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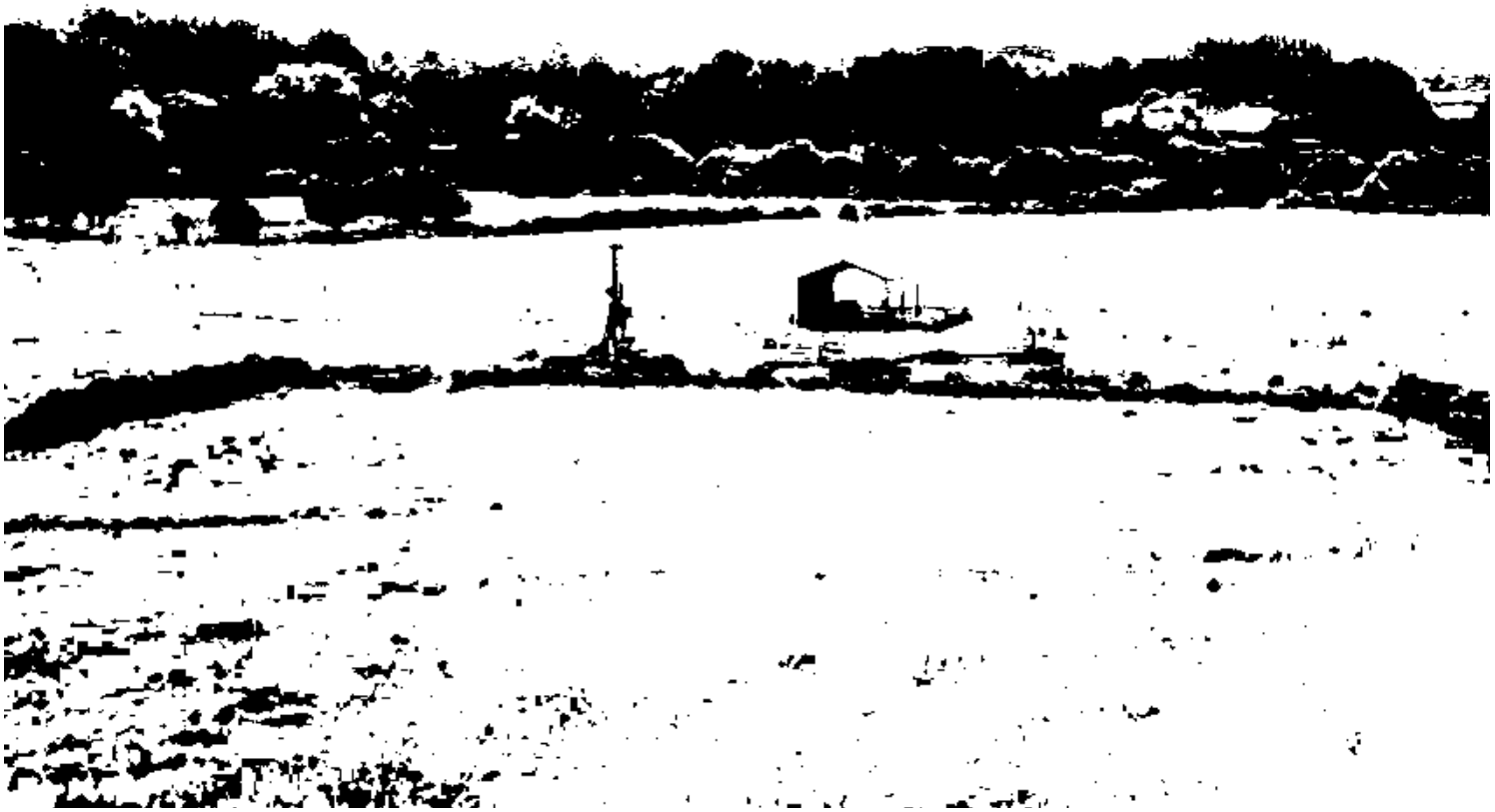
Report

Interpretative Report of Preliminary Geotechnical Investigation - CCC Halswell ODP

Prepared for Christchurch City Council

Prepared by Beca Ltd (Beca)

20 June 2014



Revision N°	Prepared By	Description	Date
1	Oliver Deutschle	Draft for Client review	16/4/14
2	Shaun Vemuri	Final report issued	23/5/14
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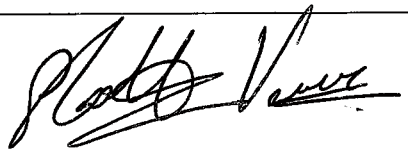
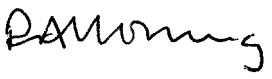
Action	Name	Signed	Date
Prepared by	**Oliver Deutschle**		20/6/14
Reviewed by	**Shaun Vemuri**		20/6/14
pp	**Gavin Alexander**		20/6/14
Approved by	**Richard Young**		20/6/14
on behalf of	Beca Ltd		

Executive Summary

Christchurch City Council (CCC) is reviewing the District Plan provisions for Christchurch, including several significant greenfield areas adjacent to Halswell (Halswell ODP Areas). As part of CCC's review, Beca Ltd (Beca) has been engaged to undertake a geotechnical study of these areas, to provide preliminary advice on the land condition and its anticipated performance during future seismic events. CCC's study area covers approximately 370 hectares of land divided into four areas and designated as R15 (West Halswell), R16 (South Halswell), R17 (South East Halswell) and R18 (Hendersons Basin).

This report provides a summary of the ground conditions and ground risks within the Halswell ODP Areas, which can be used to inform CCC's current plan change process. The work described in this report was completed by Beca for CCC in accordance with the terms and conditions given in the Consultancy Services Agreement (Contract No. 4600001175) dated 13/11/2013.

Prior to undertaking intrusive geotechnical investigations, Beca prepared a Geotechnical Desk Study report for CCC for the Halswell ODP Areas dated 11 October 2013, which should be read in conjunction with this geotechnical interpretative report.

The topography of the Halswell ODP areas is generally flat with gentle undulations, the surface being dissected by specific features such as drainage ditches and water courses. The exception to this is along the southern boundaries of R16, R17 and R18, where the ground rises at the foot of the Port Hills.

The subsurface geotechnical investigations undertaken for this study comprised 12 machine boreholes and 49 cone penetration tests (CPTs). The investigations were conducted in two phases, with the initial testing taking place in December 2013 and the second phase taking place January 2014. The target depth of the investigations was 15m, with the achieved depth varying depending on the specific ground conditions encountered.

The published geological maps indicate that the ground conditions comprise "dominantly alluvial sand and silt overbank deposits" in the order of 10 to 20m thick and some "alluvial gravel, sand, and silt of historic river flood channels" of the Yaldhurst Member of the Springston Formation. Beneath the plains the unconsolidated alluvial sediments are up to approximately 800m thick and thin towards the Port Hills, where loess and the Lyttelton Volcanic Group are present.

The soil profile encountered in the exploratory holes is consistent with the published regional geology, consisting predominantly of alluvial gravels, silts, and sands with lesser amounts of peat, but with notable vertical and horizontal variability.

Groundwater is estimated to be between 0.5m and 1.5m depth throughout the Halswell ODP areas based on the GNS Science Median Groundwater Surface Elevation map, ECan well records and observations made during the December 2013 / January 2014 field investigations.

Liquefaction analyses of the CPT data indicate that significant zones of the Halswell ODP Areas have liquefaction potential. Most of the calculated liquefaction induced settlements in R15 and R18 were greater than 50mm for a moderate earthquake (SLS event) and greater than 100mm for a major earthquake (ULS event). In R16 the liquefaction potential was less, but still significant, with most calculated liquefaction induced settlements in the range 15-50mm for a moderate earthquake (SLS event) and 25-100mm for a major earthquake (ULS event). Of all the zones R17 had the least calculated liquefaction induced

settlements with most settlements being less than 15mm for a moderate earthquake (SLS event) and less than 25mm for a major earthquake (ULS event). However, it should be noted that within each zone there was a wide range of calculated liquefaction induced settlements.

Based on the work by Bradley & Hughes the Halswell ODP areas have been subjected to approximately ULS horizontal Peak Ground Accelerations (PGAs) in September 2010 and February 2011 and SLS horizontal PGAs in June and December 2011.

Liquefaction is predicted across large parts of the Halswell ODP Areas and should be considered in some detail when considering the potential land use. It is likely to be the main governing criteria in assessing the suitability of land for future development. In addition to liquefaction, densification of coarse grained soils and cyclic strain softening of fine grained soils can occur, resulting in settlement and / or a loss of stability of the material.

The calculated seismic risks of liquefaction and lateral spreading suggest that, without treatment, large areas of land, notably in R15 and R18, would be classified as TC3 according to MBIE guidance. The R16 and R17 zones contain land classified as TC2, as well as TC3. The TC3 zones within these areas offer an opportunity to carry out site wide ground improvement, such as excavation and replacement and permanent surcharging, to bring the whole site up to a TC2 category.

The risk of lateral spreading is generally high where liquefiable soils exist near natural water courses and / or other ‘free faces’, the level of risk depending on the particular configuration of ‘free face’, stratigraphy and seismic loading. Within TC3 land, set back distances for stormwater ponds and other free faces will need to be nominated and these might be in the range of 30m to 50m.

Areas of R16 and both R15 and R17 are outside the existing and proposed Flood Management Area (FMA). The south-western corner of R16 is within the proposed FMA and large parts of R18 are within the proposed FMA for Hendersons Basin, Cashmere Stream and Hoon Hay Valley. The restrictions imposed by the FMA will need to be considered in the re-zoning of the Halswell ODP Areas.

Soft and / or compressible soils, including peat and organic silt, are often present close to ground level, and these soils will have low bearing capacity and, when loaded, undergo significant settlement. Hence the static settlement potential of the soils should be considered for any development within the Halswell ODP areas, including treating the organic soils where appropriate.

The high groundwater, and its potential to fluctuate seasonally and inter-annually, will influence storm water disposal, subsurface infrastructure construction and the seismic performance of the ground. Additionally the bearing capacity of near-surface soils will be reduced where groundwater is high.

Land stability in general is not considered a high risk for Halswell ODP areas, with the exception of areas immediately next to free edges and at the foot hills of the Port Hills.

In summary the geotechnical investigations undertaken by Beca have not uncovered any areas deemed unsuitable for development *per se*. However; there are significant geotechnical risks to be considered. It is recommended that the aspects discussed above are considered in some detail when considering the proposed zoning of the Halswell ODP areas, particularly parts of R15 and R18. Where possible it is recommended that residential and business developments be placed on TC2 land, whether this is existing TC2 land, or land brought up to that standard by site ground improvements.

Contents

Appendices

Glossary of Terms

AEP – Annual Exceedance Probability

BGL – Below ground level

BH – Borehole

CBD – Central Business District

CCC – Christchurch City Council

CERA – Canterbury Earthquake Recovery Authority

CFA – Continuous flight auger

CGD – Canterbury Geotechnical Database

CPT – Cone Penetration Test

DBH – Department of Building and Housing now, **MBIE** – The Ministry of Business, Innovation & Employment

ECan – Environment Canterbury

EQC – Earthquake Commission

FMA – Flood Management Area

GNS – Institute of Geological and Nuclear Sciences Limited

LRI – Liquefaction Resistance Index

NZS – New Zealand Standard

ODP – Outline Development Plan

PGA – Peak Ground Acceleration

RL – Reduced Level

SLS – Serviceability Limit State

SMP – Stormwater Management Plan

SWMA – Surface Water Management Area

TC – Technical Category

TSD – Total Storm Detention

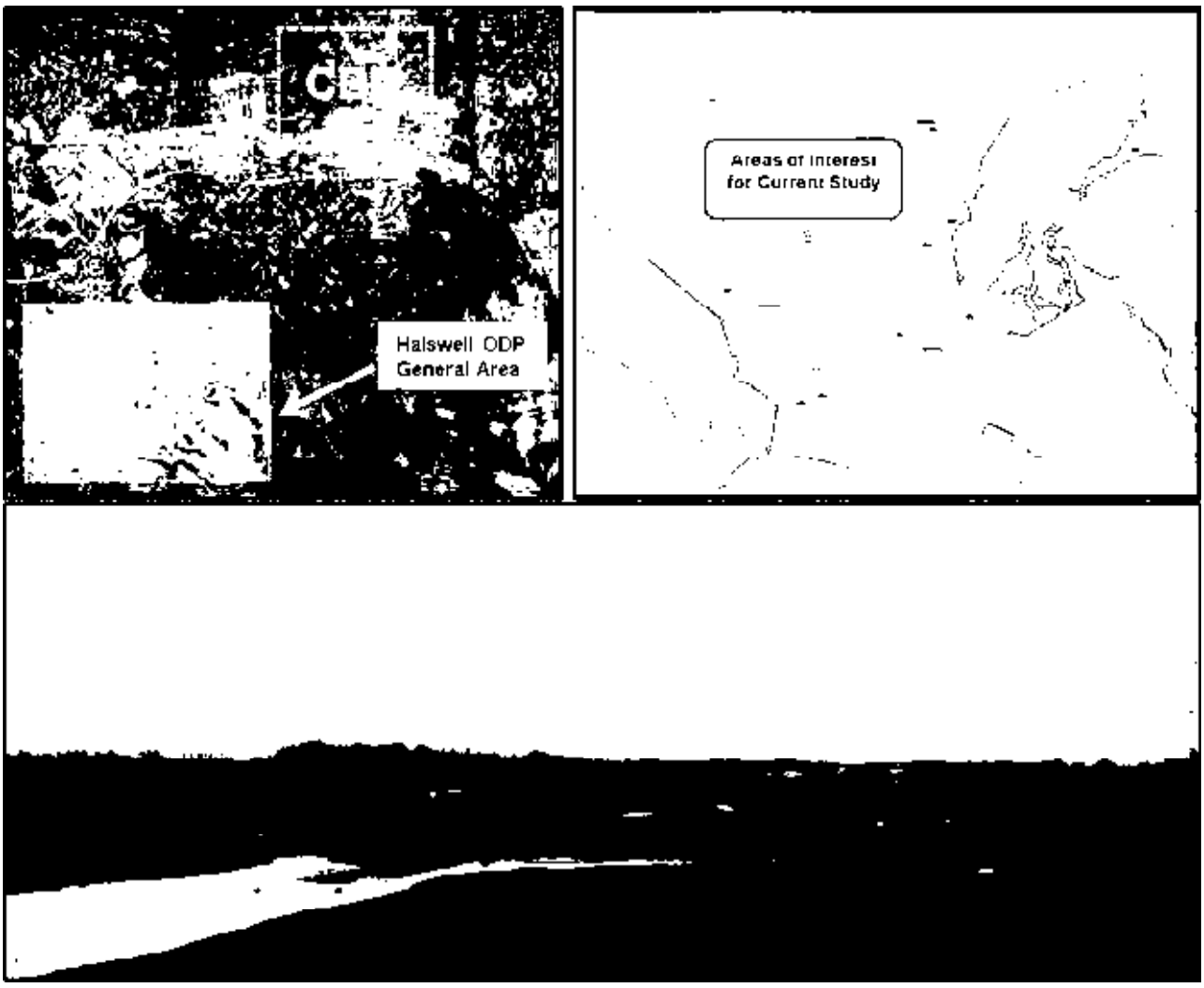
ULS – Ultimate Limit State

1 Introduction

Christchurch City Council (CCC) is reviewing the District Plan provisions for Christchurch, including several significant greenfield areas southwest of the Christchurch Central Business District (CBD), adjacent to Halswell. The Canterbury earthquake sequence has highlighted the effect the ground conditions can have on development. Hence, as part of CCC's review, Beca Ltd (Beca) has been engaged to undertake a geotechnical study of these areas, to provide preliminary advice on the land condition and its anticipated performance during future seismic events.

CCC's study area covers 370 hectares of land divided into four areas and designated as R15, R16, R17 and R18 (refer Figure 1). For the purposes of this report, the four areas, named below, have been collectively referred to as the Halswell ODP (Outline Development Plan) areas.

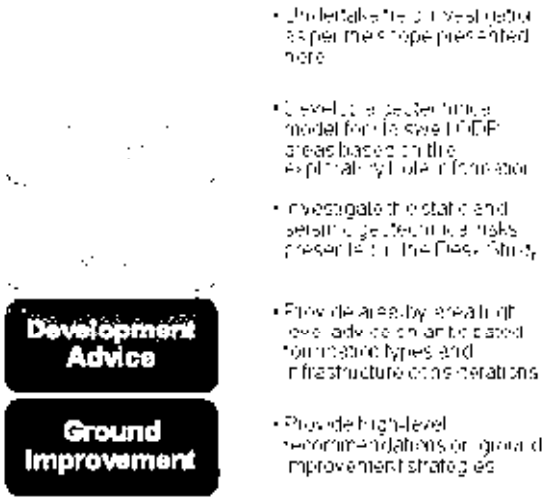
- West Halswell (R15)
- South Halswell (R16)
- South East Halswell (R17)
- Hendersons Basin (R18)



CCC is reviewing the District Plan provisions for Christchurch, including several significant blocks of rural land in the Halswell ODP areas. A preliminary geotechnical investigation has been undertaken to inform this District Plan Review and the preparation of an Outline Development Plan, which may include the re-zoning of areas for future urban and residential development. CCC wishes to investigate the geological condition of the land for potential residential and business development and associated infrastructure, comprising the following:

- Residential activities
- Business / retail activities
- Access roads
- Open space
- Drainage/storm water facilities including treatment and conveyance.

This report provides the summary results of a high-level geotechnical study of ground conditions and likely ground risks within the Halswell ODP Areas. This geotechnical assessment can be used to inform CCC's current plan change process. The work described in this report was completed by Beca for CCC in accordance with the terms and conditions given in the Consultancy Services Agreement (Contract No. 4600001175) dated 13 November 2013. A schematic summary of the stages of the assessment is presented below (Figure 2).



The scope of work undertaken comprises:

- Preparation of a single Factual Report (reported separately), comprising:
  - Exploratory hole logs,
  - Photographs,
  - CPT plots, and
  - Results of laboratory tests.
- An interpretation of the intrusive investigation data, comprising:
  - Development of a conceptual ground model for the site,
  - Evaluation of liquefaction potential (based on NZS 1170.5:2004 and the August 2011 amendment to the Building Code),

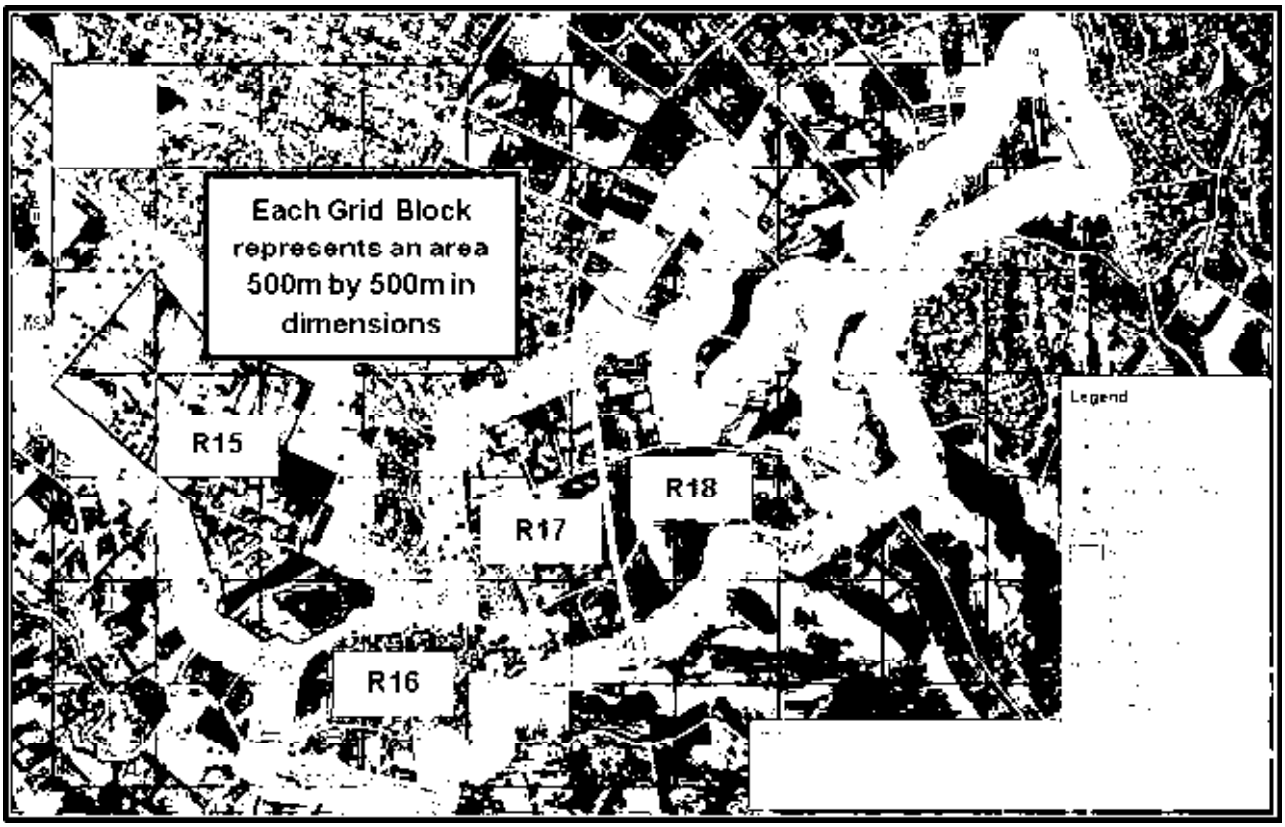
  - Estimate the seismic and liquefaction induced settlements under both ULS and SLS states,
  - An assessment of the risk of lateral spreading,
  - Advising on the suitability of the land for residential and business uses and associated roading, storm water and drainage infrastructure,
  - A preliminary assessment on the degree and extent of ground strengthening that may be required to bring the land up to suitable level for residential and business development, and
  - Providing high-level advice on the mitigation methods and indicative costs for appropriate ground improvement methods.
- Preparation of a single Geotechnical Investigation and Assessment Report, presenting the findings of the assessment and discussion on the aspects given above for the Halswell ODP areas.

The extents of the geotechnical investigation given in the Consultancy Services Agreement (Contract No. 4600001175 Variation 1) were discussed and agreed during a kick-off meeting between CCC and Beca on 20 November 2013.

2 Site Description

Prior to undertaking this intrusive geotechnical investigation, Beca prepared a Desk Study of the Halswell ODP areas for CCC. The purpose of the desk study was to use publically available information and information available from CCC sources to provide a general overview of the likely ground conditions and ground risks, without undertaking any intrusive investigation. The Geotechnical Desk Study report (NZ1-8032776) for CCC Halswell ODP dated 11 October 2013 should be read in conjunction with this geotechnical interpretative report.

The CCC defined boundaries for the four areas have been adopted as the site extents for this geotechnical investigation (refer Figure 3). For the purposes of the investigation, Beca has divided the Halswell ODP areas into an alpha-numeric grid, as shown in Figure 3. The alpha-numeric grid has been used to provide area specific geotechnical recommendations as part of this study.



The topography of the Halswell ODP areas is generally near horizontal with gentle undulations. Elevations measured across the site range from 19m to 25m Reduced Level (RL), according to the Christchurch Drainage Datum. Locally there are minor variations in elevation associated with specific features such as drainage ditches and water courses. The exception to this is along the southern boundaries of R16, R17 and R18, where the ground rises at the foot of the Port Hills to approximately 35m RL.

Area R15 is bounded by Halswell Junction Road to the north, Murphys Road to the west, Quaifes Road and Candys Road to the south, and Sabys Road and Halswell Road to the east. The area is primarily used for agriculture with several isolated residential properties also located within the area. Farmland extends south and west of R15. The area immediately to the north and east is residential.

Area R16 is bounded by Glovers Road to the north, Halswell Road to the west, and Kennedys Bush Road to the east. The area is primarily used for agriculture with several isolated residential properties also located within the area. The surrounding area is residential to the north, and rural to the east, west and south.

Area R17 is bounded by Sparks Road to the north, Kennedys Bush Road to the west, Cashmere Road to the south, and Sutherlands Road to the east. A large portion of the area is used for agriculture. The new Findlay Avenue Subdivision exists off Kennedys Bush Road and there are several isolated residential properties located within the area. A horse track and stables is located in the south-eastern corner of the area. The surrounding area is residential to the north and west, and rural to the east. A collection of houses lies directly to the south at the foot of the Port Hills.

Area R18 is bounded by Sparks Road to the north, Sutherlands Road to the west, Cashmere Road to the south, and Hoon Hay Road to the east. R18 is divided into a number of separate blocks and has irregular boundaries. The area is primarily used for agriculture, both arable and grazing, with a small number of isolated residential properties located within the area. The surrounding areas are mainly rural, with the Westmoreland subdivision (outer suburb of Christchurch) at the foot of the Port Hills located to the south and Hoon Hay to the east.

3 Recent Geotechnical Investigation

The subsurface geotechnical investigations undertaken for this study comprised 12 machine boreholes and 49 cone penetration tests (CPTs). The investigations were conducted in two phases, with the initial testing taking place in December 2013 and the second phase taking place in January 2014. The target depth of the investigations was 15m, with the achieved depth varying depending on the specific ground conditions encountered. A summary of the exploratory holes by area is provided in Table 1 below.

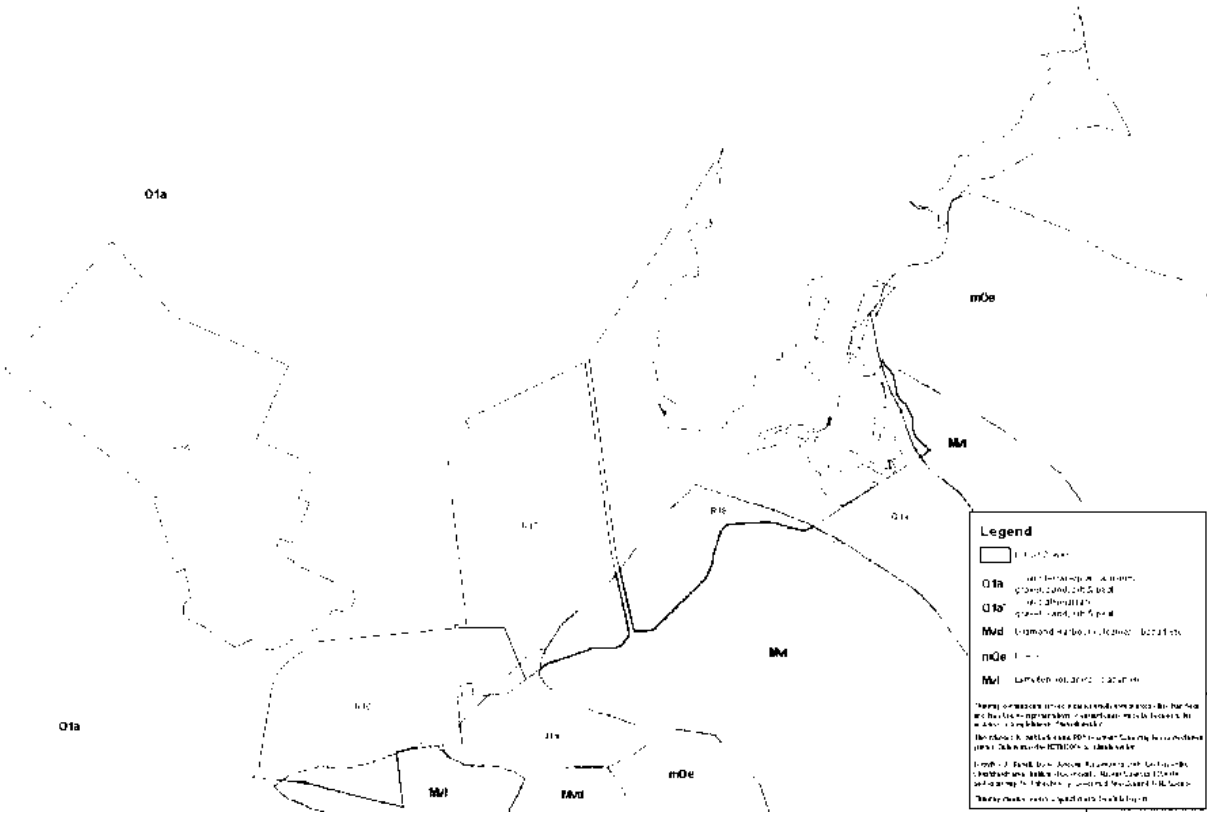
Name	Area (Ha)	# Boreholes	# Cone Penetration Tests (CPTs)	Density of Beca Investigations (Investigations/Ha)
R15	120	2	15	0.14
R16	65	3	6	0.13
R17	75	3	11	0.18
R18	110	4	17	0.19
Total	370	12	49	0.16

The GNS 1:25,000 Geology of the Christchurch Urban Area map[1] covers the northern parts of R15 and R18 of the Halswell ODP area. In these areas the map indicates that the ground conditions comprise “dominantly alluvial sand and silt overbank deposits” and some “alluvial gravel, sand, and silt of historic river flood channels” of the Yaldhurst Member of the Springston Formation. These deposits are of the Holocene age (last 10,000 years) and typically comprise laterally variable clayey silt to fine sand, with areas of fine to coarse gravel at various depths.

The GNS 1:250,000 Geology of the Christchurch Area map[2] (Figure 4 & Appendix A) covers all of the Halswell ODP area and is consistent with the 1:25,000 map, suggesting similar ground conditions across the site. The map indicates that the overbank deposits are in the order of 10 to 20m thick and overlay up to approximately 800m of unconsolidated alluvial sediments, which thin towards the Port Hills. These deposits consist of interbedded units of gravels, sand, silts, clay and peat, with the uppermost major gravel unit being the Riccarton Gravel. Beneath the south of the Halswell ODP areas, the alluvial deposits are absent and the bedrock, comprising a mixture of basalt, trachyte, tuff and pyroclastic deposits of the Lyttelton Volcanic Group, is exposed at the ground surface. Although not shown on the map, it is expected that a loess mantle is present above the bedrock.

[1] Brown, L.J.; Weeber, J.H. 1992: Geology of the Christchurch urban area. Scale 1:25 000. Institute of Geological & Nuclear Sciences geological map 1. 1 sheet + 104 p. Institute of Geological & Nuclear Sciences Limited, Lower Hutt, New Zealand.

[2] Forsyth, P.J.; Barrell, D.J.A.; Jongens, R. (compilers) 2008: Geology of the Christchurch area. Institute of Geological & Nuclear Sciences 1:250 000 geological map 16. 1 sheet + 67 p. Lower Hutt, New Zealand. GNS Science.



3.3.1 Liquefaction Interpreted from Aerial Photography

EQC and its engineers, Tonkin & Taylor visually identified the quantity of ejected material arising from the 2010/11 earthquake sequence using aerial photographs[3]. Only a small portion of the Halswell ODP areas were covered by the aerial photography interpretations, which EQC concluded showed no observed liquefaction to minor observed liquefaction. The only available post-earthquake aerial photography was from the 22 February 2011 earthquake. Beca has also reviewed this photography for evidence of liquefaction. Across the site, the liquefaction observations varied from no observed liquefaction to moderate observed liquefaction. Specific observations from each grid are presented in the Appendix B of the Beca Desk Study report.

3.3.2 Ground Cracking

EQC mapping[4] did not identify significant ground cracking in the Halswell ODP areas. However, this could potentially be due to the fact that many greenfield areas around Christchurch were outside the area of interest for EQC mapping. Only residential areas were mapped post-earthquake. Extensive cracking related

[3] Canterbury Geotechnical Database (2013) "Liquefaction Interpreted from Aerial Photography", Map Layer CGD0200 – 11 Feb 2013 retrieved [15/9/2013] from https://canterburygeotechnicaldatabase.projectorbit.com

[4] Canterbury Geotechnical Database (2012) "Observed Ground Crack Locations", Map Layer CGD0400 – 23 July 2012, retrieved [15/9/2013] from https://canterburygeotechnicaldatabase.projectorbit.com

to lateral spreading in the order of 50 to 200mm wide was observed to the north of Area R15 and to the northwest of Area R17. These cracks occurred within 100m of the Halswell River. More localised cracking, less than 100mm wide, was observed between Areas R15 and R16 and within 50m of the Halswell River.

Observed ground cracking maps for Halswell ODP areas obtained from the Digitised Ground Crack Location Map in the Canterbury Geotechnical Database are displayed in Appendix A. According to the CGD, maps of the ground cracking were derived following both the 4 September 2010 and 22 February 2011 earthquakes to assist with EQC and insurance claims and both datasets are displayed on the same figure. Ground cracks resulting from lateral spreading and other earthquake related ground movements are displayed on these figures.

Both earthquake data sets are incomplete and only show cracks observed by field staff. In particular, mapping following the 4 September 2010 earthquake had not been completed in some areas of Christchurch before the 22 February 2011 earthquake occurred. Some areas, such as road surfaces, were remediated before ground cracking could be observed. Furthermore, due to the scope of the mapping being generally limited to developed residential areas, much of the land in the Halswell ODP area was not mapped. As a result the maps should be applied for high level planning purposes only, as the extent of ground cracking may not have been limited to those areas marked on the map.

For each grid block (e.g. C1) key information has been summarised in the form of individual A4 sheets, which are provided in Appendix D. An explanation of the structure of the summary sheets and the information they contain is presented in Figure 5.

Job Name	CCC Halswell ODP Geotechnical Investigation
Date	7/03/2014
Grid Reference (Area)	C1 (R15)

General Information

Technical Category	TC3 & TC2/3
Groundwater Depth (m) (Source)	0.5 (GNS Median Depth to Water Table)

Indicative Technical Category and Groundwater Depth

Summary of Investigations	
Reference ID	**Depth of Investigation (m)**
B1	10.5
CPT01	8.98
CPT02	5.44

Summary of Beca Investigations undertaken

Generalised Soil Profile			
Ground Materials	**Approximate Depth to Top of Unit (m)**	**Thickness (m)**	**Consistency/ Relative density**
Interbedded CLAY, silty CLAY, clayey SILT & sandy SILT; silty SAND & SAND	0	4 - 7	very soft to firm/ loose
Sandy Lne to coarse GRAVEL	4 - 7	3+	Medium dense - very dense

Generalised Soil Profile based on Beca Investigations, CCC Provided Reports & Canterbury Geotechnical Database sourced Investigation

Summary of Estimated Liquefaction Induced Settlements				
	Importance		Settlement values	
ID	**Level**	**Design Life (Years)**	**1/500 (ULS, 0.35g)**	**1/25 (SLS, 0.13g)**
CPT01	2	50	116	99
CPT02	2	50	76	54

Summary of Estimated Liquefaction Induced Settlements

4 Ground Model

The general soil profile is consistent with the published regional geology, consisting predominantly of alluvial gravels, silts, and sands. Peat was encountered in a number of boreholes. Subsurface soil conditions are vertically and horizontally variable across the Halswell ODP areas, as suggested by the published geology. The upper portion of the soil profile comprises discontinuous interbedded clay, silt and sand with occasional peat lenses. Consistency of the cohesive soils ranges from very soft to stiff and the density of the sands ranges from very loose to medium dense. Across the site, the thickness of these upper units ranges from 1m to over 15m.

This upper profile is typically underlain by the loose to very dense Springston Formation gravel. The layer was discontinuous and not observed across all the Halswell ODP areas. It was encountered at depths of between 6m and 15m.

Underlying the Springston Formation gravel, the soil profile is similar in composition to the upper profile, consisting of discontinuous interbedded clay, silt, sand and occasional peat lenses of similar consistency and density. This profile thickness ranged from 13m to 15m, where investigations were terminated. This profile was not observed in the boreholes where the Springston Formation gravel extended to 15m.

The lowest major soil horizon identified during the field investigations was the medium dense to very dense Riccarton Gravel. In some instances this gravel layer was directly overlain by the Springston Formation gravel and differentiation between the two was not always obvious. The shallowest depth at which the Riccarton Gravel was encountered was 13m. The termination of boreholes at 15m meant that the Riccarton Gravel was not observed across the Halswell ODP areas. Based on the published Christchurch geology it is expected that the Riccarton Gravel is present across the site, indicatively between 15m and 20m depth, although the actual depth may vary more than this.

Generalised soil profiles for each grid relevant to the Halswell ODP areas are presented in Appendix D. These are based on a combination of Beca investigations, information from the Canterbury Geotechnical Database, and reports provided to Beca by CCC. They are generalised profiles, consistent with the density of investigations in the areas.

Indicative geological cross-sections are presented in Appendix C. These provide an interpretation of the subsurface conditions based on the evidence available. Additional information would be required to refine the interpretations to cover each complete area.

4.2.1 Area R15

4.2.1.1 **Investigation Summary**

Subsurface geotechnical investigations within the R15 area comprised two boreholes and 15 CPTs as summarised in Table 2.

Investigation ID	Grid Reference	Depth of Investigation (m bgl)
BH01	C1	10.50
BH02	F3	15.45
CPT01	C1	6.88
CPT02	C1	5.44
CPT03	C2	6.34
CPT04	C2	6.48
CPT05	D1	6.22
CPT06	D2	4.98
CPT07	D2	11.18
CPT08	D3	6.42
CPT10	D3	12.06
CPT11	E2	14.74
CPT12	E3	12.12
CPT13	E3	15.00
CPT14	E2	14.32
CPT15	F3	15.00
CPT16	F3	15.00

4.2.1.2 **Soil Conditions**

The two boreholes were drilled at the north-western and south-eastern ends of the area. The ground conditions were relatively consistent between the two. Both had an upper soil profile consisting of interbedded clay, silt and sand with occasional lenses of peat. The cohesive soils were very soft to firm and the non-cohesive soils were loose to medium dense. In BH01, in the northwest of the area, the upper soil profile was observed to a depth of 5.35m. In BH02, in the southeast of the area, it was observed to a depth of 7.1m. Underlying the upper soil profile was a medium dense to dense sandy gravel. In BH01, gravel was observed to a depth of 10.5m, where the borehole was terminated due to artesian pressures being developed in the borehole. In BH02, gravel was observed to a depth of 10.3m, and was underlain by a profile comprising firm clay, silt and peat, and loose to medium dense sand. This was observed to a depth of 14.1m. The upper 14.1m identified in the boreholes consist of alluvial deposits of the Springston Formation. The Springston Formation is underlain by dense Riccarton Gravel, which is observed to a depth of 15.45m, where BH02 was terminated.

CPT data was used to investigate the soil profile between the boreholes. The target depth of the CPTs was 15m. Shallow refusal occurred when a dense layer was encountered and it has been assumed that these refusal depths represent the top of a gravel layer, although this would need to be confirmed by further exploratory holes. The depth of refusal can generally be related to the top of the gravel layer encountered in the boreholes. As refusal occurs it has not been possible to determine the thickness of the gravel or the nature of the soil profile beneath.

The upper soil profile interpreted from the CPTs comprises clay, silt, sand and organic soil. The shallowest refusals occurred in the northwest portion of the area around BH01. CPTs 1-6 refused at depths ranging from 4.98m bgl to 6.88m bgl. This is consistent with the depth to the gravel layer identified in BH01.

Investigations carried out by Soil & Rock (2013)[5] in Grid D1 and Aurecon (2012)[6] in Grids C2, D2, E2 and D3 have been used in the assessment of ground conditions in R15. Soil & Rock and Aurecon conducted 20 CPTs each. The Soil & Rock CPTs were conducted to the south of BH01. Refusal occurred between 6.5m bgl and 14.3m bgl. The refusal depths indicate the shallowest gravel layer occurs at deeper depths to the south. It is unknown whether refusal occurred on the discontinuous Springston Formation gravel or on the deeper Riccarton Gravel.

The Aurecon CPTs covered a large area in the central portion of R15. Refusal occurred between approximately 6.5m bgl and 14.5m bgl. The CPTs towards the northwest had the shallowest refusal depths. The majority of the CPTs refused between depths of 10m bgl and 15m bgl. It is unclear whether refusal occurred on Springston Formation gravel or the Riccarton Gravel. Beca CPTs 7, 10, and 11 are consistent with the Aurecon CPTs refusing at depths of 11.18m, 12.06m, and 14.74m respectively. Beca CPT08, less than 200m to the east of Beca CPT07, had a refusal depth of 6.42m. This indicates the discontinuous nature of the gravel and how much the depth to the gravel can change over short distances. Boreholes taken from the Canterbury Geotechnical Database found in Grids C2 and D3 are relatively consistent with the depths to gravel interpreted from the adjacent CPTs.

CPTs 12-16 are the closest to BH02. CPTs 12 and 14 refused at 12.12m and 14.32m respectively. CPTs 13-16 reached the target depth of 15m. This is not consistent with BH02 which had a shallow gravel layer from 7.1-10.3m and a deeper gravel layer from 14.1m to the end of the borehole. This indicates that the upper gravel surface has a steep gradient in the area.

Indicative geological cross-sections covering R15 are presented in Appendix C.

4.2.1.3 **Groundwater Conditions**

Groundwater elevations were taken from the GNS Science Median Groundwater Surface Elevations map[7] where possible. For areas not covered by the map, ECan well data and observations made during the Beca field investigation were used. The indicative depth to groundwater and the source of the information is summarised in Table 3.

Grid Reference	Source of Information	Depth to Groundwater (m bgl)
C1	GNS Median	0.5
D1	GNS Median	0.5
C2	GNS Median	1.0
D2	GNS Median	0.5
E2	ECan Wells (M36-1285, M36-5731, M36-7169)	1.5
F2	ECan Wells (M36-5731, M36-7169)	1.5
D3	GNS Median	1.5

[5] Soil & Rock Consultants (2013) Geotechnical Investigation Report Proposed New Residence 70 Quaifes Road, Halswell (Ref: C12277).

[6] Aurecon (2012) Quaifes Road Geo Report (Ref: 227054).

[7] GNS Science (2013) Median water table elevation in Christchurch and surrounding area after the 4 September 2010 Darfield Earthquake, GNS Science Report 2013/01, March 2013, 66p and 8 Appendices.

Grid Reference	Source of Information	Depth to Groundwater (m bgl)
E3	ECan Wells (M36-5731, M36-7169)	1.5
F3	ECan Wells (M36-0823, M36-0811)	1.5

4.2.2 Area R16

4.2.2.1 Investigation Summary

Subsurface geotechnical investigations within the R16 area comprised three boreholes and six CPTs as summarised in Table 4.

Investigation ID	Grid Reference	Depth of Investigation (m bgl)
BH03	G4	15.45
BH04	F5	15.45
BH05	G3	15.45
CPT17	F3	9.26
CPT18	G3	5.18
CPT19	G3	4.62
CPT20	G3	6.94
CPT21	G4	1.10
CPT22	F5	8.20

4.2.2.2 Soil Conditions

Based on borehole observations, the upper soil profile in R16 consists of interbedded clay, silt and sand of the Springston Formation. No peat was observed. Cohesive soils were very soft to firm and non-cohesive soils were very loose to medium dense. The depth of this layer ranged from 3.9m to 7.95m. This is underlain by a layer of mostly medium dense to dense Springston Formation gravel. Gravel was observed to depths ranging from 10m to 14m. Across the area, the gravel layer had a thickness of 3.2m to 6.4m. The gravel was underlain by interbedded clay, silt, sand and peat. Cohesive soils were very soft to stiff, non-cohesive soils were loose to medium dense and the peat was very soft to firm. This soil profile was observed to a depth of 15.45m where the boreholes were terminated, without encountering the Riccarton Gravel above this depth.

The upper soil profile interpreted from the CPT data comprised interbedded clay, silt, sand and occasional lenses of organic soil. CPTs refused at depths ranging from 1.1m to 9.26m. CPTs 17-20 are relatively consistent with BH05, showing an expected amount of variability in the depth to the inferred gravel layer. The gravel layer appears to be deeper to the north (by about 3m), shallower to the west and southwest (by about 1 to 2m) and at a consistent depth to the south. CPT21, which refuses at 1.1m bgl, occurs in the southern portion of the area and is approximately equidistant from BH03 and BH05. It suggests that the gravel layer is significantly shallower in this area. CPT22, which was located approximately 200m east of BH04, refused at 8.2m depth, suggesting a change in the depth to the gravel layer of 4.3m over this distance as gravel was encountered in BH04 at 3.9m.

Aurecon (2011)[8] carried out an investigation within R16 in Grids F4 and G4 consisting of 22 test pits and 22 CPTs. They identified an upper soil profile comprising interbedded silt and sand with occasional lenses of peat and organic silt. Of the 22 test pits undertaken gravel was observed in 15 of them at depths ranging from 1.9m to 3.4m. Of the 22 CPTs, 12 refused at depths shallower than 6m. The remaining CPTs refused at depths of greater than 7.3m or were able to probe to the target depth of 15m bgl. The area of shallow gravel was encountered in most of Grid F4 and G4. The exceptions are the northwest of Grid F4 and the southeast of Grid G4.

BH03 and BH04 are consistent with the Aurecon observations. BH03 was located in the area of deeper gravel, which was encountered at 7.95m. In BH04 gravel was encountered at 3.9m which is consistent with the area of shallow gravel.

