

Rotorua Lakes Council

Museum, Government Gardens, Oruawhata Drive, Rotorua

Geotechnical Interpretative Report

16592
19 May 2017

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Geotechnical Interpretative Report

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1. INTRODUCTION AND SCOPE OF WORK

Cheal Consultants (Cheal) has been engaged by Rotorua Lakes Council (Client) to carry out an investigation to assess existing below ground features immediately adjoining the Rotorua Museum with emphasis to the seismic behaviour of foundation ground and, if applicable, to propose and design geotechnical seismic strengthening.

The work has been carried out in accordance with our proposal¹ of 28 February 2017 and this report summarises our findings. The main objectives of the work were:

- To carry out desk study of existing foundation and historical geotechnical remedial works;
- To perform geotechnical investigation to comment on findings of historical geotechnical reports and historical geotechnical works; and
- To complete a geotechnical assessment of the site with emphasis to the seismic behaviour of foundation ground.

Details of the geotechnical investigation carried out by Cheal were presented in our Geotechnical Factual Report dated 15 May 2017.

The scope of work for the Geotechnical Interpretative Report comprised:

- Desk study of available geotechnical and geological information;
- Desk study of existing geotechnical reports;
- Evaluation of soil investigation data;
- Development of a subsoil geotechnical model;
- Preparation of four cross-sections based on historical and current Scala Penetrometer tests;
- Preparation of one geological cross section;
- Liquefaction analysis based on CPT results; and
- Comment on the results and provide recommendations based on this.

It should be noted that this report is not detailed geotechnical design but rather review of existing geotechnical foundation and historical geotechnical remedial works with recommendations for additional geotechnical work (if considered required) presented in the end of this report.

2. SITE CONDITIONS

2.1 Site Description

The site is located within the Government Gardens area to the east of Rotorua central business district and is located on the east side of Oruawhata Drive, on the north side of Hatupatu Drive and on the south side of Queens Drive. The surrounding area is characterised by geothermal activity: Sulphur Point in Lake Rotorua is located approximately 60m south from the southern extent of the building; the Polynesian Spa and the Blue Baths are located nearby.

¹ Cheal Consultants Limited (2017), "Rotorua District Council, Government Gardens, Oruawhata Drive, Rotorua, Cost estimate report – Stage 1B and 2A, Geotechnical Investigation & Reporting, Rev 01", 28 February 2017

The site around museum building is generally flat with elevation varied approximately from RL +285 at the western central part to RL +282 at the east-south corner. Following historical documents, we understand the ground level along the western site of the building (RL +235m) is formed by earth fill placed between 1906 and 1908².

An aerial photograph of the site is shown on the following Figure 1. The site investigation plan including location of historical investigation up to 2009 is attached in Appendix 1 (drawing 16592-02).

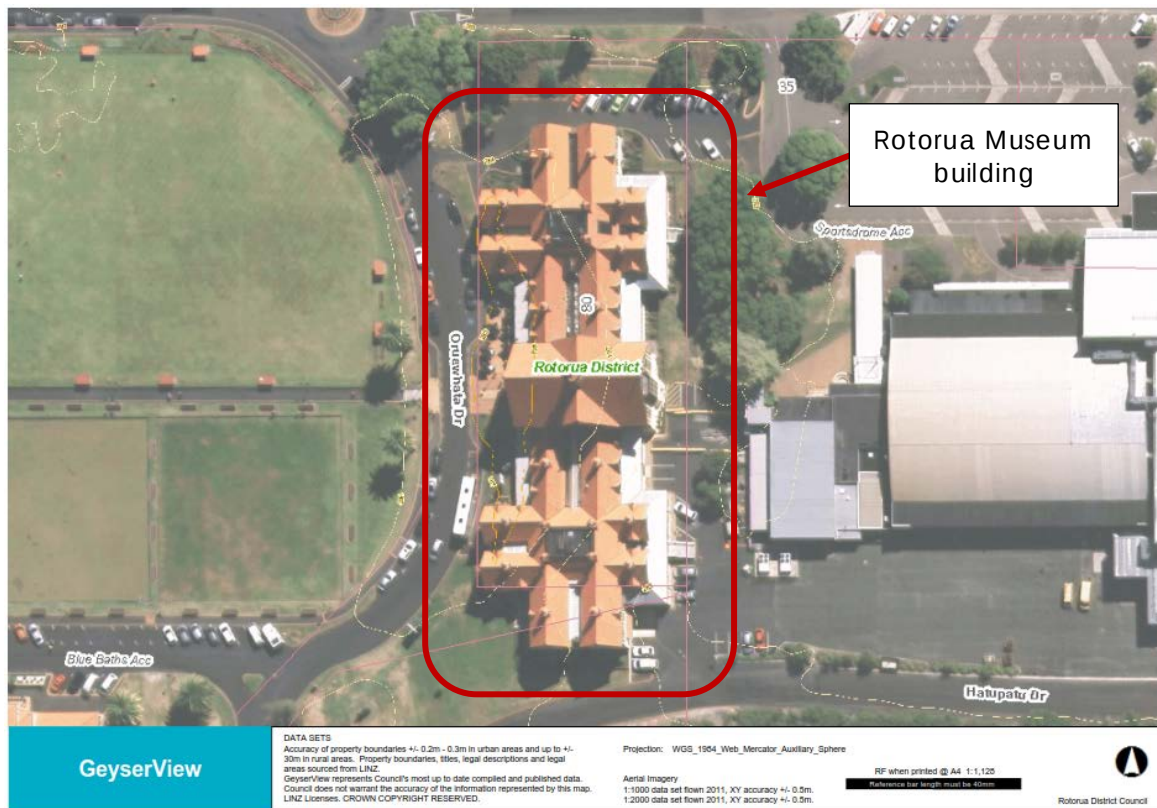


Figure 1: Aerial photograph of the site³

2.2 Natural Hazards

The following potential natural hazards have been reviewed with Rotorua District Council's GIS map viewer – Geyserview 5² and available technical documents:

- Flood levels
- Inundation restriction levels
- Geothermal field
- Faults (2010)
- Landslide susceptibility

² Terrane (2009), "Rotorua Bath House, Government Gardens, Rotorua, Proposed South Wing Extension, Geotechnical Design Report", ref. 3278.SouthExt.desrep, 27 May 2009

³ http://geodev.rdc.govt.nz/HTML5_EXT/Index.html?viewer=Geyserview

- Soft ground
- Liquefaction

The GIS map indicates there is no risk of flood and no inundation restriction on the site and geothermal field on the site. There are no active faults located on the site or in its neighbourhood. There is very low landslide susceptibility over the whole site.

The soft ground map indicates the site is located in Zone D: Site of Holocene (last 10,000 years) swamp deposits and Holocene lake or delta sediments.

The liquefaction hazard map⁴ indicates that the site is located in the area with moderate liquefaction susceptibility.

The site is located in geothermal field suitable for urban use.

3. SITE GEOLOGY

The published geology for the site indicates that the site is, in general, underlain by Holocene river deposits comprising alluvial gravel, sand, silt, mud and clay with local peat, includes modern river beds. Geological map of the local area is presented on Figure 2 below.

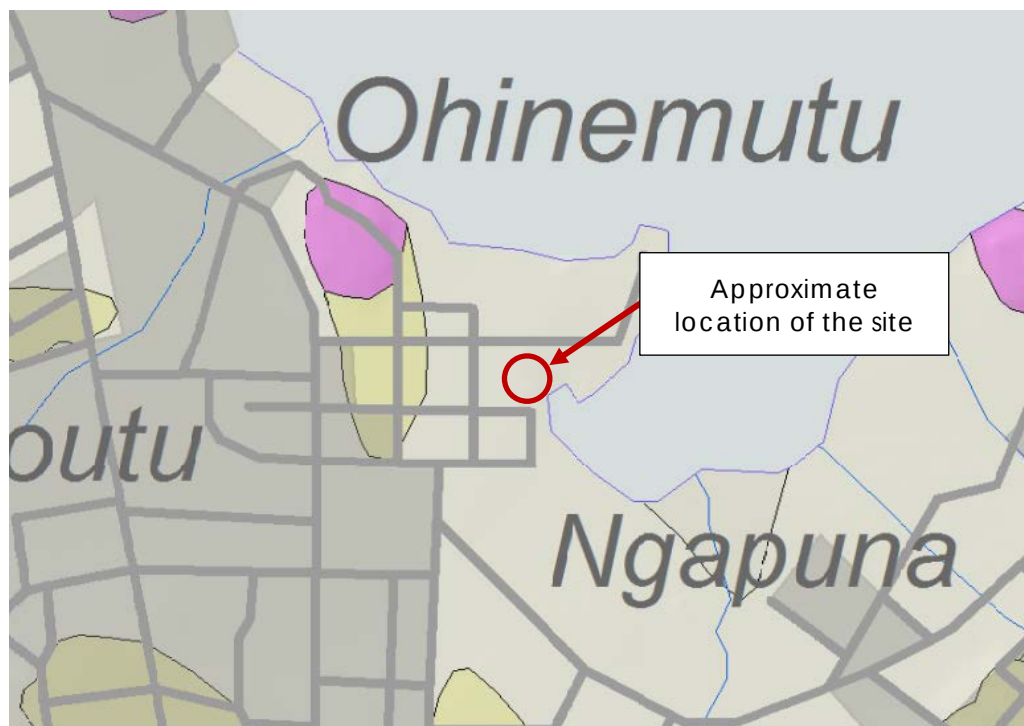


Figure 2: Published geology for Rotorua showing the location of the site

⁴ Institute of Geological & Nuclear Sciences Limited (1999), *Liquefaction Hazard within the Environment BOP region*, Scale 1:500 000

4. GEOTECHNICAL DESK STUDY

4.1 History of Rotorua Museum Building

Rotorua museum building can be divided to three parts:

- Historical part of museum building also called Bath House;
- New South Wing extension; and
- New North Wing extension.

Aerial photograph of the building with each part highlighted is shown on the following Figure 3.

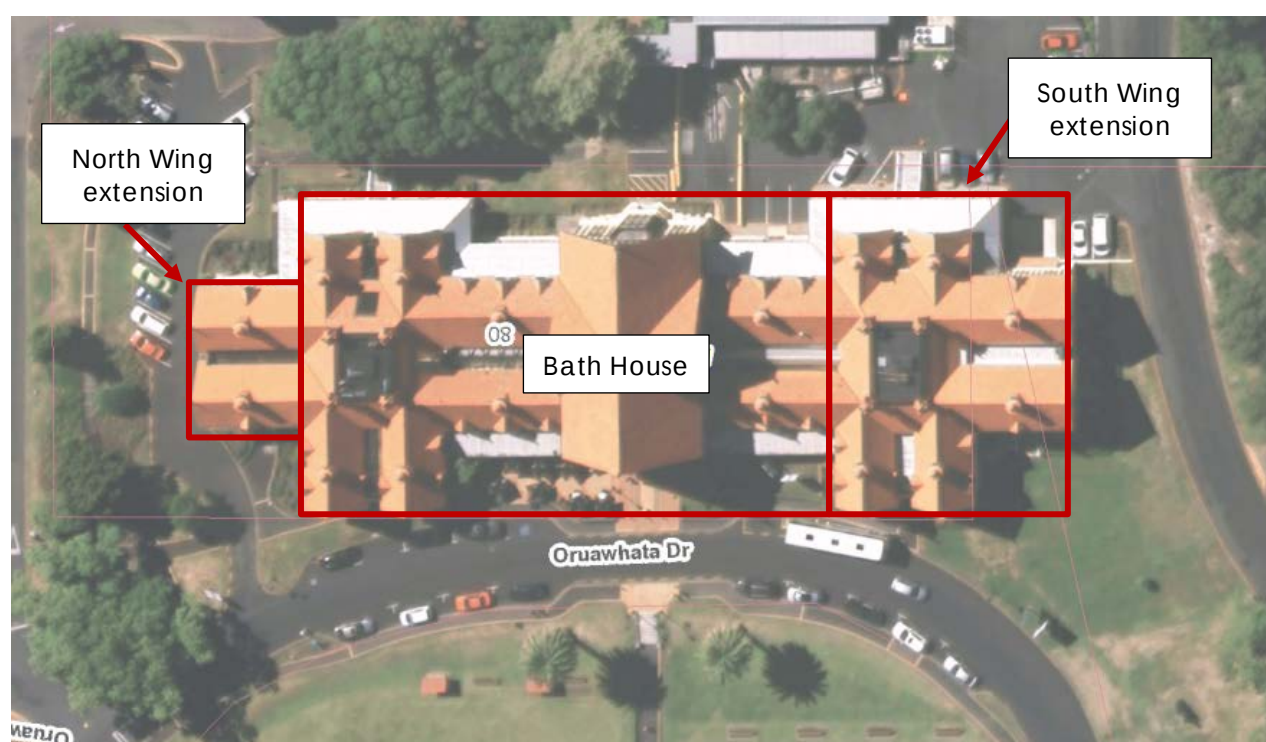


Figure 3: Aerial photograph of the site⁵

4.2 Bath House

The historical Bath House building was constructed in 1906 on the flat ground within the Government Gardens. Based on review of the available drawings and reports, foundation of the Bath House is formed by unreinforced concrete columns founded on shallow pad footings in combination with internal and external unreinforced concrete walls on shallow strip foundation. These drawings and reports also state that the shallow pad footings and strip foundations are formed by unreinforced pumiceous concrete. No ground investigation data or design drawings are available for the construction of the original building in 1906.

⁵ http://geodev.rdc.govt.nz/HTML5_EXT/Index.html?viewer=GeyserView

4.2.1 Kerslake Foundation Review

In 1985 Kerslake and Partners Consulting Registered Engineers (Kerslake) were engaged to investigate the condition of existing foundations within the Tudor Towers complex (historical Bath House building). The work is described in detail in the following report:

- Kerslake and Partners Consulting Registered Engineers (1985), "Report on Foundations for Tudor Towers, Government Gardens, Rotorua", C.N. 4602, July 1985

Kerslake undertook a number of Scala penetrometer tests in the building basement. Based on these results, Kerslake calculated required structural bearing capacity. In their report, Kerslake stated there is possibly an issue with the bearing capacity of the supporting ground and suggested two options for consideration:

- *"Leave the subsoil as existing on the basis that the bearing has proven adequate for approximately 80 years under many varying load conditions and will continue to be adequate"*
- *"Undertake a more extensive foundation investigation to ascertain a safety factor against a bearing failure. Should the safety factor against failure be unrealistic the load must be reduced or the bearing capacity of the soft layers of subsoil increased."*

The report suggests possible remedial works including increasing the area of the existing shallow foundations, underpinning or soil improvement.

Additional foundation inspections were undertaken by Kerslake in 1991, 1996 and 2000. The 1991 report is not available. Foundation inspections performed in 1996 and 2000 are described in the following reports:

- Kerslake and Partners Consulting Registered Engineers (1996), "Rotorua Museum of Art & History, Foundation Inspection, Report No.3 for Rotorua District Council", C.N. 7210, April 1996
- Kerslake and Partners Consulting Registered Engineers (2000), "Rotorua Museum of Art & History, Foundation Inspection, Report No.4 for Rotorua District Council", C.N. 1002, April 2000

Both reports are more concentrated to structural aspect of foundation and not providing any additional geotechnical comments and recommendations.

4.2.2 Grouting Below Bath House

As we understand, in 2007 Terrane Consultants Limited (Terrane) was engaged by Sigma Consultants Limits (Sigma) to undertake a geotechnical investigation and design of geotechnical foundation remediation as a part of Rotorua Museum Building Foundation Strengthening Project. Thirty-one Scalas and 4 Hand Augers were carried out in the basement of historical Bath House building. A geothermal and petrological study was carried out by GNS Science between 2008 and 2009. The following summary of key points was presented in Terrane report from July 2009:

- *“The foundations of the original part of the Museum buildings is underlain by highly variable, soft to extreme soft, soils to a depth of approximately 2.0 metres. The material contains cavities, some of which extend directly underneath the foundations. The soil would be classified as having a collapsible structure;*
- *The risk of local failure of the foundations is accentuated by the absence of a surface hardbar which would otherwise help to raft over the very soft soils;*
- *The building has previously been classified as being earthquake prone. The severity of the ground conditions further increases the susceptibility to earthquake shaking”*

Terrane proposed and designed ground improvement below the Bath House foundations consisting of application of grouting below historical Bath House. The design was peer reviewed by ICE GEO & CIVIL and the grouting was undertaken in 2010 by Grouting Service Ltd with RDT Pacific Ltd as project manager and Terrane present as supervisor during the works. The grout improvement was undertaken up to the 6m below foundation level with three-pass approach - 2.5 to 6m (non-pressure), 0.3 to 3m (pressure 30 psi) and 0 to 0.7m (non-pressure).

Based on review of the available information, the extents of the grouting is unclear. An as-built record is available for the ground below the “Tarawera Gallery” section of the Bath House. The anticipated degree of improvement of the ground due to the grouting works is unclear.

It is understood verification testing of the ground following grouting was undertaken by Terrane. However, these test results have not been made available.

Geotechnical foundation strengthening of historical Museum Bath House is described in more detail in the following reports:

- Terrane (2009), “Rotorua Bath House/museum building, Rotorua, Investigation of existing foundations”, ref. 3278.02-01, 30 July 2009
- GNS Science (2009), “Petrological Study of Samples Excavated from the Rotorua Museum Construction Site”, 27 July 2009
- Terrane (2009), “Rotorua Museum Building, Queens Drive: Existing Building, Geotechnical Engineering Inputs, ref. 3278.02.r2, 11 August 2009
- ICE GEO & CIVIL (2010), “Rotorua Museum Existing Building Remediation: Geotechnical Peer Review, 24 March 2010
- Sigma (2010), “Rotorua museum of art and history – Earthquake prone building assessment”, 14 May 2010
- Terrane (2010), “Rotorua District Council, Rotorua Museum Building, Foundation Strengthening Project, Geotechnical Factual Report”, ref. 3278.02FactRep.doc, 14 May 2010

- Terrane (2010), “Rotorua Museum Building: Foundation Strengthening Project, Tarawera Gallery Injection Grouting – Completion Report, ref. 3278.02-06, 23 August 2010

4.3 South Wing Extension

The South Wing Extension of Rotorua Museum was designed and constructed between 2007 and 2012. Ground investigation and design of the building foundation was carried out by Terrane Consultants Limited and peer reviewed by ICE GEO & CIVIL. The geothermal study was carried out by GNS Science. The work is described in detail in the following reports:

- Terrane (2007), “Rotorua Museum of art and history, Rotorua, Southern extension – cost estimate, ref. 3278, 24 September 2007
- Terrane (2007), “Southern extension, Rotorua Museum of art and history, Rotorua – Interim assessment report, ref. 3278, 5 October 2007
- Terrane (2009), “Rotorua Bath House, Government Gardens, Rotorua, Proposed South Wing Extension, Geotechnical Design Report”, ref. 3278.SouthExt.desrep, 27 May 2009
- ICE GEO & CIVIL (2009), “Rotorua Museum South Wing Extension: Geotechnical Peer Review, 24 June 2009
- Transmittal to Sigma Consultants from Terrane, Rotorua Museum Southern Extension, Progress report to 17 November 09, 18 November 2009

From review of the above reports, we understand that the south extension is founded on cellular foundation/concrete slab with soil replacement up to 2.2m below basement level, 0.8m below lift shafts and 1.0m from the edge of the building. This approximately corresponds with 4.5m below existing ground level around the South Wing Extension. The soil replacement consists of WHAP 40 compacted hardfill underlain by thin layer (typically 300mm) of crusher dust. A gas venting system and gas membrane with geotextile separator were installed directly below foundation slab. Typical excavation sections presented in Terrane report from April 2009 listed above is show in the following Figure 4.

No as-built records or testing of the excavation during construction is available.

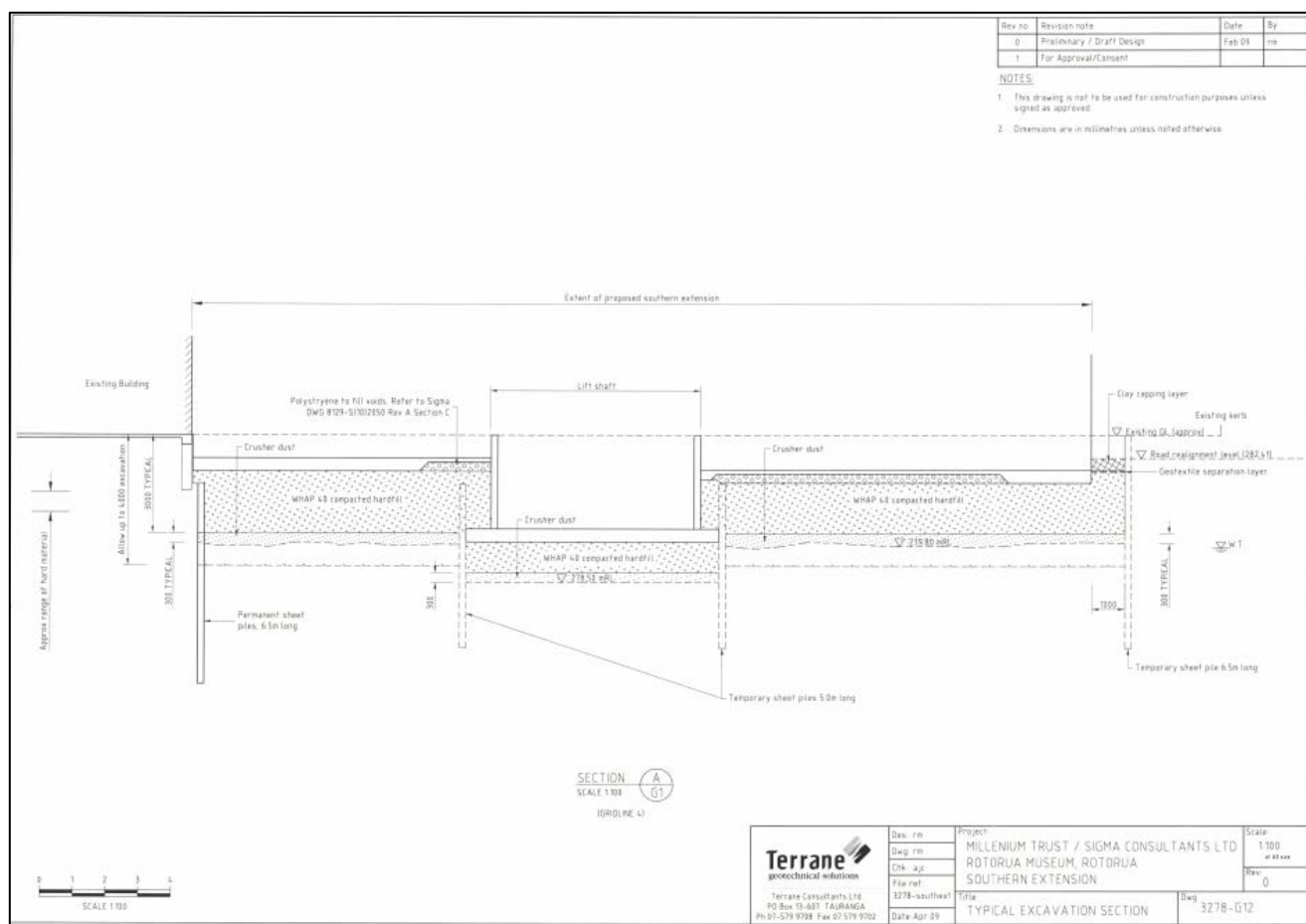


Figure 4: Typical excavation section, Dwg 3278-G12, Terrane, April 2009

4.4 North Wing Extension

The North Wing Extension of Rotorua Museum was designed and constructed at the same time as the South Wing Extension, i.e. between 2007 and 2012. Geotechnical investigation and design of foundation was also carried out by Terrane Consultants Limited. Peer review report is not available. Geothermal assessment report was prepared GNS Science. Only one report from Terrane was available for us during this study:

- Terrane (2007), "Rotorua Bath House, Government Gardens, Rotorua, Proposed North Wing Extension, Site Investigation Report", ref. 3278.1, August 2007

The report states that the ground conditions below the proposed North Wing Extension are significantly better than below South Wing Extensions. We understand that the North Wing Extension was founded on cellular foundation with shallow ground replacements consisting of 150mm of compacted hardfill. Based on available information the excavation level including soil replacement was approximately 1.5m below ground level. As below South Wing Extension, a gas venting system and gas membrane with geotextile separator were designed to be directly below the foundation slab. Typical foundation detail is show in the following Figure 5.

No as-built records or testing of the excavation during construction is available.

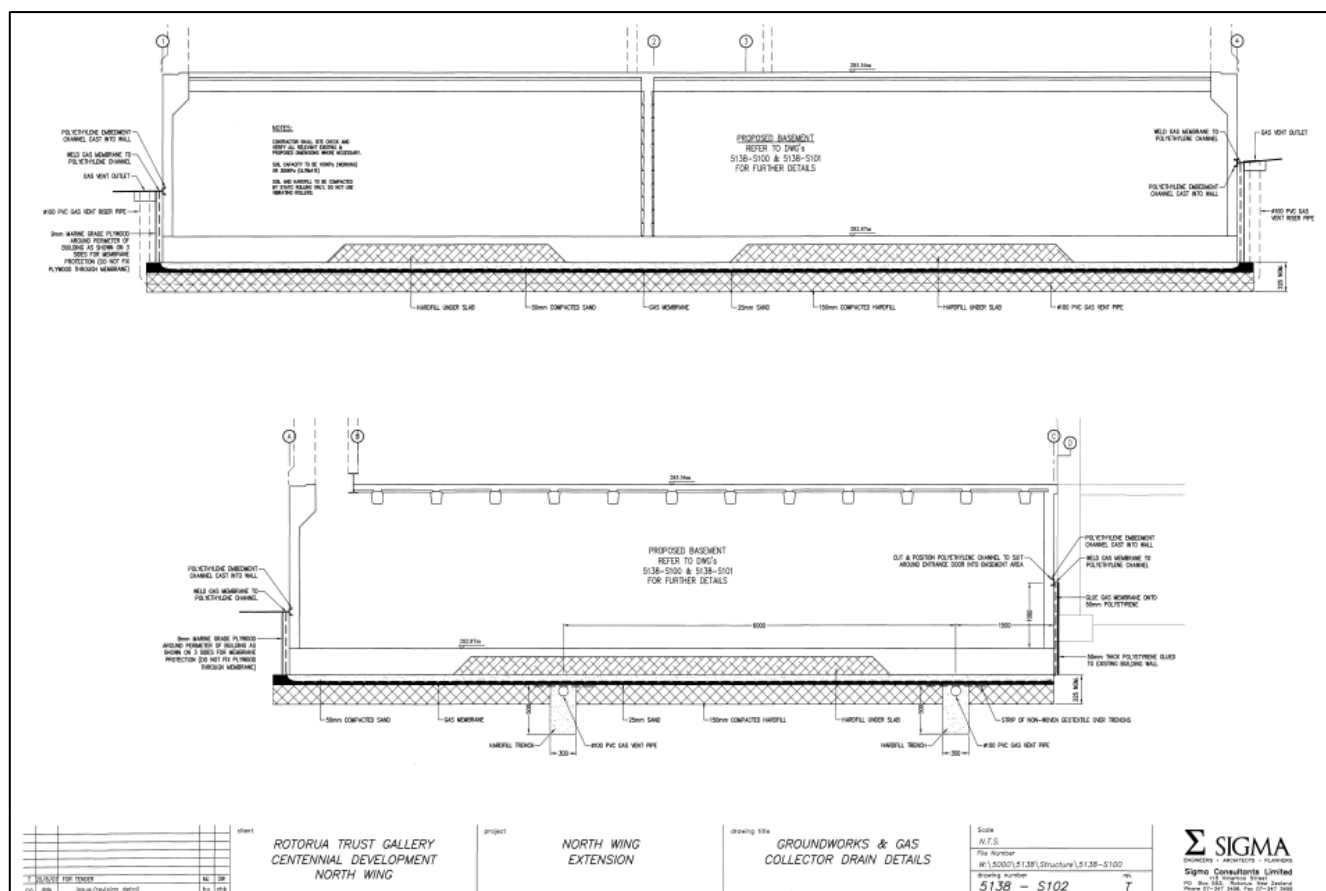


Figure 5: Sigma (2007), Groundworks & Gas collector drain details, Drawing no 5138-S102, Rev T

5. GROUND INVESTIGATIONS

5.1 Historical Soil Investigation

A historical soil investigation was carried out by Sigma in 1980, Kerslake in 1985 and Terrane in 2007/2009. No ground investigation data is available for the original building. The overview is available, and the most representative historical soil investigation can be found in the following reports:

- Terrane (2009), "Rotorua Bath House/museum building, Rotorua, Investigation of existing foundations", ref. 3278.02-01, 30 July 2009
- Terrane (2009), "Rotorua Bath House, Government Gardens, Rotorua, Proposed South Wing Extension, Geotechnical Design Report", ref. 3278.SouthExt.desrep, 27 May 2009
- Terrane (2007), "Rotorua Bath House, Government Gardens, Rotorua, Proposed North Wing Extension, Site Investigation Report", ref. 3278.1, August 2007

As mentioned in Terrane reports, 31 Scala Penetrometer Tests (Scala) and 4 Hand Augers (HA) were carried out for the Bath House foundations strengthening project. Five Machine Drilled Boreholes (BH), 9 Cone Penetration Tests (CPT), 3 HAs, and 3 Scalas were undertaken for the South Wing Extension geotechnical design, and 2 Cone Penetration Tests (CPT), 4 HAs and 8 Scalas were carried out for the North Wing Extension geotechnical design. Geothermal assessment of the site was prepared by GNS Science for each site and is attached to reports mentioned above.

The following laboratory tests were carried out as a part of Terrain soil investigation and are presented in 3278.02-01, 30 July 2009 report:

- 9 Bulk density and Void ration tests;
- 2 Consolidated Drained Triaxial Compression Tests;
- 2 Unconsolidated Undrained Triaxial Compression Test;
- 9 pH and Sulphate tests.

