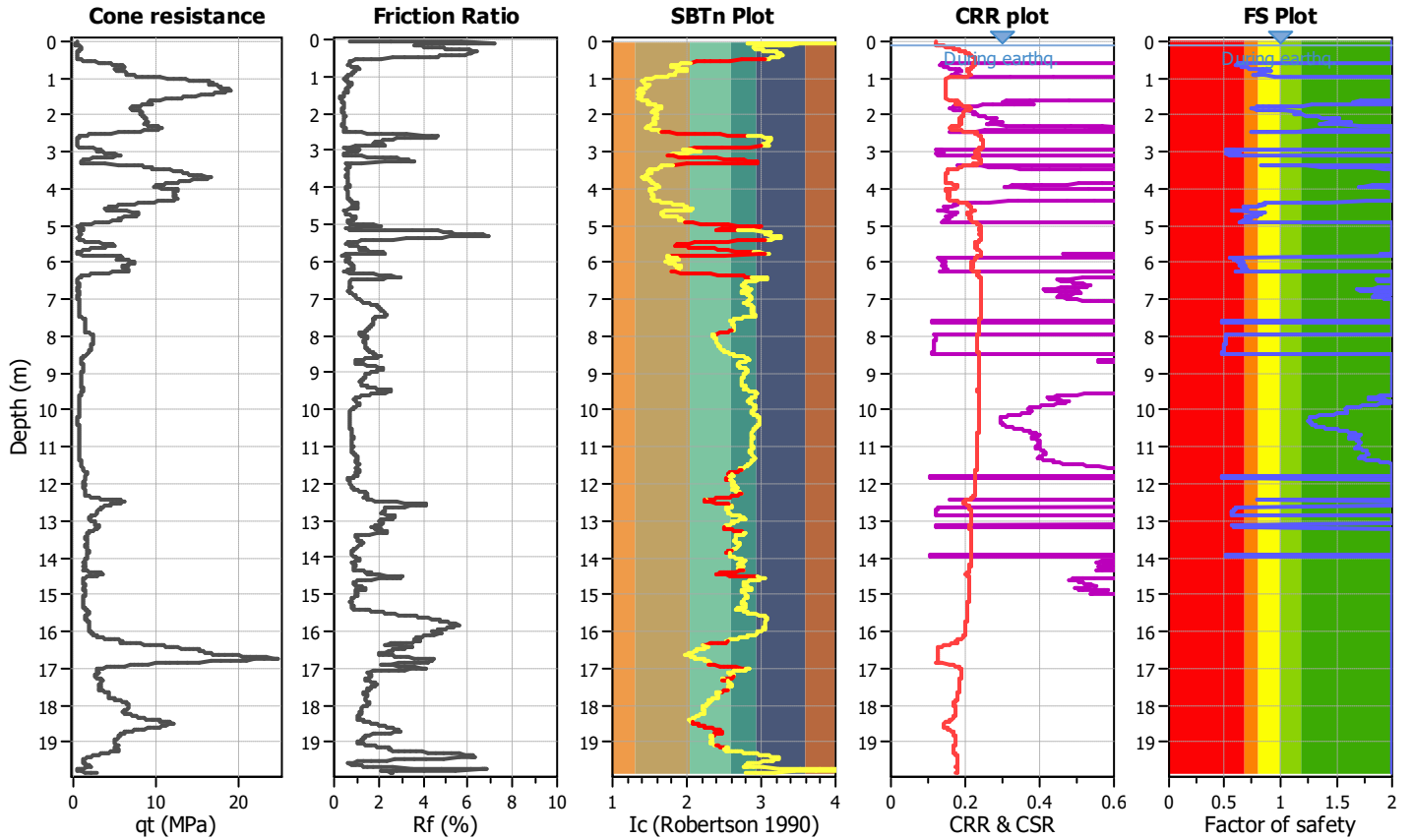
Project title : HD631 - Rotokauri North SHA Geo

Location : Rotokauri North

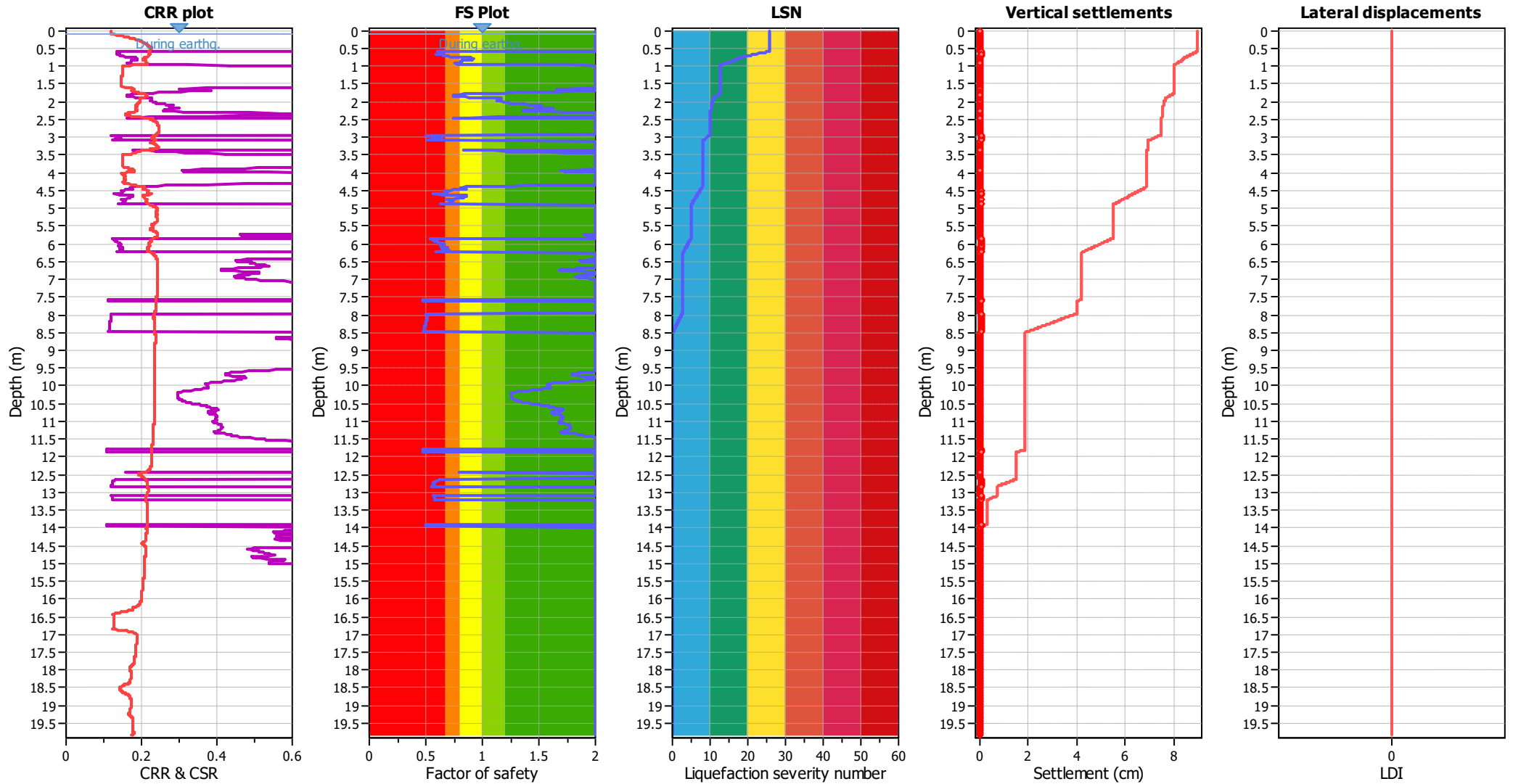
CPT file : CPT01

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.):	0.10 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:	15.00 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		



Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (earthq.):	0.10 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:	15.00 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

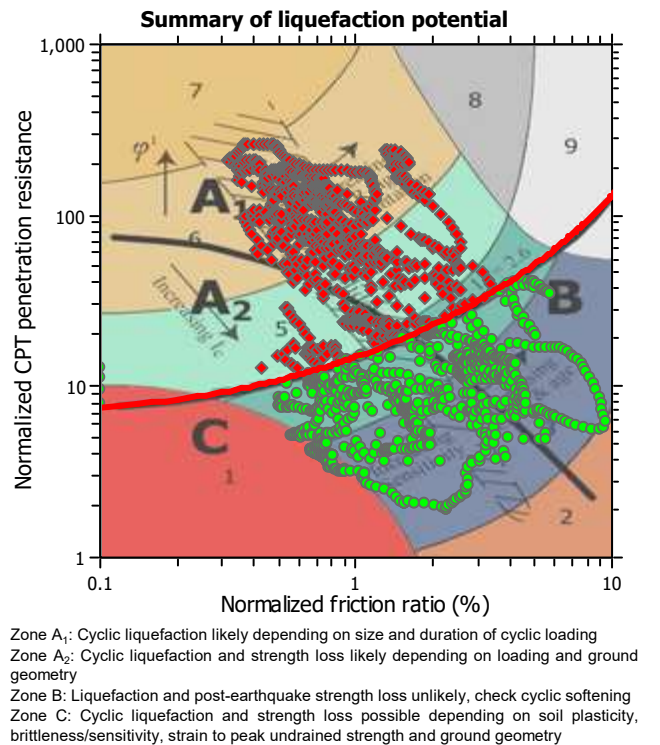
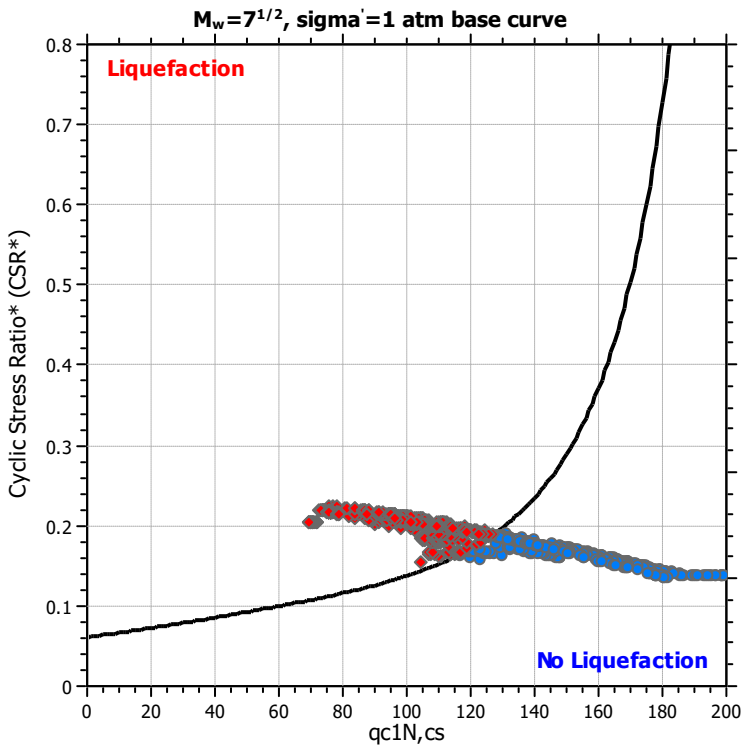
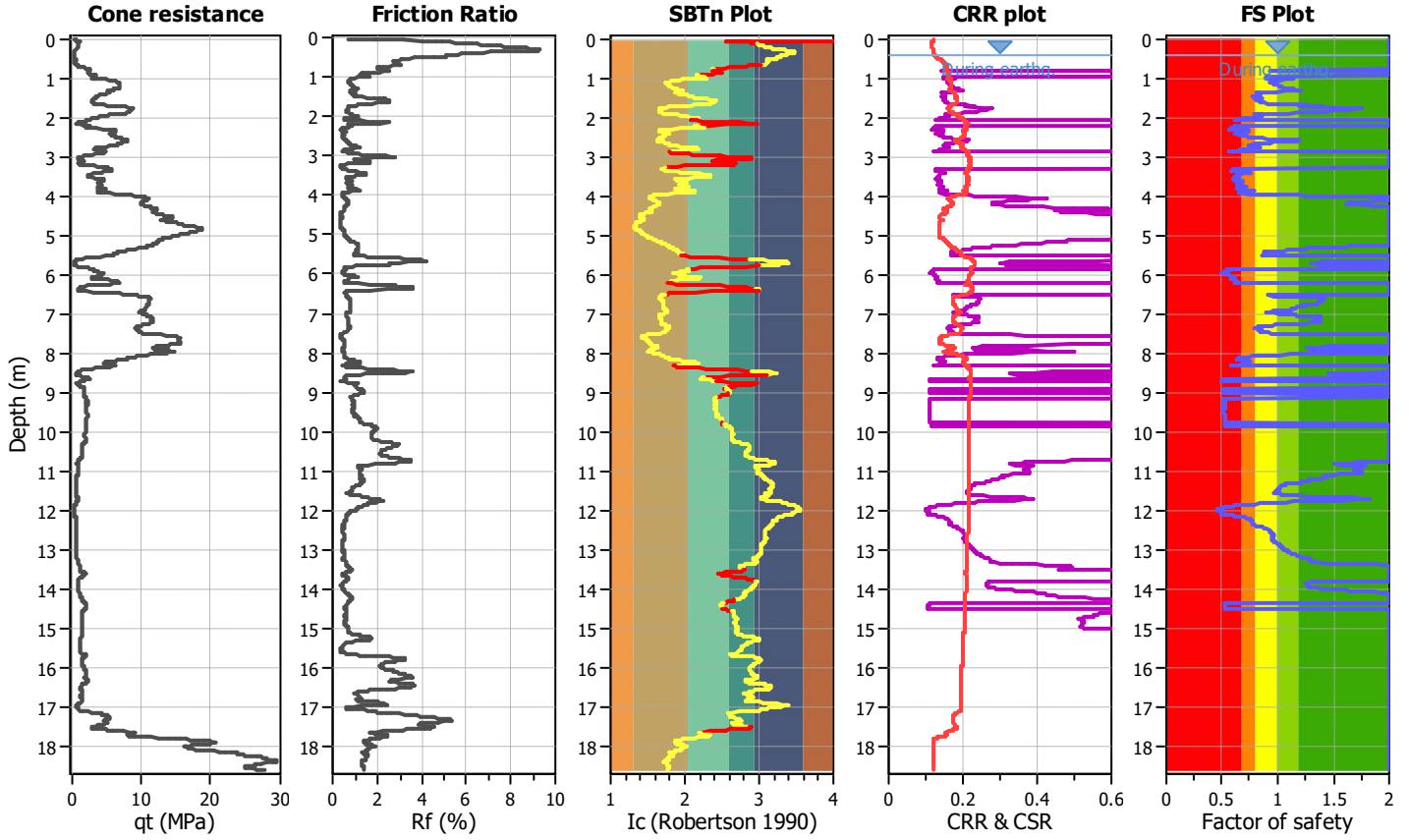
LIQUEFACTION ANALYSIS REPORT