A indicative geological cross-section covering R16 is presented in Appendix C.

4.2.2.3 **Groundwater Conditions**

The depth to groundwater and source of the information is summarised in Table 5.

Grid Reference	Source of Information	Depth to Groundwater (m bgl)
F3	ECan Wells (M36-4927)	1.5
G3	ECan Wells (M36-4938, M36-4510)	1.5
F4	ECan Wells (M36-0809, M36-1908)	1.5
G4	ECan Wells (M36-4938)	1.5
F5	ECan Wells (M36-1284, M36-4575, M36-5237)	1.5

4.2.3 Area R17

4.2.3.1 **Investigation Summary**

Subsurface geotechnical investigations within the R17 area comprised three boreholes and 11 CPTs as summarised in Table 6.

Investigation ID	Grid Reference	Depth of Investigation (m bgl)
BH06	D5	15.45
BH07	E5	15.45
BH08	E5	15.45
CPT23	D5	2.70
CPT24	D5	4.34
CPT25	E5	3.76
CPT26	D6	3.38
CPT27	E5	6.00

[8] Aurecon (2011) Kennedy's Bush Road Residential Development Geotechnical Report (Ref: 225897)

Investigation ID	Grid Reference	Depth of Investigation (m bgl)
CPT28	E5	1.86
CPT29	E6	4.16
CPT30	F5	1.50
CPT31	E5	7.56
CPT32	F6	7.00
CPT33	F5	10.24

4.2.3.2 **Soil Conditions**

BH06, 07 and 08 are roughly aligned north-south in R17. They each have a thin upper soil profile comprised of predominantly very loose to loose sand and silty sand, with minor amounts of clay and gravel. The thickness of this upper profile is 1 to 2.6m, being deeper in the south. This is underlain by loose to very dense gravel of the Springston Formation. In BH06, gravel is observed from 1m to the base of the borehole, in BH07 from 1.1m to 6.45m, and in BH08 from 2.6 to 6m. From north to south the gravel layer occurs at greater depths. It is also observed to thin from over 14m in BH06 to less than 3.5m in BH08. In BH07 and 08 the Springston Formation gravel is underlain by interbedded clay, silt, sand and occasional peat, also of the Springston Formation. Cohesive soils are very soft to stiff, non-cohesive soils are loose to medium dense, and the peat is soft. In BH08 these soils are observed to the base of the borehole. A lower, medium dense to dense gravel layer was observed in BH07 from 13m to the base of the borehole, which is interpreted to be Riccarton Gravel.

The soil profile interpreted from the CPT data comprises interbedded clay, silt and sand. Silty sands and sands tend to dominate the profiles across the area. Refusal depths range from 1.5m to 10.24m. Seven of the 11 CPTs in the area refused at depths of less than 5m indicating that across the site the gravel layer is inferred to be generally relatively shallow. Deeper refusals may suggest localised pockets of deeper gravel. In the southern portion of R17 there is a noticeable deepening of the Springston Formation gravel layer with refusals of 10.24m and 7m.

A indicative geological cross-section covering R17 is presented in Appendix C.

4.2.3.3 **Groundwater Conditions**

The depth to groundwater and source of the information is summarised in Table 7.

Grid Reference	Source of Information	Depth to Groundwater (m bgl)
D5	GNS Median	1.5
D6	GNS Median	1.0
E5	ECan Wells (M36-4440)	1.5
E6	Beca CPT	1.0
F5	ECan Wells (M36-1284, M36-4575, M36-5237)	1.5
F6	ECan Wells (M36-1284, M36-4575, M36-5237)	1.5

4.2.4 Area R18

4.2.4.1 Investigation Summary

Subsurface geotechnical investigations within the R18 area comprised four boreholes and 17 CPTs as summarised in Table 8.

Investigation ID	Grid Reference	Depth of Investigation (m bgl)
BH09	E6	15.45
BH10	C6	15.45
BH11	D7	15.45
BH12	A10	15.45
CPT34	C6	15.14
CPT35	D6	9.56
CPT36	E6	8.94
CPT37	D7	5.28
CPT38	E7	4.30
CPT39	E7	8.92
CPT40	D7	8.72
CPT41	E8	15.00
CPT42	D8	7.30
CPT43	D7	9.10
CPT44	D8	15.00
CPT45	C8	11.92
CPT46	C8	8.68
CPT47	B6	15.06
CPT48	C6	14.26
CPT49	A10	12.20
CPT50	C7	10.10

4.2.4.2 Soil Conditions

The upper soil profile in the R18 area as observed in the boreholes and interpreted from the CPTs comprises interbedded clay, silt, sand and occasional peat layers. Cohesive soils are very soft to stiff and the non-cohesive soils are very loose to medium dense. The layers in the upper soil profile are highly discontinuous both laterally and vertically. The thickness of the upper profile ranges from 4.3m to over 15m. The upper profile is thickest in Grid C5. The profile is 13.95m thick in BH10 where it is underlain by dense gravel interpreted to be Riccarton Gravel. CPTs 34, 47 and 48 are consistent with a deep upper soil profile. CPTs 34 and 47 did not refuse before the 15m target depth and CPT48 refused at 14.26m. CPT41 in Grid E8 and CPT44 in Grid D8 also indicate a deep upper soil profile, both CPTs reaching the 15m target depth. Both CPTs are located at the base of the Port Hills. The rest of the main body of the site has an upper profile of varying thickness. In BH09 the upper soil profile was 7.9m thick, and in BH11 it was 7.5m thick. The CPTs over this area refused at depths ranging from 4.3m to 11.92m, although most refused shallower than 10m. The upper profile is underlain by medium dense to dense Springston Formation gravel. In BH09 this gravel was observed from 7.9m to 15.45m, interbedded with a layer of medium dense to dense sand from 12.45m to 13.6m. In BH11 gravel was observed from 7.5m to 15.45m, interbedded with layers of dense sand from 8.2m to 9.4m and 10.25m to 10.5m. The gravel was interpreted to be Riccarton Gravel from 13.95m. In the north east of the area the upper soil profile had a thickness of 8.9m to 12.2m, being thicker to the east.

Medium dense gravel of the Springston Formation was observed from 8.9m to the end of the hole at 15.45m in BH12.

Indicative geological cross-sections covering R16 are presented in Appendix C.

4.2.4.3 **Groundwater Conditions**

The depth to groundwater and source of the information is summarised in Table 9.

Grid Reference	Source of Information	Depth to Groundwater (m bgl)
C6	GNS Median	0.5
D6	GNS Median	1.0
E6	Beca CPT	1.0
B7	GNS Median	0.5
D7	GNS Median	1.0
E7	Beca CPT	1.25
C8	GNS Median	1.0
D8	GNS Median	1.0
E8	Beca CPT	1.0
B9	GNS Median	1.5
A10	GNS Median	1.5

5 Geotechnical Considerations

5.1.1 Settlement and Ground Displacement Aspects

Settlement of underlying soils under static conditions should be considered for any development within the Halswell ODP areas. Settlement will result from stress changes in the ground, such as loads from earthquakes, buildings, infrastructure etc. and/or from environmental changes such as a lowering of groundwater levels. Significant areas of the near-surface soils within Halswell ODP areas are generally silty materials which will experience both elastic settlement (immediate in nature) and consolidation settlement (which is time dependent) when subject to stress changes.

Areas with weak bearing soils (such as those listed in Table 16), if loaded beyond their allowable capacity, can suffer bearing capacity deformation. Proper care should be taken in designing the foundations in areas with weak bearing soils, so as not to exceed the safe (dependable) or allowable bearing capacity. The strength and stiffness of the soils could be improved through area wide methods, such as surcharging, excavation and re-compaction, ground improvement, etc. before construction, although the economic viability of these methods would need to be considered in some detail. If foundations for future development are to be designed on a site-specific basis, care must be taken to understand the site-specific ground conditions

The extent of layers of peat and organic soils encountered in the boreholes during the December 2013 / January 2014 geotechnical investigation are presented in Table 17. Depending on the proposed type of development, the foundation depth, structural performance requirements, etc., careful consideration will need to be given to development above the peat. Peat layers are weaker and much more compressible than soils without organic material and suffer settlement over time, irrespective of any stress change within them. This increases the risk of adverse total and differential settlement affecting any structures placed above them. Care should be taken to ensure the peat layers are either removed, if shallow, or their effects taken into consideration during any development or foundation design above them.

5.1.2 Foundation Options

Where the ground corresponds to TC1 the design of lightweight timber structures within the Halswell ODP areas can follow the relevant NZS 3604 guidance. Given the ground risks within the Halswell ODP areas, it is likely that the seismic case will govern the foundation design for both residential and non-residential buildings for TC2 and TC3 areas.

5.1.3 Slope Instability

Slope instability, in general, is not considered a high risk for Halswell ODP areas as the areas are relatively flat in topography. However, the exception to this would be areas immediately next to ‘free faces’ (natural or man-made). Land immediately next to ‘free-faces’, particularly if it is able to become saturated, could be at an increased risk of instability, although the extent of such instability is likely to be limited. Instability of the areas at the foot hills of the Port Hills are not expected to pose a major risk, subject to specific assessment.

5.1.4 Groundwater Effects

Groundwater, in general, was found to be shallow (less than 2 meters bgl) within the Halswell ODP areas. This will need to be considered in relation to the bearing capacity of near-surface soils, the feasibility of stormwater disposal to ground, the effect on surface water courses and the seismic implications (refer to Section 6).

5.1.5 Pavements

Near surface soils within Halswell ODP areas generally consist of silt, silty sand and sand. The current CCC IDS standards for pavement construction cover the soils encountered in the geotechnical investigation and it is recommended that these be followed. A preliminary assessment of the near-surface silts suggests an indicative CBR of 1% to 3% may apply and for competent sand and / or gravel a CBR of 5 to 8%, or possibly greater may apply. However, because of the wide variability, it is recommended that site-specific ground conditions are investigated and assessed to confirm the ground conditions and appropriate CBR value, before carrying out any design or construction.

5.2.1 Liquefaction Assessment

5.2.1.1 General

The loose to medium dense sands and non-plastic silts that are found in the study area are susceptible to liquefaction under earthquake shaking.

5.2.1.2 Methodology

Liquefaction analyses of the CPT data were carried out using *CLiq*[9], following the method of Idriss & Boulanger (2008)[10], including fines correction. For the calculation of post-liquefaction induced settlements, the method of Zhang et al. (2002)[11] was used. These published empirical equations were inferred from databases compiled from many historical international earthquakes. Earthquakes are unique and impose different levels of shaking in different directions on different sites. The results of the liquefaction assessment presented in this report are based on the current probabilistic regional seismic demands and the methods referred to above. It is important to note that the actual future performance may vary from that which has been described in this assessment.

5.2.1.3 Peak Ground Accelerations (PGAs)

Interim recommendations for PGA values for geotechnical design in Canterbury are provided in the MBIE Guidelines[12]. These recommendations are shown in Table 10 and are slightly higher than the PGAs determined using NZS1170 (0.11g for an SLS event and 0.34g for a ULS event). For the purposes of this assessment the PGA values provided in the MBIE Guidelines have been used. The anticipated design working life is assumed to be 50 years and buildings are assumed to have an Importance Level 2.

[9] CLiq v.1.7 (GeoLogismiki).

[10] Idriss, I.M. and Boulanger, R.W. (2008) “Soil liquefaction during earthquakes”, Earthquake Engineering Research Institute Monograph MN012.

[11] Zhang, Robertson and Brachman (2002) “Estimating Liquefaction-Induced Ground Settlements from CPT for Level Ground”, Can. Geotech. J. (39), 1168-1180.

[12] MBIE (2012) Repairing and rebuilding houses affected by the Canterbury earthquakes, Ministry of Business, Innovation and Employment

Annual probability of exceedance (average over next 50 years)	PGA (g) for deep or soft soil (Class D) sites. Liquefaction-triggering analysis only
1/25	0.13
1/500	0.35

A comparison with the conditional PGA values for site specific liquefaction assessments provided by Bradley & Hughes[13] shows that the Halswell ODP areas have been subjected to approximately ULS horizontal PGAs for the September 2010 and February 2011 events and SLS horizontal PGAs for the June and December 2011 events, all of which have potential to cause liquefaction, depending on the specific ground conditions.

5.2.1.4 **Results of Liquefaction Risk Assessment**

Liquefaction potential has been estimated at discrete locations based on CPT data at these locations, considering the design ULS and SLS cases. These values reflect 'greenfield' settlements and do not reflect loading by building foundations; or loss of ground by ejecta, both of which can lead to greater settlement. The calculated values are given to provide an indicator of the potential extent and range of effects. Liquefaction characteristics need to be assessed over the full depth of the soil profile as settlements resulting from soil liquefaction beneath intermediate 'non-liquefiable' layers do contribute to total ground settlements. Hence settlement estimates from CPTs with shallow refusals should be taken as minimum potential settlement. Estimated settlements are presented in the Tables 11-14 below. Technical categories are based on liquefaction deformation limits (refer to Section 5.2.1.5, Table 15).

CPT ID	Depth of CPT (m)	Total thickness of potentially liquefiable layers (m)		Settlement (mm)		Technical Category
		ULS	SLS	1/500 (ULS, 0.35g)	1/25 (SLS, 0.13g)	
CPT01	6.88	3.7	3.2	120	100	TC3
CPT02	5.44	2.6	2.4	80	50	TC3
CPT03	6.34	2.8	2.2	90	60	TC3
CPT04	6.48	3.0	2.7	90	70	TC3
CPT05	6.22	3.5	1.4	100	40	TC2
CPT06	4.98	2.0	1.6	60	50	TC2
CPT07	11.18	6.5	4.7	180	110	TC3
CPT08	6.42	1.2	0.0	20	0	TC1
CPT10	12.06	7.1	3.6	210	80	TC3
CPT11	14.74	5.4	3.3	240	60	TC3
CPT12	12.12	6.6	3.5	220	90	TC3
CPT13	15.0	7.8	5.0	260	150	TC3
CPT14	14.32	9.3	3.3	350	90	TC3
CPT15	15.0	9.2	7.3	270	180	TC3

[13] Bradley, A.B. and Hughes, M. (2012) Conditional Peak Ground Accelerations in the Canterbury Earthquakes for Conventional Liquefaction Assessment, Technical Report for the Ministry of Business, Innovation and Employment

CPT ID	Depth of CPT (m)	Total thickness of potentially liquefiable layers (m)		Settlement (mm)		Technical Category
		ULS	SLS	1/500 (ULS, 0.35g)	1/25 (SLS, 0.13g)	
CPT16	15.0	9.3	4.0	220	90	TC3

CPT ID	Depth of CPT (m)	Total thickness of potentially liquefiable layers (m)		Settlement (mm)		Technical Category
		ULS	SLS	1/500 (ULS, 0.35g)	1/25 (SLS, 0.13g)	
CPT17	9.26	3.2	3.1	90	60	TC3
CPT18	5.18	2.4	1.5	70	20	TC2
CPT19	4.62	1.5	1.0	50	20	TC2
CPT20	6.94	2.7	1.2	70	20	TC2
CPT21	1.10	0.0	0.0	0	0	TC1
CPT22	8.20	3.8	3.4	170	120	TC3

CPT ID	Depth of CPT (m)	Total thickness of potentially liquefiable layers (m)		Settlement (mm)		Technical Category
		ULS	SLS	1/500 (ULS, 0.35g)	1/25 (SLS, 0.13g)	
CPT23	2.7	0.9	0.0	20	0	TC1
CPT24	4.34	0.0	0.0	0	0	TC1
CPT25	3.76	0.2	0.0	5	0	TC1
CPT26	3.38	0.0	0.0	0	0	TC1
CPT27	6.0	2.4	0.2	50	5	TC2
CPT28	1.86	0.0	0.0	0	0	TC1
CPT29	4.16	0.0	0.0	0	0	TC1
CPT30	1.5	0.0	0.0	0	0	TC1
CPT31	7.56	0.8	0.1	10	5	TC1
CPT32	7.0	2.7	2.7	100	70	TC3
CPT33	10.24	5.0	3.2	200	130	TC3

CPT ID	Depth of CPT (m)	Total thickness of potentially liquefiable layers (m)		Settlement (mm)		Technical Category
		ULS	SLS	1/500 (ULS, 0.35g)	1/25 (SLS, 0.13g)	
CPT34	15.14	8.9	7.0	240	180	TC3
CPT35	9.56	5.7	4.5	160	120	TC3
CPT36	8.94	4.8	2.8	130	70	TC3

CPT ID	Depth of CPT (m)	Total thickness of potentially liquefiable layers (m)		Settlement (mm)		Technical Category
		ULS	SLS	1/500 (ULS, 0.35g)	1/25 (SLS, 0.13g)	
CPT37	5.28	2.5	1.7	90	40	TC2
CPT38	4.3	1.2	1.0	40	20	TC2
CPT39	8.92	4.6	4.1	130	90	TC3
CPT40	8.72	5.4	4.3	160	90	TC3
CPT41	15.0	11.1	10.4	350	300	TC3
CPT42	7.3	2.1	1.4	50	40	TC2
CPT43	9.1	4.4	2.6	110	60	TC3
CPT44	15.0	9.5	7.5	300	210	TC3
CPT45	11.92	7.6	4.7	320	170	TC3
CPT46	8.68	3.9	2.4	130	50	TC3
CPT47	15.06	9.5	5.2	330	130	TC3
CPT48	14.26	7.2	5.8	210	160	TC3
CPT49	12.2	7.7	4.3	260	80	TC3
CPT50	10.1	5.8	4.2	160	110	TC3

5.2.1.5 **Comparison with CERA Zoning and MBIE Technical Categories**

Following the Canterbury Earthquake sequence the Canterbury Earthquake Recovery Authority (CERA) zoned areas of flat land in Christchurch as either red or green. The criteria for this zoning, and division between red and green zones, are not known. The Ministry of Business, Innovation & Employment (MBIE)[14] developed a classification system to clarify repair and reconstruction options for residential properties in the CERA Green Zone. Residential properties were assigned a technical category (TC1, TC2 or TC3) reflecting both the liquefaction and damage experienced through the earthquakes and a prediction of the land's future performance.

The foundation technical categories defined by MBIE were as follows:

- **TC1 –** future land damage from liquefaction is unlikely, and ground settlements from liquefaction effects are expected to be within normally accepted tolerances.
- **TC2 –** minor to moderate land damage from liquefaction is possible in future large earthquakes.
- **TC3 –** moderate to significant land damage from liquefaction is possible in future large earthquakes.

The MBIE guidance provides a method for estimating future land performance based on the expected liquefaction settlement estimated from deep exploratory holes. Depending on the amount of predicted liquefaction settlement the foundation technical category can be assigned as summarised in Table 15 below.

[14] MBIE (2012) Repairing and rebuilding houses affected by the Canterbury earthquakes, Ministry of Business, Innovation and Employment

Technical Category	Liquefaction Deformation Limits (mm)				Likely Implications for House Foundations (subject to individual assessment)
	Vertical		Lateral Spread		
	SLS	ULS	SLS	ULS	
TC1	15	25	nil	nil	Standard NZ 3604 – like foundations with tied slabs
TC2	50	100	50	100	DBH enhanced foundation solutions (section 5.2) of the 2011 *Repairing and rebuilding houses affected by the Canterbury earthquakes*
TC3	>50	>100	>50	>100	Site specific foundations after engineering input

For the purpose of this geotechnical assessment, the technical categories have been assigned based on the MBIE guidance. These categories provide an indication of the MBIE Residential Technical Categories, but it is important to note that they may not be the definitive categories. This is based on our understanding that the DBH categories were based on multiple data sources, each ranked according to their perceived importance, not just the predicted liquefaction settlement. However Beca was not party to this information or how the factors were weighted. Hence it is possible that a review of the other input data used to develop the technical categories could revise the indicative zoning within the Halswell ODP area presented here.

Additionally consideration would need to be given to whether any of the land would be zoned 'red' as defined by CERA. For example in the event of a SLS earthquake vertical settlements up to 300mm were calculated and in the event of a ULS earthquake vertical settlements of up to 350mm were calculated.

Generally, of the 49 CPTs conducted, 30 of them had calculated settlements corresponding to TC3 land, noting that some of them refused at depths of less than 10m. TC3 land is most prevalent in Areas R15 and R18.

Land interpreted to be classified as TC1 and TC2 is most prevalent in Areas R16 and R17. Some CPTs corresponding to TC1 and TC2 land refused at depths shallower than 10m. Borehole data was used to confirm the presence of gravel as the reason for refusal in the general vicinity; however, it is recommended that where the boreholes are some distance from the CPTs, the gravel thickness is proved to at least 15m depth by additional exploratory holes.

The density of investigation and geological setting is such that the technical categories for the Halswell ODP areas could vary over relatively short distances and certainly within the individual grids adopted in this study. Carrying out further, location specific, deep exploratory holes would further inform this aspect.

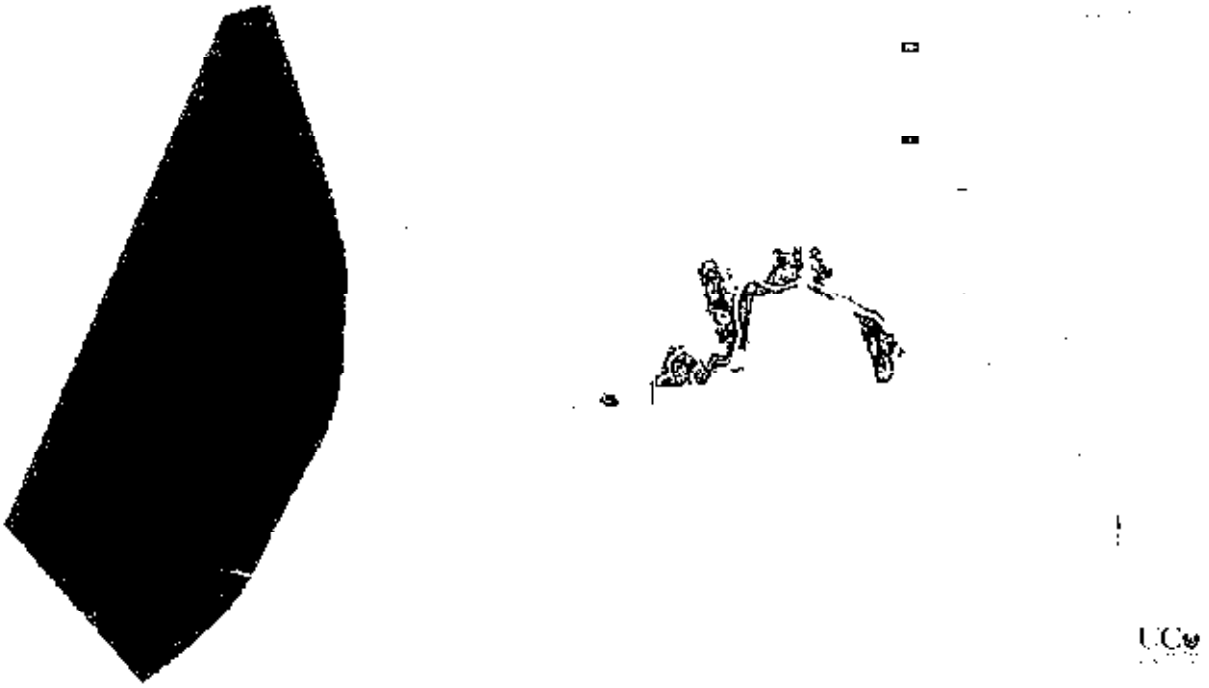
5.2.1.6 **Indicative Technical Category Maps**

Maps showing the indicative technical category distribution are presented in Appendix E. A sample map is shown in Figure 6 below.

5.2.1.7 **Liquefaction Resistance Index Map**

The Liquefaction Resistance Index (LRI) for large areas of Christchurch is given in the CCC Infrastructure Design Standards (IDS) Part 4, Appendix IV (Page 4-33). The LRI is based on the assessed severity of liquefaction damage observed following the earthquake(s), with Zone 0 having the lowest resistance and Zone 4 the highest. Most of the Halswell ODP areas are outside the limits of the LRI Map[15] except for a small portion of Area R15 which is zoned as LRI 2 (Figure 7), with the areas bordering other areas also zoned 2. As post-earthquake observation data for the remainder of the Halswell ODP areas is not available it has not been possible to compute the LRI.

[15] Liquefaction Resistance Index (Zoning) of Christchurch at Water Table Depth, December 2011.



6 Geotechnical Risks

Based on the results of the geotechnical investigation, the following priority geotechnical risks have been identified to inform CCC's consideration of the rezoning of the Halswell ODP areas. The risks relate to CCC's Outline Development Plan review, which we understand is currently in an information gathering phase, and are based on the preliminary geotechnical investigation data discussed in this report. The priority risks are related to developing land from rural to residential or business use and specific to the anticipated ground conditions.

It should be noted that no un-engineered fill was encountered during the geotechnical investigation. In areas which may have been affected by man's activity there is the possibility that such material exists, although based on the available evidence the risk is low. The potential for un-engineered fill to be present, which without treatment is unlikely to be suitable as foundation bearing material, should be considered on a case by case basis.

A list of known areas where soft and / or compressible soils have been encountered in the boreholes is presented in Table 16 below. Similarly the CPTs indicate areas of soft and / or compressible soils distributed widely, both vertically and horizontally. Peat has been identified in the boreholes. The extent and thickness of peat is summarised in Table 17.

Investigation ID	Area	Grid Reference	Depth to the Top of Layer (m bgl)	Thickness (m)
BH01	R15	C1	0.4 1.9 4.5	0.5 1.1 0.9
BH02		F3	0.7 3.0 10.3 11.7	1.9 4.1 0.1 0.2
BH03	R16	G4	0.4 6.7 14.0	5.5 1.3 1.0
BH04		F5	0.6 4.5 10.2	1.7 1.5 4.2
BH05		G3	0.4 9.6 13.1	5.9 2.1 0.1
BH06	R17	D5	0.6	0.4
BH07		E5	0.0 6.0 8.7 12.8	3.0 0.4 0.3 0.2

Investigation ID	Area	Grid Reference	Depth to the Top of Layer (m bgl)	Thickness (m)
BH08		E5	0.4 6.0 8.3 9.2	2.2 2.0 0.7 3.6
BH09	R18	E6	0.4	7.5
BH10		C6	1.5 9.4 13.1	7.2 3.0 0.2
BH11		D7	0.4 5.5	4.1 0.5
BH12		A10	0.5 7.5	6.3 1.1

Investigation ID	Area	Grid Reference	Depth to the Top of Layer (m bgl)	Thickness (m)
BH02	R15	F3	2.85 4.3 11.35 11.9	0.07 0.2 0.35 2.2
BH03	R16	G4	14.0	0.3
BH04		F5	14.6	0.6
BH05		G3	12.0 13.1	0.8 0.1
BH08	R17	E5	12.3 13.15	0.5 0.1
BH11	R18	D7	2.6 3.5	0.15 0.06

As indicated by the boreholes the soft and / or compressible soils are often present close to ground level. Soft soils close to ground level pose a hazard to any development above them due to their low bearing capacity. Additionally when they are loaded significant settlements can result. Where peat or organic material is present settlement continues over time, irrespective of any stress change in the ground from surface loading or groundwater lowering. Such phenomena will need to be considered in any development on the site. Based on the available information, the presence of soft and / or compressible soils is considered a moderate risk to the Halswell ODP areas.

Groundwater is estimated to be between 0.5m and 1.5m depth throughout the Halswell ODP areas based on the GNS Science Median Groundwater Surface Elevation map, ECan well records and observations made during the December 2013 / January 2014 field investigations. Table 18 lists the grid areas where groundwater was encountered in the December 2013 / January 2014 field investigations at a higher level

than that given as the GNS median depth to groundwater[16]. Groundwater can be expected to fluctuate seasonally and on an inter-annual basis, with the range reported by van Ballegooy[17], et al, to be in the order of 2m. It is of note that the GNS median depth to groundwater map does not cover large parts of the ODP area.

Investigation ID	Area	Grid Reference	GNS Median Depth to Groundwater (m bgl)	Measured Depth to Groundwater (m bgl)
BH01	R15	C1	0.5	0.25
BH06	R17	D5	1.5	0.9
BH10	R18	C6	0.5	Artesian (i.e. above ground level)
CGD BH 31825	R15	C2	1.0	0.3
CGD BH 14898	R15	C2	1.0	0.9
CGD BH 14896	R15	C2	1.0	0.6

In relation to the geotechnical hazards, high groundwater can influence stormwater disposal, subsurface infrastructure construction and the seismic performance of the ground. Seismically shallow groundwater tends to increase the potential for liquefaction induced settlements and ground damage, which would increase the Technical Category class and hence the foundation requirements. Where groundwater is deeper, and it creates a thicker 'crust' of non-liquefiable soil, the risks are reduced.

As the available groundwater data indicates that groundwater is typically at 1m bgl and may be present from ground level to 3m bgl, it will be important to better define the depth and seasonal range across the Halswell ODP areas before undertaking any specific design.

For the purposes of informing the District Plan review, the following should be considered in areas of high groundwater:

- Storm water disposal may need to be via surface water courses, with associated detention and storage facilities, as disposal to ground is unlikely to be feasible
- Constructing subsurface infrastructure can be limited to drier periods and can be subject to uplift pressures, which need to be overcome by correct detailing
- The liquefaction risk and associated ground damage are higher (refer below)
- A suitable thickness of 'crust' may not be present, necessitating the adoption of more robust foundations for structures (or a means of permanently lowering the groundwater level).

High groundwater is considered to be a moderate to high risk in the Halswell ODP areas.

[16] GNS Science (2013) Median water table elevation in Christchurch and surrounding area after the 4 September 2010 Darfield Earthquake, GNS Science Report 2013/01, March 2013, 66p and 8 Appendices.

[17] van Ballegooy, S., Cox, S.C, Thurlow, C., & Reynolds, T. (2013), Development of a median groundwater table surface for Christchurch, Proc. 19th NZGS Geotechnical Symposium. Ed. CY Chin, Queenstown

Liquefaction is predicted across large parts of the Halswell ODP and should be considered in some detail when considering the potential land use. It is likely to be one of the governing criteria in assessing the suitability of land for future development. Table 19 presents the DBH equivalent technical categories for all grid areas and the likelihood of surface ground damage for ground accelerations of approximately 0.2g determined using the empirically based Ishihara method[18].

Grid Reference	DBH Equivalent Technical Category	Potential Surface Ground Damage (Y/N)
C1	TC3 & TC2/3	Y
C2	TC3 & TC2/3	Y
C3	TC3 & TC2	Y
D1	TC3 & TC2/3	Y
D2	TC3, TC2 & TC2/3	Y
D3	TC3 & TC2	Y
E2	TC3 & TC2	Y
E3	TC3	Y
F2	TC3	Y
F3	TC3	Y
F4	TC3 & TC2	Y (in the west) & N (in the east)
G3	TC3 & TC2	Y
G4	TC3 & TC2	Y
F5	TC3 & TC2	Y & N
D5	TC2	Y (in the east and south) & N (in the north)
E5	TC3 & TC2	Y (in the northwest) & N (remaining area)
D6	TC3, TC2 & TC2/3	Y (in the east) & N (in the west)
E6	TC3 & TC2	Y (in the east) & N (in the west)
F6	TC3 & TC2	Y
A10	TC3	Y
B7	TC3	Y
B9	TC3	Y
B10	TC3	Y
C6	TC3	Y
C7	TC3	Y
C8	TC3	Y
D7	TC3 & TC2/3	Y
D8	TC3	Y
D9	TC3	Y
E7	TC3 & TC2/3	Y
E8	TC3	Y
F7	TC3 & TC2/3	Y

[18] Ishihara, K. (1985) Stability of natural deposits during earthquakes.

Across the Halswell ODP areas, 3% of the grids are classified as TC2, 41% as TC3 and 56% as a combination of TC2, TC3 and TC2/3.

The predicted magnitudes of liquefaction settlement estimated in this study relate to 'free-field' settlements. Where additional (to the earthquake) shear stress is imparted to the soil, for instance due to loading from a foundation or an earth embankment, there is potential for the displacement of the soil to be greater. Recent studies of the effects of the Canterbury earthquake sequence suggest that particularly large displacements can occur where a foundation is situated above a thin layer of liquefiable material. Larger than predicted displacements can also occur in areas where large volumes of ejecta develop.

In addition to liquefaction, densification of coarse grained soils and cyclic strain softening of fine grained soils can occur. Densification will result in settlement of the soil. Cyclic strain softening will result in a loss of shear strength and if the soil is loaded, for instance by a foundation, the stability of the material can be compromised.

The potential for liquefaction presents the key risk to the development of the Halswell ODP areas.

The risk of lateral spreading is generally high where liquefiable soils exist near natural water courses and / or other 'free faces'. The level of risk depends on the particular configuration of 'free face', stratigraphy and seismic loading. Based on the predicted liquefaction risk for each grid square and the presence of significant water course(s), Table 20 provides a summary of the grid areas where the risk of lateral spreading is high for a portion of the grid block.

Grid Reference	Lateral Spreading Risk
C2	Halswell River runs through northeast of grid area
C3	Halswell River runs through centre of grid area
F3	Halswell River runs through centre of grid area between Areas R15 & R16
G3	Halswell River runs through southwest of grid area

The magnitude of lateral spreading can range from a few millimetres up to several metres. It is worth noting that the recent Canterbury earthquakes have demonstrated that near Kaiapoi the most significant lateral spread effects resulted in lateral displacement in the order of 2 metres spread over a distance of 600m from the free face. These values are considerably larger then would conventionally be calculated using existing techniques. The MBIE guidance notes that where land is within 200 m of a free edge then the potential effects of lateral spreading shall be assessed. Additionally this guidance states that where the distance is less than 50m from a significant waterway and steep change in ground level occurs, minor to moderate global lateral movement can be assumed in TC3 areas.

Maps showing official and unofficial water courses, which are presented in Appendix A, can be used as a guide for identifying the areas with increased risk of lateral spreading. However, it is recommended that a site-specific survey of the water courses be undertaken in order to quantify the risk. Any land development will need to take into consideration both official and unofficial water courses and / or 'free faces' when quantifying the risk of lateral spreading.

The lateral spreading associated with the potential for liquefaction presents a major risk to the development of the Halswell ODP areas.

7 Development Considerations

It is recommended that any residential development follow the MBIE guidelines[19] and that non-residential development have specific engineering investigation and design carried out. The MBIE guidelines were developed to provide "robust and well-balanced engineering solutions for repairing and rebuilding earthquake-damaged houses in the Canterbury region", which would apply to new residential developments in the Halswell ODP areas. For suitable foundation recommendations in TC1 and TC2 land reference should be made to MBIE Guidance Part A: Technical Guidance (Version 3, 2012). For TC3 land reference should be made to MBIE Guidance Part C: Assessing, repairing and rebuilding foundations in TC3 (Version C, 2012).

The results of Beca's geotechnical investigations and previously conducted desk study indicate the Halswell ODP areas to be indicatively TC2 or TC3 land, based on the liquefaction assessments undertaken. Investigations to sufficient depth have not proved TC1 land; however, this should not be taken as conclusive evidence of the absence of TC1 land, as further investigation may prove such land to be present in some limited areas. The Technical Category maps presented in Appendix E provide an indication of the ground conditions expected across the Halswell ODP areas.

7.3.1 General

Beca has carried out a high-level review of the flood risk for the Halswell ODP areas only. This is presented below. It is understood that much of the surrounding areas are situated at a low level and are susceptible to flooding. This was not considered as part of this review.

7.3.2 Methodology

Beca has reviewed the areas against the existing Flood Management Area (FMA) defined in the current City Plan, and the proposed Flood Management Area (Option 1 - 0.5m sea level rise) published by CCC for consultation as part of the District Plan Review. It is understood that CCC is also considering a proposed Flood Management Area Option 2 of 1.0m sea level rise, although maps for Option 2 have not yet been published[20]. For non-tidal areas, the FMA is based on the 200 year flood plus an allowance for freeboard. The 200 year flood levels have been derived by CCC using hydraulic modelling.

The existing and proposed FMA is shown on the plan Existing & Proposed Flood Management Area (FMA) 0.5m Sea-Level Rise, dated 15/03/2014, included in Appendix F1. The existing FMA and the Zone Areas are shown on the plans included in Appendix F2. The proposed FMA (0.5m sea level rise) was not available to Beca in a GIS format and therefore it has not been included on the maps in Appendix F2. It is shown on the relevant District Plan Review Draft Maps 44, 45, 49 and 50, dated 15/03/2014, which are included in

[19] MBIE (2012) Repairing and rebuilding houses affected by the Canterbury earthquakes, Ministry of Business, Innovation and Employment

[20] Christchurch City Council, District Plan Review
http://www.ccc.govt.nz/thecouncil/policiesreportsstrategies/districtplanning/districtplanreview/index.aspx

Appendix F3. We have also compared the areas with the South-West Christchurch Stormwater Management Plan (SMP)[21]. Plans showing CCC's proposed stormwater management facilities for South-West Christchurch are included in Appendix F4.

Under its South-West Christchurch SMP, CCC proposes to provide water quantity mitigation for development in South-West Christchurch by providing stormwater management facilities which include detention capacity for 2% AEP critical duration events. These stormwater management facilities will discharge via slow release to surface water, or soakage to ground where site conditions are suitable based on CCC's investigations (as indicated in the SMP). The detention basins are sized to a total storm detention (TSD) standard for development on the flat, which requires the detention basin to contain the total stormwater volume of a critical duration 2% AEP event. Water quality treatment is also incorporated in the proposed stormwater management facilities.

7.4.1 Area R15

7.4.1.1 **Waterways**

The R15 area is in the Halswell River catchment. There are a number of waterways and drains within the R15 area including:

- Quaifes Drain and Creamery Drain along the south and south-western boundary of the R15 area
- Nottingham Stream along the eastern boundary of the area
- Dalgety Drain and Parkinsons Drain, tributaries of Quaifes Drain, which run through the area
- Coxs Drain, Talbots Stream and Paynes Drain, tributaries of Creamery Drain, which run through the area.

7.4.1.2 **Flood Risk**

The R15 area is outside both the existing FMA and proposed FMA (0.5m sea level rise) for the Halswell River. Refer Appendix F2 and Appendix F3.

7.4.1.3 **Stormwater Management**

The R15 area is within the 'Knights Stream-South West Halswell' Surface Water Management Area (SWMA) of the South-West Christchurch SMP. Under the SMP runoff from approximately 256ha of residential land will be managed in this SWMA, and mitigated by five proposed stormwater management facilities. These include

- The Knights facility servicing an area of the Marshs Road and Carrs Road sub-catchments
- The Quaifes-Springlands facility, Quaifes-Coxs facility and Creamery facility in the Creamey Stream sub-catchment
- The Nottingham facility in the Nottingham Stream sub-catchment.

The proposed Quaifes-Coxs, Creamery and Nottingham facilities are within the R15 area.

[21] Christchurch City Council/Golder Associates (NZ) Ltd, *Water Quantity Assessment, South-West Christchurch Integrated Catchment Management Plan Technical Series Report No. 4,* 2007.

7.4.2 Area R16

7.4.2.1 **Waterways**

The R16 area is in the Halswell River catchment. There are two waterways/drains within the R16 area:

- Glovers Drain runs north-south through the R16 zone area, discharging to Green Stream
- Green Stream runs east-west through the R16 zone area. Green Stream discharges to the Halswell River on the west side of Halswell Road, just beyond the R16 area boundary.

7.4.2.2 **Flood Risk**

A small area of the south-western corner of the R16 area is within the proposed FMA (0.5m sea level rise) for the Halswell River (refer Draft Map 49, in Appendix F3).

No part of the R16 area is within the existing FMA (refer Appendix F2).

7.4.2.3 **Stormwater Management**

The R16 area is within the 'South Halswell-Kennedys Bush' Surface Water Management Area (SWMA) of the South-West Christchurch SMP. Under the SMP approximately 132ha of residential land and 162ha of rural land will be managed in this SWMA, and mitigated by four proposed stormwater management facilities:

- The Greens facility and Van Asch facility within the Halswell Quarry sub-catchment
- The Rossendale Basin and KBD Basin within the Lansdowne Valley catchment

The proposed Greens facility is within the R16 area.

7.4.3 Area R17

7.4.3.1 **Waterways**

This area is within the Heathcote River catchment. There are four waterways/drains within the R17 area:

- The headwaters of Cashmere Stream
- Thornton Drain runs north-south, discharging to Cashmere Stream
- Two branches of the Quarry Road Drain (also a tributary of Cashmere Stream) run west-east through the R17 area.

7.4.3.2 **Flood Risk**

The R17 area is outside both the existing FMA (refer Appendix F2) and proposed FMA (0.5m sea level rise) (refer Draft Maps 49 and 50, in Appendix F3).

7.4.3.3 **Stormwater Management**

The R17 area is within the 'Sparks Road - Hendersons Basin' and 'South East Halswell-Hoon Hay Valley' Surface Water Management Areas (SWMA) of the South-West Christchurch SMP.

Under the SMP approximately 328ha of residential land, 12ha of business land and 22ha of parks will be managed in the 'Sparks Road - Hendersons Basin' SWMA, and mitigated by a number of stormwater management facilities. These include the Days Drain, Bishops Green, Douglas Clifford, Sparks Road, Lower

Milns, Milns Drain, and Dunbars Drain facilities. Approximately 45ha of flat residential land and 106ha of hill residential land, and 58ha of rural land will be managed in the 'South East Halswell Hoon Hay Valley' SWMA, and mitigated by Hendersons Basin ponding area.

There are no South-West Christchurch SMP stormwater facilities proposed within the R17 area.

7.4.4 Area R18

7.4.4.1 **Water ways**

The R18 area is within the Heathcote River catchment. Cashmere Stream and a number of its tributary drains and waterways run through or adjacent to this area including Hoon Hay Valley Stream, Quarry Road Drain, Miln Drain, Dunbar Waterway, Hendersons Drain, Ballintines Drain and Luney Drain.

7.4.4.2 **Flood Risk**

Large parts of the R18 area are within the proposed FMA (0.5m sea level rise) for Hendersons Basin, Cashmere Stream and Hoon Hay Valley (refer Draft Maps 45 and 50, in Appendix F3). Parts of the R18 zone area are also within the existing FMA (refer Appendix F2). The existing and proposed FMA in this vicinity cover different areas, as can be seen in Appendix F1 (light blue area extent compared to dashed black line).

7.4.4.3 **Stormwater Management**

The R18 area is within the 'Sparks Road - Hendersons Basin' and 'South East Halswell-Hoon Hay Valley' Surface Water Management Areas of the South-West Christchurch SMP. The areas managed in these SWMAs and proposed facilities are noted under section 7.4.3.3. The proposed Dunbars Drain and Milns Drain facilities are partially within the R18 area.

7.4.5 Development within the Flood Management Area

Development of new residential areas within the FMA is generally undesirable due to the risk of inundation and the incremental effect of filling within the floodplain.

Under the current City Plan rules[22] (Variation 48) the erection of any building or addition within the FMA is a restricted discretionary activity, with the Council's discretion restricted to the floor level of the building. Filling within the FMA is either a restricted discretionary activity (within a Living Zone) or controlled activity (within a Business, Cultural, or Open Space Zone).

The Council is currently undertaking a District Plan Review, including the Flood Management Area Rules in the Natural Hazards chapter. From the draft Natural Hazards chapter dated 15 March 2014 the underlying assessment criteria appear to be similar, although the rules in relation to Flood Management Areas are changing.

Any new houses within the FMA would be required to have a minimum floor set at the 200 year flood level plus 400mm freeboard. These levels would be determined by CCC's surface water engineers, using CCC's flood modelling.

[22] Christchurch City Council, City Plan Online
http://www.ccc.govt.nz/thecouncil/policiesreportsstrategies/districtplanning/cityplan/electroniccityplan.aspx

The near-surface soils within the Halswell ODP areas are consistent with the expected Christchurch geology, predominantly comprising silty soils. In relation to the earthworks risks associated with such soils, the following should be considered for Halswell ODP areas:

- Potential water logging of surface materials
- Difficult workability of soils due to wet conditions
- Instability of saturated soils during excavations
- High groundwater levels requiring temporary dewatering
- The need for drying of soils prior to compaction
- Enhanced surface water management requirements due to high groundwater table, and
- Extra control required on amount of sediment entering receiving environments.

Many of the risks mentioned above can be mitigated by undertaking earthworks during drier months. If that cannot be achieved, a more robust surface water management plan, erosion control plan and overall better earthworks planning will be required, although the risks of delays will be increased. Earthworks will need to adhere to all local and regional regulatory criteria to reduce the impact of earthworks on surrounding environment, including effective erosion and sediment control plans.

7.6.1 General

Foundations on TC2 land should be designed to accommodate liquefaction-induced vertical settlement and resist lateral spreading, where predicted. Light construction materials are recommended in order to lessen the load on sub-soils and reduce the settlement potential. A summary of preliminary foundation solutions available for residential developments on TC2 land is presented in Table 21 below. The foundation solutions are based on the relevant MBIE criteria.