5.2 Cheal Soil Investigation

Geotechnical soil investigation consists of 16 Scalas, 3 BHs including Standard Penetration Tests (SPT) and push tube sampling, 4 CPTs with soil temperature measurement and 2 Trial Pits (TP) was undertaken by Cheal technician on 15 March 2017 (Scalas) and Drillcore on 3 to 7 April 2017. Six Push tube samples were collected from the BH1 and BH3 for laboratory testing, carried out by Geotechnics Ltd between 27 April and 10 May 2017.

The amount, type and location of the soil investigation has been chosen in order to understand soil conditions below Rotorua Museum building, confirm ground investigation findings within historical geotechnical reports and the extent of historical grouting below the Bath House, and, if needed, recommend additional geotechnical work. The following methodology has been followed:

- 16 Scala tests were carried out in the basement of the historical Bath House to confirm grouting works performed in 2010 (see Chapter 5.2);
- 1 inclined BH (BH02) drilled at an angle of 60° from horizontal to below the museum and located approximately 2m from the Bath House was undertaken to assess grout depth;
- 2 BHs (BH 01 and 03) with Standard Penetration Tests (SPT) and shear vane tests at the bottom of a barrel were drilled next to the South and North Wing Extension to describe soil conditions and collect soil samples for laboratory testing;
- 4 CPTs with temperature measurement were carried out to assess liquefaction potential of the site and test geothermal field;
- 2 Trial Pits (TP) were excavated next to the South and North Wing Extension to confirm their foundation types; and
- The following laboratory tests were carried out to understand in more details liquefaction and deformation behaviour of the soil undelaying museum building:
 - Four natural water contents and Atterberg limits (LL, PL, PI)

- Four Fines Contents passing 75µm and 63µm sieve
- One one-dimensional consolidation test

Results of our geotechnical investigation including site investigation plan, Scala tests, BH logs, CPT data and laboratory test results are presented in our Geotechnical Factual Report from 15 May 2017.

Site investigation plan including the location of Terrane soil investigation is presented in Appendix 1.

6. GEOTECHNICAL ASSESSMENT

6.1 Laboratory Tests Results

As described in our Geotechnical Factual report, the following laboratory tests were carried out:

- Four natural water contents and Atterberg limits (LL, PL, PI)
- Four Fines Contents passing 75µm and 63µm sieve
- One one-dimensional consolidation test

Summary of performed laboratory tests is presented in Table 1 below:

Table 1 – Laboratory tests

Sample		Natural water content	Atterberg limits (LL, PL, PI)	Fines Content passing 75µm and 63µm sieve	One one-dimensional consolidation test
Pushed tube samples	BH03 5.6-5.65m bgl	No	No	No	$m_v=0.42-0.64$ m ² /MN
	BH03 7.5-7.9m bgl	66.7%	78, 41, 37	30.4%, 28.5%	No
Core box sample	BH03 4.5-4.8m bgl	92.5%*	47, 36, 11	82.8%, 81.6%	No
	BH03 5.0-5.3m bgl	71.9%*	59, 40, 19	96.4%, 95.9%	No
	BH03 6.8-7.0m bgl	74.4%*	50, 44, 6	26.8%, 23.5%	No

* Measured values are not representative and only for indication

The values of Fines Content (>20%)⁶ and Atterberg limits (in general $PI \geq 7$)⁷ indicate low susceptibility to liquefaction.

⁶ Kohji Tokimatsu, Yoshiaki Yoshimi (1984), "Criteria of Soil Liquefaction with SPT and Fines Content", Proceedings of the 8th World Conference on Earthquake Engineering, San Francisco, Calif., 3, pp. 255-262

⁷ Ross W. Boulanger, I. M. Idriss (2006), "Liquefaction Susceptibility Criteria for Silts and Clays", Journal of Geotechnical and Geoenvironmental Engineering, November 2006, pp. 1413

6.2 Ground Conditions

6.2.1 Bath House

As mentioned above 16 Scalas and 1 BH (BH02) were carried out in the basement of the Bath House and next to the building respectively to confirm presence and extent of the grouting installed below the Bath House building in 2010. Two CPTs (CPT02 and 03) were carried out to assess liquefaction risk.

To compare soil conditions before and after grouting we created similar cross section as Terrane (presented in Terrane report 3278.02-01, 30 July 2009) with shown approximate top level of hard layer, and compared it with historical data. Cross sections 1 to 4 are attached in Appendix 1.

Based on comparison of pre- and post-grouting Scala tests undertaken, there is evidence of increased top level of the hard layer (considered to be 8 blows per 100mm penetration) before and after grouting. Terrain is describing soil overlaying the hard layer as “*Very soft soil and void infilling*” with extremely low safe bearing capacity (<10–15 kPa). Recent (Cheal) Scala test results indicate the soil overlaying the hard layer described within the Terrane report has in general safe bearing capacity >80kPa (Ultimate Geotechnical bearing capacity >250kPa, based on correlations with M. J. Stockwell⁸) with some local soft spots, most probably located between historical grouting boreholes.

BH02 was drilled approximately 2m next to the central part of the historical Bath House with an inclination of 60° from horizontal line. The material encountered approximately 2m vertically below existing ground level and 1m horizontally from the outside edge of the Bath House was cemented fine to medium pumice Sand. The material was more cemented than similar material encountered at similar depths within other boreholes, suggesting the presence of grout. Silty Sand and/or Gravel (generally pumiceous) with different level of cementation were continuing up to approximately 7.2m vertically below existing ground level and was underlain by medium to coarse Sand. Groundwater level was encountered 2.4m below existing ground level. However, it should be noted that the groundwater level was recorded immediately after drilling and, consequently, is influenced by drilling mud and not considered to be accurate.

CPT indicated increasing soil temperature with depth in accordance with data presented in Terrane report.

Geological cross section with indicated approximate extent of grouting works is presented in Appendix 1, Cross section 5-5.

The above testing indicates that some grouting has been undertaken below the full extent of the Bath House. The results typically show an increase in the strength of the ground following grouting, typically a decrease in depth to the “hard pan” discussed above and increased bearing capacity.

⁸ M.J. Stockwell (1977), *Determination of allowable bearing pressure under small structures*, New Zealand Engineering (32, 6), June 1977

6.2.2 South Wing Extension

One BH (BH03) and one TP (TP02) were carried out next to the South Wing Extension to describe soil conditions and obtain samples for laboratory analysis to further inform liquefaction assessment. One CPT (CPT04) was undertaken next to the BH03 to assess liquefaction risk.

BH03 encountered very soft, thermally altered, sensitive silty soil with sulphur odour between approximately 1 and 4.5m below existing ground level. The soil investigation results were in accordance with aforementioned Terrane report. Groundwater level was encountered 2.8m below existing ground level. However, it should be noted that the groundwater level was recorded immediately after drilling and, consequently, is influenced by drilling mud and not considered to be accurate.

Soil temperature was measured with CPT04. Temperature of 61.60°C was encountered approximately 8m below existing ground level. This value is lower than measured by Terrane and can reflect either seasonal variations or ground changes due to the construction of the South Wing Extension.

TP02 was excavated 1.2m below existing ground level next to the existing foundation of the South Wing Extension. TP encountered layer of geomembrane and geotextile located on the side of building foundation and bottom of excavation. The soil is described as a sandy fill.

Based on review of the available drawings, we understand the South Wing Extension is founded on cellular foundation/concrete slab with soil replacement up to 2.2m below basement level and 0.8m below lift shafts, what is approximately up to 4.5m below existing ground level.

Geological cross section with approximate extend of soil replacement below the South Wing Extension is presented in Appendix 1, Cross section 5-5.

6.2.3 North Wing Extension

One BH (BH01) and one TP (TP01) were carried out next to the North Wing Extension to describe soil conditions and obtain samples for laboratory analysis to further inform liquefaction assessment. One CPT (CPT01) was undertaken next to the BH03 to assess liquefaction risk.

BH01 indicates better soil conditions than below the South Wing Extension. Encountered soil is more sandy and gravelly without presence of very soft and very sensitive silty layers. Groundwater level was encountered 2.8m below existing ground level. However, it should be noted that the groundwater level was recorded immediately after drilling and, consequently, is influenced by drilling mud and not considered to be accurate.

Soil temperature was measured with CPT01. Temperature of 43.70°C was encountered approximately 6m below existing ground level.

TP01 was excavated 1.3m below existing ground level next to the existing foundation of the North Wing Extension. TP encountered layer of geomembrane and geotextile located on the side of building foundation. The soil is described as a sandy fill.

As we understand the South Wing Extension is founded on cellular foundation with shallow ground replacements consists of 150mm of compacted hardfill, what is approximately up to 1.5m below existing ground level.

Geological cross section with approximate extend of soil replacement below North Wing Extension is presented in Appendix 1, Cross section 5-5.

6.3 Liquefaction Assessment

Liquefaction hazard was assessed by Terrain (and peer reviewed by ICE GEO & CIVIL) with the following conclusions:

- South Wing Extension
 - *“The borehole and CPT results clearly indicate the surficial soils are too fine-grained to be classified as liquefiable, while the cemented sinter sands are too cemented to liquified. This, plus the sub-excavation and replacement ground improvement measures, mean that a more detailed assessment of liquefaction potential is not required. Overall, the level of liquefaction risk to the South Wing extension is considered to be within acceptable limits.”*
- North Wing Extension
 - *“Any liquefaction-related settlement which did occur should remain within the tolerance of the proposed structure and not become manifest at the ground surface. Overall, the level of liquefaction risk to the proposed North Wing extension appears to be within acceptable limits.”*

To confirm Terrane conclusions, we carried out liquefaction assessment as described below.

6.3.1 Site Seismic Category

Based on the results of the soil investigation and following our experience from the area we consider the site is Class D – Deep soil sites in accordance with NZS 1170.5:2004 – Structural design actions, Earthquake actions.

6.3.2 Liquefaction

Four CPT tests were carried out to assess liquefaction risk for the historical Bath House, North Wing Extension and South Wing Extension.

An assessment of liquefaction was undertaken using software CLiq v2.0.6.85 and Boulanger & Idriss (2014) calculation method. The following parameters were determined to identify the likely vulnerability to liquefaction damage at ground surface:

- The cumulative thickness of liquefiable layer;
- The depth at which liquefaction triggering was assessed; and
- Free field post-liquefaction vertical settlement S_{V1D} based on Zhang et al. (2002)

As agreed with GDC we assumed the proposed development to have an importance level of 3 and we followed NZS 1170.5-2004 rather than Bridge manual. Assuming the design life of 50 years, the annual probability of earthquake for Serviceability limit state (SLS) and Ultimate limit state (ULS) is 1 in 25 years and 1 in 1000 years respectively. Following NZS 1170.5-2004, section 3.1, the liquefaction assessments were undertaken for an SLS Peak ground acceleration (PGA) of 0.07g and M 7.5, and ULS PGA of 0.35 and M 7.5. Ground water level was assumed to be 3m below existing ground level for all calculations.

The results of liquefaction assessment are presented in Table 2 below.

Table 2: Liquefaction Results for SLS and ULS states

CPT data	State	Analysed annual probability of exceedance and PGA	Depth of liquefiable layers [mbgl] with thickness $\geq 0.2\text{m}$	Cumulative thickness [m] of liquefiable layers with thickness $\geq 0.2\text{m}$	S_{v1D} [mm]
CPT01	SLS1	1/25, 0.07g	N/A	0	0
	ULS	1/1000, 0.35g	N/A	0	0
CPT02 ¹	SLS1	1/25, 0.07g	N/A	0	0
	ULS	1/1000, 0.35g	6	1.0	40
CPT03 ¹	SLS1	1/25, 0.07g	N/A	0	0
	ULS	1/1000, 0.35g	6.5	1.2	55
CPT04	SLS1	1/25, 0.07g	N/A	0	0
	ULS	1/1000, 0.35g	4	1.6	80

¹ We assumed 6m of non-liquefiable grouted soil layer

As shown in Table 2 above liquefaction should not occur during SLS even. There is indication of possible minor liquefaction below the historical Bath House and South Wing Extension during ULS event. However, following laboratory tests results and soil Fine Content and Plastic Limit⁹ the liquefaction manifestation during ULS event will be negligible.

Following our liquefaction calculations and considering 6m grouted, non-liquefiable layer below the historical Bath House and up to 3m thick non-liquefiable fill below South Wing extension we agree with Terrane statement that liquefaction risk is considered to be within acceptable limits. However, we are suggesting the settlement values will be discussed with GDC structural engineers.

⁹ Ross W. Boulanger, I. M. Idriss (2006), "Liquefaction Susceptibility Criteria for Silts and Clays", Journal of Geotechnical and Geoenvironmental Engineering, November 2006, pp 1413

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Cheal has been engaged by Rotorua Lakes Council to carry out a geotechnical investigation to assess existing below ground features immediately adjoining the Rotorua Museum with emphasis to the seismic behaviour of foundation ground and, if applicable, to propose and design geotechnical seismic strengthening.

The main objectives of this report were to present:

- Overview of geotechnical desk study of historical geotechnical remedial works;
- Interpretation of our geotechnical investigation and comparison with historical data;
- Geotechnical assessment of the ground seismic behaviour;
- Proposal for additional works (if required)

For the purpose of this report the Rotorua Museum was divided to three parts:

- Historical building (Bath House) constructed in 2006;
- North Wing Extension constructed in 2012; and
- South Wing Extension constructed in 2012.

Bath House building:

The Bath House is founded on shallow footings in combination with shallow strip foundations. The grouting works were proposed by Terrane in 2009 as a part of foundation strengthening project, and executed in 2010. Sixteen Scalas, 1 BH and 2 CPTs were carried out by Cheal in the Bath House basement and next to the building respectively.

The above testing indicates that some grouting has been undertaken below the full extent of the Bath House. The results typically show an increase in the strength of the ground following grouting, typically a decrease in depth to the “hard pan” and increased bearing capacity.

South and North Wing Extension:

Foundations of the extensions were design by Terrane and peer reviewed by ICE GEO & CIVIL (not available for North Wing Extension) in 2007/2010. Review of available drawings and reports for the foundations for the North and South Wing Extensions have been undertaken. Based on the drawings, the South Wing Extension foundation sits on upwards of 2.2m of compacted fill and the North Wing Extension sits on 150mm of compacted fill.

The seismic (liquefaction) aspect of foundation design was considered and is commented in design and peer review reports and therefore can be assumed to have been analysed to current standards.

Two BHs, 2 Trial Pits and 2 CPTs were carried out in the close vicinity of South and North Wing Extension. Ground investigation undertaken confirms that ground conditions encountered near the North Wing Extension are better than those encountered at the South Wing Extension.

Liquefaction:

An assessment of liquefaction was undertaken using software CLiq v2.0.6.85 and Boulanger & Idriss (2014) calculation method. Results are presented in Table 2. The following calculations and results show liquefaction should not occur during a SLS event. There is indication of possible minor liquefaction below the historical Bath House and South Wing Extension during an ULS event. Following laboratory tests results and soil Fine Content and Plastic Limit¹⁰ the liquefaction manifestation during an ULS event will be negligible. However, the magnitude of settlement due to an ULS event presented in Section 7.3.2 should be commented on by a structural engineer.

7.2 Recommendations

We believe at the moment there is no need for any additional geotechnical works in relation to seismic strengthening.

However, based on a site visit, discussions with Rotorua Museum and GDC representatives there is an issue of cracking of sections of the museum and possible foundation movement not related to seismic performance of the ground. At this stage, the reason behind the cracking is unclear. Therefore, it is recommended that long term monitoring of the foundations is undertaken to determine where movement may be occurring.

Monitoring procedure with proposed alert and alarm levels of total and differential settlement should be prepared in cooperation between a geotechnical and structural engineer.

¹⁰ Ross W. Boulanger, I. M. Idriss (2006), "Liquefaction Susceptibility Criteria for Silts and Clays", Journal of Geotechnical and Geoenvironmental Engineering, November 2006, pp 1413

8. DISCLAIMER

This Report has been prepared solely for the use of our client with respect to the particular brief given to Cheal Consultants.

No liability is accepted in respect of its use for any other purpose or by any other person or entity. All future owners of this property should seek professional geotechnical advice to satisfy themselves as to its ongoing suitability for their intended use.

The opinions, recommendations and comments given in this Report are the result from the application of accepted industry methods of site investigation. As factual evidence over much of the site has been obtained solely from 3 Bore holes, 4 Cone Penetration Tests, 2 Trial Pits and 16 Scala Penetrometer Tests, which by their nature only provide information about that exact location, there may be special conditions pertaining to this site which have not been identified by the investigation and which have not been taken into account in the report. Any groundwater levels measured during the investigation may change over time.

If variations in the subsoils occur from those described or assumed to exist then the matter should be referred back to Cheal Consultants immediately.

CHEAL CONSULTANTS LIMITED
19 May 2017

Appendix 1

Site Investigation Plan and Geological Cross Sections

NOTES:

1. All dimensions are in metres unless noted otherwise.
2. Coordinate Datum: Bay of Plenty Circuit 2000, Moturiki Vertical Datum 1953.
3. Aerial photo sourced from Google Earth.

LEGEND



Machine Drilled Borehole (CHEAL, 2017)



CPT (CHEAL, 2017)



Trail Pit (CHEAL, 2017)



Scala Penetrometer Test (CHEAL, 2017)



Machine Drilled Borehole (TERRANE, 2007/2009)



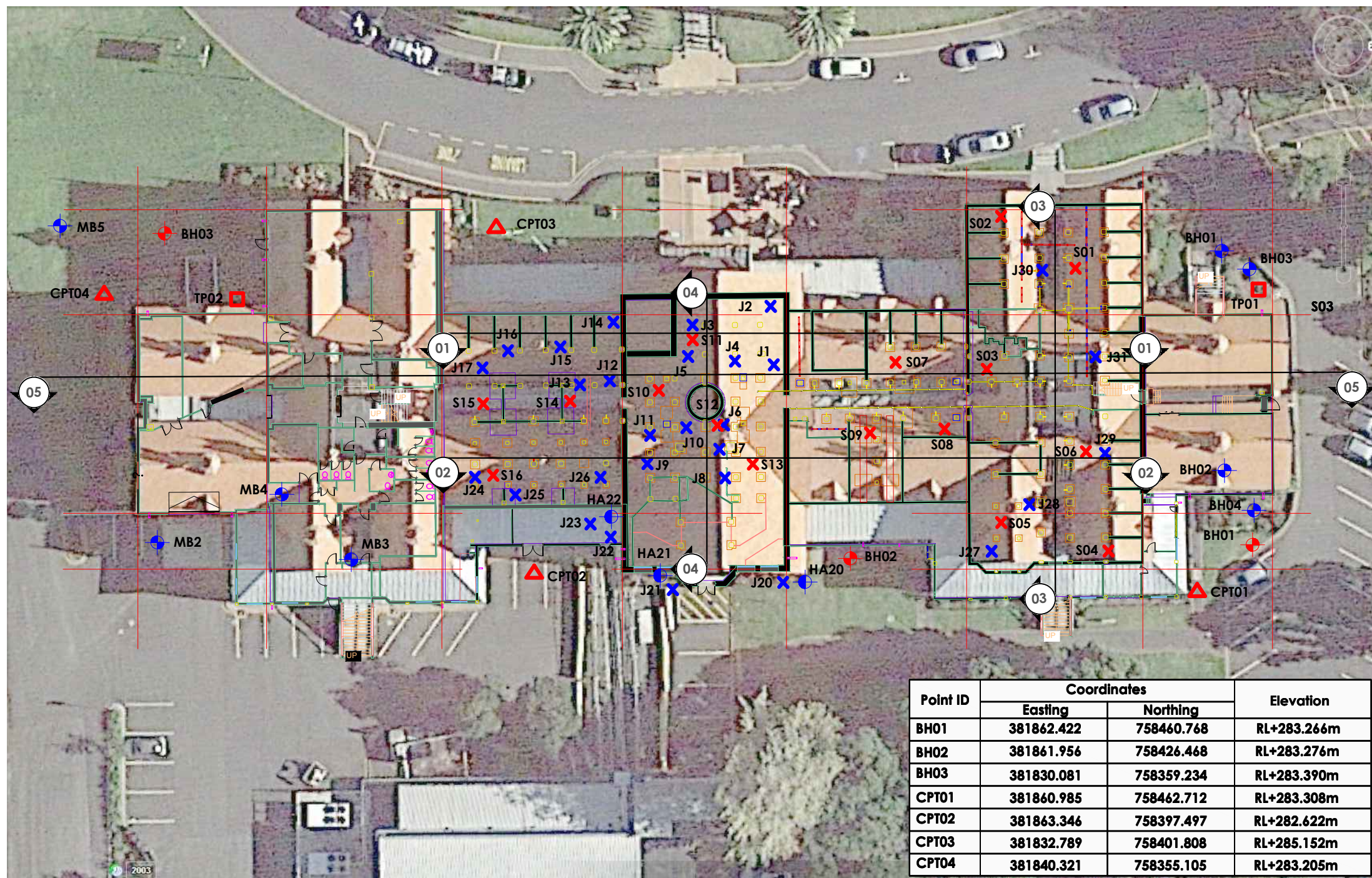
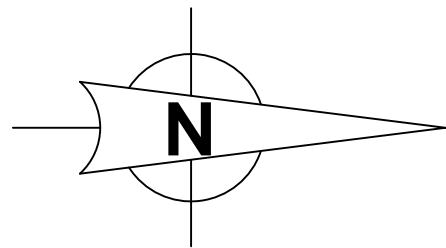
Hand Auger (TERRANE, 2007/2009)



Scala Penetrometer Test (TERRANE, 2007/2009)



Machine Borehole and Push Tube (TERRANE, 2009)



Client Ref

A	11/05/2017	For Information	KD	FH	AM
Rev	Date	Amendment	By	Chk	App

Project Title

Rotorua Lakes Council
Museum, Government Gardens
Oruawhata Drive, Rotorua

Drawing Title

Site Investigation Plan
with Historical Data up to 2009

Surveyed			
Designed	K Dhattarwal	11/05/2017	KD
Drawn	K Dhattarwal	11/05/2017	KD
Checked	F Havel	11/05/2017	FH
Approved	A Moss	11/05/2017	AM

Status For Information

Scale Not to Scale | A3

Drawing Number 16592-02 | Rev A

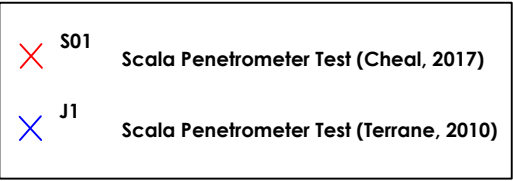
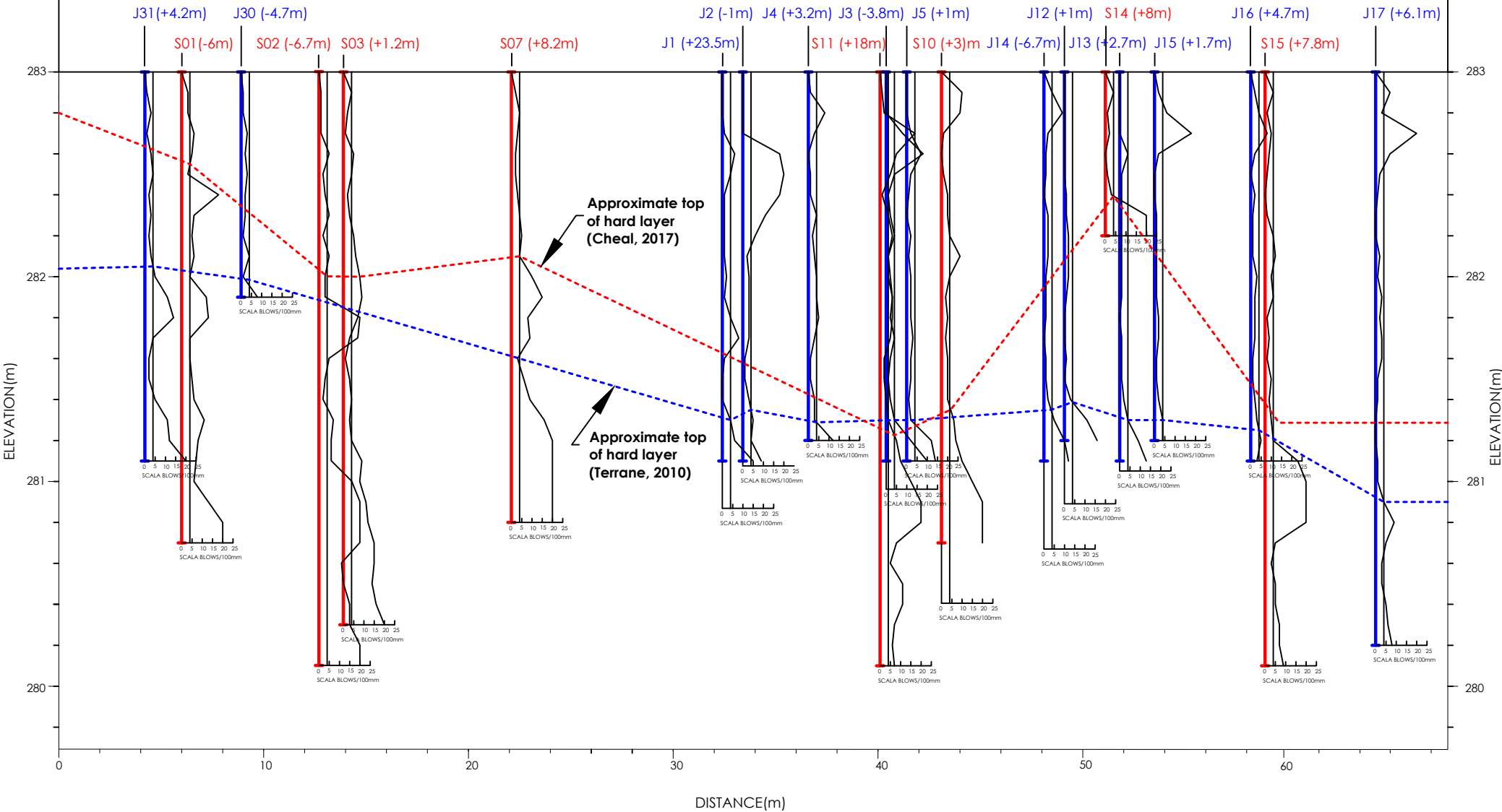
NOTES:

1. All dimensions are in metres unless noted otherwise.

NORTH
WING
EXTENSION

BATH HOUSE BUILDING

SOUTH
WING
EXTENSION



Client Ref				
A	12/05/2017	For Information	KD	FH
Rev	Date	Amendment	By	Chk App

Project Title
Rotorua Lakes Council
Museum, Government Gardens
Oruawhata Drive, Rotorua

Drawing Title
Cross Section
1-1

Surveyed			
Designed	K Dhattarwal	12/05/2017	KD
Drawn	K Dhattarwal	12/05/2017	KD
Checked	F Havel	12/05/2017	FH
Approved	A Moss	12/05/2017	AM

Status
For Information

Scale
1:250 Horizontal
1:25 Vertical
A3

Drawing Number
16592-03
Rev
A

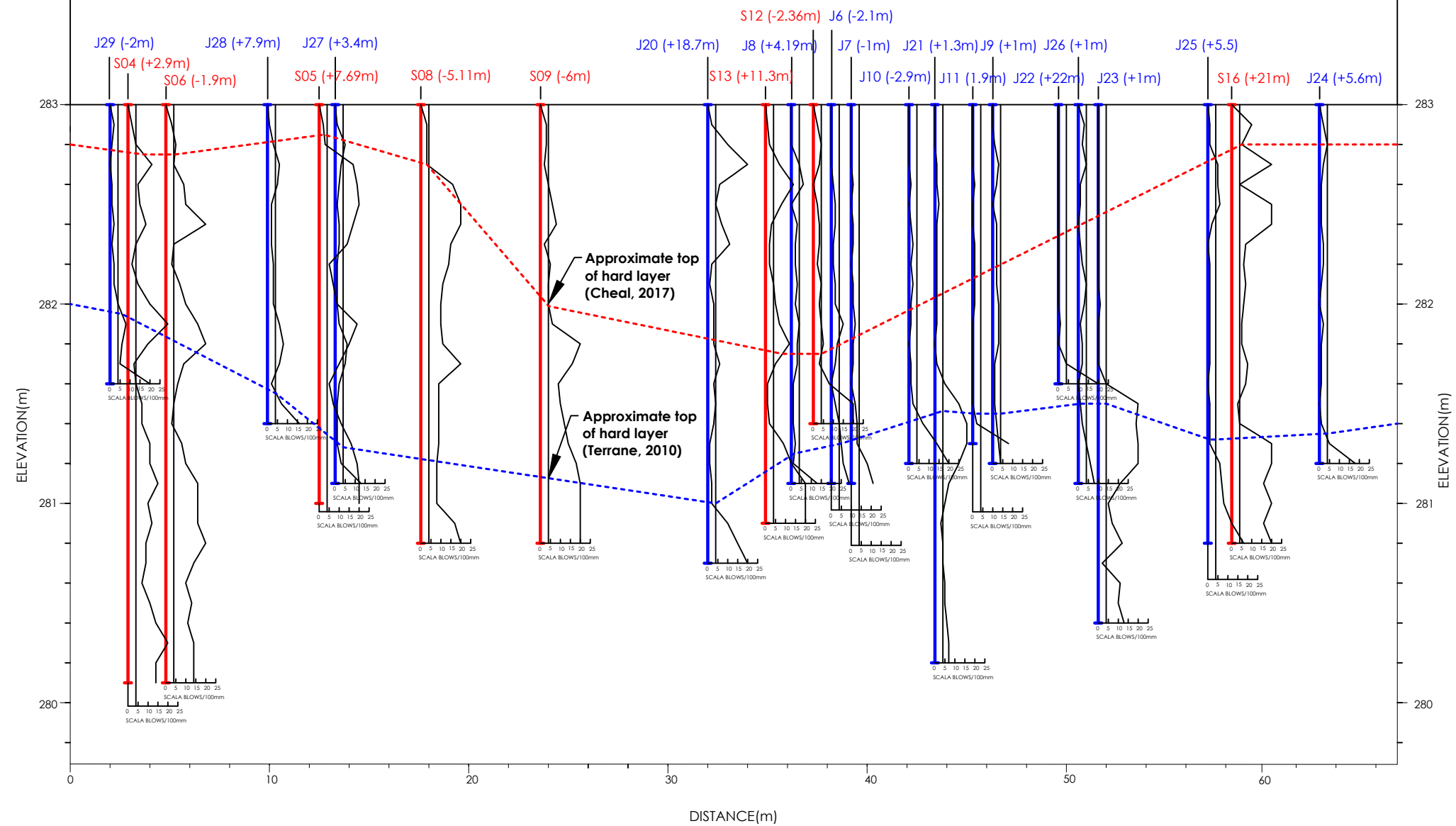
NOTES:

1. All dimensions are in metres unless noted otherwise.

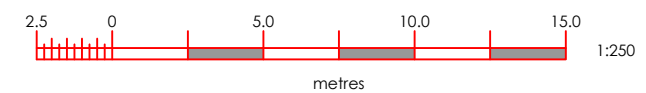
NORTH
WING
EXTENSION

BATH HOUSE BUILDING

SOUTH
WING
EXTENSION



✕ S01 Scala Penetrometer Test (Cheal, 2017)
✕ J1 Scala Penetrometer Test (Tarrane, 2010)



Client Ref

A	12/05/2017	For Information	KD	FH
Rev	Date	Amendment	By	Chk

Project Title

Rotorua Lakes Council
Museum, Government Gardens
Oruawhata Drive, Rotorua

Drawing Title

Cross Section
2-2

Surveyed			
Designed	K Dhattarwal	12/05/2017	KD
Drawn	K Dhattarwal	12/05/2017	KD
Checked	F Havel	12/05/2017	FH
Approved	A Moss	12/05/2017	AM

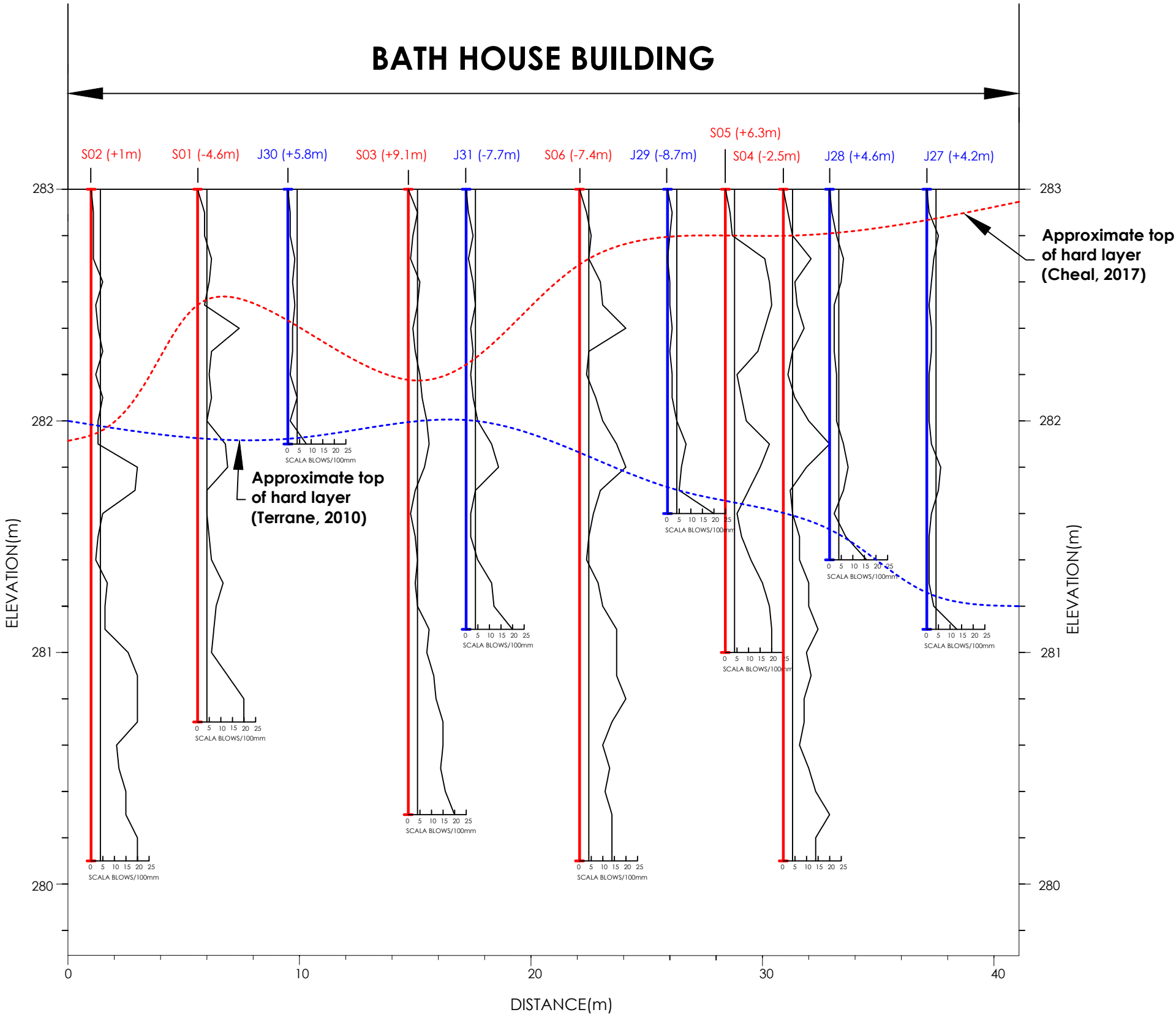
Status For Information

Scale 1:250 Horizontal A3
1:25 Vertical

Drawing Number 16592-04 Rev A

NOTES:

1. All dimensions are in metres unless noted otherwise.



Client Ref

A	12/05/2017	For Information	KD	FH
Rev	Date	Amendment	By	Chk

Project Title
Rotorua Lakes Council
Museum, Government Gardens
Oruawhata Drive, Rotorua

Drawing Title
Cross Section
3-3

Surveyed			
Designed	K Dhattarwal	12/05/2017	KD
Drawn	K Dhattarwal	12/05/2017	KD
Checked	F Havel	12/05/2017	FH
Approved	A Moss	12/05/2017	AM

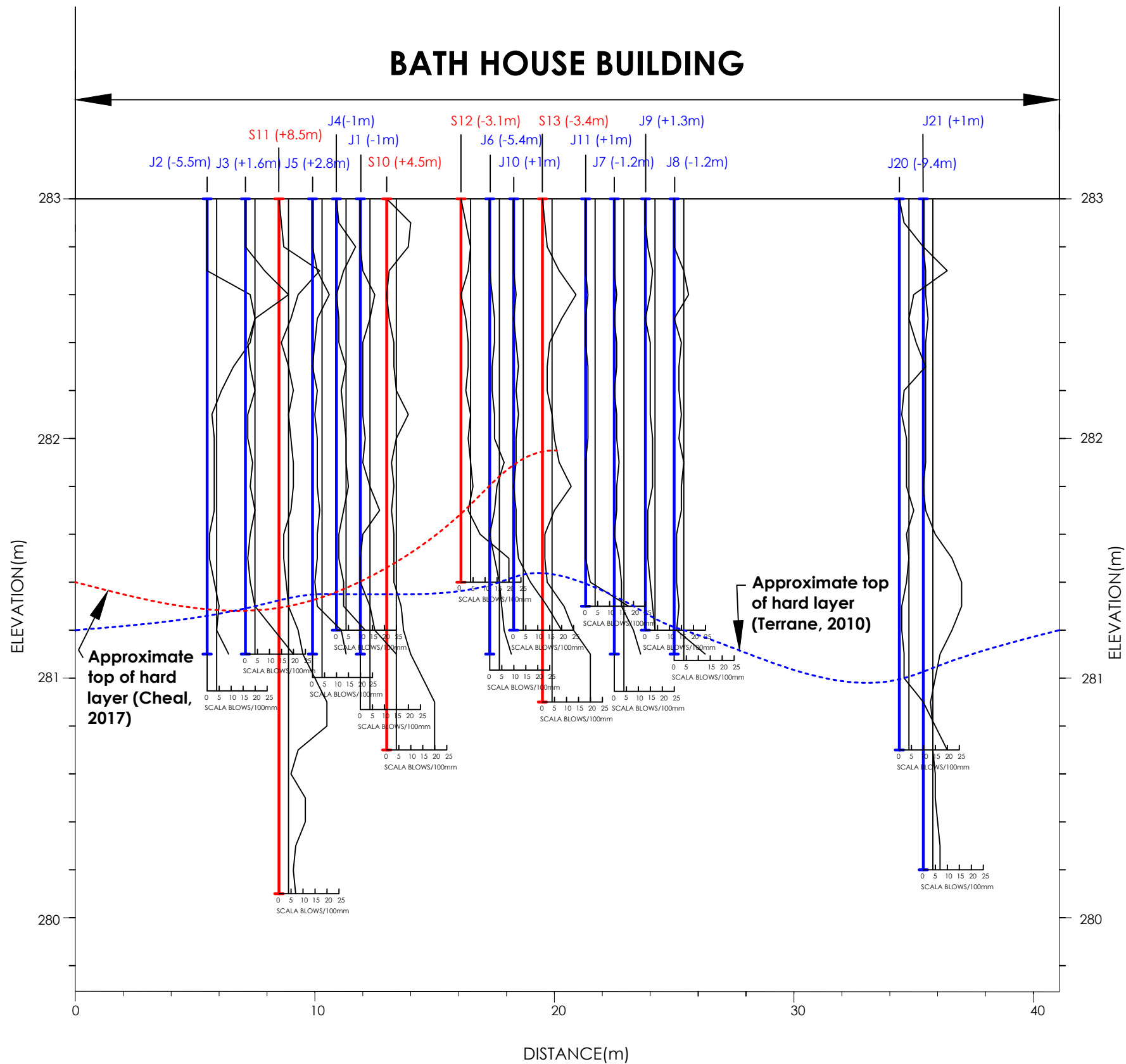
Status
For Information

Scale
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1:25 Vertical
A3

Drawing Number
16592-05
Rev
A

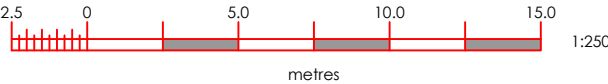
NOTES:

1. All dimensions are in metres unless noted otherwise.



Section 4-4

×	S01	Scala Penetrometer Test (Cheal, 2017)
×	J1	Scala Penetrometer Test (Terrane, 2010)



Client Ref

A	12/05/2017	For Information	KD	FH
Rev	Date	Amendment	By	Chk App

Project Title
Rotorua Lakes Council
Museum, Government Gardens
Oruawhata Drive, Rotorua

Drawing Title
Cross Section
4-4

Surveyed			
Designed	K Dhattarwal	12/05/2017	KD
Drawn	K Dhattarwal	12/05/2017	KD
Checked	F Havel	12/05/2017	FH
Approved	A Moss	12/05/2017	AM

Status
For Information

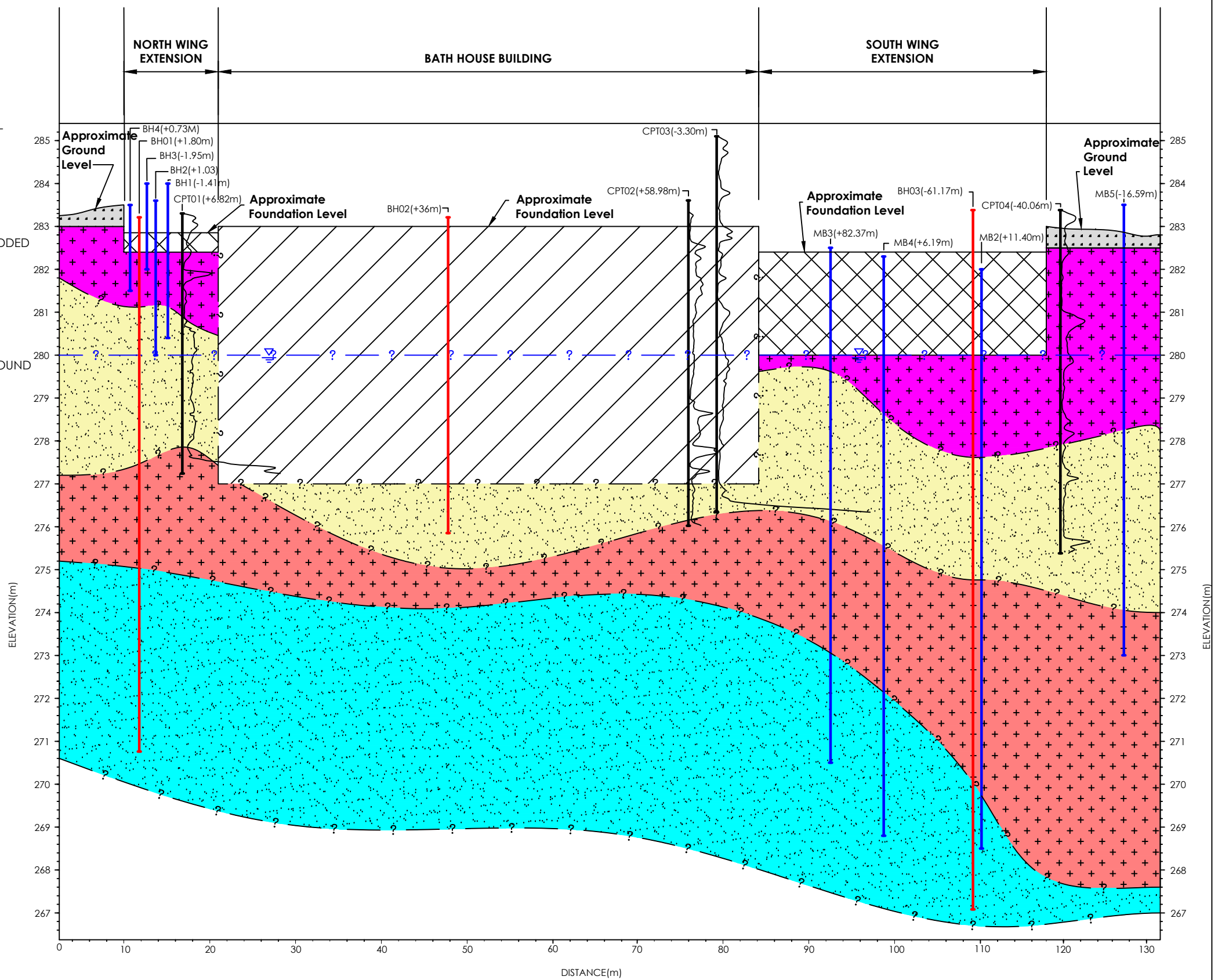
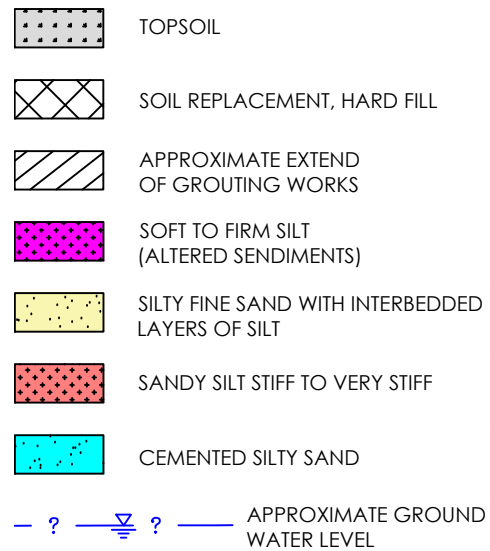
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Drawing Number
16592-06
Rev
A

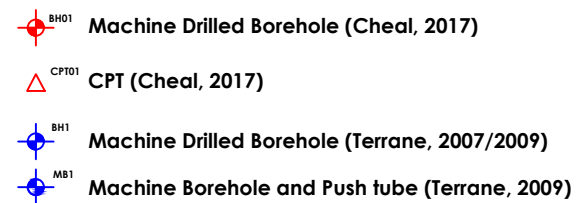
NOTES:

1. All dimensions are in metres unless noted otherwise.
2. Nature and continuity of subsoil conditions away from presented BHs and CPTs can vary. There may be special conditions pertaining to the site which have not been identified by the investigation.

LEGEND



Section 5-5



Client Ref

Rev	Date	Amendment	By	Chk	App
A	15/05/2017	For Information	KD	FH	AM

Project Title

Rotorua Lakes Council
Museum, Government Gardens
Oruawhata drive, Rotorua

Drawing Title

Cross Section
5-5

Surveyed			
Designed	K Dhattarwal	15/05/2017	KD
Drawn	K Dhattarwal	15/05/2017	FH
Checked	F Havel	15/05/2017	AM
Approved	A Moss	15/05/2017	AM

Status For Information

Scale 1:250 Horizontal | A3
1:100 Vertical

Drawing Number 16592-07 | Rev A

Appendix 2

Liquefaction Calculations

LIQUEFACTION ANALYSIS REPORT

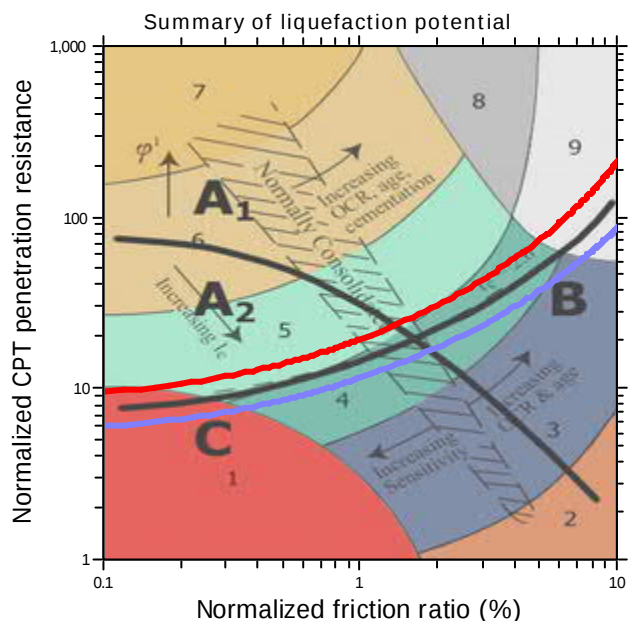
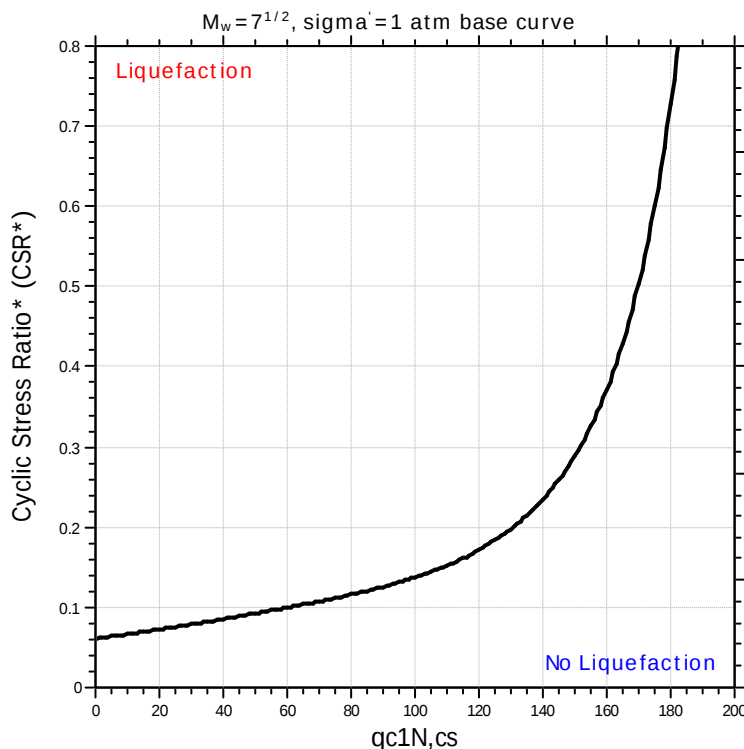
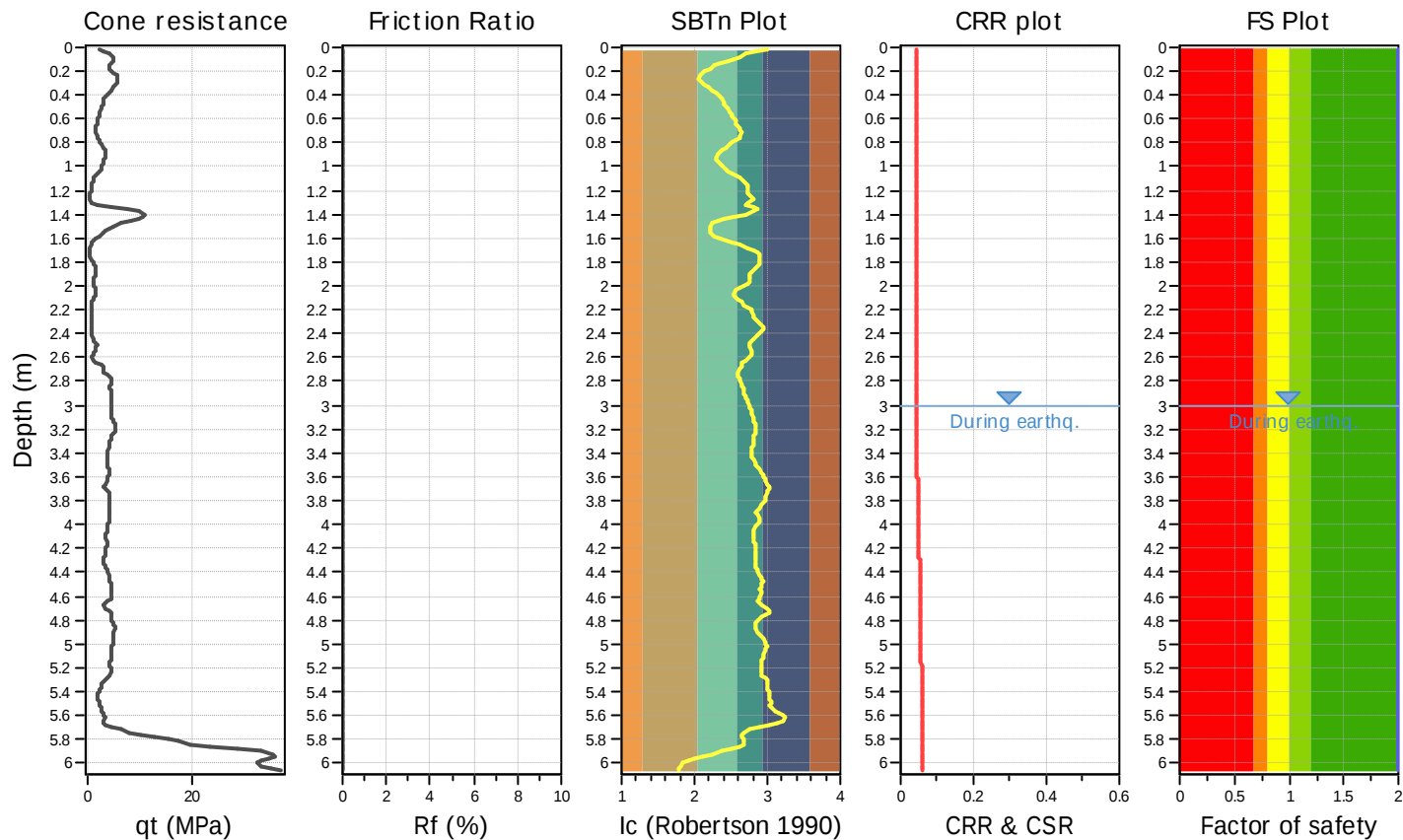
Project title :

Location :

CPT file : CPT01 SLS

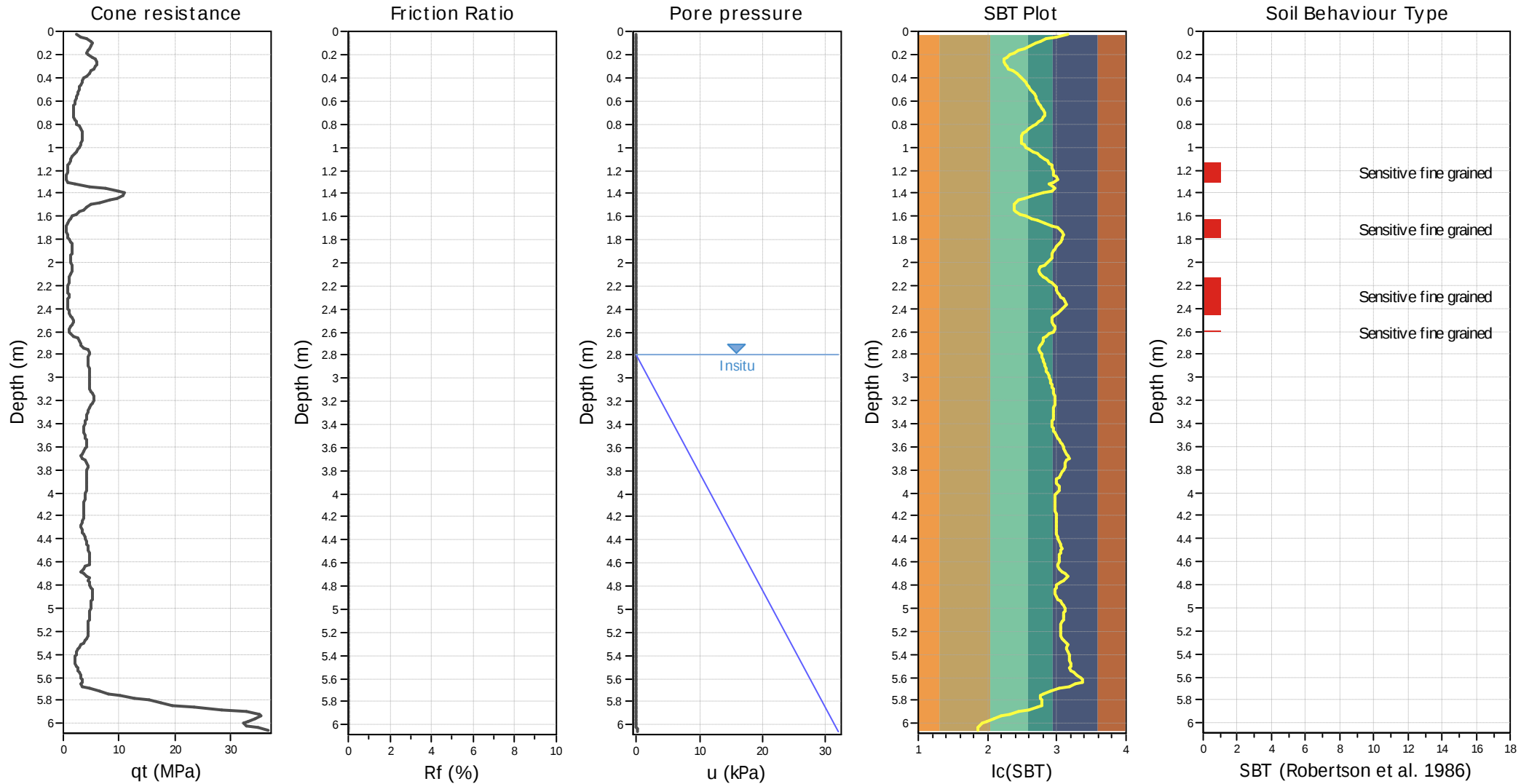
Input parameters and analysis data

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Fines correction method:	B&I (2014)	G.W.T. (earthq.):	3.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method
Peak ground acceleration:	0.07	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		