Project title : HD631 - Rotokauri North SHA Geo
CPT file : CPT02

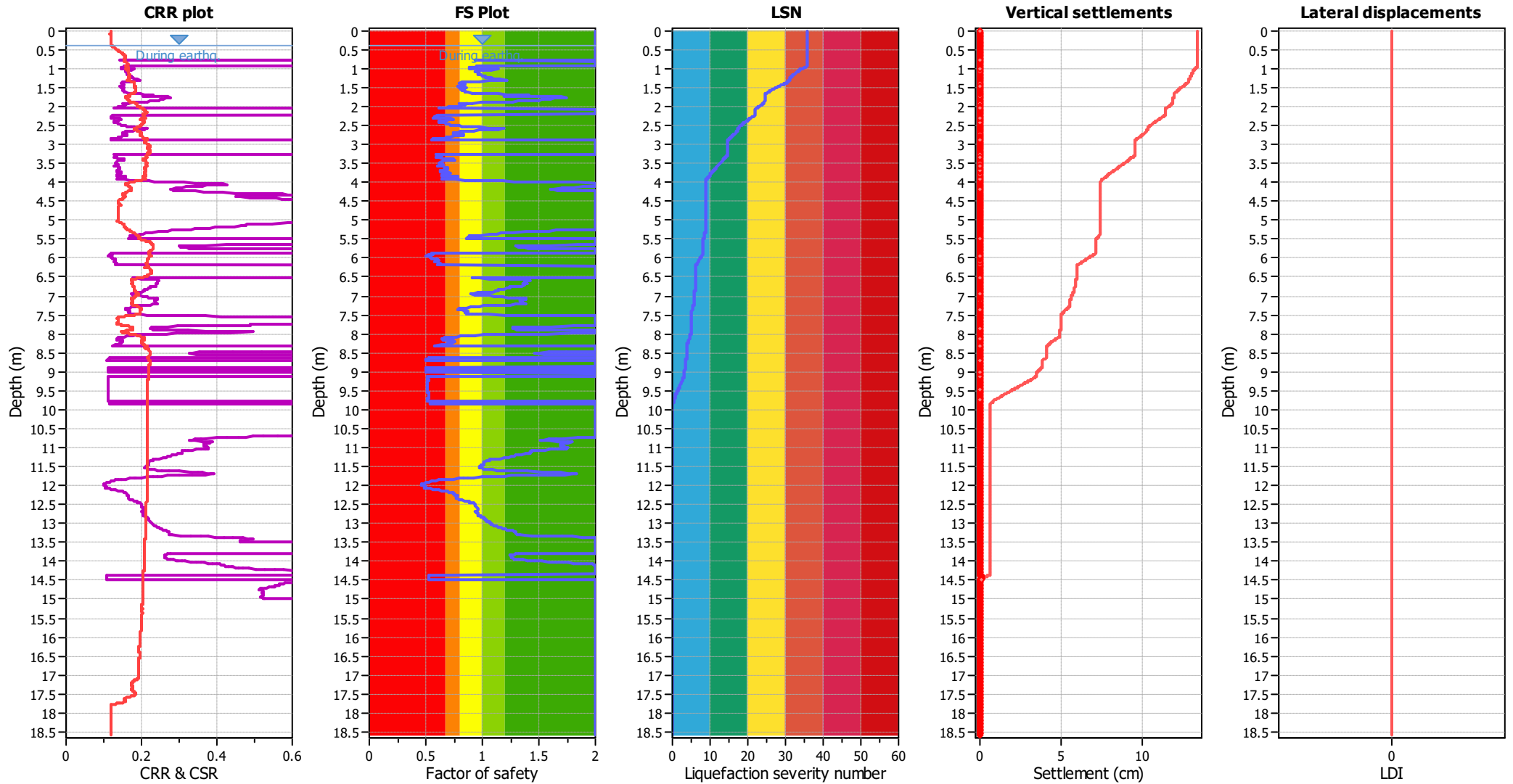
Location : Rotokauri North

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.):	0.40 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:	15.00 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_g applied:	Yes		



Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.40 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:	15.00 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

LIQUEFACTION ANALYSIS REPORT

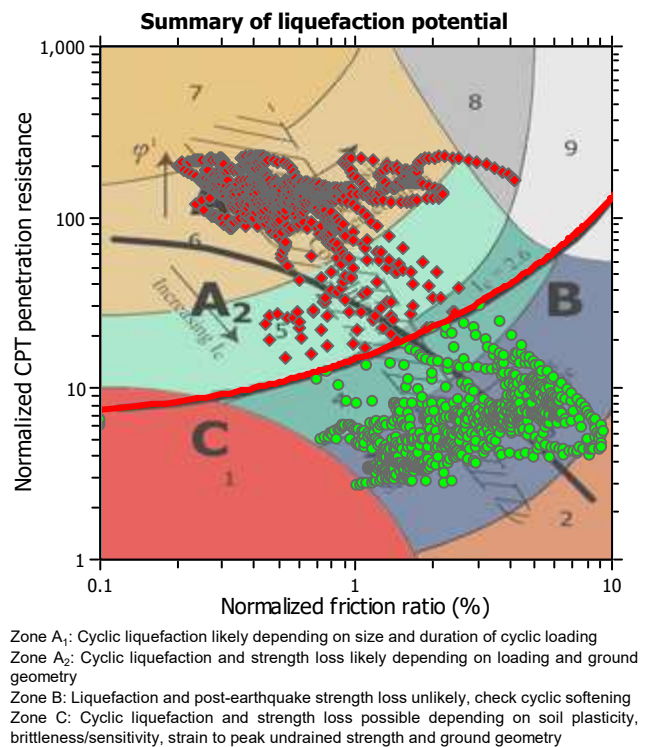
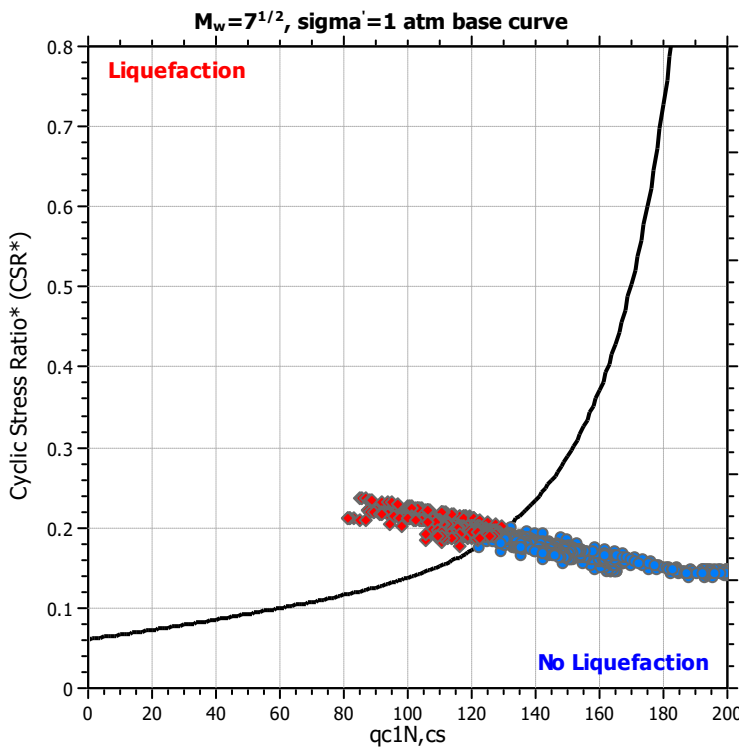
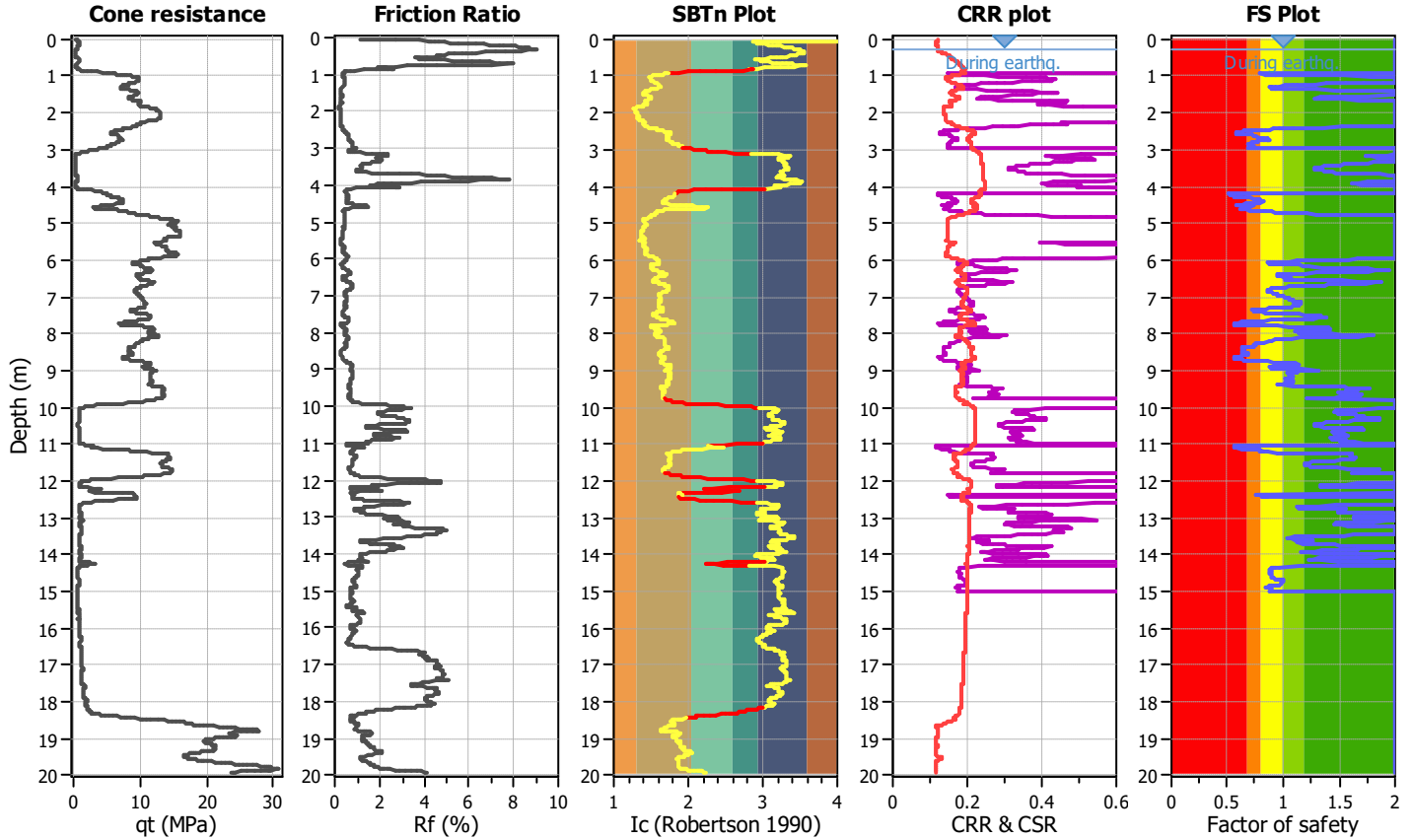
Project title : HD631 - Rotokauri North SHA Geo

