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28 March 2013

Andytek Enterprises Ltd.
140 Taane Road
Cambridge, RD 2
3492

Dear Per

Lot 8 Hydro Road, Karapiro: House Site Liquefaction Assessment (Revision 1)

1.0 Introduction

AECOM were engaged by Andytek Enterprises Ltd to provide a liquefaction assessment of the rural residential property located at Lot 8, Hydro Road, Karapiro.

We understand that a two storey residential dwelling is to be constructed on the property, and that this dwelling will be setback approximately 400m from the cliff edge adjacent to the Waikato River.

2.0 Site Description

The property is located adjacent to the Waikato River, downstream of Lake Karapiro (on the true right bank). The property is located on the river terraces adjacent to the Waikato River, which flows along the south western boundary of the property. The Waikato River at this location flows through a steep sided gorge, with the bank of along the edge of the property approximately 40m high.

The property is currently grassed.

3.0 Site Investigation

Two Cone Penetrometer Tests (CPTs) were undertaken at the site by Geotech Drilling Ltd. These CPTs were undertaken to a depth of approximately 7.2 metres, where upon further penetration was not possible due to the total friction on the CPT rods. The CPTs indicated that the soil at the site consists of interbedded sand and silty sand for the entire depth of the CPTs. The groundwater table was inferred to be located at 1.1m below ground level, however it is noted that these CPTs were undertaken during a dry summer period. For the purposes of this assessment, a typical ground water table has been taken as 0.5m below ground surface.

No AECOM representative was onsite during the drilling of these CPTs, and the exact locations of these CPTs in relation to the dwelling and the site layout are unknown. Thus this assessment has been undertaken assuming that the CPTs are representative of the geology and stratigraphy present across the entire site.

4.0 Geological Setting

Based on the 1:250 000 geological map of the region (GNS), the soil at the site is likely to belong to the Hinuera formation. The Hinuera formation is typically described as laminated, commonly cross-bedded fluvial sand and gravel, which agrees with the results obtained from the CPTs. This alluvial formation comprises mainly sandy volcaniclastic sediments, derived from rhyolitic eruptions in the mid North Island that were deposited on an older highly eroded surface underlain by mixed alluvial sediments, peat and pyroclastic flows.

When deposition of the Hinuera Formation fan alluvium ceased, the Waikato River cut down into its present course. The Waikato River is adjacent to the western boundary of the site.

The geological properties in combination with the alluvial deposition of the Hinuera formation result in a loose, sandy deposit. Under saturated conditions, such deposits may be prone to liquefaction during earthquakes.

5.0 Liquefaction

The cyclic ground motion induced by earthquakes can cause a build-up of excess pore pressure within the soil. If this excess pore pressure is great enough, liquefaction can occur which causes a loss of bearing strength. As this excess pore pressure dissipates following an earthquake, densification through settlement of the soil can occur which may further damage structures. Such densification and liquefaction typically occurs in loose saturated fine to medium grained non-cohesive and low plasticity soils.

Liquefaction can also induce lateral displacement (lateral spread) of the soil. Lateral spread usually occurs when a liquefiable soil layer is adjacent to a free face such as a trench, river bank or depression. As the soil liquefies, it allows the unliquefied soil above to flow under the force of gravity towards the free face.

6.0 Earthquake Hazard

There has been no site specific earthquake hazard assessment undertaken for the site, therefore the New Zealand Standard: Structural Design Actions, Part 5: Earthquake Actions – New Zealand NZS 1170.5:2004 has been used for design. Based on the results obtained from the CPTs undertaken at the site, the site is assumed to be Class C – a shallow soil site.

Two design cases have been considered; the ultimate limit state (ULS) and the serviceability limit state (SLS). The ULS case considers an earthquake with a return period of approximately 500 years. For a residential development with a design life of 50 years, there is 10% probability that such an earthquake will occur within the lifetime of the building.

The SLS case considers an earthquake with a return period of approximately 25 years. Thus, for a residential development with a design life of 50 years, the dwelling is expected to experience two earthquakes which cause ground accelerations of this magnitude.

The design peak ground accelerations for geotechnical design for the ULS and SLS are shown in Table 1 and were used for this assessment.

Table 1 Design Peak Ground Accelerations

Factor	Description	ULS Case	SLS Case
$C_h(T)$	Site subsoil Class C	1.33	1.33
Z	Located in Cambridge	0.18	0.18
R	Return period (ULS =1 in 500 years, SLS = 1 in 25 years)	1.0	0.25
N	No near faults	1	1
C(T)	Peak ground acceleration	**0.24**	**0.06**

7.0 Liquefaction Assessment Results

The liquefaction assessment was undertaken using the software package cLiq (developed by Geologismiki), using the Idriss and Boulanger (2008) methodology. The groundwater was assumed to be at 0.5m below ground surface for this liquefaction assessment.

7.1 SLS Case

Based on the parameters detailed above, in our opinion it is unlikely that the site will experience severe liquefaction should the SLS design earthquake occur. The liquefaction potential index is below 1, indicating that the effects of liquefaction are likely to be minor.

The factor of safety against liquefaction is high, remaining above 1.5 for the entire depth of the CPT.

Vertical settlements induced by this liquefaction are predicted to remain under 10mm.

The lateral spread should this liquefaction occur is likely to be negligible (less than 10 mm). This assumes that the soil layer is approximately 10m deep at the cliff edge (and thus the effective height of which the liquefiable layer can spread is 10m), and the house is set 400m back from the cliff face.

7.2 ULS Case

Based on the parameters detailed above, in our opinion it is likely that the site will experience significant liquefaction should the ULS design earthquake occur. The liquefaction potential index ranges from 5 to 14, indicating that the effects of liquefaction are likely to be at least moderate.

The factor of safety against liquefaction is below 1 for approximately the upper 1.7m of soil. Beneath 1.7m, one of the CPTs indicates the factor of safety will remain at approximately 1, fluctuating above and beneath unity throughout the remainder of the CPT depth. The other CPT indicates that the factor of safety will decrease to approximately 0.5 at a depth of 3.2m, and remain at this level for the remaining depth of the CPT.

Vertical settlements induced by this liquefaction are predicted to range from 70 to 130mm.

The lateral spread should this liquefaction occur is likely to be in the range of 100 to 230mm. This indicates that there is a minor risk of the lateral spread having an impact on the proposed dwelling. This assumes that the soil layer is approximately 10m deep at the cliff edge (and thus the effective height of which the liquefiable layer can spread is 10m), and the house is set 400m back from the cliff face.

8.0 Foundation Recommendations

This liquefaction analyses suggests that should the ULS design earthquake occur, the effects of liquefaction could be severe, and result in significant vertical and moderate lateral displacements. Under SLS design conditions, major liquefaction is unlikely to occur at the site, and the resulting ground displacements are likely to be negligible.

Accordingly, we recommend that the foundation for the dwelling consists of a raft style foundation with sand replacement of any soft soil beneath the foundation. This foundation type should minimise the risk of significant damage to the structure due to differential settlement which may occur at the site.

Such foundations will mitigate the risk of minor differential vertical and lateral displacements such as those expected in the SLS event. However, should an earthquake which causes equivalent design accelerations to the ULS case considered in this analysis occur, minor damage to the dwelling foundation is likely to occur. The recommended foundations will however limit the damage to prevent failure of the structure i.e. the structure may be damaged and need minor repair but collapse will be prevented.

Due to the ground conditions at the site, foundations should be designed by a suitably qualified geotechnical engineer.

9.0 Limitations

The professional opinion expressed in this letter is given to Andytek Enterprises Ltd for their purposes alone on the express condition that it will not be relied upon by any other person and does not remove the necessity for the normal inspection of foundation conditions and excavations at the time of erection of any structures.

Recommendations and opinions in this report are based solely on CPT test records provided to AECOM by the client, for the purposes of liquefaction assessment only. No assessment of bearing capacity requirements has been undertaken. Inferences about the nature and continuity of ground conditions away from investigation locations are made but cannot be guaranteed.

During development of the site, ground conditions should be examined by a geotechnical specialist competent to judge whether the conditions are compatible with the assumptions made in this report. In all circumstances, if ground conditions differ from those described or assumed to exist, then the matter should be referred back to AECOM.

The results of the cLiq analyses have been attached for your information.

Yours faithfully

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Andrew Holland
Principal Geotechnical Engineer
andrew.holland@aecom.com

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Direct Dial: +64 7 834 8991
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AECOM NZ Ltd
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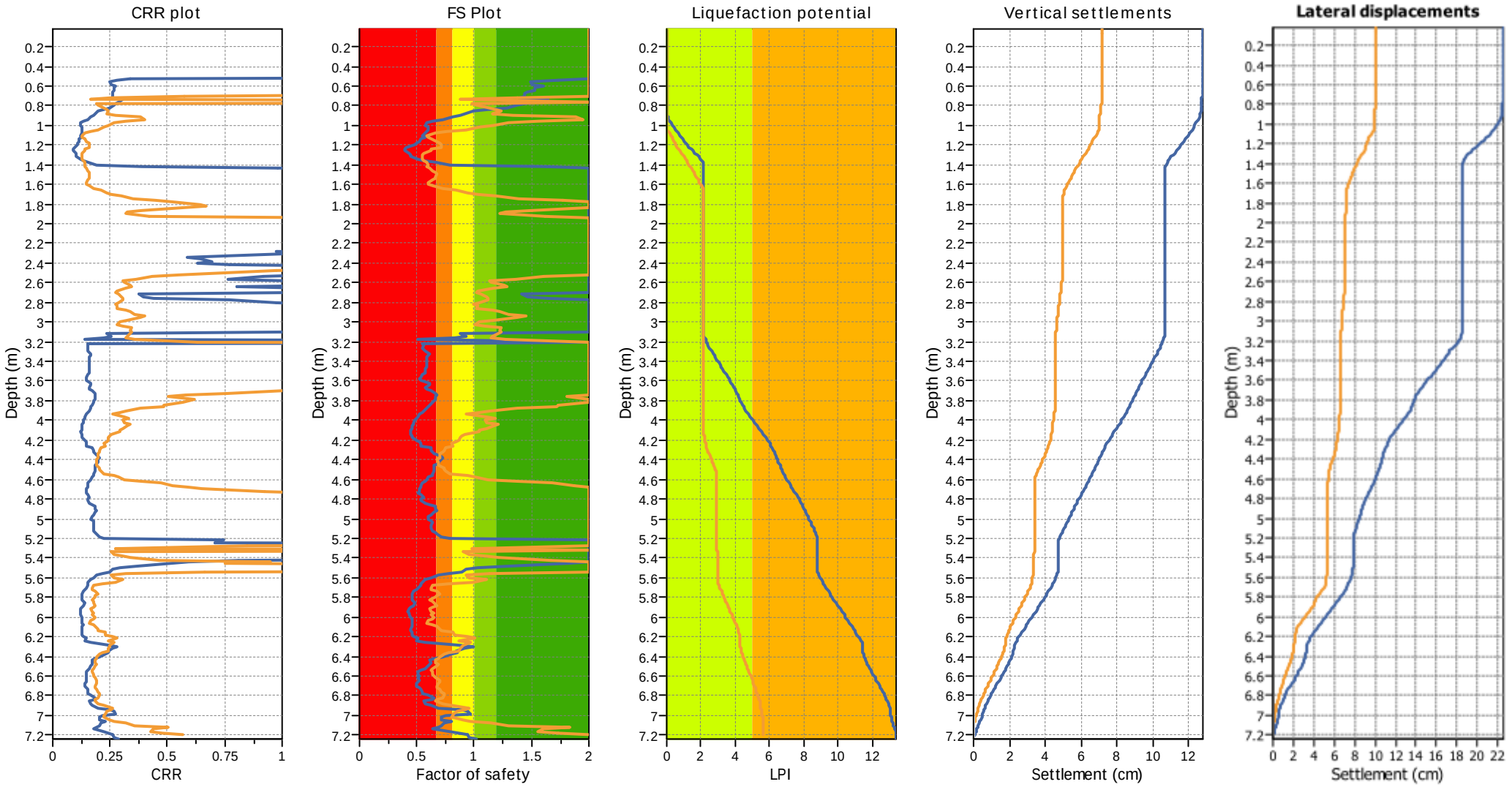
ULS DESIGN CASE

Project:

Overlay Cyclic Liquefaction Plots



AECOM NZ Ltd
121 Rostrevor Street
Hamilton
New Zealand

LIQUEFACTION ANALYSIS REPORT

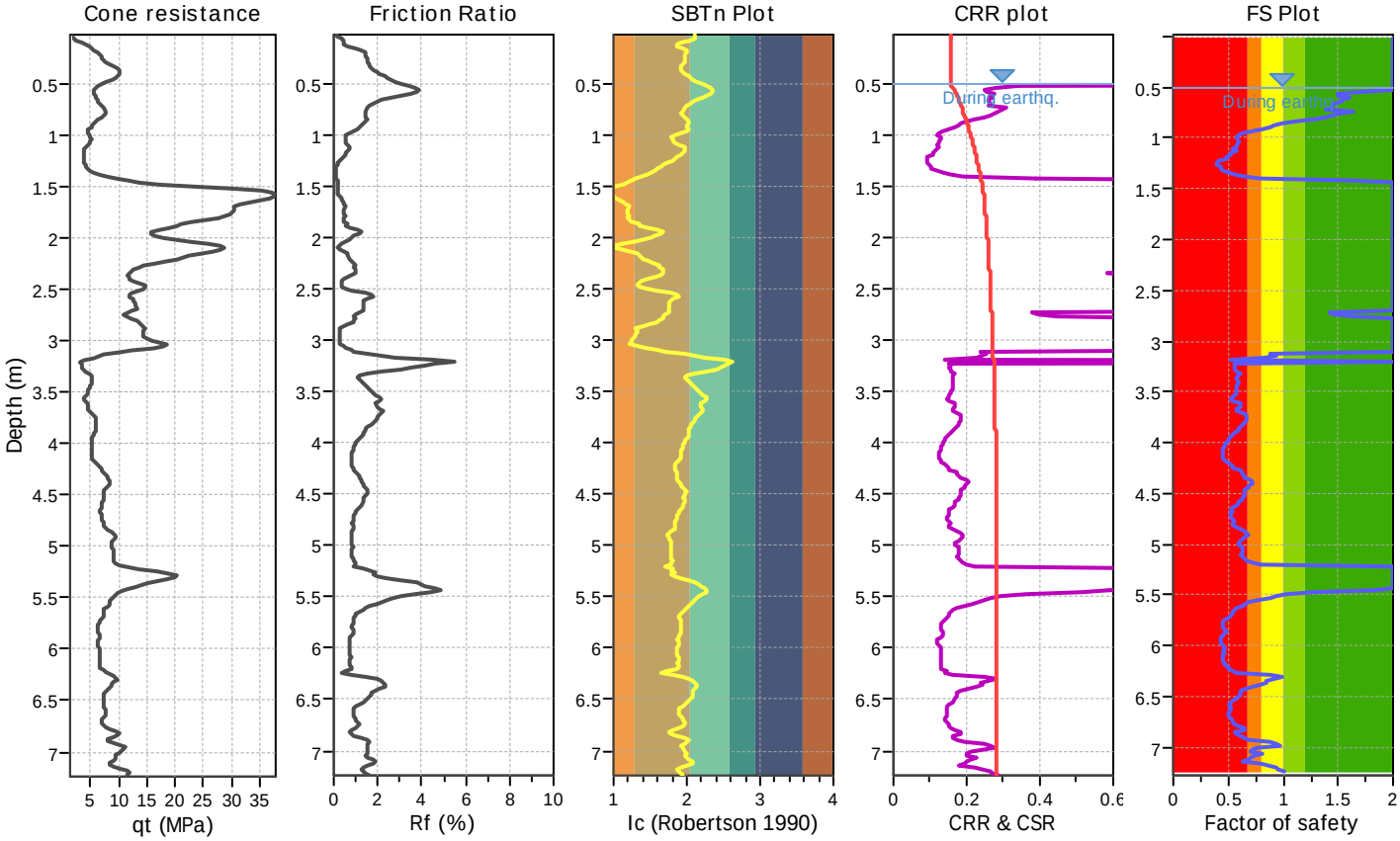
Project title :

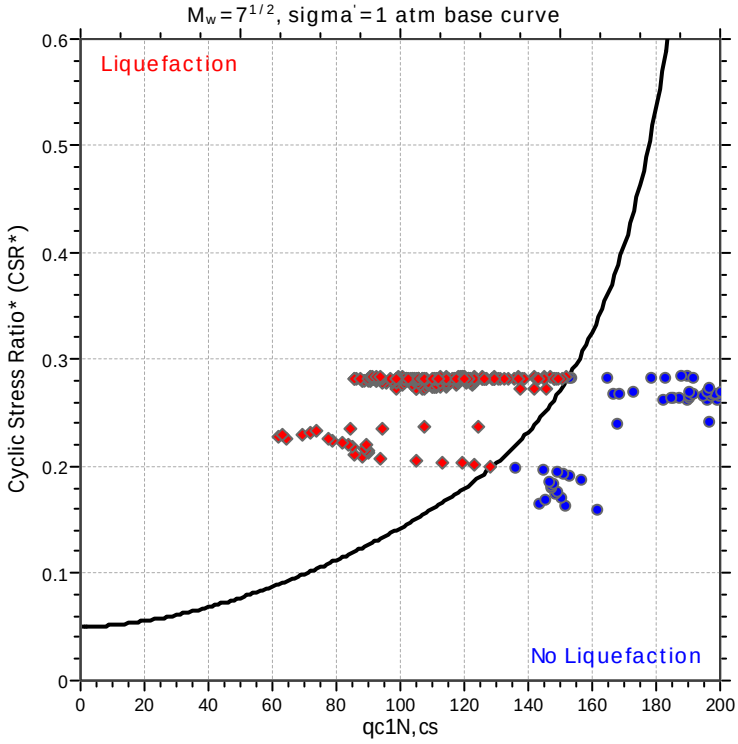
Location : 8 Hydro Road

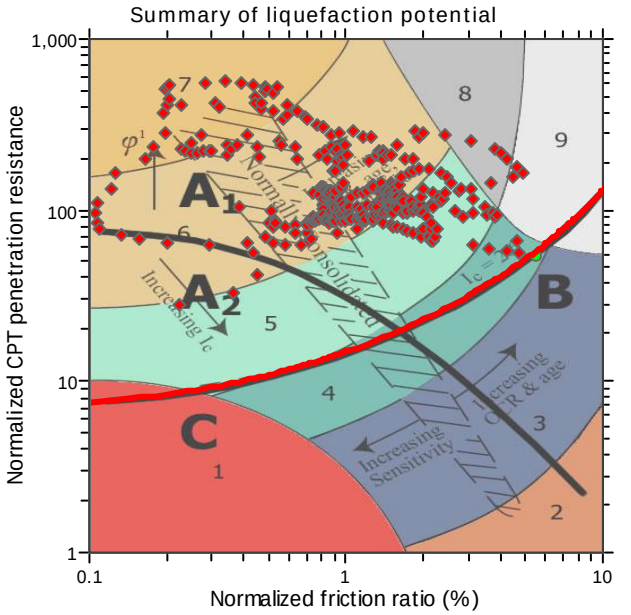
CPT file : CPT 1

Input parameters and analysis data

Analysis method:	I&B (2008)	G.W.T. (in-situ):	0.50 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	R&W (1998)	G.W.T. (earthq.):	0.50 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		
Peak ground acceleration:	0.24	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