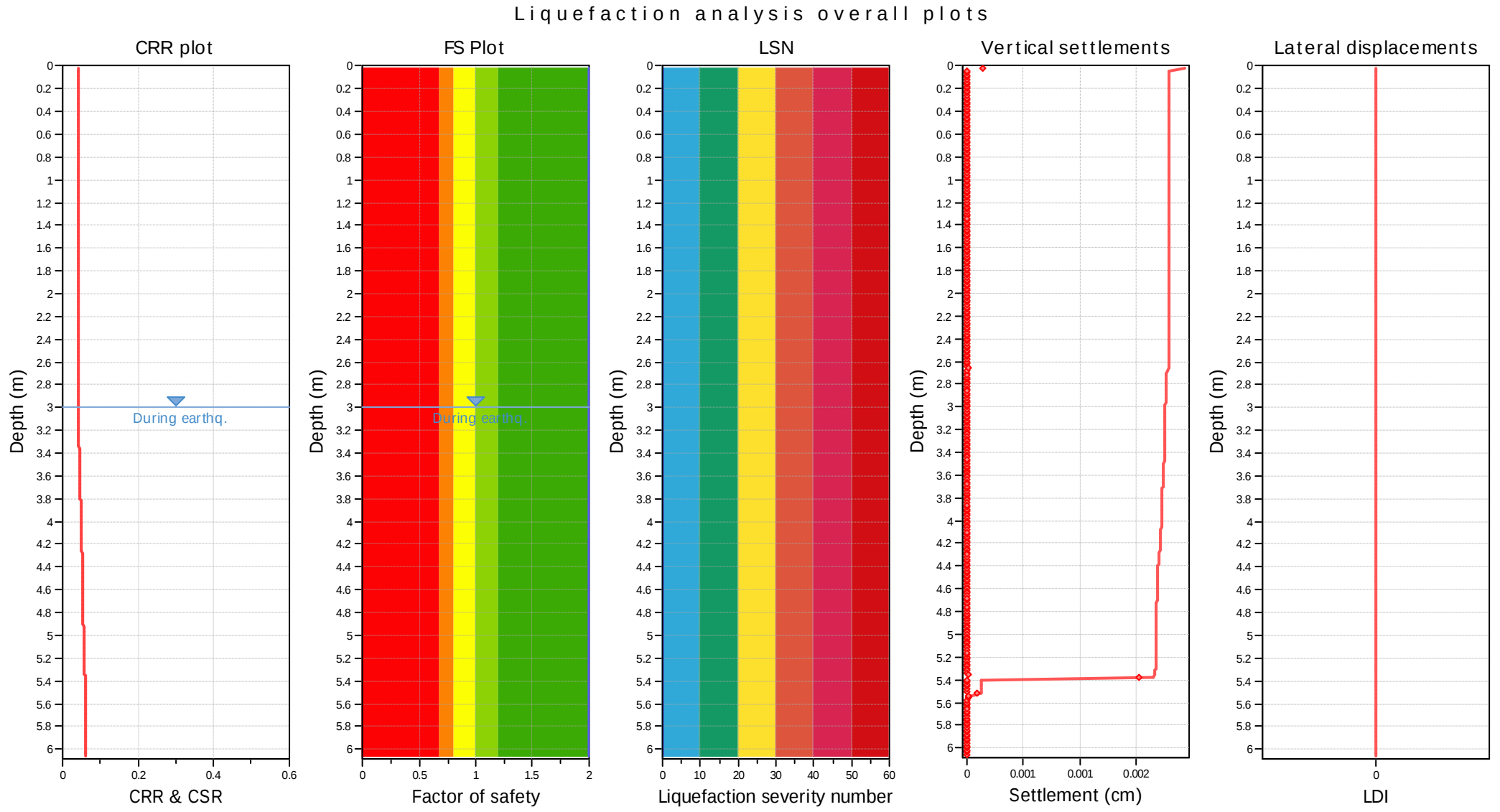
Zone A₁: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A₂: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength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

CPT basic interpretation plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	3.00 m	Fill weight:	N/A	SBT legend		
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No			
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _σ applied:	Yes	1. Sensitive fine grained	4. Clayey silt to silty	7. Gravely sand to sand
Earthquake magnitude M _w :	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only	2. Organic material	5. Silty sand to sandy silt	8. Very stiff sand to
Peak ground acceleration:	0.07	Use fill:	No	Limit depth applied:	No	3. Clay to silty clay	6. Clean sand to silty sand	9. Very stiff fine grained
Depth to water table (insitu):	2.80 m	Fill height:	N/A	Limit depth:	N/A			



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (earthq.):	3.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _σ applied:	Yes
Earthquake magnitude M _w :	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.07	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	2.80 m	Fill height:	N/A	Limit depth:	N/A

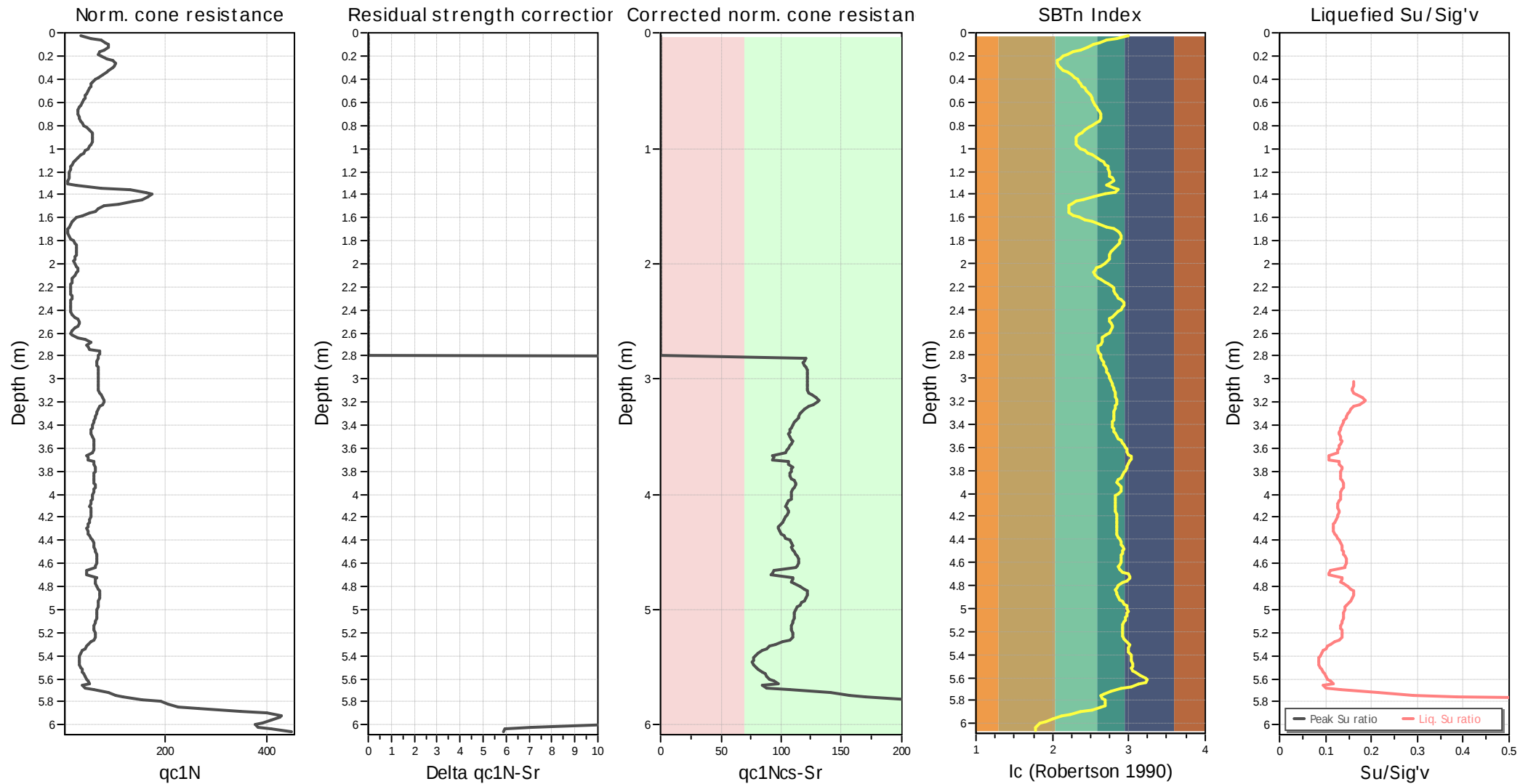
F.S. color scheme

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

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

Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	3.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_0 applied:	Yes
Earthquake magnitude M_w :	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.07	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	2.80 m	Fill height:	N/A	Limit depth:	N/A

LIQUEFACTION ANALYSIS REPORT

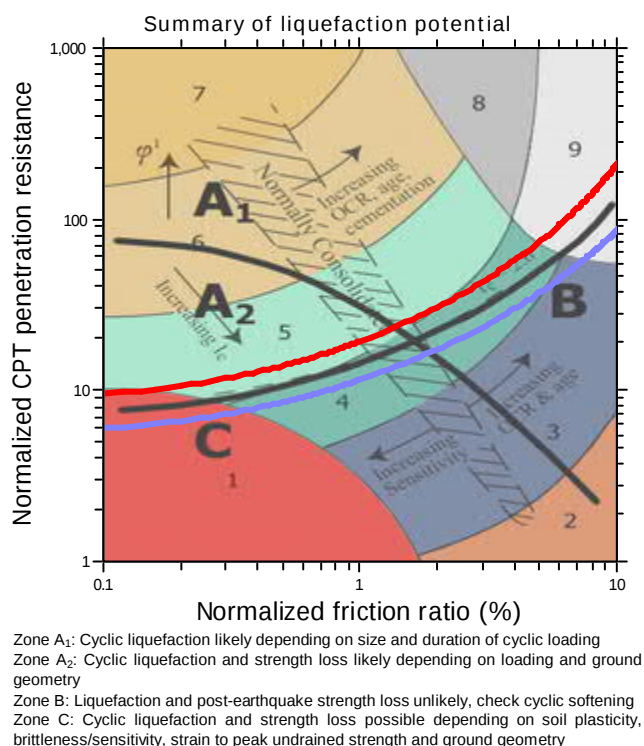
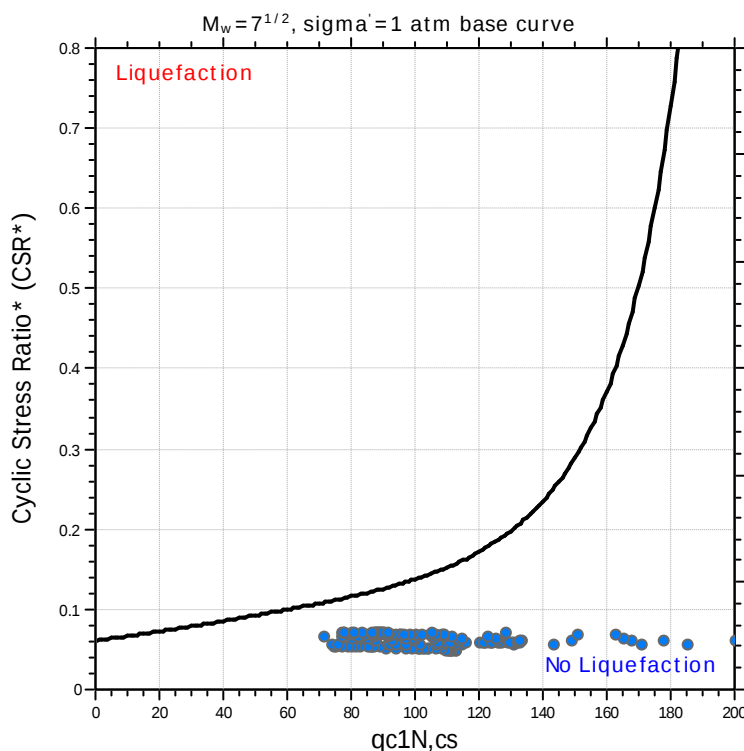
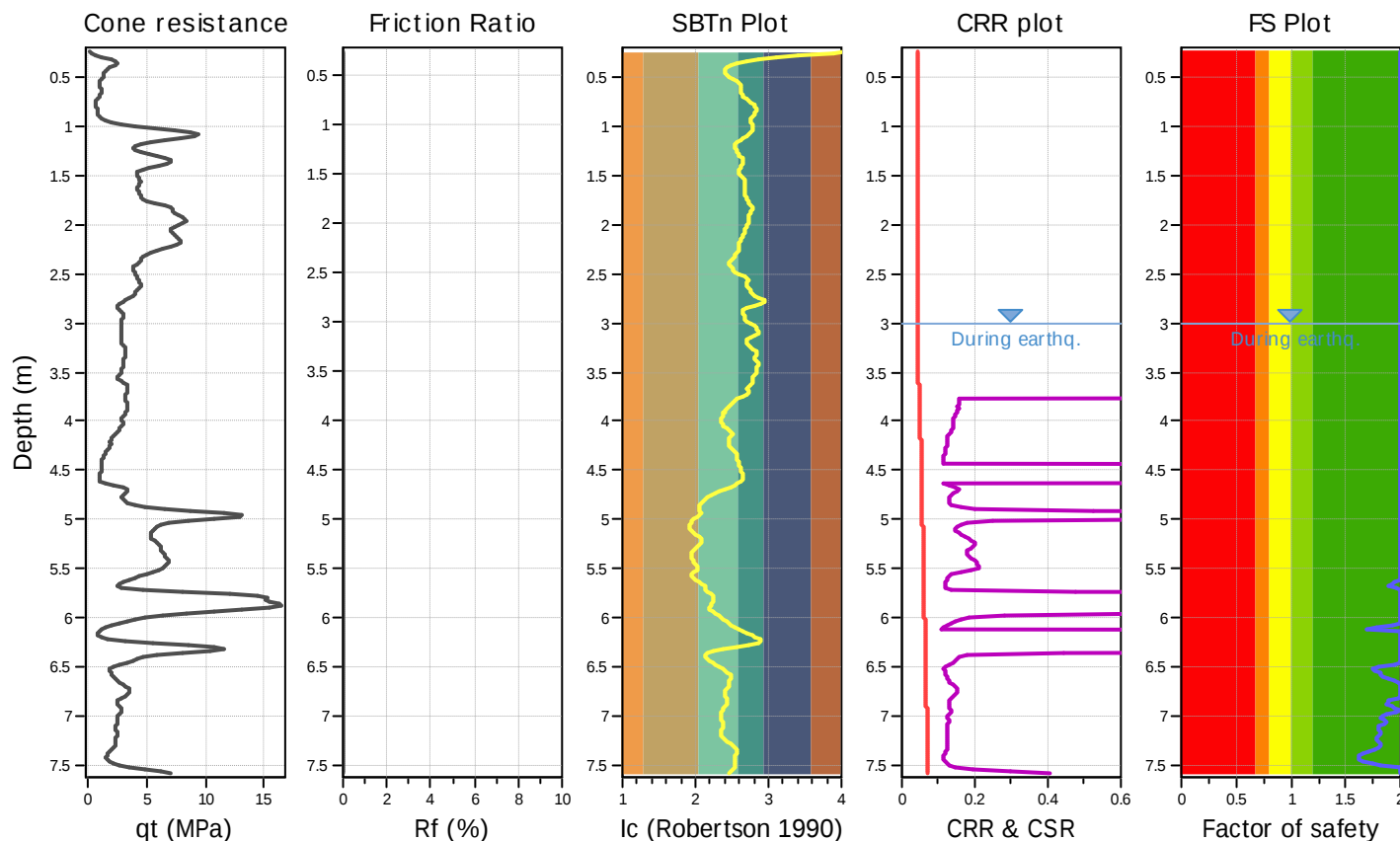
Project title :

Location :

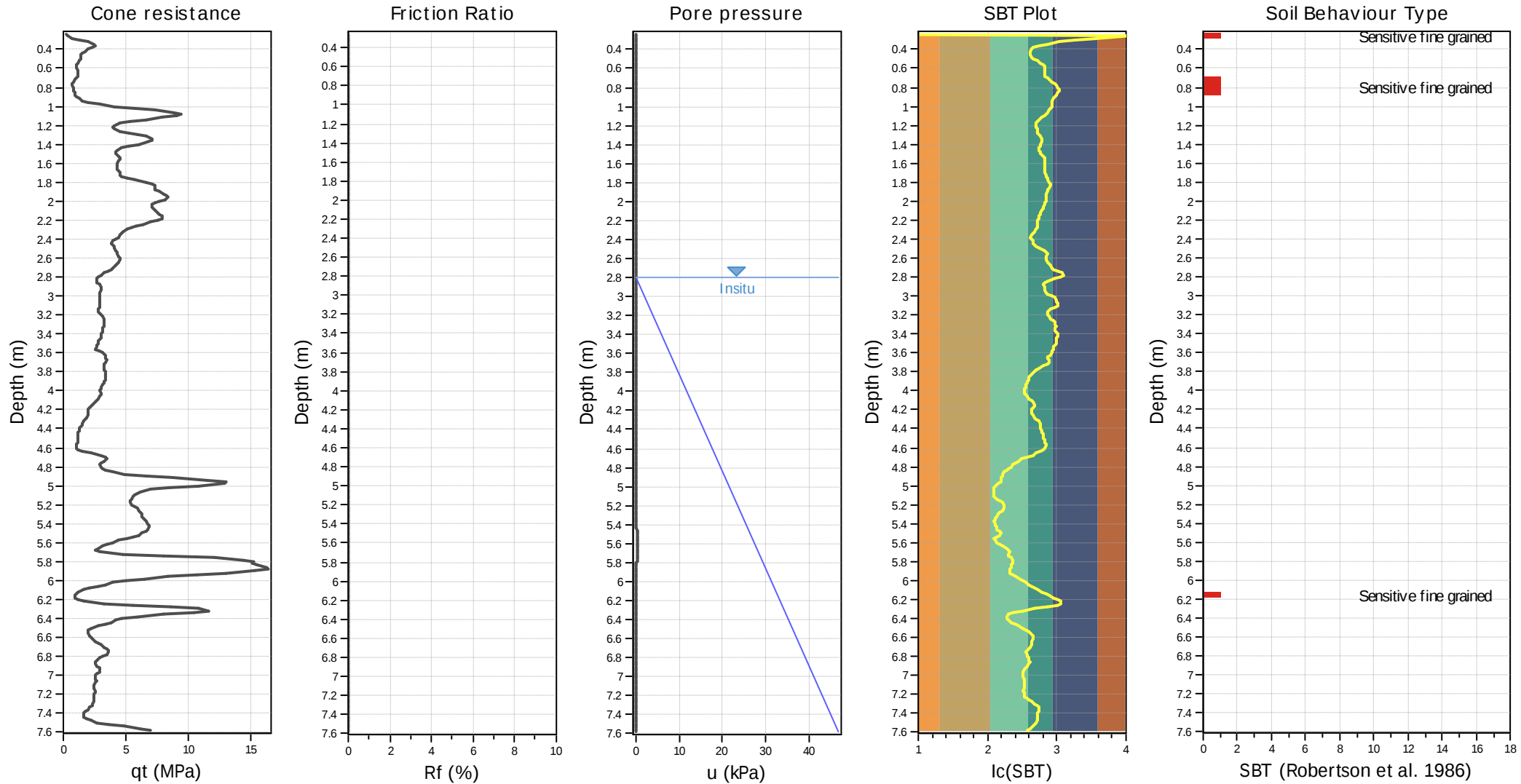
CPT file : CPT02 SLS

Input parameters and analysis data

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Fines correction method:	B&I (2014)	G.W.T. (earthq.):	3.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method
Peak ground acceleration:	0.07	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		



CPT basic interpretation plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	3.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _σ applied:	Yes
Earthquake magnitude M _w :	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.07	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	2.80 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

1. Sensitive fine grained

2. Organic material

3. Clay to silty clay

4. Clayey silt to silty

5. Silty sand to sandy silt

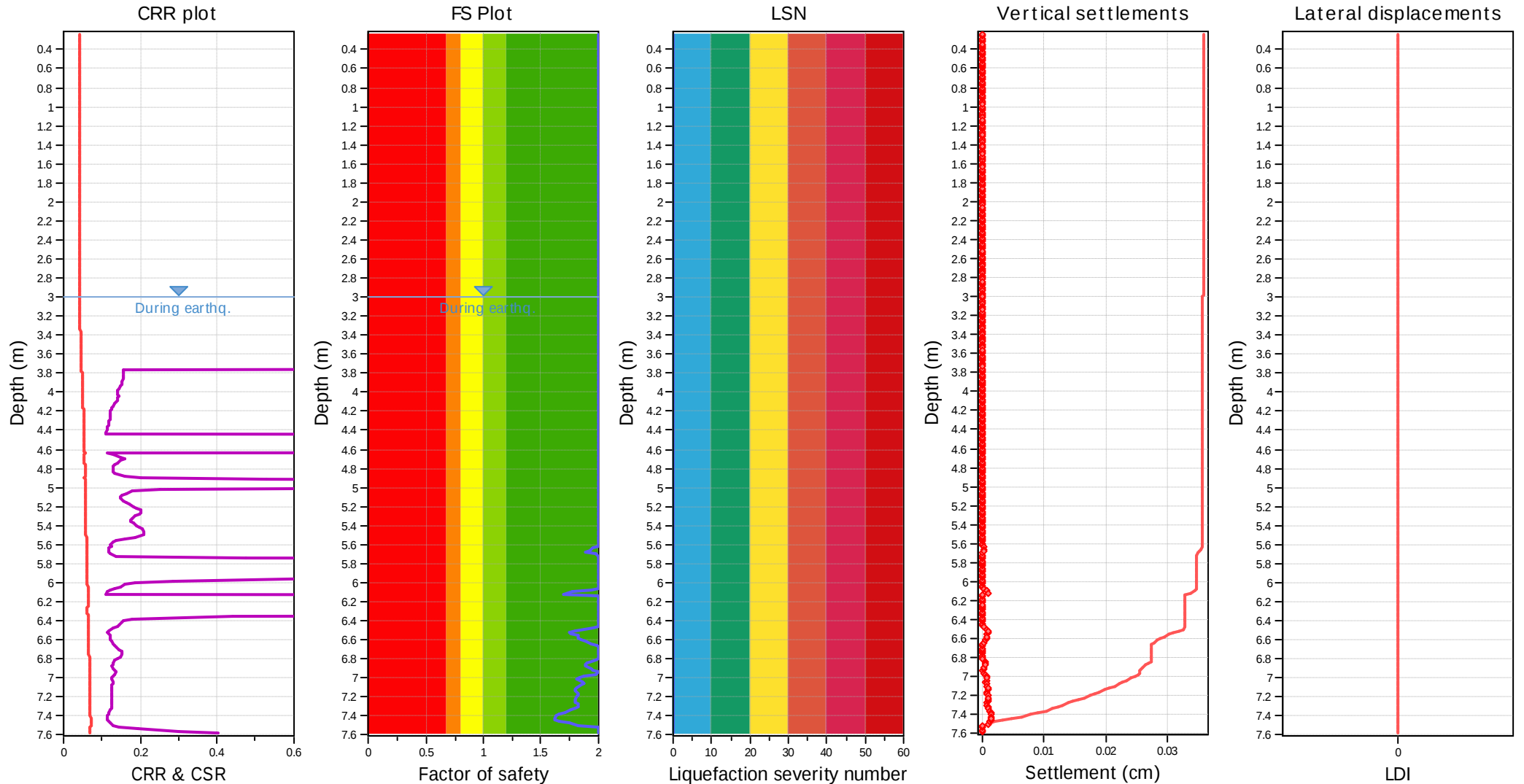
6. Clean sand to silty sand

7. Gravely sand to sand

8. Very stiff sand to

9. Very stiff fine grained

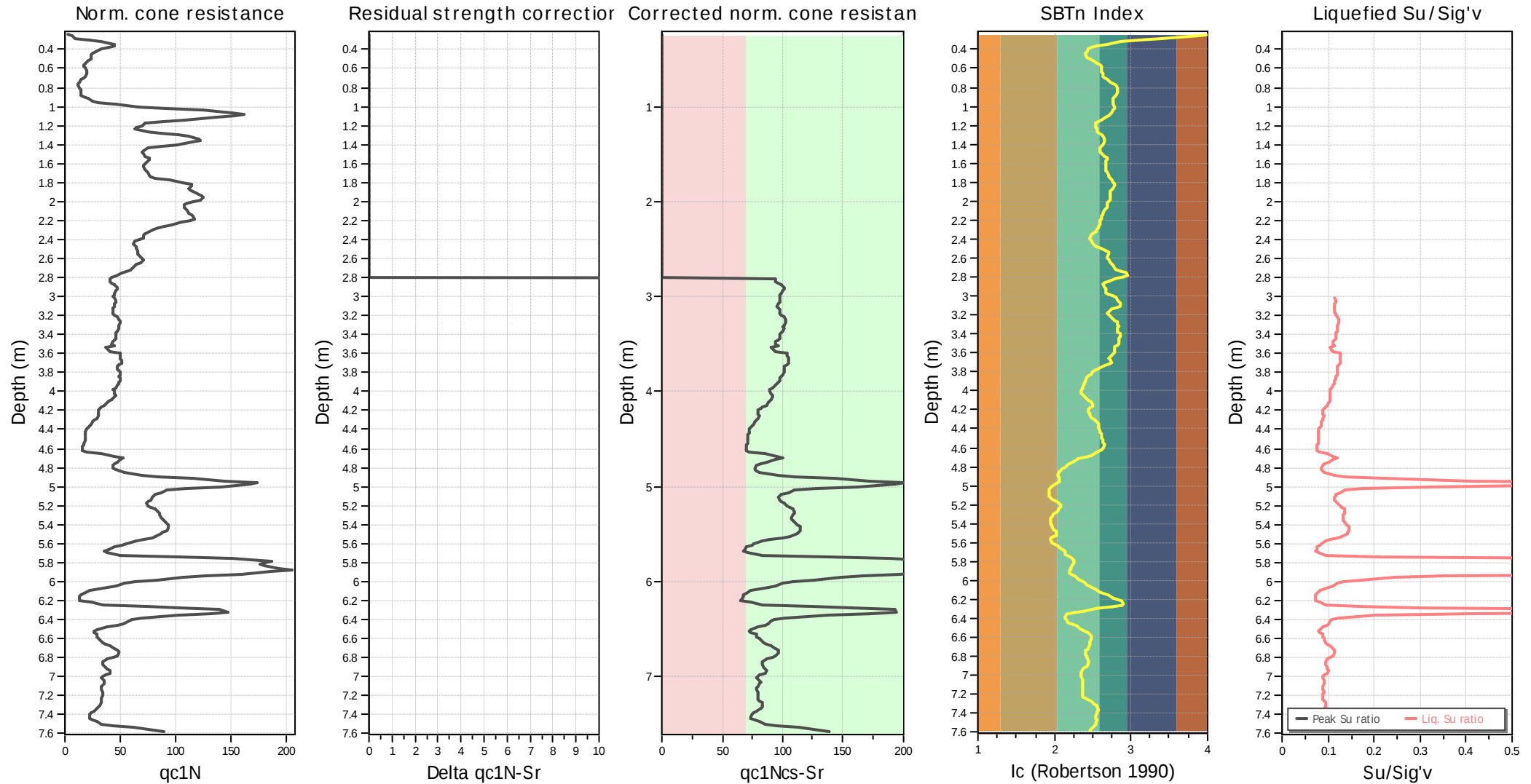
Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (earthq.):	3.00 m	Fill weight:	N/A	F.S. color scheme	LSN color scheme
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No	Almost certain it will liquefy	Severe damage
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _σ applied:	Yes	Very likely to liquefy	Major expression of liquefaction
Earthquake magnitude M _w :	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only	Liquefaction and no liq. are equally likely	Moderate to severe exp. of liquefaction
Peak ground acceleration:	0.07	Use fill:	No	Limit depth applied:	No	Unlike to liquefy	Moderate expression of liquefaction
Depth to water table (insitu):	2.80 m	Fill height:	N/A	Limit depth:	N/A	Almost certain it will not liquefy	Minor expression of liquefaction
							Little to no expression of liquefaction

Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	3.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K ₀ applied:	Yes
Earthquake magnitude M _w :	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.07	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	2.80 m	Fill height:	N/A	Limit depth:	N/A