Location : Rotokauri North

CPT file : CPT03

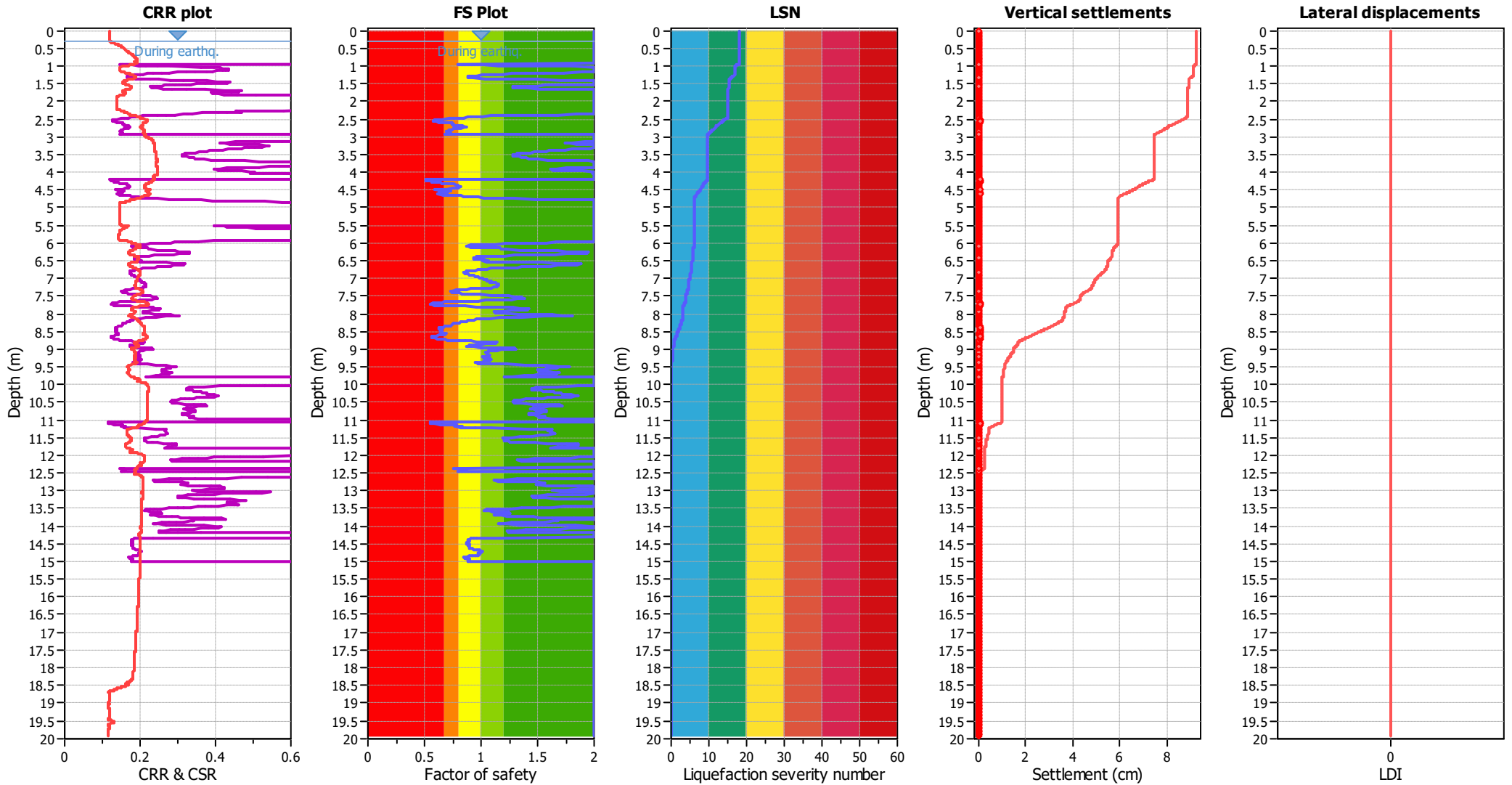
Input parameters and analysis data

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.):	0.30 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:	15.00 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 A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading
 Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
 Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
 Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (earthq.):	0.30 m
Fines correction method:	B&I (2014)	Average results interval:	3
Points to test:	Based on Ic value	Ic cut-off value:	2.60
Earthquake magnitude M_w :	5.90	Unit weight calculation:	Based on SBT
Peak ground acceleration:	0.22	Use fill:	No
Depth to water table (insitu):	0.30 m	Fill height:	N/A

Fill weight:	N/A
Transition detect. applied:	Yes
K_σ applied:	Yes
Clay like behavior applied:	Sand & Clay
Limit depth applied:	Yes
Limit depth:	15.00 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

LIQUEFACTION ANALYSIS REPORT

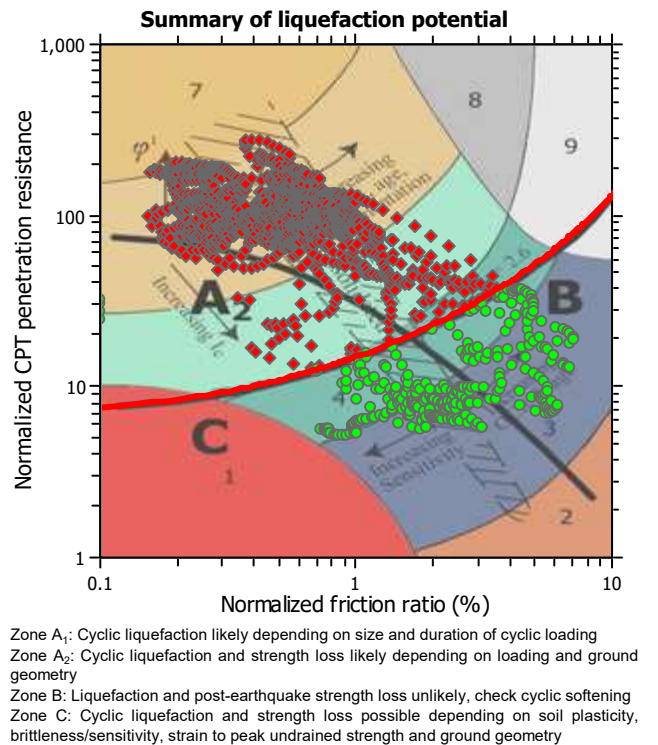
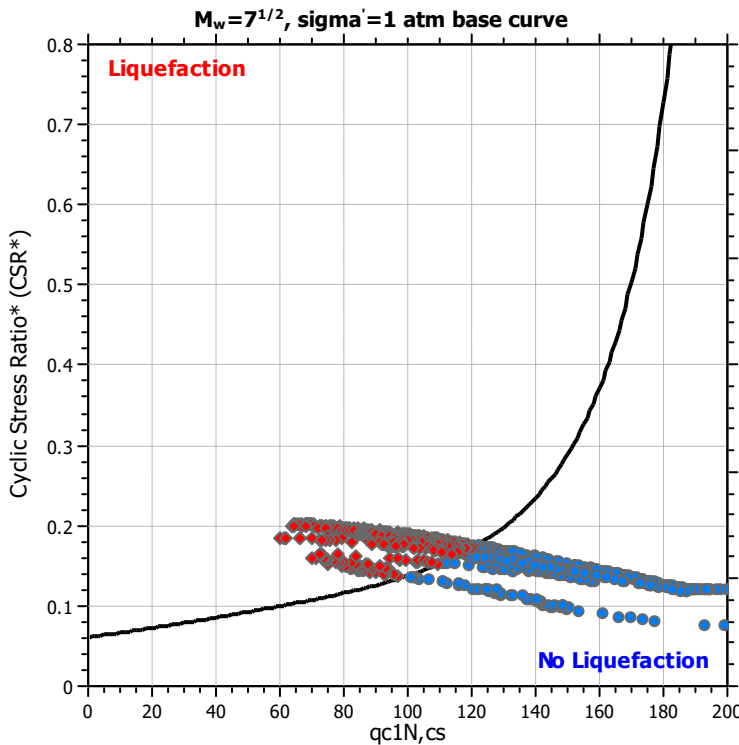
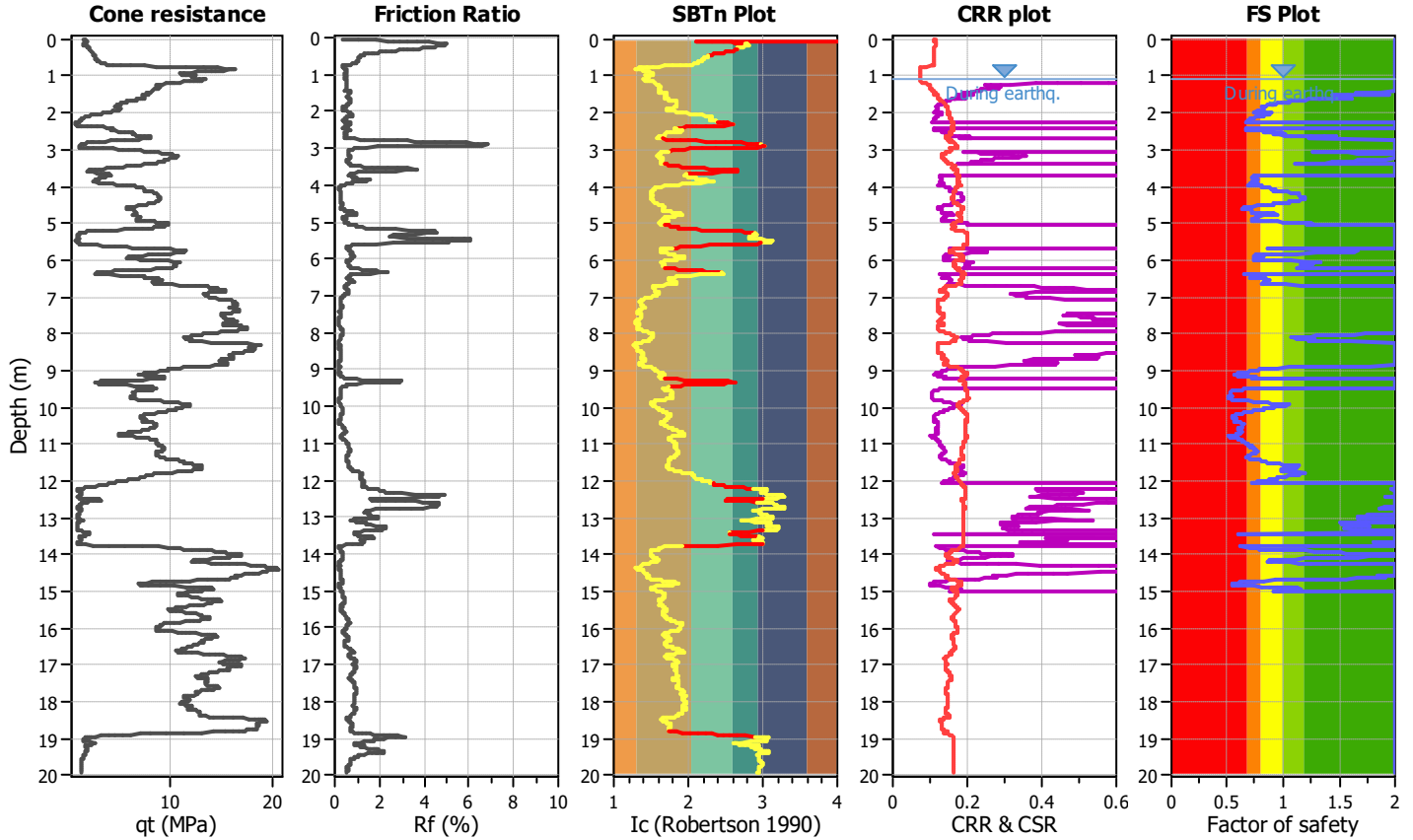
Project title : HD631 - Rotokauri North SHA Geo