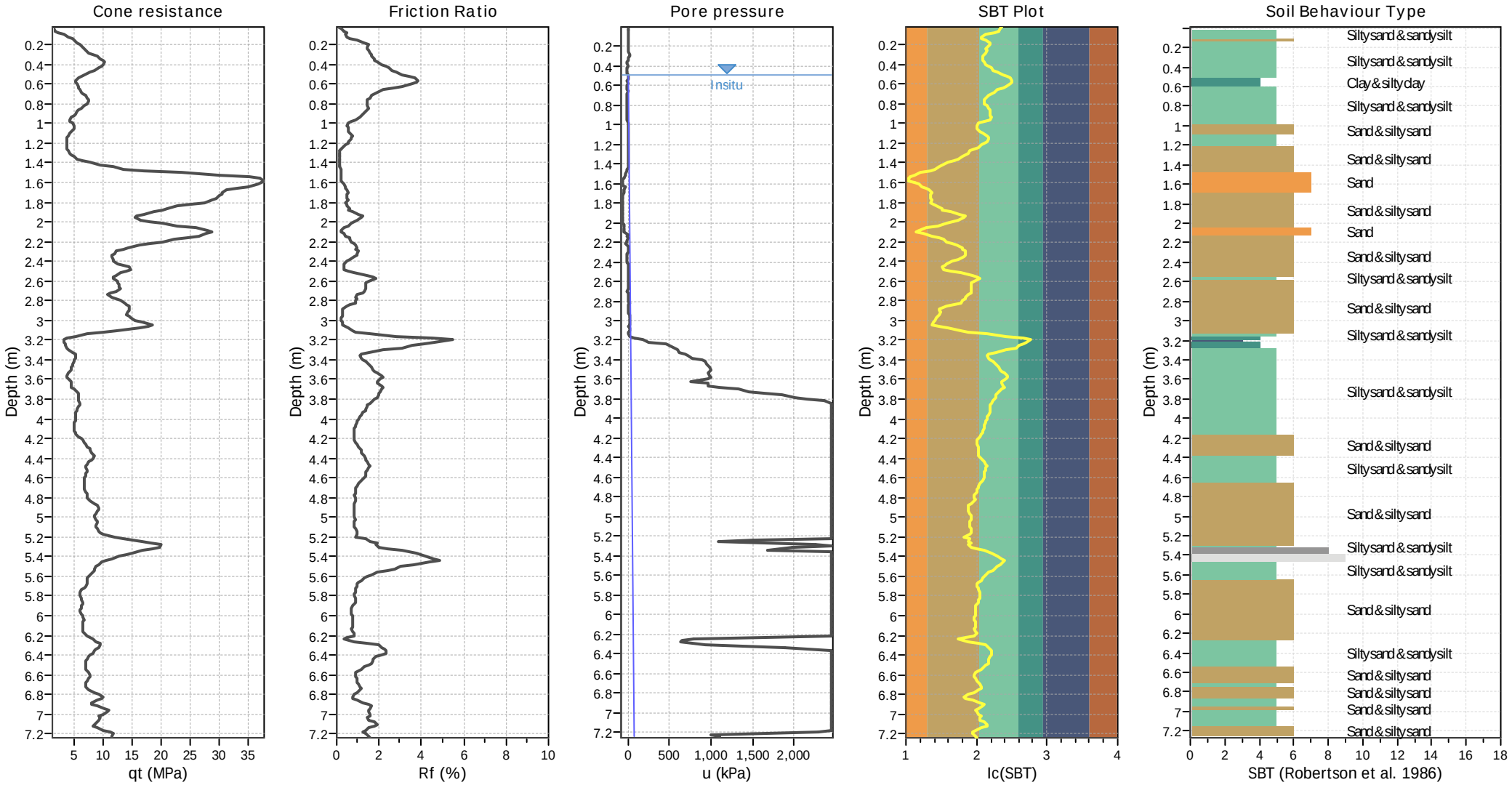






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and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

CPT basic interpretation plots



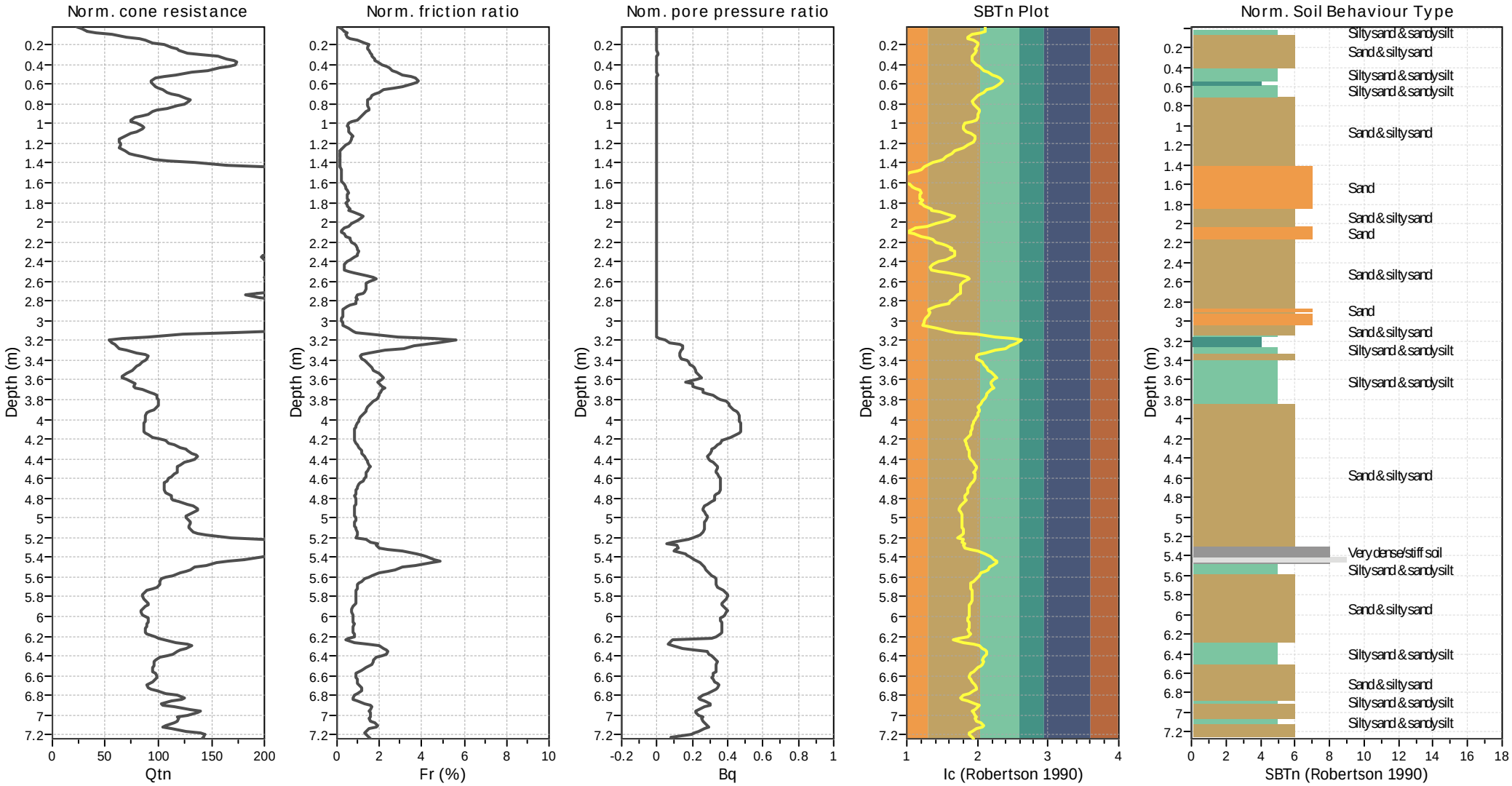
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
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:	.
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 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

CPT basic interpretation plots (normalized)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
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:	.
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn legend

1. Sensitive fine grained
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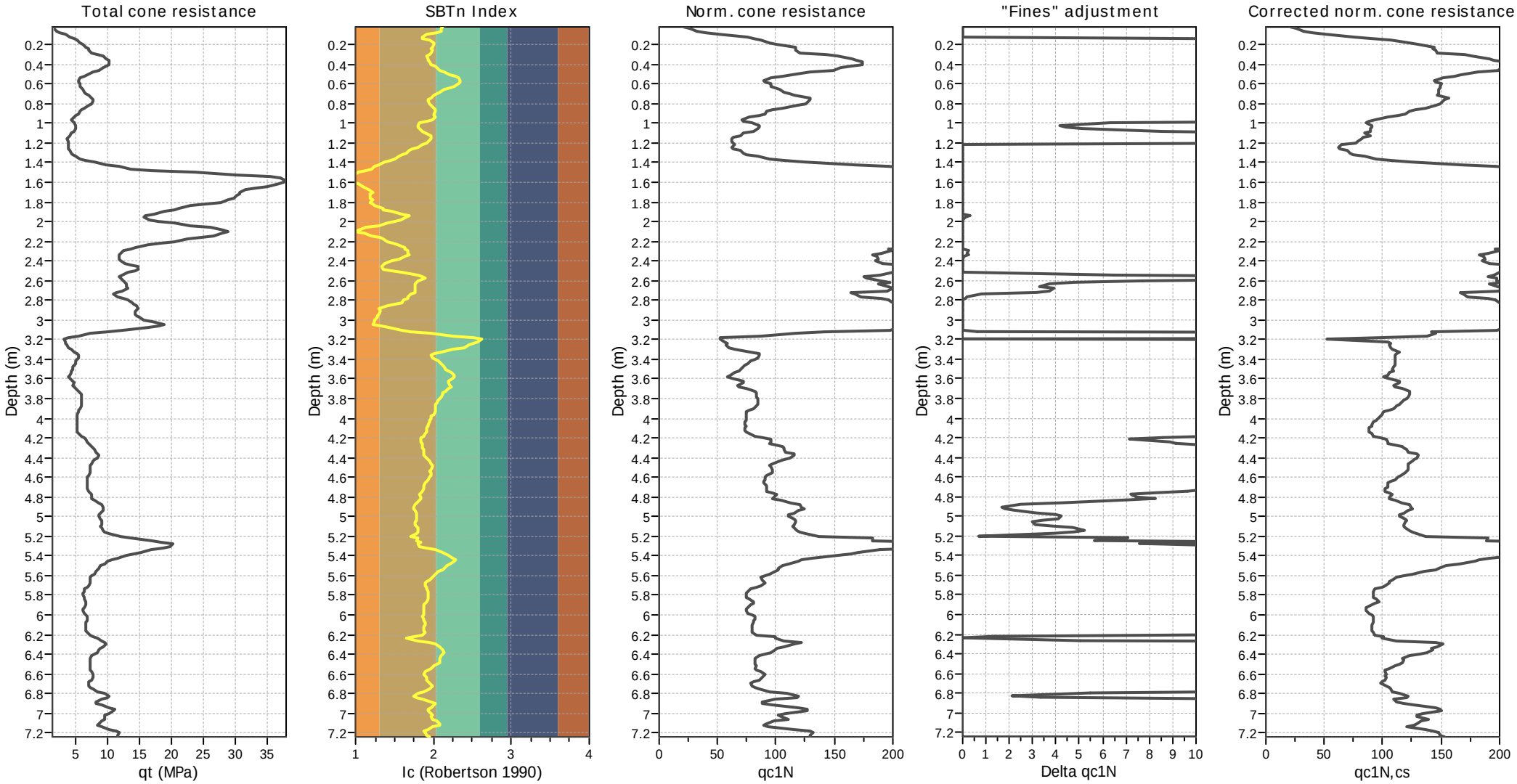
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

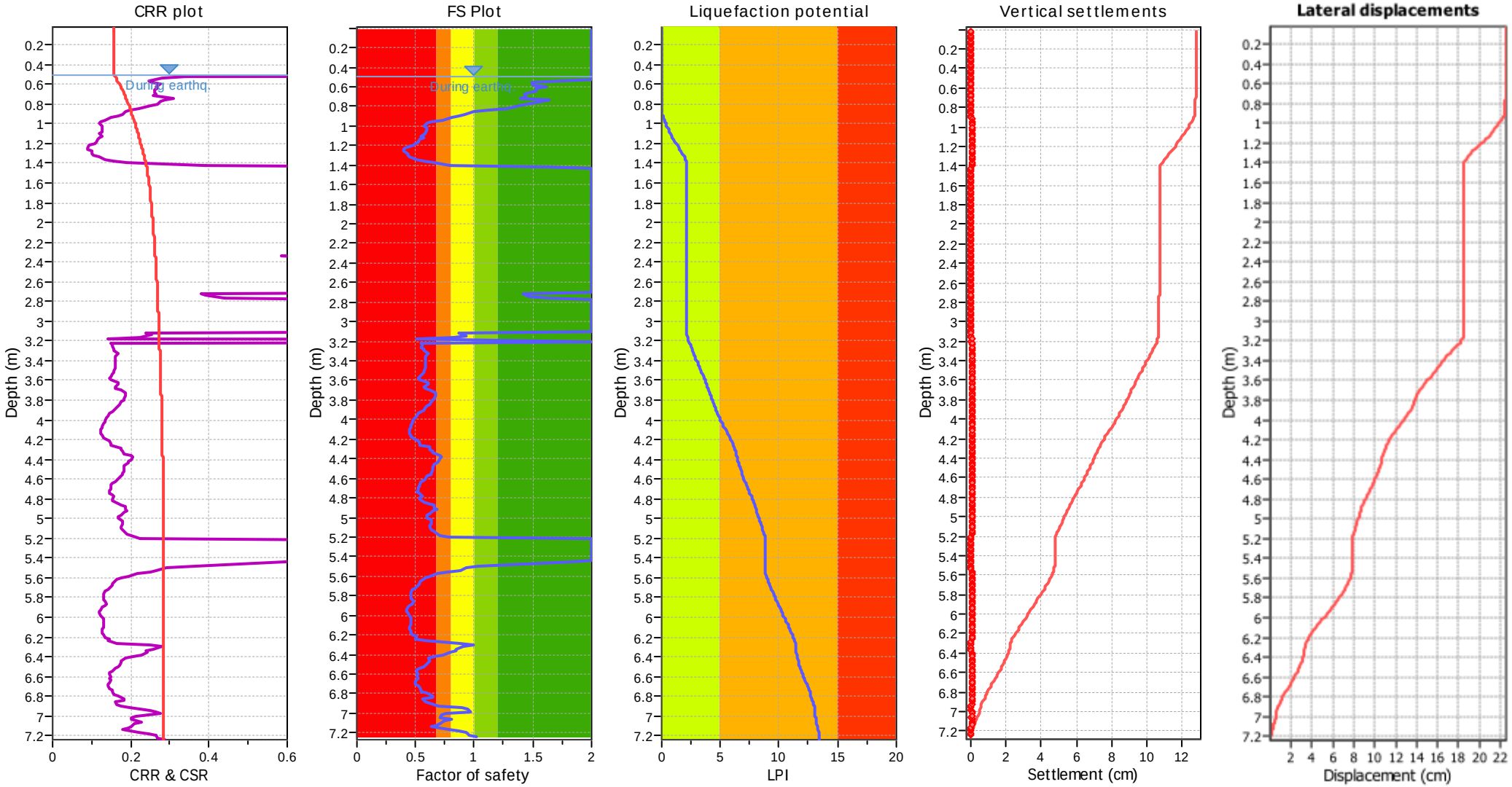
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
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:	.
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 m	Fill height:	N/A	Limit depth:	N/A

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
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:	.
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 m	Fill height:	N/A	Limit depth:	N/A