LIQUEFACTION ANALYSIS REPORT

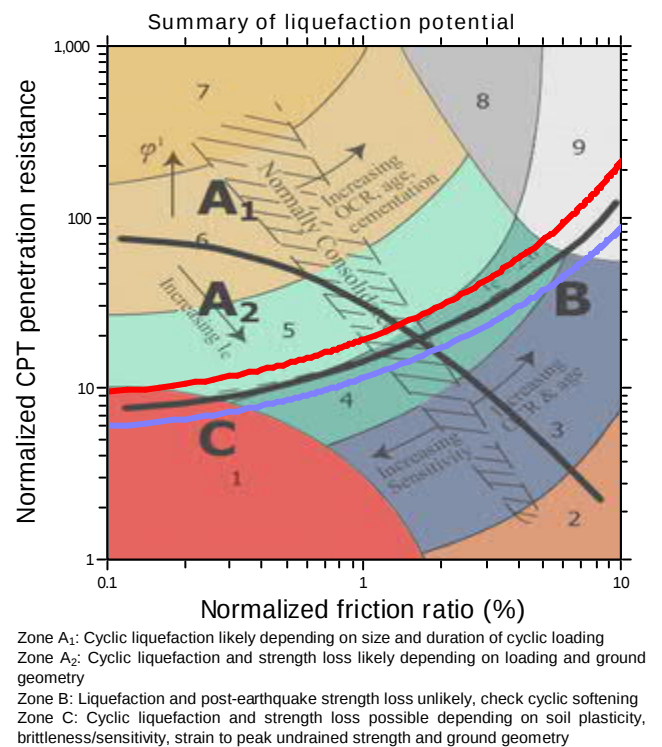
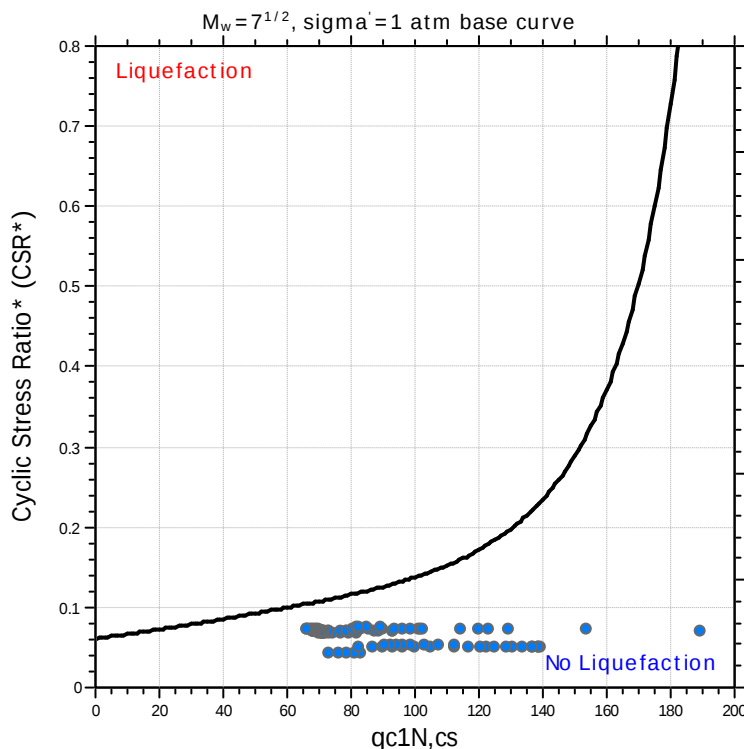
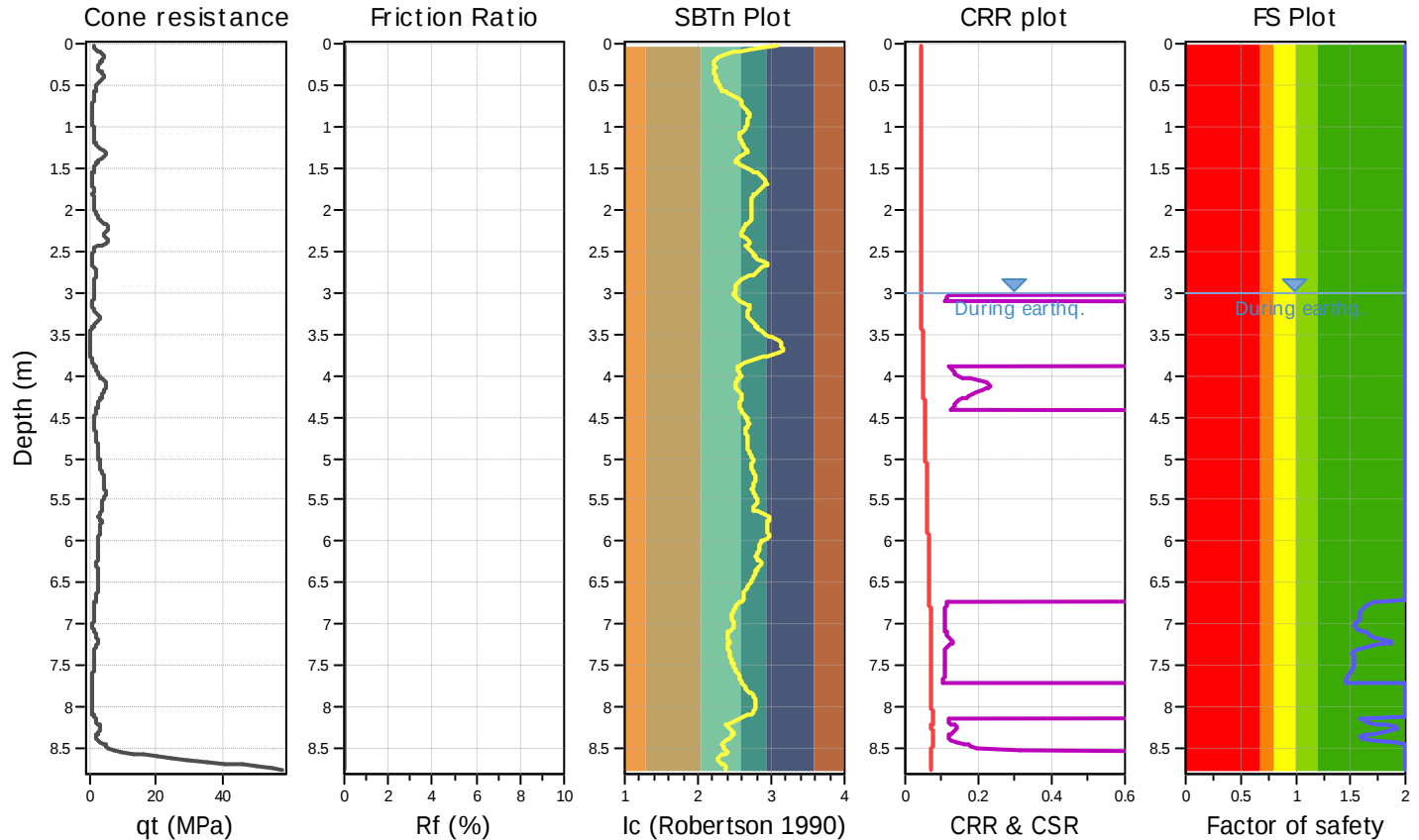
Project title :

Location :

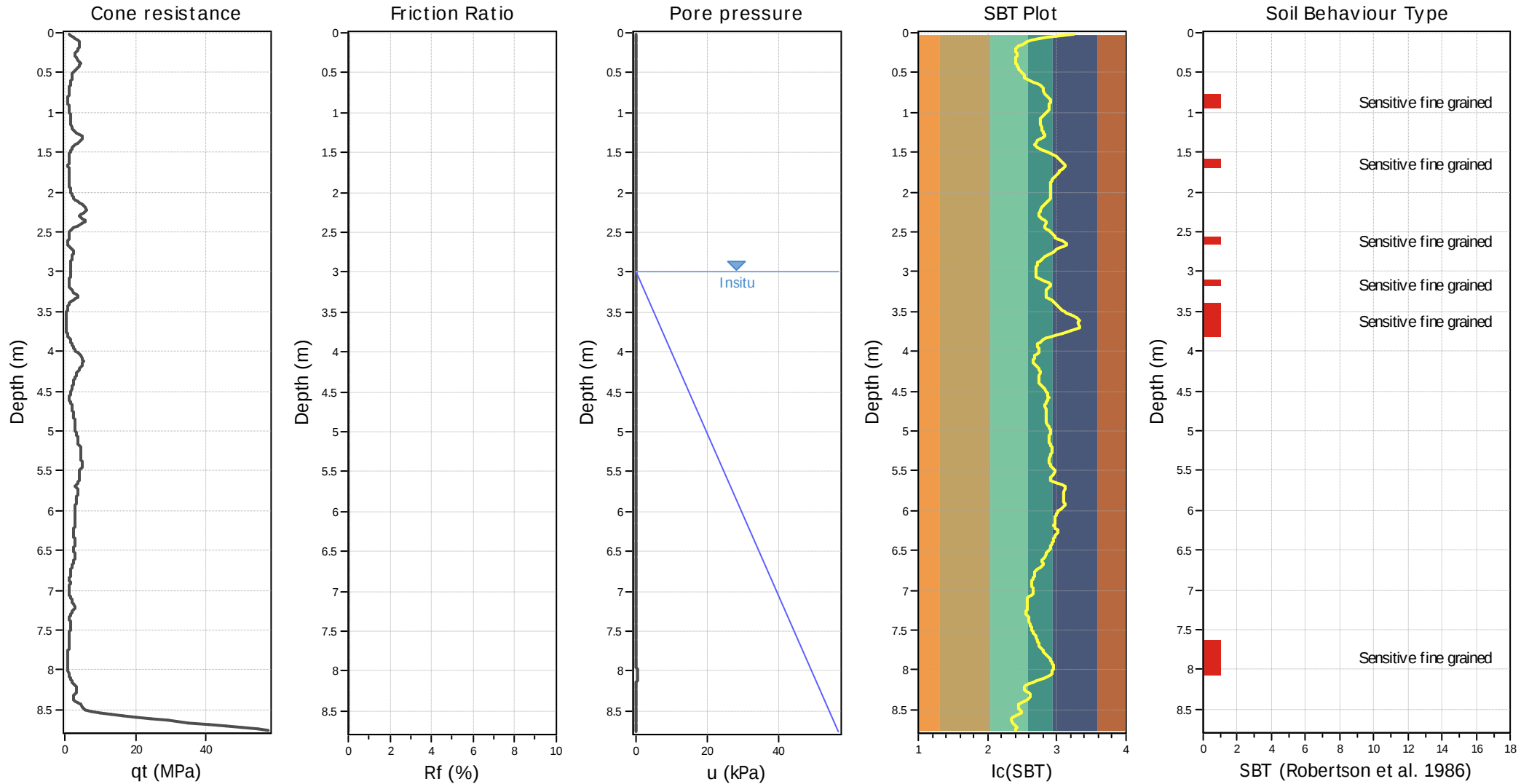
CPT file : CPT03 SLS

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	3.00 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	3.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method
Peak ground acceleration:	0.07	Unit weight calculation:	Based on SBT	K_0 applied:	Yes		



CPT basic interpretation plots

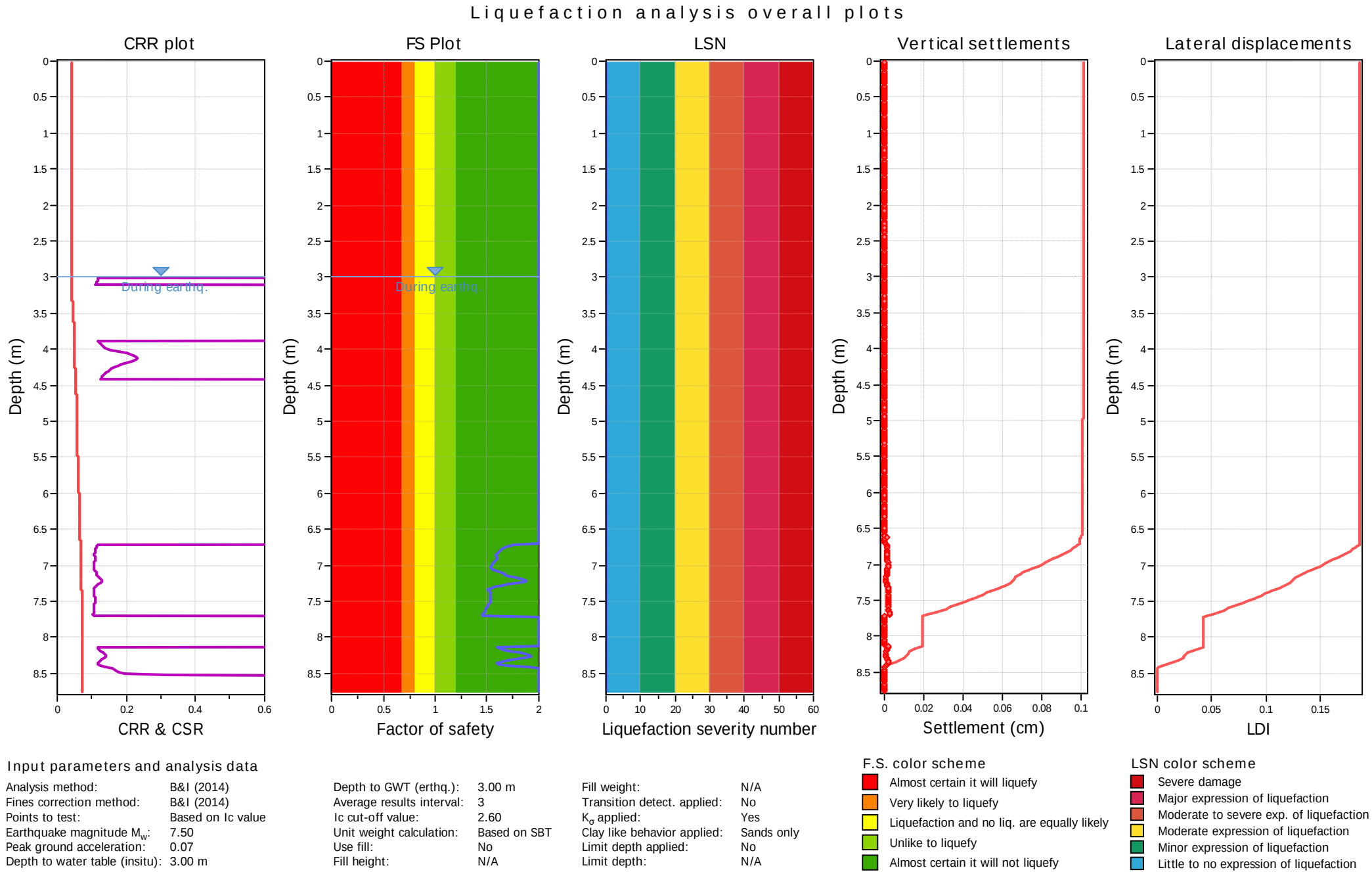


Input parameters and analysis data

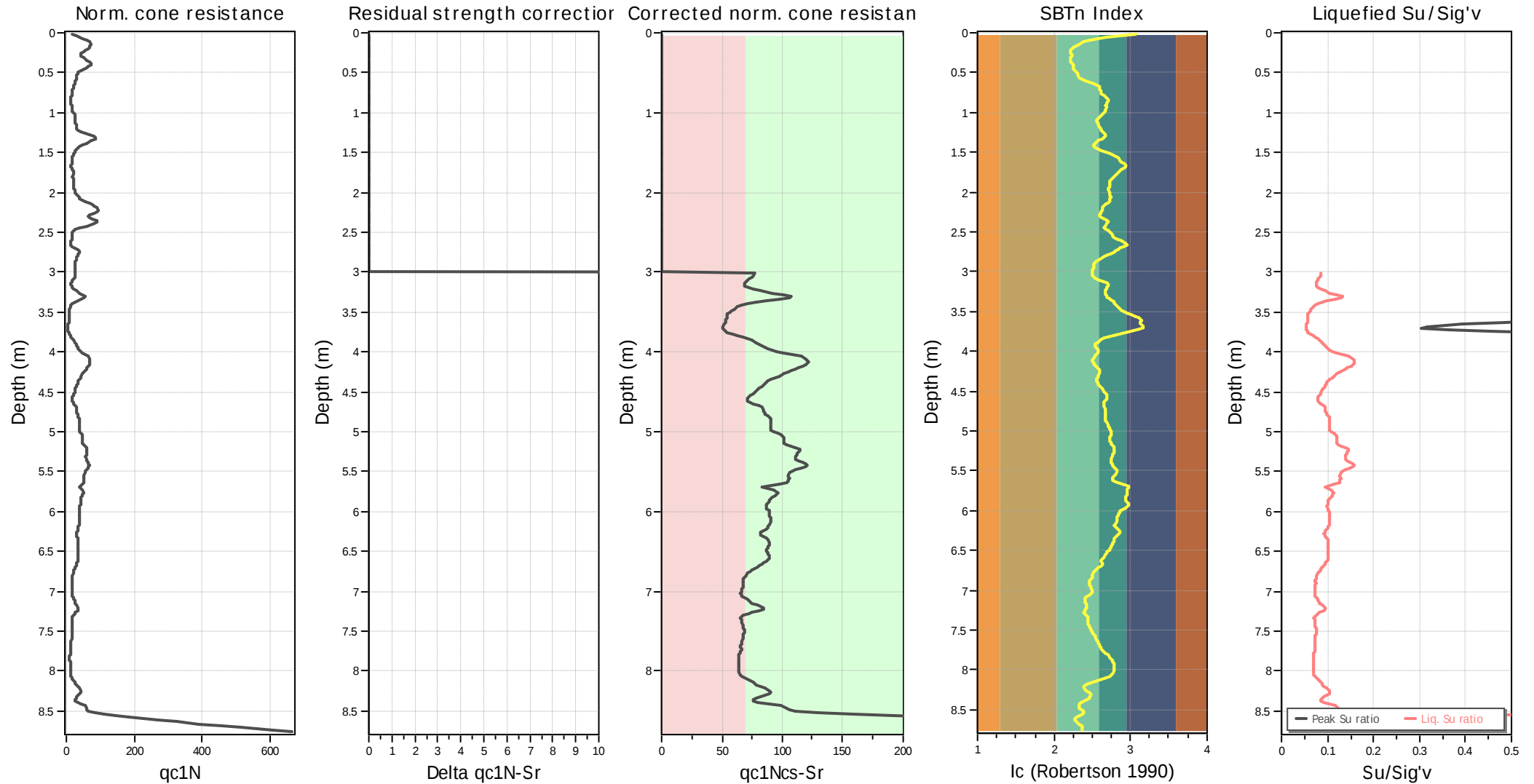
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Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K ₀ applied:	Yes
Earthquake magnitude M _w :	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.07	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	3.00 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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



Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	3.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _σ applied:	Yes
Earthquake magnitude M _w :	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.07	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	3.00 m	Fill height:	N/A	Limit depth:	N/A

LIQUEFACTION ANALYSIS REPORT

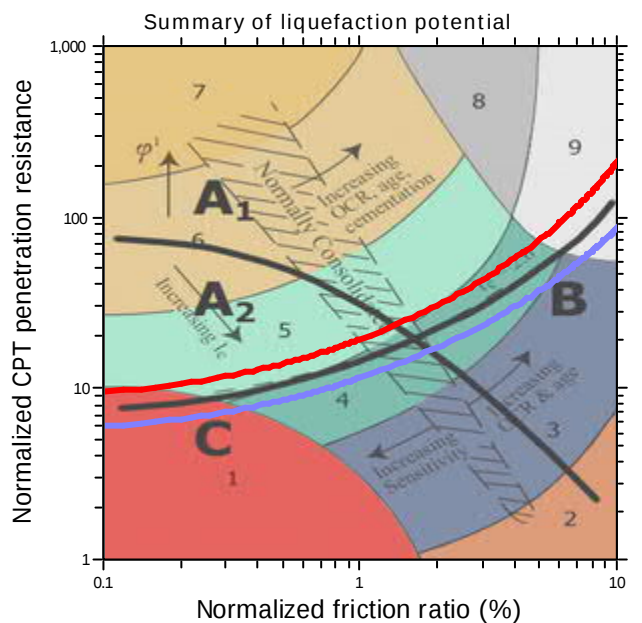
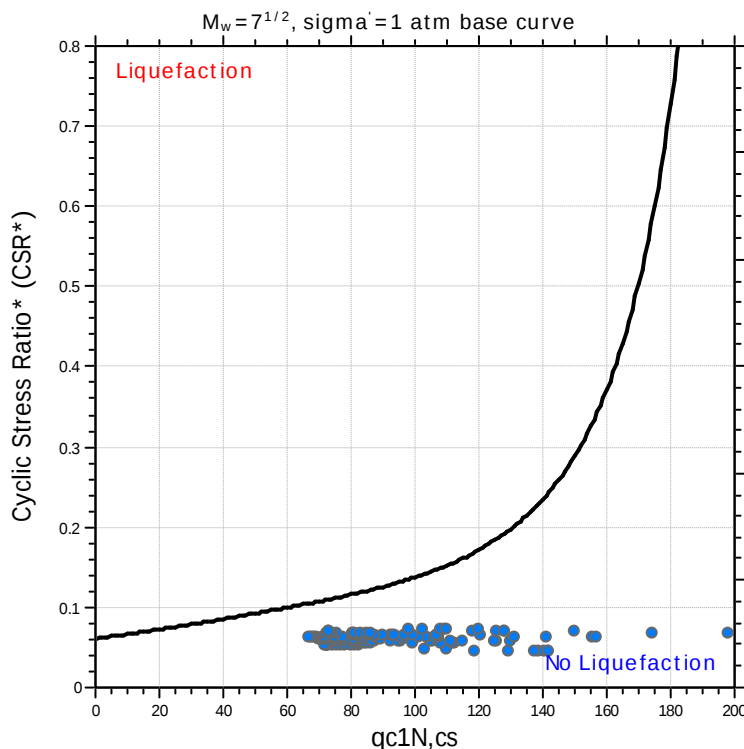
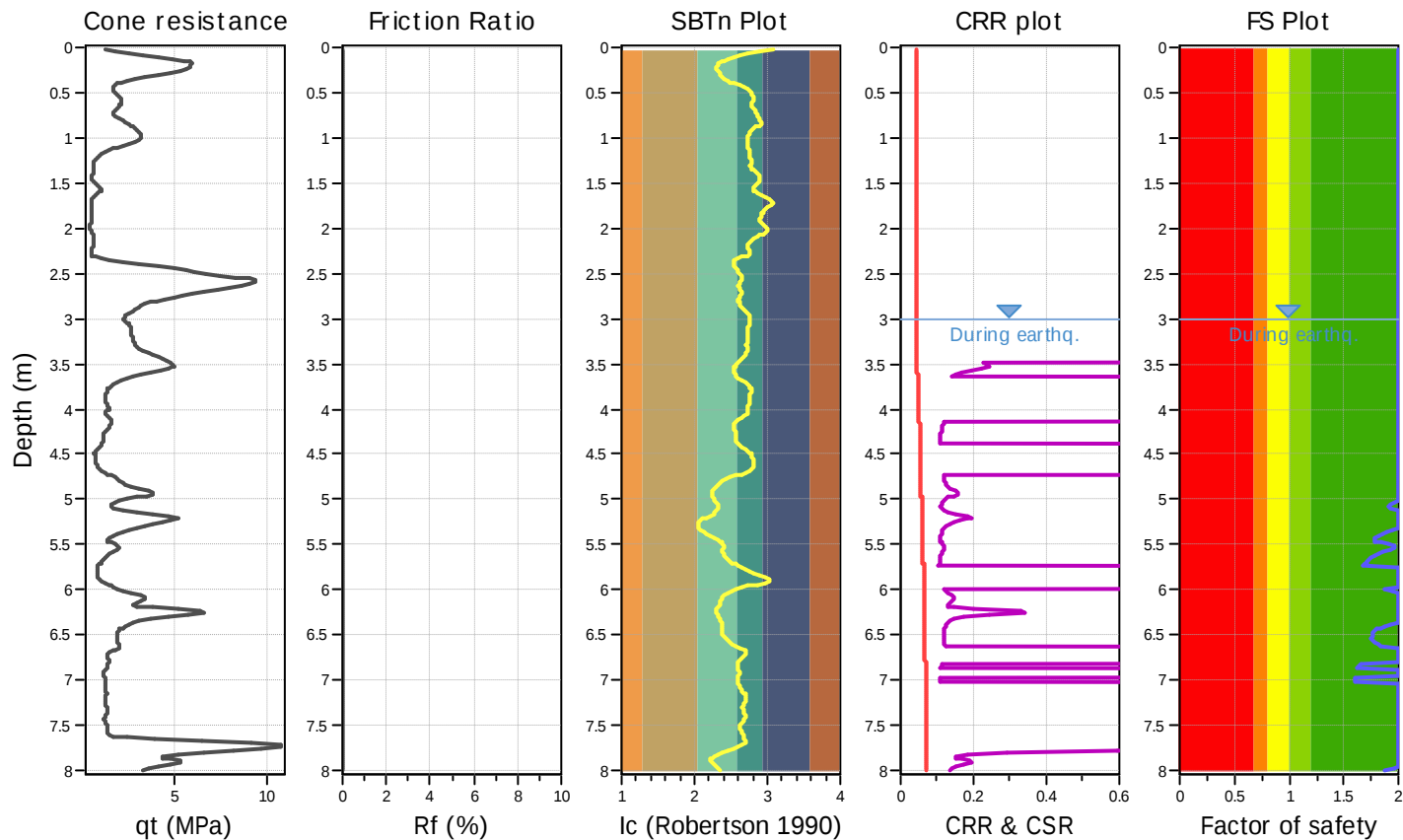
Project title :

Location :

CPT file : CPT04 SLS

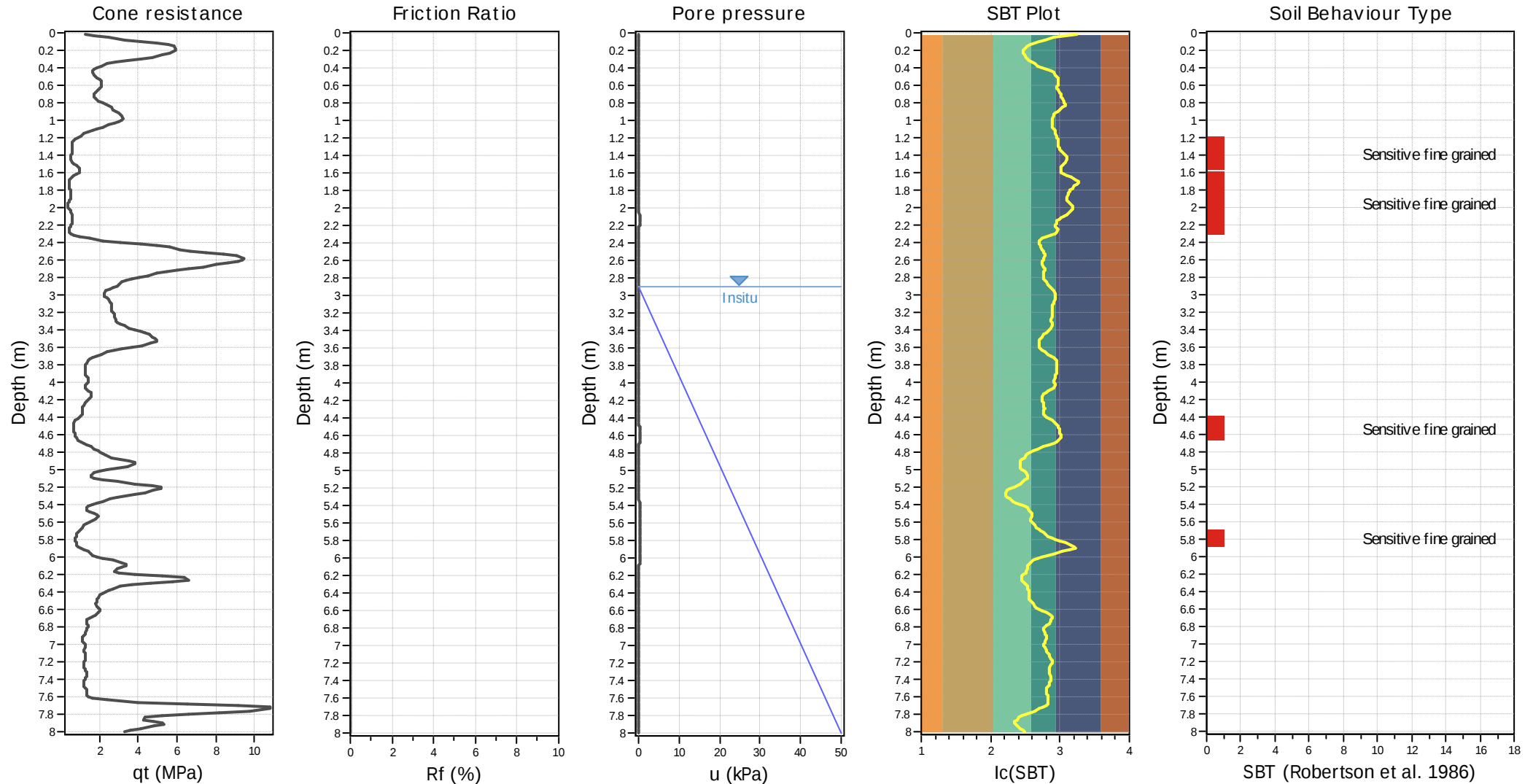
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	2.90 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	3.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method
Peak ground acceleration:	0.07	Unit weight calculation:	Based on SBT	K_g 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

CPT basic interpretation plots



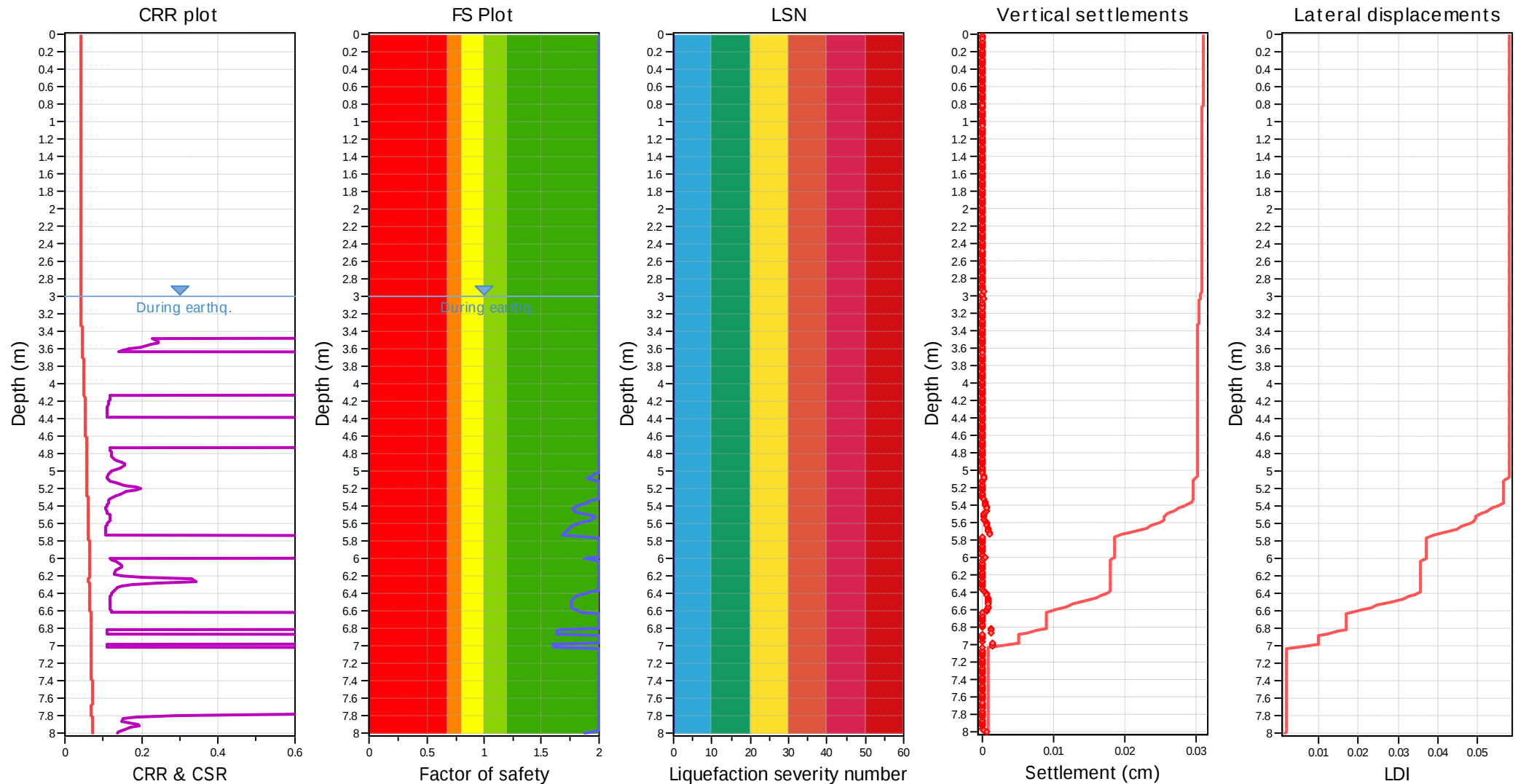
Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	3.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on I_c value	I_c cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w :	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.07	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	2.90 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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