Location : Rotokauri North

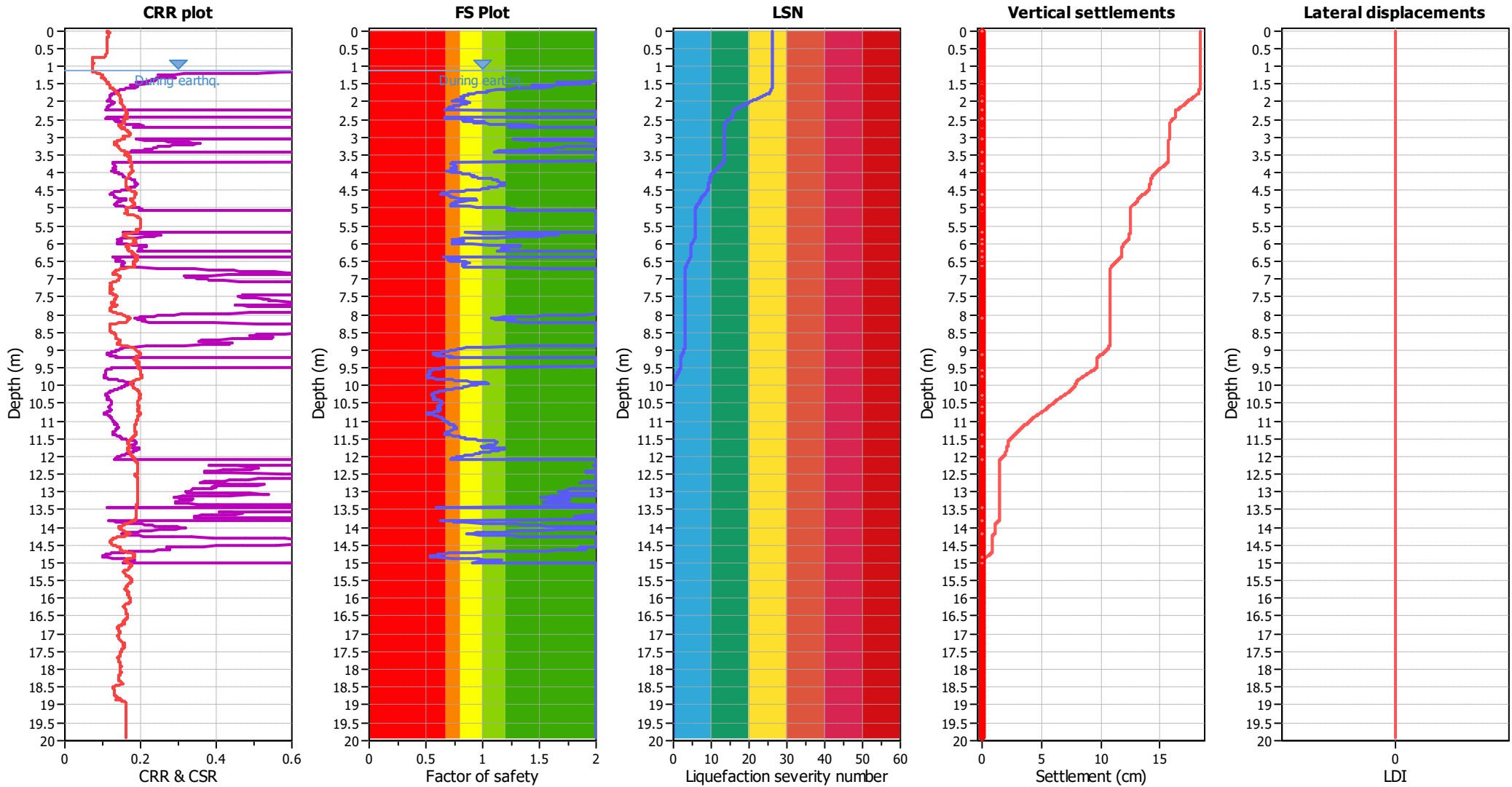
CPT file : CPT04

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.):	1.10 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:	15.00 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		



Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.10 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:	15.00 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

LIQUEFACTION ANALYSIS REPORT

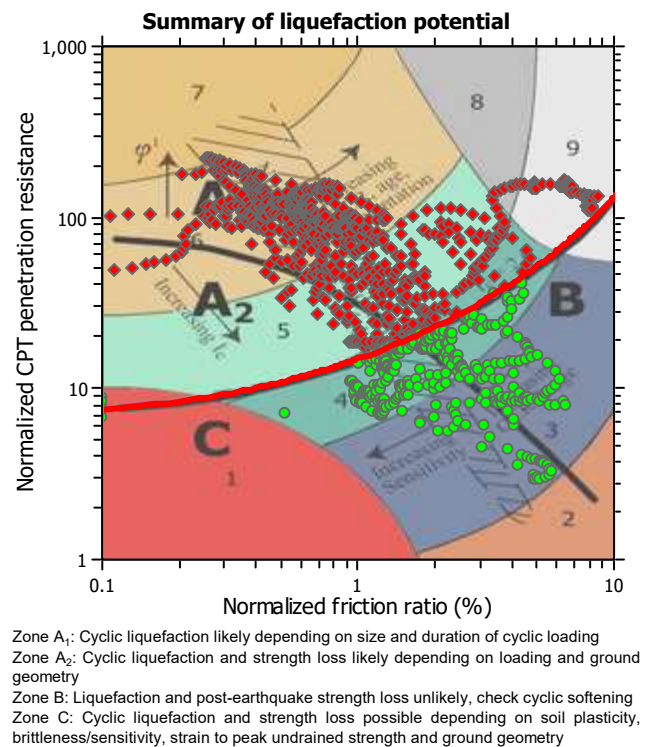
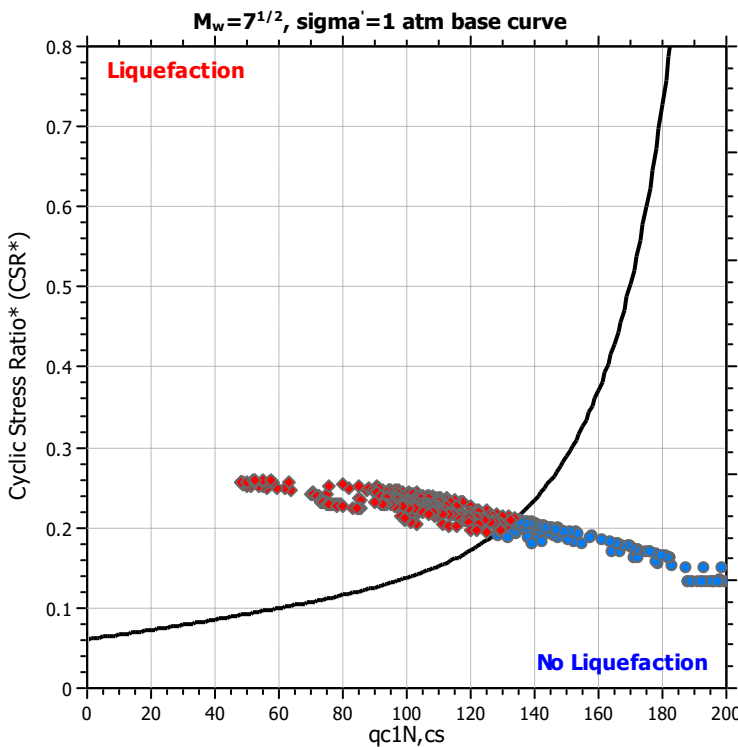
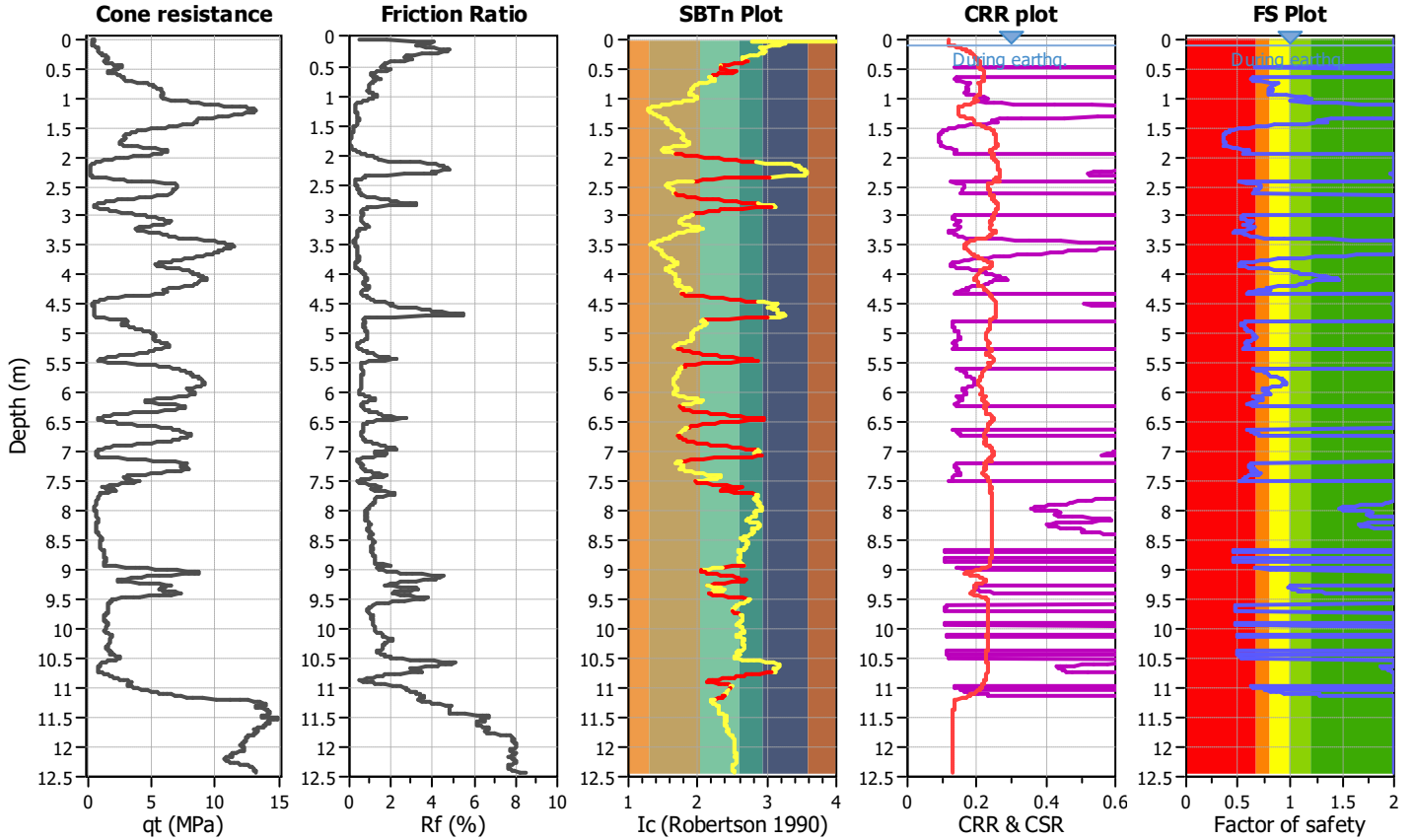
Project title : HD631 - Rotokauri North SHA Geo