Geotechnical ULS Bearing Capacity	Foundation Solutions for new foundations on the flat
>300 kPa	■ NZS 3604 timber piled foundations (Type A) or, ■ An enhanced perimeter foundation wall (Type B) or, ■ Specific engineering design
>200 kPa	■ Enhanced raft slab foundations (Type C – Options 1-4) or, ■ Specific engineering design
<200 kPa	■ Specific engineering design

It should however be noted that NZS 3604 timber piled foundations (Type A) and enhanced perimeter foundation walls (Type B) are only suitable for use in TC2 land where the site has been proved “Good Ground” by a site specific shallow geotechnical investigation. The requirements of such investigations are described in MBIE Guidance Part A.

In the Halswell ODP areas, there may be limited areas where “Good Ground” exists, hence an enhanced raft slab foundation (Type C), may be a more appropriate foundation solution. The MBIE Guidelines recommend four enhanced raft slab foundations for use in TC2 land. These options are summarised in Table 22. In all

cases it will be necessary to prove that the natural ground immediately beneath the foundation has a minimum ultimate bearing capacity of 200 kPa.

Option	Description
1	Excavation and replacement of the upper layers of soil with compacted, well graded gravels and construction of a reinforced NZS 3604 slab foundation
2	Construction of a thick (300mm) slab foundation over the existing soil. For two-storey heavy-weight construction with either a heavy or light roof cladding, the thickness of the slab needs to increase to 400mm
3	Construction of a generic beam grid and slab foundation. A variation to this option involves post-tensioning the slab. This option requires specific engineering design
4	Construction of a waffle slab over the existing soil. Shear ties in accordance with NZS 3101 are required in the ribs

Specific engineering design is required when the ground conditions do not meet the 300 kPa requirement for 'good ground' or the 200 kPa requirement for Type C foundation solutions. In many cases simple alterations to Type C foundation design are expected to be sufficient to meet the minimum requirements of foundations in TC2 land.

When the minimum requirements cannot be met a specifically designed solution must be devised.

7.7.1 General

Foundations on TC3 land should be designed to accommodate liquefaction-induced vertical settlement and lateral spread. The following three foundation solutions have been used in Canterbury to counter the vertical settlements and lateral spreading associated with the Canterbury earthquakes:

- Deep Piles.
- Surface structures with shallow foundations.
- Site ground improvement.

Table 23 is taken from MBIE Guidance and summarises the objectives and limitations of each foundation as they apply to the Halswell ODP areas.

Type	Objectives	Dwelling Constraints	Land Constraints
Deep piles	Negligible settlement in both small and larger earthquakes	No height and/or material constraints likely	Not suitable where either major or severe lateral movement likely or dense non-liquefiable bearing layer not present
Surface structures with shallow foundations	Repairable damage in future moderate events	Only suitable for light and medium wall cladding combined with light roofs, regular in plan	In the absence of ground improvement, Type 1 & 2a options only suitable for minor to moderate vertical settlement and varying lateral stretch. Type 2b can accommodate up to 200mm SLS settlement

Type	Objectives	Dwelling Constraints	Land Constraints
			Type 3 (specific design) concepts can be designed for major lateral stretch and some for potentially significant vertical settlement
Site ground improvement	Improving the ground to receive a TC2 foundation	Limits on some two-storey/heavy wall types and plan configurations	Some ground improvements can be specified to accommodate major lateral stretch

7.8.1 General

Various techniques are available to improve site performance. The upper soils in TC3 areas contain a varying proportion of silt and peat, which will influence the effectiveness of certain methods of ground improvement. Those methods which are likely to warrant further consideration, where there is an absence of peat and/or organic soils, are summarised in Table 24 below.

Ground Improvement Methods	Options
Improvement of crust and/or deeper liquefiable soils	■ Excavation and replacement ■ Permanent surcharging ■ Groundwater lowering ■ Mass stabilisation
Deep Strengthening	■ Deep soil-cement mixed columns ■ Jet grouting ■ High modulus columns

The MBIE Guidelines include five methods of ground improvement including both shallow soil treatments and deep treatments, as follows:

- Densified raft (Type 1)
- Stabilised crust (Type 2)
- Deep soil mixing (Type 3)
- Stone columns (Type 4)
- Low mobility grout columns (Type 5)

The effectiveness of stone columns in reducing the liquefaction potential of the site soils, particularly non-plastic silts, is expected to be poor and variable. It should be demonstrated through a trial or trials before considering them further.

The ground improvement methods which are likely to be applicable to the Halswell ODP areas are summarised in Table 25 (extracted from MBIE Guidance).

Type	Description	Considerations					
		Organics >5%	Groundwater <1m (no dewatering)	Dewatering to 2m bgl	Stockpile area required?	Use in major lateral stretch zones	Depth to dense non liquefiable zone >10m
Shallow treatments							
1a	Densified crust – excavate and backfill	Y	Specific engineering design	Required	Required	N/A*	N*
2a	Stabilised crust (excavate, mix and replace)	Y*	N	Required	Required	Y (with geogrid)	N* N/A*
2b	Stabilised crust (in place mixing)	N	Y	Not required	Not required	N	N*
Deep treatments							
3	Deep soil mixing & jet grouting	N	Y	Not required	Not required	Y	Y
5	Low mobility grout	Y*				N/A*	Y

Notes:

Y = Method suitable.

N = Method not suitable.

N/A* denotes outside the scope of application of MBIE guidance but could be specific applicable with specific detailed engineering design input.

Y* = Effectiveness to be established.

N* = Not suitable unless restrictions outlined in MBIE Guidance Part C, Section 5.3.4 adhered to.

The appropriateness of any ground improvement option will need to be reviewed and confirmed by further geotechnical investigations and assessment. Areas of peat/highly organic soil will likely need to be separately treated by excavate and replace techniques before improvements for seismic performance are constructed.

7.8.2 Shallow Treatments

7.8.2.1 **Excavation and Replacement**

This method would require a densified block of soil to a depth of 2 m or more to be formed by excavation of the subsoils and recompaction or replacement with imported materials. This method would be considered suitable where the depth of liquefiable materials is limited to 10 m below the ground surface. Excavation and replacement for the Halswell ODP areas would need to consider where excavation and temporary drawdown of the water table is feasible and the methodology for earthworking.

7.8.2.2 **Permanent Surcharging**

This method would require the placing of engineered fill to raise the ground level above the groundwater level to provide a crust that was sufficiently thick to mitigate the effects of liquefaction. A preliminary qualitative assessment suggests that such a crust would need to be of the order of 3m thick, although this would need to be confirmed by further assessment. As with excavation and replacement, this method would likely be suitable where the depth of liquefiable materials is limited to 10 m below the ground surface. However, unlike excavation and replacement, temporary drawdown of the water table is generally not required. If this is to be considered further the wider effects of flooding need to be addressed.

7.8.2.3 **Groundwater Lowering**

This method would require the permanent lowering of groundwater to a depth to provide a crust that was sufficiently thick to mitigate the effects of liquefaction. As with the previous method a preliminary qualitative assessment suggests that such a crust would need to be of the order of 3m thick, although this would need to be confirmed by further assessment. Groundwater is historically observed at between 0.5m and 1.5m depth, so such a gravity groundwater lowering system designed to keep groundwater below 3m depth is unlikely to be feasible. Any assessment of such a scheme would need to take account of the inter annual and seasonal fluctuations in groundwater level and whether a gravity system is feasible, or whether a pumped system would be required.

7.8.2.4 **Mass Stabilisation**

This method would create a solidified block of soil, similar to the excavation and replacement option. The depth of treatment required is likely to be to a depth of 2 m or more, where the depth of liquefiable materials is limited to 10 m below the ground surface. The mixing can be carried out ex situ or in situ, although the later requires specialist equipment. Unlike excavation and replacement there is no need to temporarily drawdown the water table for the in situ mixing option. Peat soils are unlikely to be suitable for this form of treatment.

7.8.3 Deep Treatments

7.8.3.1 **Deep Soil Mixing**

This method requires the use of specialist plant which drills through the soil profile to the design depth. The drill is then rotated as it is extracted while a cement binder is pumped into the soil profile via ‘cutters’ which mix the cement and soil. The amount of cement added is a function of the performance requirements of the treatment and the characteristics of the ground. Depending on the design, single columns, rows of columns or mass stabilisation of a soil block can be undertaken. Deep soil mixing would be effective for the soil types anticipated beneath the Halswell ODP areas, with the exception of peat and/or organic soils.

7.8.3.2 **Jet Grouting**

Jet grouting is a similar ground improvement technique to deep soil mixing, except high pressure grout jets are used to erode the soil below the ground and mix in the binder. This process creates columns of soilcrete that improve the overall liquefaction resistance of the soil. Because this ground improvement method is based on soil erodibility, the characteristics of the soils in designing the treatment become very important. It is anticipated that jet grouting could be successfully used in treating the soils expected beneath the Halswell ODP areas, with the exception of peat and/or organic soils.

7.8.3.3 **Low Mobility Grout Columns**

Low mobility grout columns require the use of specialist plant. The process entails drilling to the design depth, at which point grout is pumped through the drill to create a 'bulb' of grout. Once this is formed the drill is extracted a short distance and another bulb of grout is formed. This process is repeated until a column of grout has been formed. Subsequent columns are positioned to sufficiently densify the soil and create stiffer elements that improve the overall liquefaction resistance of the soil. The characteristics of the soils in designing the treatment are important, with non-plastic silty soils and organic soils not anticipated to densify to a great degree; hence its use may be limited in treating the soils expected beneath the Halswell ODP areas.

7.8.4 Indicative Ground Improvement Costs

The cost to carry out any ground improvements will be a function of the specifics for the site in question, including (but not limited to) - (i) the underlying ground and groundwater conditions, (ii) the proposed development and (iii) the performance requirements. Considerable further work will be required to develop a design to which reliable cost estimates could be applied for the various zones within the Halswell ODP areas. For the purposes of comparing different treatments, the following indicative preliminary cost estimates have been provided (Table 26).

Method	Indicative approximate cost / m^2 (unit treatment net cost)
Excavation and replacement	$50 - $150
Permanent surcharging	$50 - $150
Groundwater lowering	$50 - $150
Mass stabilisation	$150 - $300
Deep Soil Mixing	$500 - $1000
Jet Grouting	$1000 - $2000
Low mobility grout columns	$1000 - $2000

It should be noted that the preliminary high level estimates provided above are not a statement of absolute cost, rather they will have an accuracy range commensurate with various factors such as the extent of relevant information provided, the certainty of data and the level of detail available at the time of preparation.

Should you require these estimates for critical financial planning decisions, or they are of material commercial significance, please advise Beca accordingly and it may be appropriate for an independent review to confirm the accuracy of the estimates to be carried out. Prior to commissioning such a review we recommend that the appropriate type and extent of any ground improvement be estimated on the basis of a thorough site-specific geotechnical design, which is beyond the scope of this study.

There are two components of lateral spreading to consider:

- Global lateral movement – translational block movement towards a free edge. Structures on robust shallow raft foundations can potentially accommodate such movement providing the structure is located within the block that moves although any service connections are at risk. Piled foundations that extend through the sliding block can experience substantial lateral forces that would need to be designed for.

- Lateral stretch of the ground surface across a zone extending back from the free face, i.e. differential lateral movement across the zone. This can have serious consequences as the structure is effectively being pulled apart.

A preliminary assessment suggests that geotechnical setback distances of 30m to 50m from the top of banks/slopes may be required, although this is subject to specific design at the Plan Change and subdivision stages. Even beyond these distances some movement can be expected, which for the purposes of this study has been taken to be the distance recommended by DBH beyond which minor to moderate global lateral movement (0 to 300mm) and lateral stretch across a building footprint (0 to 200mm) can be assumed in TC3 land. Foundations for residential buildings located beyond the setback distance can be designed in accordance with the MBIE Guidance Part C.

Ground improvement could be carried out within the setback zone to reduce the lateral spreading risk and thereby reduce the setback distance. Such ground improvement would need to be implemented over a large area to be effective. The lateral spreading hazard will need to be considered when planning suitable locations for critical infrastructure and service corridors, as well as structures.

8 Suitability of Land for Development

The Halswell ODP areas are underlain by alluvial soils, the upper horizons of which are dominated by silt and sand with isolated areas of near surface gravel. Zones within the silt are weak and peat was encountered in a number of the boreholes. Such weak and compressible soils present a static constraint to development that can be overcome with appropriate design measures. This may include (but not limited to) - (i) allowing for reduced safe (dependable) and/or allowable bearing capacities and (ii) allowing for higher than usual settlement tolerances during and post construction.

Earthworks in the predominantly silty soils will be primarily governed by the environmental conditions, particularly the effect of wet weather on the moisture sensitive silt. Carrying out earthworks in the drier summer months is recommended.

Groundwater across the Halswell ODP areas is shallow, typically expected to be between 0.5m and 1.5m below existing ground level over significant portions of all areas. High groundwater will limit the ability to discharge stormwater to ground and constrain stormwater disposal to detention ponds and controlled outflows. Additionally, groundwater lowering may be required for construction of structures, utilities and / or earthworks below the groundwater table.

When it comes to flood risk, both R15 and R17 are outside the existing and proposed FMA. Such is not the case for R16 and R18. Although R16 is not within the existing FMA, a small portion in the south-western corner is within the proposed FMA. For R18, large parts of the area are within the proposed FMA for Hendersons Basin, Cashmere Stream and Hoon Hay Valley. Parts of the R18 area are also within the existing FMA.

The seismic risks of liquefaction and lateral spreading pose significant constraints to zones of the development area. Without treatment of large areas of land, notably in R15 and R18, the land in these zones would be classified as TC3 according to the current MBIE guidance. Areas within R16 and R17 are TC2 (as well as TC3) and the TC3 zones within these areas also offer an opportunity to carry out site wide ground improvement to bring the whole site up to a TC2 category. Options, such as excavation and replacement, permanent surcharging and groundwater lowering (but unlikely to be by gravity), may prove viable in this regard.

Liquefaction is also a key risk that needs to be considered for buried infrastructure. Liquefaction can impact upon stormwater and gravity sanitary sewerage facilities by causing flotation of pipes and manholes. This may result in breakage/separation and loss of adequate grade for flow under gravity. Liquefaction may also cause partial filling/blocking of pipes with liquefied material. Due consideration should be given in designing these and other subsurface infrastructure.

Within TC3 land, set back distances for stormwater ponds and other free faces will need to be adopted and these might be in the range of 30m to 50m.

In summary the geotechnical investigations undertaken by Beca have not uncovered any areas deemed unsuitable for development *per se*. However, considerable work will be required to prepare much of the area to a state where “standard” (in the Christchurch sense) development can proceed. It is recommended that the aspects discussed above are considered in some detail when considering the proposed zoning of the Halswell ODP areas, particularly parts of R15 and R18. Where possible it is recommended that residential and business developments be placed on TC2 land, whether this is existing TC2 land, or land brought up to that standard by site ground improvements.

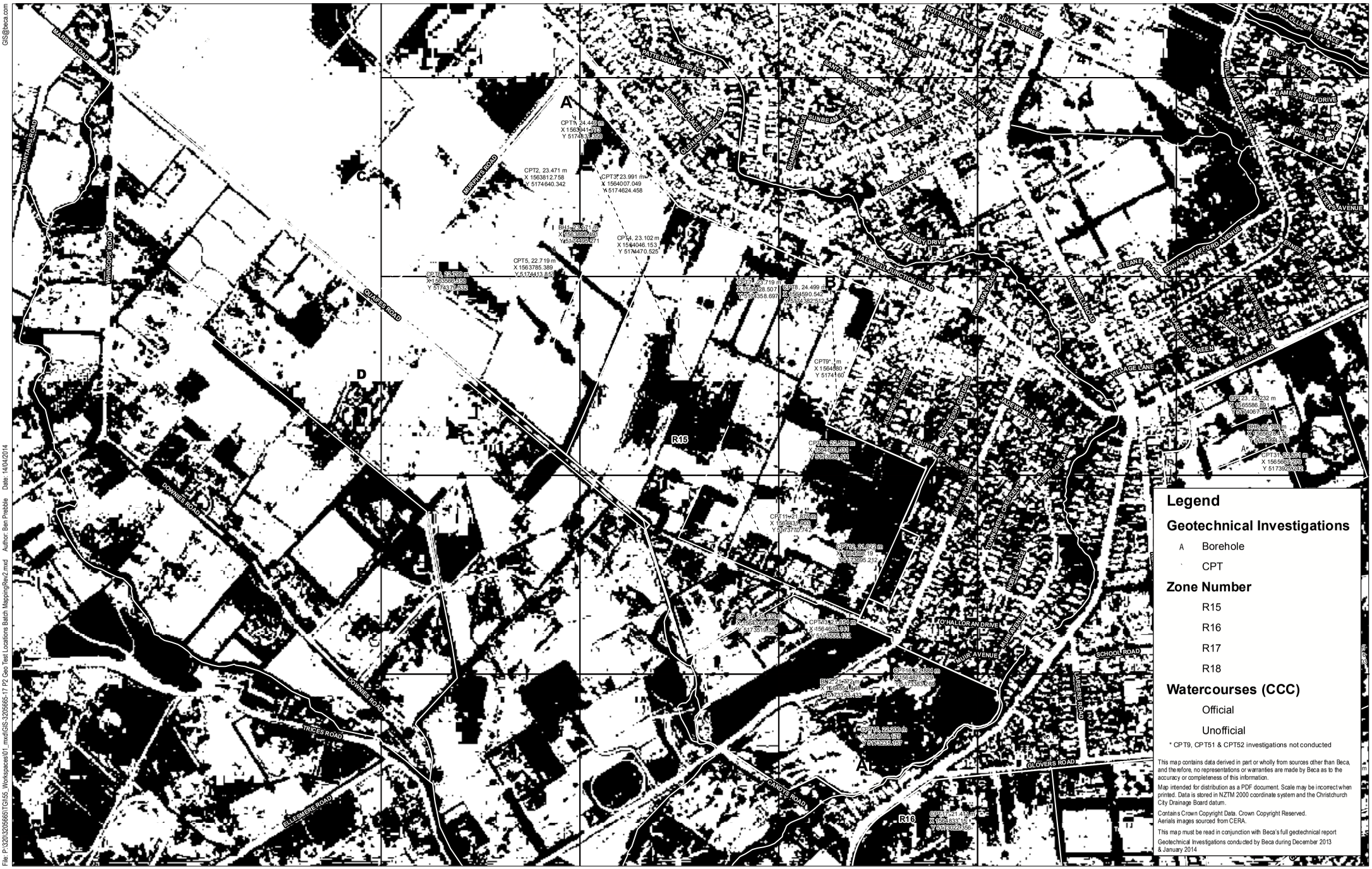
9 Applicability

This report has been prepared by Beca on the specific instructions of our Client. It is solely for our Client's use for the purpose for which it is intended in accordance with the agreed scope of work. Any use or reliance by any person contrary to the above, to which Beca has not given its prior written consent, is at that person's own risk.

All recommendations and opinions in this report are preliminary in nature and are subject to confirmation during the future design phases of the project once appropriate additional geotechnical investigations and engineering assessment has been completed.

Should you be in any doubt as to the applicability of this report and/or its recommendations for the proposed development as described herein, and/or encounter materials on site that differ from those described herein, it is essential that you discuss these issues with the authors before proceeding with any work based on this document.

Figures



Legend

Geotechnical Investigations

- A Borehole
- CPT

Zone Number

- R15
- R16
- R17
- R18

Watercourses (CCC)

- Official
- Unofficial

* CPT9, CPT51 & CPT52 investigations not conducted

This map must be read in conjunction with Beca's full geotechnical report

Geotechnical Investigations conducted by Beca during December 2013 & January 2014

Map Scale @ A3: 1:6,000

0 40 80 160 240 320 400

Metres

Revision	Author	Verified	Approved	Date
1	BGP	BAP	SCV	19/03/2014

Title: Geotechnical Investigation Plan CCC Halswell ODP R15 Zone Map

Client: Christchurch City Council

Project: CCC Halswell ODP Geotechnical Investigations

Beca

Discipline: GIS

Drawing No: GIS-3205665-17

Legend

Geotechnical Investigations

- A Borehole
- CPT

Zone Number

- R15
- R16
- R17
- R18

Watercourses (CCC)

- Official
- Unofficial

* CPT9, CPT51 & CPT52 investigations not conducted

This map must be read in conjunction with Beca's full geotechnical report

Geotechnical Investigations conducted by Beca during December 2013 & January 2014

File: P:\320\32056651\TG\55_Workspaces\01_mxd\GIS-3205665-17 P2 Geo Test Locations Batch Mapping Rev2.mxd Author: Ben Prebble Date: 14/04/2014
GIS@beca.com

Map Scale @ A3: 1:3,000

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Metres

±

Revision	Author	Verified	Approved	Date
1	BGP	BAP	SCV	19/03/2014

Title: **Geotechnical Investigation Plan**
CCC Halswell ODP
R16 Zone Map

Client: Christchurch City Council

Project: CCC Halswell ODP
Geotechnical Investigations

Beca

Discipline: GIS

Drawing No: GIS-3205665-17

Legend

Geotechnical Investigations

- A Borehole
- CPT

Zone Number

- R15
- R16
- R17
- R18

Watercourses (CCC)

- Official
- Unofficial

* CPT9, CPT51 & CPT52 investigations not conducted

This map must be read in conjunction with Beca's full geotechnical report

Geotechnical Investigations conducted by Beca during December 2013 & January 2014

File: P:\320\320566501\TG\55_Workspaces\01_mxd\GIS-3205665-17 P2 Geo Test Locations Batch MappingRev2.mxd Author: Ben Prebble Date: 14/04/2014
GIS@beca.com

Map Scale @ A3: 1:4,000

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Metres

Revision	Author	Verified	Approved	Date
1	BGP	BAP	SCV	19/03/2014

Title: **Geotechnical Investigation Plan**
CCC Halswell ODP
R17 Zone Map

Client: Christchurch City Council

Project: CCC Halswell ODP
Geotechnical Investigations

Beca

Discipline: GIS

Drawing No: GIS-3205665-17

GIS@beca.com

File: P:\320\32056651\GIS\5_Workspaces\01_mxd\GIS-3205665-17 P2 Geo Test Locations Batch MappingRev2.mxd Author: Ben Prebble Date: 14/04/2014

Map Scale @ A3: 1:8,000

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Metres

Revision	Author	Verified	Approved	Date
1	BGP	BAP	SCV	19/03/2014

Title: **Geotechnical Investigation Plan**
CCC Halswell ODP
R18 Zone Map

Client: Christchurch City Council

Project: CCC Halswell ODP
Geotechnical Investigations

Beca

Discipline: GIS

Drawing No: GIS-3205665-17

GIS@beca.com

File: P:\320\32056651\GIS5_Workspaces\01_mxd\GIS-3205665-20 QMAP and Lurp Zones.mxd Author: Ben Prebble Date: 14/04/2014

Map Scale @ A3:1:10,000

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Metres

Revision	Author	Verified	Approved	Date
1	RJL	BAP	SCV	11/04/2014

Title:
1:250000 Geology of Christchurch Area Map
CCC Halswell ODP

Client: Christchurch City Council

Project: CCC Halswell ODP
Geotechnical Investigations

Beca

Discipline: GIS

Drawing No: GIS-3205665-20

Ground Crack Location Map A

Project	**Halswell ODP**
Grid References Covered	**C1, C2, D1, D2, D3, E2 & E3**
ODP Areas	**R15**

Observed Crack Locations

N

Post 22 Feb 2011
(for lateral spreading)

- > 200 mm Cracks
- 50 to 200 mm Cracks
- 10 to 50 mm Cracks
- < 10 mm Cracks
- Unclassified Cracks

4 Sept 2010 to 22 Feb 2011
(many properties unmapped)

- > 100 mm Cracks
- 50 to 100 mm Cracks
- < 50 mm Cracks

Beca

Canterbury Geotechnical Database (2012) "Observed Ground Crack Locations", Map Layer CGD0400 - 23 July 2012, retrieved [10/04/2014] from https://canterburygeotechnicaldatabase.projectorbit.com

Ground Crack Location Map B

Project	**Halswell ODP**
Grid References Covered	**E2, E3, E5, F3, F4, F5, G3 & G4**
ODP Areas	**R15, R16 & R17**

Beca

Canterbury Geotechnical Database (2012) "Observed Ground Crack Locations", Map Layer CGD0400 - 23 July 2012, retrieved [10/04/2014] from https://canterburygeotechnicaldatabase.projectorbit.com

Ground Crack Location Map C

Project	**Halswell ODP**
Grid References Covered	**D5, D6, E5 & E6**
ODP Areas	**R17 & R18**

Observed Crack Locations

Post 22 Feb 2011
(for lateral spreading)

- > 200 mm Cracks
- 50 to 200 mm Cracks
- 10 to 50 mm Cracks
- < 10 mm Cracks
- Unclassified Cracks

4 Sept 2010 to 22 Feb 2011
(many properties unmapped)

- > 100 mm Cracks
- 50 to 100 mm Cracks
- < 50 mm Cracks

Canterbury Geotechnical Database (2012) "Observed Ground Crack Locations", Map Layer CGD0400 - 23 July 2012, retrieved [10/04/2014] from https://canterburygeotechnicaldatabase.projectorbit.com

Ground Crack Location Map D

Project	**Halswell ODP**
Grid References Covered	**A10 & B9**
ODP Area	**R18**

Observed Crack Locations

N

Post 22 Feb 2011
(for lateral spreading)

- > 200 mm Cracks
- 50 to 200 mm Cracks
- 10 to 50 mm Cracks
- < 10 mm Cracks
- Unclassified Cracks

4 Sept 2010 to 22 Feb 2011
(many properties unmapped)

- > 100 mm Cracks
- 50 to 100 mm Cracks
- < 50 mm Cracks

Results of CPT Liquefaction Assessment

Beca Ltd
Geotechnical Engineers
www.beca.com

Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

CPT file : CPT01_163bHalswellJunctionRd

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:	Sand & Clay
Fines correction method	I&B (2008)	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		
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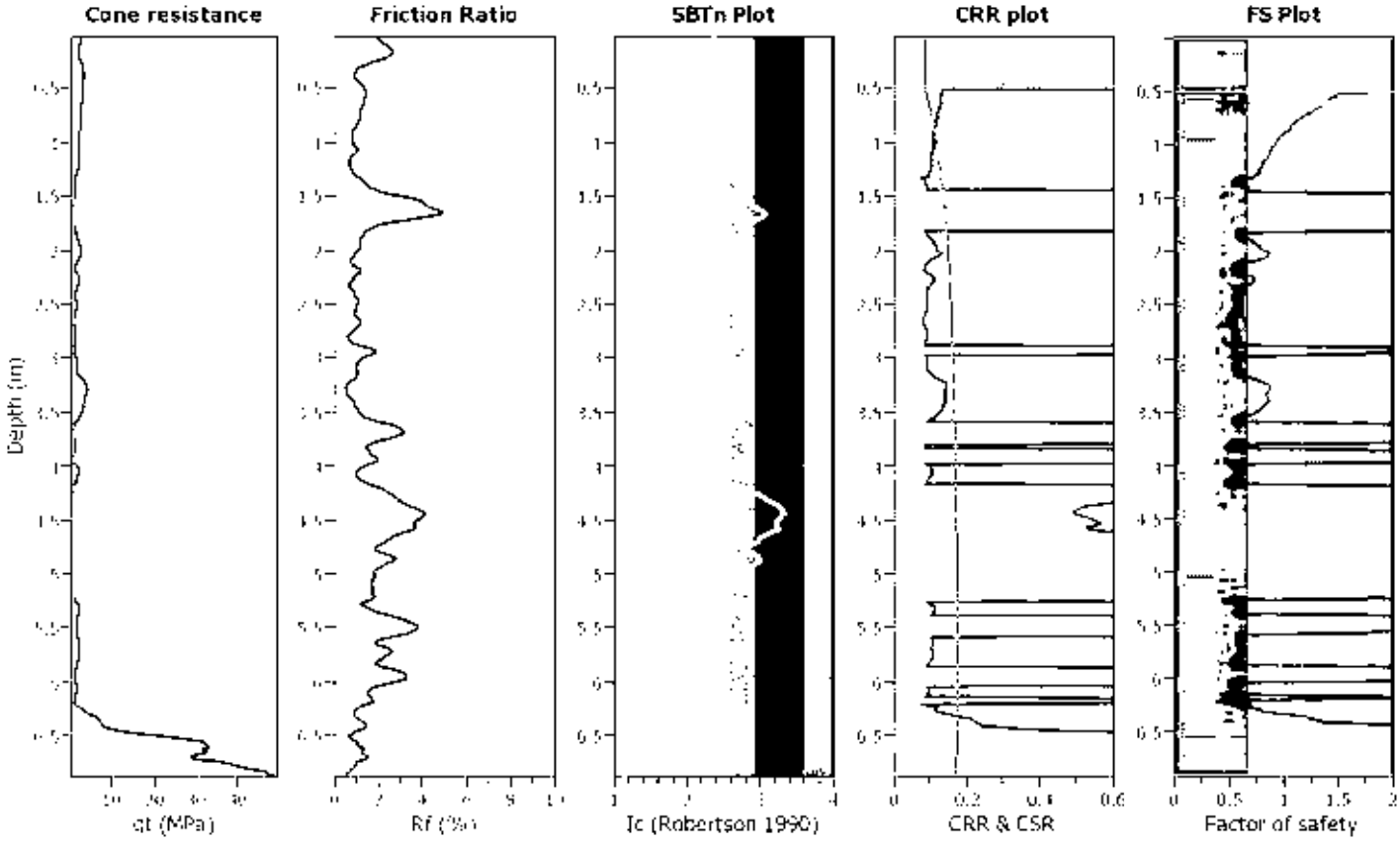
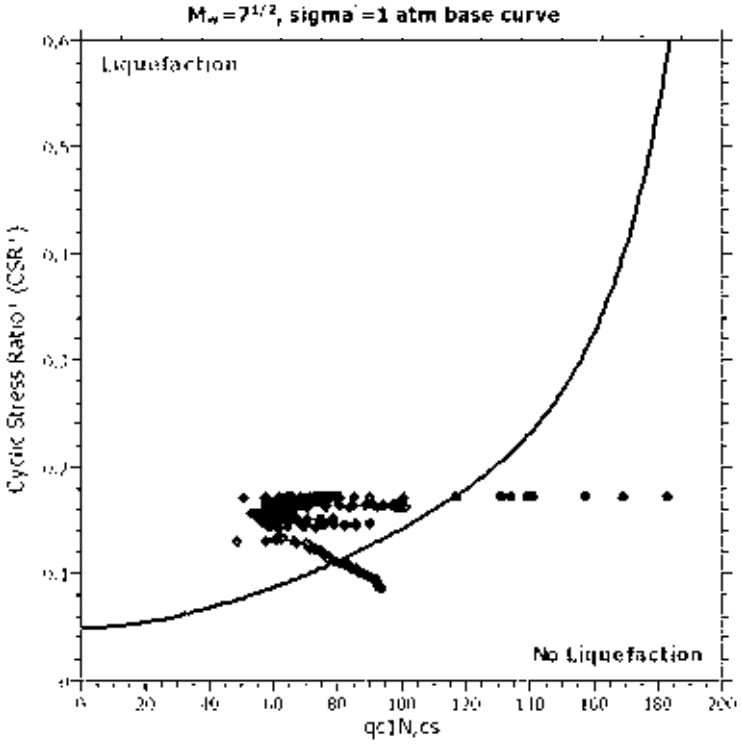
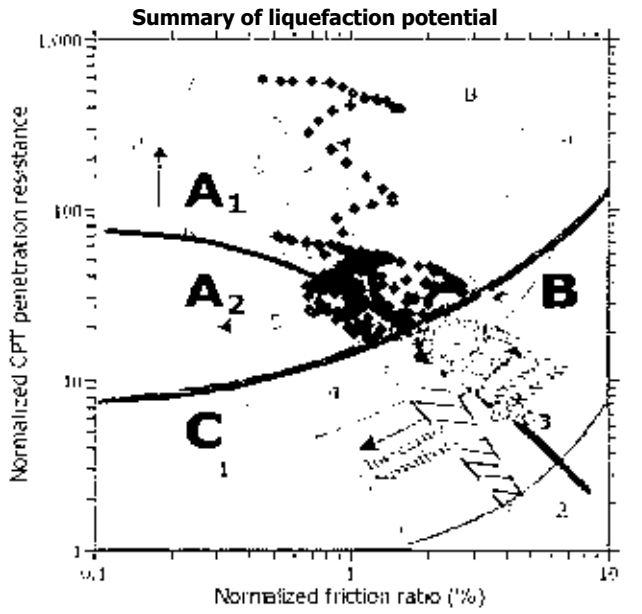
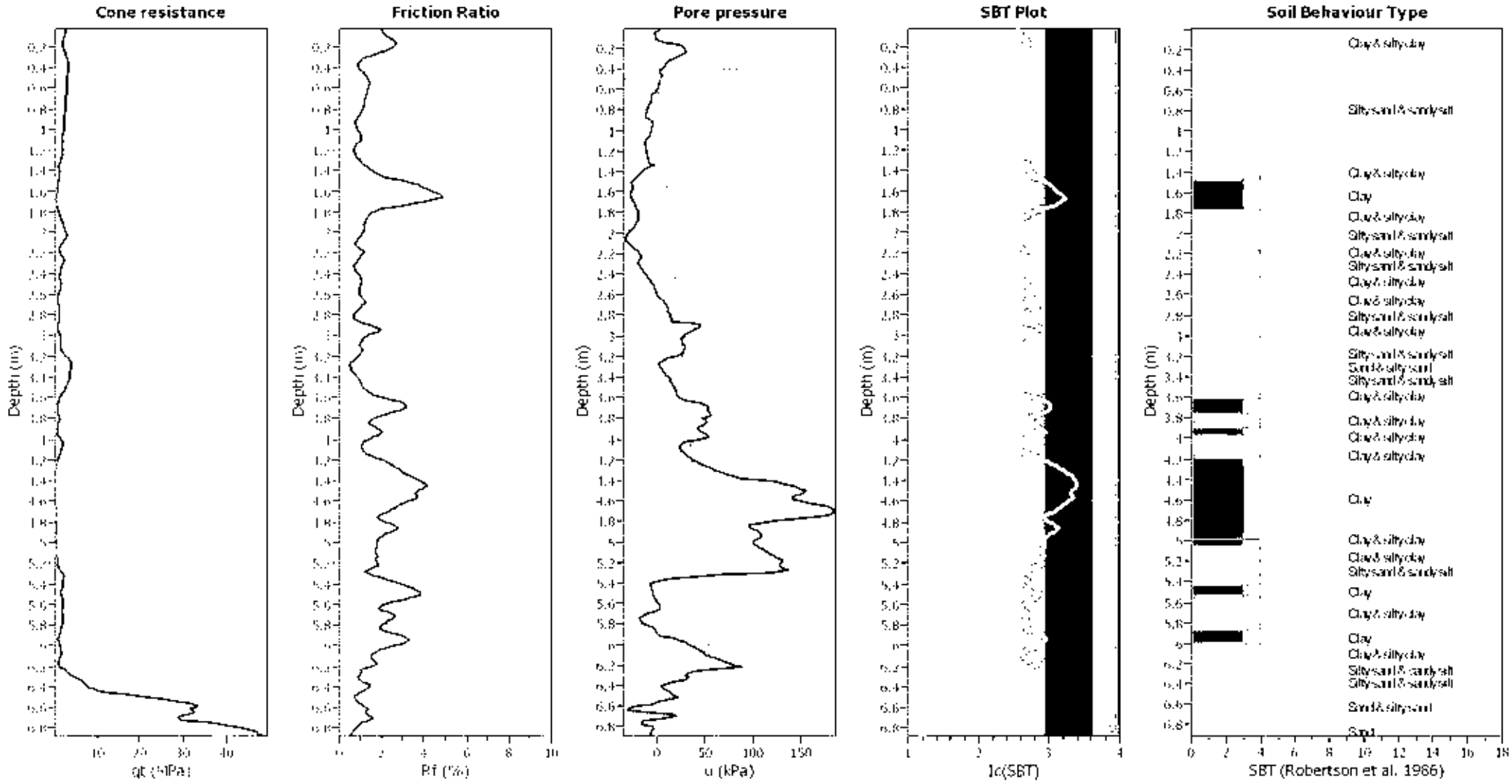






CPT basic interpretation plots



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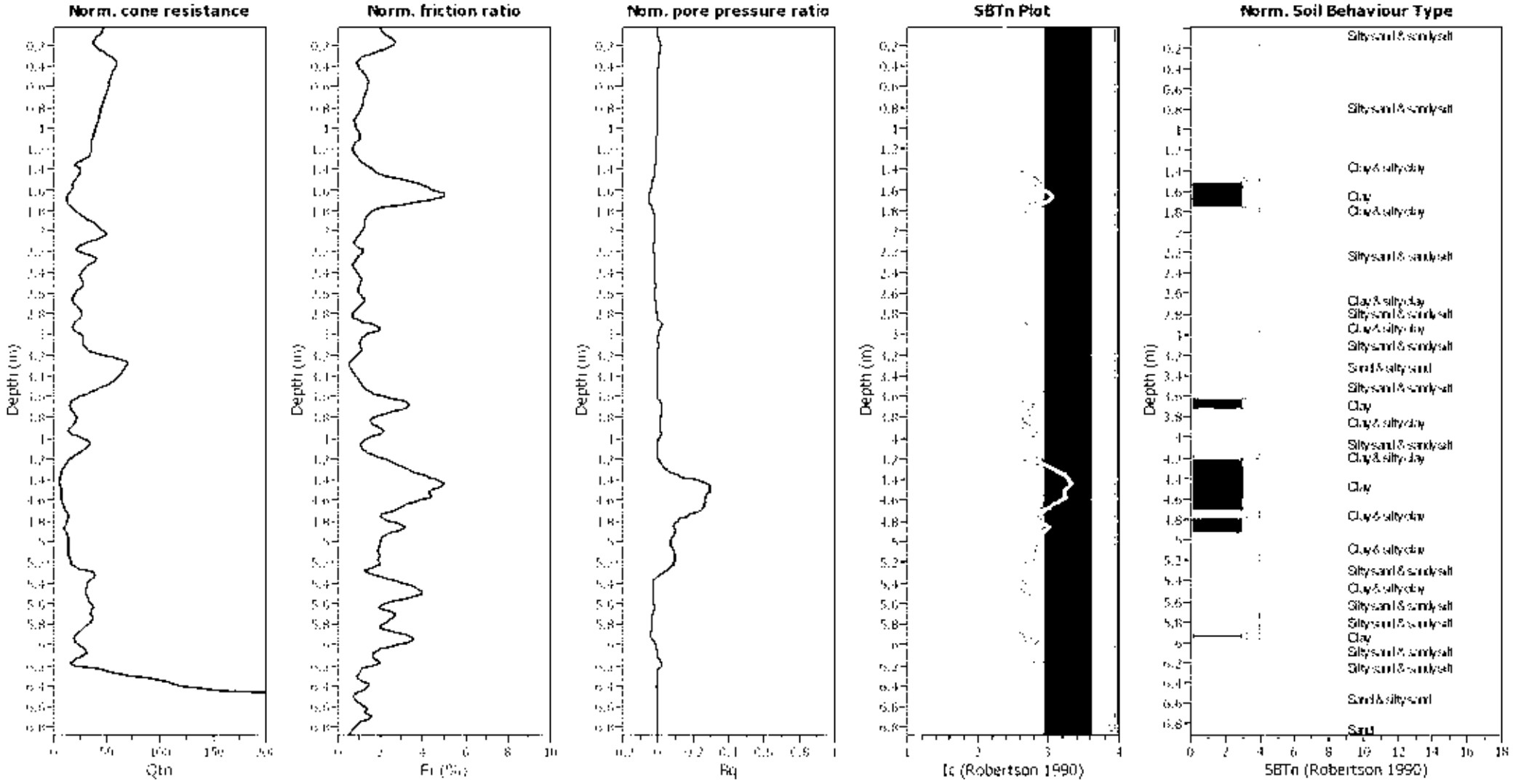
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 m	Fill height:	N/A	Limit 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

CPT basic interpretation plots (normalized)



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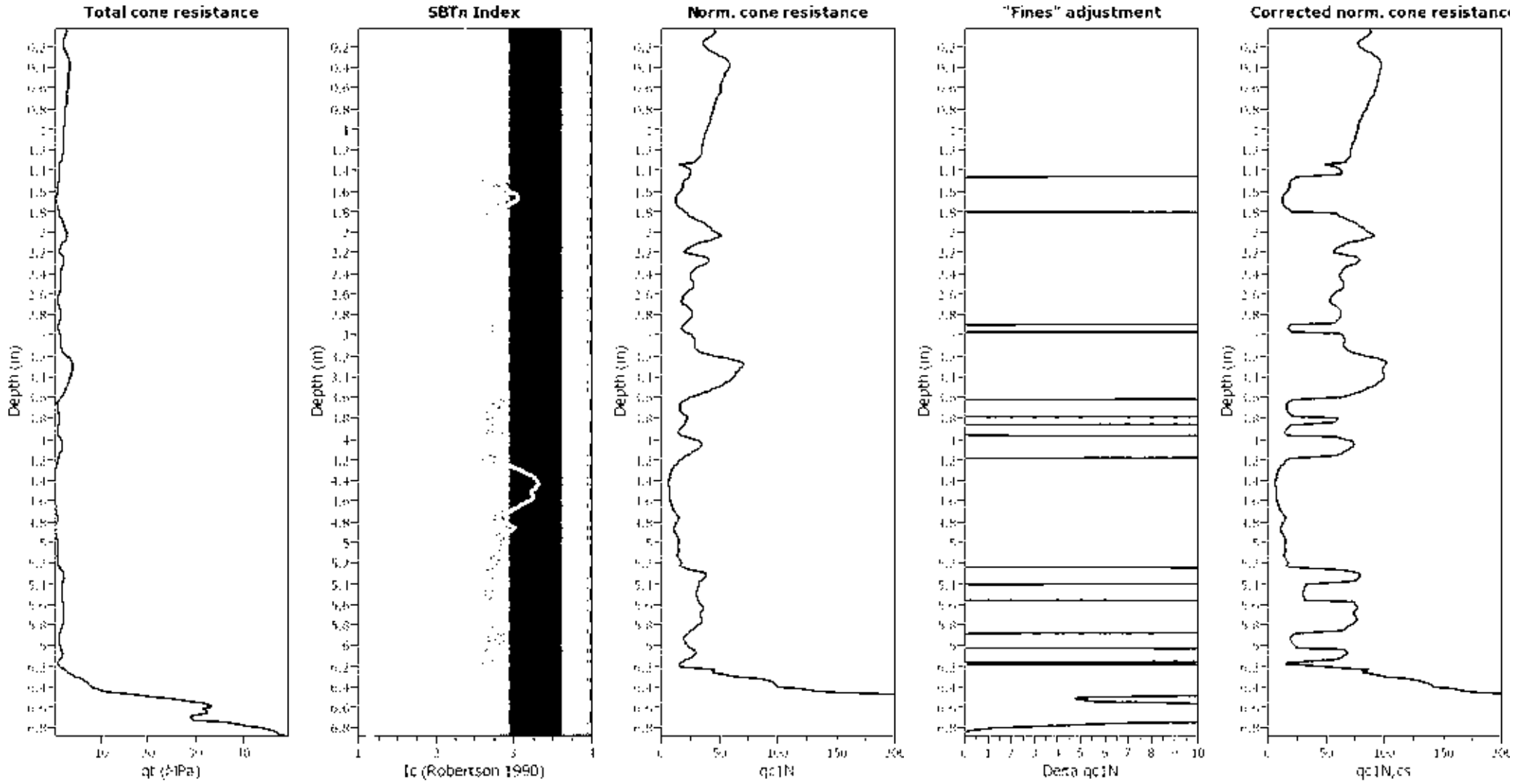
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn legend