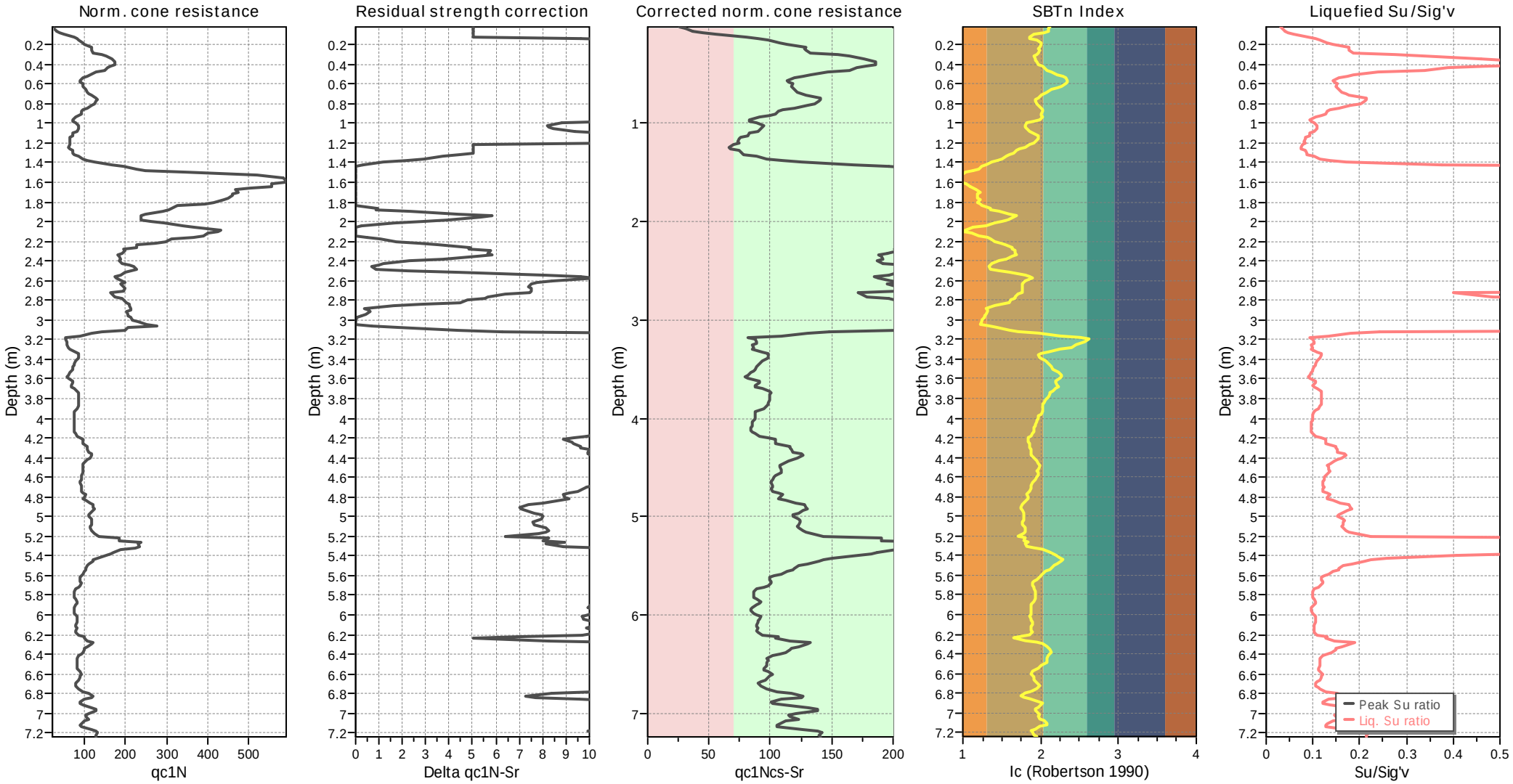
F.S. color scheme

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

LPI color scheme

- Very high risk
- High risk
- Low risk

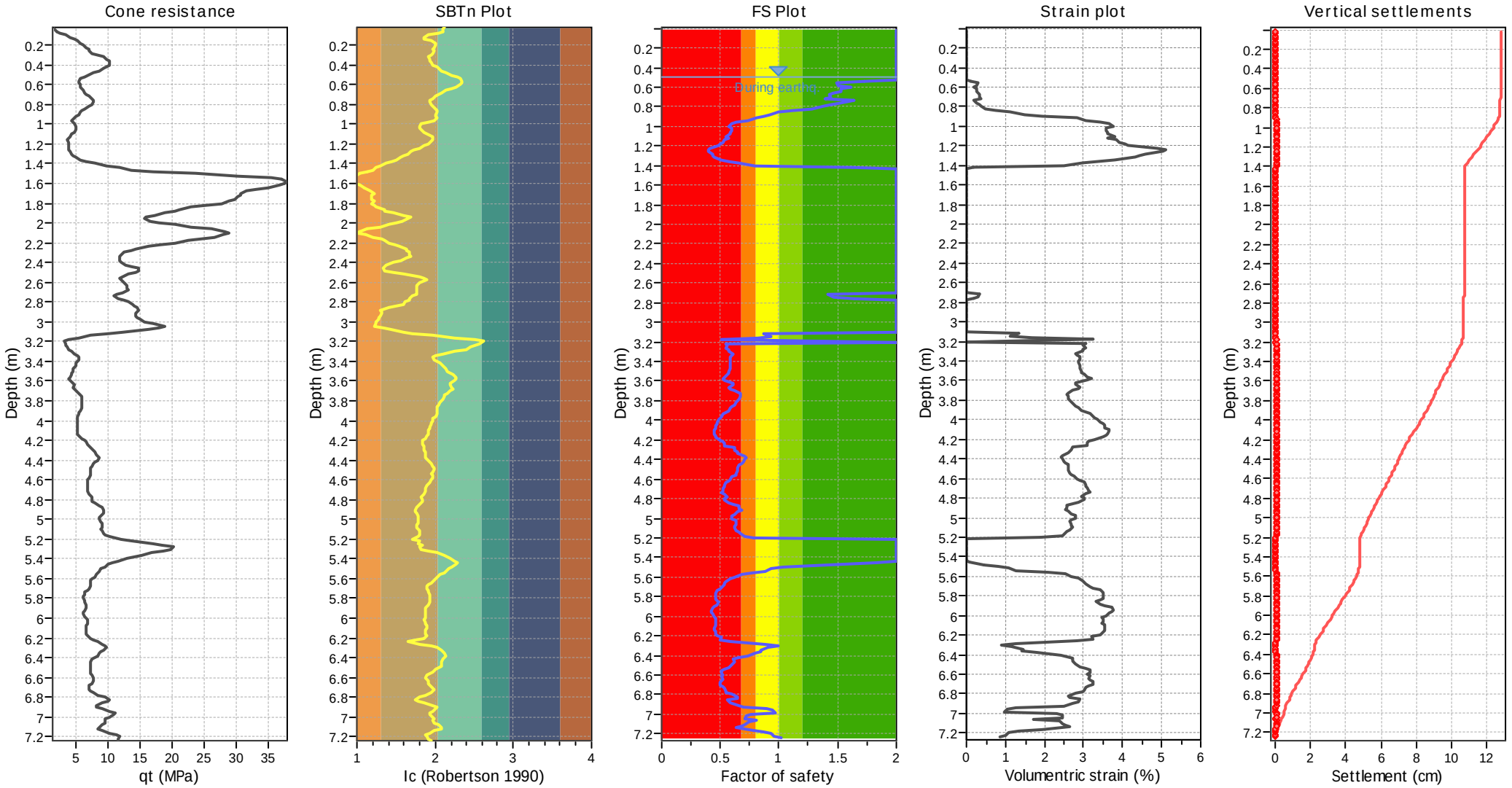
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
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:	.
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 m	Fill height:	N/A	Limit depth:	N/A

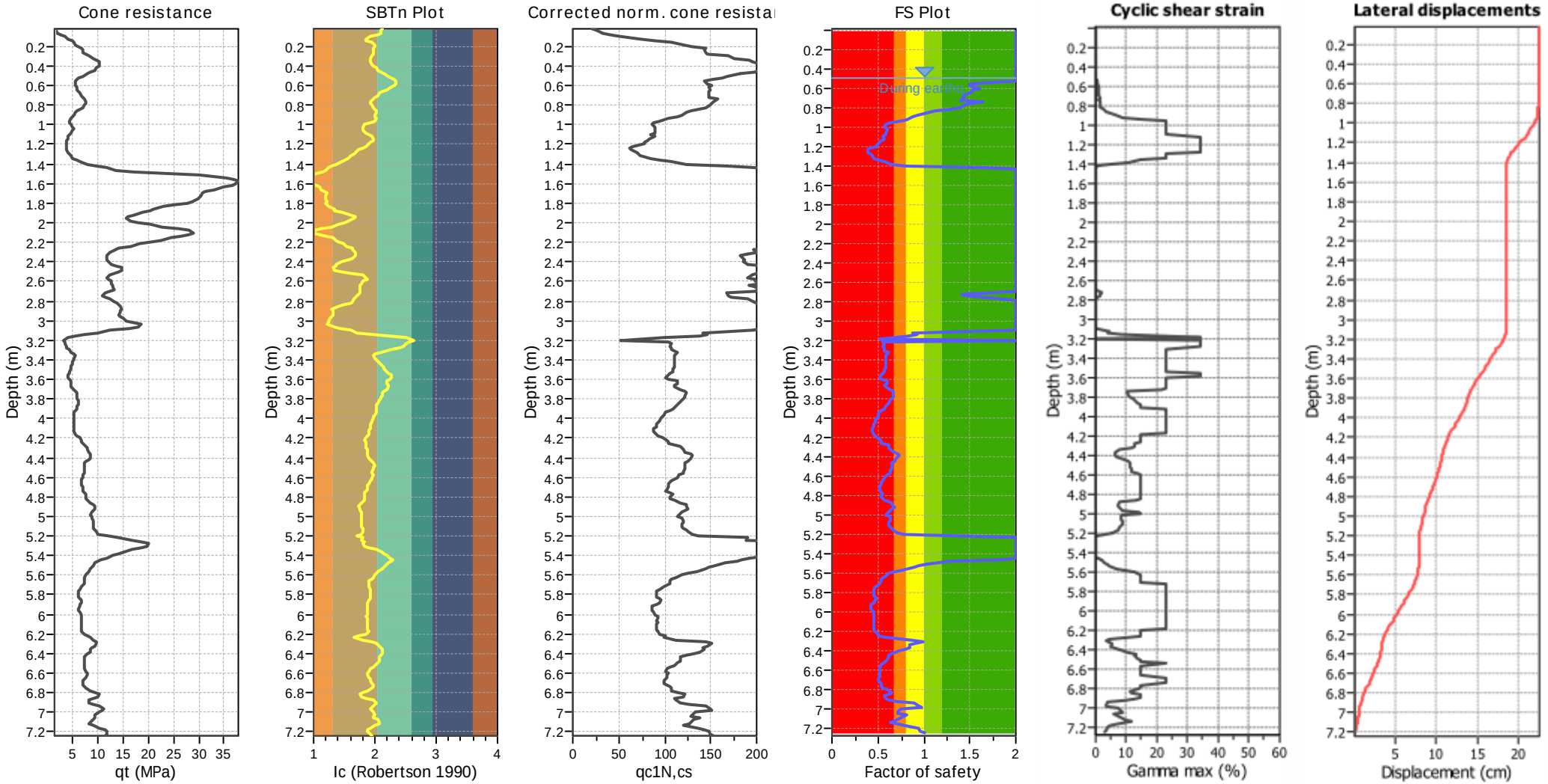
Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

Estimation of post-earthquake lateral Displacements



Abbreviations

q_t: Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c: Soil Behaviour Type Index
$q_{c1N,cs}$: Equivalent clean sand normalized CPT total cone resistance
F.S.: Factor of safety
γ_{max}: Maximum cyclic shear strain
LDI: Lateral displacement index

AECOM NZ Ltd
121 Rostrevor Street
Hamilton
New Zealand

LIQUEFACTION ANALYSIS REPORT

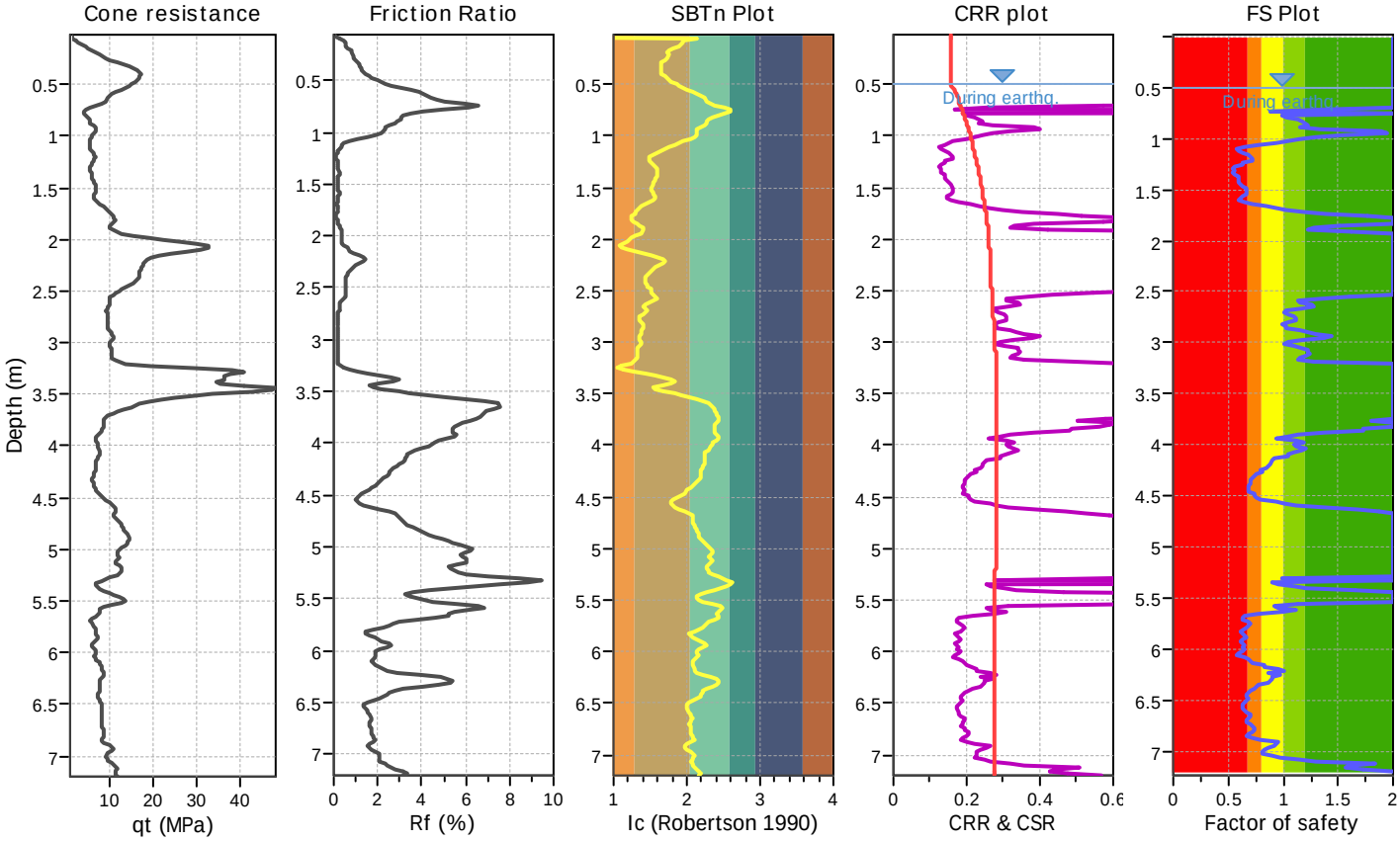
Project title :

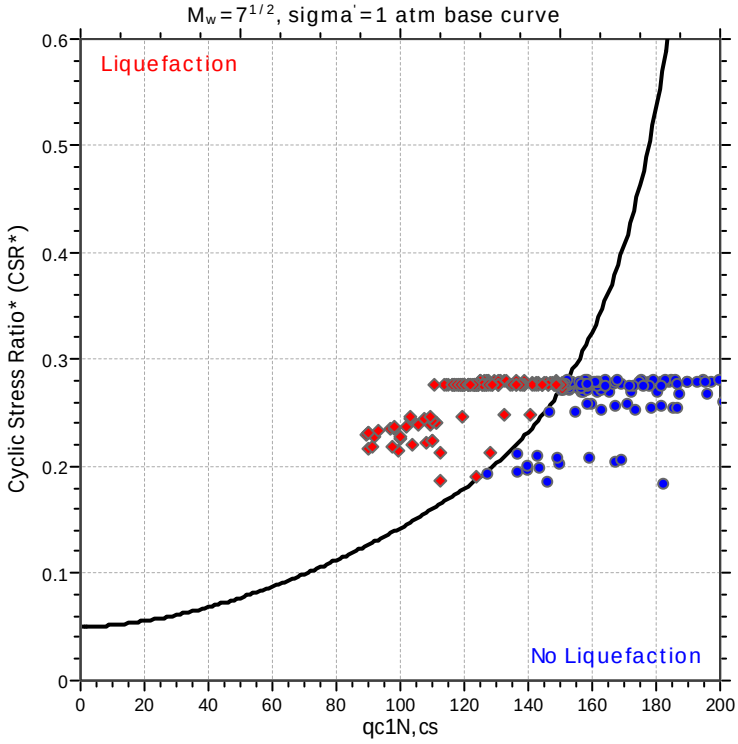
Location : 8 Hydro Road

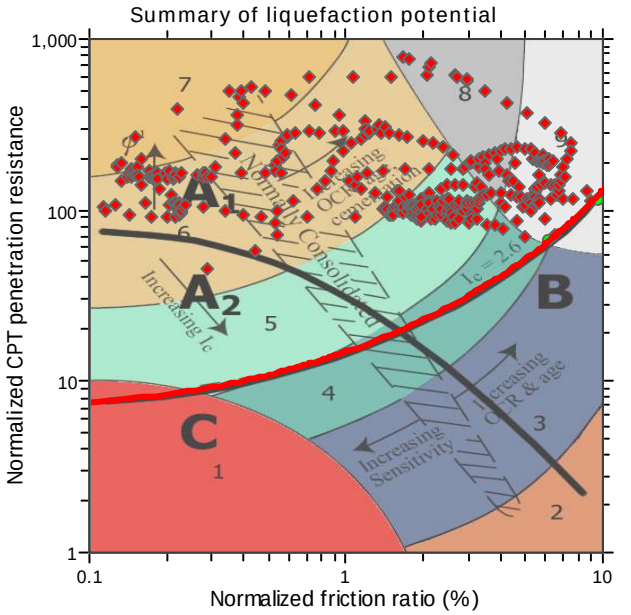
CPT file : CPT02

Input parameters and analysis data

Analysis method:	I&B (2008)	G.W.T. (in-situ):	0.50 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	R&W (1998)	G.W.T. (earthq.):	0.50 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		
Peak ground acceleration:	0.24	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		







Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
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Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
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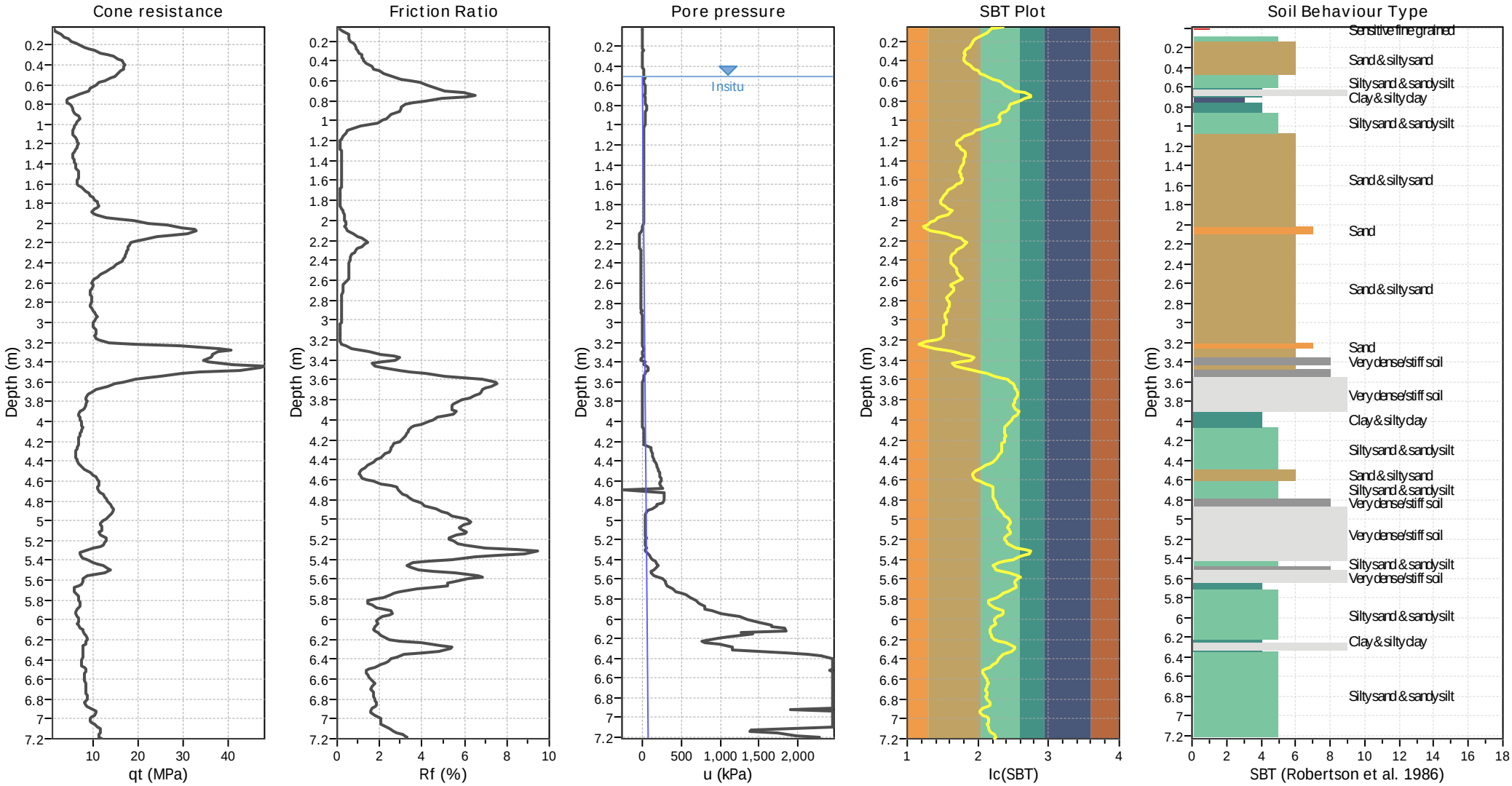
CPT basic interpretation plots