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 I_c value
 Earthquake magnitude M_w : 7.50
 Peak ground acceleration: 0.07
 Depth to water table (insitu): 2.90 m

Depth to GWT (earthq.): 3.00 m
 Average results interval: 3
 I_c 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: No
 K_σ applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

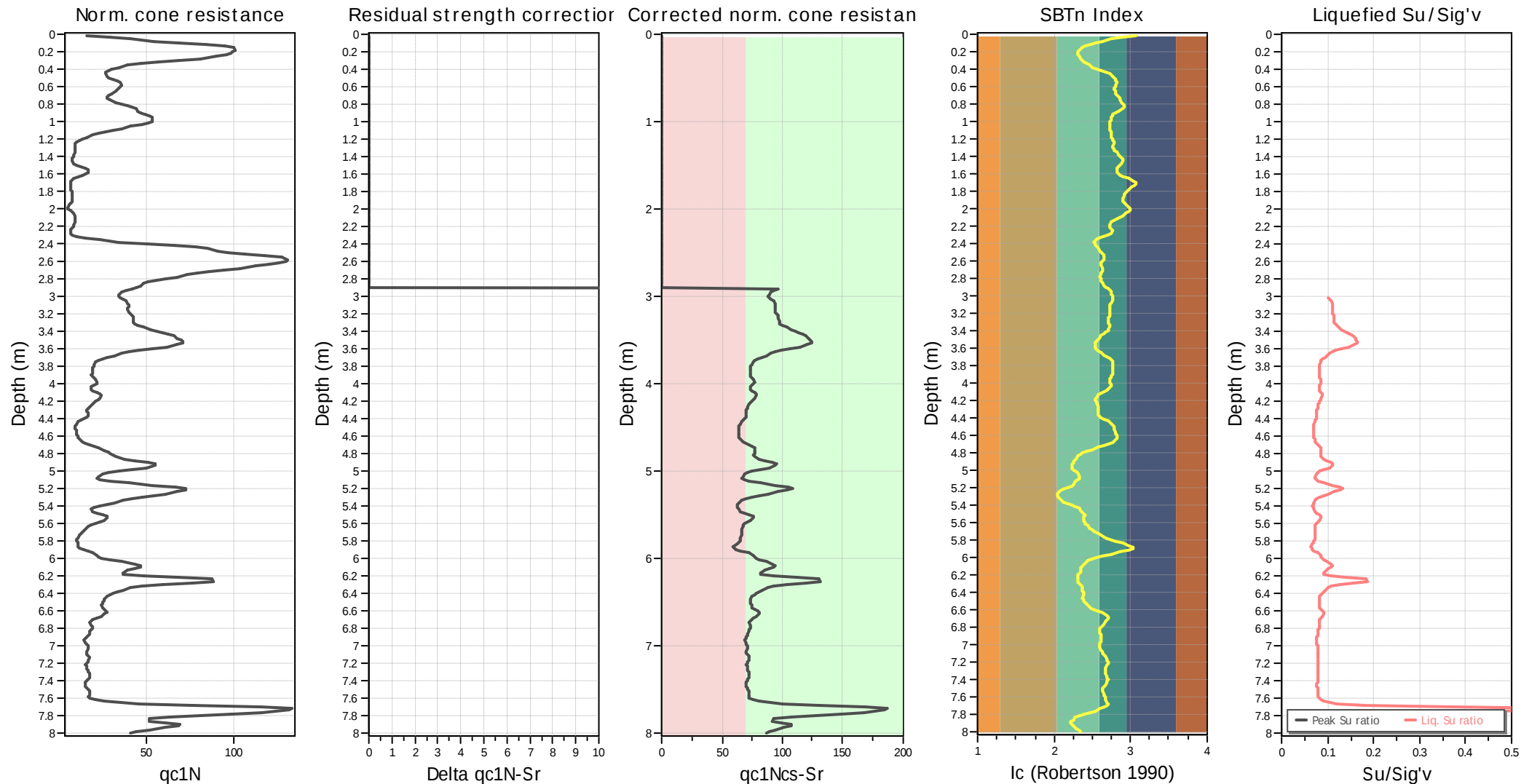
F.S. color scheme

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

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

Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	3.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_{σ} applied:	Yes
Earthquake magnitude M_w :	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.07	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	2.90 m	Fill height:	N/A	Limit depth:	N/A

LIQUEFACTION ANALYSIS REPORT

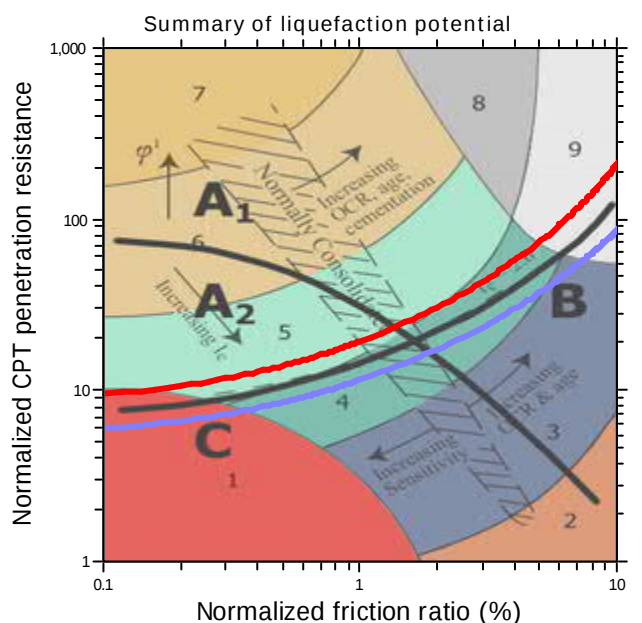
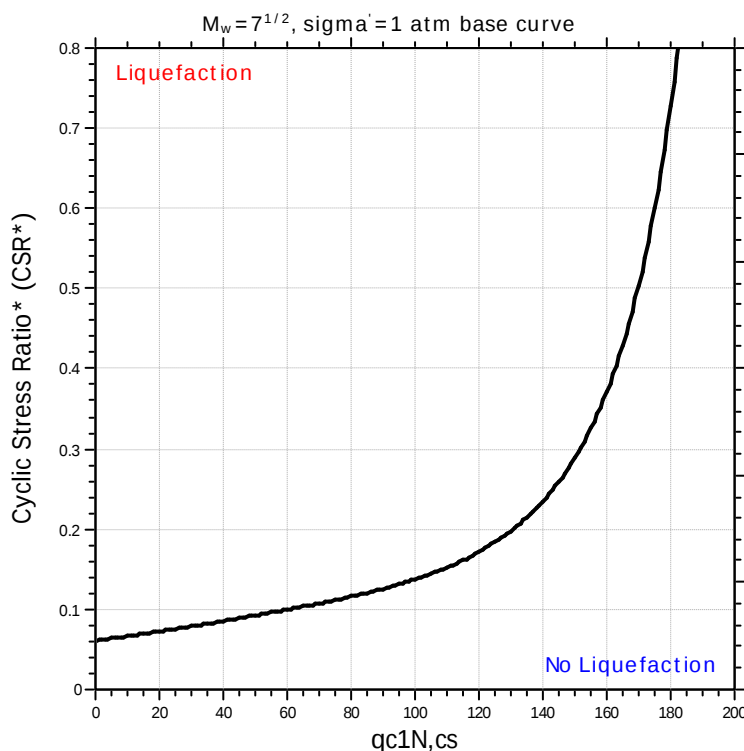
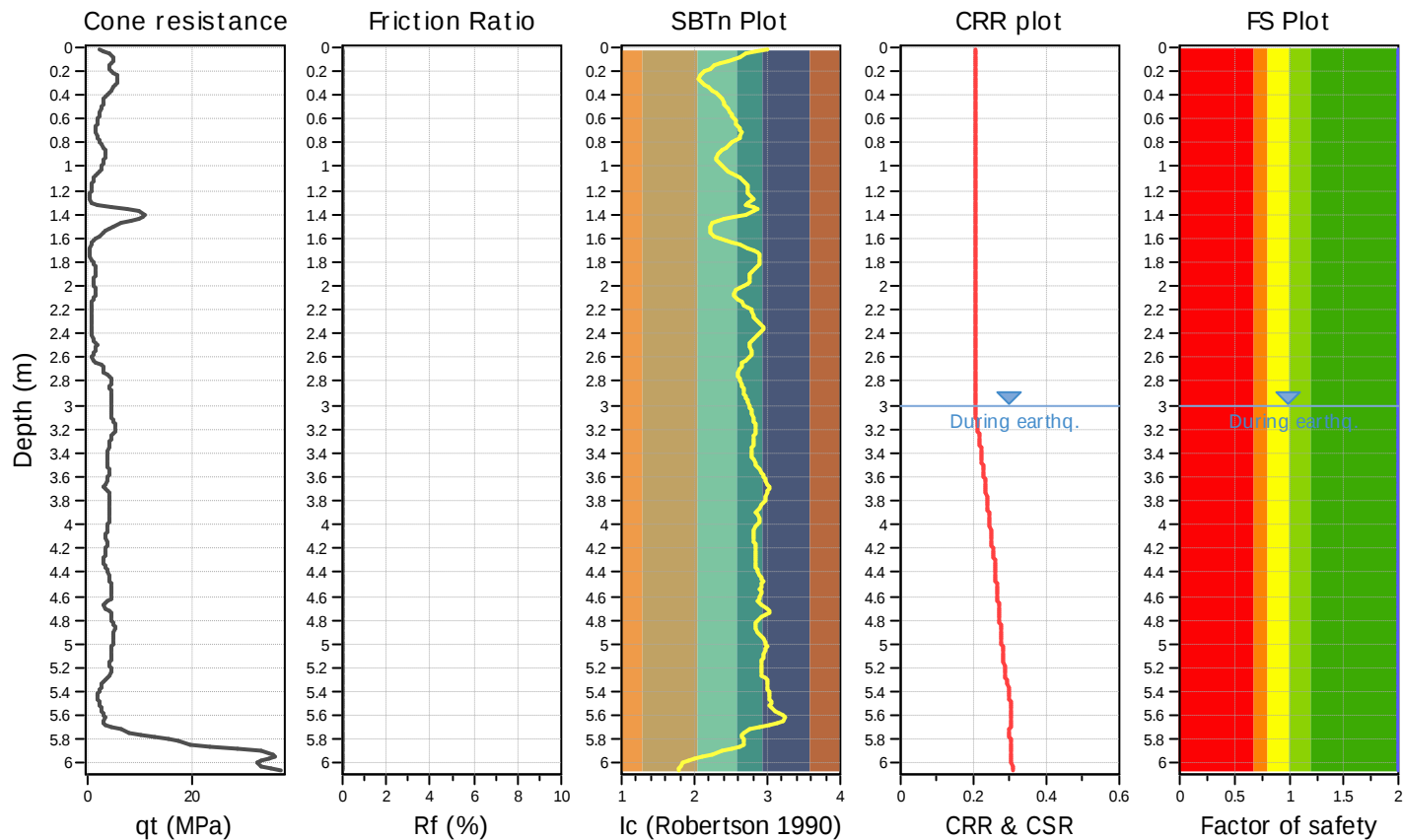
Project title :

Location :

CPT file : CPT01 ULS

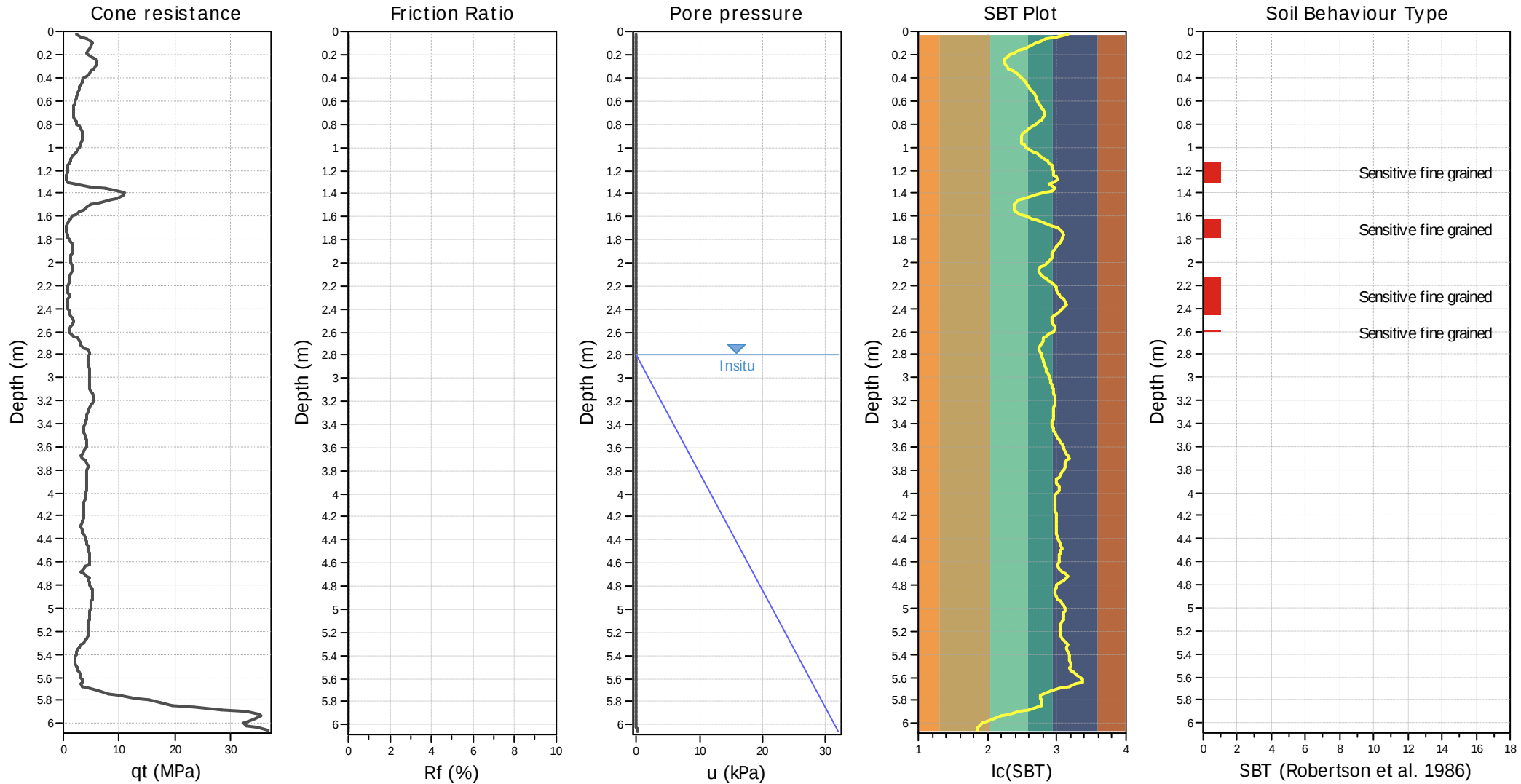
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	2.80 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	3.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_0 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

CPT basic interpretation plots



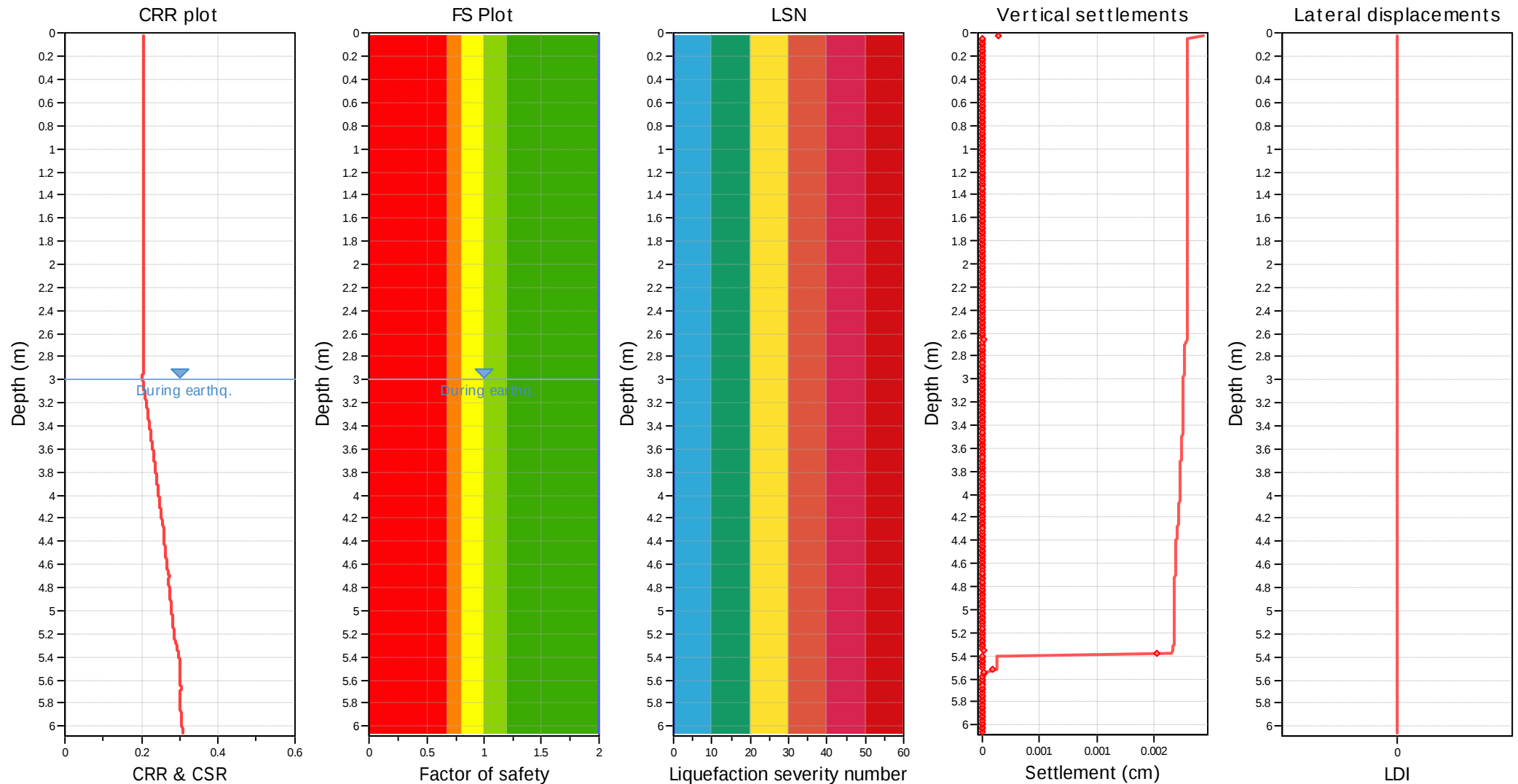
Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	3.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _σ applied:	Yes
Earthquake magnitude M _w :	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	2.80 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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

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 I_c value
 Earthquake magnitude M_w : 7.50
 Peak ground acceleration: 0.35
 Depth to water table (insitu): 2.80 m

Depth to GWT (earthq.): 3.00 m
 Average results interval: 3
 I_c 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: No
 K_σ applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

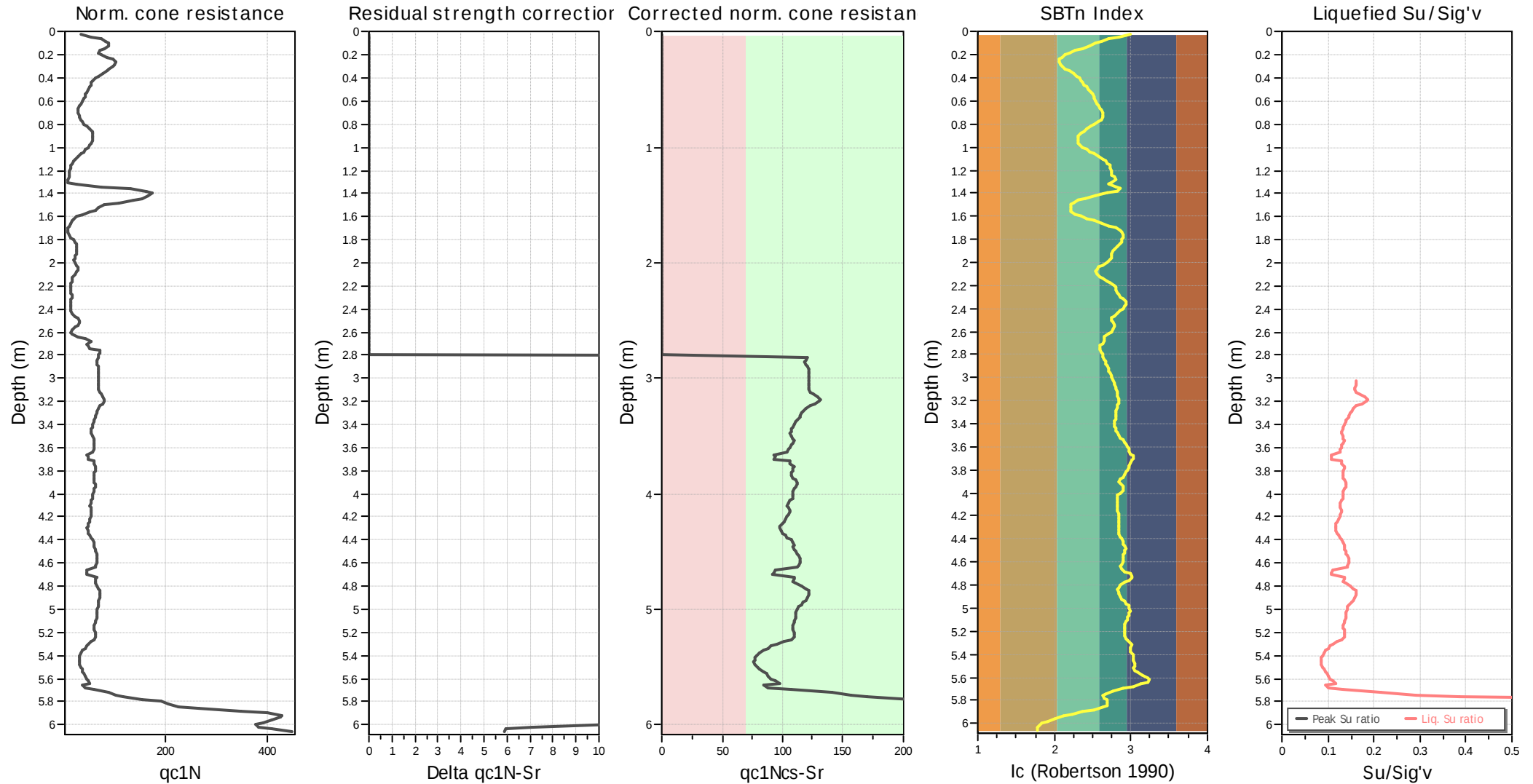
F.S. color scheme

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

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

Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	3.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_0 applied:	Yes
Earthquake magnitude M_w :	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	2.80 m	Fill height:	N/A	Limit depth:	N/A

LIQUEFACTION ANALYSIS REPORT

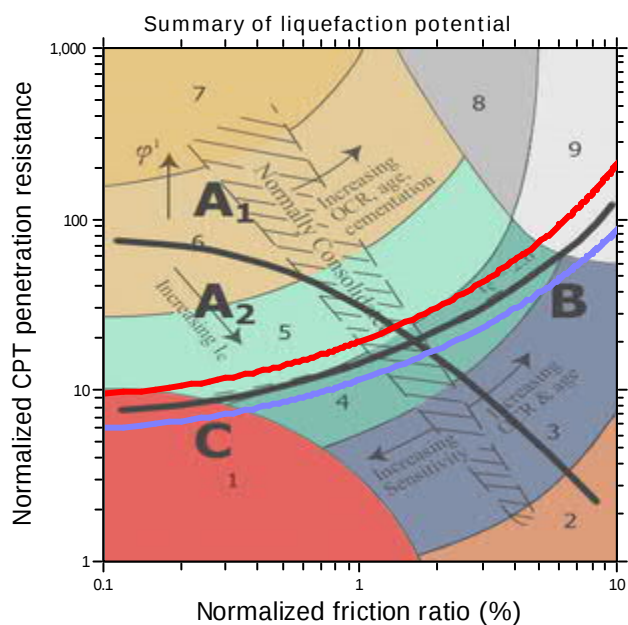
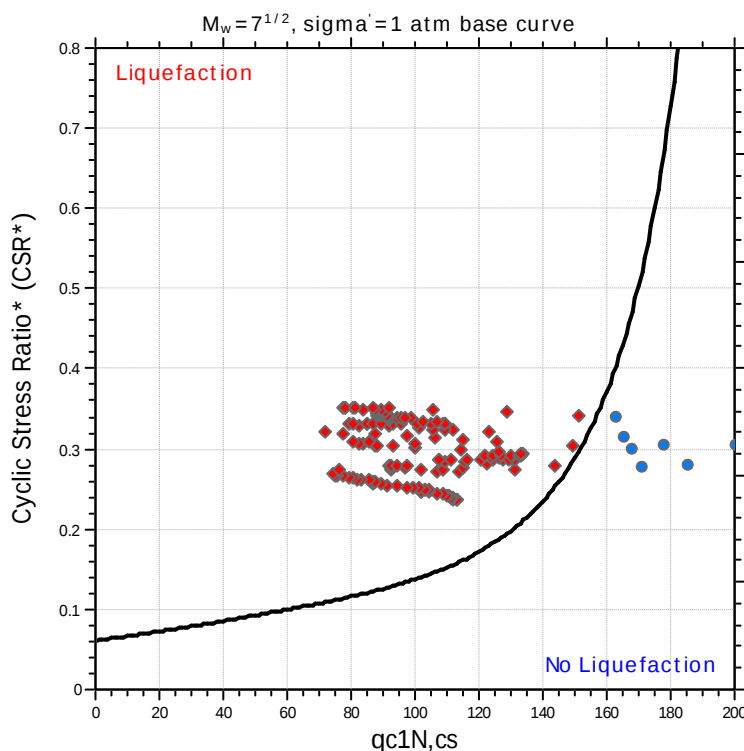
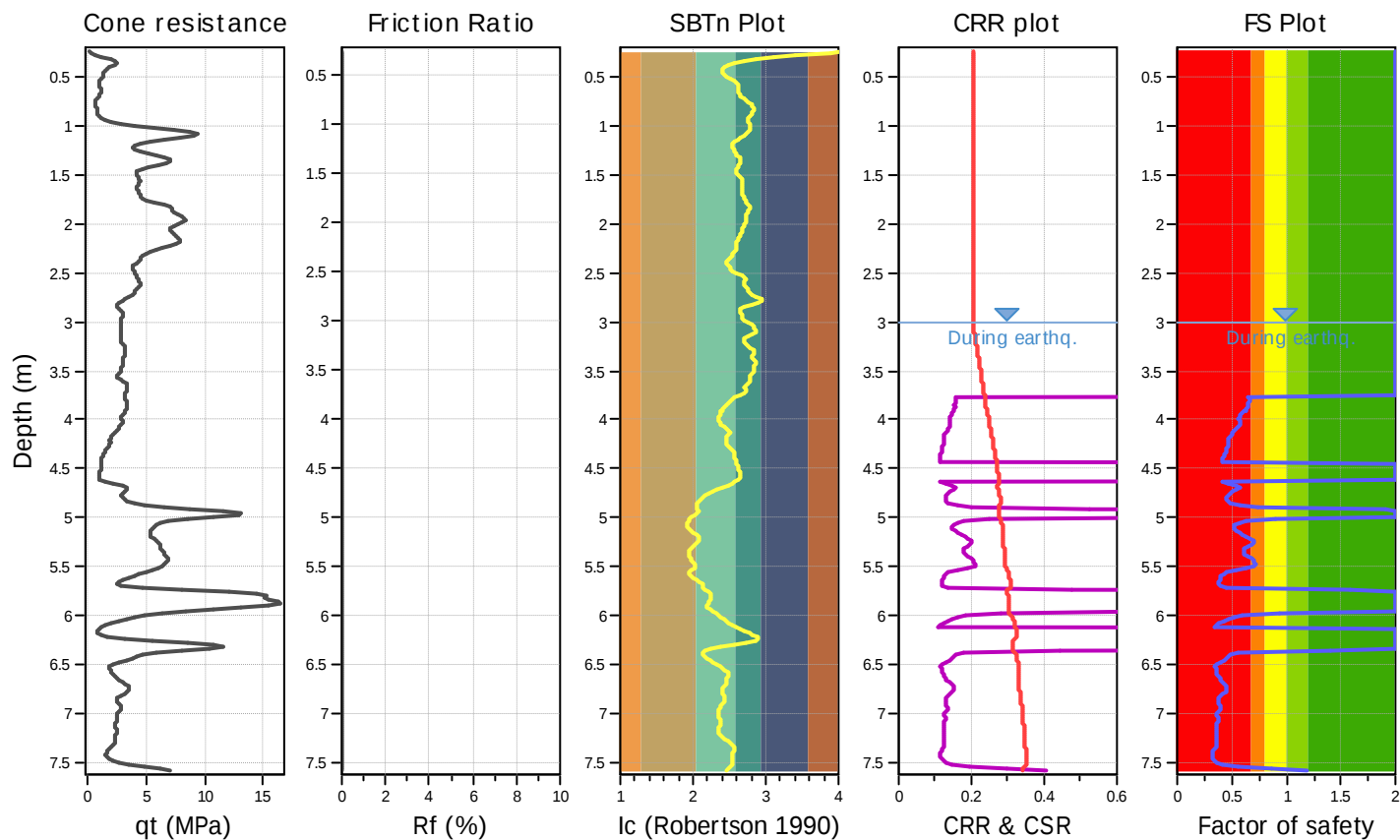
Project title :

Location :