1. Sensitive fine grained	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 (intermediate results)



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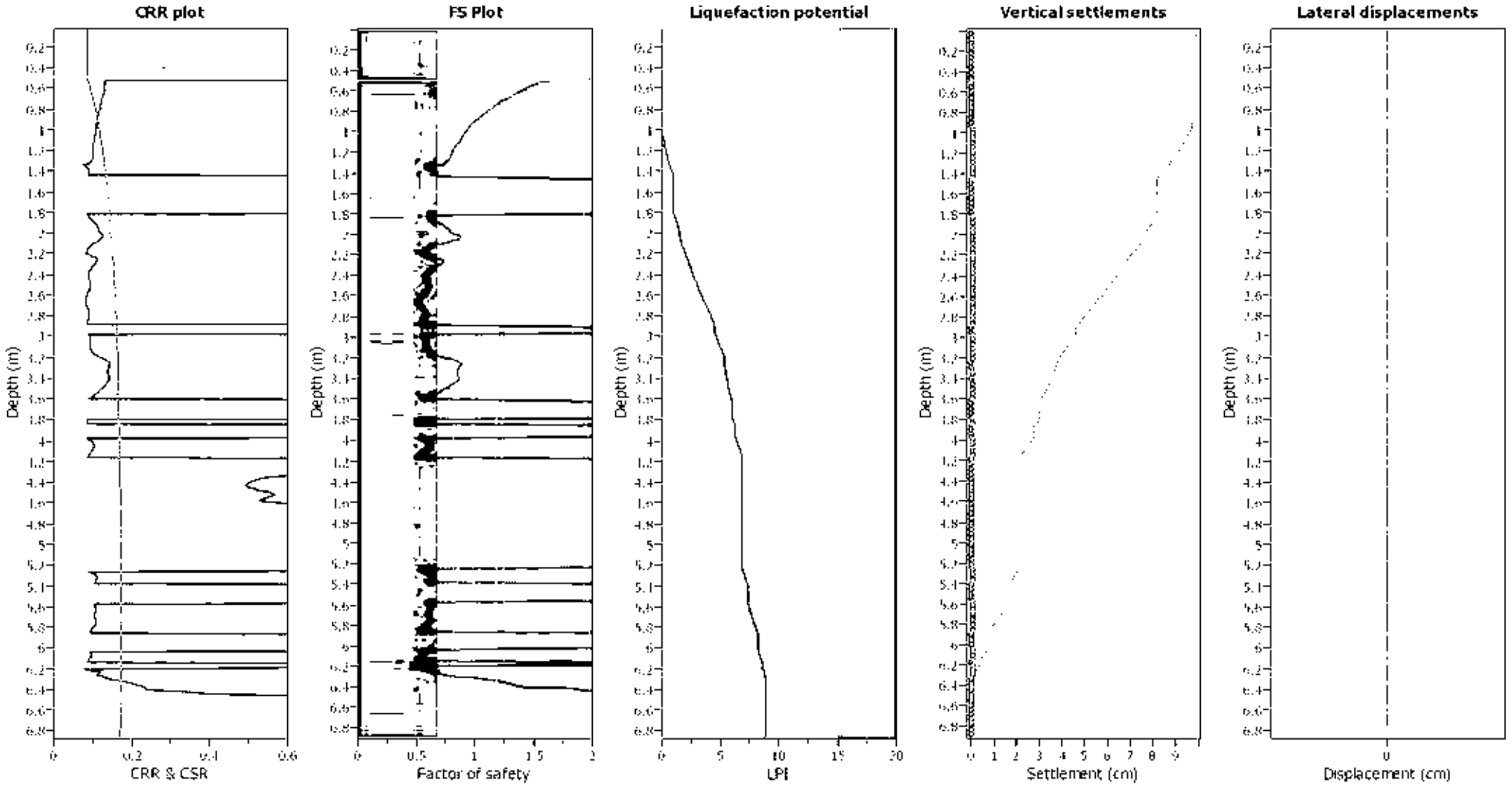
Liquefaction analysis overall plots



Input parameters and analysis data

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Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 m	Fill height:	N/A	Limit depth:	N/A

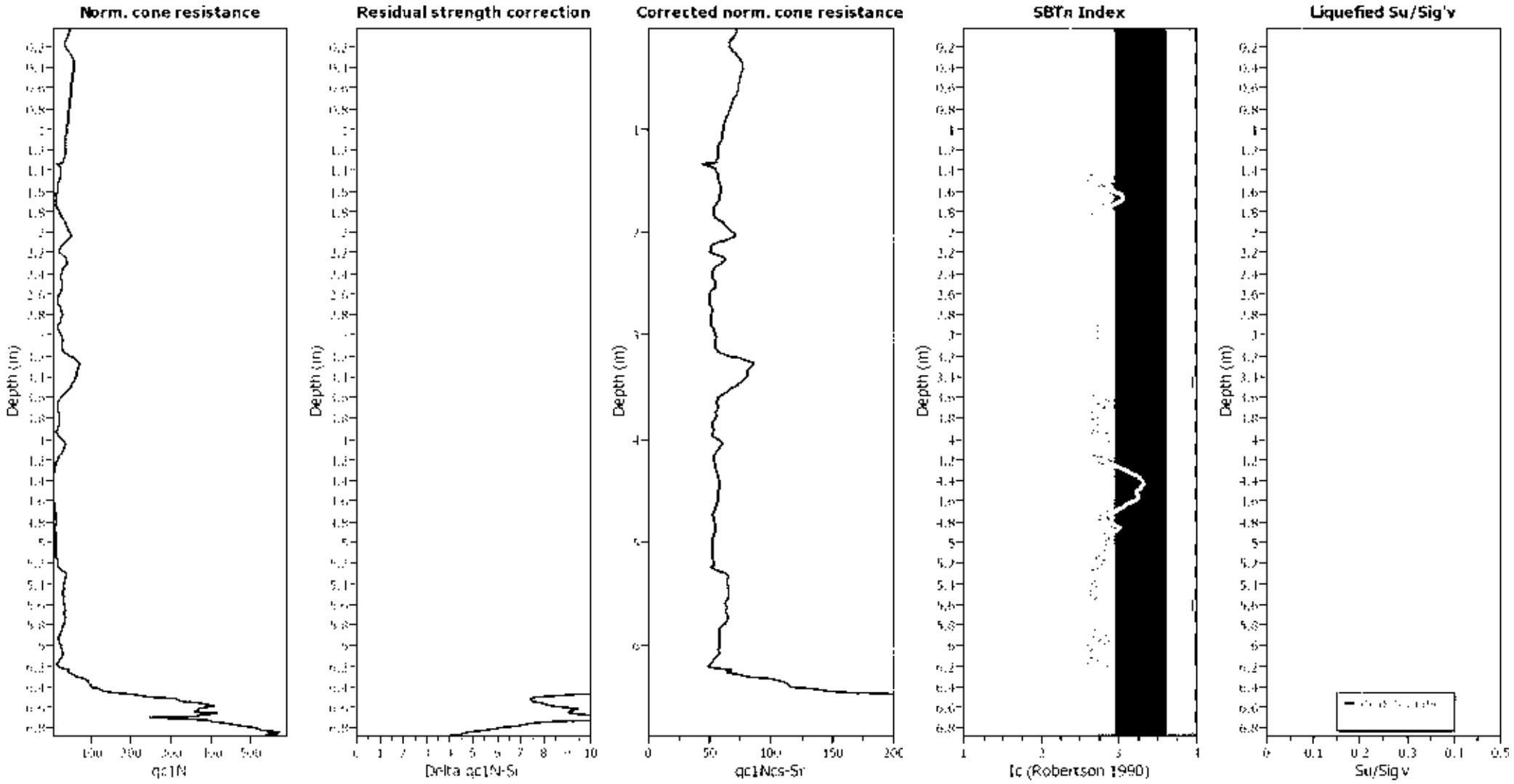
F.S. color scheme

- ☐ 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

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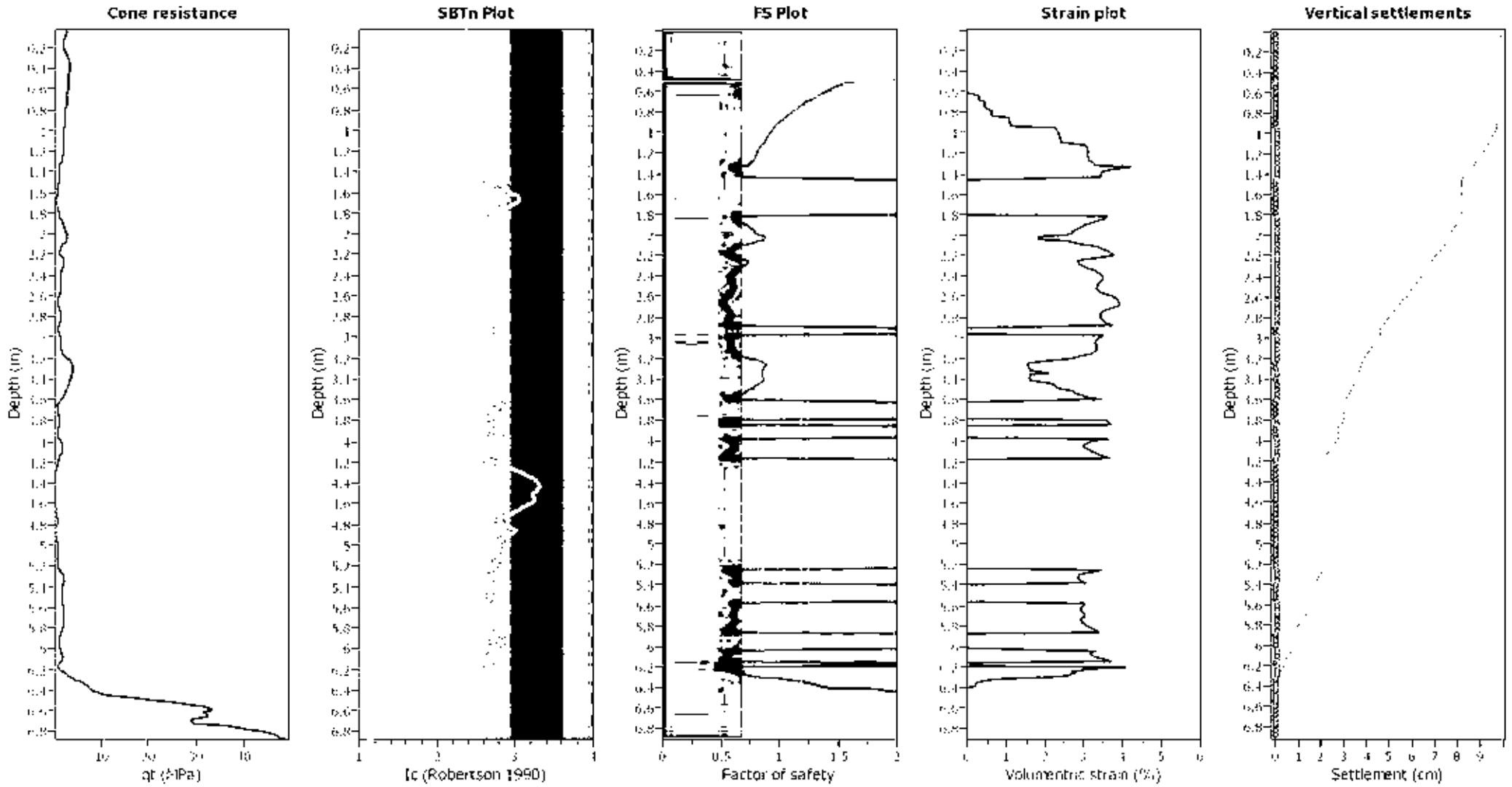
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 m	Fill height:	N/A	Limit depth	N/A

Estimation of post-earthquake settlements



Abbreviations

qt:	Total cone resistance (cone resistance q corrected for pore water effects)
Ic:	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumentric strain:	Post liquefaction volumentric strain

Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

CPT file : CPT02_163bHalswellJunctionRd

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:	Sand & Clay
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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		
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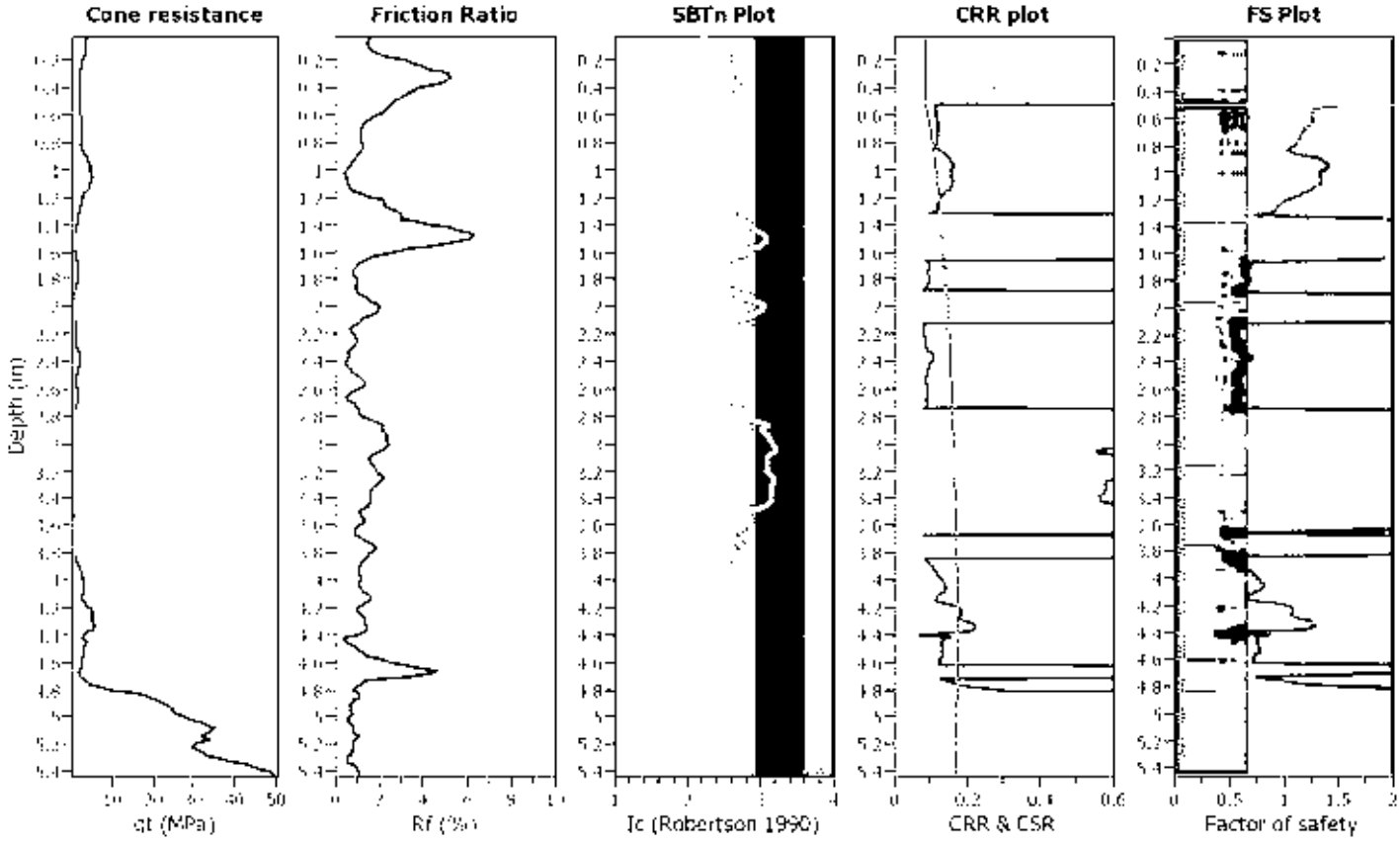
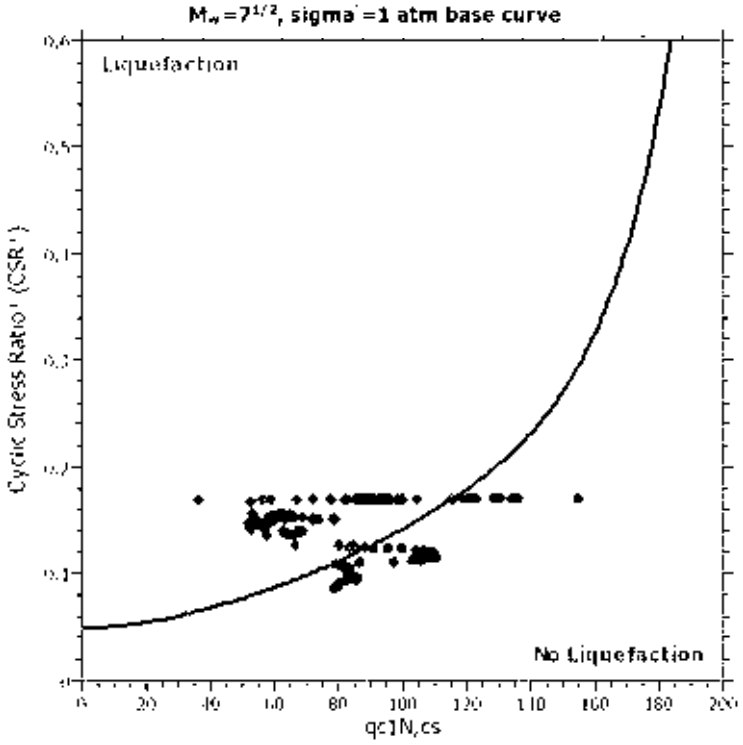
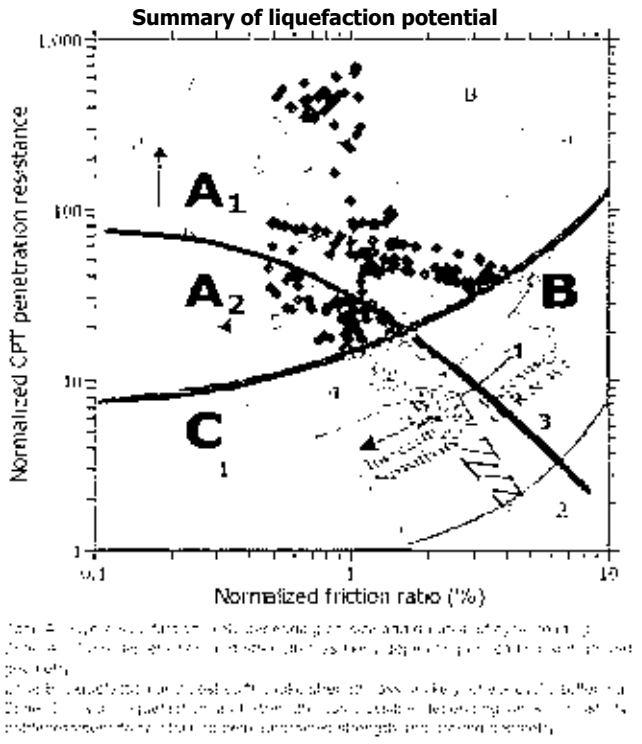
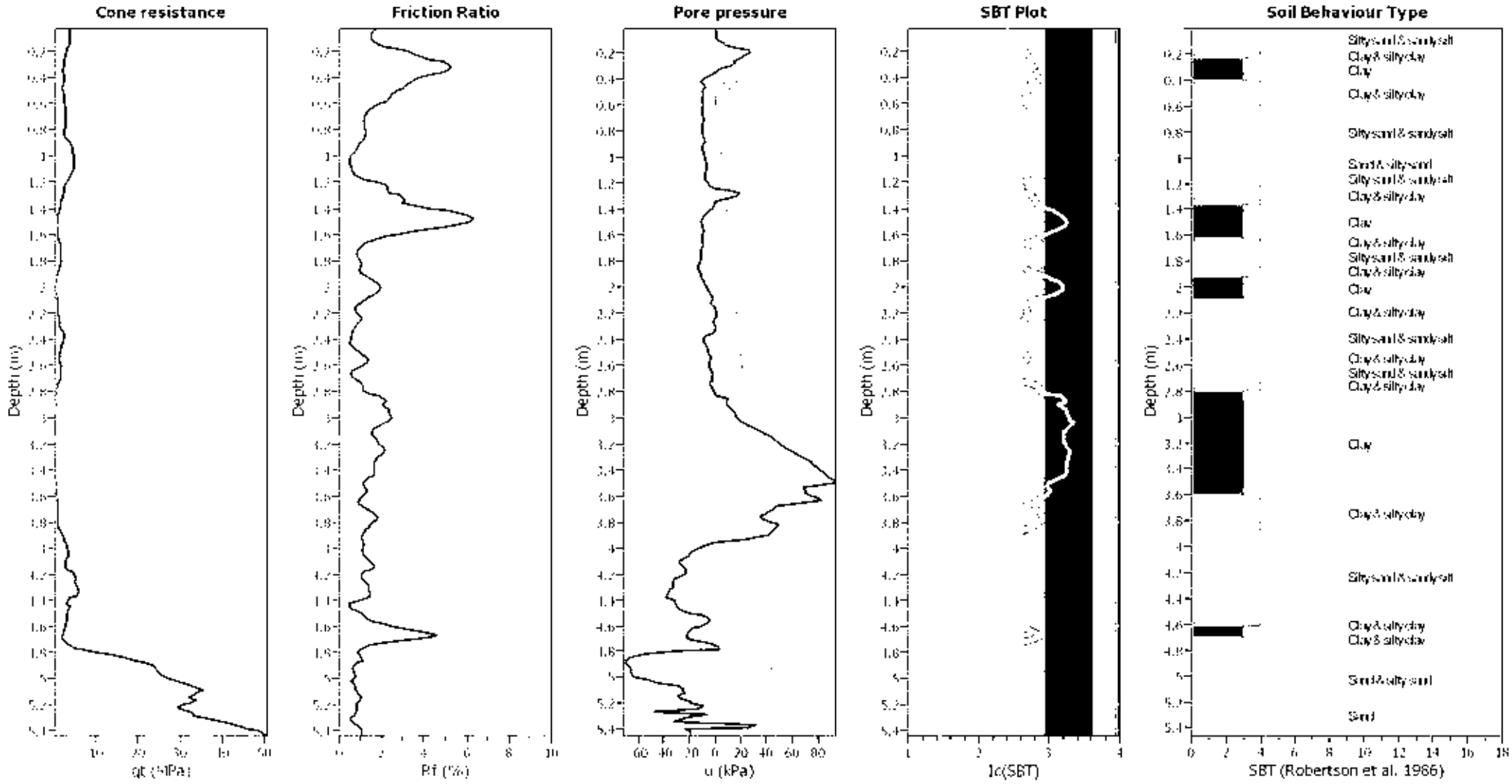






CPT basic interpretation plots



Input parameters and analysis data

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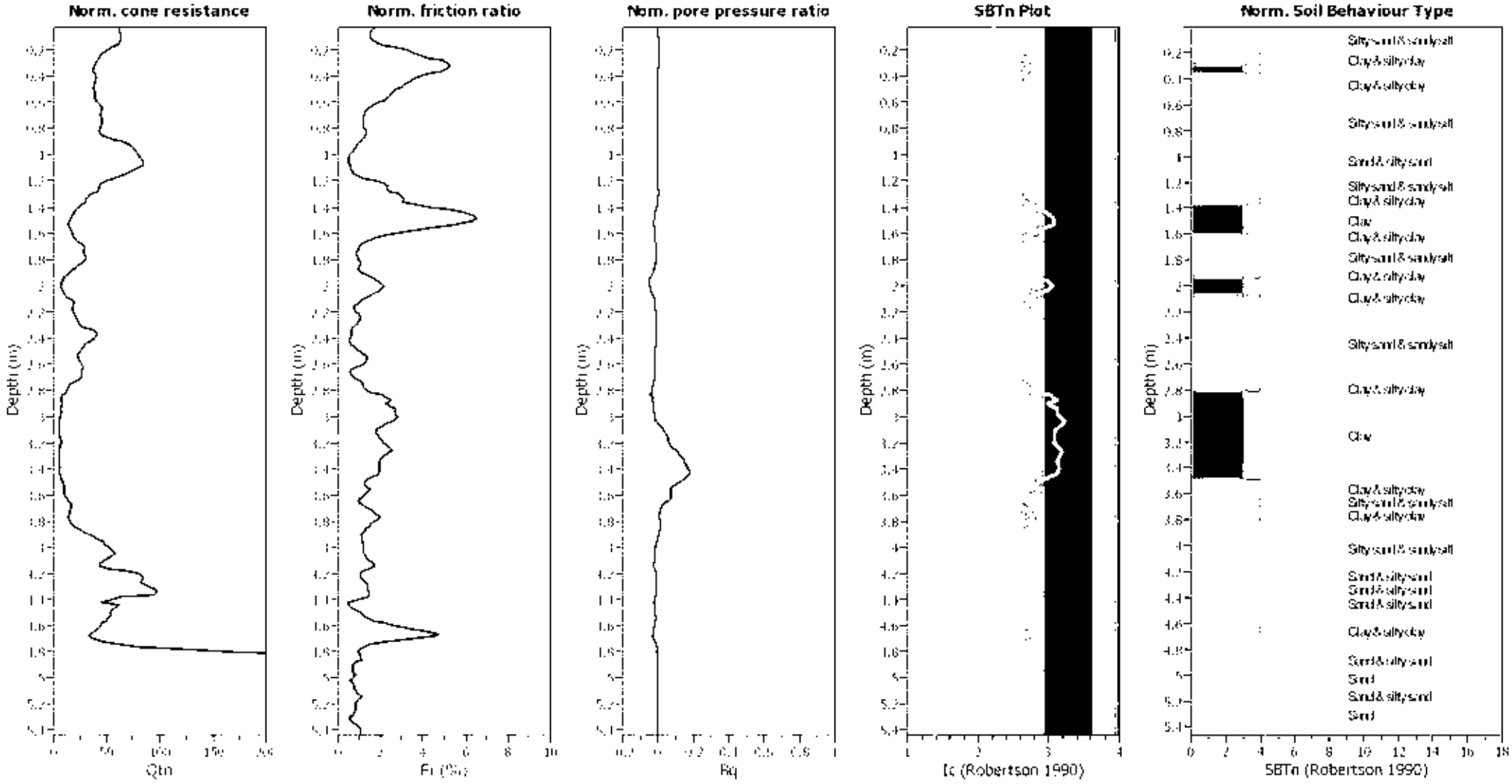
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 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

CPT basic interpretation plots (normalized)



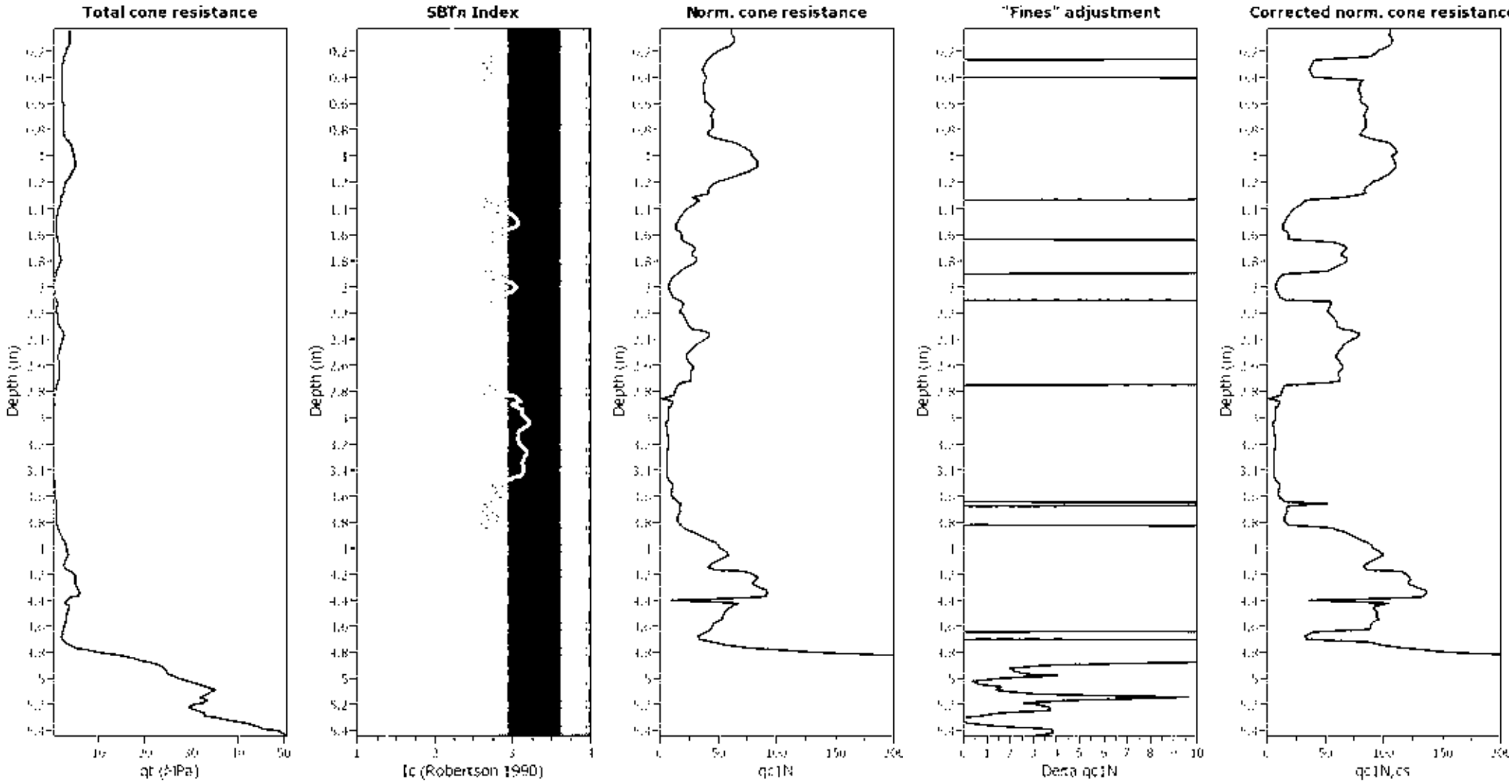
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	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	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

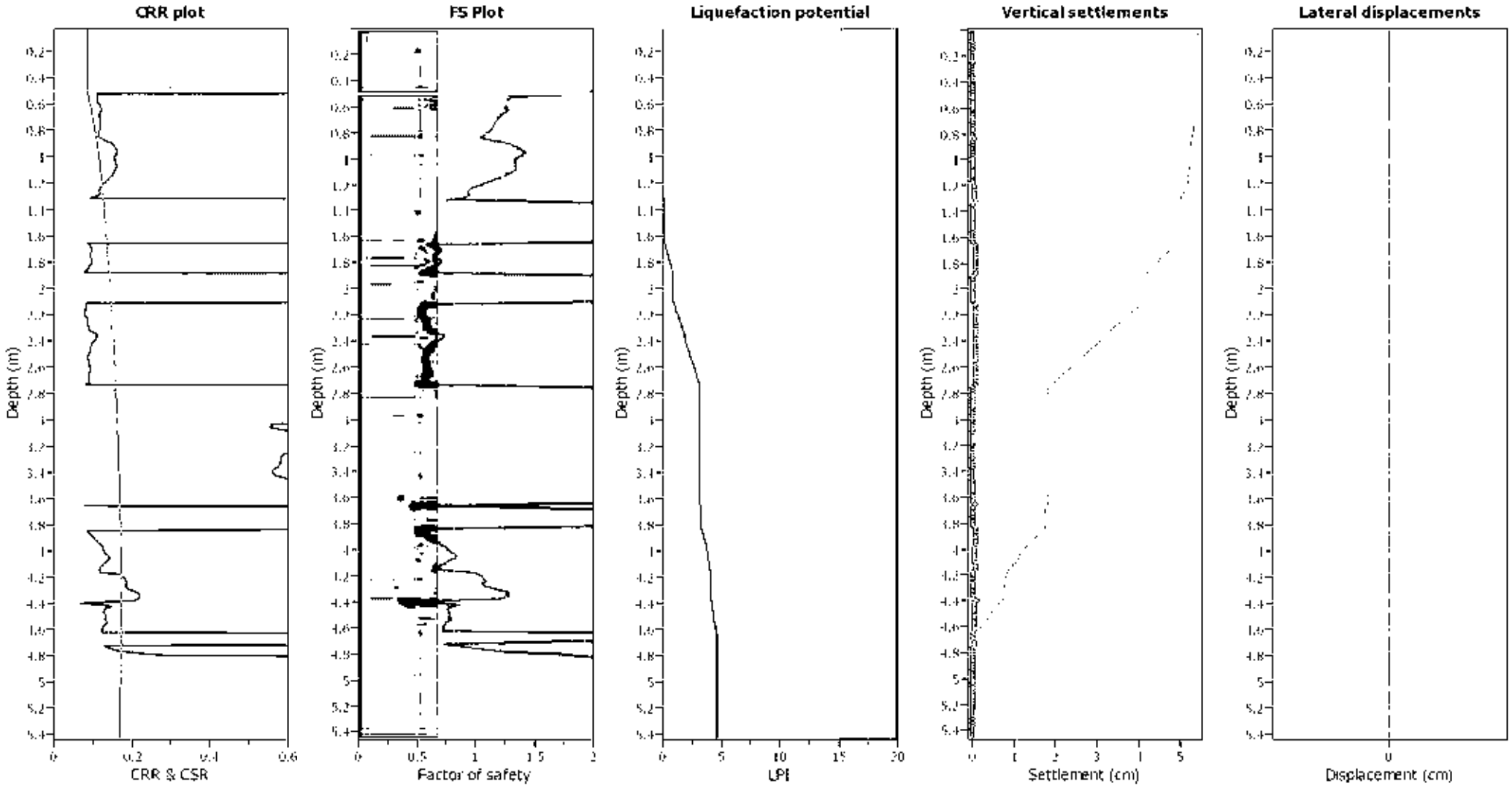
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	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
Liquefaction correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 m	Fill height:	N/A	Limit depth:	N/A

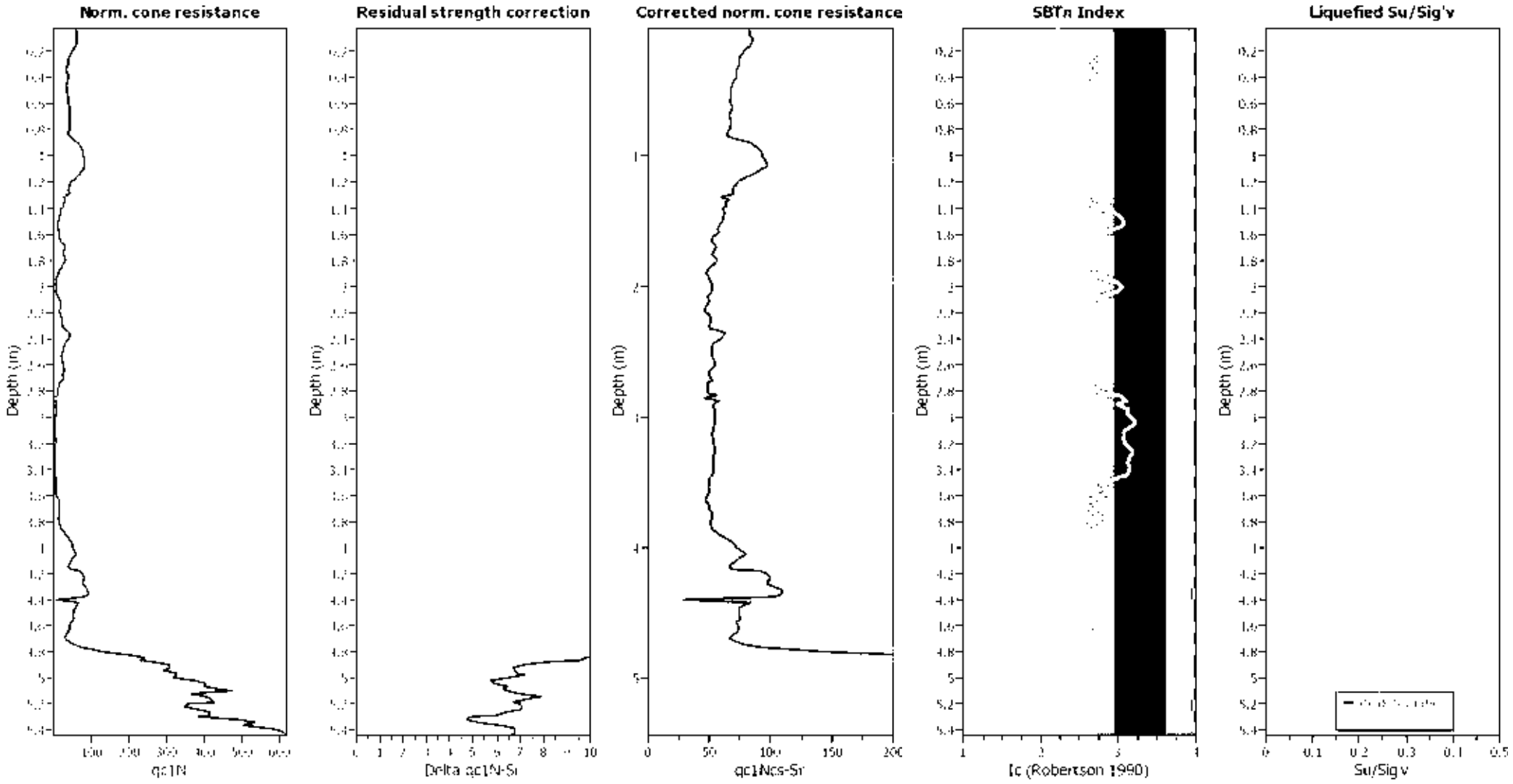
F.S. color scheme

- ☐ 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

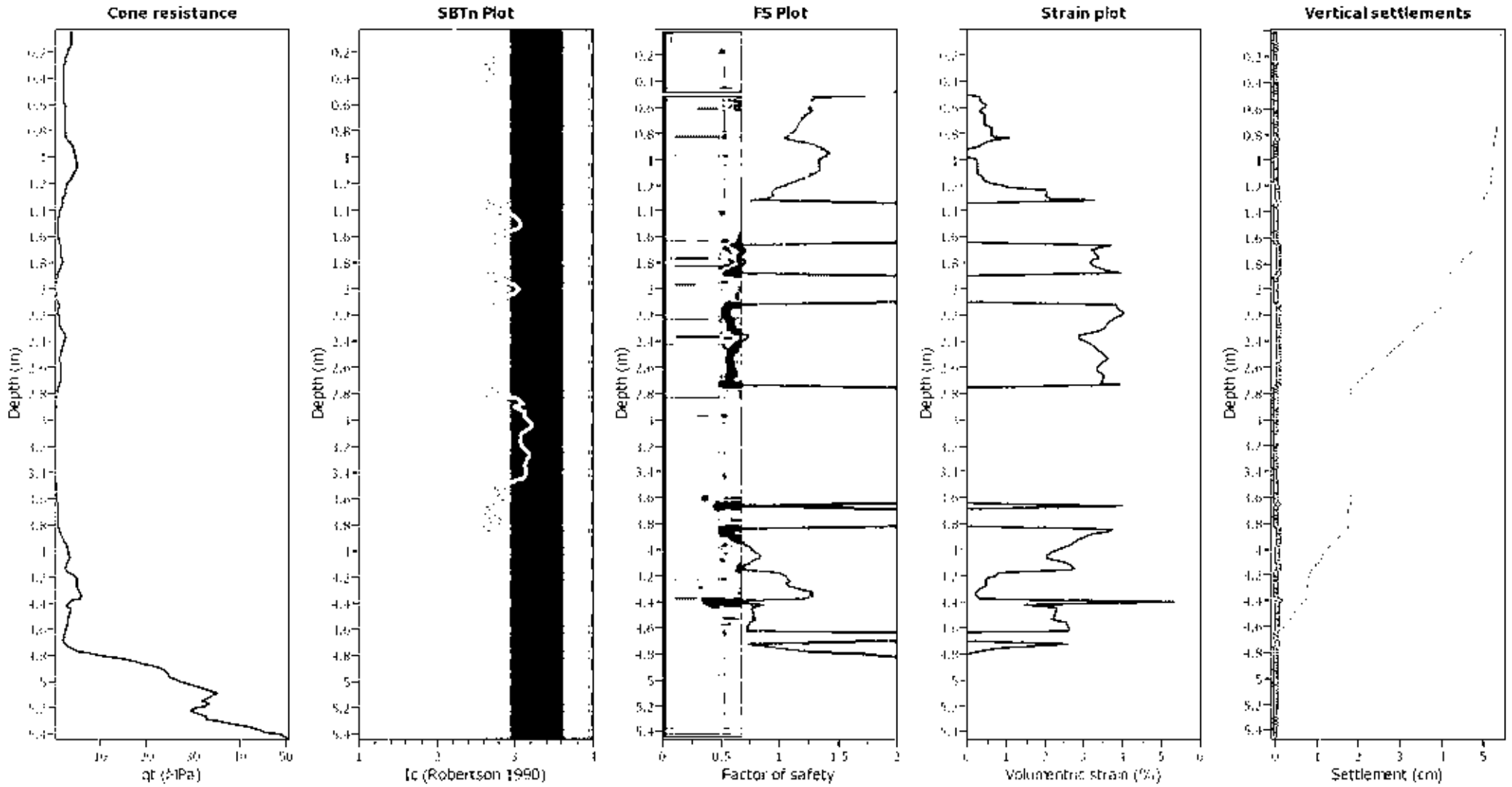
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 m	Fill height:	N/A	Limit depth:	N/A

Estimation of post-earthquake settlements



Abbreviations

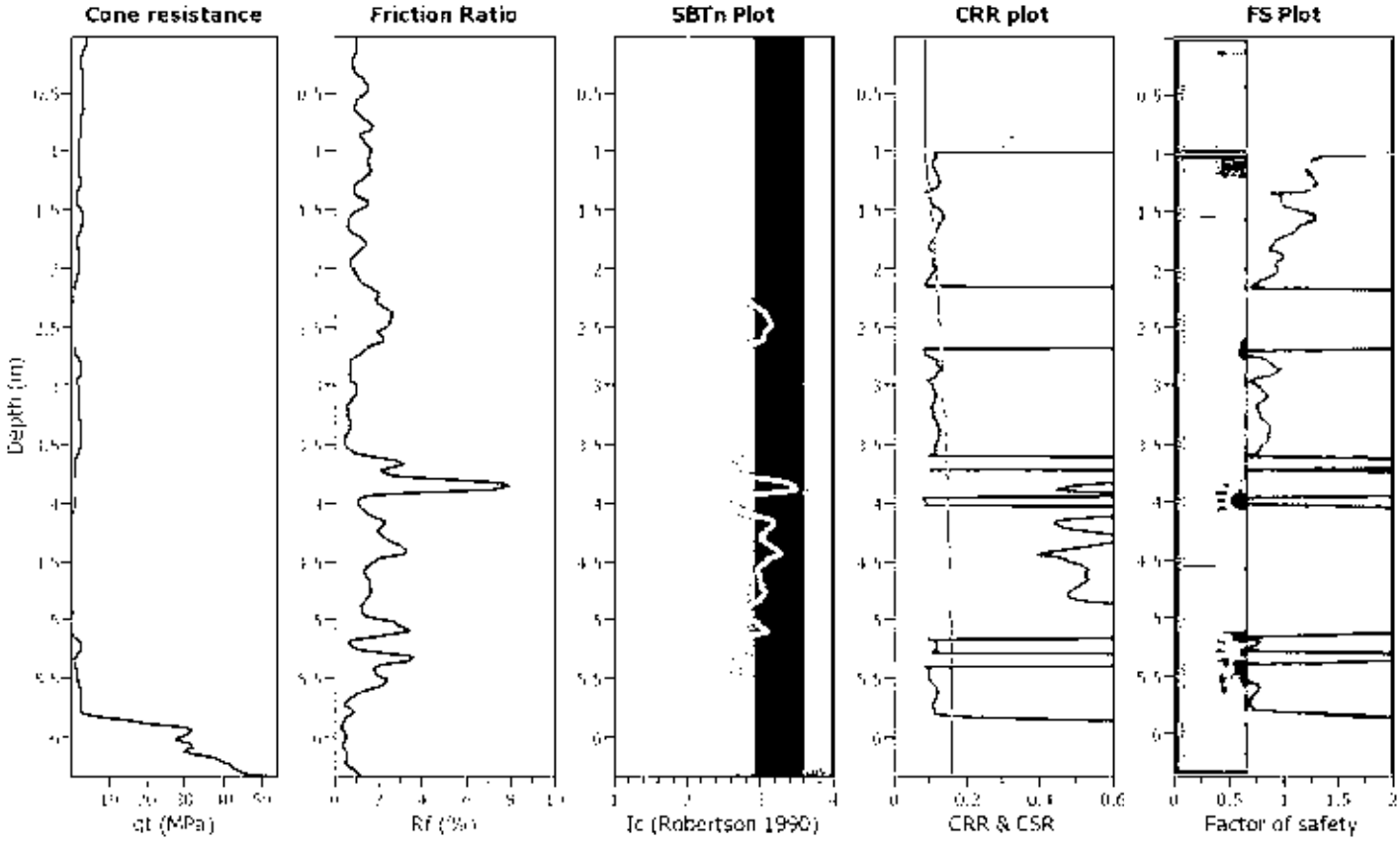
qt	Total cone resistance (cone resistance q corrected for pore water effects)
Ic	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumentric strain:	Post liquefaction volumentric strain