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Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
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:	.
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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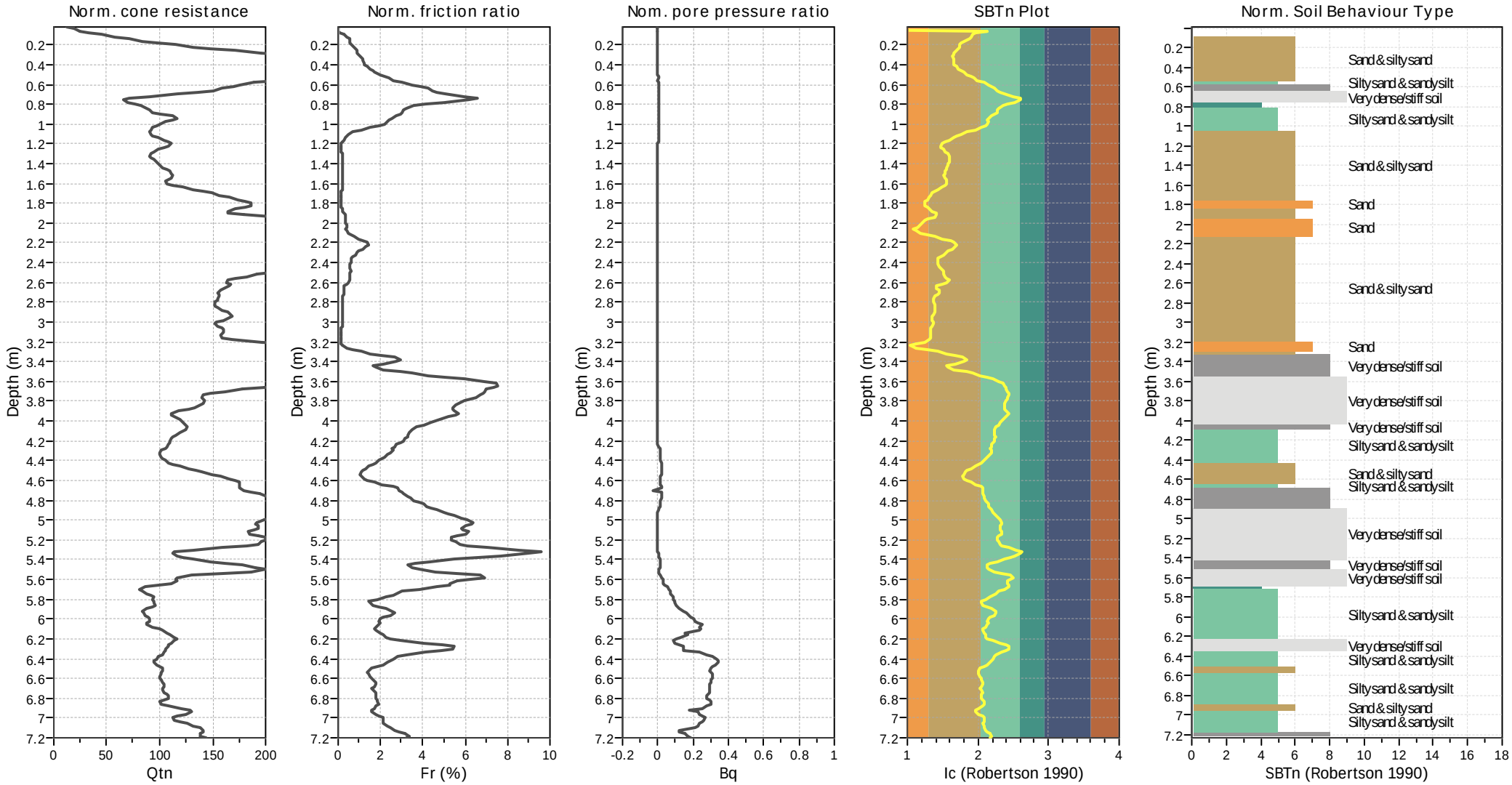
8. Very stiff sand to
9. Very stiff fine grained

CPT basic interpretation plots (normalized)



Input parameters and analysis data

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Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
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:	.
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 m	Fill height:	N/A	Limit depth:	N/A

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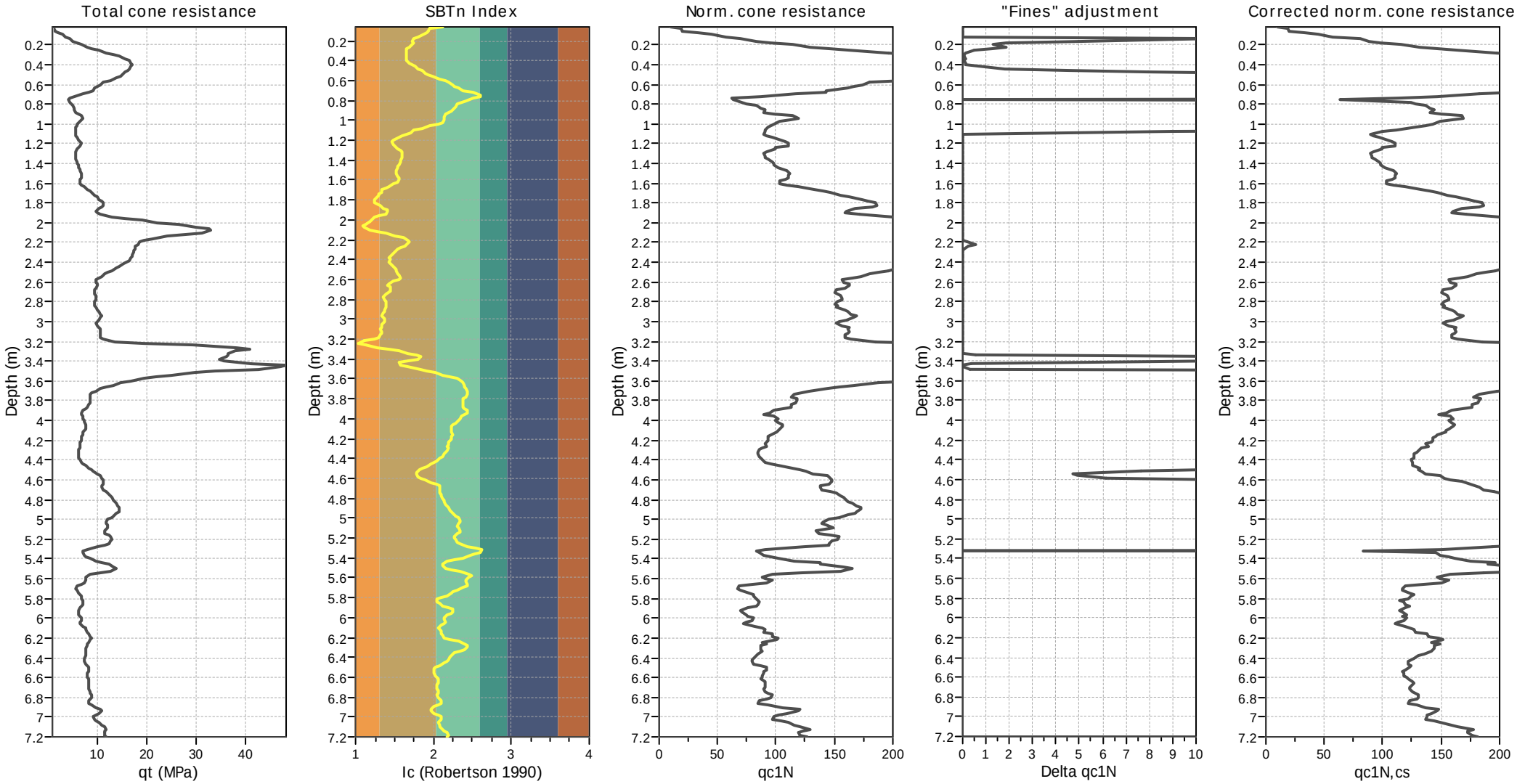
9. Very stiff fine grained

Liquefaction analysis overall plots (intermediate results)



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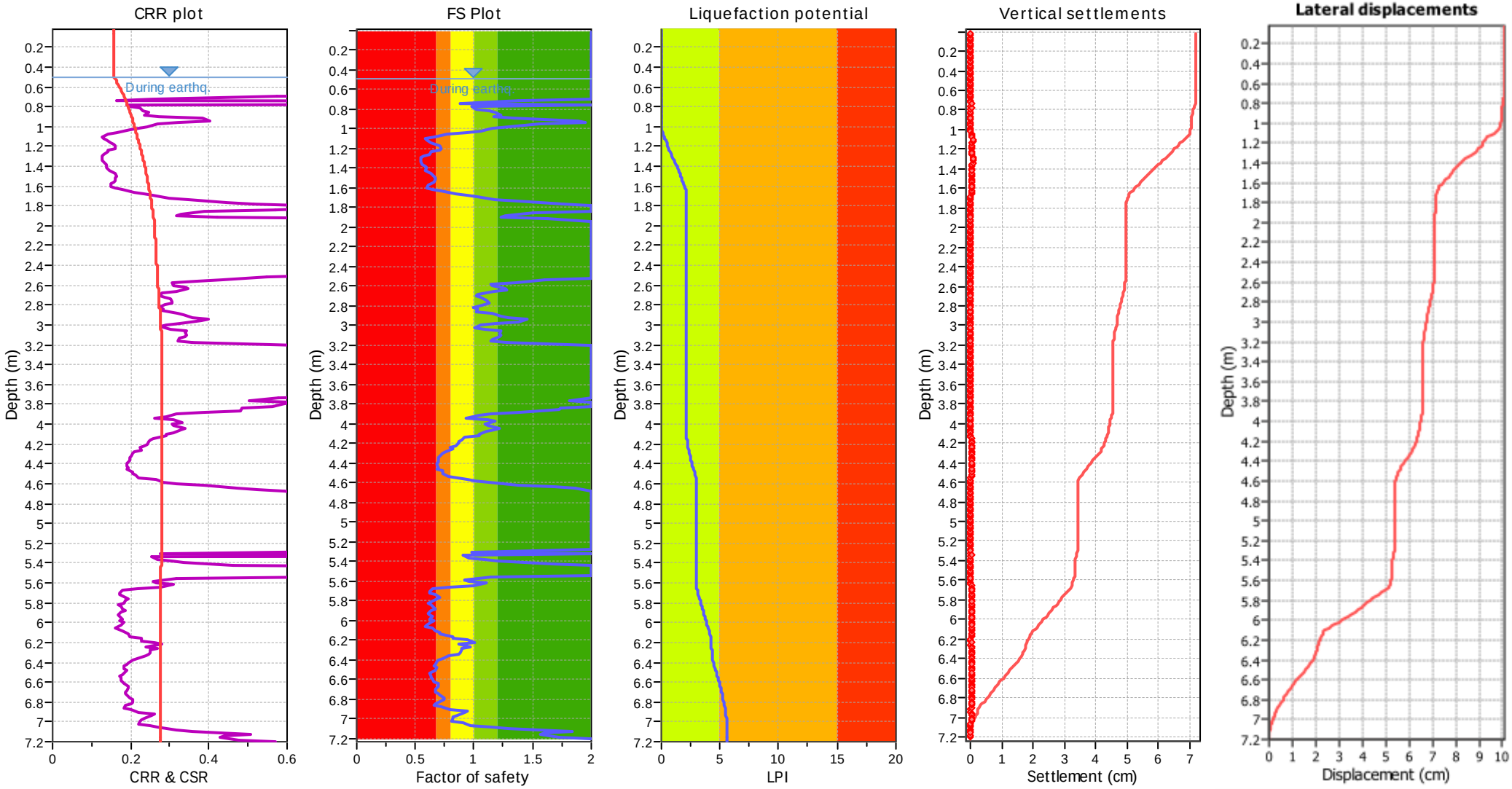
Liquefaction analysis overall plots



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- High risk
- Low risk

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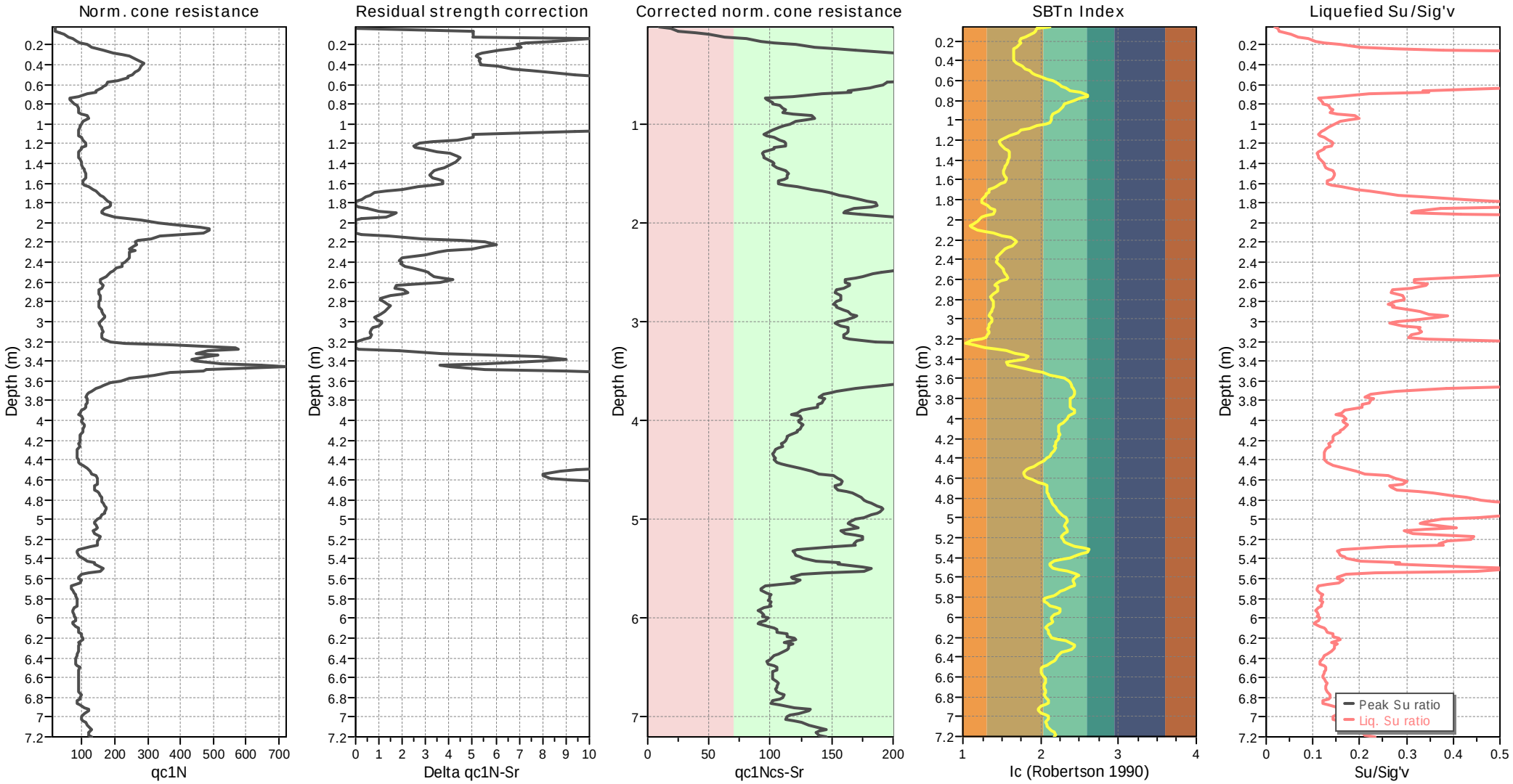
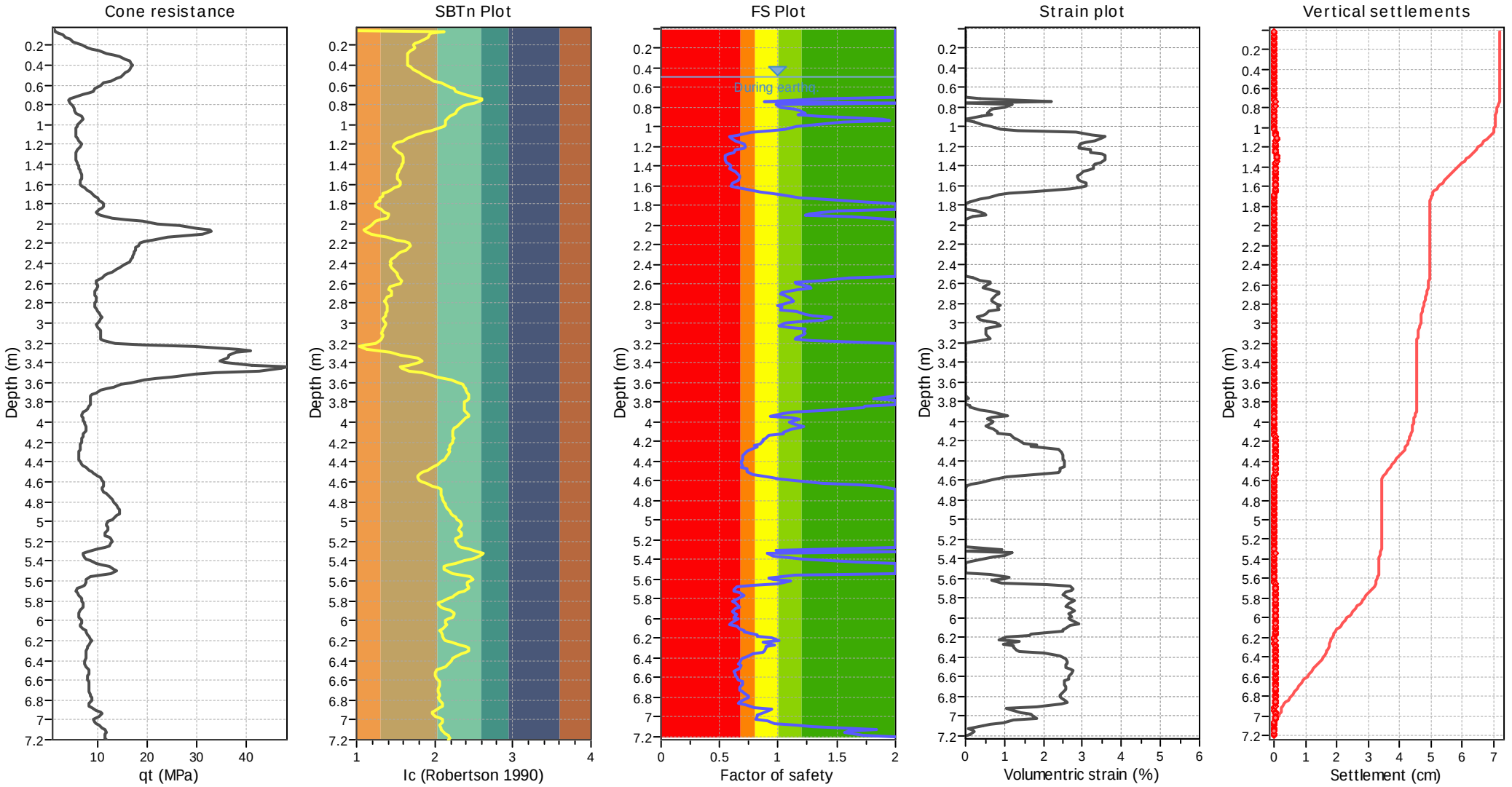


Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
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:	.
Peak ground acceleration:	0.24	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 m	Fill height:	N/A	Limit depth:	N/A