CPT file : CPT02 ULS

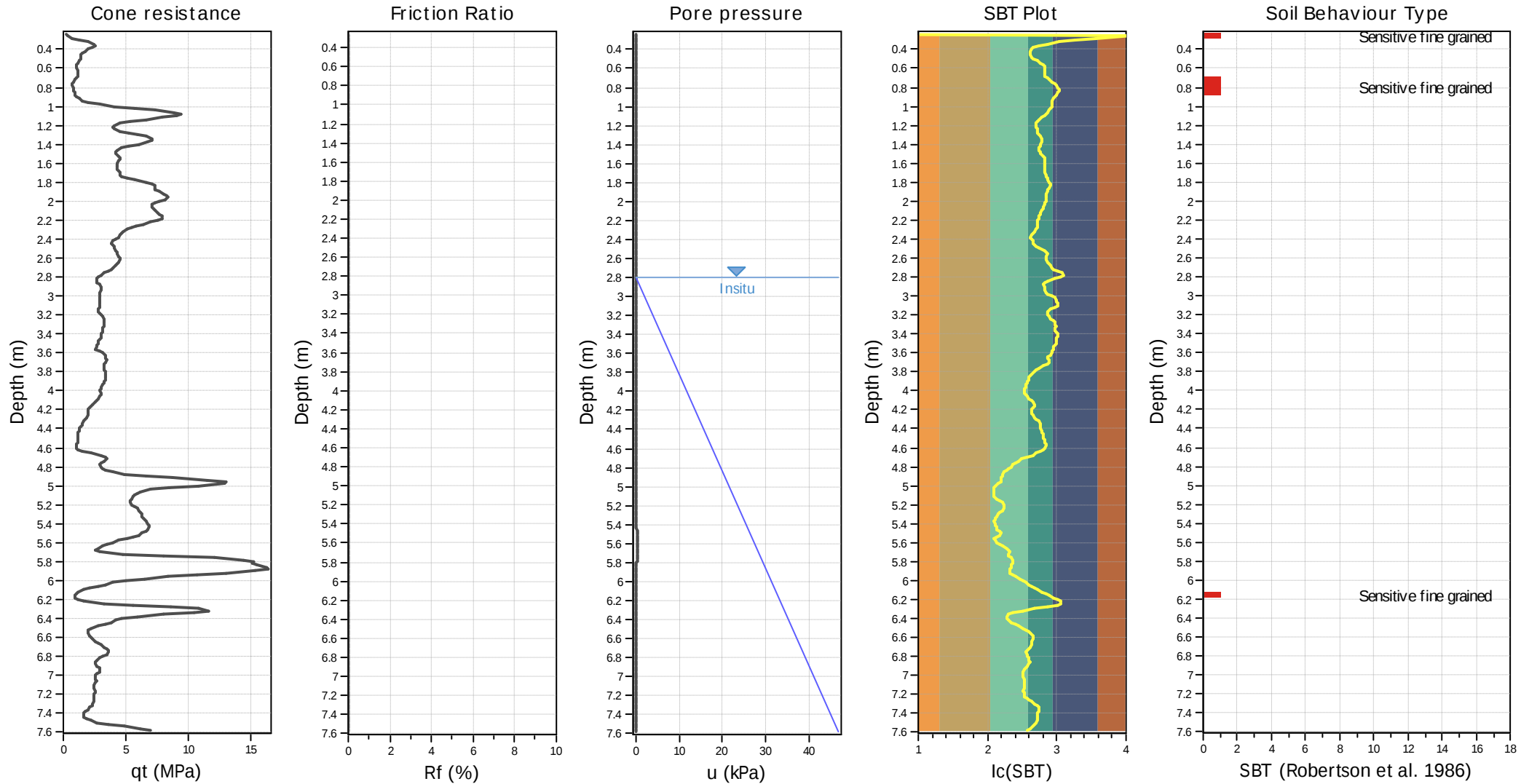
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	2.80 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	3.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method
Peak ground acceleration:	0.35	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

CPT basic interpretation plots



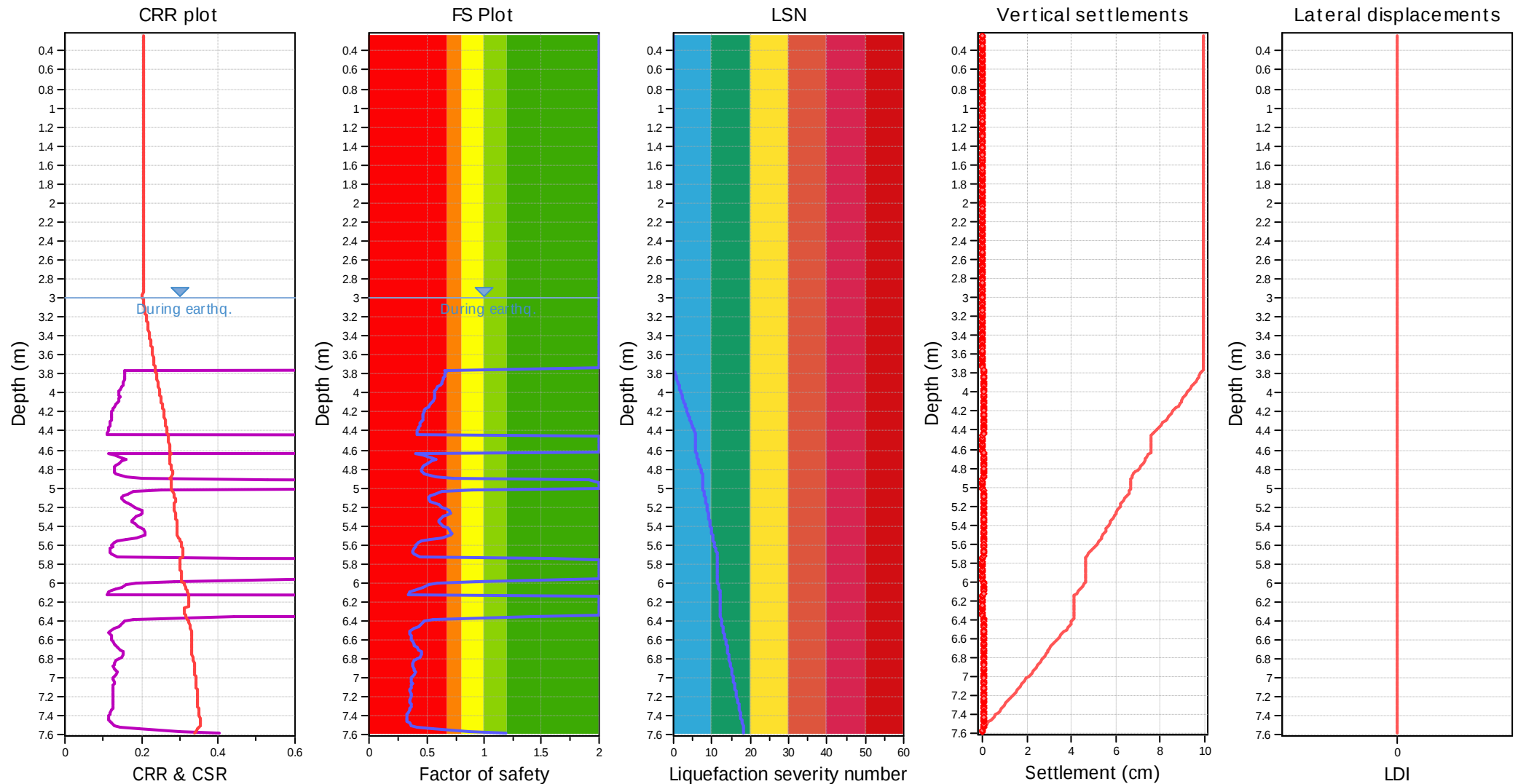
Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	3.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _σ applied:	Yes
Earthquake magnitude M _w :	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	2.80 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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

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 I_c value
 Earthquake magnitude M_w : 7.50
 Peak ground acceleration: 0.35
 Depth to water table (insitu): 2.80 m

Depth to GWT (earthq.): 3.00 m
 Average results interval: 3
 I_c 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: No
 K_σ applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

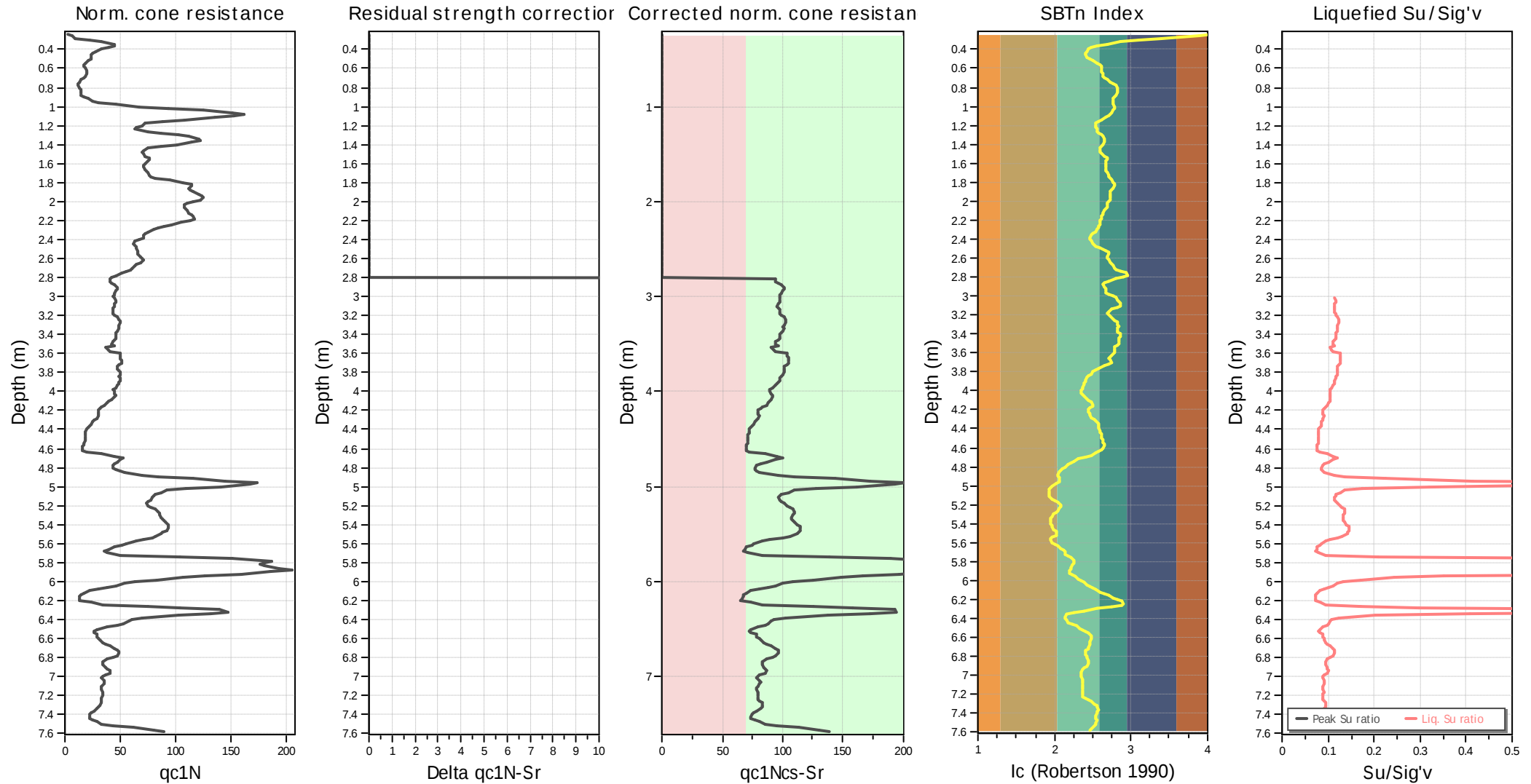
F.S. color scheme

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

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

Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	3.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _σ applied:	Yes
Earthquake magnitude M _w :	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	2.80 m	Fill height:	N/A	Limit depth:	N/A

LIQUEFACTION ANALYSIS REPORT

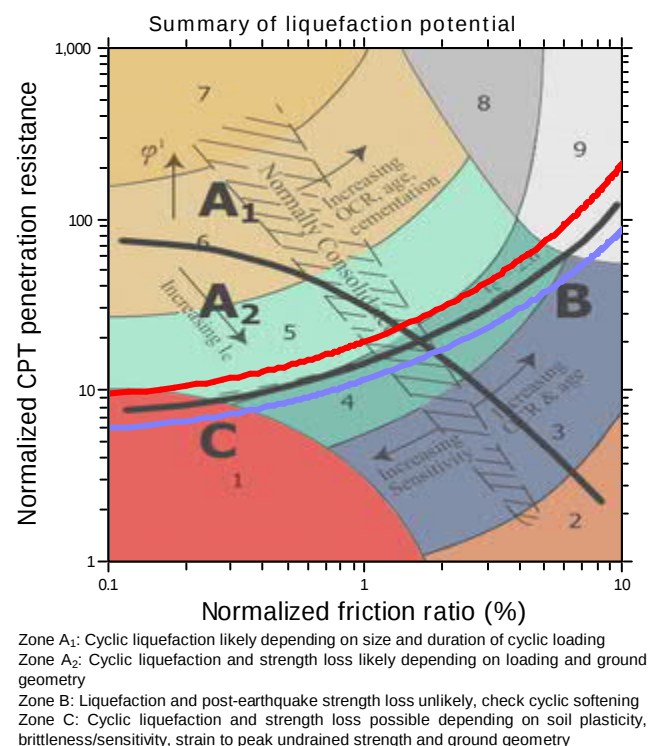
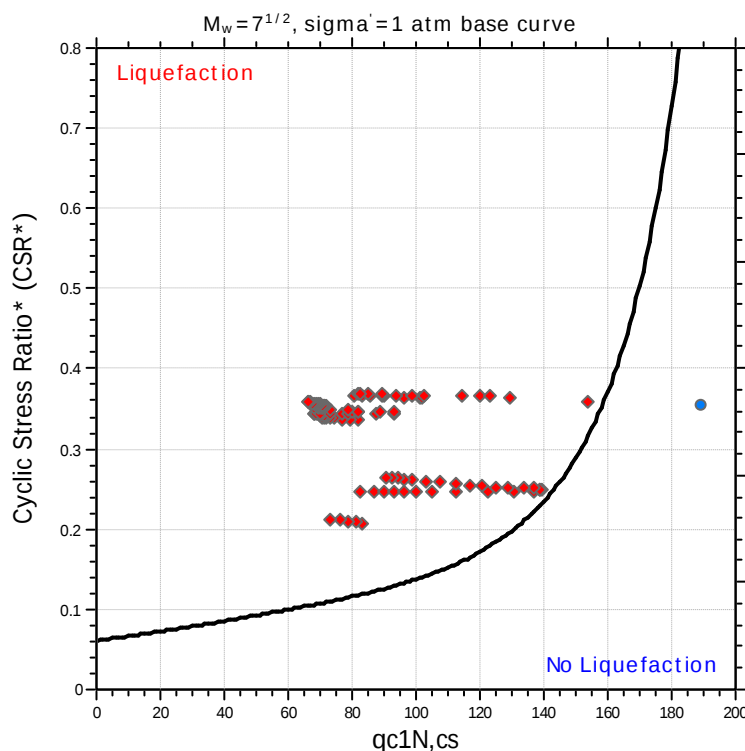
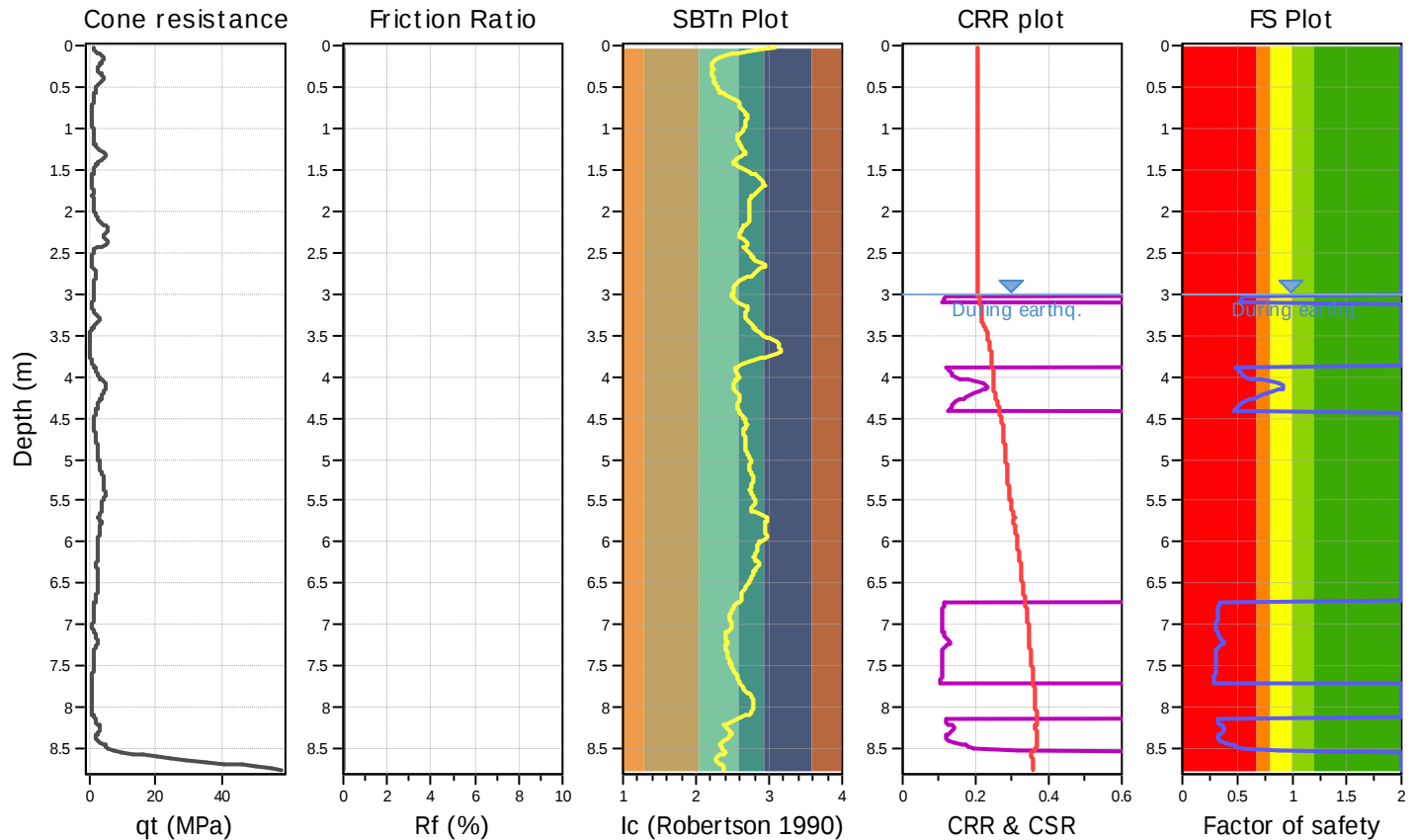
Project title :

Location :

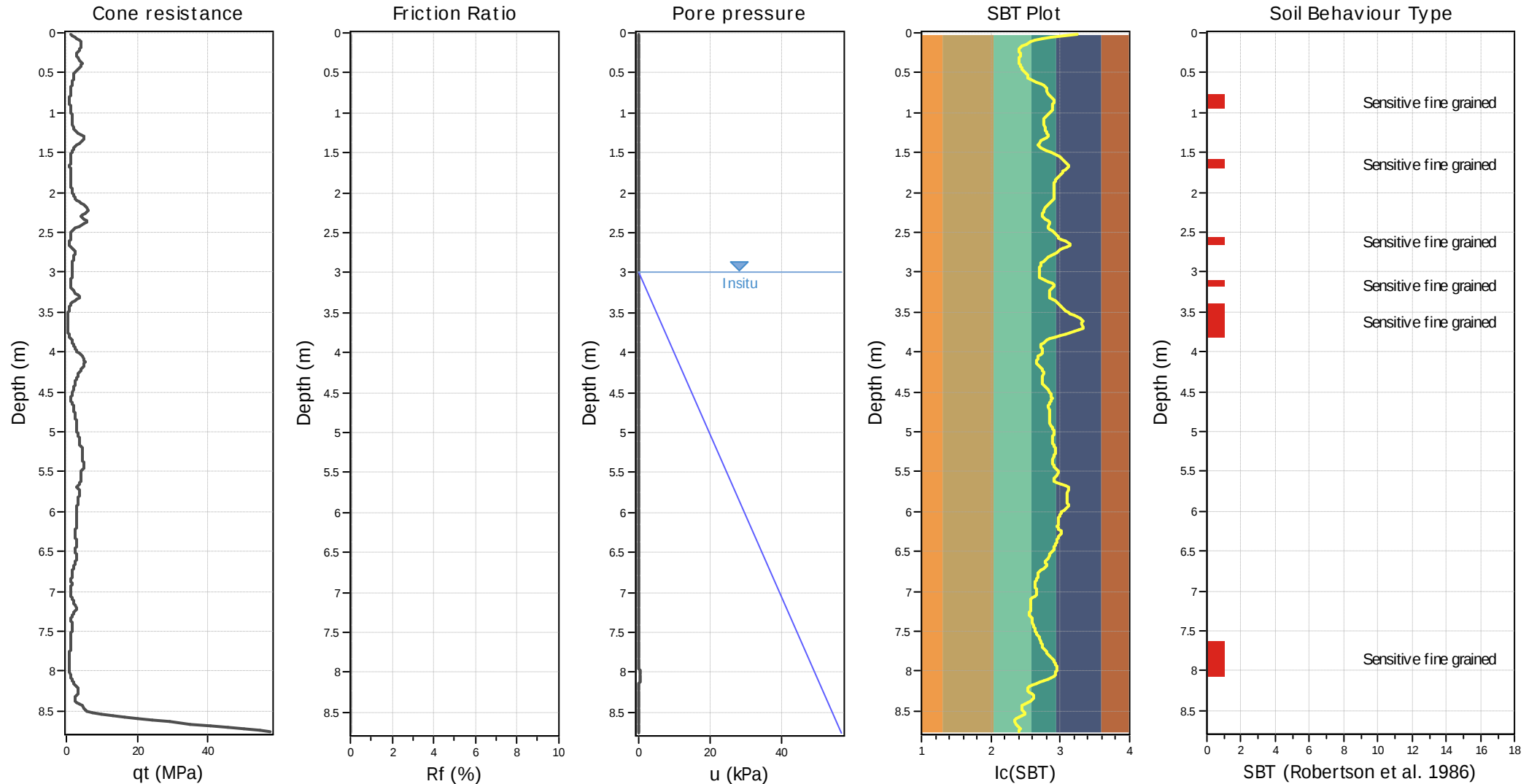
CPT file : CPT03 ULS

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	3.00 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	3.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		



CPT basic interpretation plots



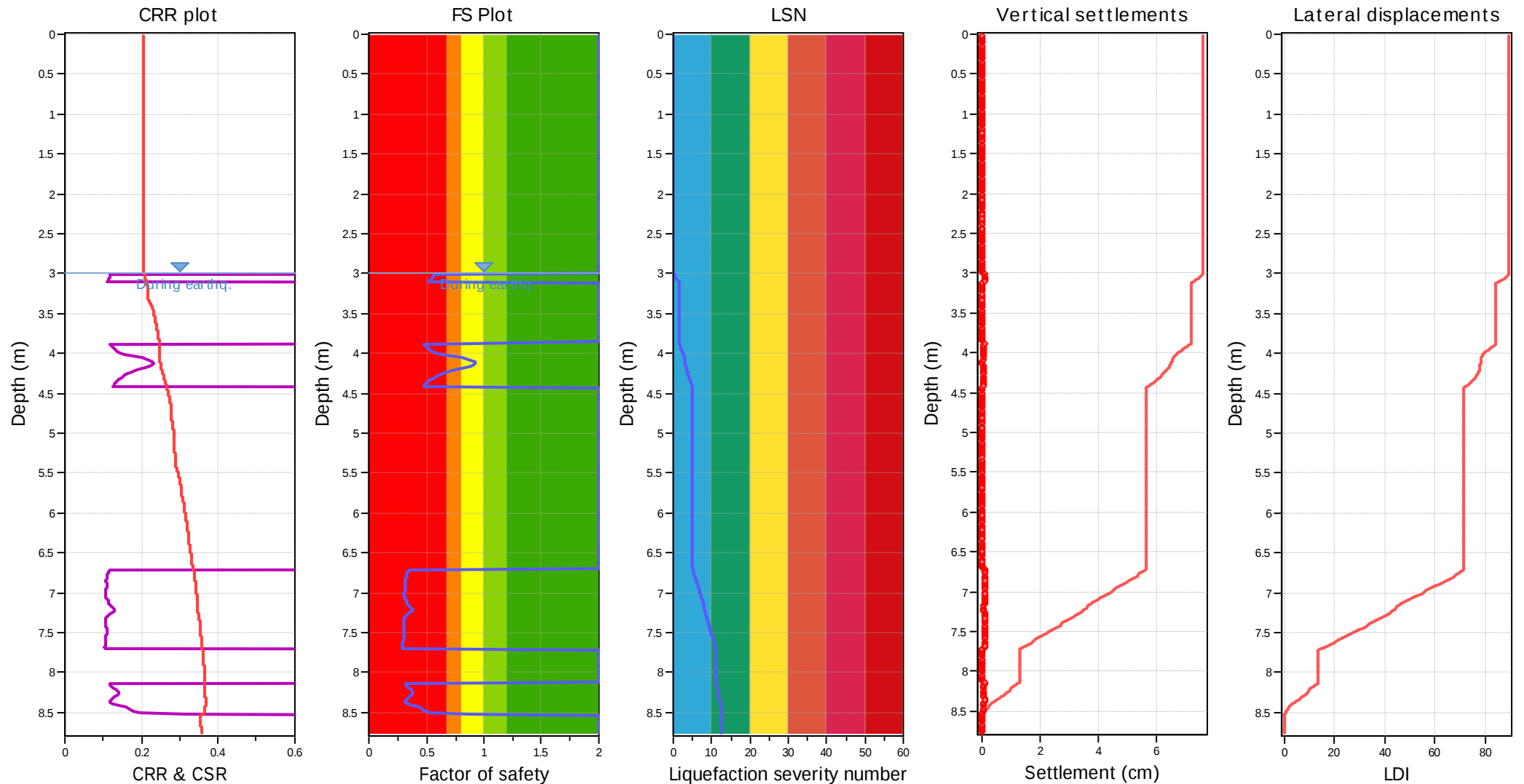
Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	3.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on I_c value	I_c cut-off value:	2.60	K_0 applied:	Yes
Earthquake magnitude M_w :	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	3.00 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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

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 I_c value
 Earthquake magnitude M_w : 7.50
 Peak ground acceleration: 0.35
 Depth to water table (insitu): 3.00 m

Depth to GWT (earthq.): 3.00 m
 Average results interval: 3
 I_c cut-off value: 2.60
 Unit weight calculation: Based on SBT
 Use fill: No
 Fill height: N/A

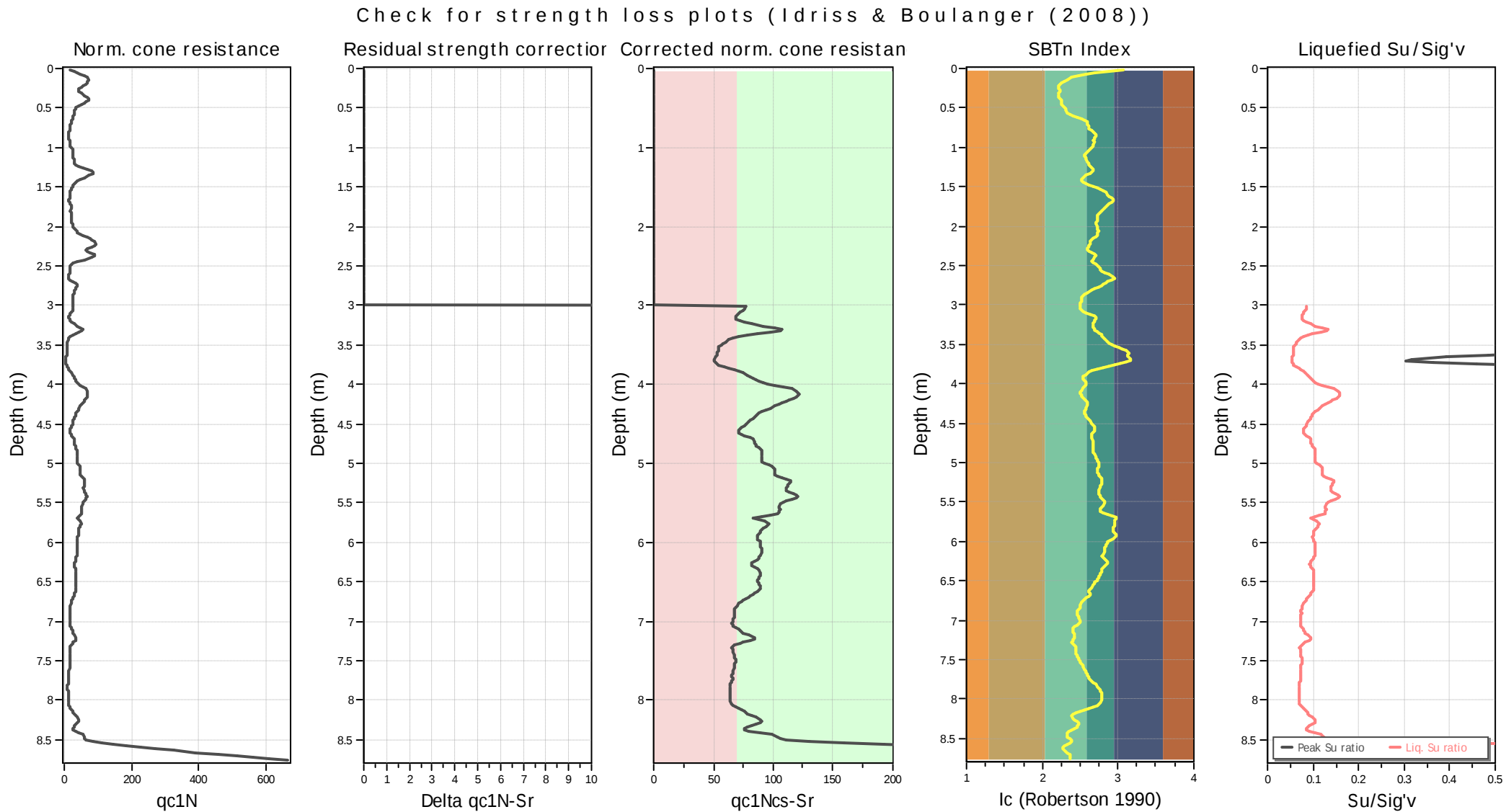
Fill weight: N/A
 Transition detect. applied: No
 K_σ applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