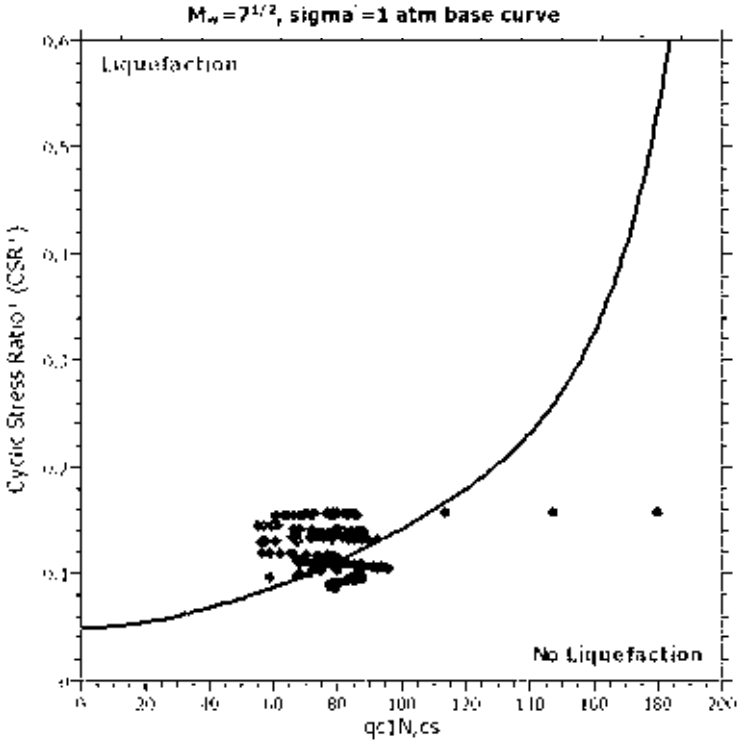
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

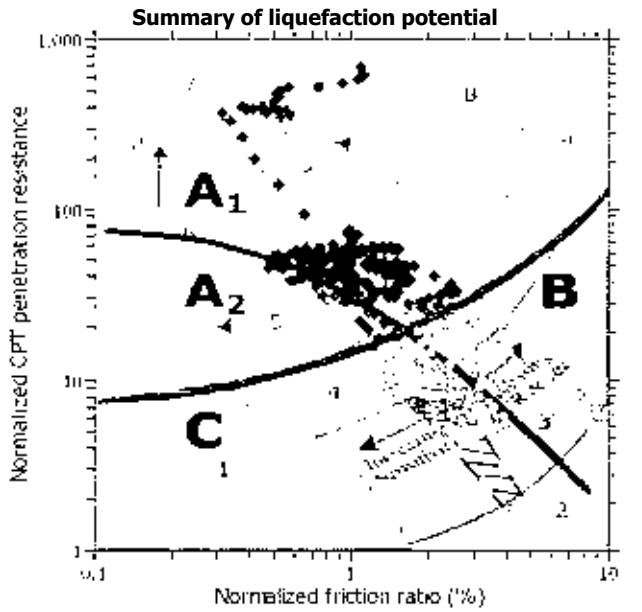
CPT file : CPT03_163bHalswellJunctionRd

Input parameters and analysis data

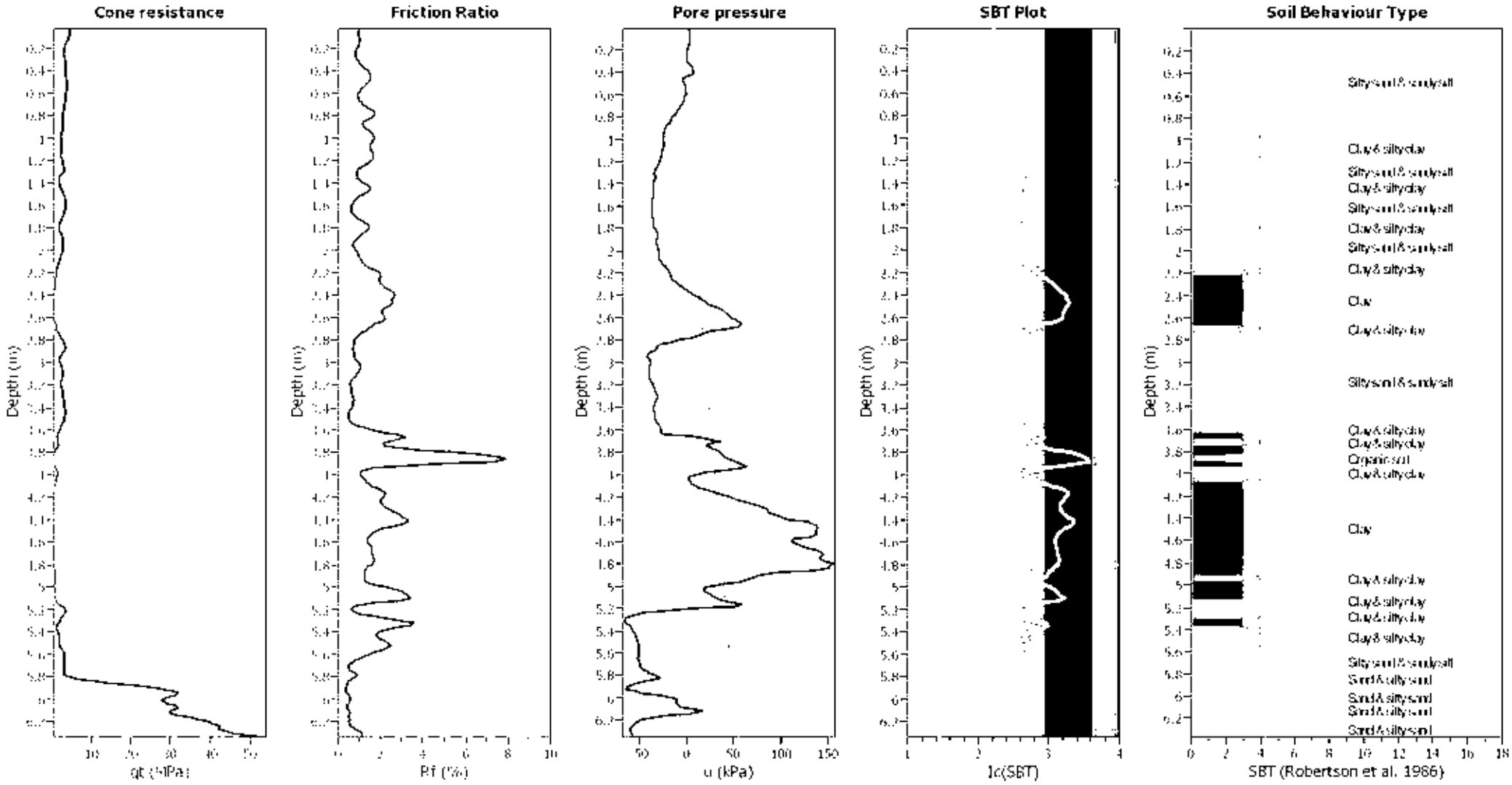
Analysis method:	I&B (2008)	G.W.T. (in-situ):	1.00 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	I&B (2008)	G.W.T. (earthq.):	1.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration:	0.13	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



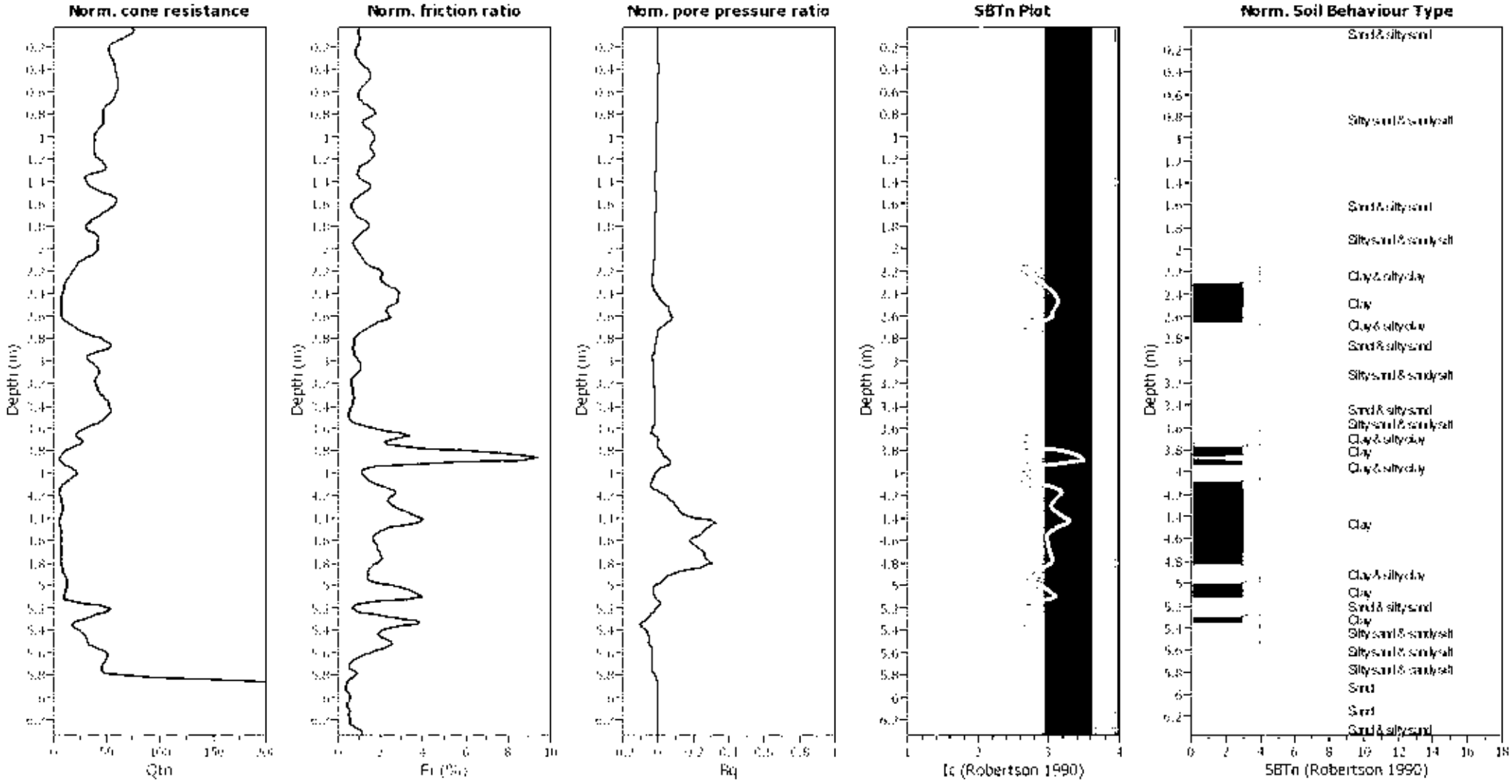
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 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

CPT basic interpretation plots (normalized)



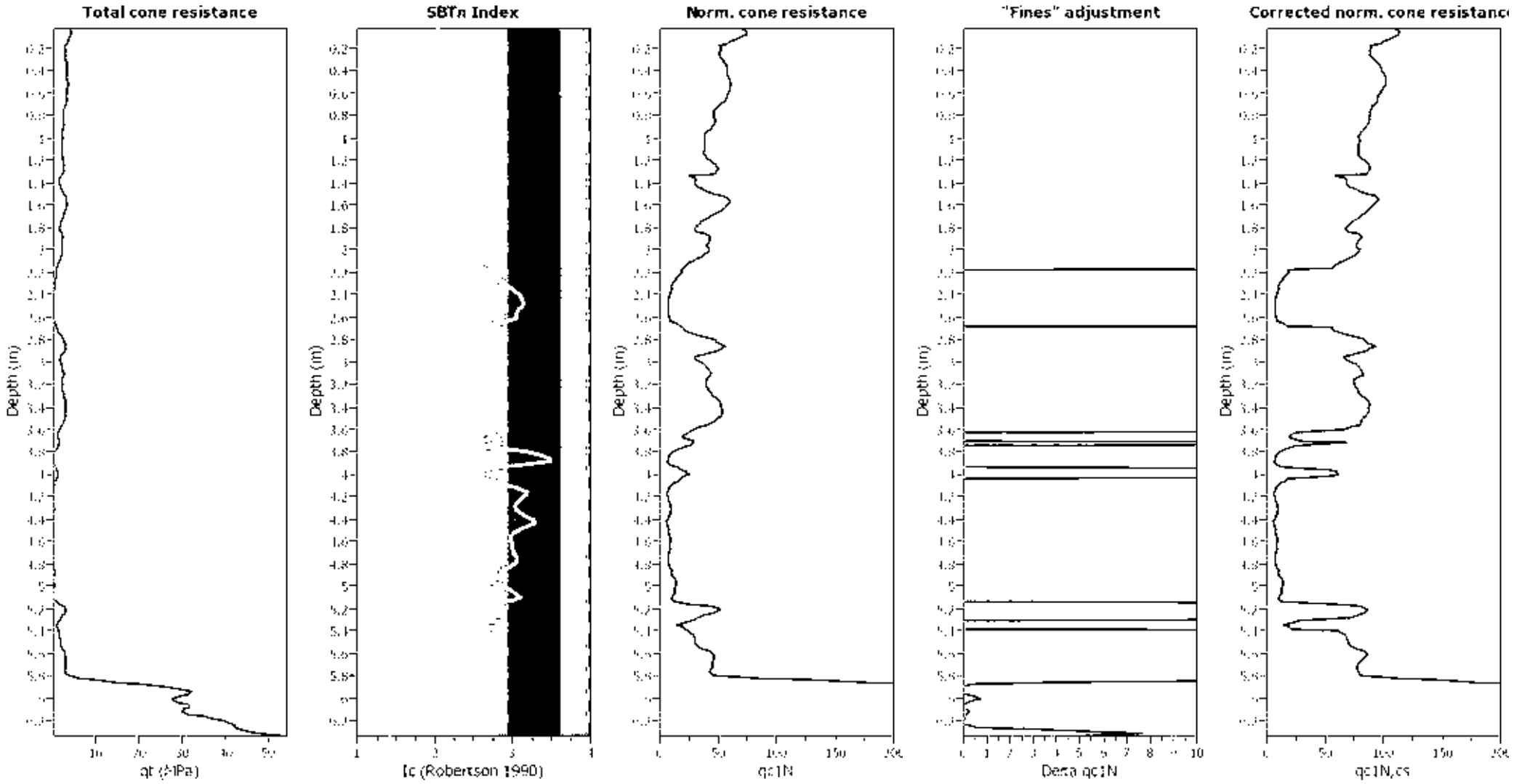
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

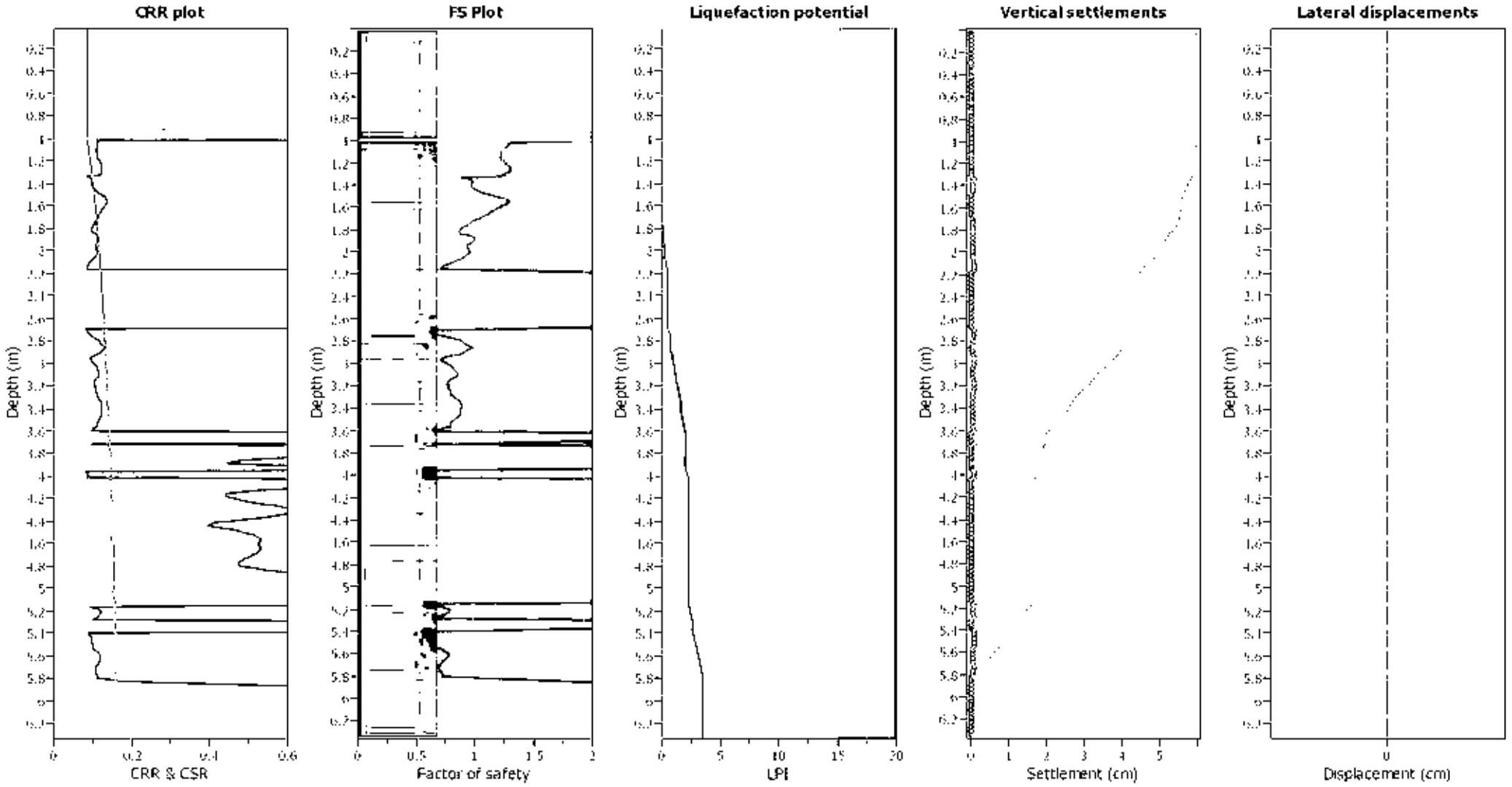
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 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.):	1.00 m	Fill weight:	N/A
Liquefaction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.00 m	Fill height:	N/A	Limit depth:	N/A

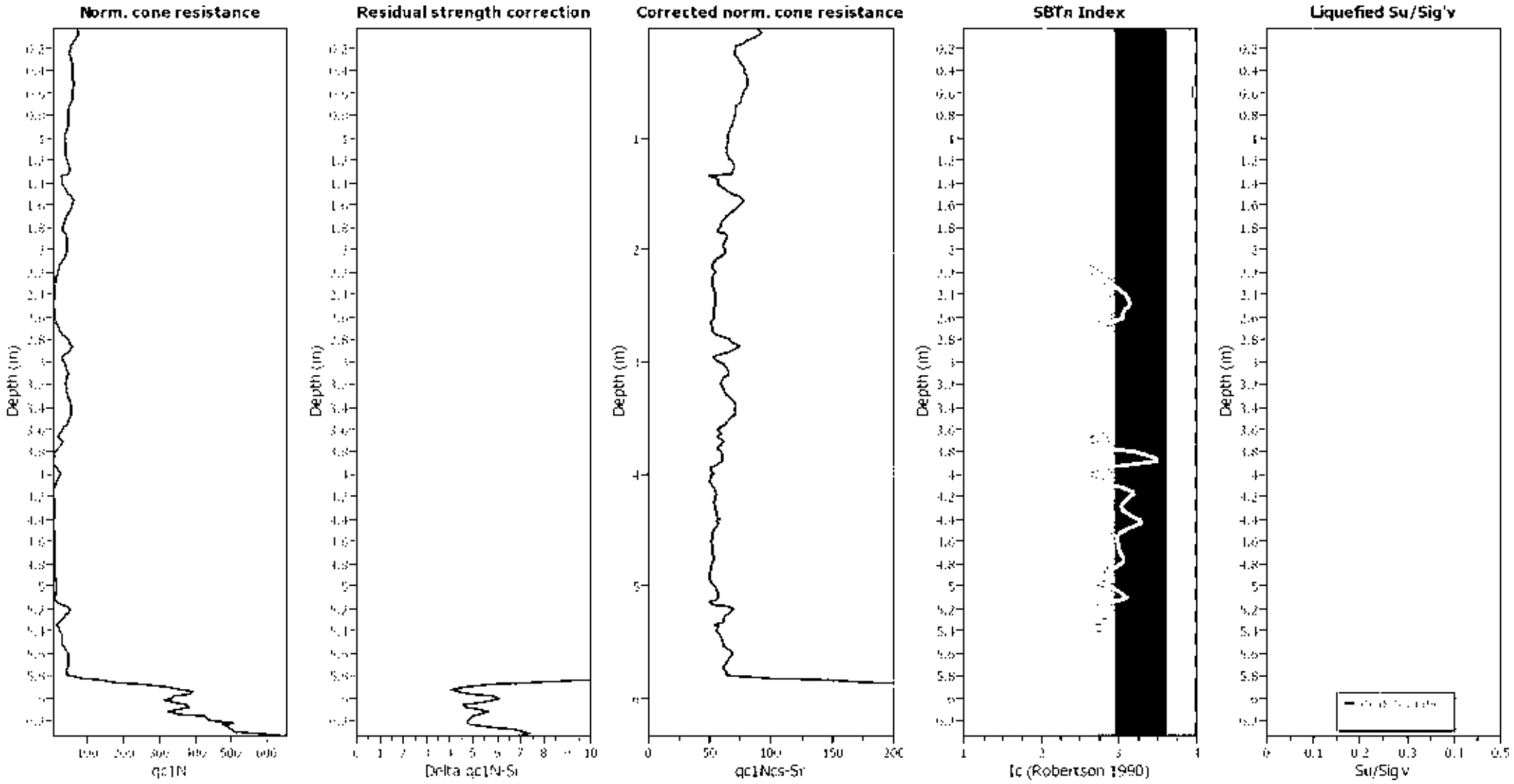
F.S. color scheme

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

LPI color scheme

- ☐ Very high risk
- ☐ High risk
- ☐ Low risk

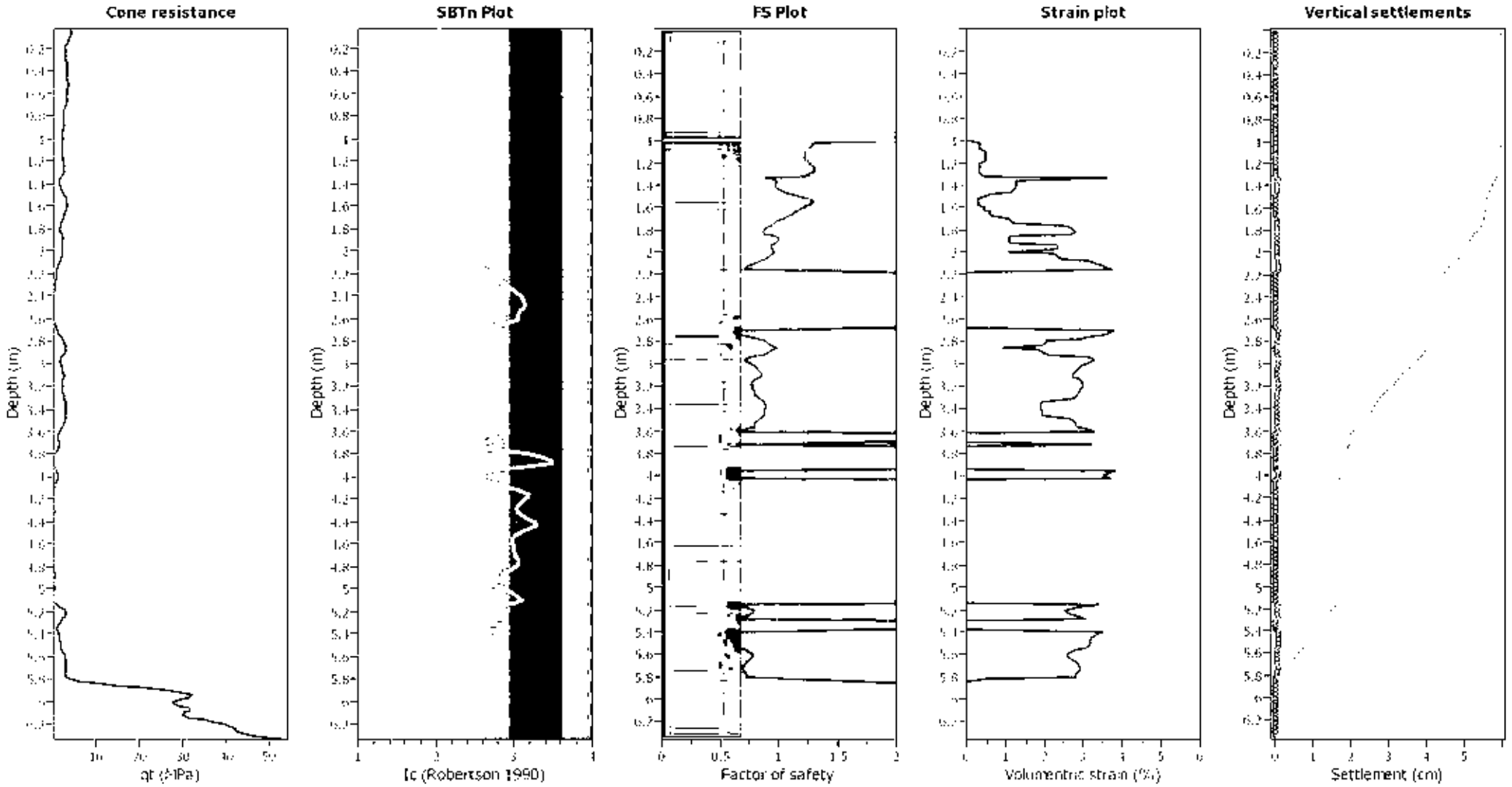
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.00 m	Fill height:	N/A	Limit depth:	N/A

Estimation of post-earthquake settlements



Abbreviations

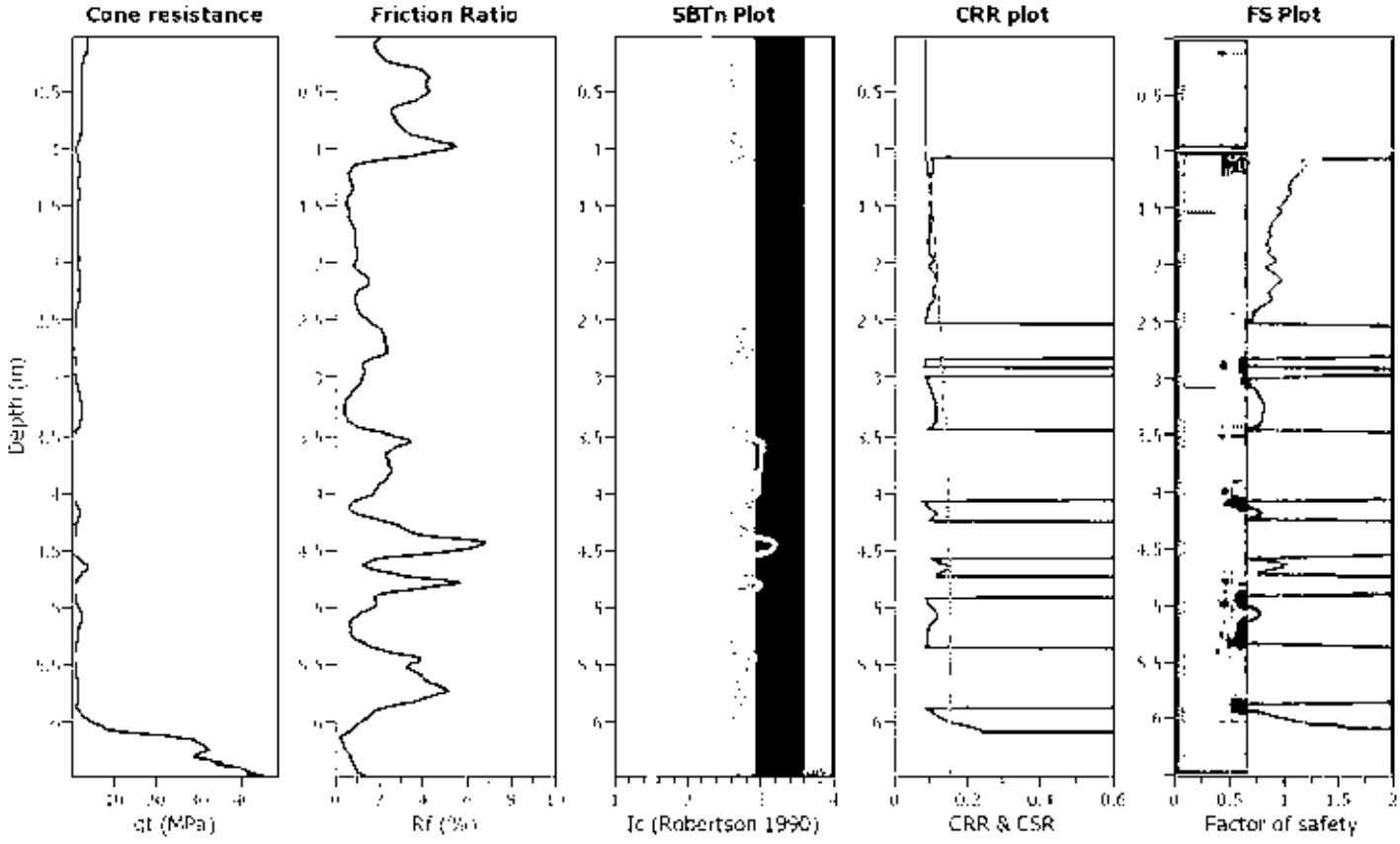
qt	Total cone resistance (cone resistance q corrected for pore water effects)
Ic	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumentric strain:	Post liquefaction volumentric strain

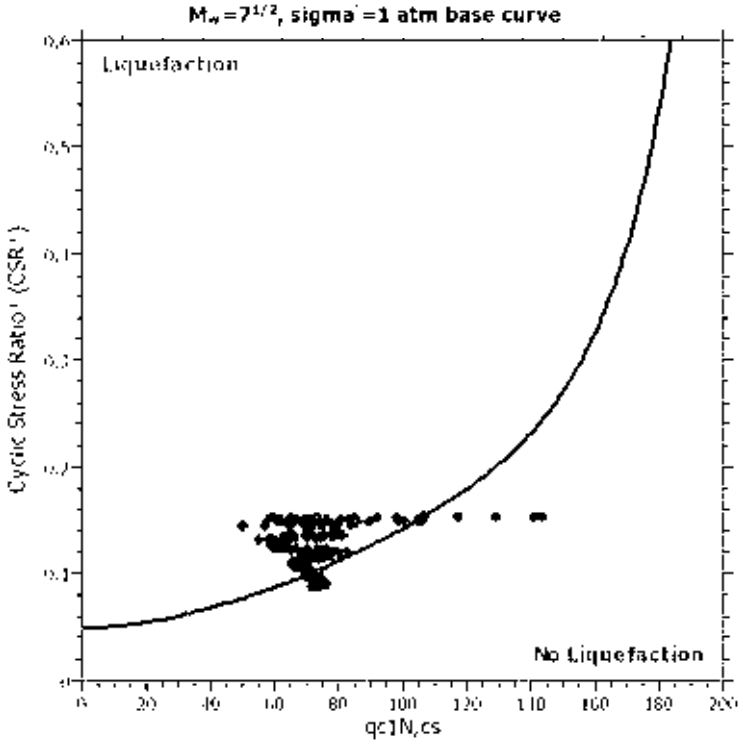
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

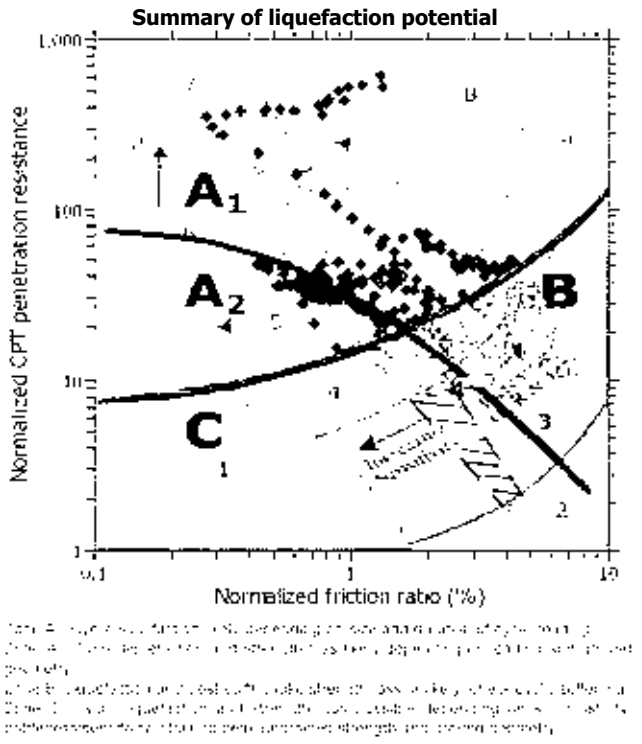
CPT file : CPT04_163bHalswellJunctionRd

Input parameters and analysis data

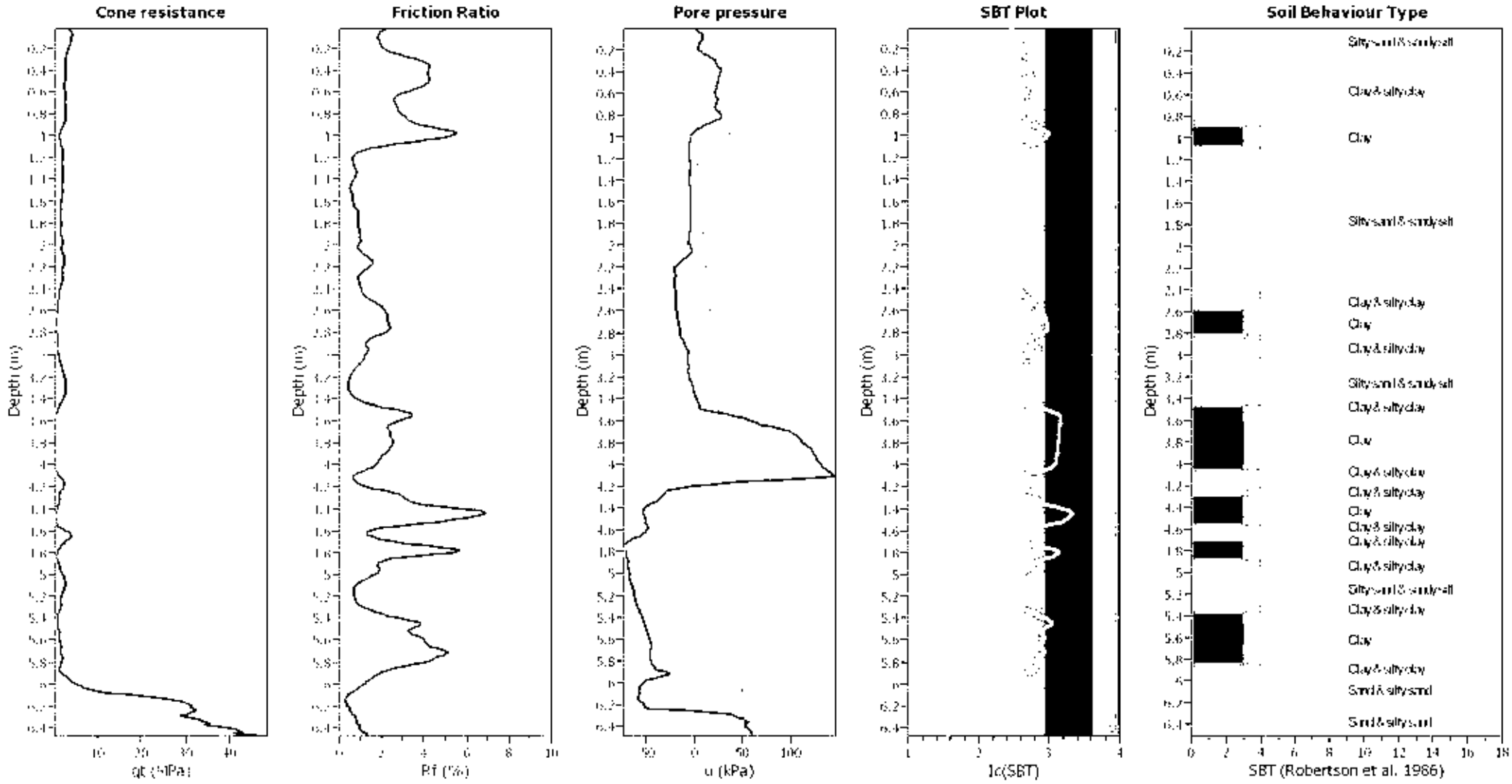
Analysis method:	I&B (2008)	G.W.T. (in-situ):	1.00 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	I&B (2008)	G.W.T. (earthq.):	1.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration:	0.13	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



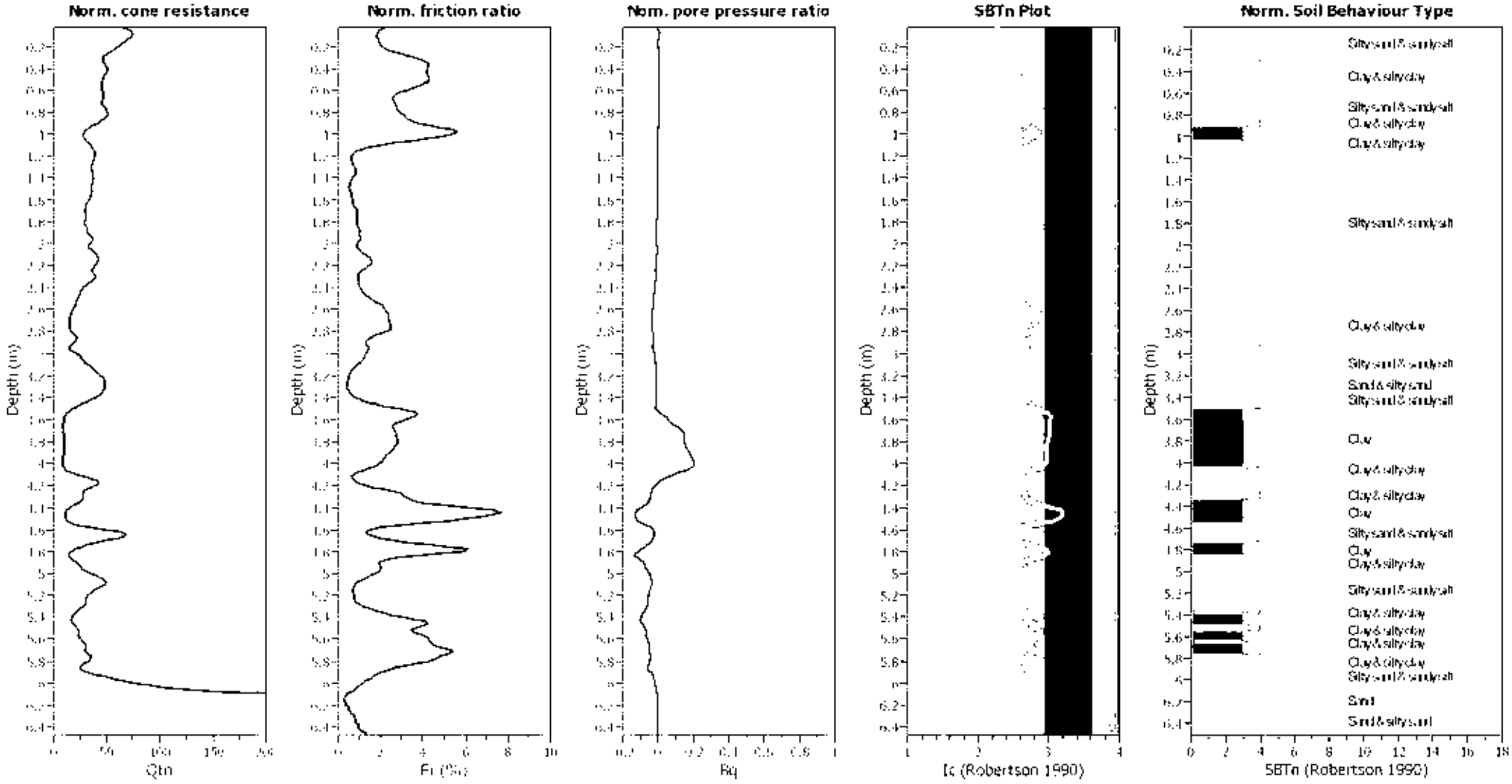
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 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

CPT basic interpretation plots (normalized)



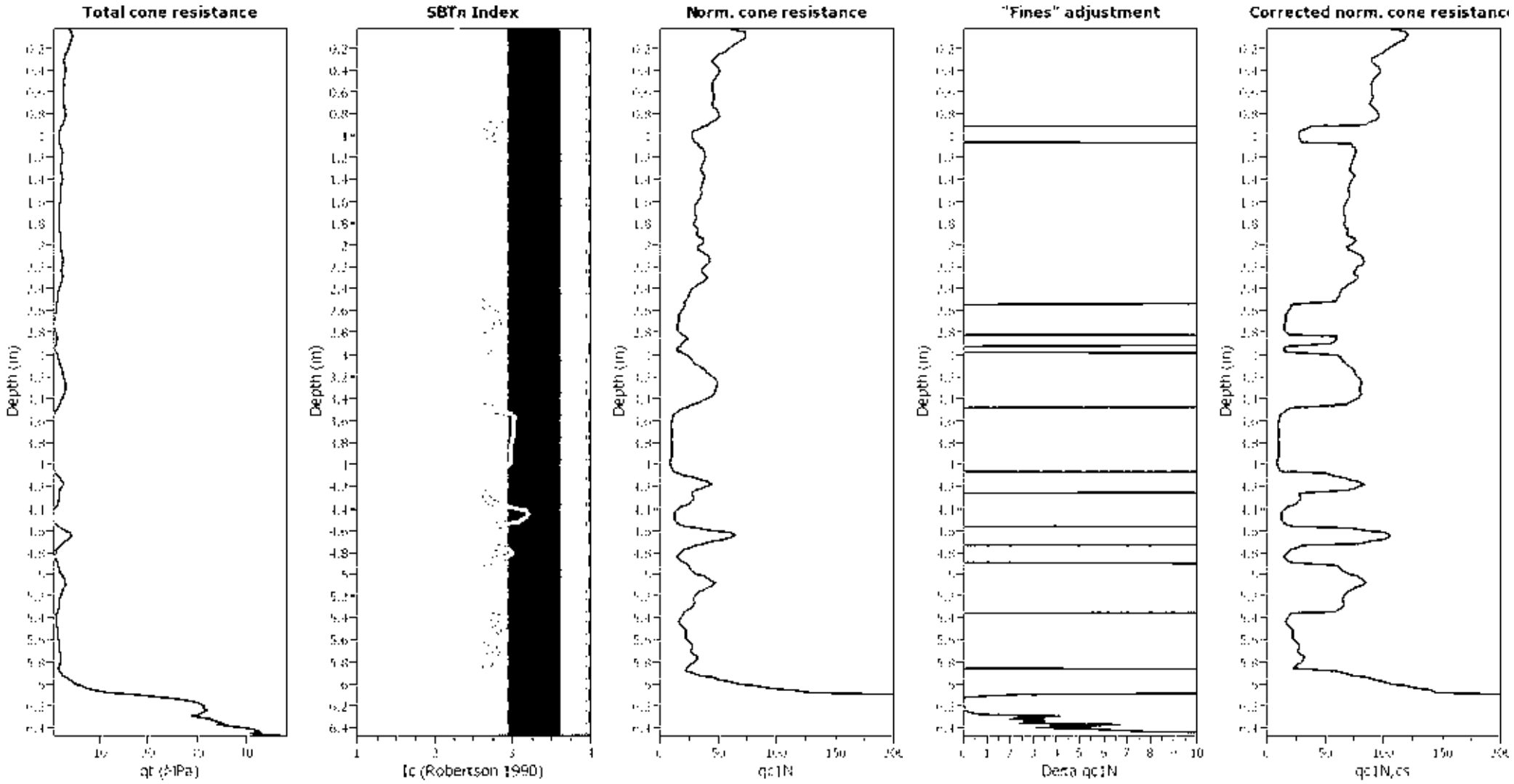
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