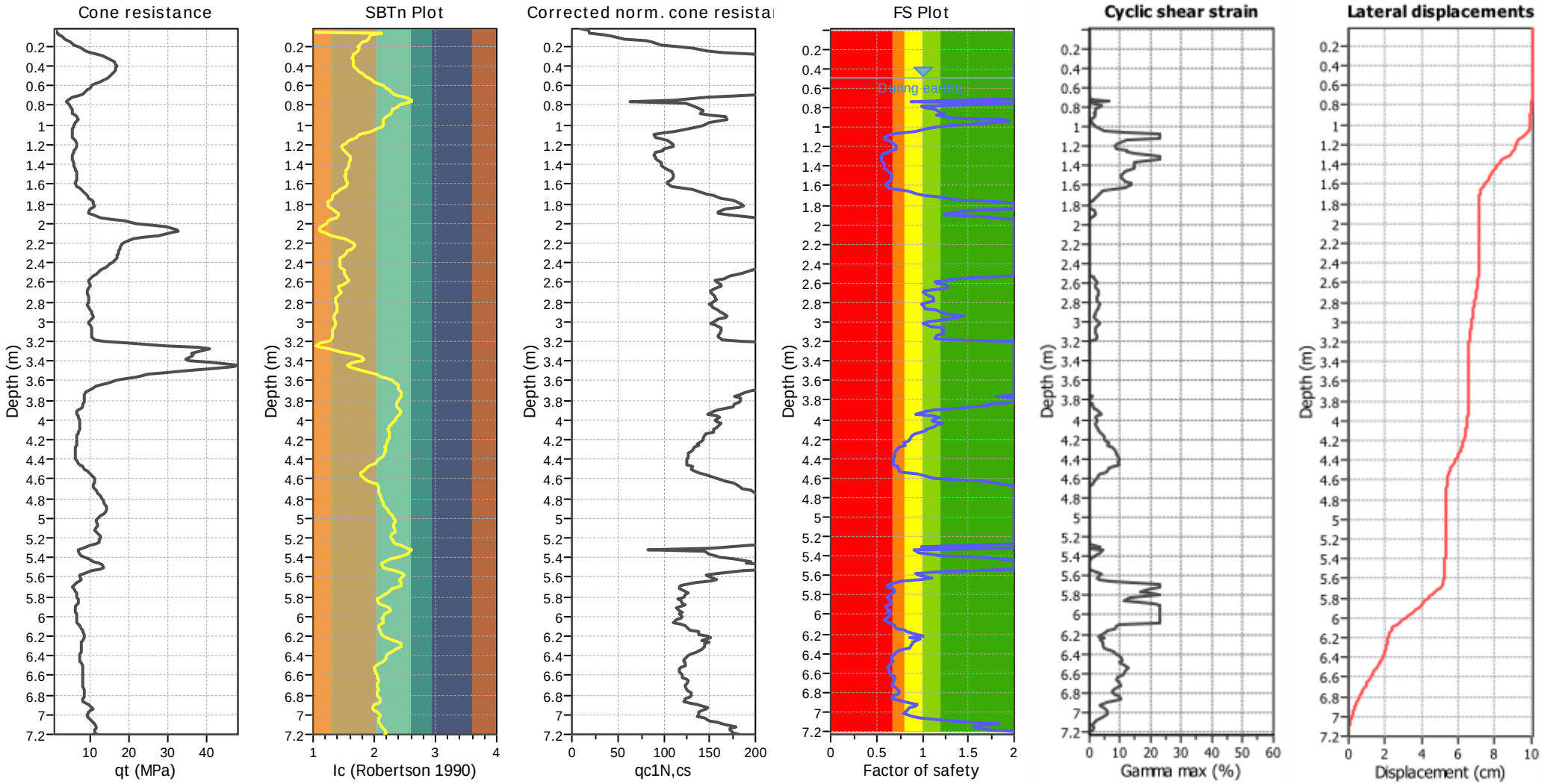
Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

Estimation of post-earthquake lateral Displacements



Abbreviations

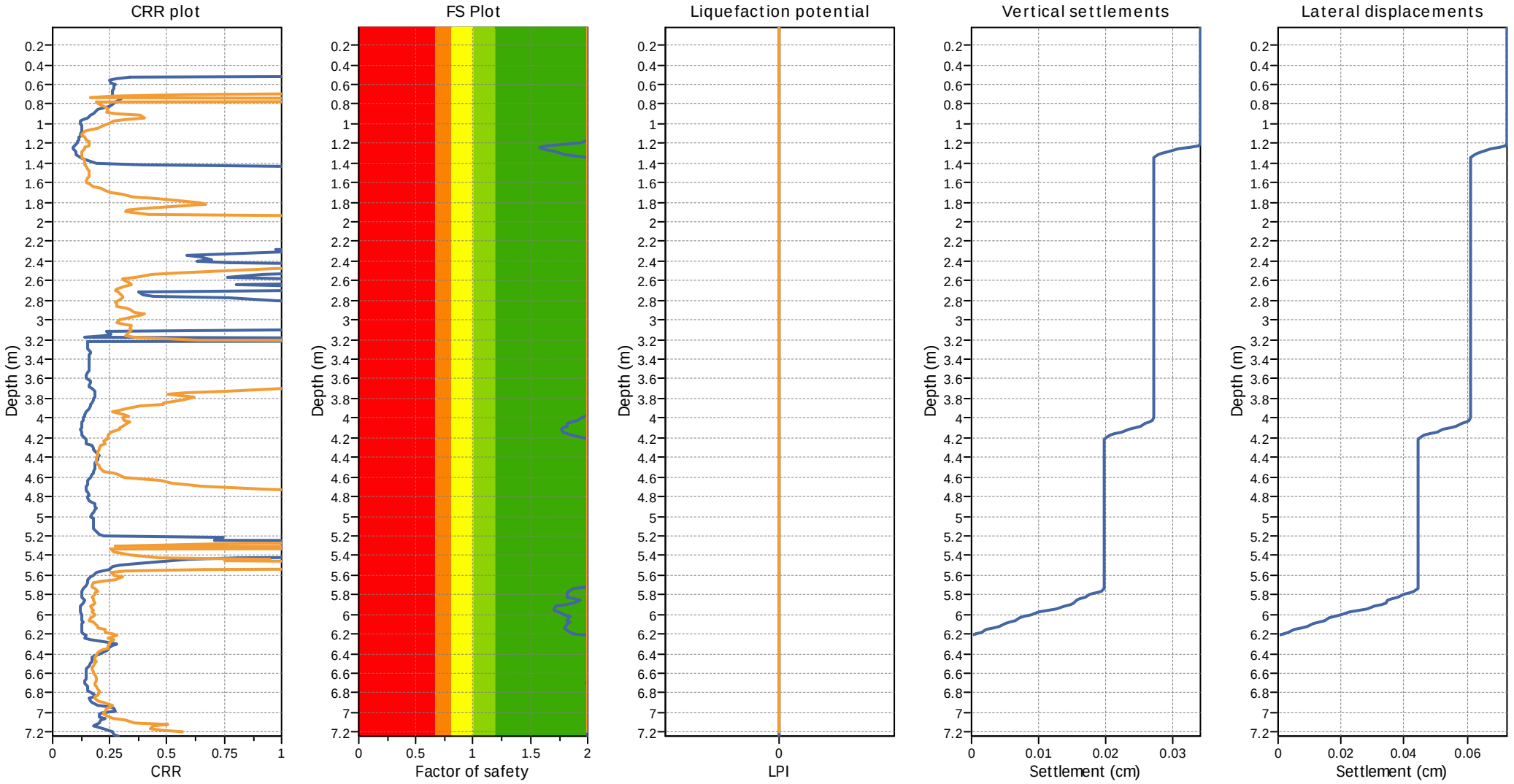
q_t: Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c: Soil Behaviour Type Index
$q_{c1N,cs}$: Equivalent clean sand normalized CPT total cone resistance
F.S.: Factor of safety
γ_{max}: Maximum cyclic shear strain
LDI: Lateral displacement index

AECOM NZ Ltd
121 Rostrevor Street
Hamilton
New Zealand

SLS DESIGN CASE

Project:

Overlay Cyclic Liquefaction Plots



AECOM NZ Ltd
121 Rostrevor Street
Hamilton
New Zealand

LIQUEFACTION ANALYSIS REPORT

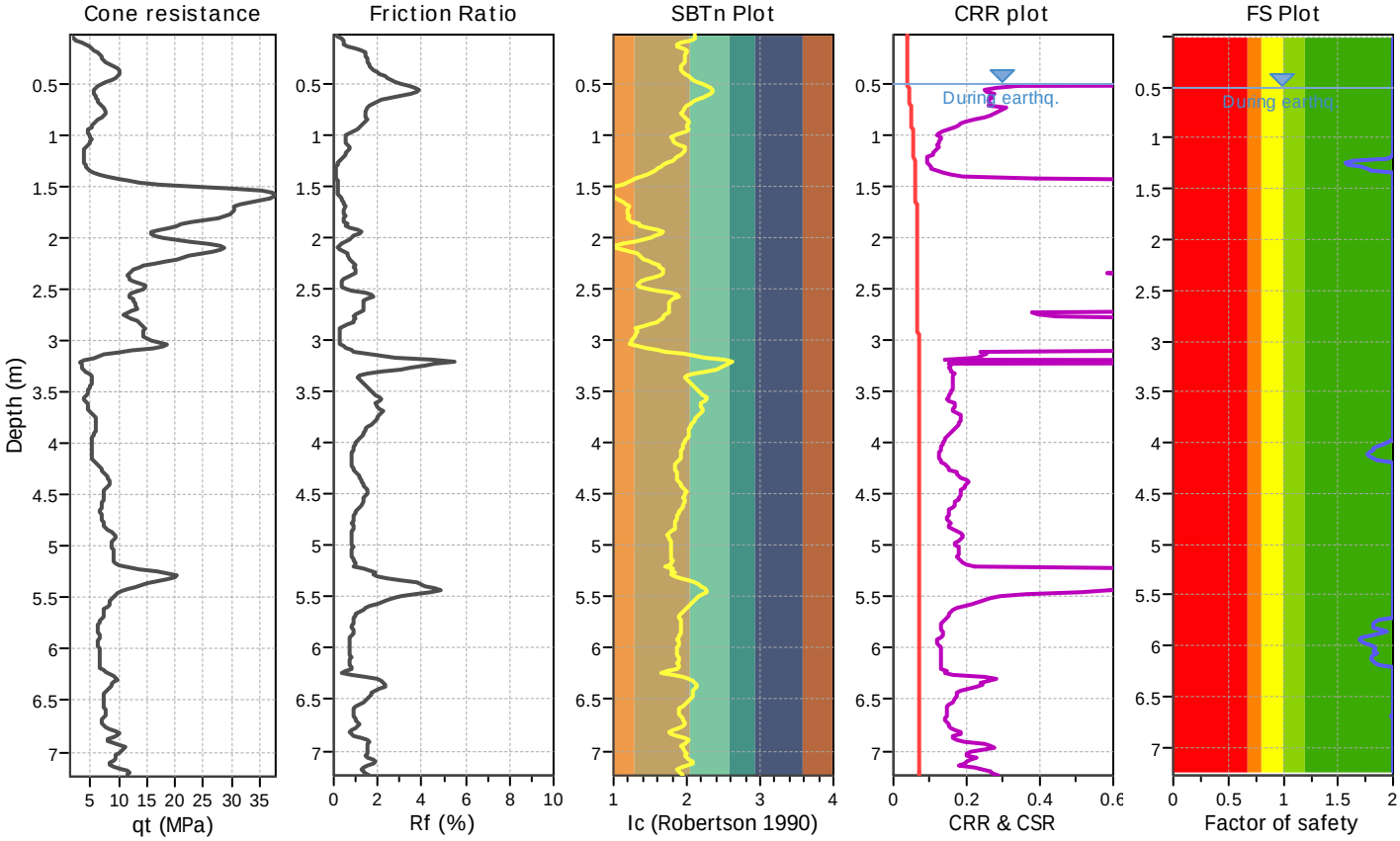
Project title :

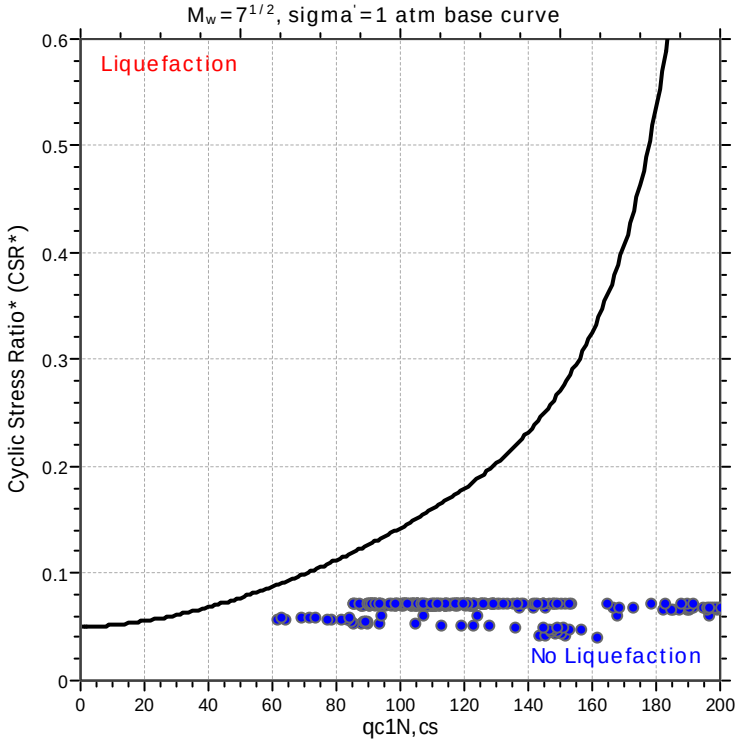
Location : 8 Hydro Road

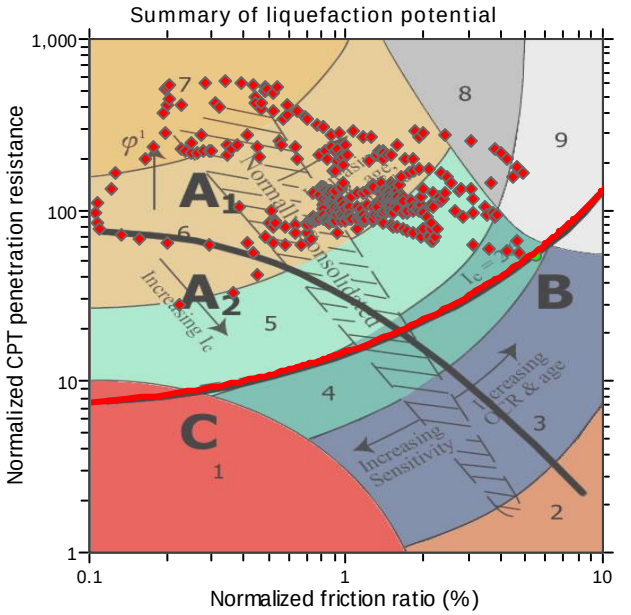
CPT file : CPT 1

Input parameters and analysis data

Analysis method:	I&B (2008)	G.W.T. (in-situ):	0.50 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	R&W (1998)	G.W.T. (earthq.):	0.50 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		
Peak ground acceleration:	0.06	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

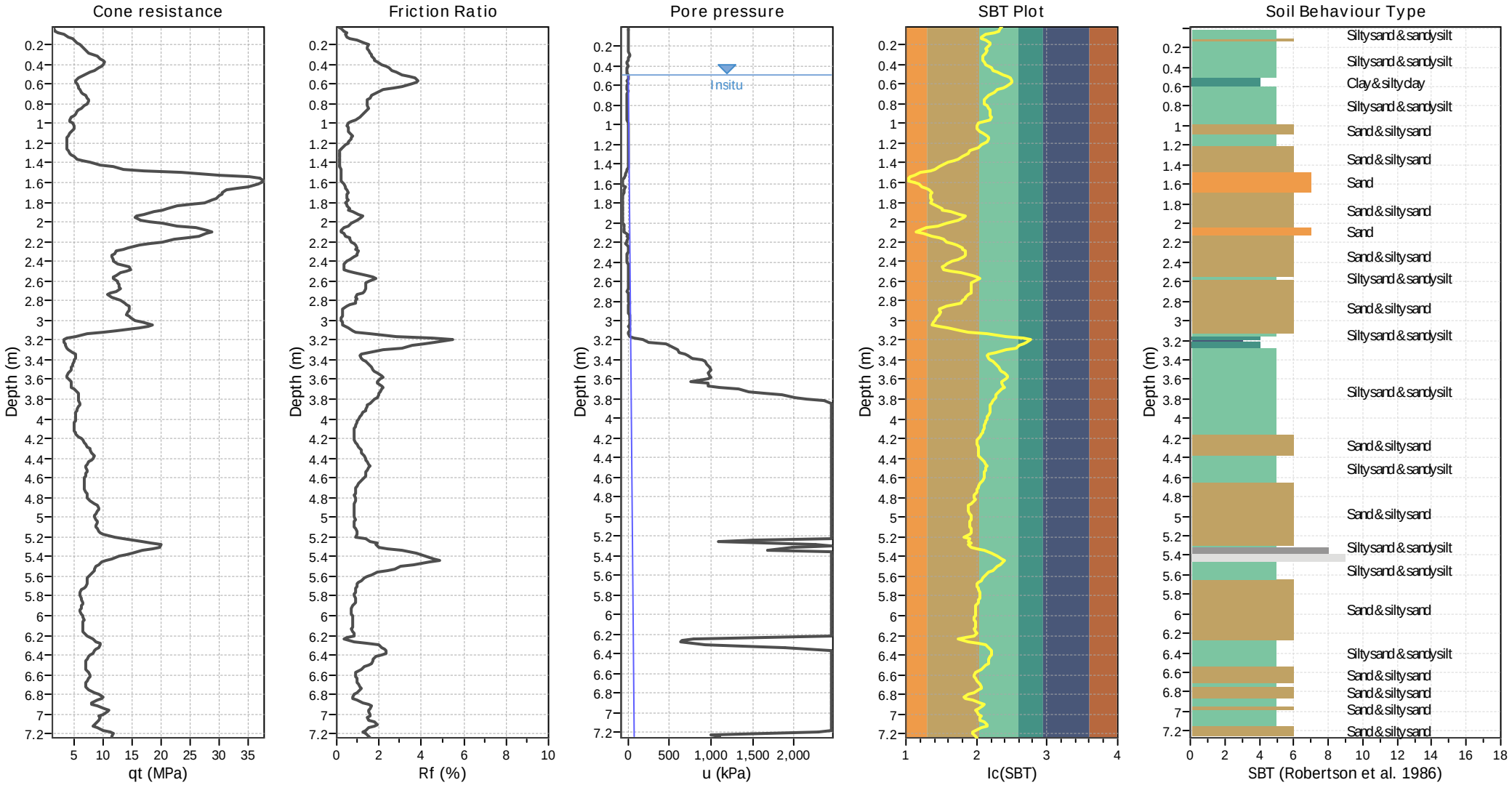






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and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