Location : Rotokauri North

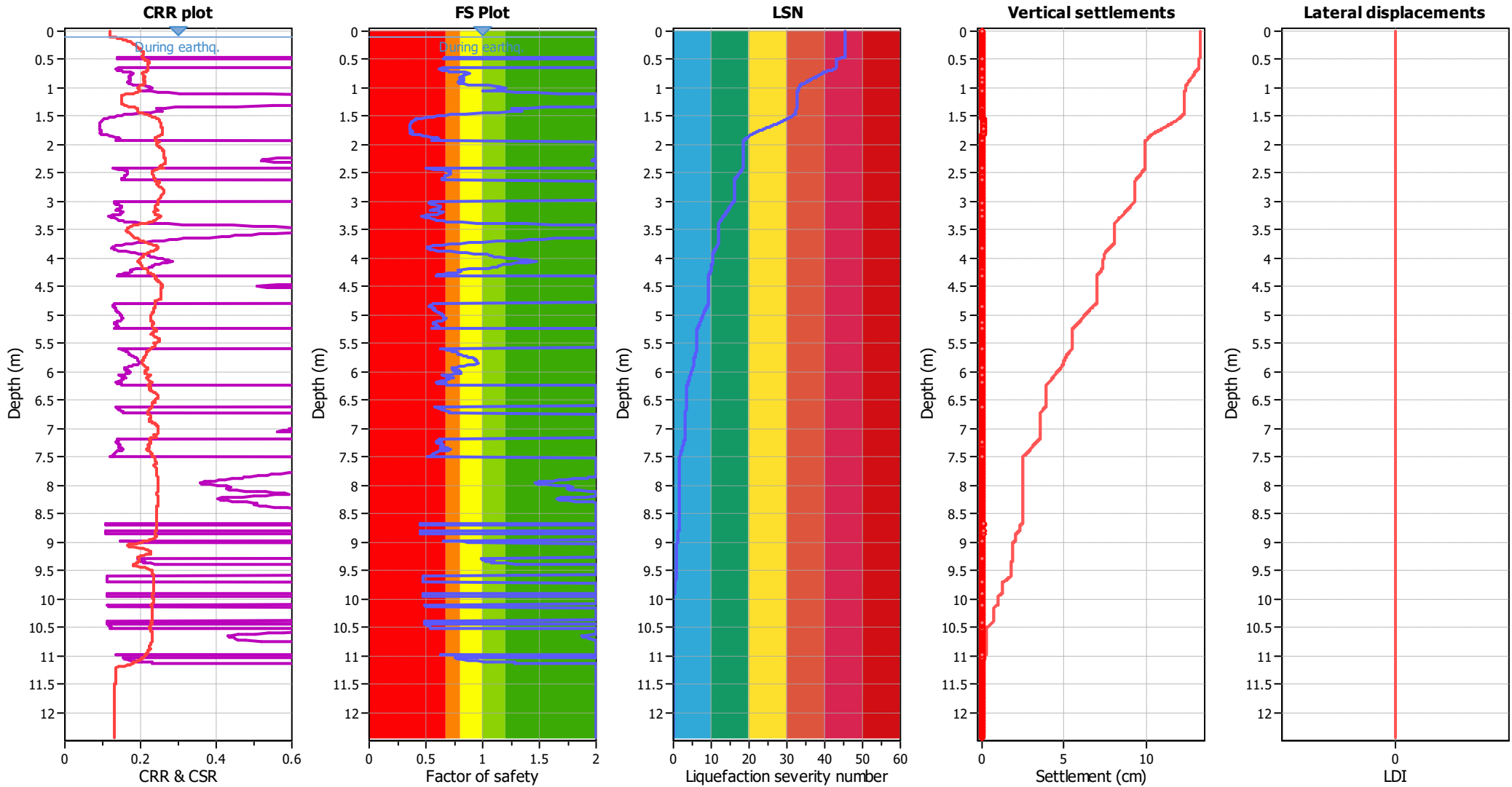
CPT file : CPT05

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.):	0.10 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:	15.00 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		



Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method: B&I (2014)
 Fines correction method: B&I (2014)
 Points to test: Based on Ic value
 Earthquake magnitude M_w : 5.90
 Peak ground acceleration: 0.22
 Depth to water table (insitu): 0.10 m

Depth to GWT (erthq.): 0.10 m
 Average results interval: 3
 Ic cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

Fill weight: N/A
 Transition detect. applied: Yes
 K_{σ} applied: Yes
 Clay like behavior applied: Sand & Clay
 Limit depth applied: Yes
 Limit depth: 15.00 m

F.S. color scheme

- Red: Almost certain it will liquefy
- Orange: Very likely to liquefy
- Yellow: Liquefaction and no liq. are equally likely
- Light Green: Unlike to liquefy
- Dark Green: Almost certain it will not liquefy

LSN color scheme

- Red: Severe damage
- Dark Red: Major expression of liquefaction
- Orange: Moderate to severe exp. of liquefaction
- Yellow: Moderate expression of liquefaction
- Light Green: Minor expression of liquefaction
- Blue: Little to no expression of liquefaction

LIQUEFACTION ANALYSIS REPORT

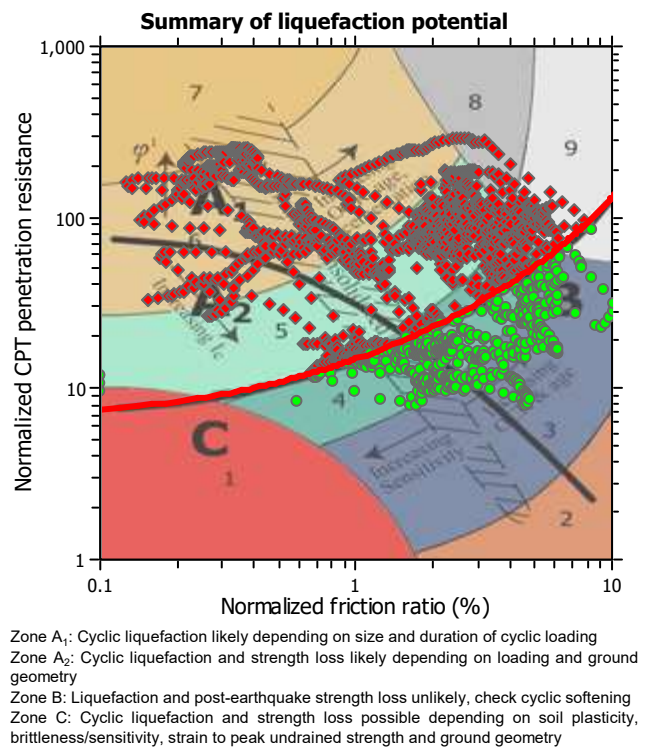
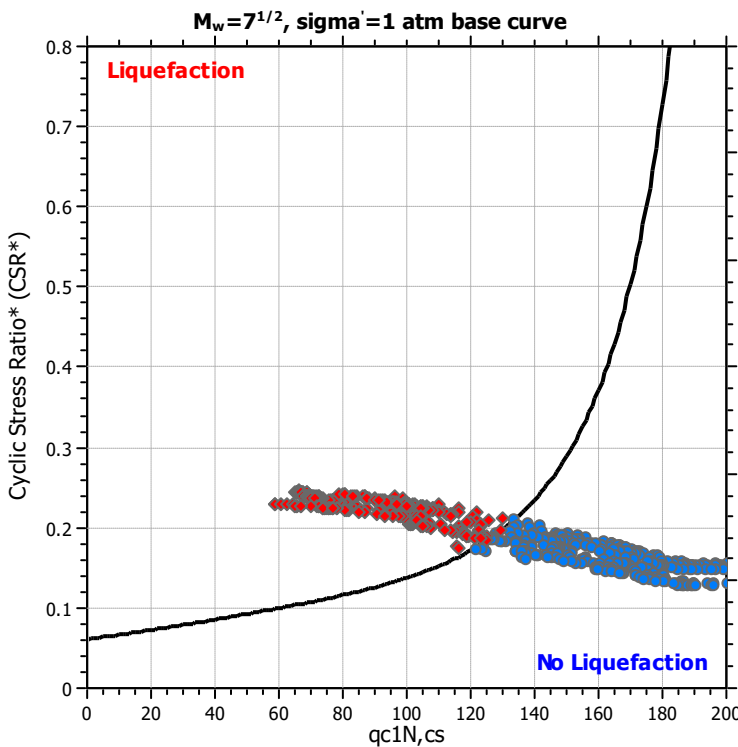
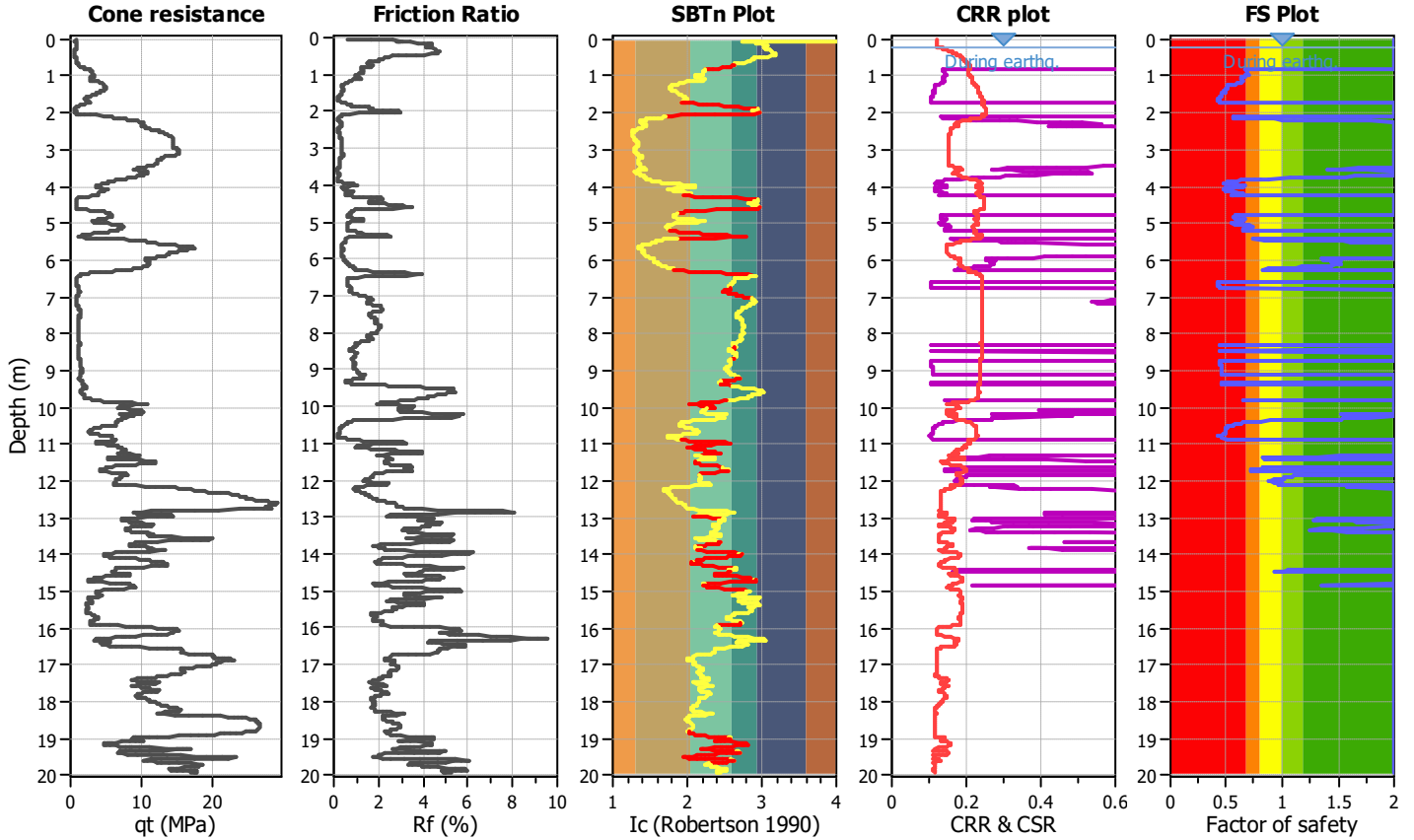
Project title : HD631 - Rotokauri North SHA Geo