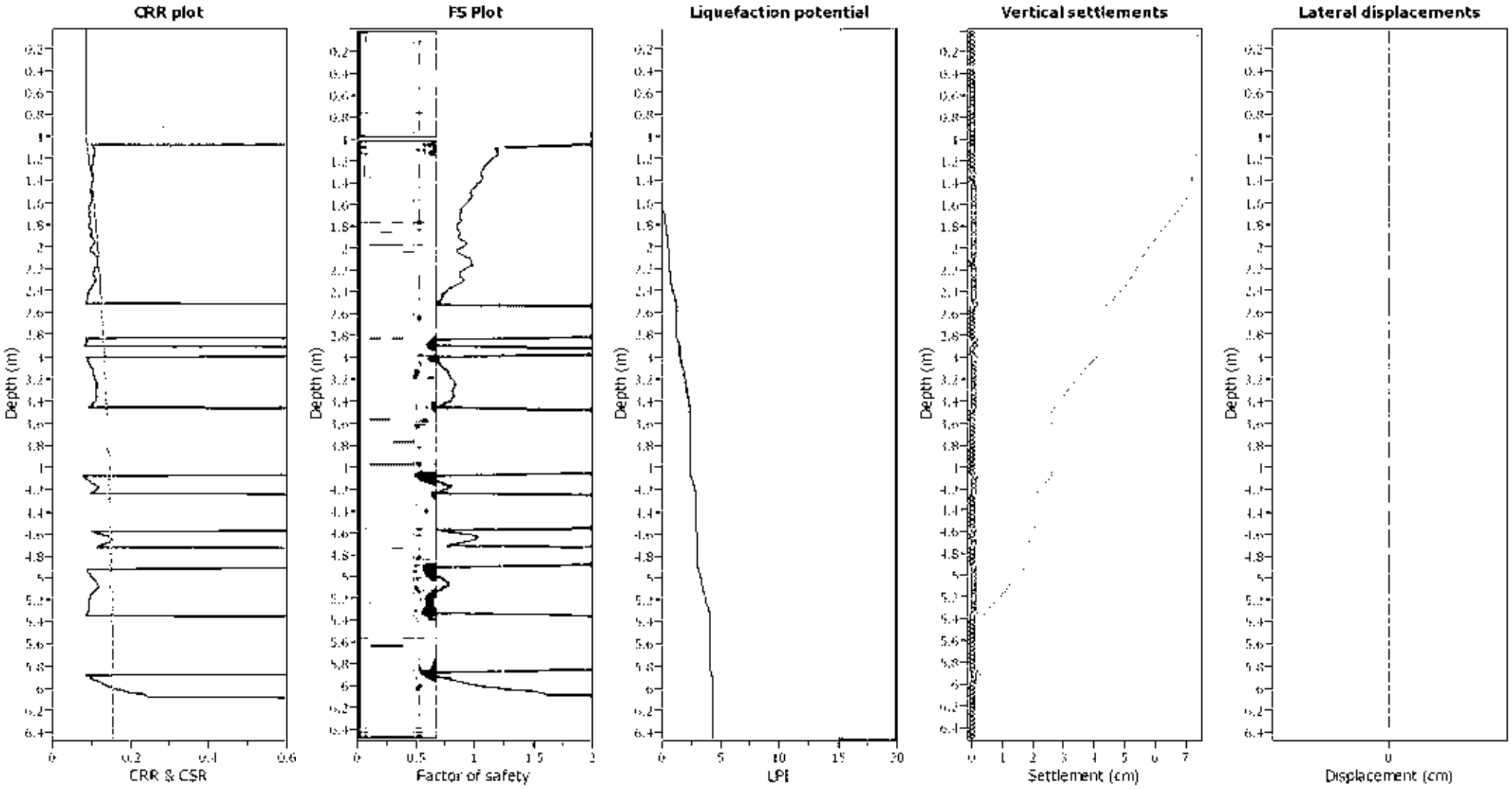
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 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.):	1.00 m	Fill weight:	N/A
Liner correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.00 m	Fill height:	N/A	Limit depth:	N/A

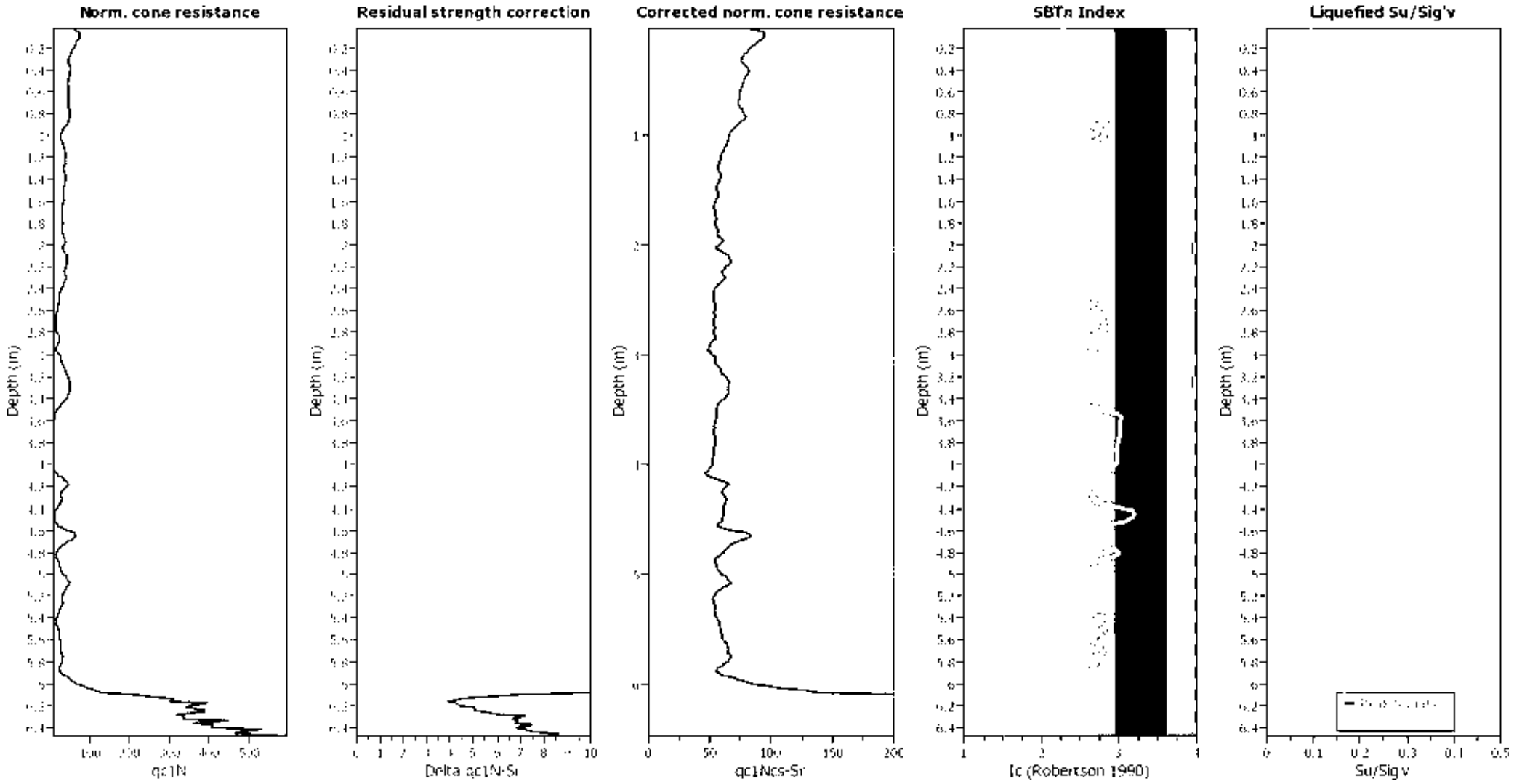
F.S. color scheme

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

LPI color scheme

- ☐ Very high risk
- ☐ High risk
- ☐ Low risk

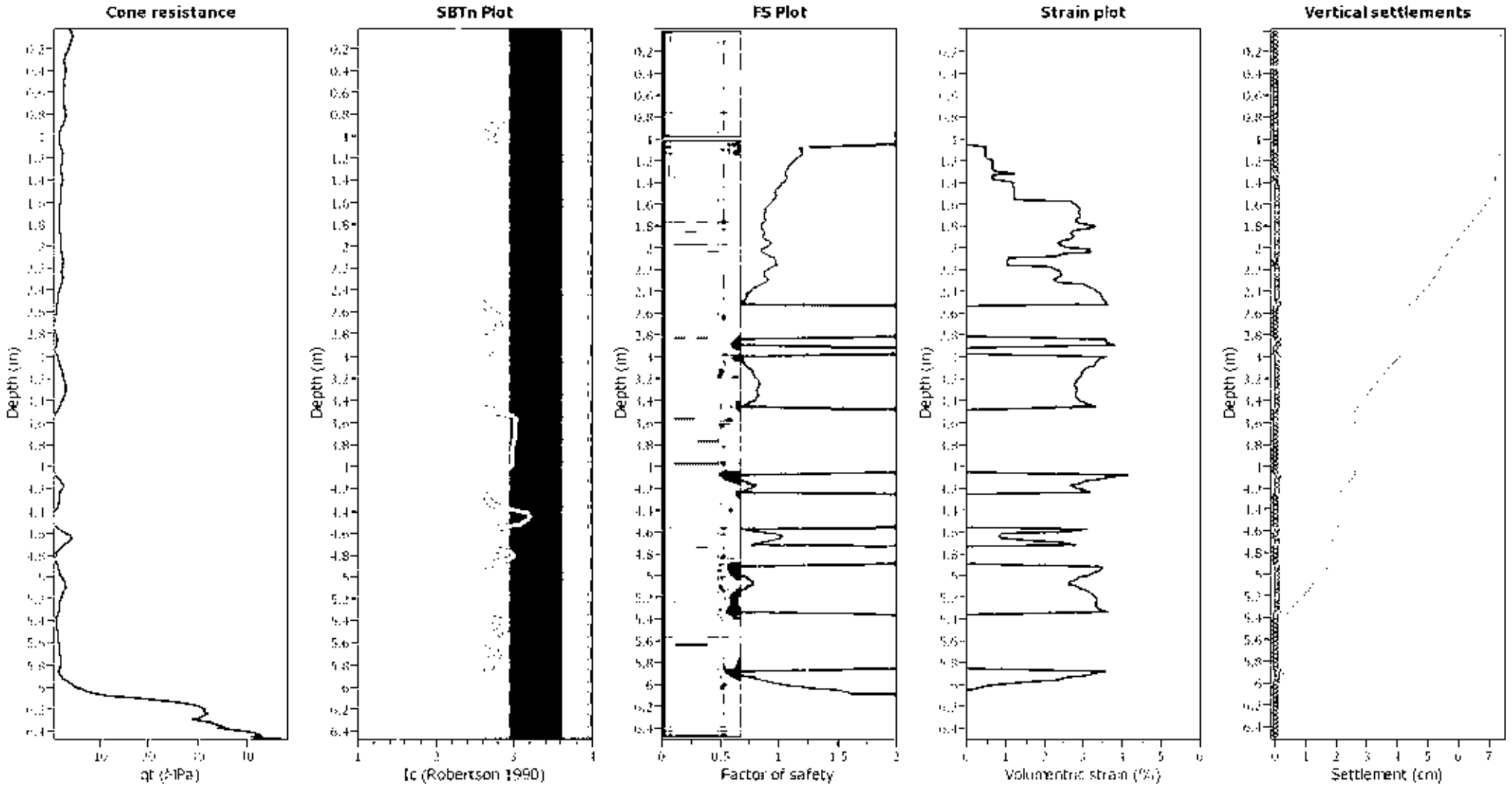
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Liquefaction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.00 m	Fill height:	N/A	Limit depth	N/A

Estimation of post-earthquake settlements



Abbreviations

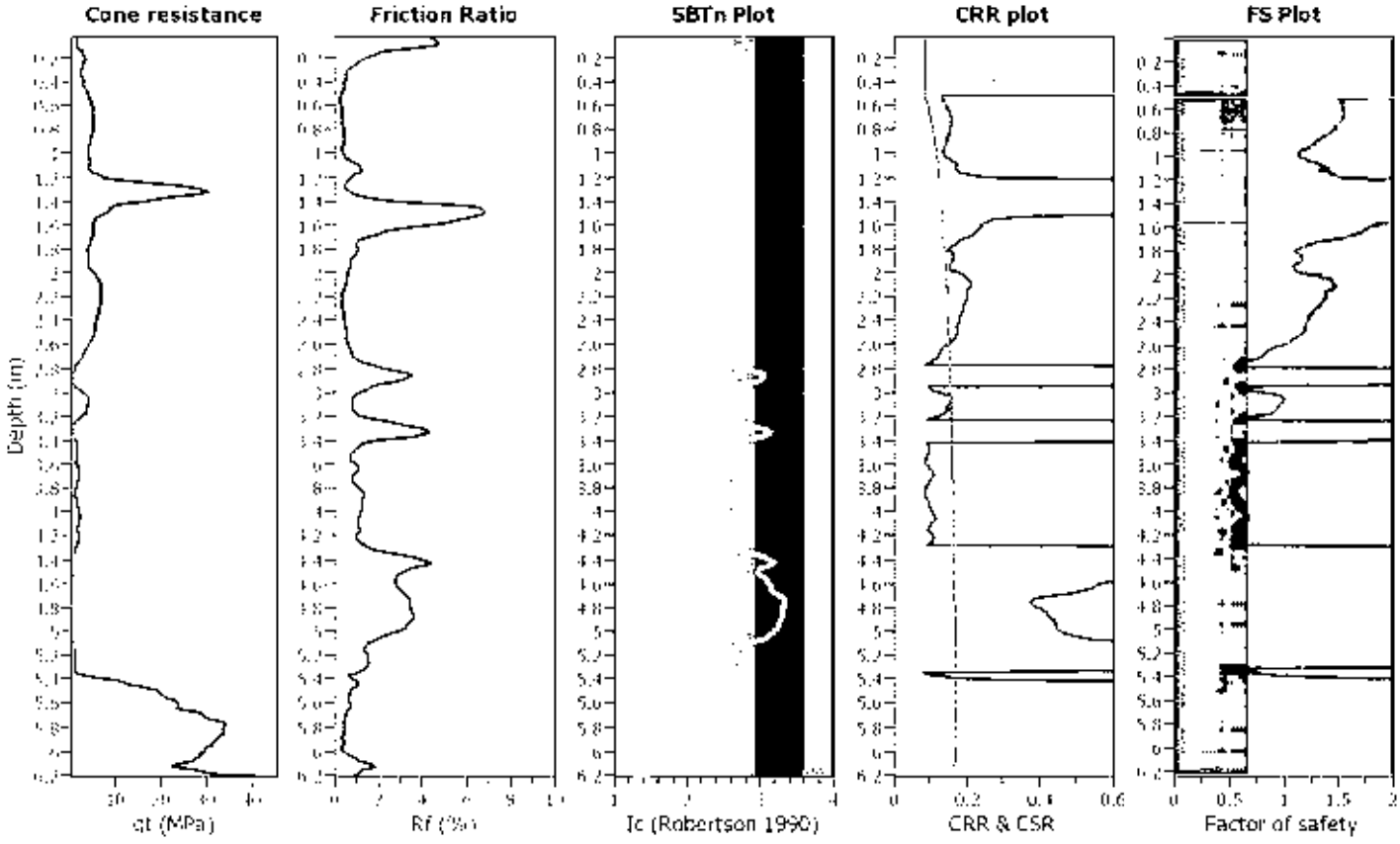
qt	Total cone resistance (cone resistance q corrected for pore water effects)
Ic	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumentric strain:	Post liquefaction volumentric strain

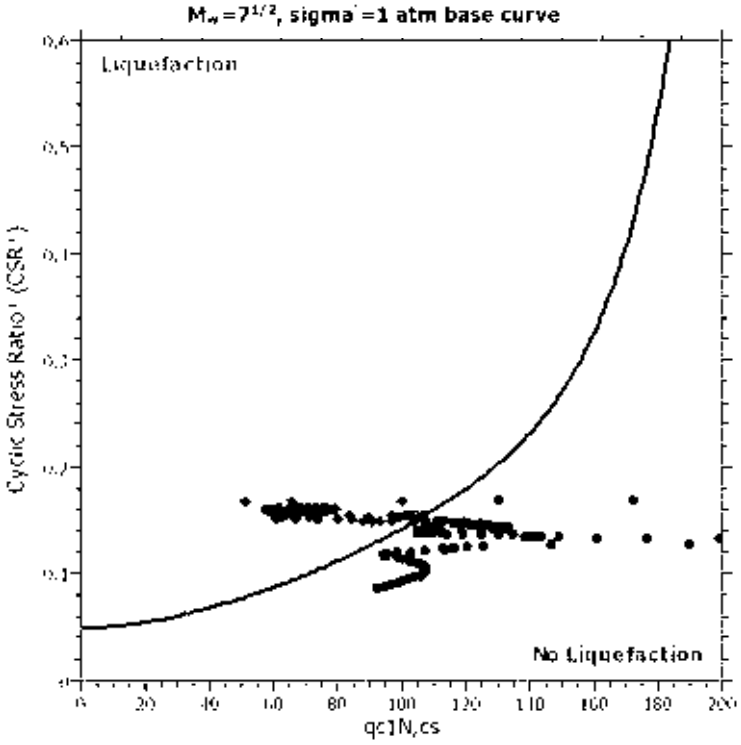
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

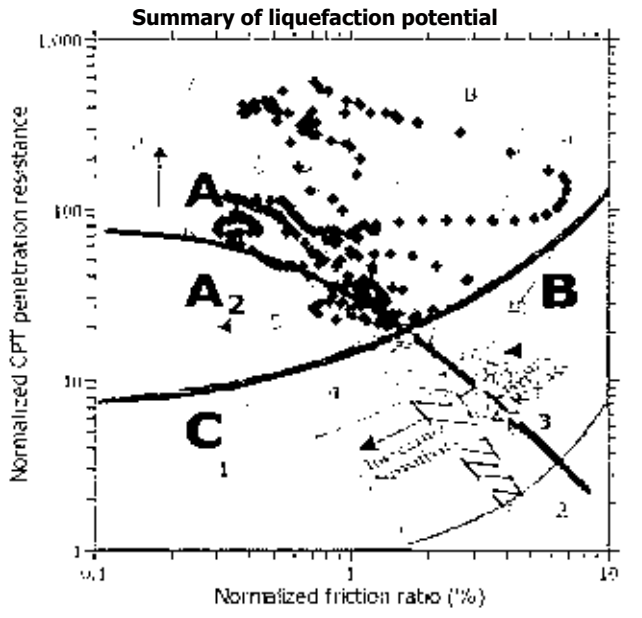
CPT file : CPT05_163bHalswellJunctionRd

Input parameters and analysis data

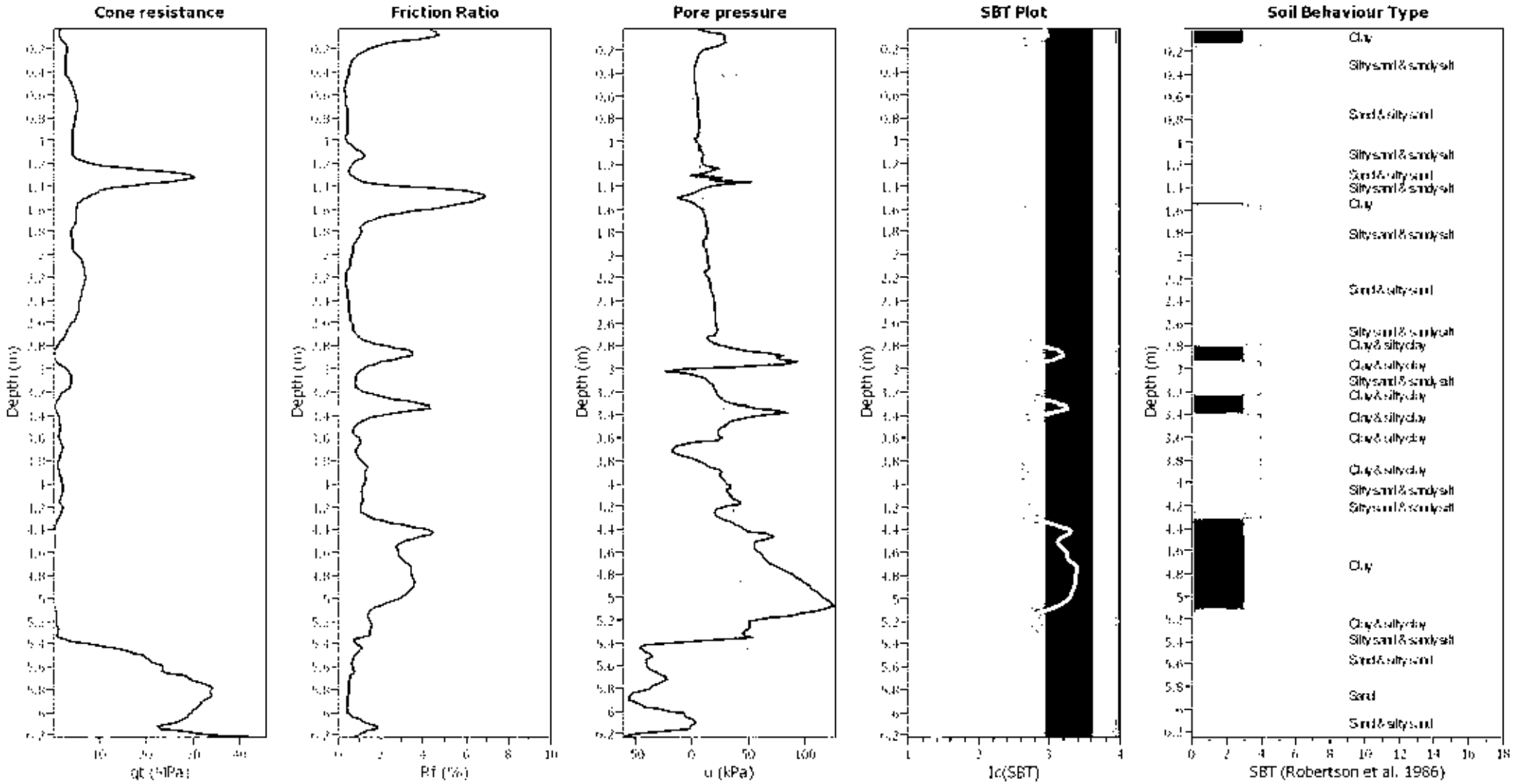
Analysis method:	I&B (2008)	G.W.T. (in-situ):	0.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	I&B (2008)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration:	0.13	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



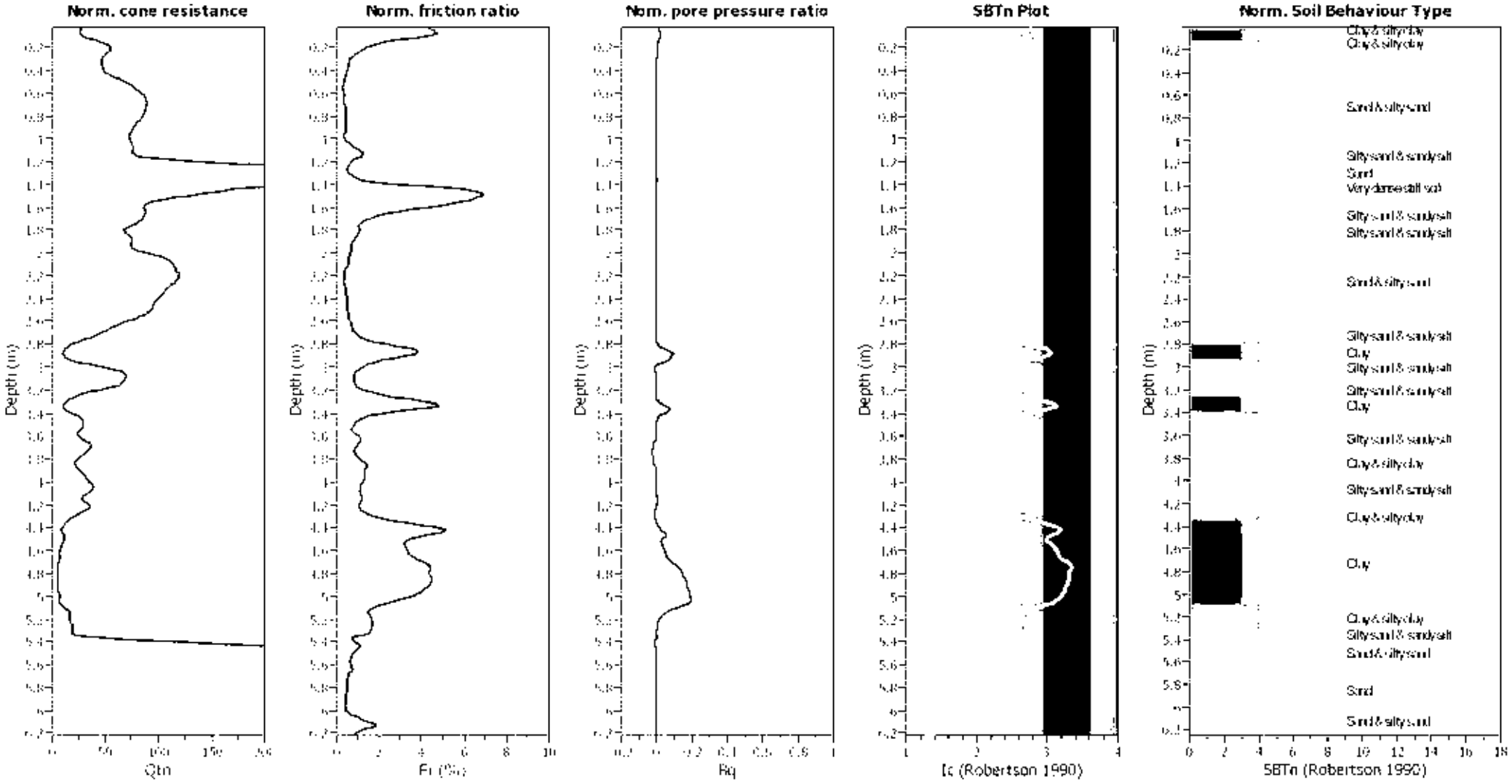
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	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	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

CPT basic interpretation plots (normalized)



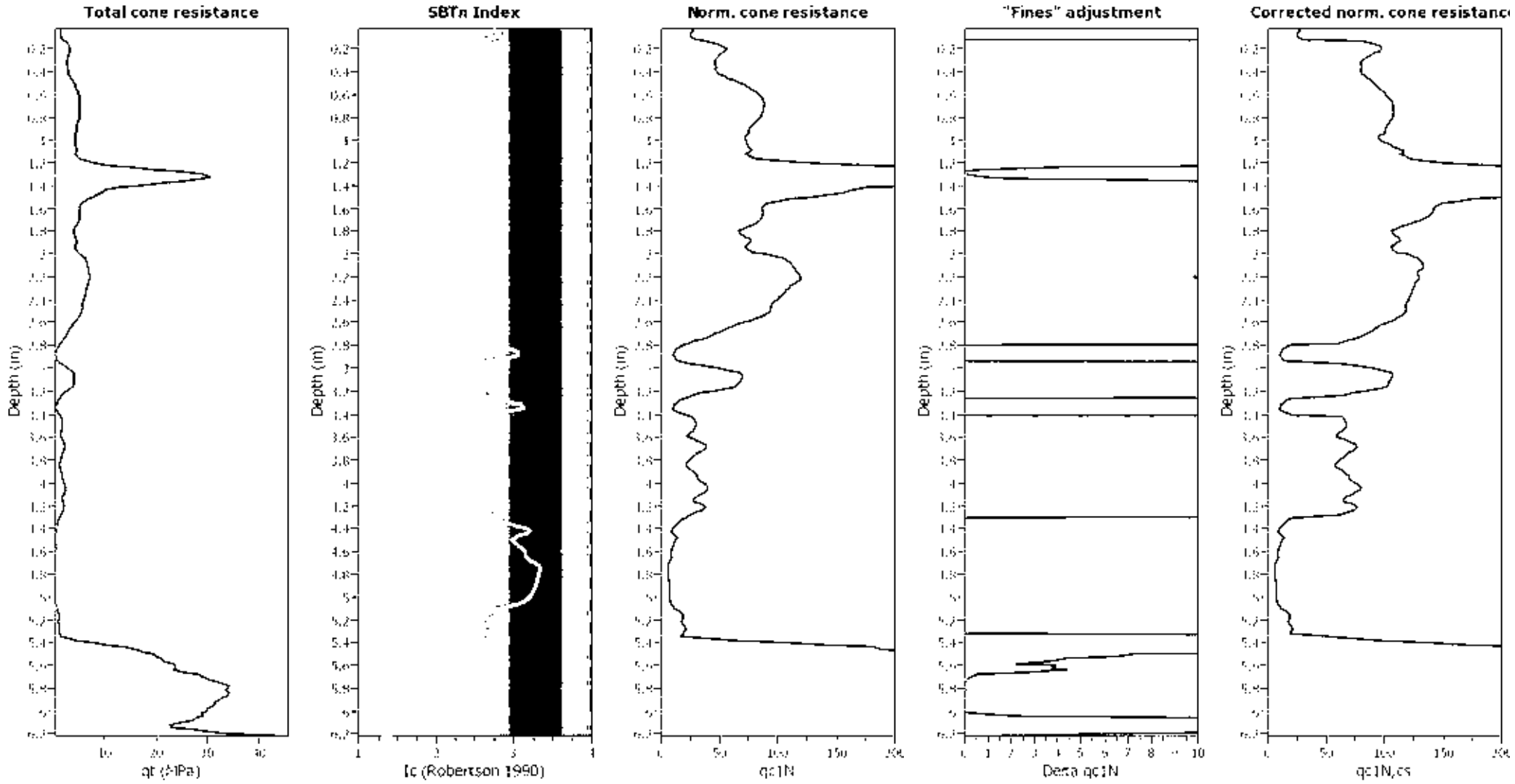
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	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	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

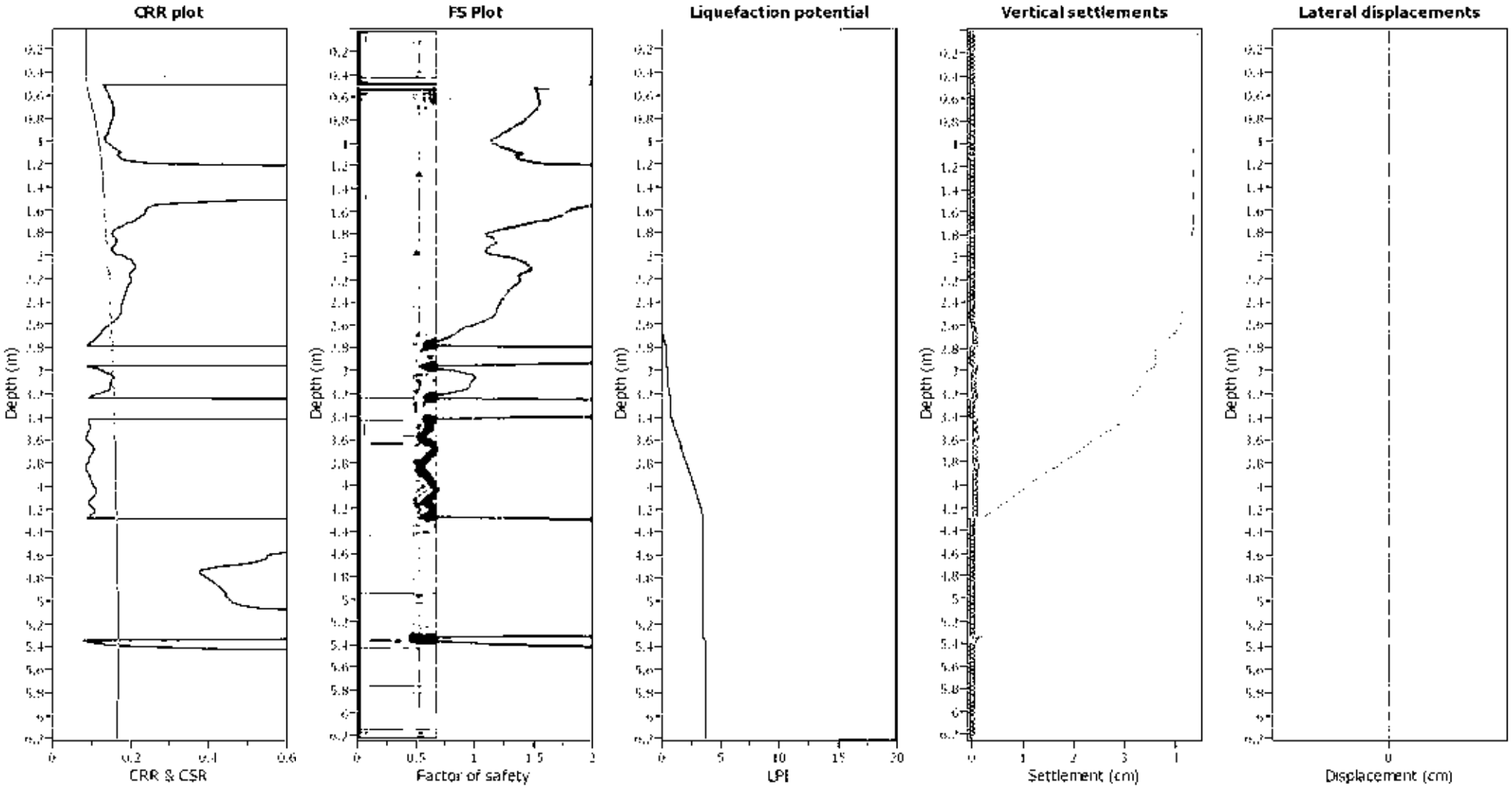
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	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
Liquefaction correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 m	Fill height:	N/A	Limit depth:	N/A

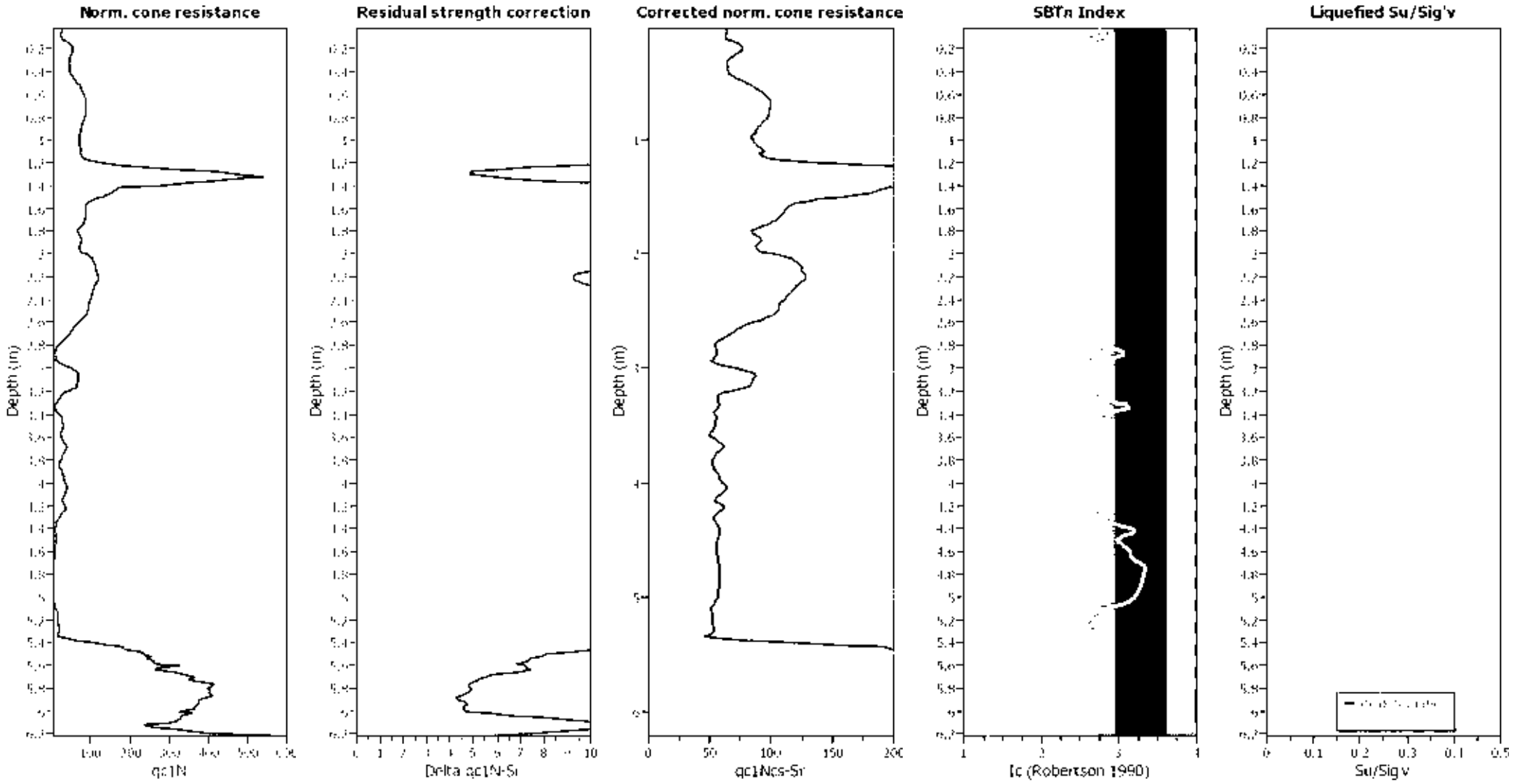
F.S. color scheme

- ☐ 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

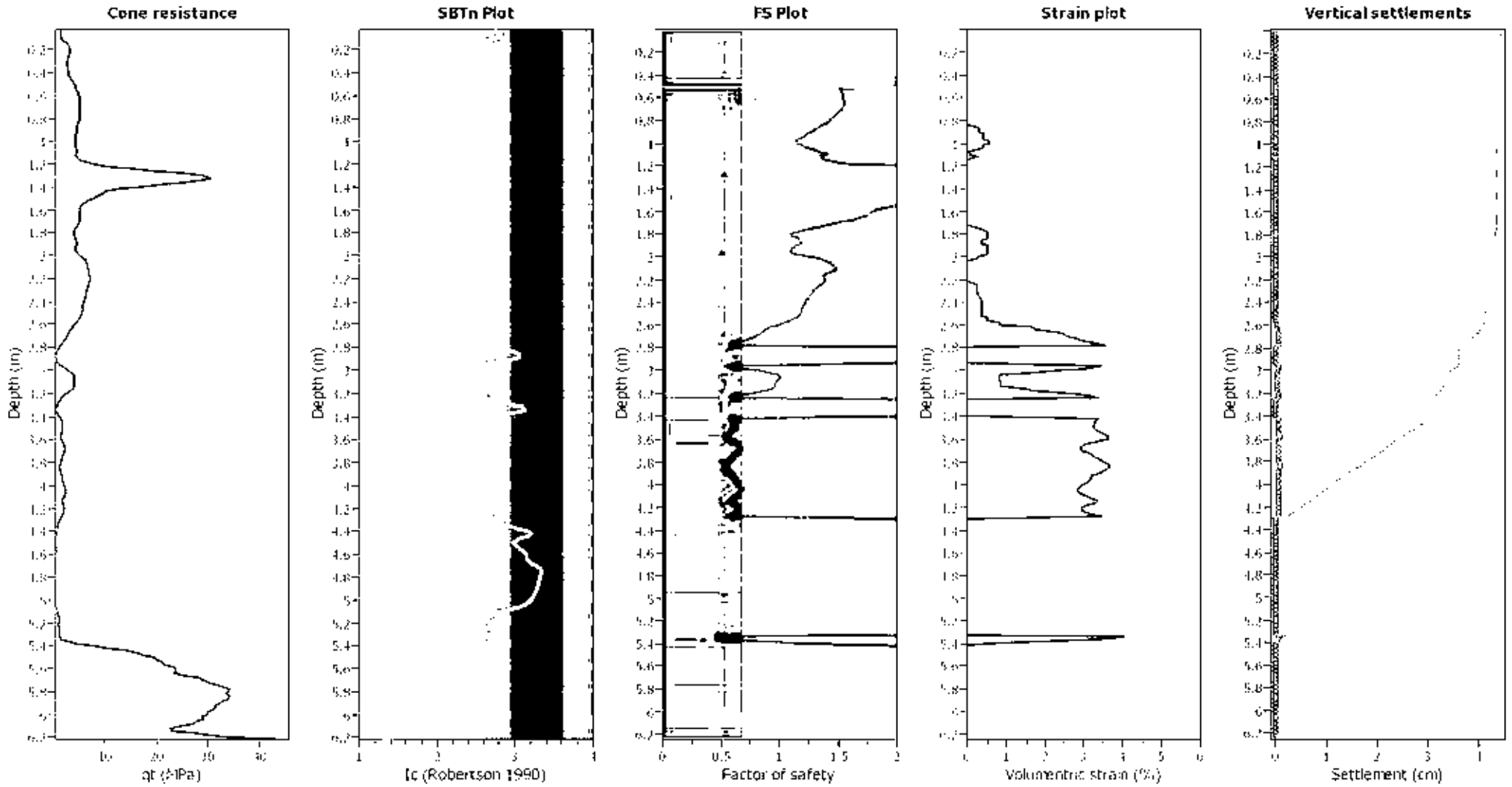
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 m	Fill height:	N/A	Limit depth:	N/A

Estimation of post-earthquake settlements



Abbreviations

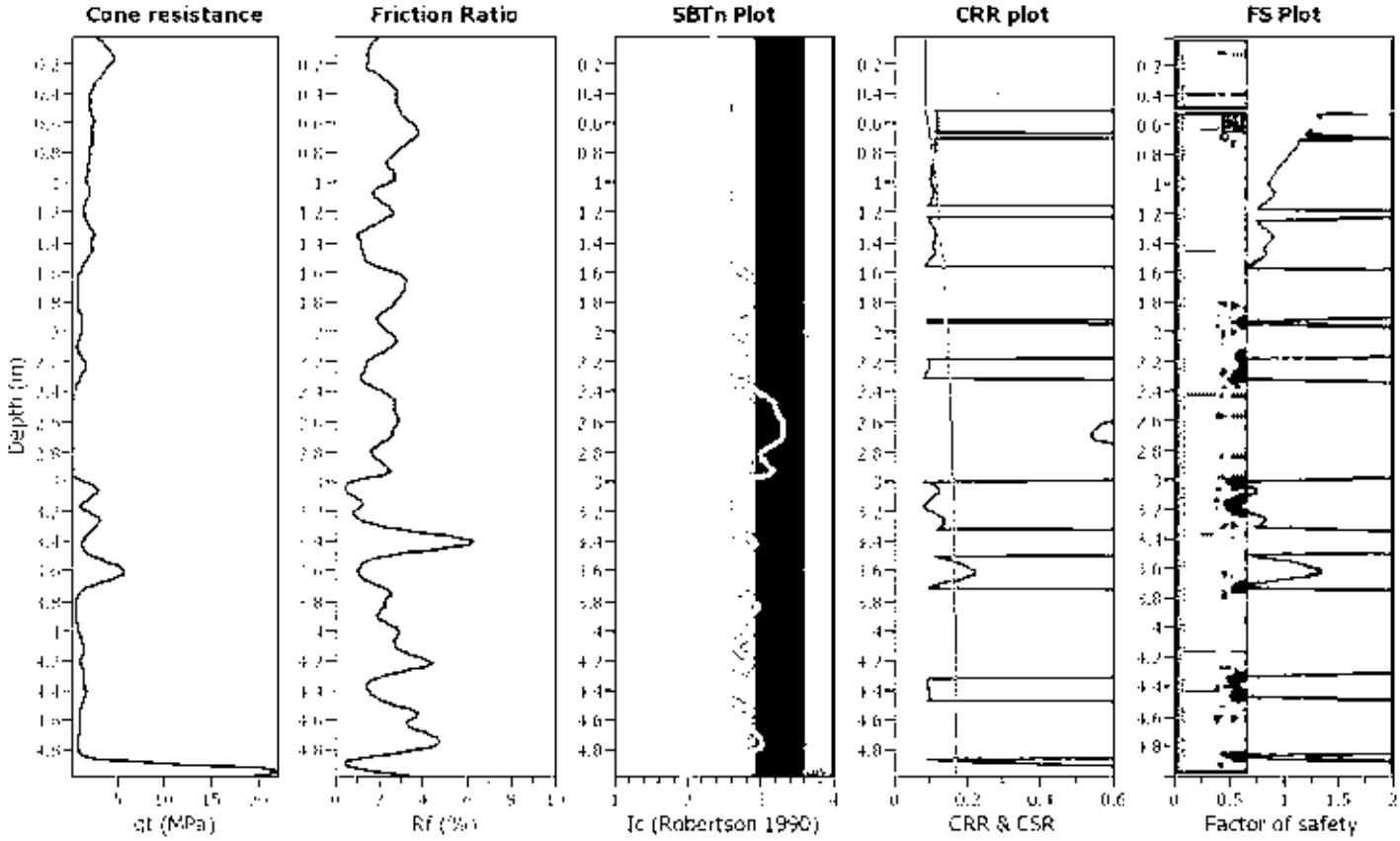
qt	Total cone resistance (cone resistance q corrected for pore water effects)
Ic	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumentric strain:	Post liquefaction volumentric strain