CPT basic interpretation plots



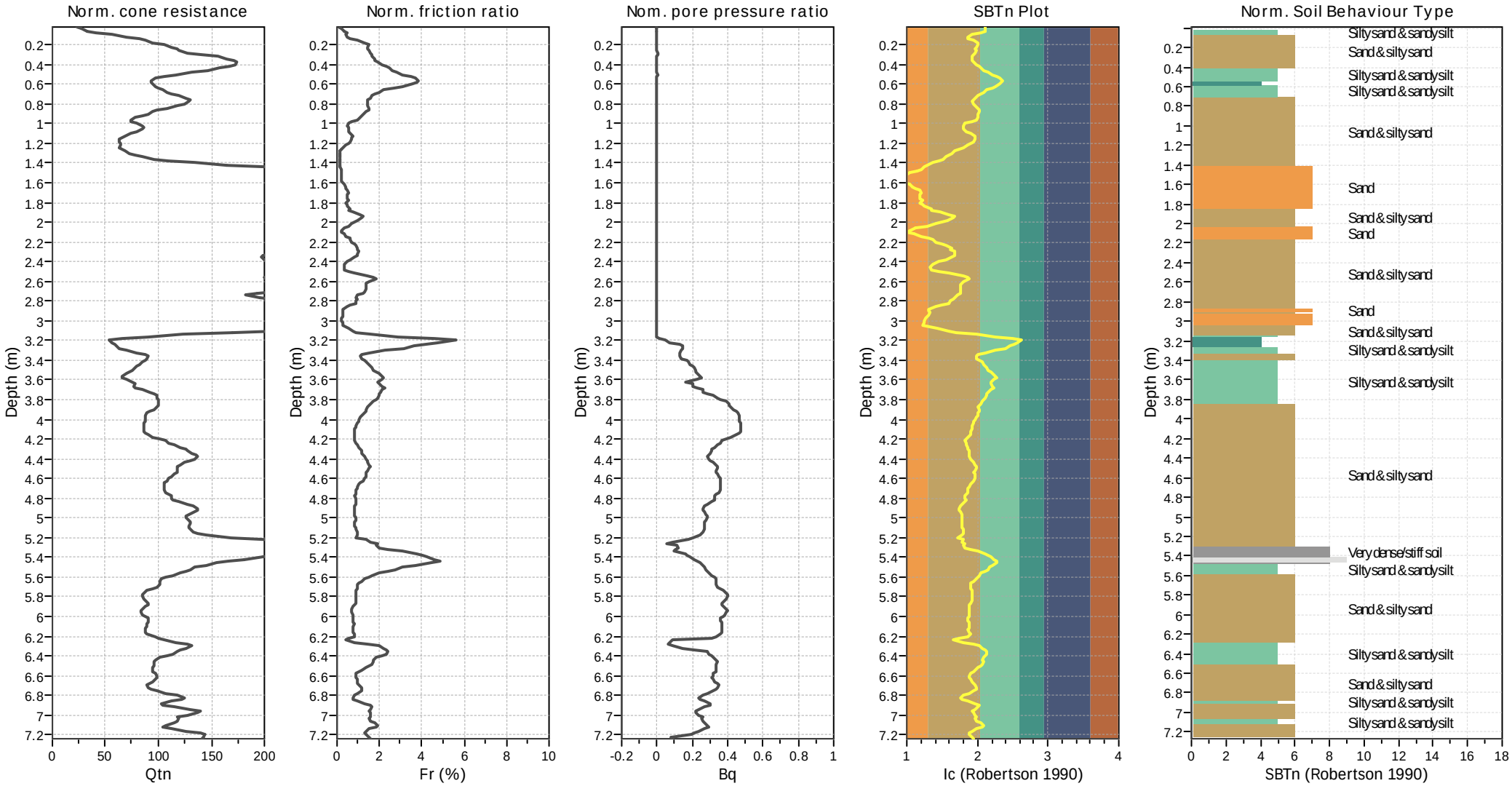
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
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:	.
Peak ground acceleration:	0.06	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 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

CPT basic interpretation plots (normalized)



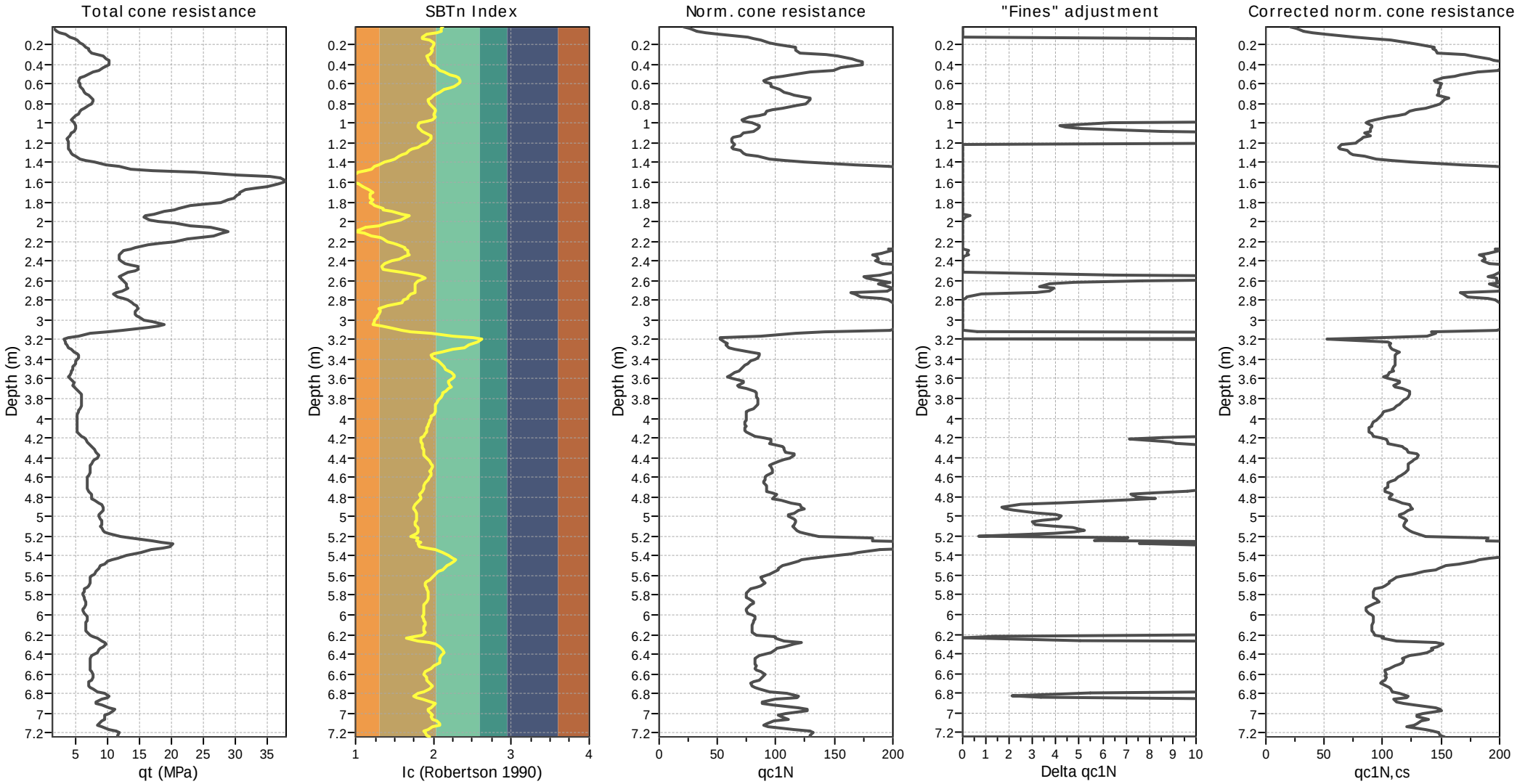
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
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:	.
Peak ground acceleration:	0.06	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

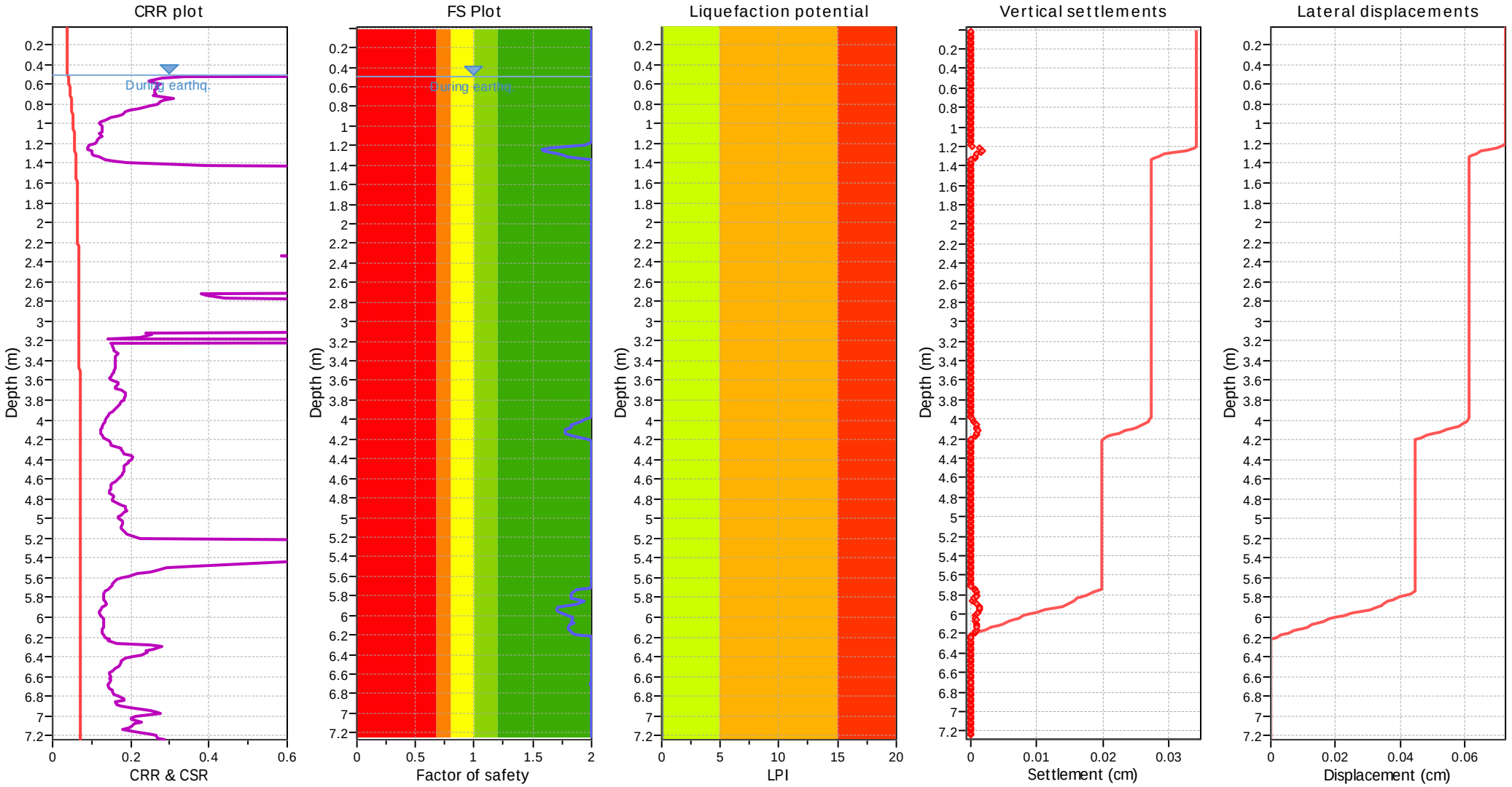
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
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:	.
Peak ground acceleration:	0.06	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 m	Fill height:	N/A	Limit depth:	N/A

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
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:	.
Peak ground acceleration:	0.06	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 m	Fill height:	N/A	Limit depth:	N/A

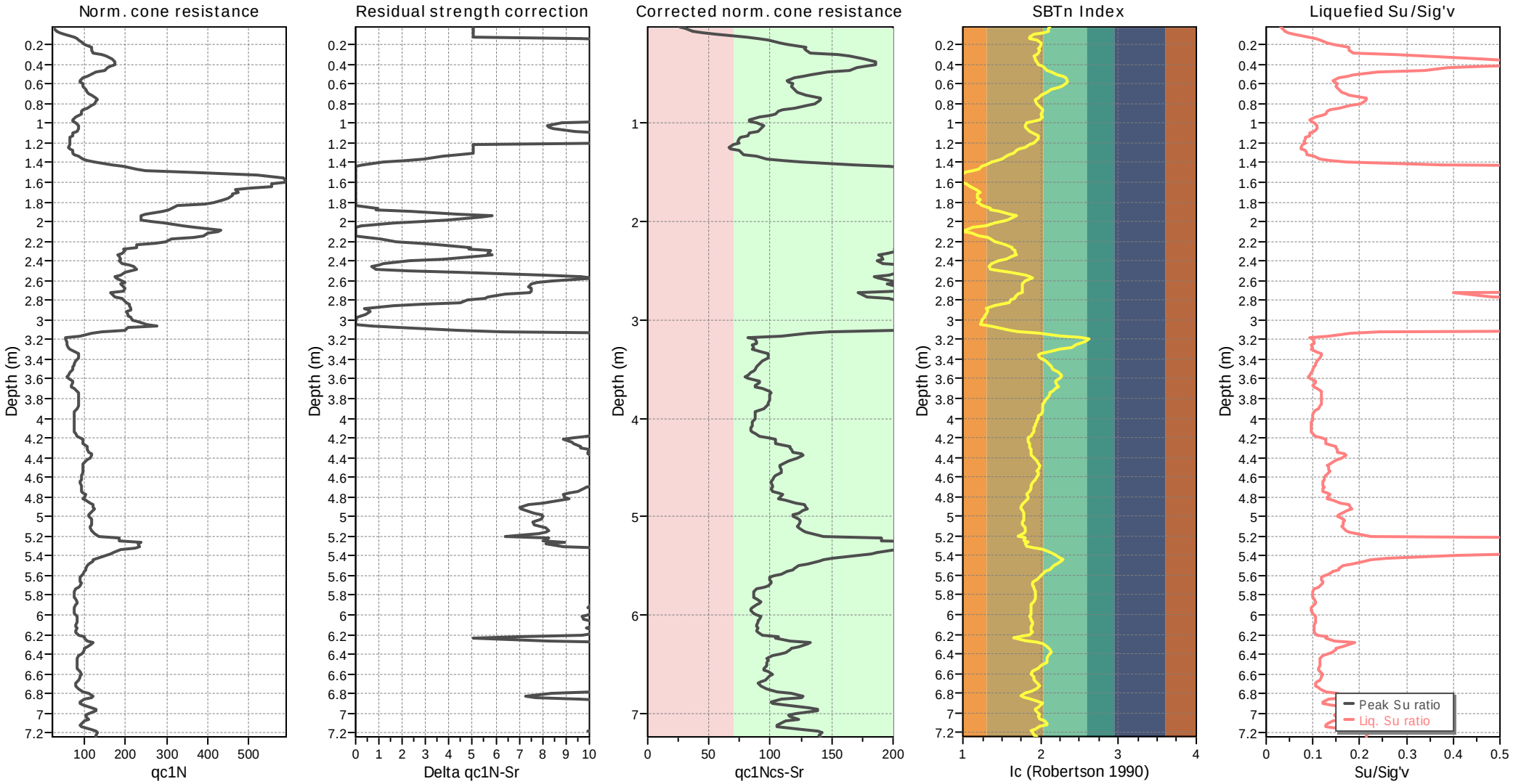
F.S. color scheme

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

LPI color scheme

- Very high risk
- High risk
- Low risk

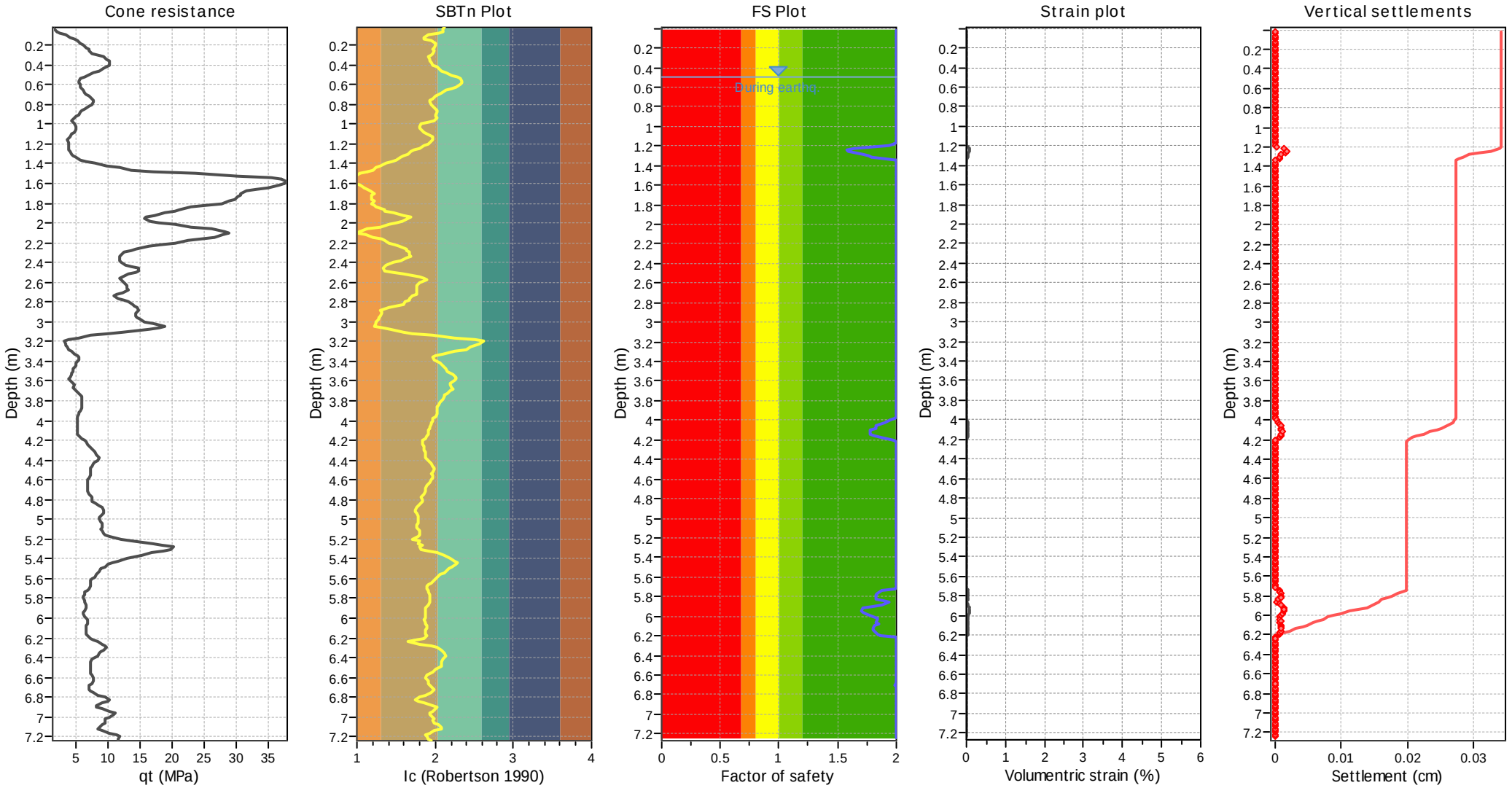
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
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:	.
Peak ground acceleration:	0.06	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 m	Fill height:	N/A	Limit depth:	N/A