F.S. color scheme

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

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



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	3.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _σ applied:	Yes
Earthquake magnitude M _w :	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	3.00 m	Fill height:	N/A	Limit depth:	N/A

LIQUEFACTION ANALYSIS REPORT

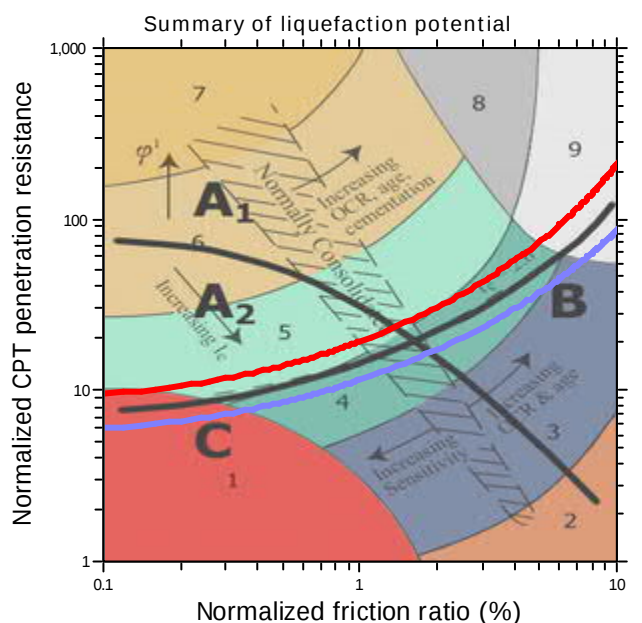
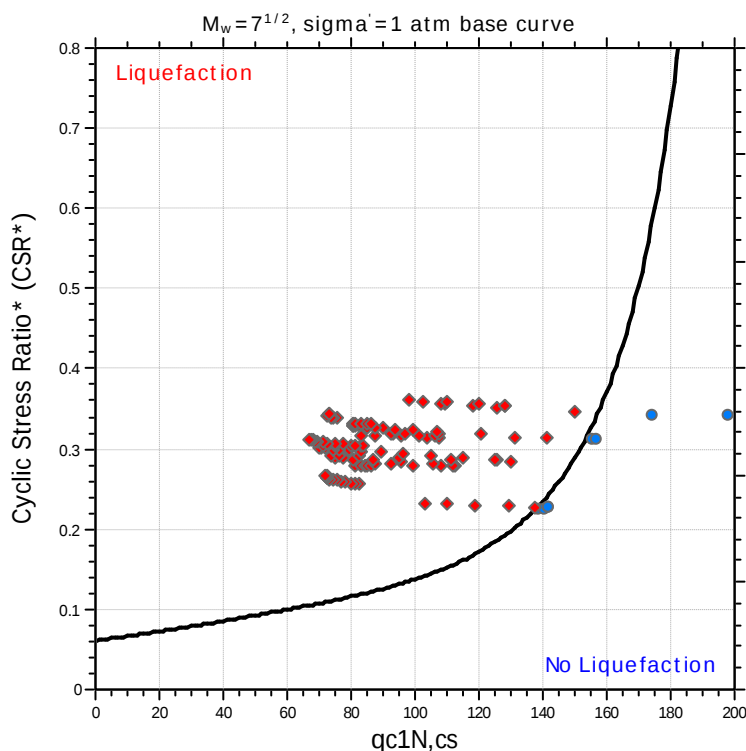
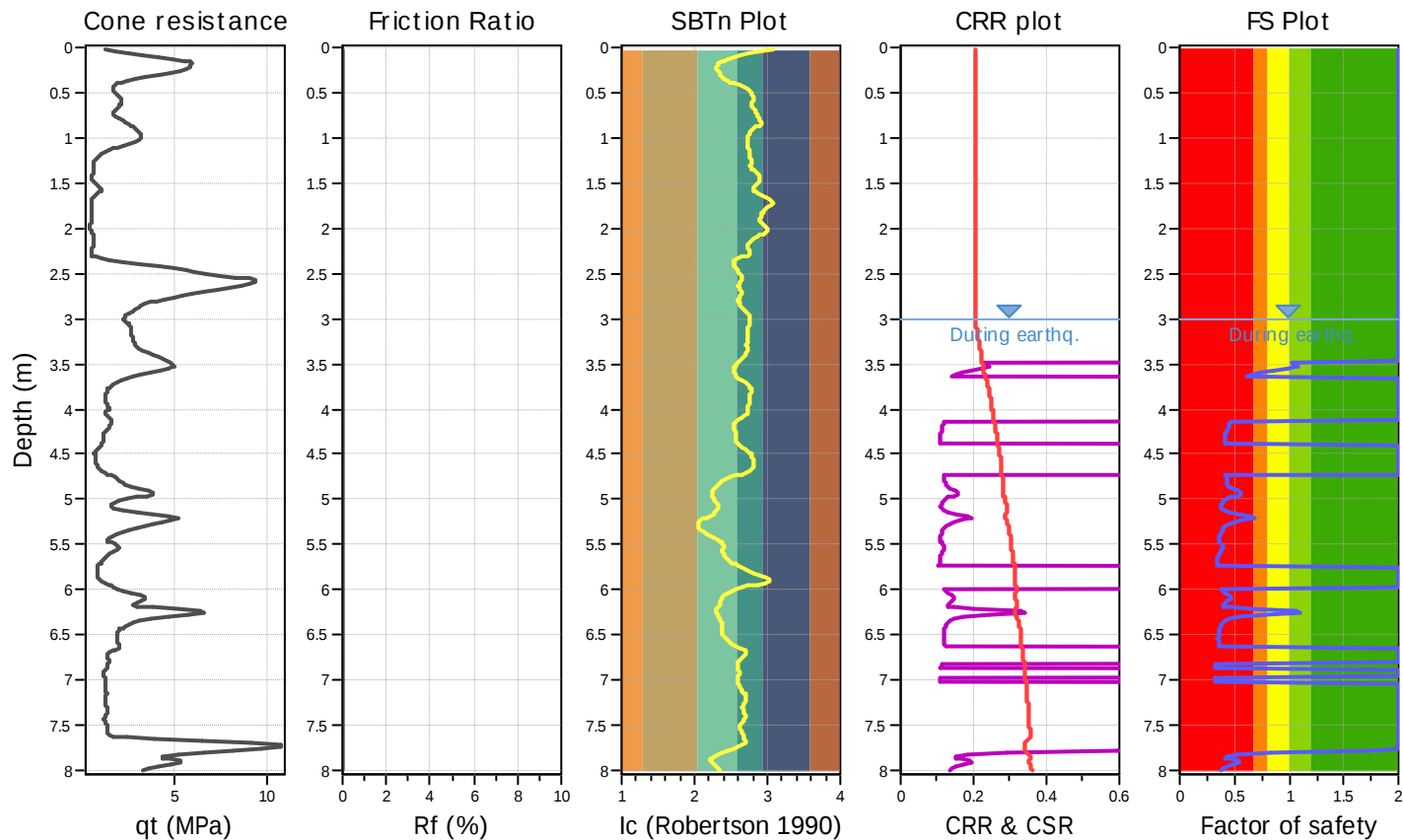
Project title :

Location :

CPT file : CPT04 ULS

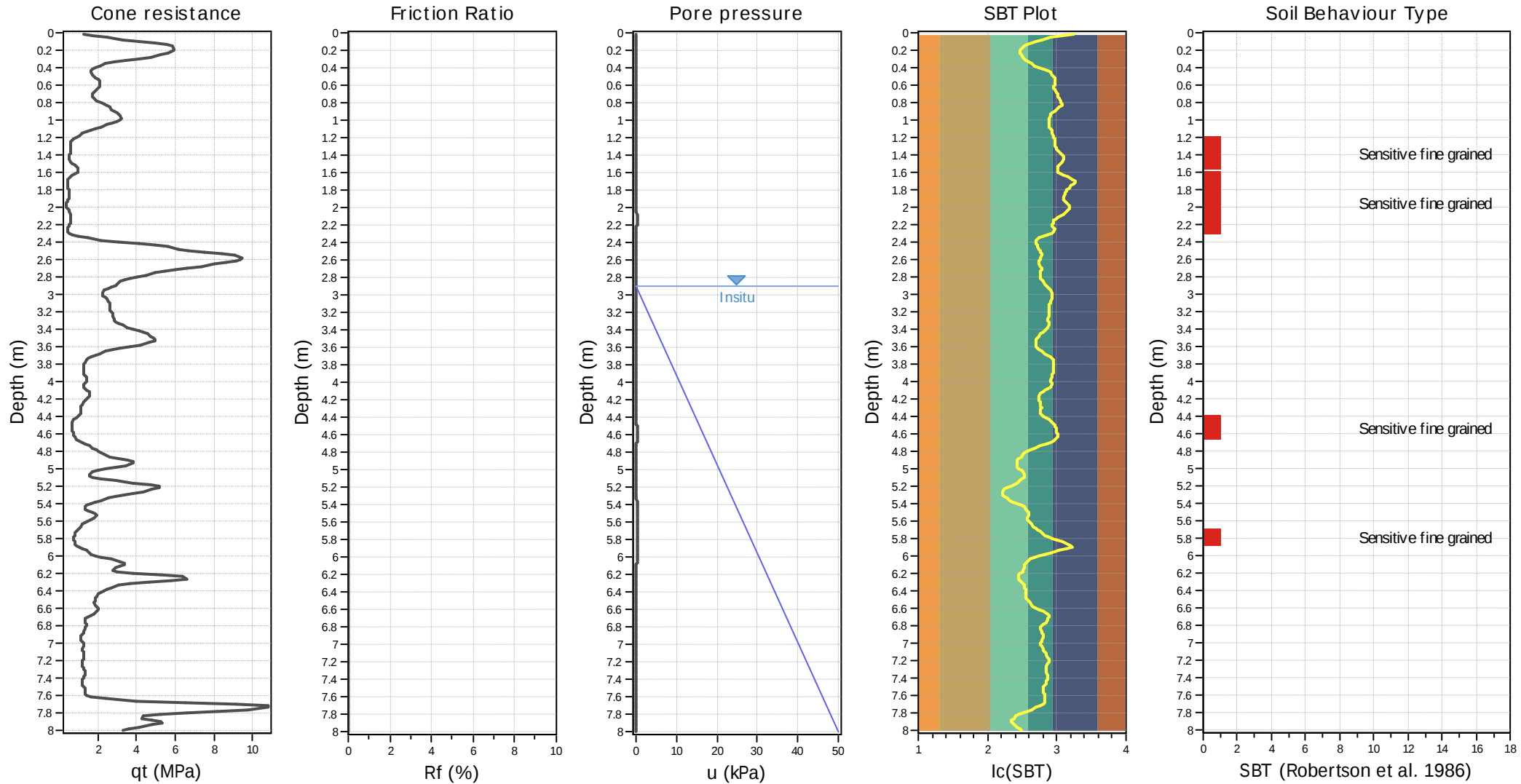
Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	2.90 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	3.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w :	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method
Peak ground acceleration:	0.35	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

CPT basic interpretation plots



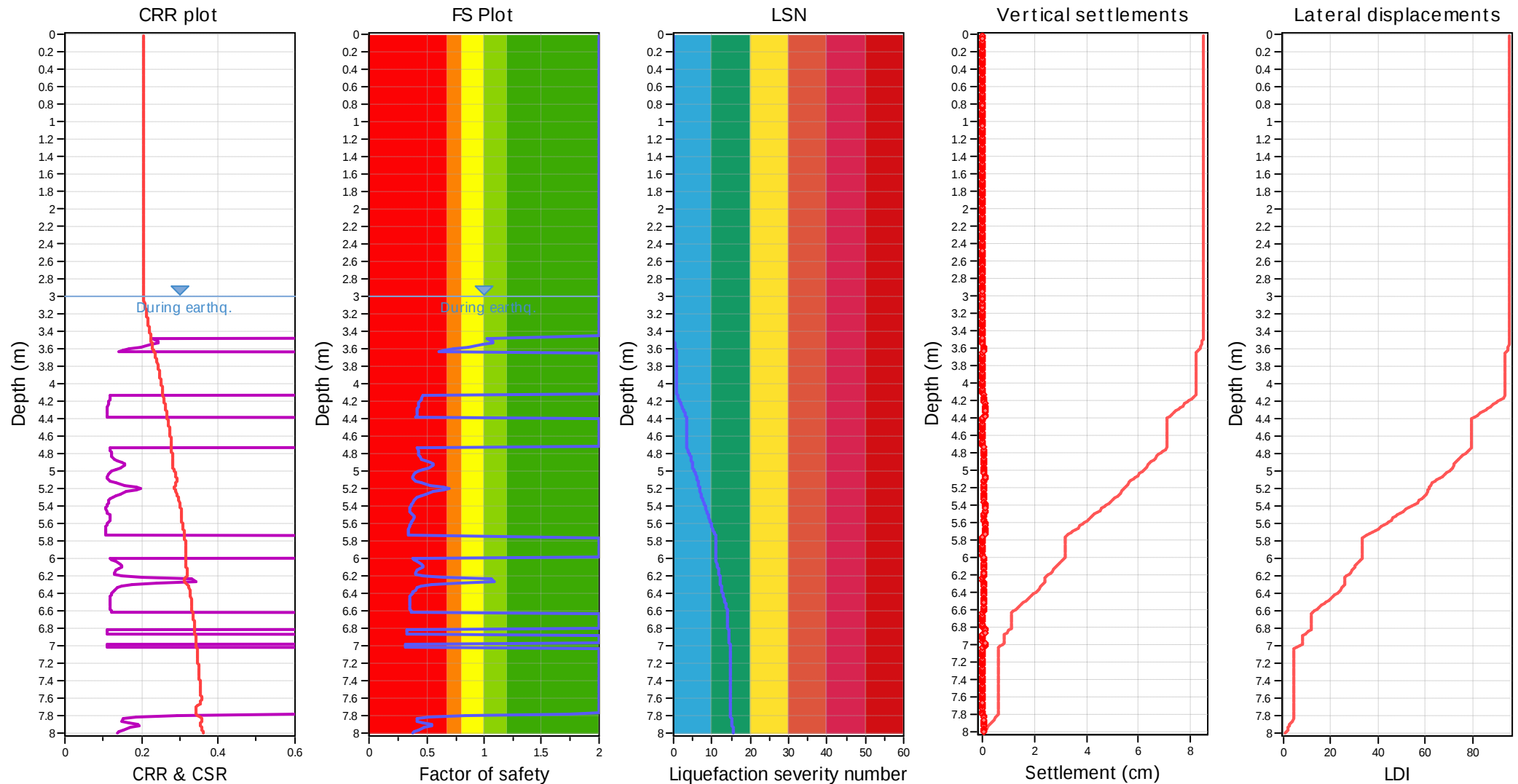
Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	3.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K _σ applied:	Yes
Earthquake magnitude M _w :	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	2.90 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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

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 I_c value
 Earthquake magnitude M_w : 7.50
 Peak ground acceleration: 0.35
 Depth to water table (insitu): 2.90 m

Depth to GWT (earthq.): 3.00 m
 Average results interval: 3
 I_c 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: No
 K_σ applied: Yes
 Clay like behavior applied: Sands only
 Limit depth applied: No
 Limit depth: N/A

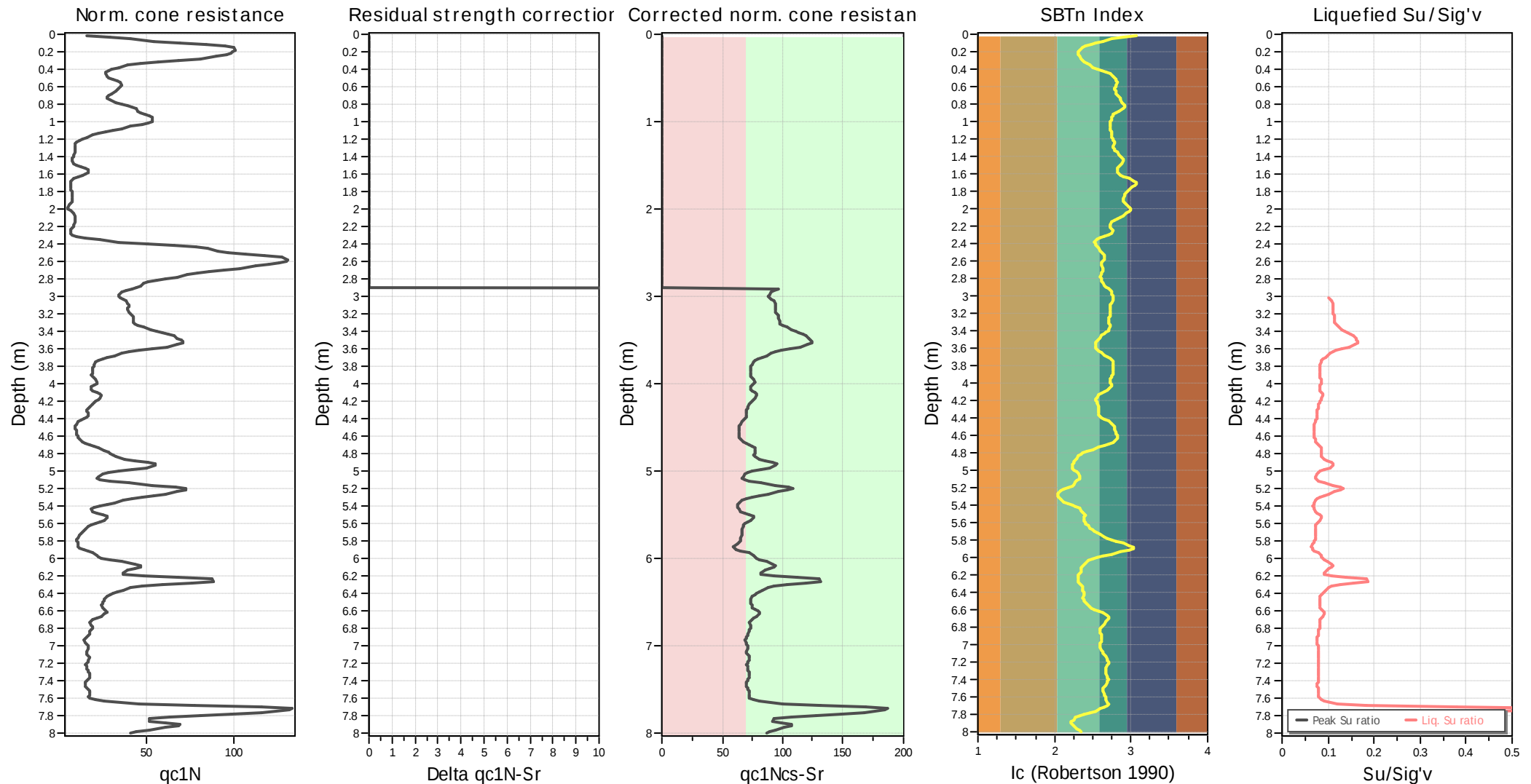
F.S. color scheme

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

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

Check for strength loss plots (Idriss & Boulanger (2008))



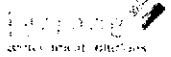
Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	3.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w :	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	2.90 m	Fill height:	N/A	Limit depth:	N/A

Appendix 3

Terrance Scala
Penetrometer Tests –
Bath House, 2009

Terrane Scala Penetrometer Tests 2009

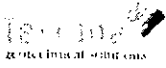
 SCALA PENETROMETER TESTS								Job No: 3278 Date: 7-Jul-09	
Project: Southern Extension, Rotorua Museum Location: Basement of Rotorua Museum Datum:								Test Numbers: J1 to J9	
Test Number	J1	J2	J3	J4	J5	J6	J7	J8	J9
Depth below datum to start of test (m)	0.30	0.35	0.25	0.10	0.25	0.40	0.35	0.25	0.20
mm Driven:									
50						C	C		
100				1		O	O		
150				2		R	R		
200				6		E	E		1
250			2	2	2	O	D	2	2
300	1		6	1	0			2	1
350	2	8	13	0	2		1	2	1
400	4	10	5	0	5	1	0	4	1
450	3	15	3	1	1	0	0	0	0
500	1	15	1	0	1	2	0	0	0
550	0	10	0	0	1	1	0	1	0
600	1	8	1	1	0	1	1	2	2
650	0	3	0	1	0	0	0	1	1
700	1	8	2	3	0	1	1	1	1
750	1	3	2	1	1	0	0	1	1
800	0	3	2	1	1	1	0	1	1
850	1	1	1	2	0	1	1	2	1
900	0	1	0	1	1	1	0	1	1
950	1	1	1	2	1	1	1	1	1
1000	1	2	0	2	1	1	0	1	2
1050	1	2	1	2	1	4	1	2	2
1100	0	1	2	2	1	2	1	2	1
1150	2	2	1	2	1	2	1	2	2
1200	2	1	1	3	1	1	0	1	1
1250	4	2	1	2	1	1	1	2	1
1300	4	1	3	1	2	1	0	1	0
1350	1	1	1	1	1	0	0	1	0
1400	0	0	1	0	1	0	0	0	1
1450	0	0	0	0	1	0	1	1	0
1500	0	1	1	1	1	2	1	0	1
1550	0	1	1	1	0	1	1	0	1
1600	0	2	1	2	1	3	2	1	1
1650	1	2	1	2	0	3	1	1	2
1700	3	3	3	1	2	2	2	1	1
1750	2	2	3	2	5	2	3	0	2
1800	4	2	9	10	7	4	5	1	2
1850	6	4	10	8	7	4	7	8	2
1900	9	5	11		7	5	4	5	
1950									
2000									
2050									
2100									
2150									
2200									
2250									
2300									
2350									
2400									
2450									
2500									
2550									
2600									
2650									
2700									
2750									
2800									
2850									

Test Method: NZS 4402:1988 Test 5.5.2 Dynamic Cone Penetrometer

Tested by:

Checked by:

Terrane Scala Penetrometer Tests 2009

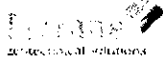
 SCALA PENETROMETER TESTS									Job No. 3278 Date: 7-Jul-09	
Project: Southern Extension, Rotorua Museum Location: Basement of Rotorua Museum Datum:									Test Numbers: J10 to J17	
Test Number	J10	J11	J12	J13	J14	J15	J16	J17		
Depth below datum to start of test (m)	0.35	0.35	0.55	0.35	0.10					
mm Driven:										
50	C	C	C	C		1	1	5		
100	O	O	O	O	4	1	1	2		
150	R	R	R	R	6	1	1	2		
200	E	E	E	E	3	5	3	1		
250	D	D	D	D		13	7	5		
300					1	5	1	16		
350	1	1		3	1	1	2	3		
400	0	0		1	0	1	0	4		
450	0	0		0	1	0	0	1		
500	0	0		1	0	0	0	1		
550	1	0	1	0	0	0	1	0		
600	0	0	0	1	0	0	1	1		
650	1	0	1	1	0	1	1	0		
700	1	1	0	0	2	0	0	0		
750	0	0	1	1	1	1	1	0		
800	1	1	1	0	1	0	0	0		
850	1	0	1	1	1	1	1	1		
900	1	1	1	0	1	0	0	1		
950	0	1	1	1	0	1	1	1		
1000	1	0	1	0	1	0	2	0		
1050	1	0	1	1	1	1	1	1		
1100	0	0	0	0	0	0	1	2		
1150	0	0	0	0	0	1	1	1		
1200	0	0	0	0	1	1	1	1		
1250	1	0	0	1	0	1	1	1		
1300	0	0	0	0	0	1	1	2		
1350	1	0	1	1	1	1	1	2		
1400	0	0	0	0	0	0	0	0		
1450	1	0	0	0	1	1	1	1		
1500	1	0	0	1	0	0	0	0		
1550	2	0	1	1	1	1	1	1		
1600	5	2	2	1	1	1	1	0		
1650	5	7	2	1	2	2	1	0		
1700	9	11	9	3	3	2	2	0		
1750	12	17	8	4	5	2	2	0		
1800	14		8	5	5	2	3	0		
1850			13	6	7	10	2	1		
1900				7	5		1	0		
1950								1		
2000								0		
2050								1		
2100								3		
2150								5		
2200								4		
2250								2		
2300								3		
2350								2		
2400								1		
2450								1		
2500								2		
2550								2		
2600								3		
2650								3		
2700								3		
2750								4		
2800								4		
2850								3		

Test Method: NZS 4402:1988 Test 5.5.2 Dynamic Cone Penetrometer

Tested by: _____

Checked by: _____

Terrane Scala Penetrometer Tests 2009

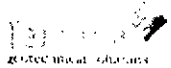
 SCALA PENETROMETER TESTS										Job No: 3278
										Date: 9-Jul-09
Project: Southern Extension, Rotorua Museum Location: Basement of Rotorua Museum Datum:										Test Numbers: J18 to J26
Test Number	J18	J19	J20	J21	J22	J23	J24	J25	J26	
Depth below datum to start of test (m)	0.30	0.20			1.05	1.00				
mm Driven:										
50			1	0			1	1	1	
100			1	0			1	0	2	
150			2	0			3	0	1	
200		1	8	0			1	1	1	
250		0	14	0			1	2	3	
300	1	2	9	1			1	3	1	
350	4	4	4	1			1	2	0	
400	2	10	2	0			0	3	1	
450	2	15	3	1			1	4	1	
500	4	15	1	1			0	2	0	
550	1	6	3	1			0	1	0	
600	1	2	4	1			1	1	0	
650	0	0	9	0			1	0	1	
700	1	1	2	1			1	0	0	
750	0	0	1	1			1	0	1	
800	0	0	1	0			1	1	1	
850	1	1	1	1			0	0	1	
900	0	0	0	0			1	1	1	
950	1	4	1	0			0	1	2	
1000	0	0	2	1		1	0	0	1	
1050	1	2	1	0	1	0	1	1	0	
1100	0	0	2	1	0	0	1	0	1	
1150	1	0	1	0	0	0	0	1	1	
1200	1	2	2	0	0	0	1	0	1	
1250	0	0	3	1	1	0	1	1	1	
1300	1	1	3	0	3	0	0	0	1	
1350	1	2	1	2	7	0	0	0	0	
1400	1	1	2	3	12	4	1	0	0	
1450	1	1	2	4	15	10	0	1	1	
1500	1	0	2	8		11	0	0	0	
1550	1	2	2	9		10	1	1	1	
1600	1	2	1	7		9	0	0	1	
1650	1	1	0	9		16	1	0	1	
1700	0	0	1	7		16	4	1	3	
1750	1	1	0	7		14	8	3	3	
1800	1	1	1	5		10	10	3	3	
1850	0	1	1	4		6	8	3	3	
1900	1	0	1	3		5		4	5	
1950	1	1	1	3		3		4		
2000	1	0	1	2		2		4		
2050	1	1	4	2		3		4		
2100	2	0	6	1		4		8		
2150	1	1	7	2		5		8		
2200	1	1	8	2		7		10		
2250	2	1	8	2		2				
2300	1	1	13	2		0				
2350	2	1		3		4				
2400	2	1		2		7				
2450	2	1		2		8				
2500	2	2		3		5				
2550	2	1		3		6				
2600	1	1		3		7				
2650	2	1		4		5				
2700	2	2		3						
2750	2	1		4						
2800	2	1		3						
2850	1	1		3						

Test Method: NZS 4402:1988 Test 5.5.2 Dynamic Cone Penetrometer

Tested by:

Checked by:

Terrane Scala Penetrometer Tests 2009

 SCALA PENETROMETER TESTS						Job No: 3278 Date: 9-Jul-09	
Project: Southern Extension, Rotorua Museum Location: Basement of Rotorua Museum Datum:						Test Numbers: J27 to J31	
Test Number	J27	J28	J29	J30	J31		
Depth below datum to start of test (m)							
mm Driven:							
50	0	1	0	0	0		
100	1	0	2	1	1		
150	3	1	0	0	2		
200	2	2	1	1	1		
250	2	0	0	2	0		
300	1	6	0	1	1		
350	1	4	0	1	1		
400	1	1	1	1	2		
450	0	1	1	2	2		
500	1	1	0	1	2		
550	1	1	1	1	1		
600	1	1	1	1	1		
650	1	1	1	1	2		
700	1	1	0	1	1		
750	0	2	1	0	1		
800	1	1	1	1	1		
850	0	2	1	2	2		
900	1	1	1	2	1		
950	0	2	1	1	2		
1000	1	1	3	0	3		
1050	1	2	4	0	5		
1100	1	4	4	8	6		
1150	3	4	4	10	8		
1200	3	4	2		6		
1250	3	4	1		3		
1300	2	2	4		1		
1350	1	1	9		1		
1400	1	1	15		1		
1450	0	2			1		
1500	1	5			1		
1550	1	8			2		
1600	0	8			3		
1650	1	10			6		
1700	0				5		
1750	2				6		
1800	1				6		
1850	5				9		
1900	8				12		
1950							
2000							
2050							
2100							
2150							
2200							
2250							
2300							
2350							
2400							
2450							
2500							
2550							
2600							
2650							
2700							
2750							
2800							
2850							

Test Method: NZS 4402:1988 Test 5 5.2 Dynamic Cone Penetrometer

Tested by _____

Checked by _____