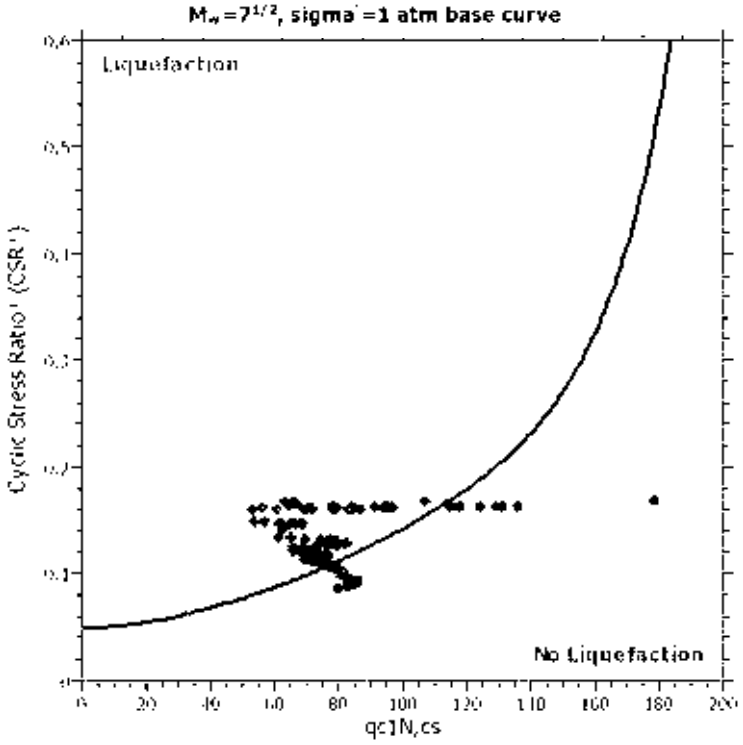
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

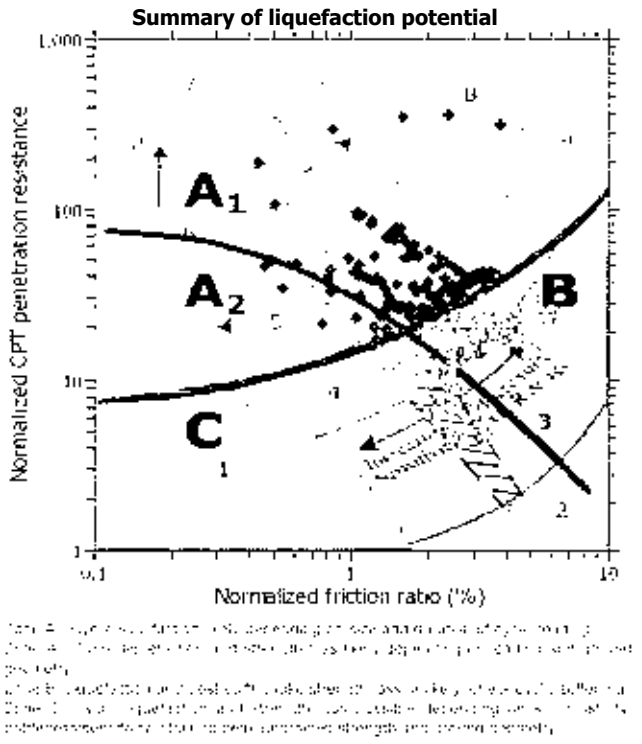
CPT file : CPT06_163bHalswellJunctionRd

Input parameters and analysis data

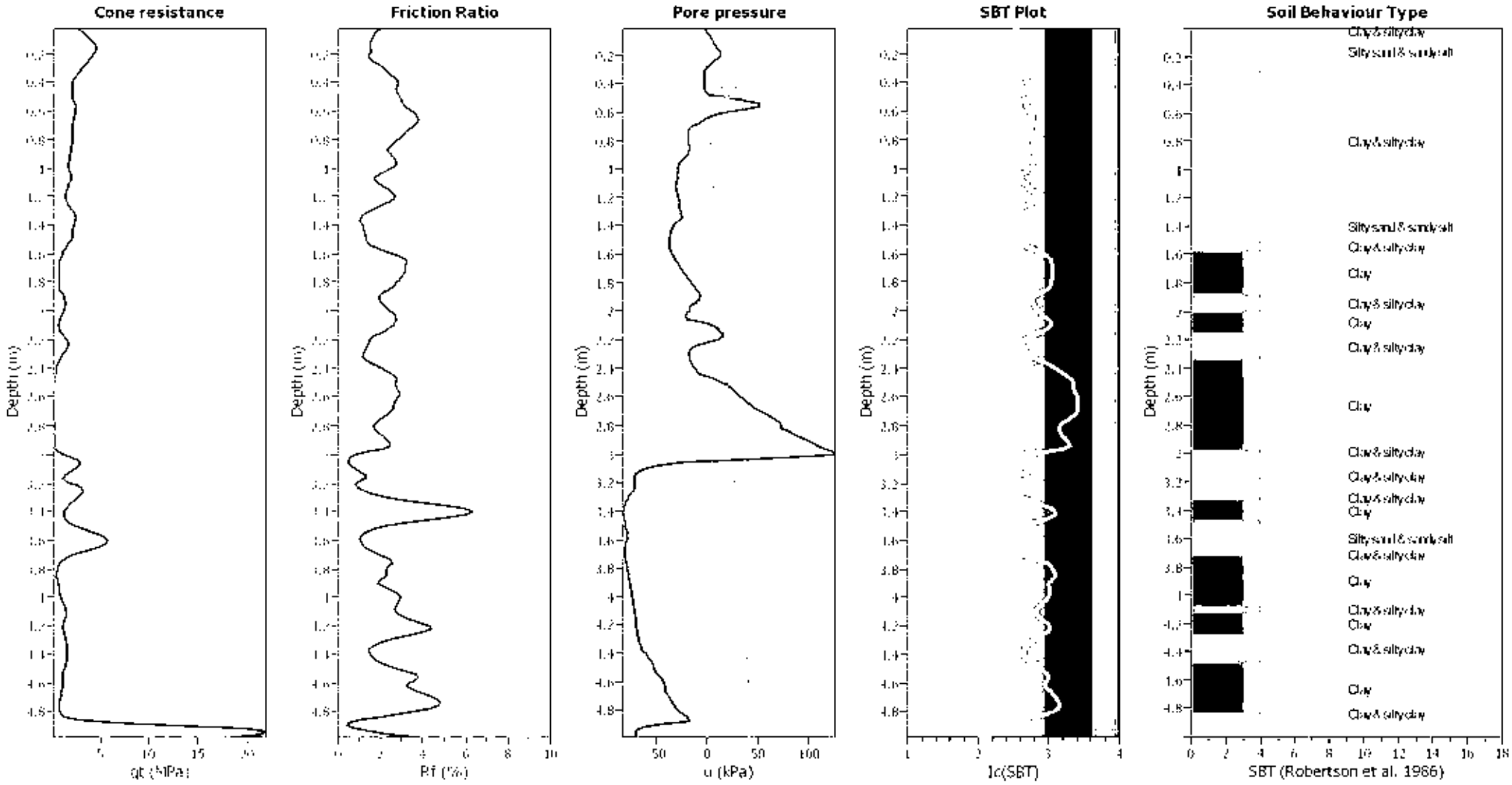
Analysis method:	I&B (2008)	G.W.T. (in-situ):	0.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	I&B (2008)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration:	0.13	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



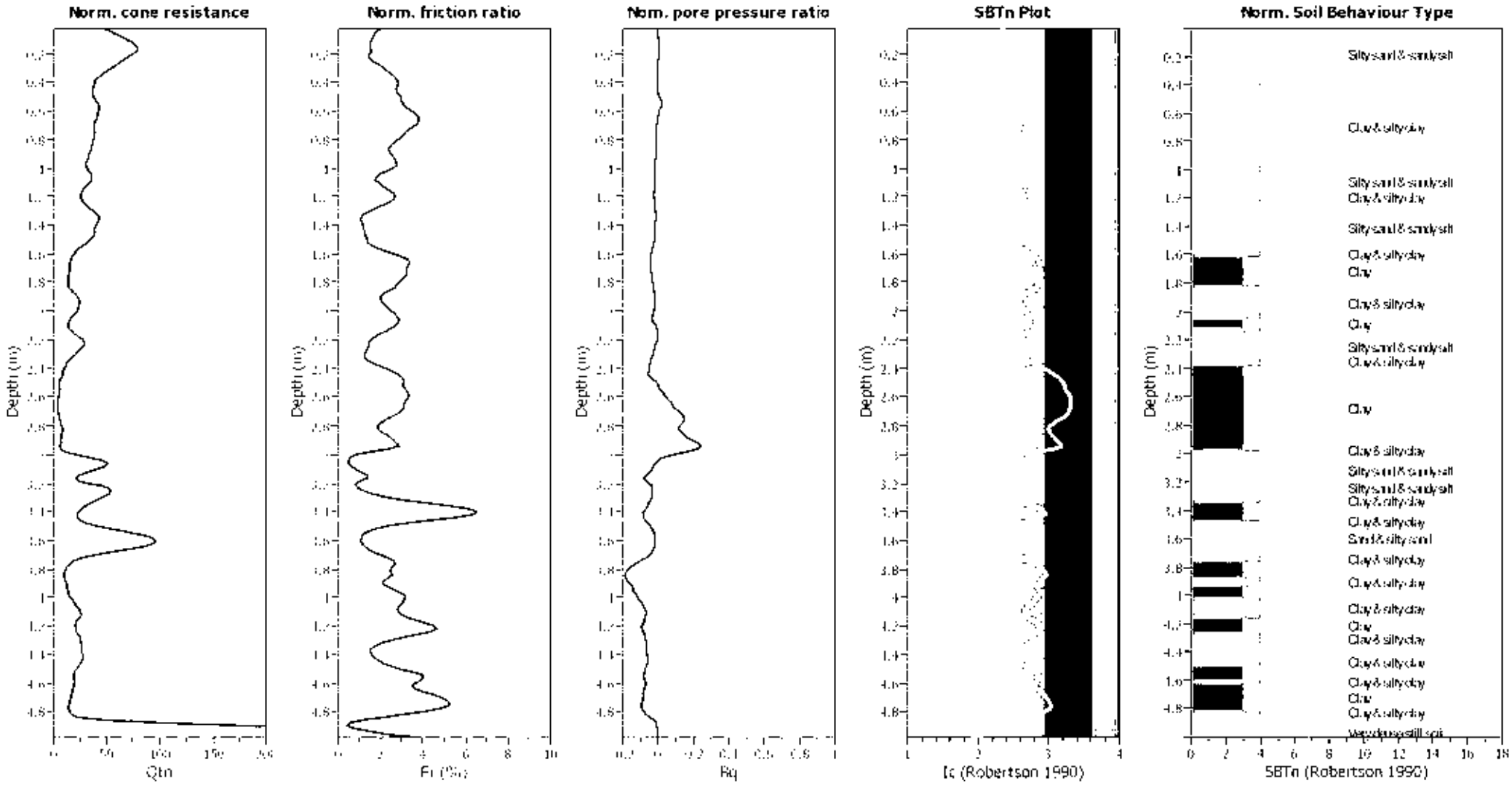
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	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	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

CPT basic interpretation plots (normalized)



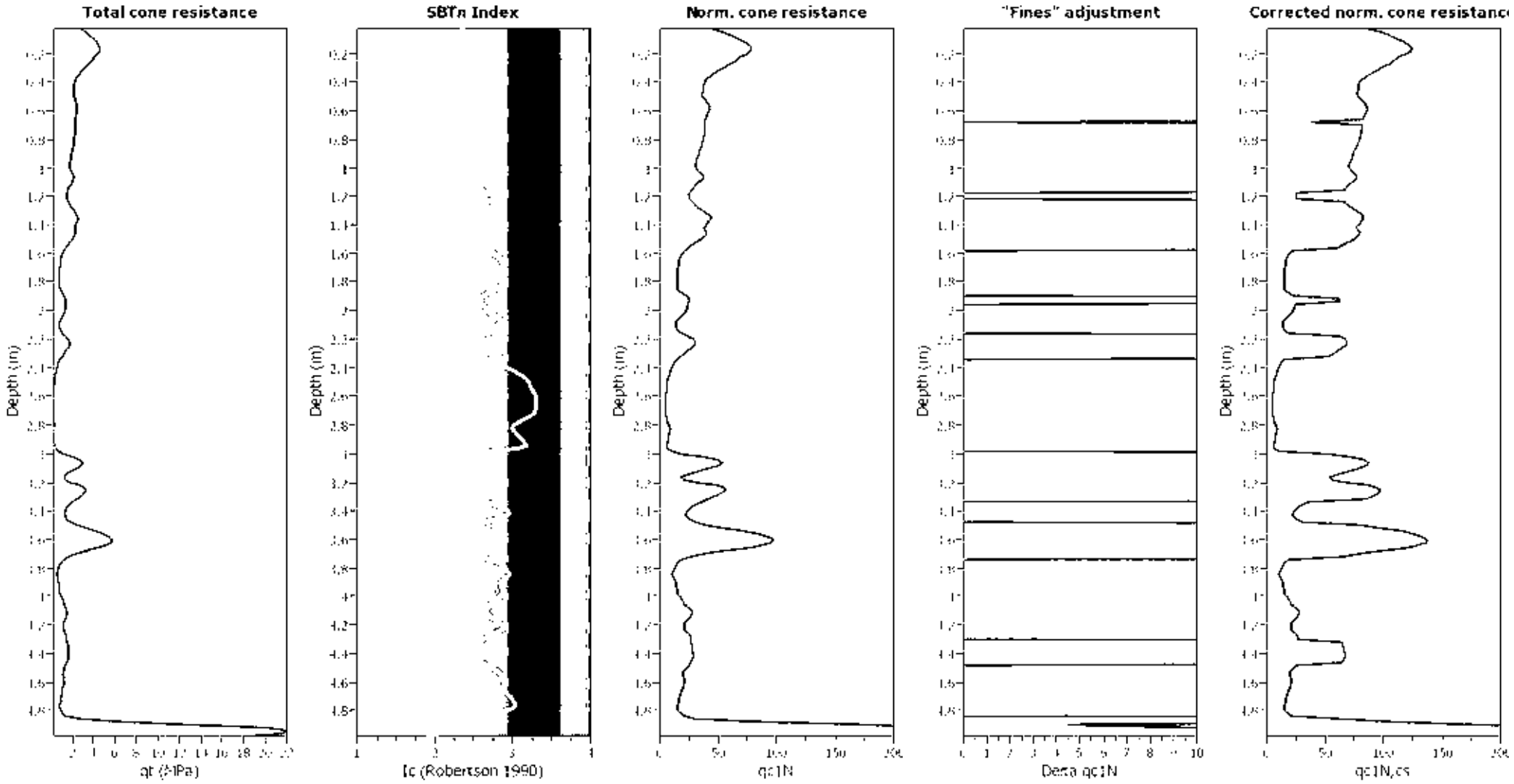
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	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	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

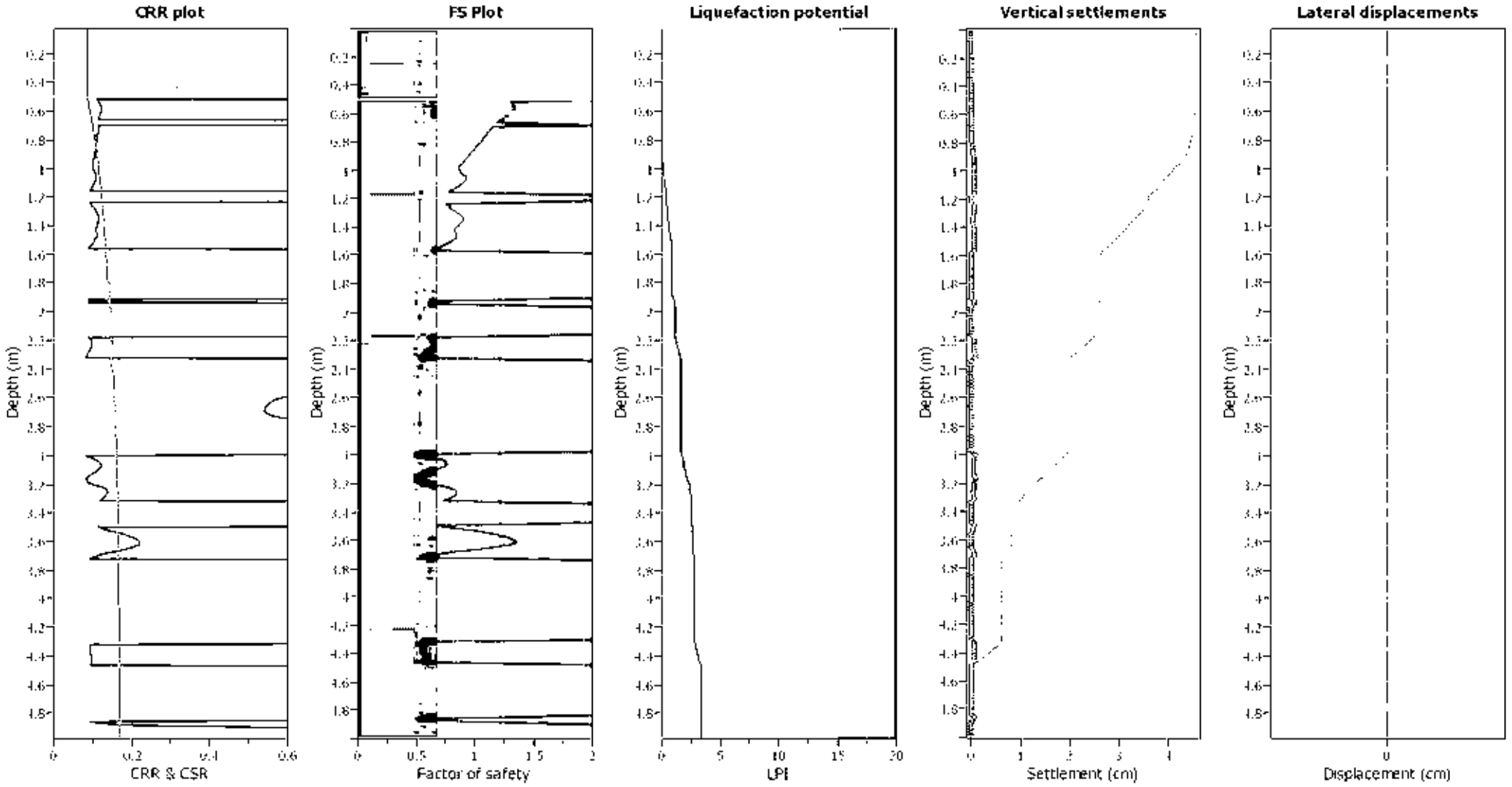
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	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
Liner correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (m/s):	0.50 m	Fill height:	N/A	Limit depth:	N/A

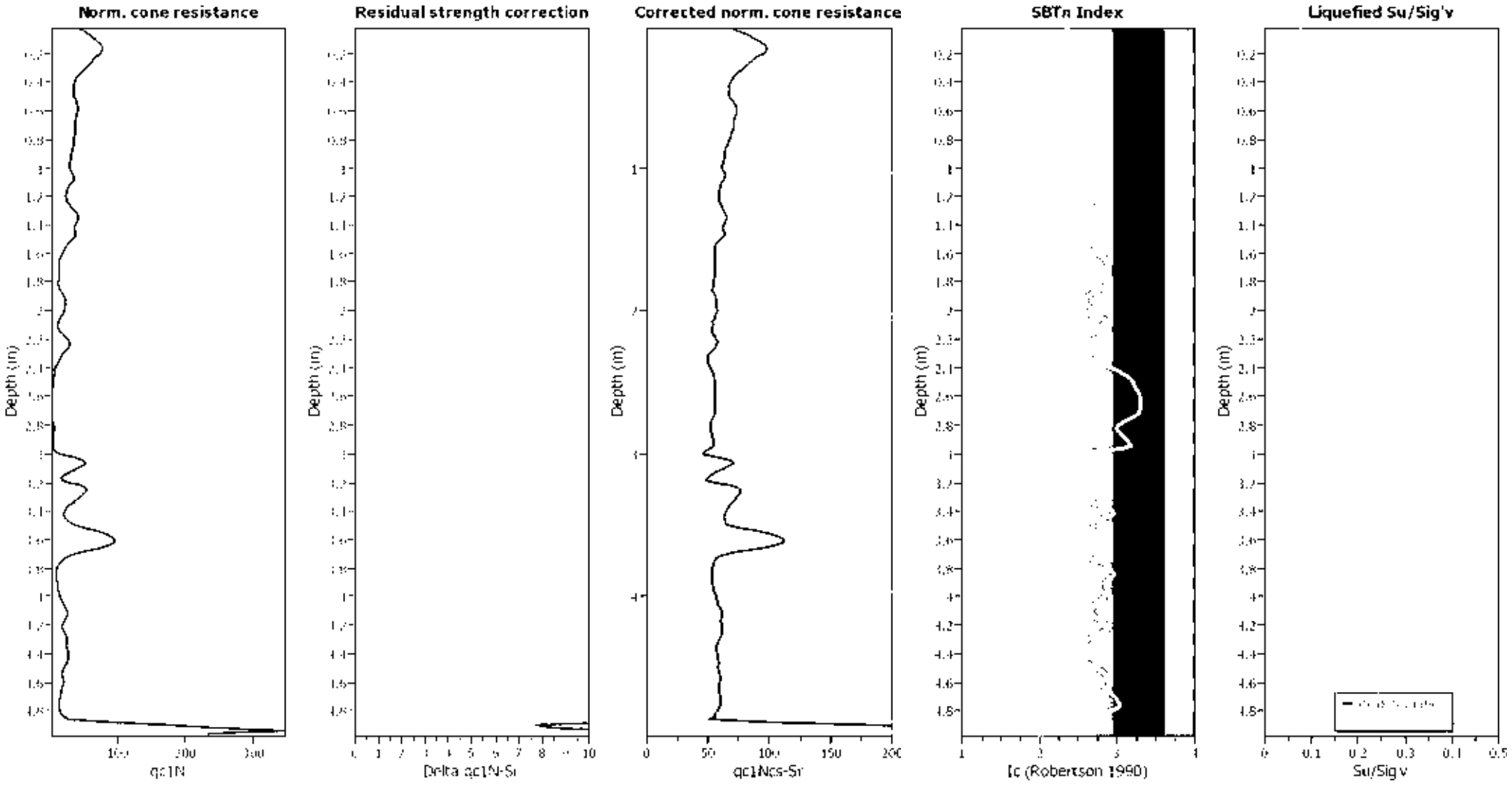
F.S. color scheme

- ☐ 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

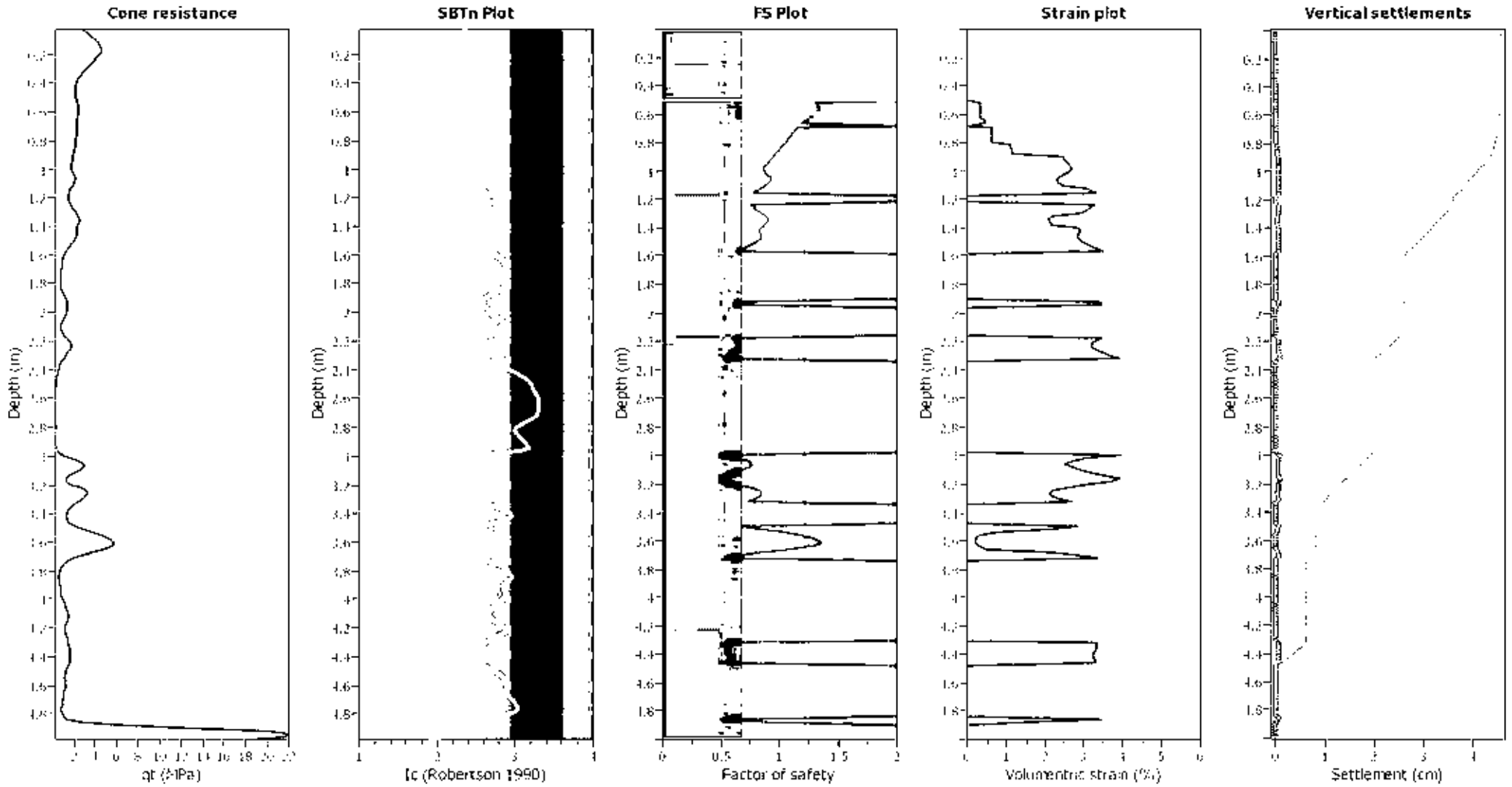
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Liquefaction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	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

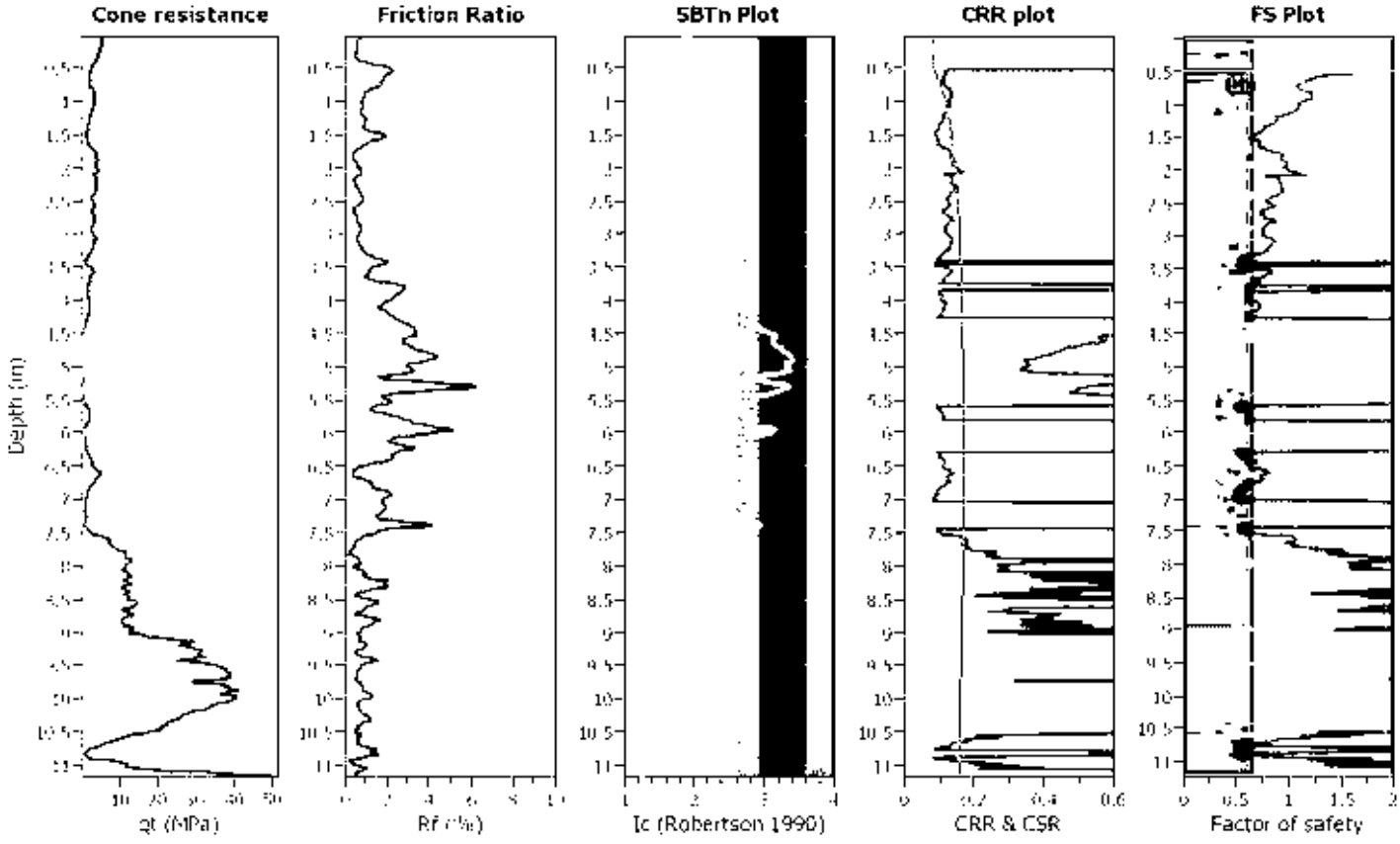
qc	Total cone resistance (cone resistance q corrected for pore water effects)
Ic	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumentric strain:	Post liquefaction volumentric strain

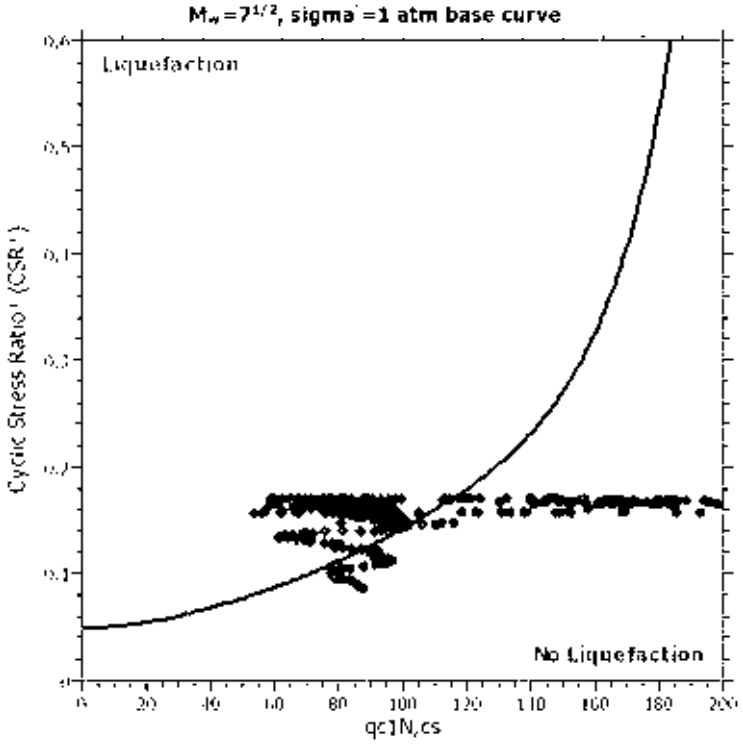
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

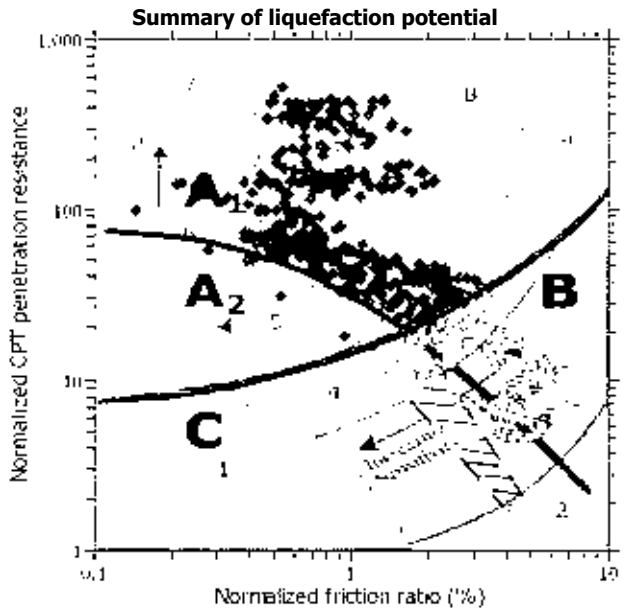
CPT file : CPT07_117HalswellJunctionRd

Input parameters and analysis data

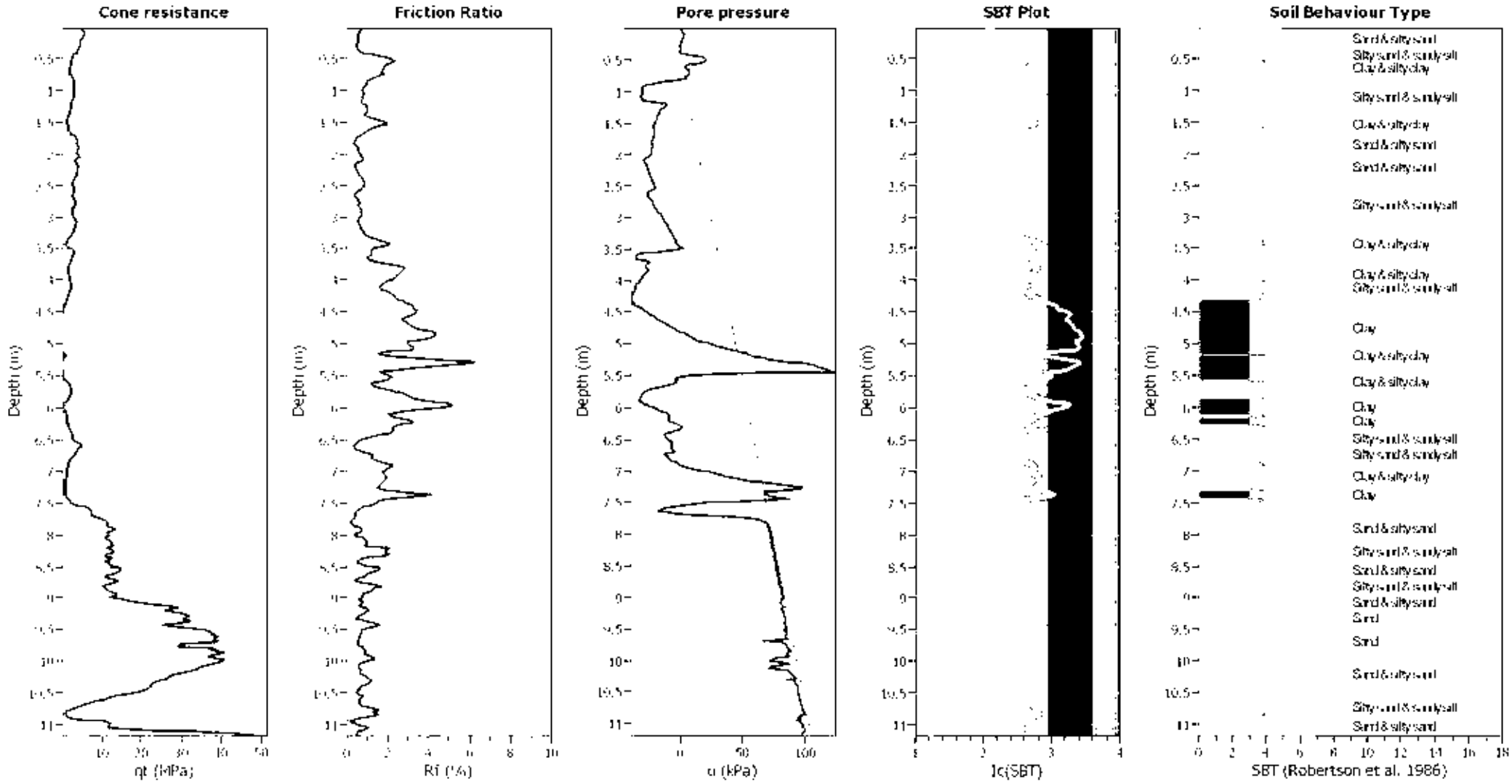
Analysis method	I&B (2008)	G.W.T. (in-situ):	0.50 m	Use fill	No	Clay like behavior applied:	Sand & Clay
Fines correction method	I&B (2008)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration	0.13	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



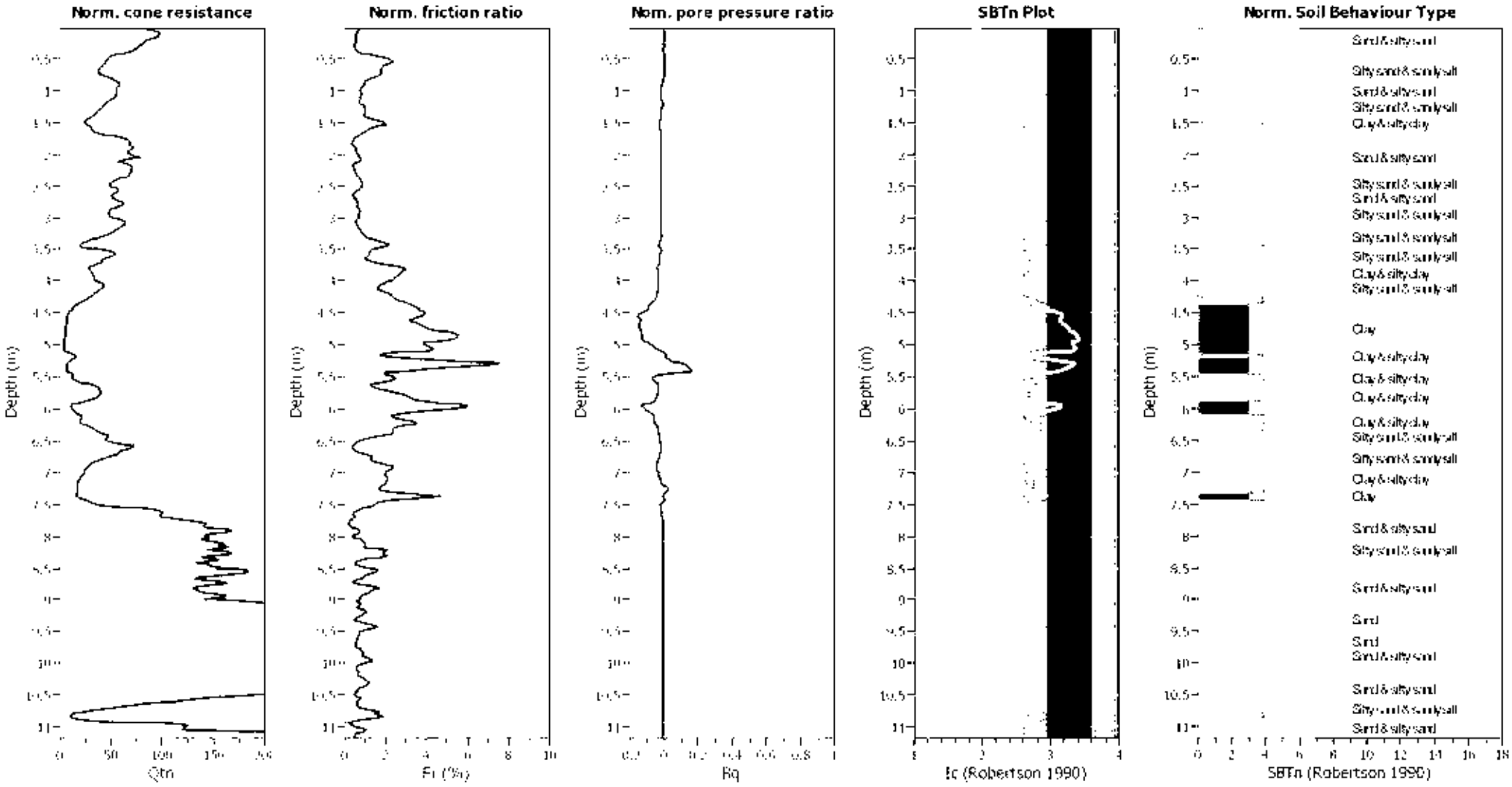
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	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	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

CPT basic interpretation plots (normalized)



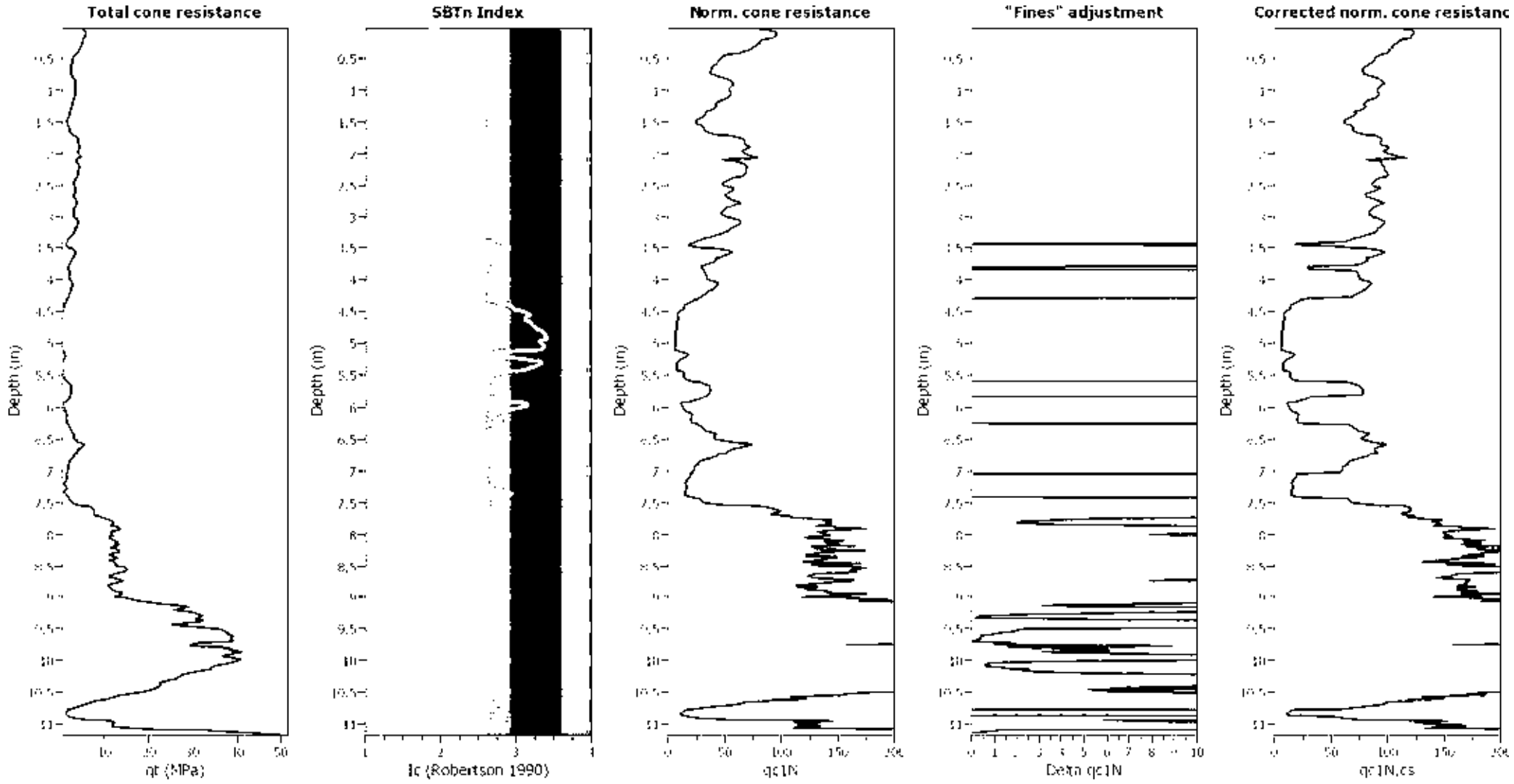
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