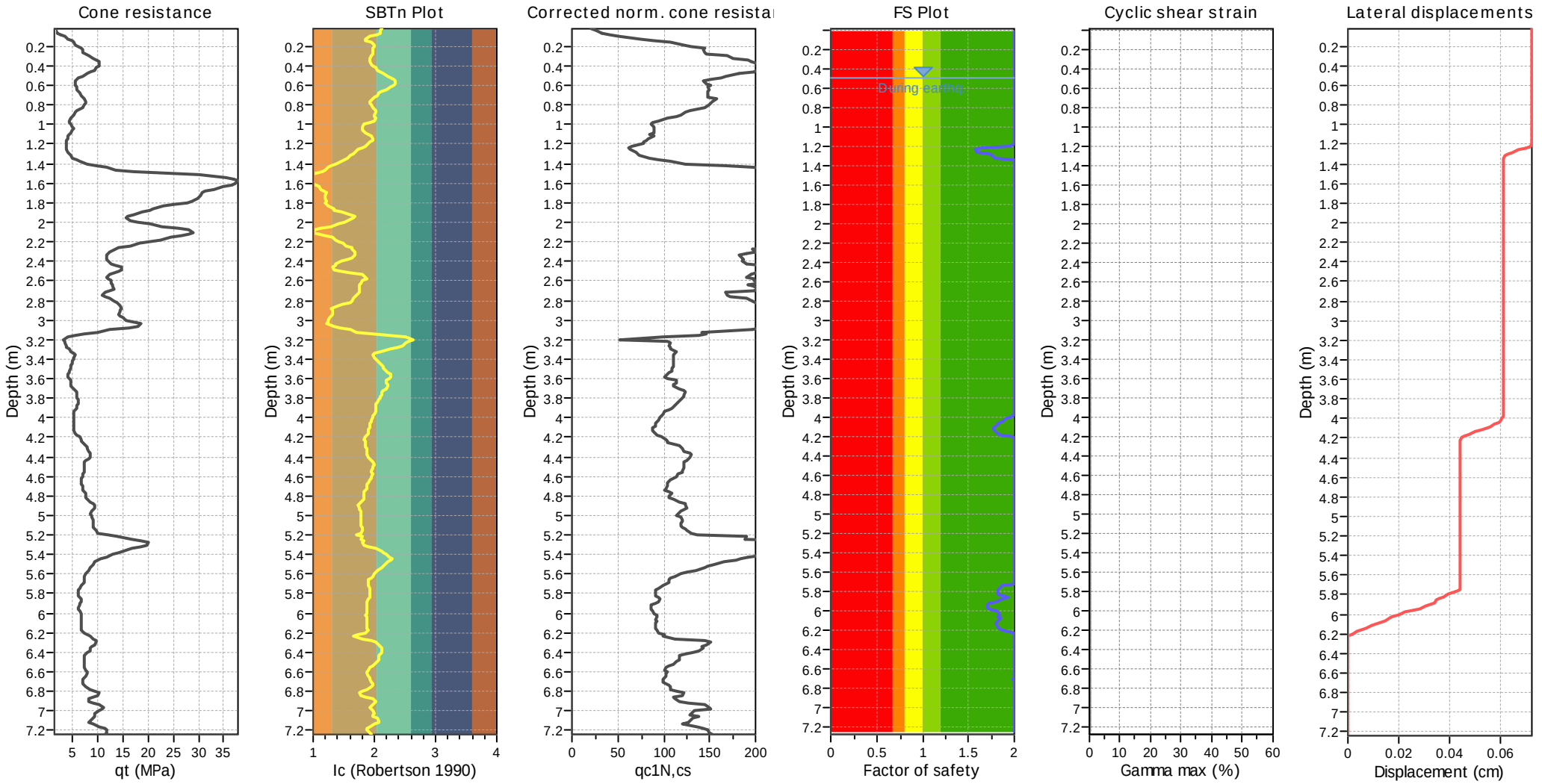
Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

Estimation of post-earthquake lateral Displacements



Abbreviations

q_t: Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c: Soil Behaviour Type Index
$q_{c1N,cs}$: Equivalent clean sand normalized CPT total cone resistance
F.S.: Factor of safety
γ_{max}: Maximum cyclic shear strain
LDI: Lateral displacement index

AECOM NZ Ltd
121 Rostrevor Street
Hamilton
New Zealand

LIQUEFACTION ANALYSIS REPORT

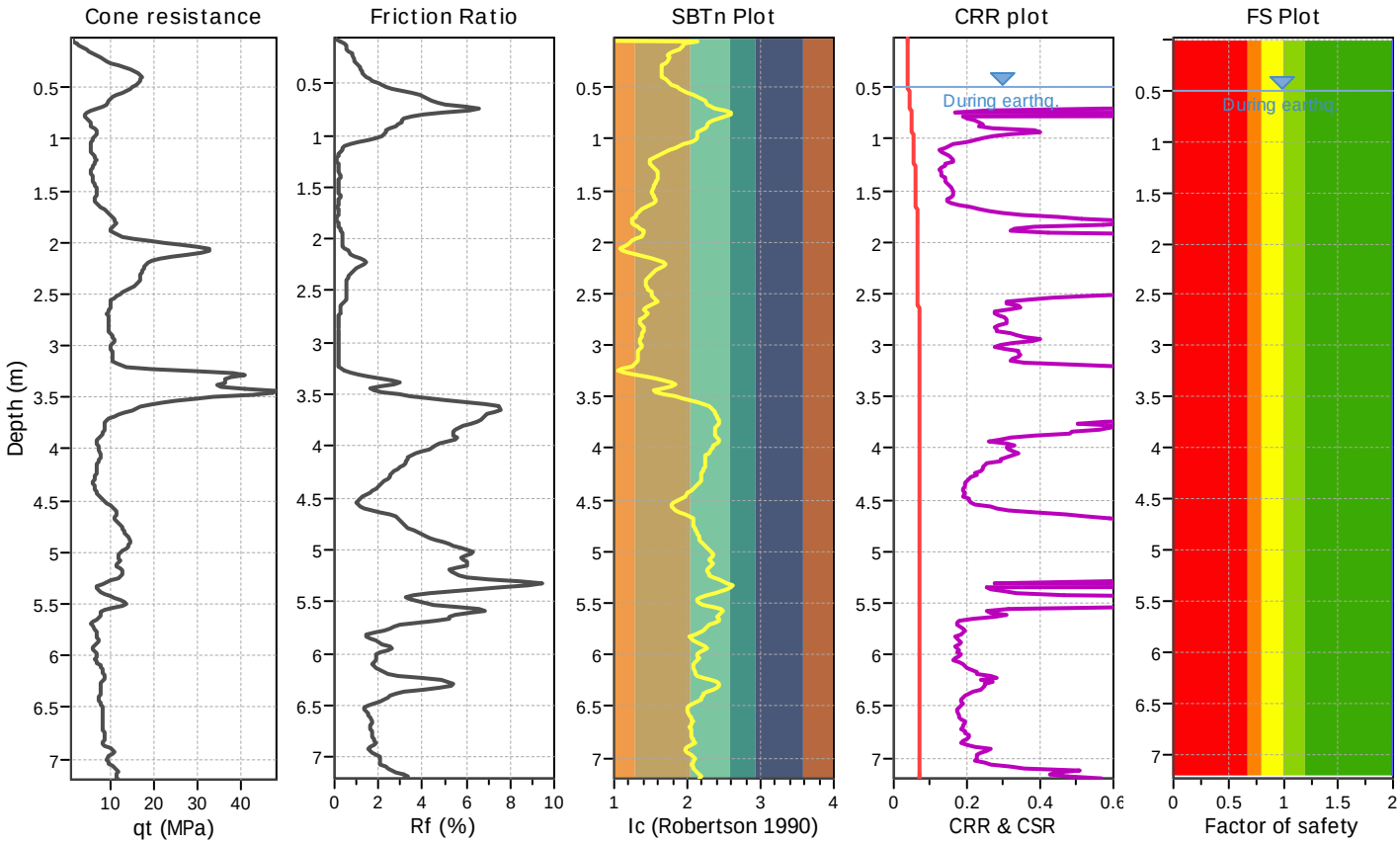
Project title :

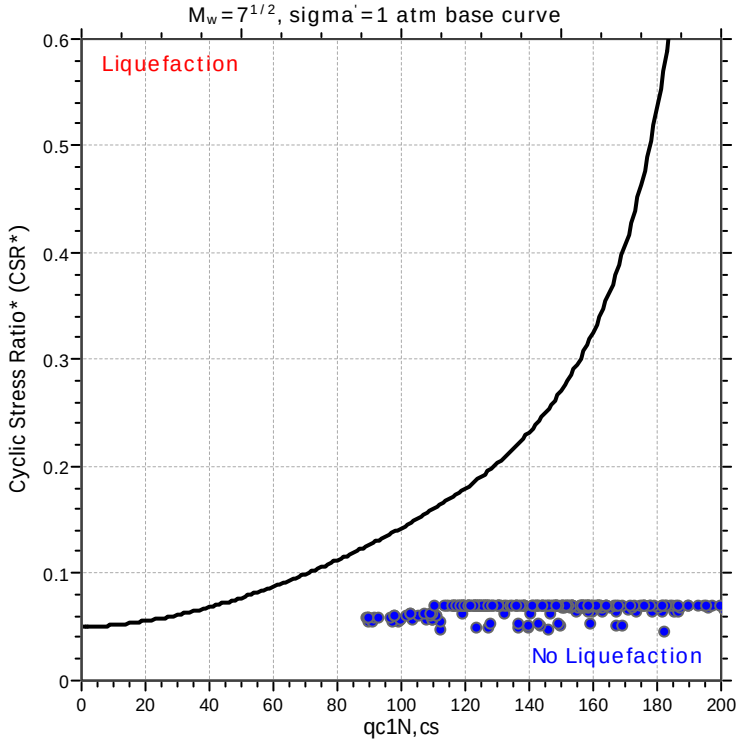
Location : 8 Hydro Road

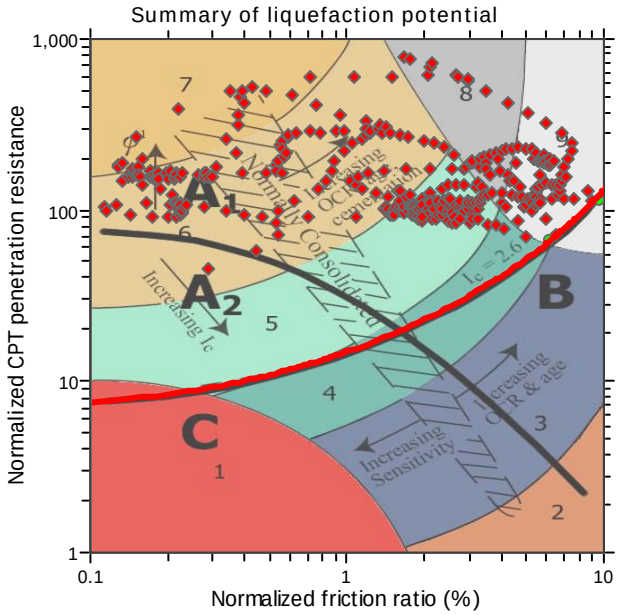
CPT file : CPT02

Input parameters and analysis data

Analysis method:	I&B (2008)	G.W.T. (in-situ):	0.50 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	R&W (1998)	G.W.T. (earthq.):	0.50 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		
Peak ground acceleration:	0.06	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

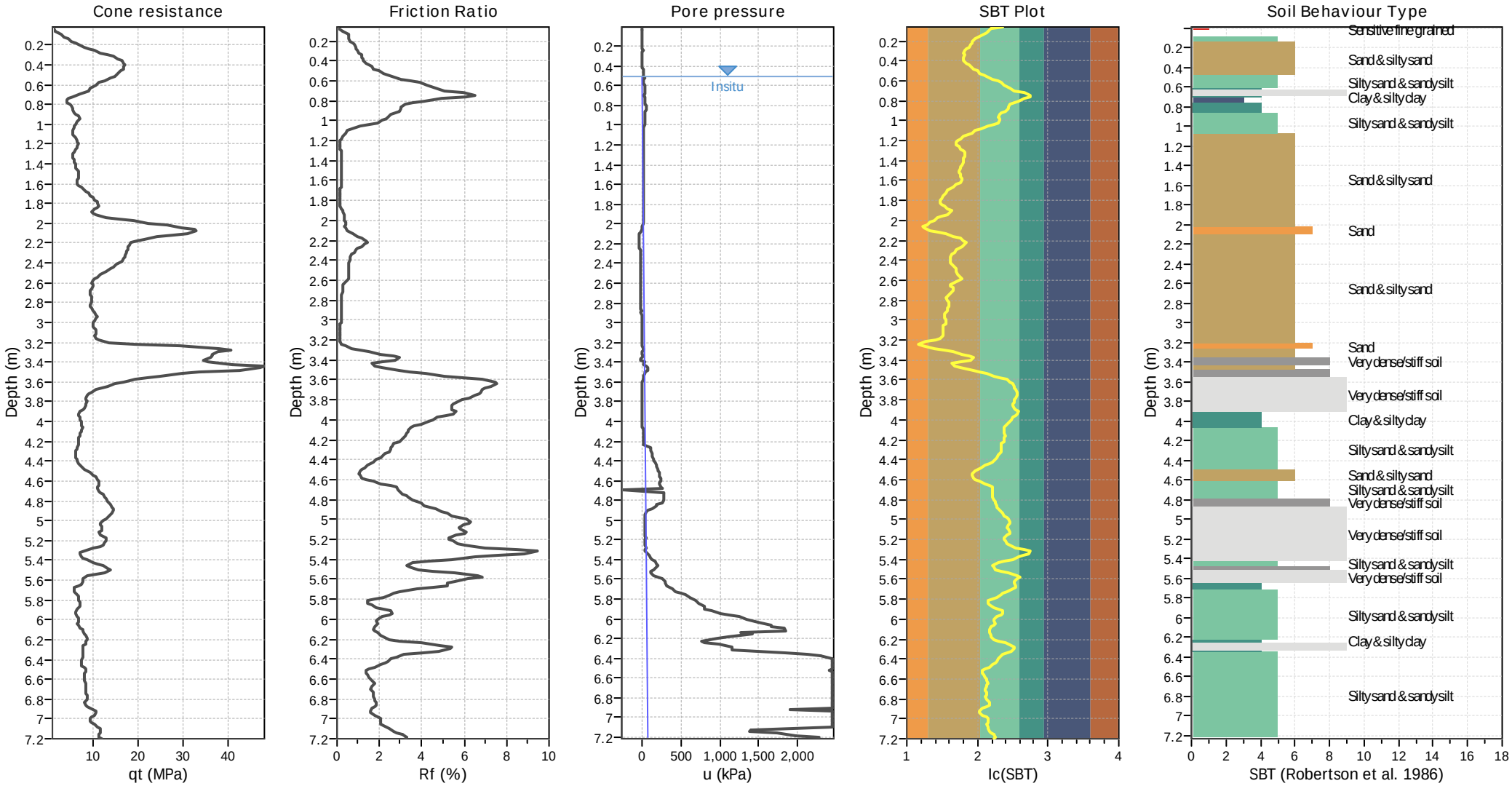






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and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

CPT basic interpretation plots



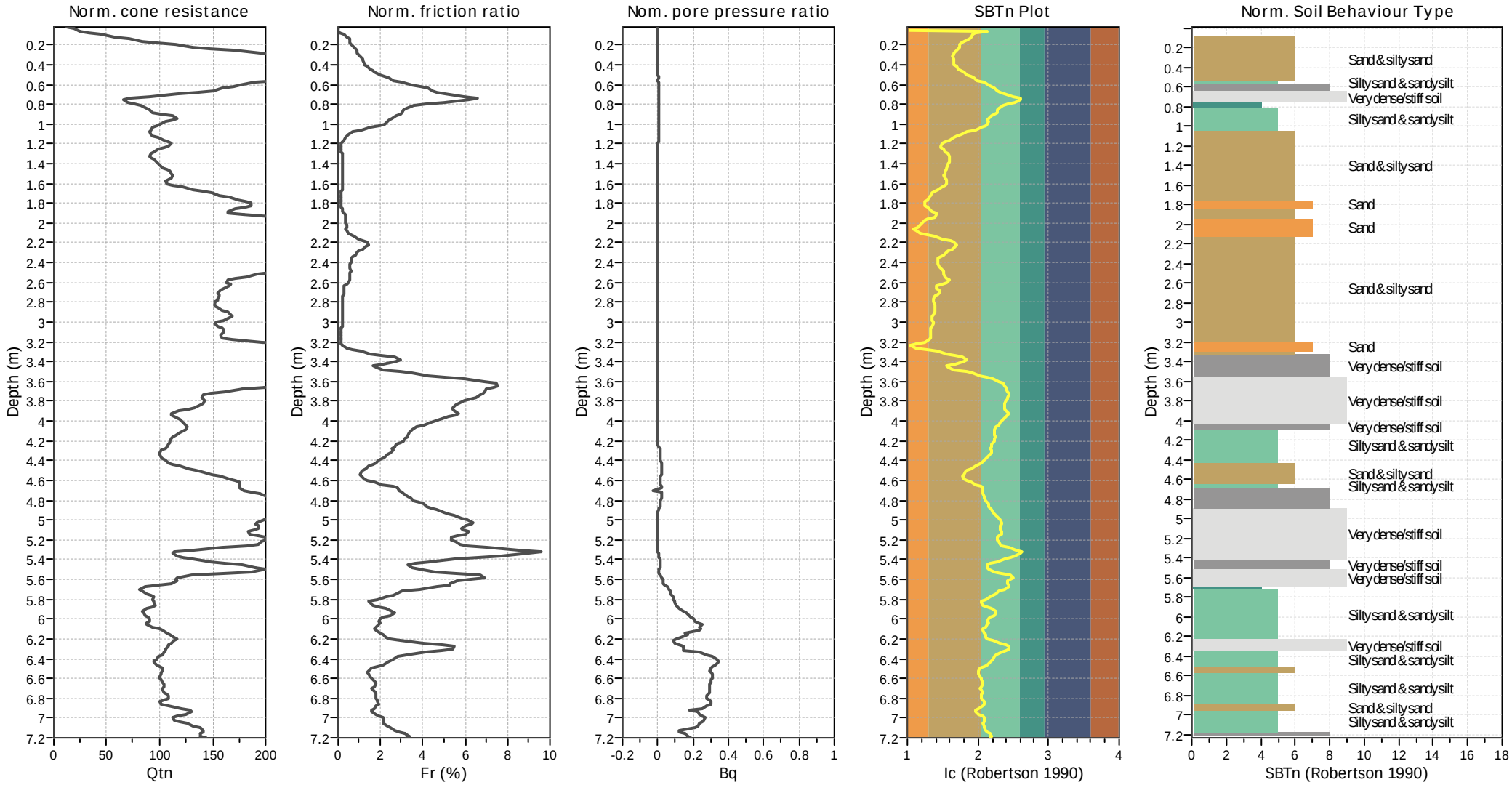
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
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:	.
Peak ground acceleration:	0.06	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 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

CPT basic interpretation plots (normalized)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
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:	.
Peak ground acceleration:	0.06	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn legend