Location : Rotokauri North

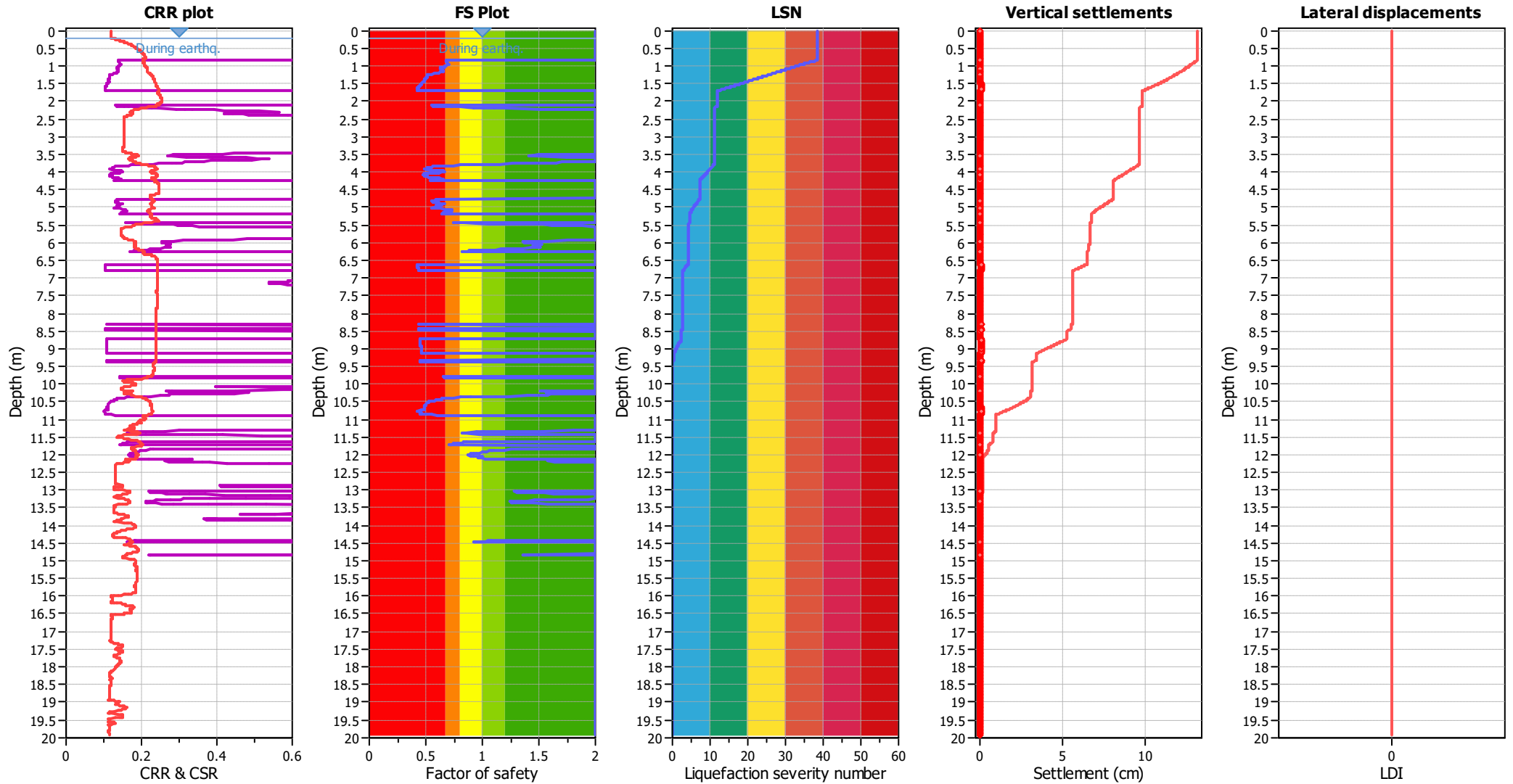
CPT file : CPT06

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.):	0.20 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:	15.00 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		



Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (earthq.):	0.20 m
Fines correction method:	B&I (2014)	Average results interval:	3
Points to test:	Based on Ic value	Ic cut-off value:	2.60
Earthquake magnitude M_w :	5.90	Unit weight calculation:	Based on SBT
Peak ground acceleration:	0.22	Use fill:	No
Depth to water table (insitu):	0.20 m	Fill height:	N/A

Fill weight:	N/A
Transition detect. applied:	Yes
K_{σ} applied:	Yes
Clay like behavior applied:	Sand & Clay
Limit depth applied:	Yes
Limit depth:	15.00 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

LIQUEFACTION ANALYSIS REPORT

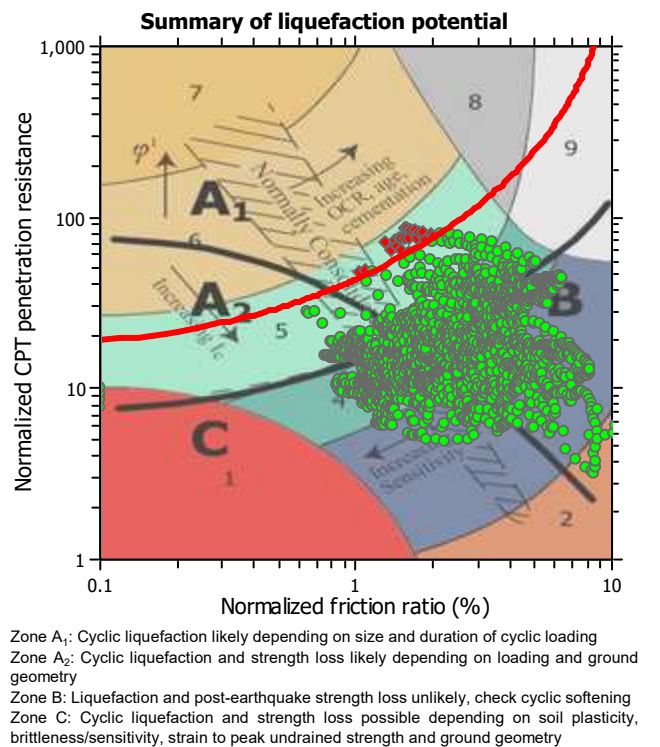
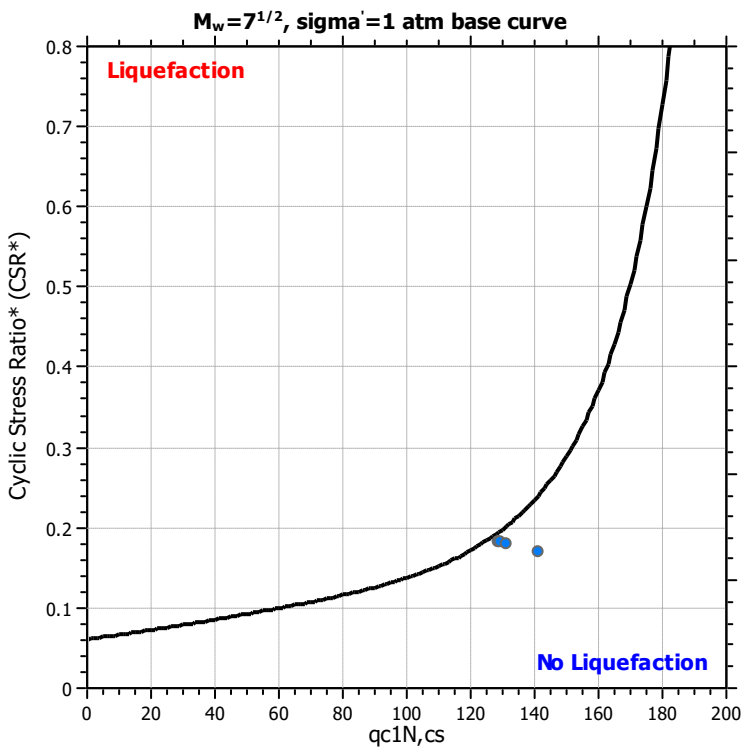
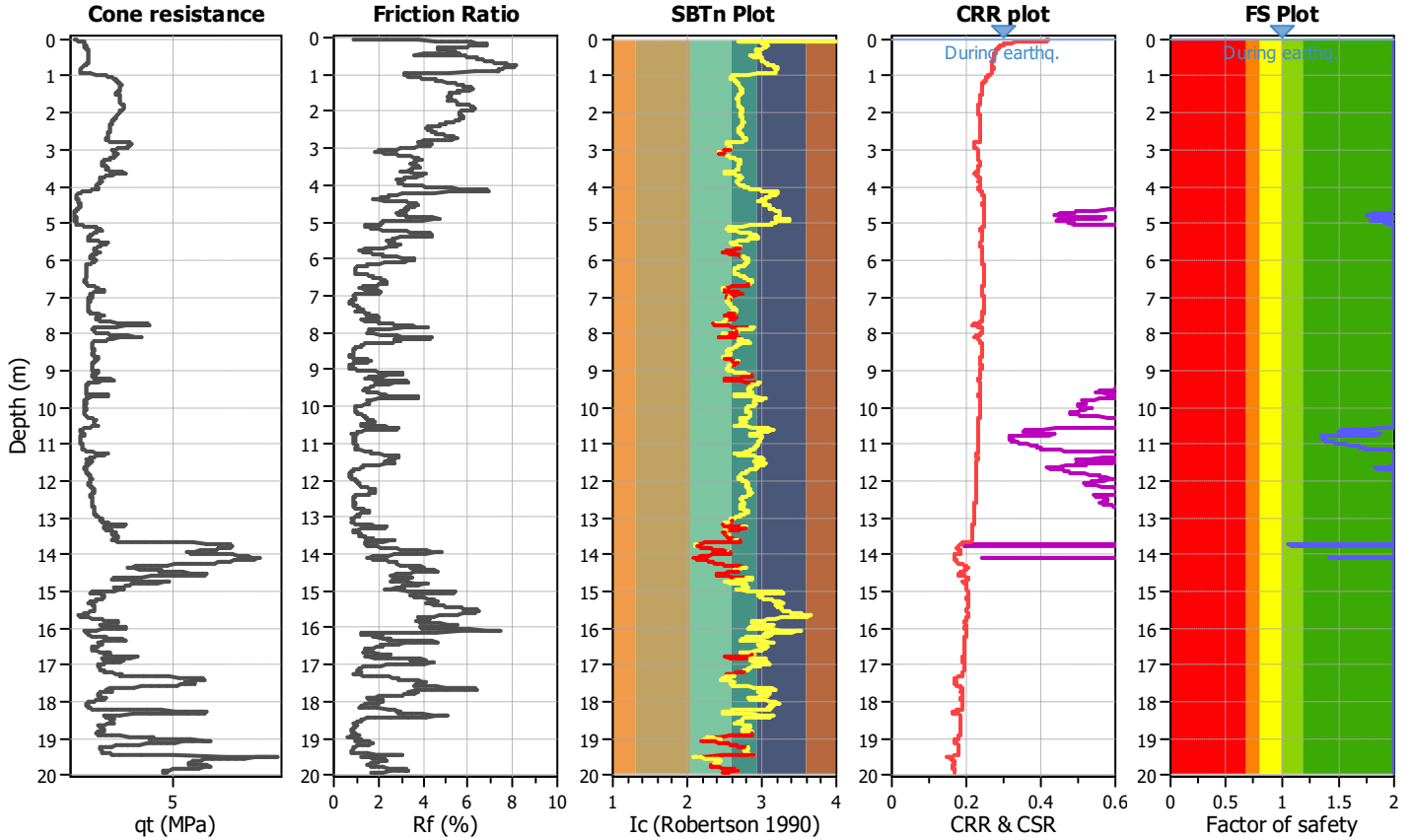
Project title : HD631 - Rotokauri North SHA Geo

Location : Rotokauri North

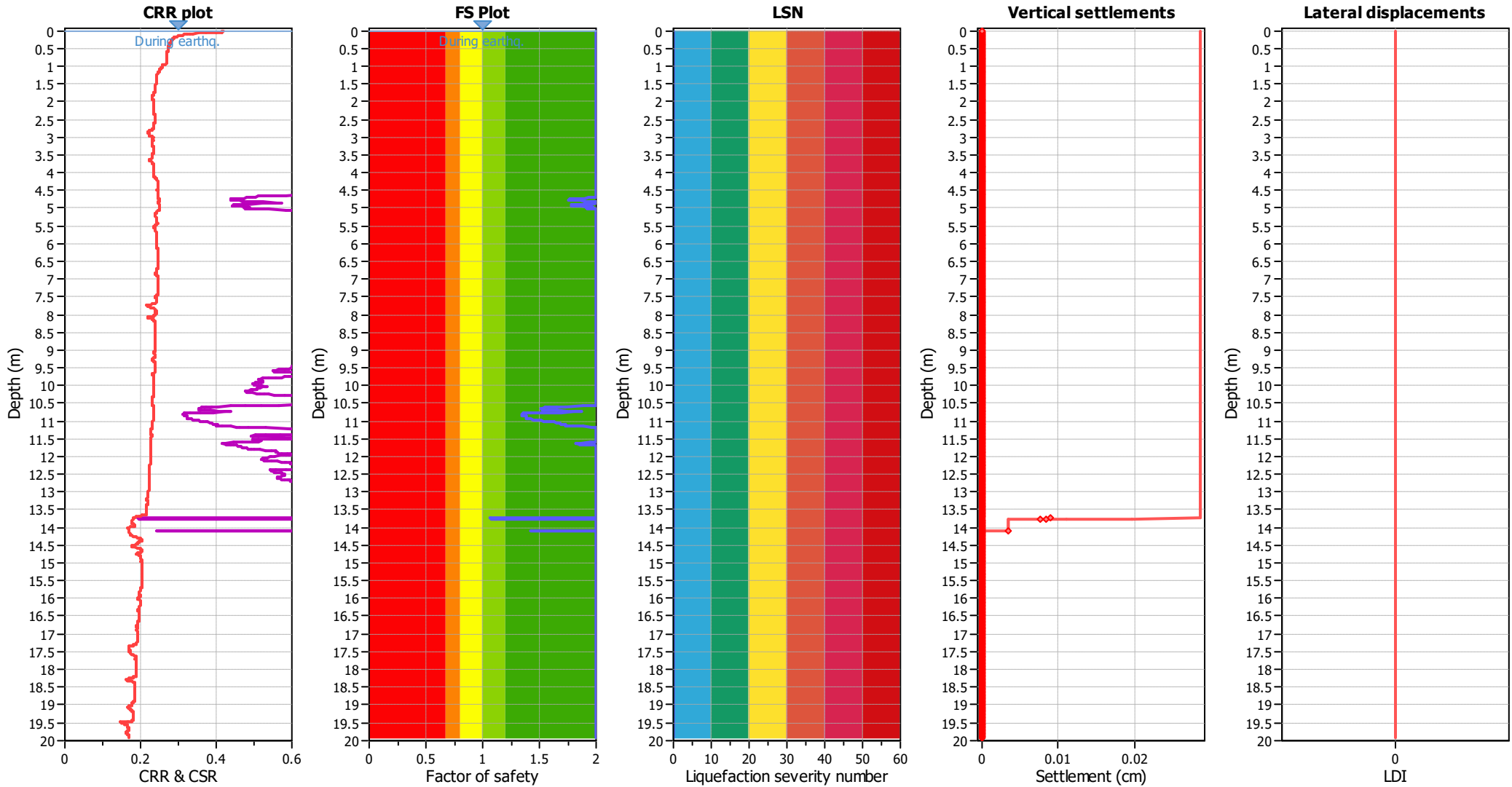
CPT file : CPT07

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.):	0.00 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:	15.00 m
Earthquake magnitude M_w :	5.90	Ic cut-off value:	2.20	Trans. detect. applied:	Yes	MSF method:	Method
Peak ground acceleration:	0.22	Unit weight calculation:	Based on SBT	K_g applied:	Yes		



Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.20	K_f 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:	15.00 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

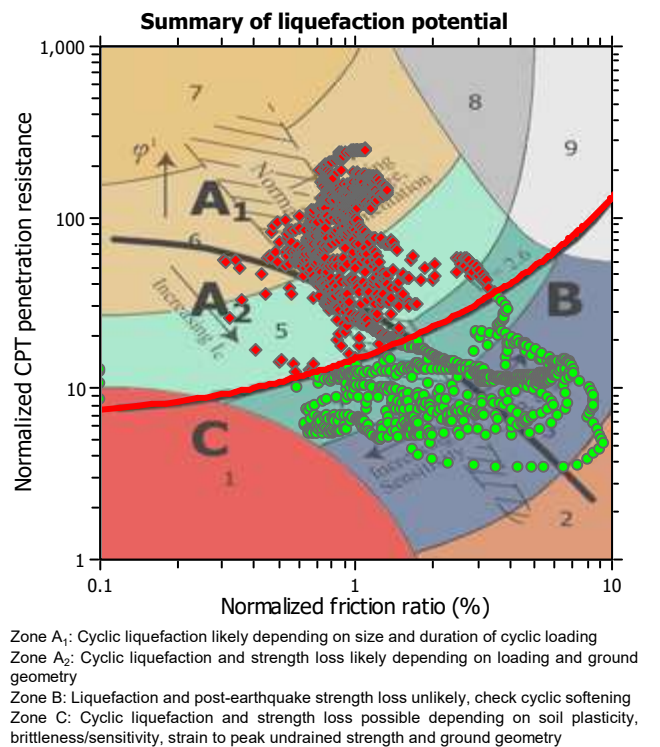
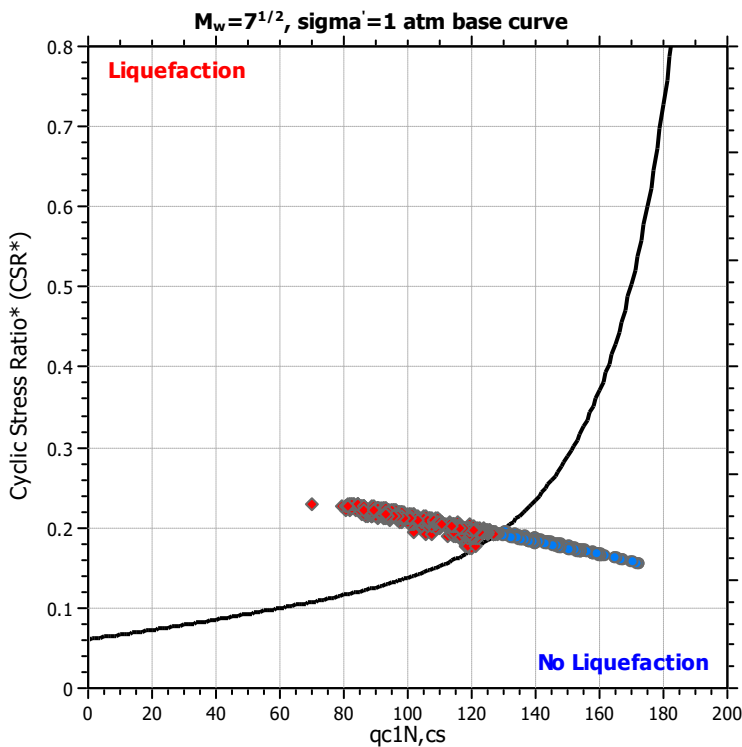
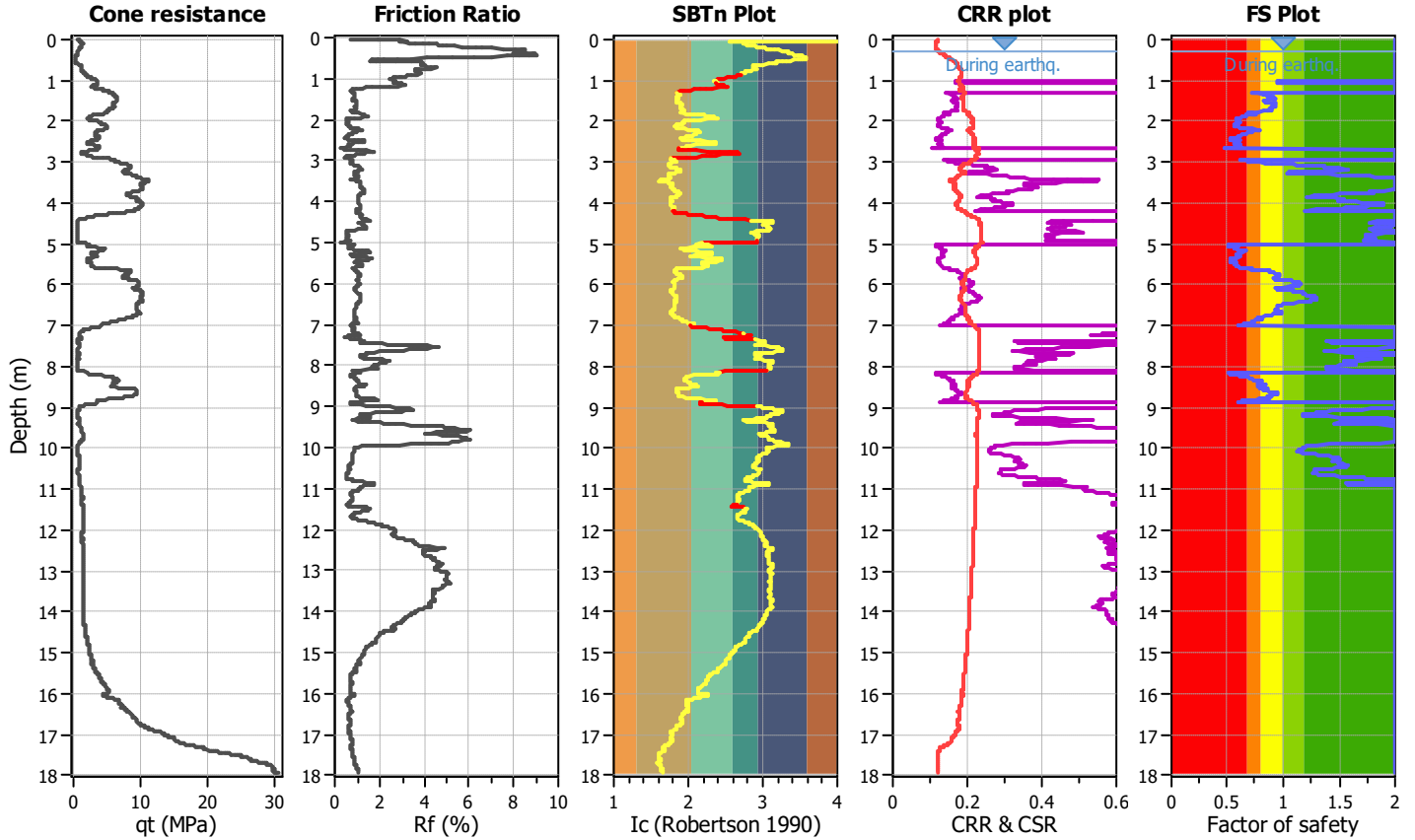
LIQUEFACTION ANALYSIS REPORT

Project title : HD631 - Rotokauri North SHA Geo
CPT file : CPT08

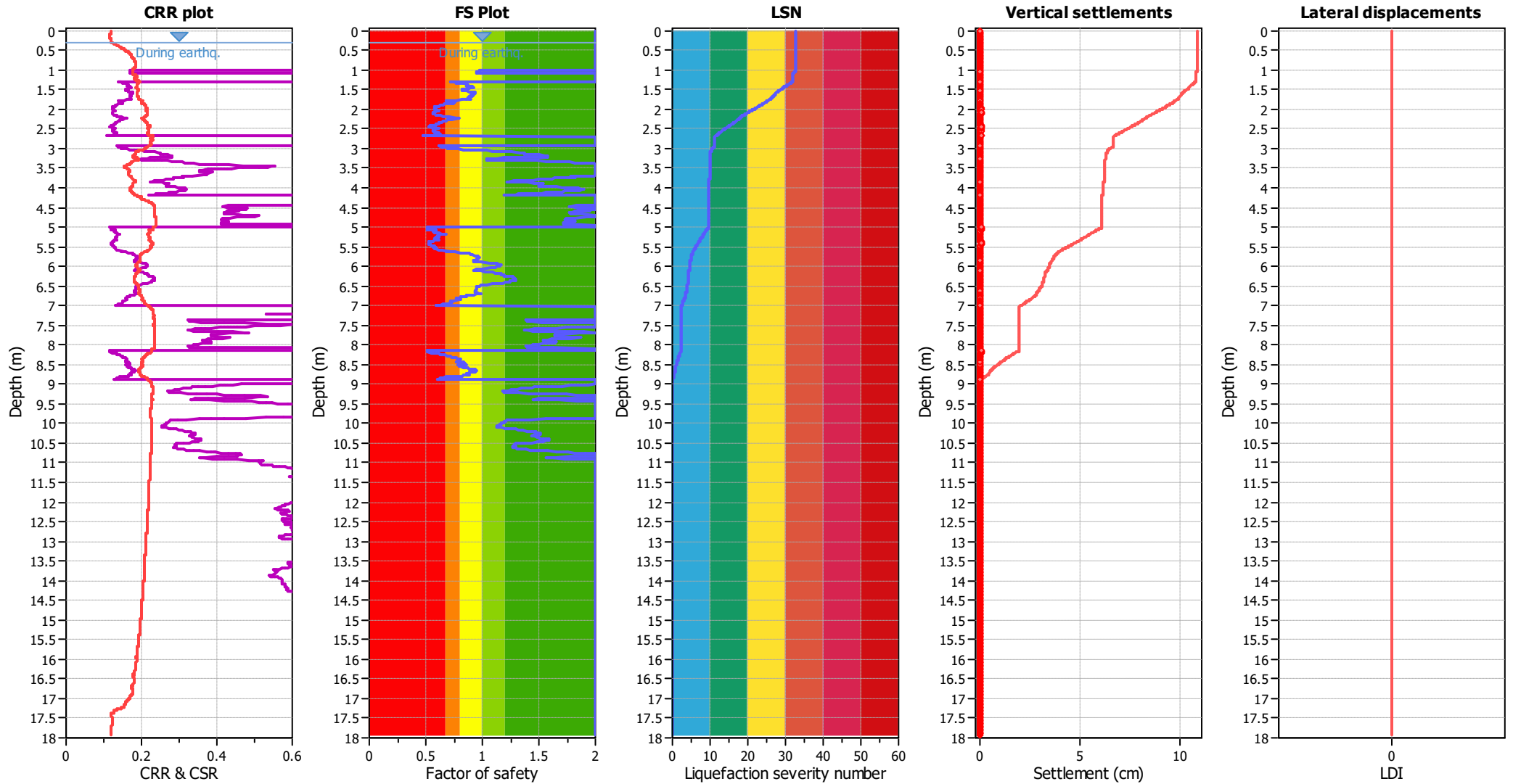
Location : Rotokauri North

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.):	0.30 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:	15.00 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		



Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	0.30 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:	15.00 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

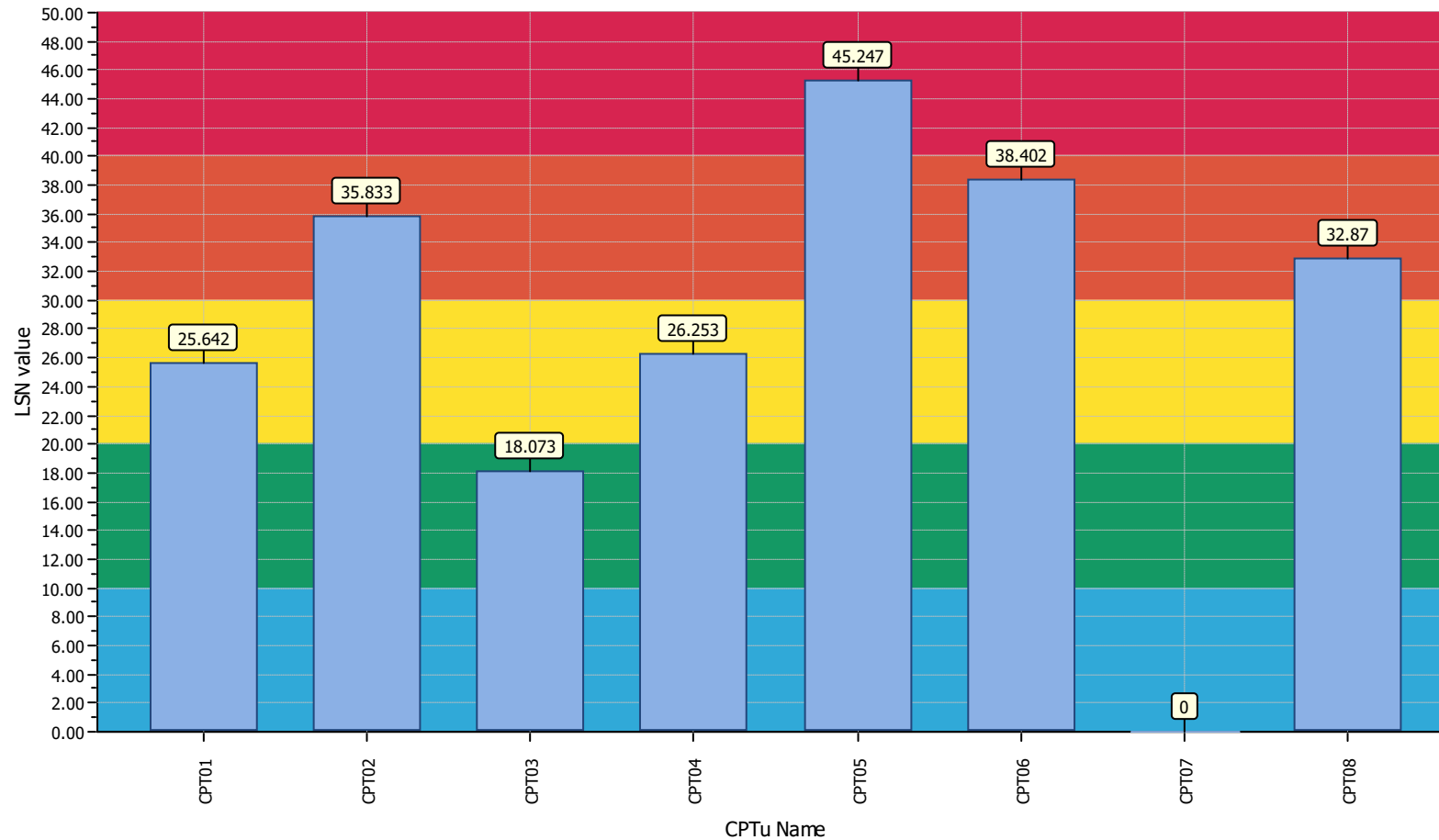
- Severe damage
- Major expression of liquefaction
- Moderate to severe exp. of liquefaction
- Moderate expression of liquefaction
- Minor expression of liquefaction
- Little to no expression of liquefaction



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

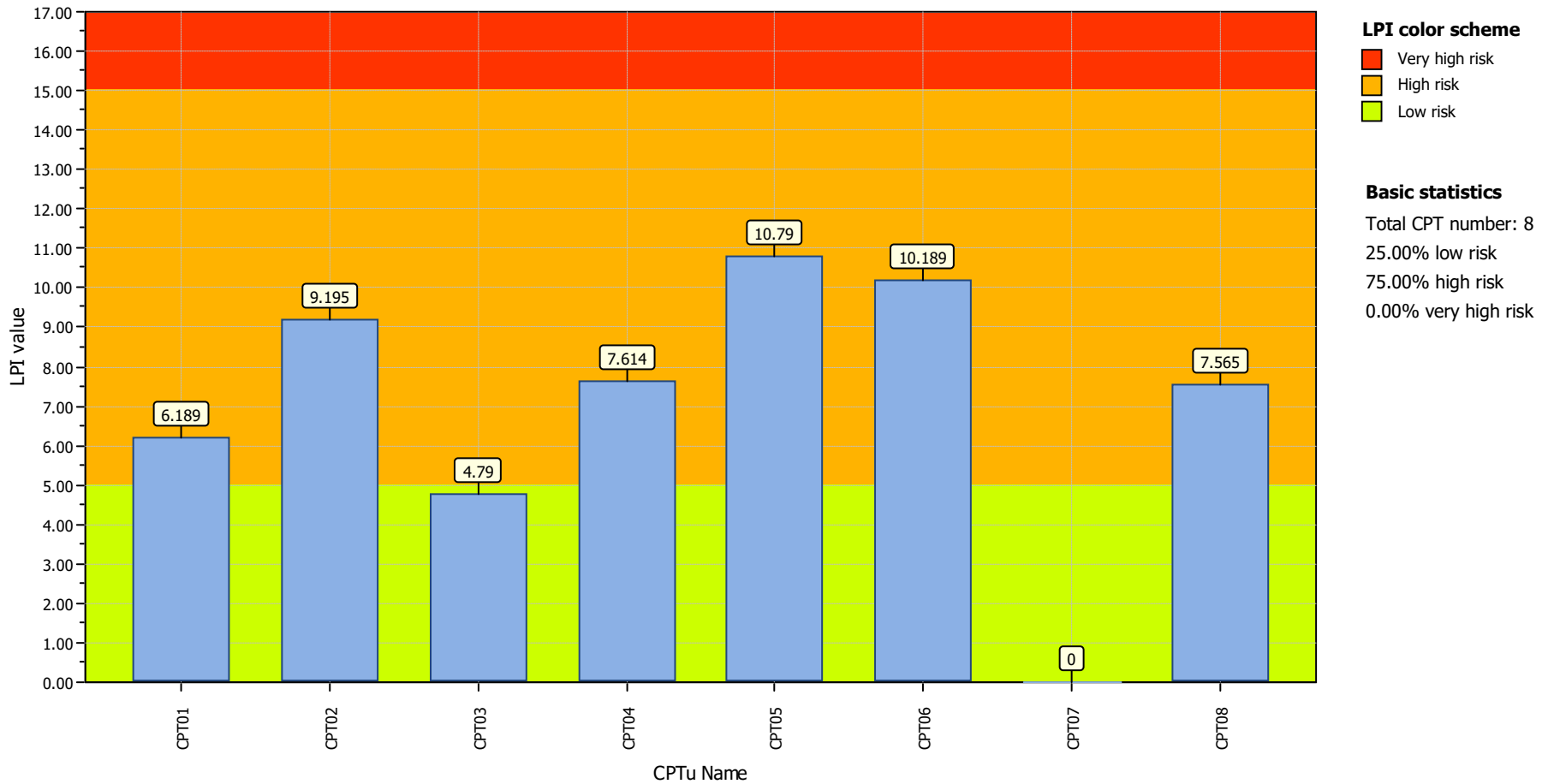
- Total CPT number: 8
- 12.50% little liquefaction
- 12.50% minor liquefaction
- 25.00% moderate liquefaction
- 37.50% moderate to major liquefaction
- 12.50% major liquefaction
- 0.00% severe liquefaction



Project title : HD631 - Rotokauri North SHA Geo

Location : Rotokauri North

Overall Liquefaction Potential Index report

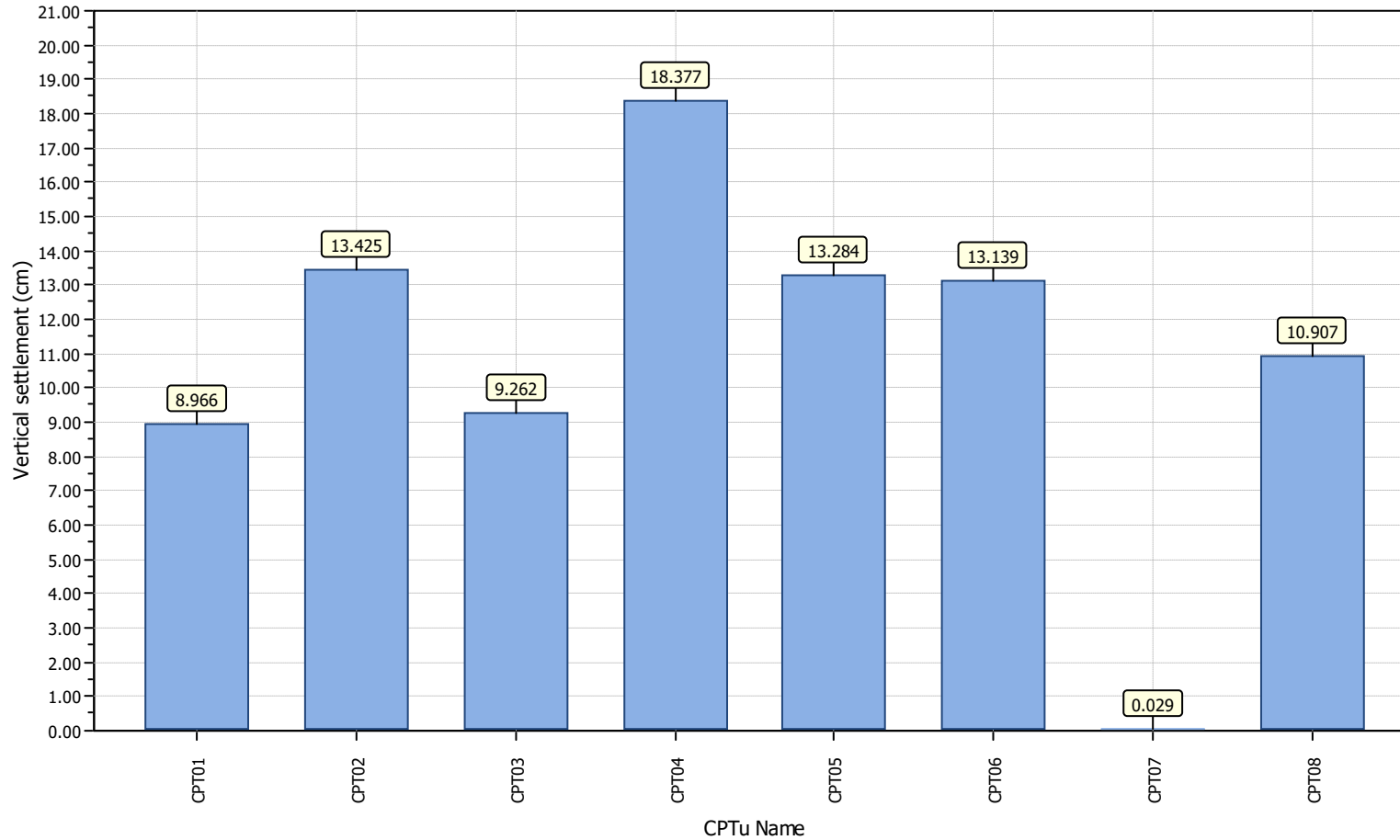




Project title : HD631 - Rotokauri North SHA Geo

Location : Rotokauri North

Overall vertical settlements report



APPENDIX E – HISTORIC AERIAL IMAGERY



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Figure 1. Aerial imagery from 1943. Site boundary in red.

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Figure 2. Historical imagery from 1952. Site boundary in red.

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Figure 3. Historical Imagery from 1963. Site boundary in red.



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Figure 4. Historical Imagery from 1974. Site boundary in red.