1. Sensitive fine grained
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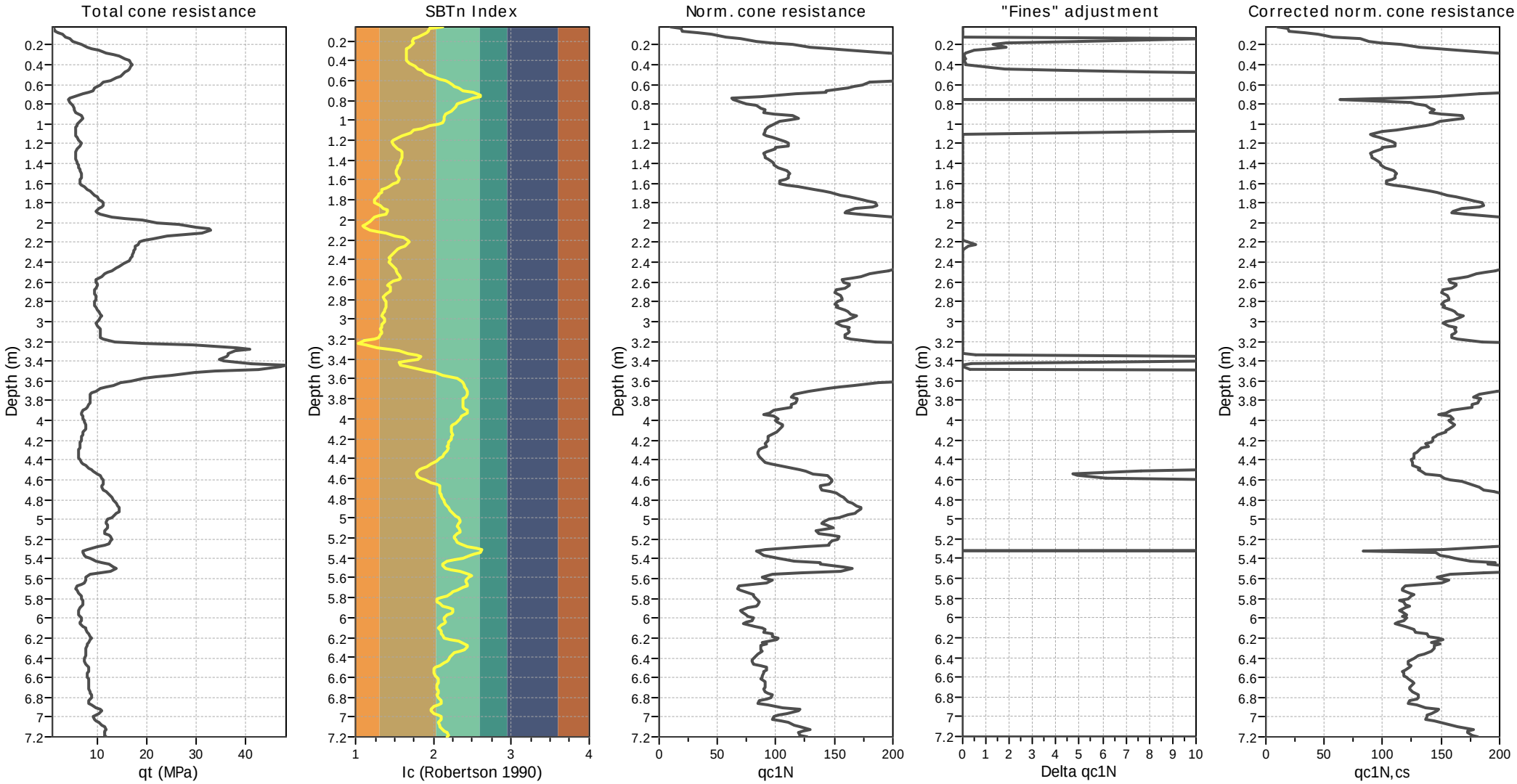
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

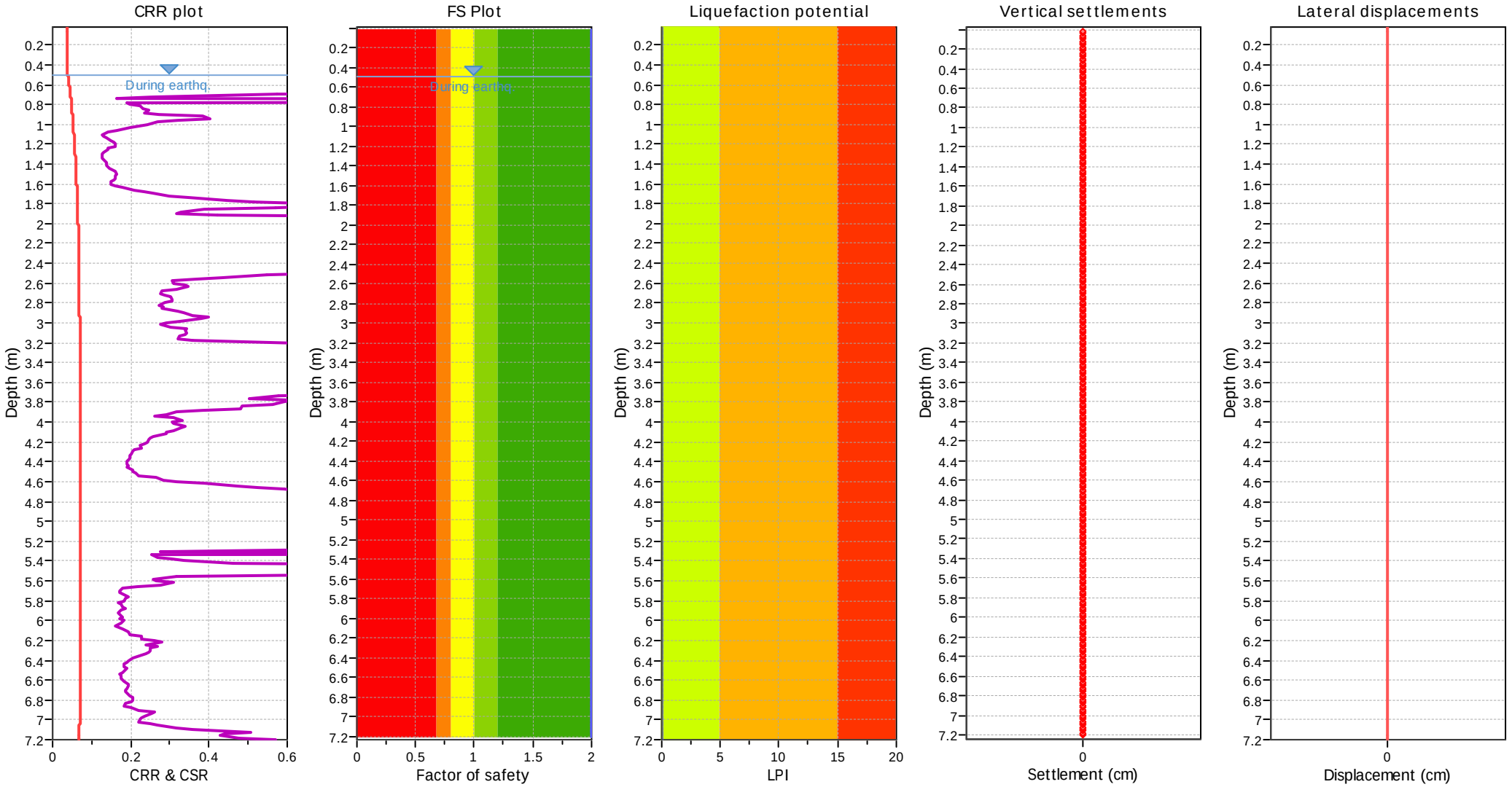
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
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:	.
Peak ground acceleration:	0.06	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 m	Fill height:	N/A	Limit depth:	N/A

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
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:	.
Peak ground acceleration:	0.06	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 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 liquefaction are equally likely
- Unlike to liquefy
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LPI color scheme
- Very high risk
- High risk
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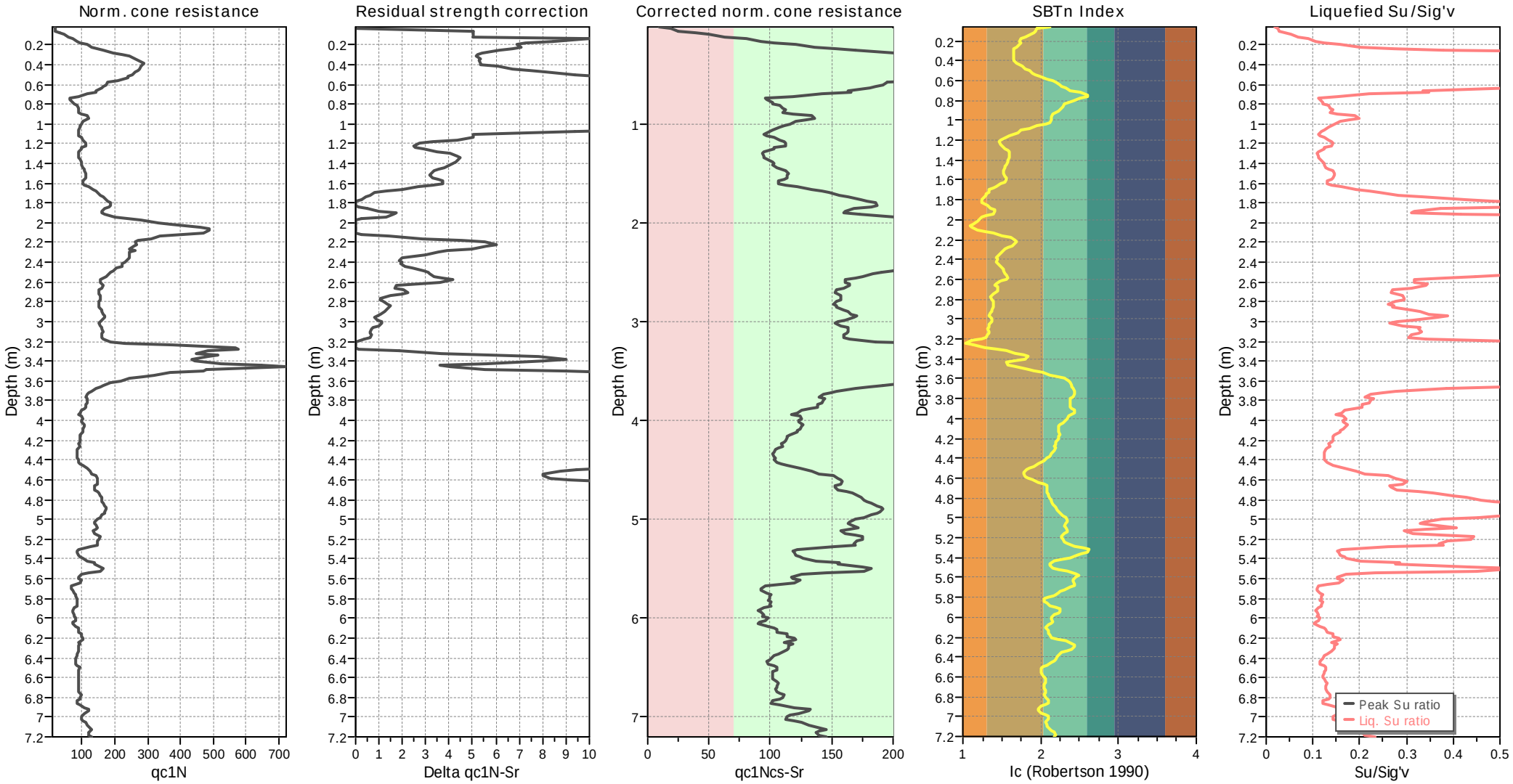
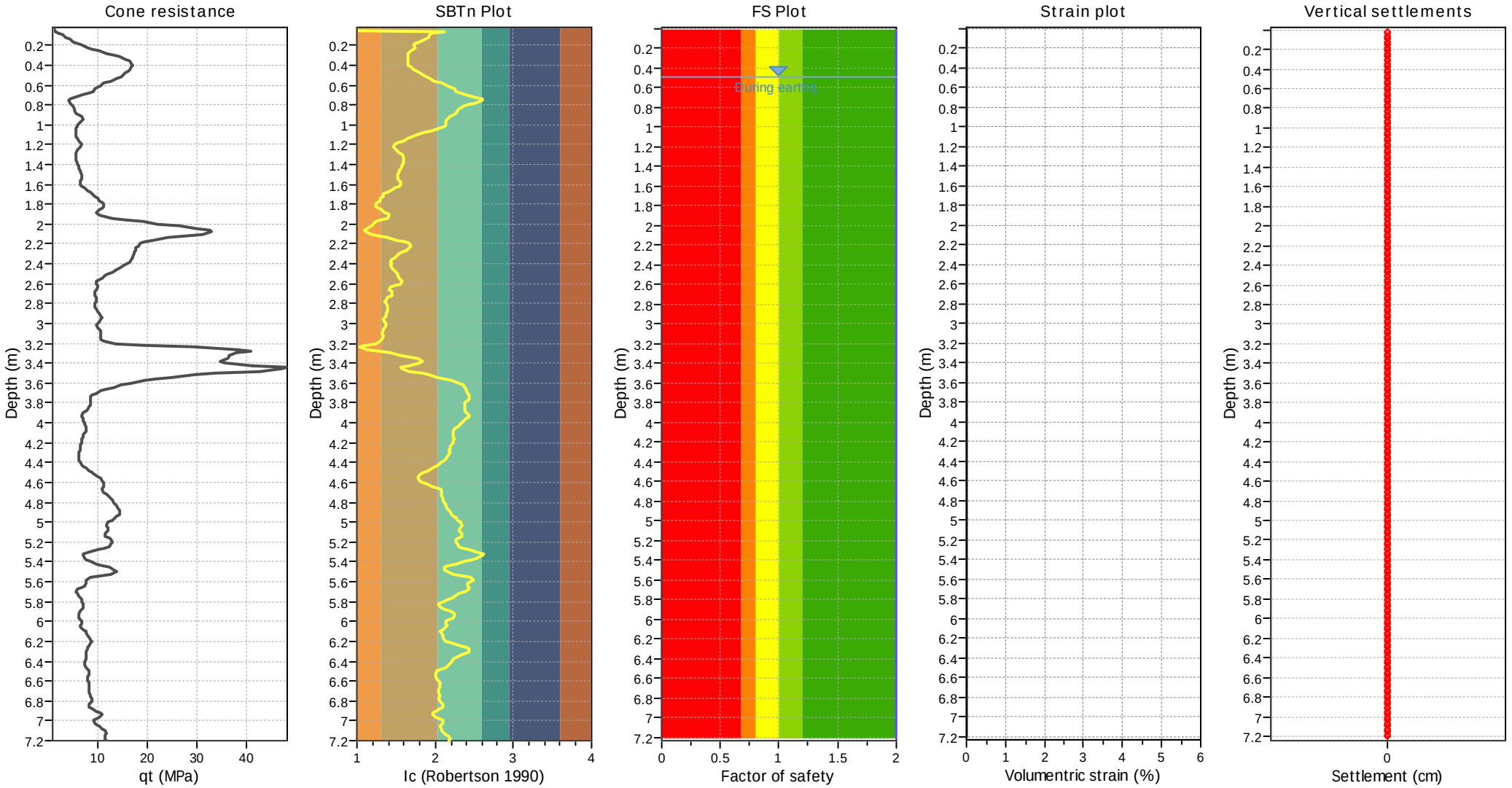
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
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:	.
Peak ground acceleration:	0.06	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 m	Fill height:	N/A	Limit depth:	N/A

Estimation of post-earthquake settlements



Abbreviations

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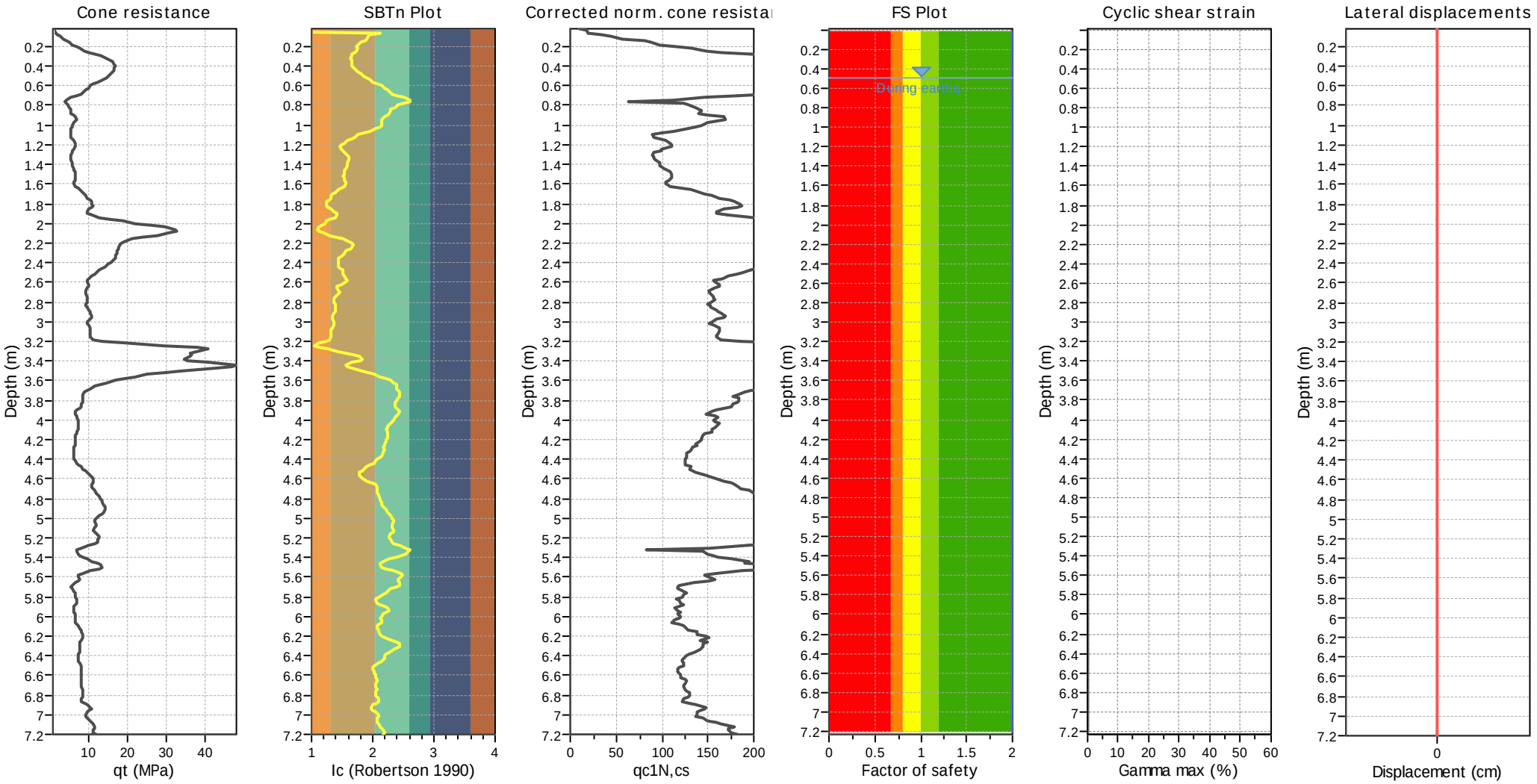
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

Estimation of post-earthquake lateral Displacements



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I_c: Soil Behaviour Type Index
$q_{c1N,cs}$: Equivalent clean sand normalized CPT total cone resistance
F.S.: Factor of safety
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