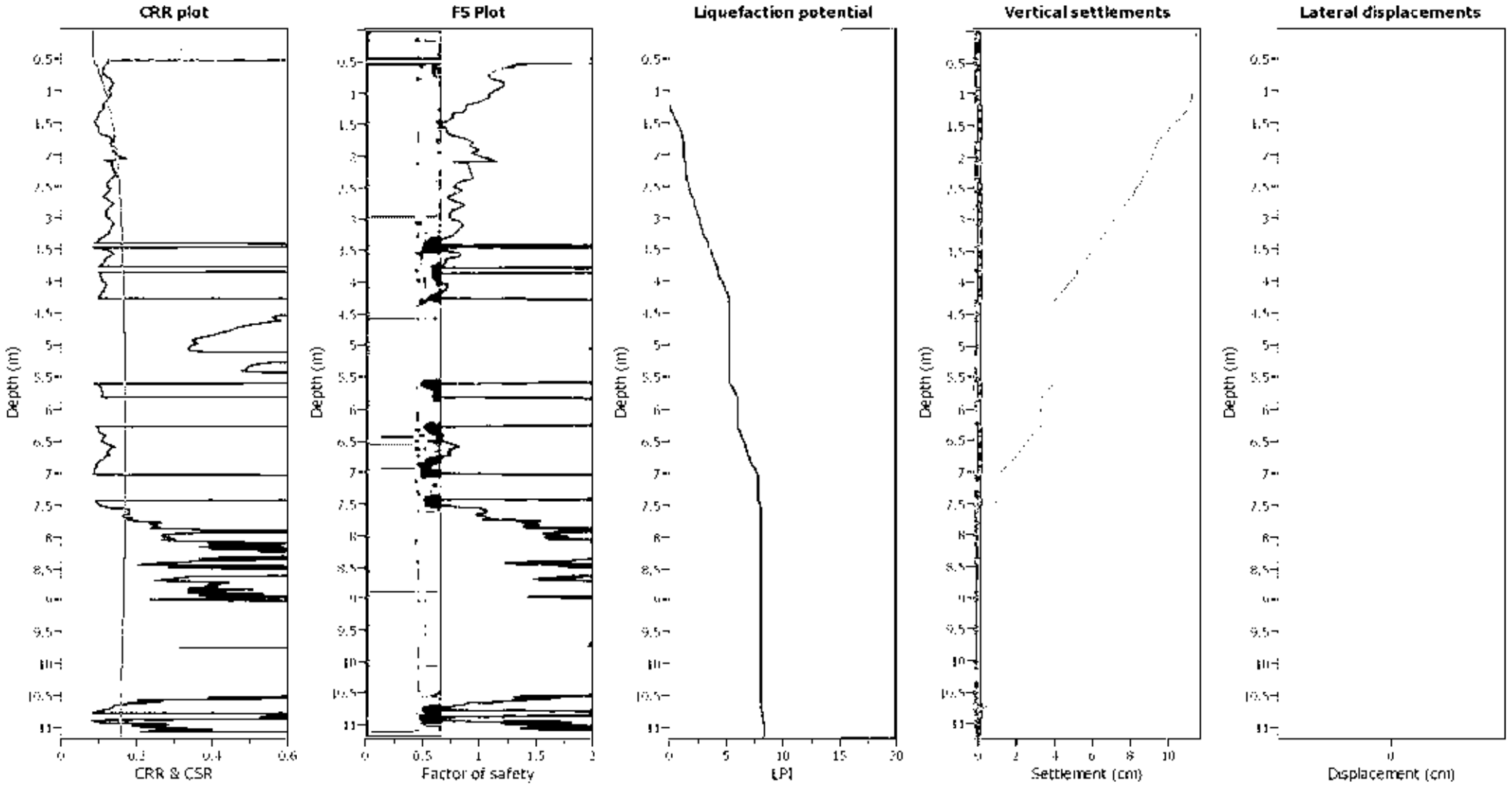
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	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:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.50 m	Fill height:	N/A	Limit depth:	N/A

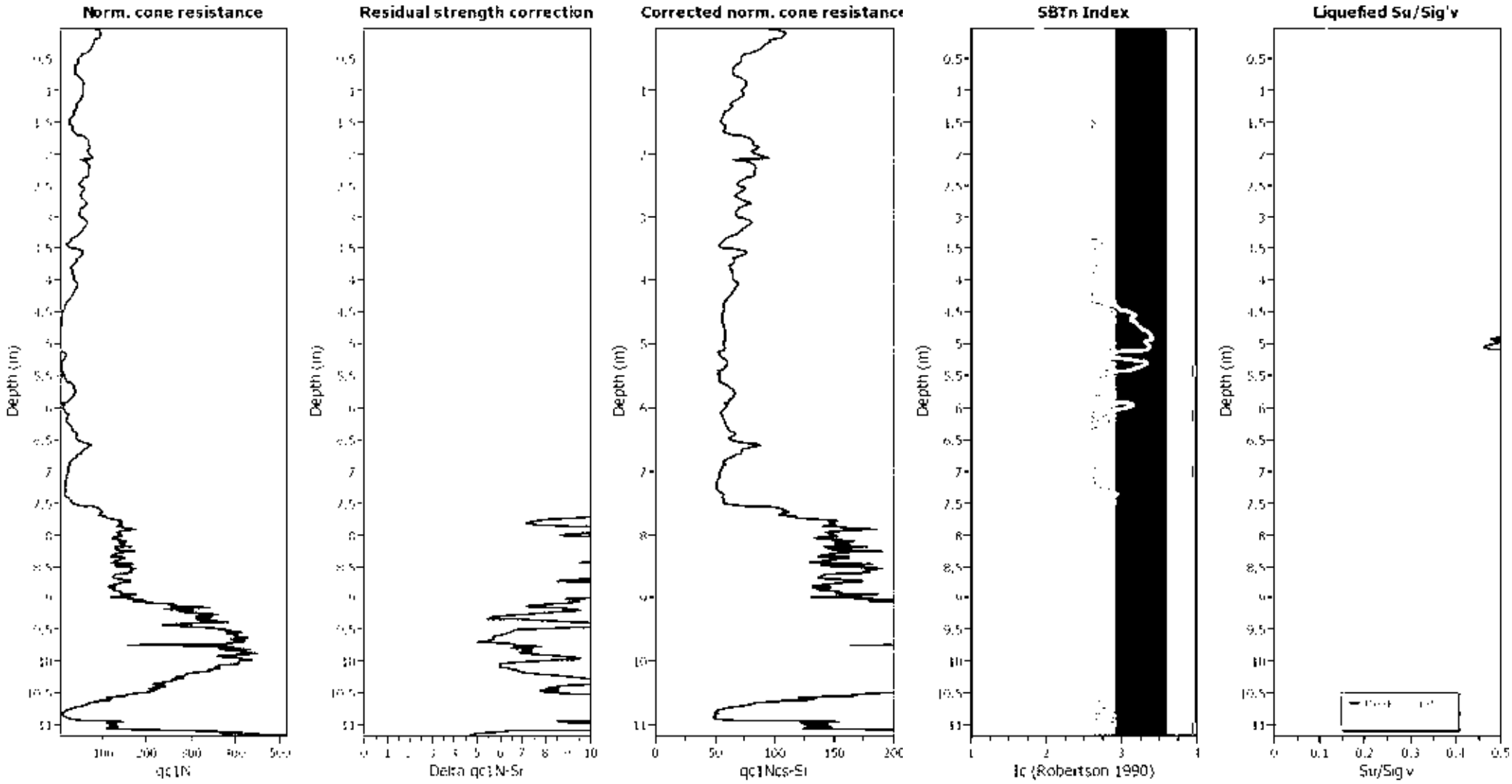
F.S. color scheme

- ☐ 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

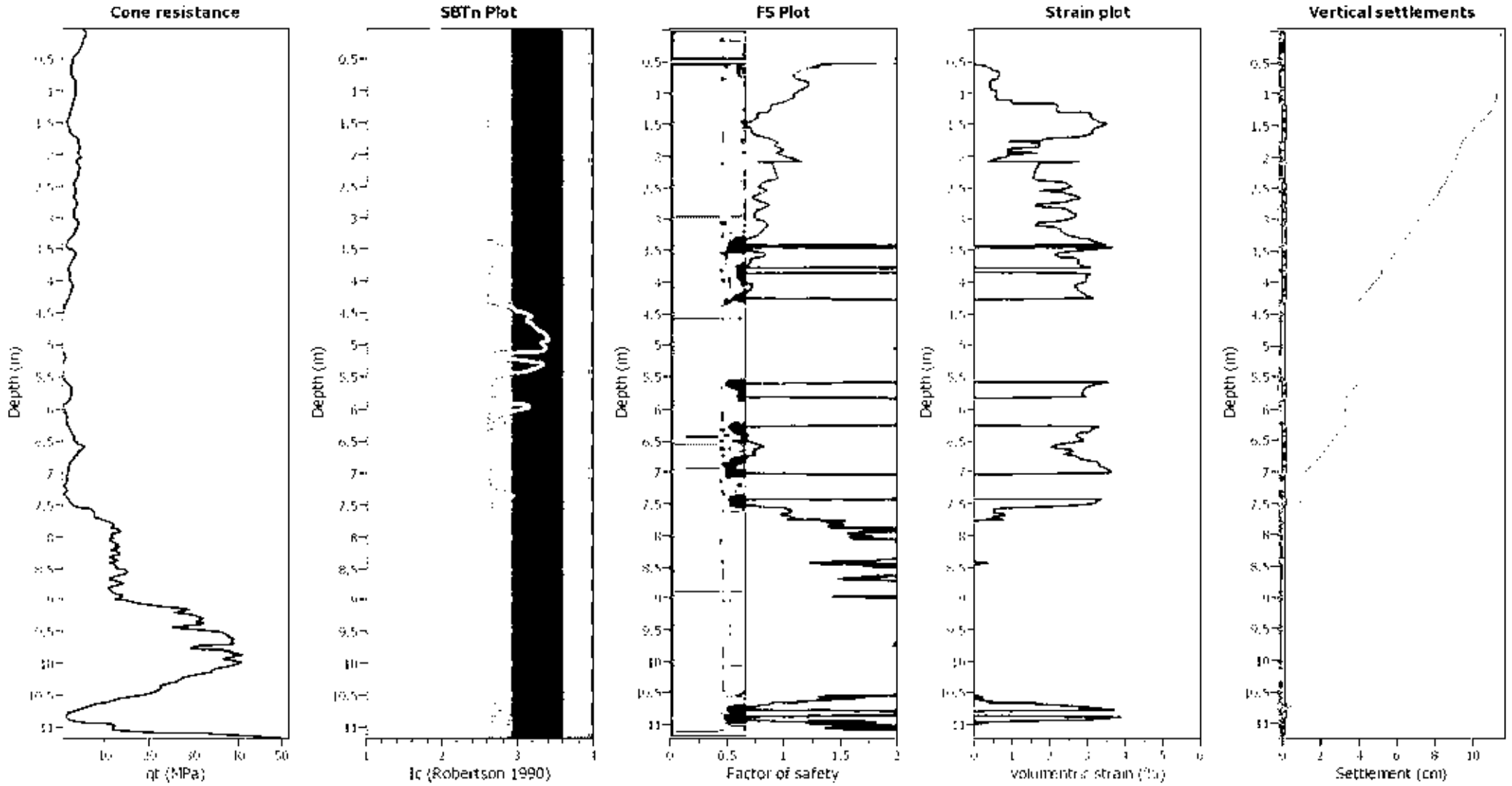
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 m	Fill height:	N/A	Limit depth	N/A

Estimation of post-earthquake settlements



Abbreviations

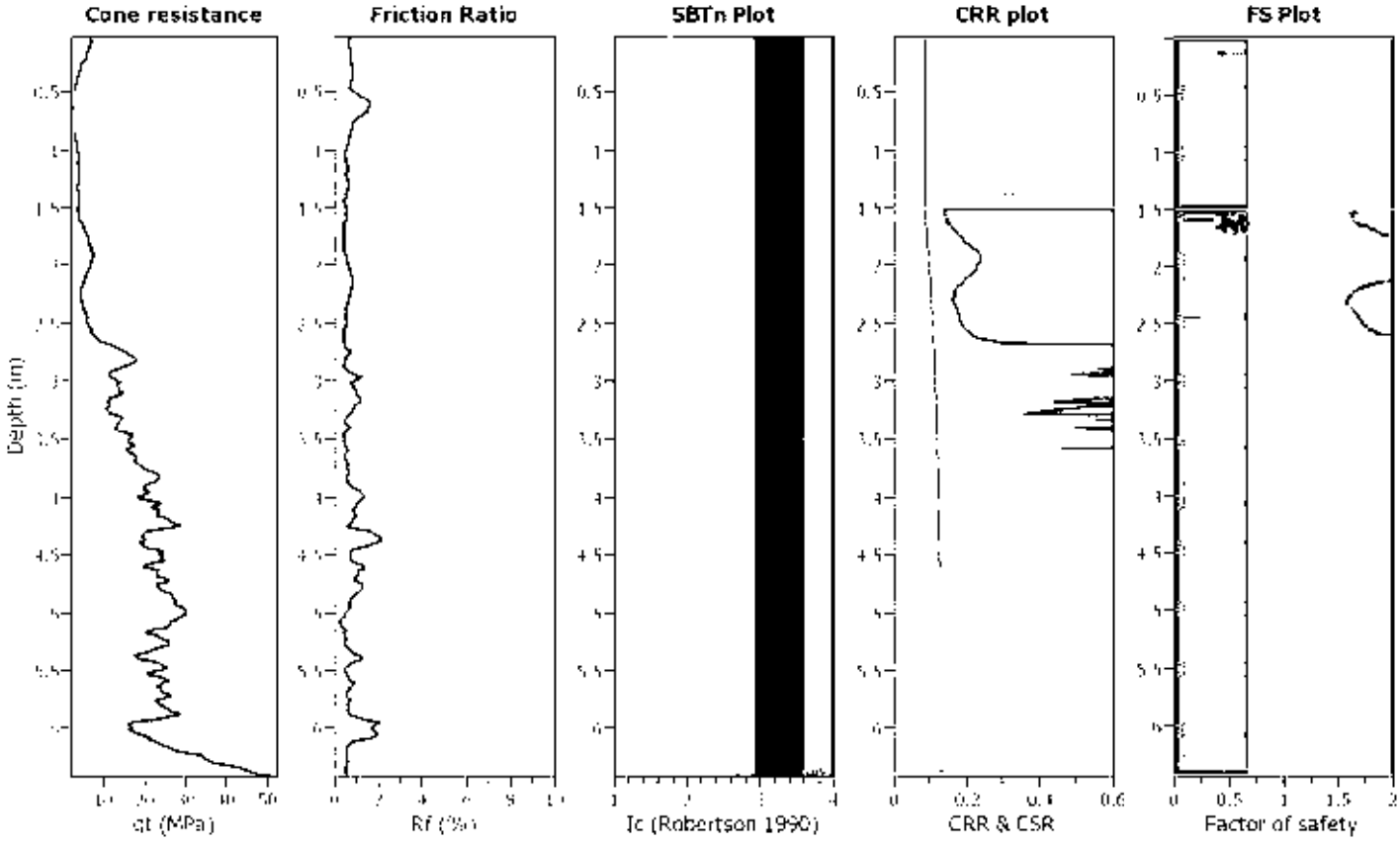
qt	Total cone resistance (cone resistance q corrected for pore water effects)
Ic	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumetric strain:	Post liquefaction volumetric strain

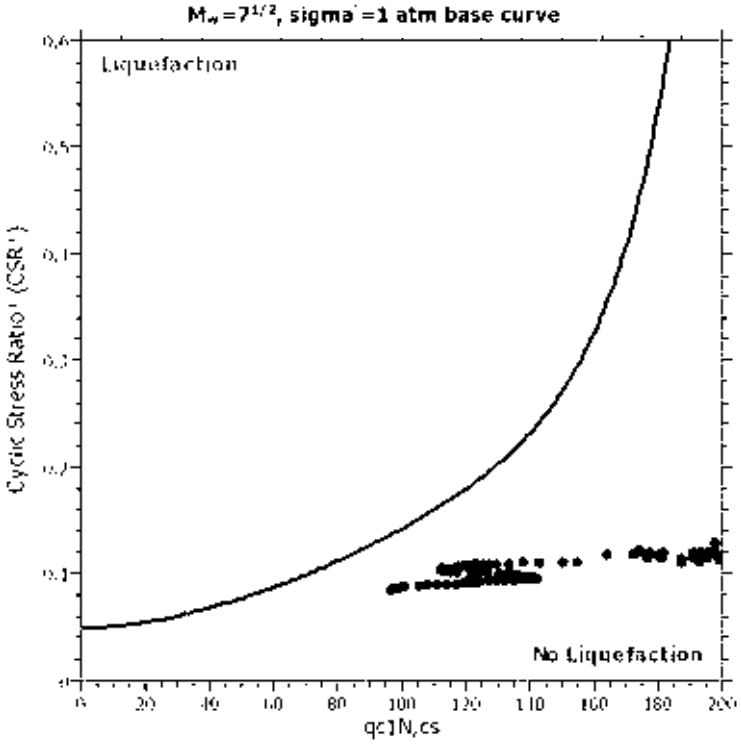
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

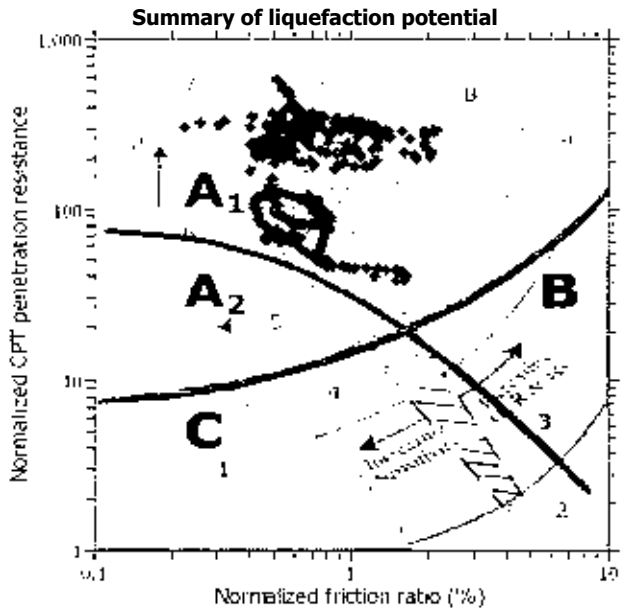
CPT file : CPT08_103HalswellJunctionRd

Input parameters and analysis data

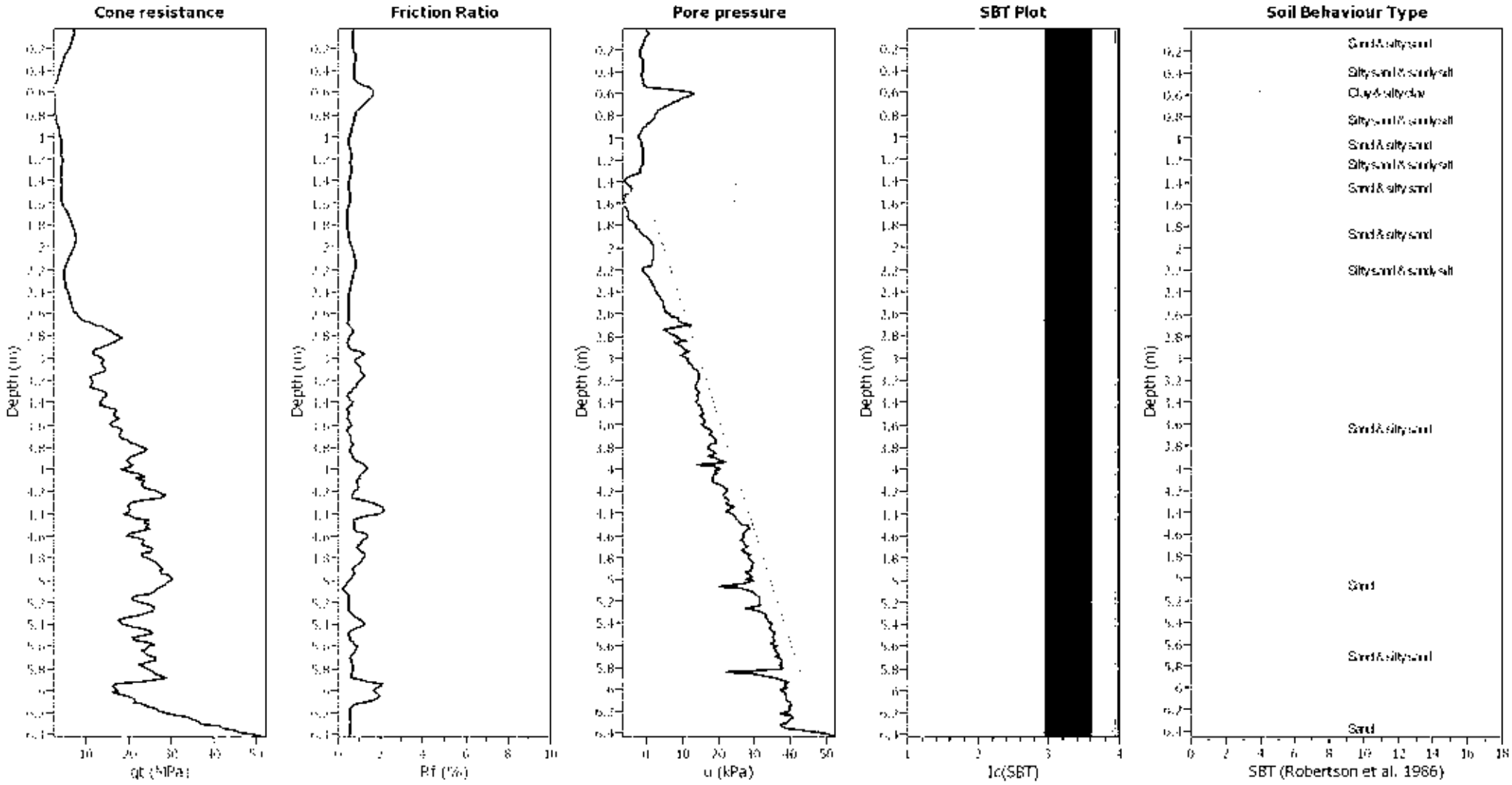
Analysis method	I&B (2008)	G.W.T. (in-situ):	1.50 m	Use fill	No	Clay like behavior applied:	Sand & Clay
Fines correction method	I&B (2008)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration	0.13	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



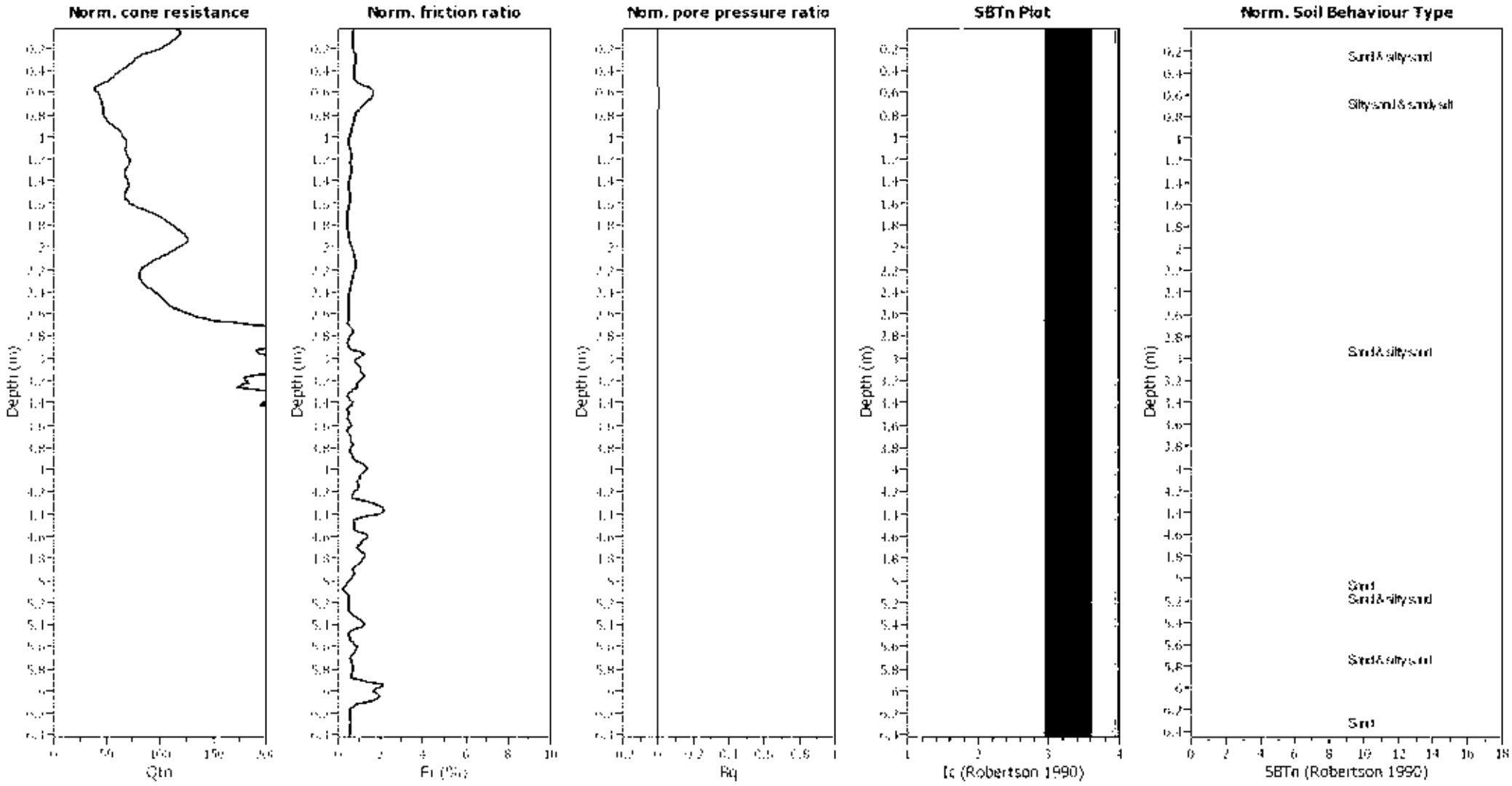
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 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

CPT basic interpretation plots (normalized)



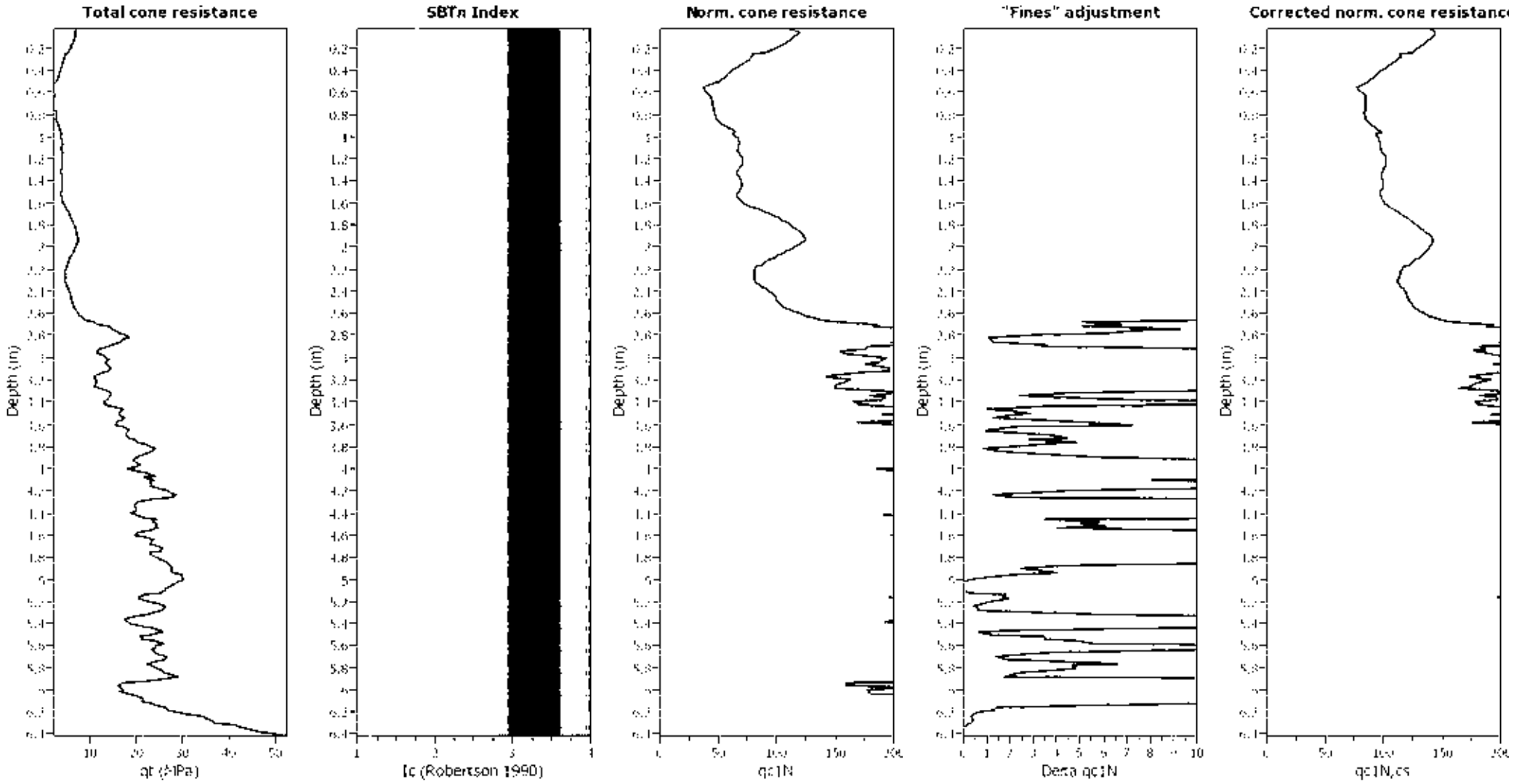
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

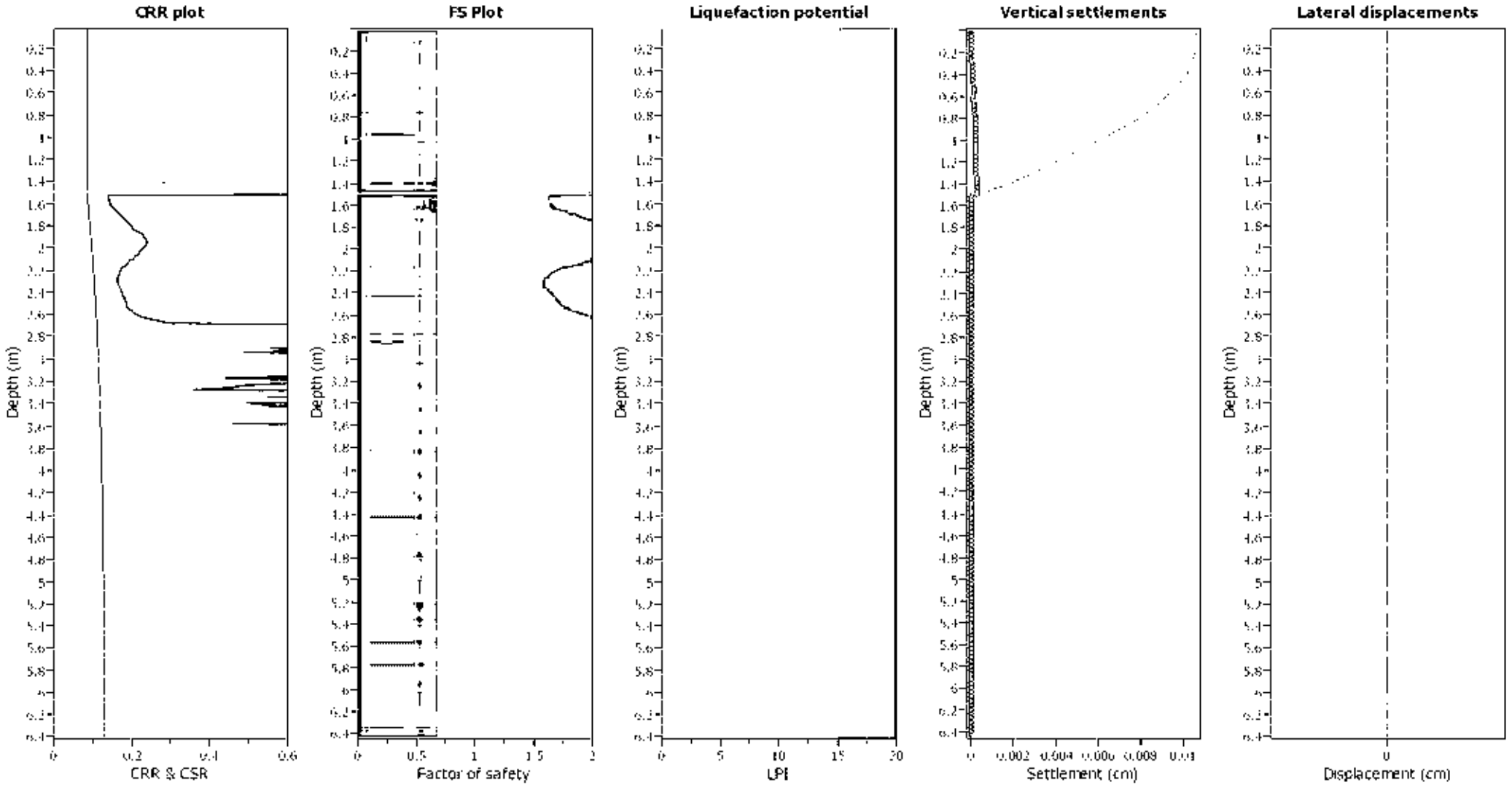
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 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.):	1.50 m	Fill weight:	N/A
Liner correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 m	Fill height:	N/A	Limit depth:	N/A

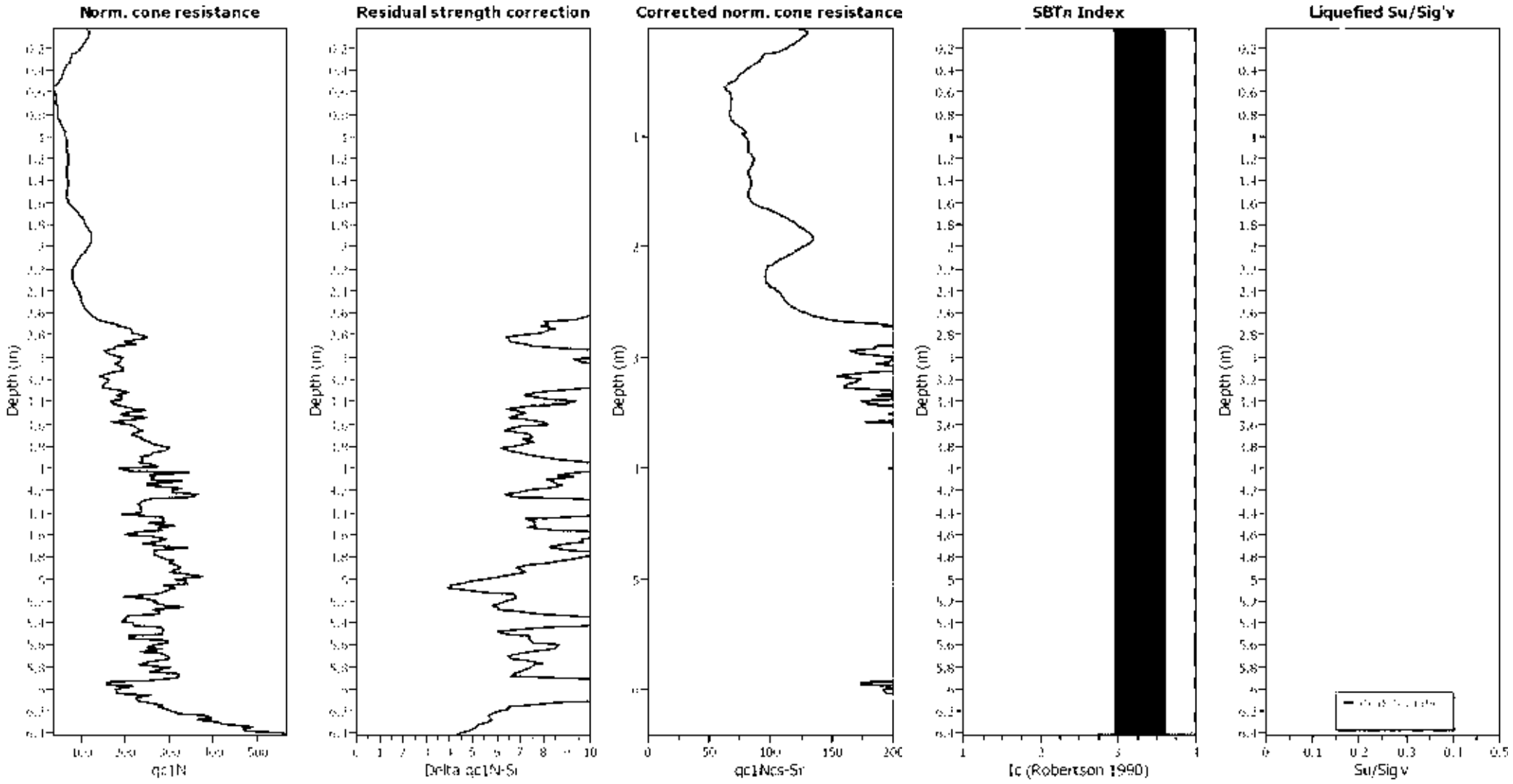
F.S. color scheme

- ☐ 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

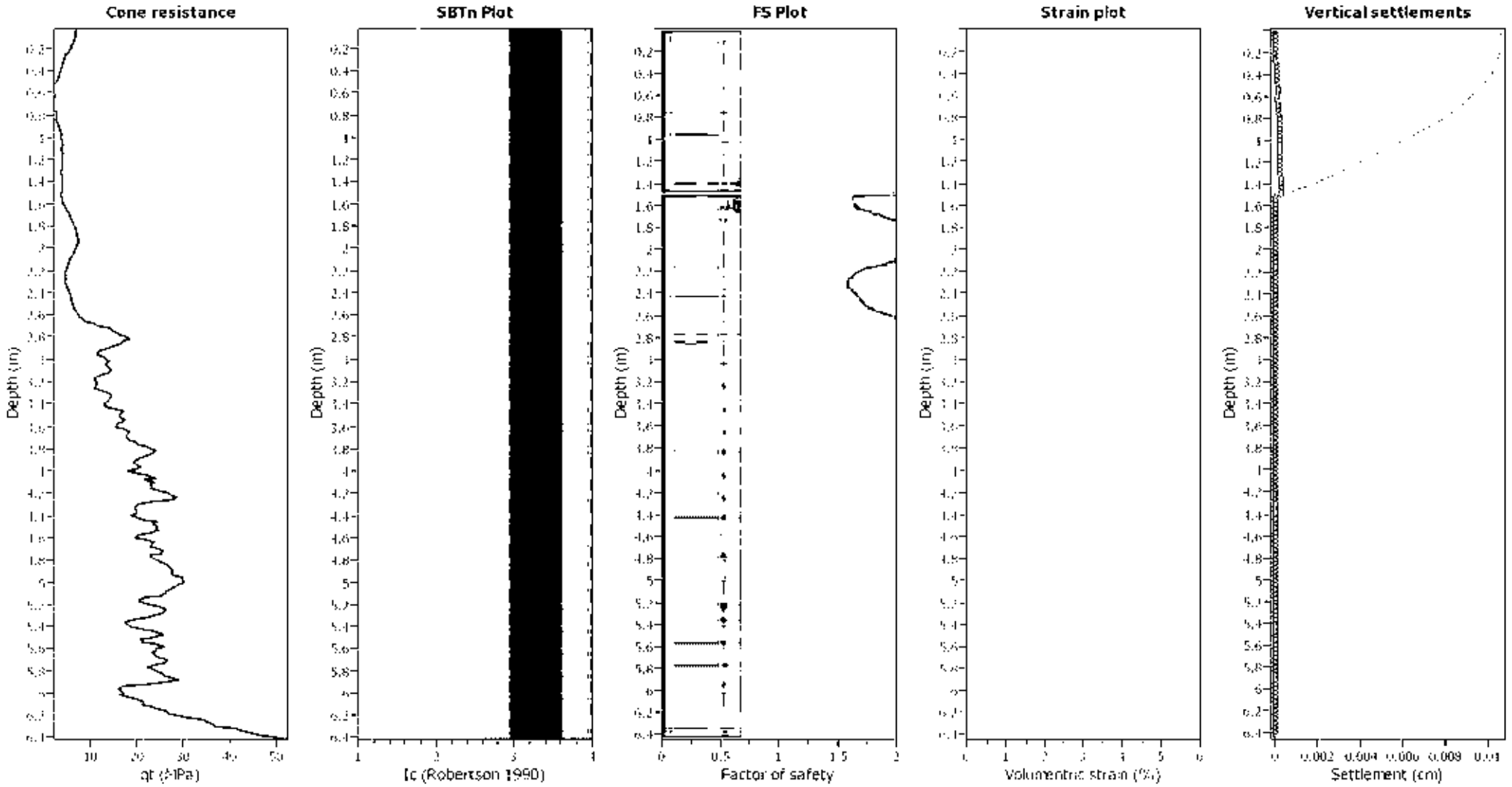
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Liner correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 m	Fill height:	N/A	Limit depth	N/A

Estimation of post-earthquake settlements



Abbreviations

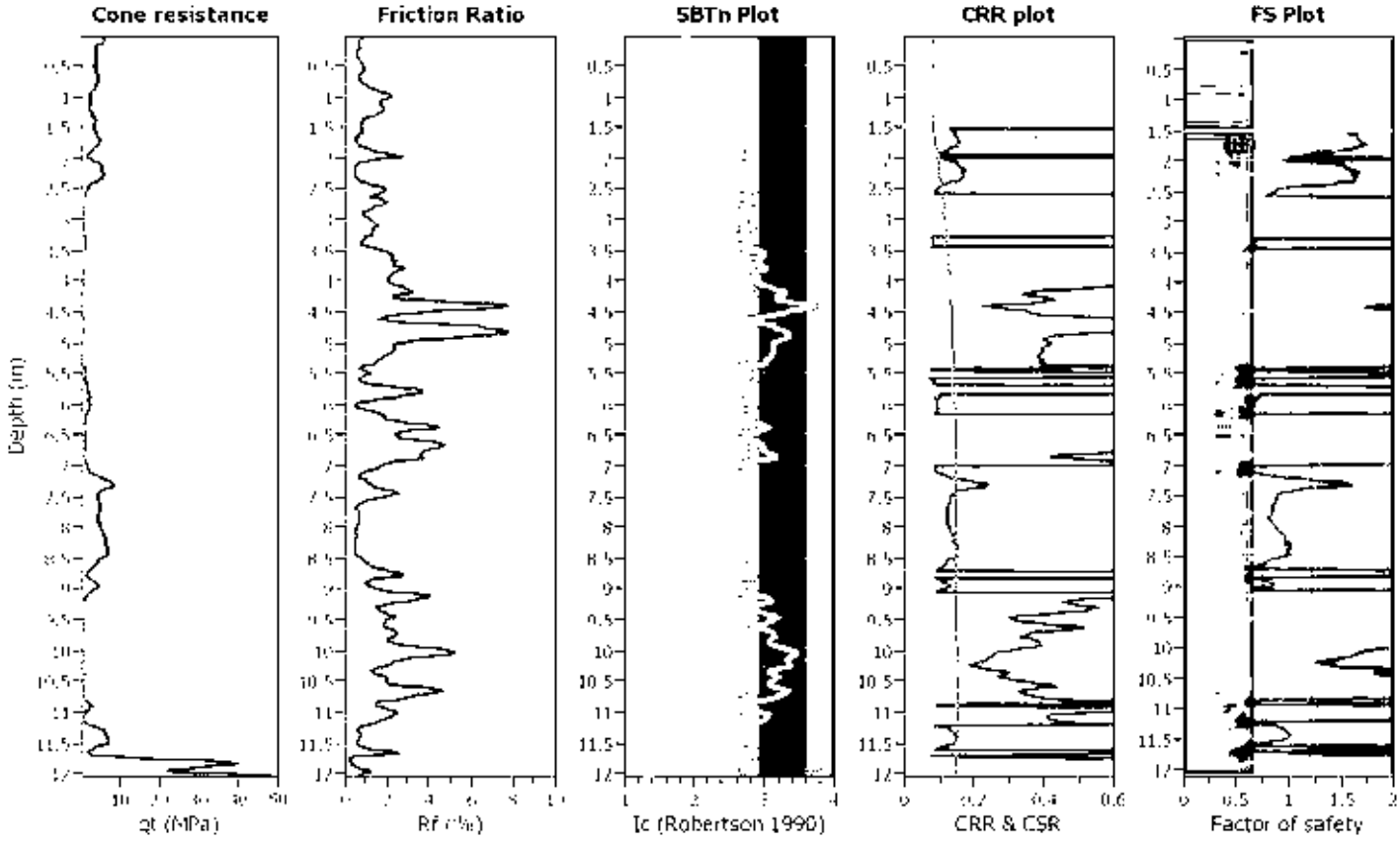
qt:	Total cone resistance (cone resistance q corrected for pore water effects)
Ic:	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumentric strain:	Post liquefaction volumentric strain

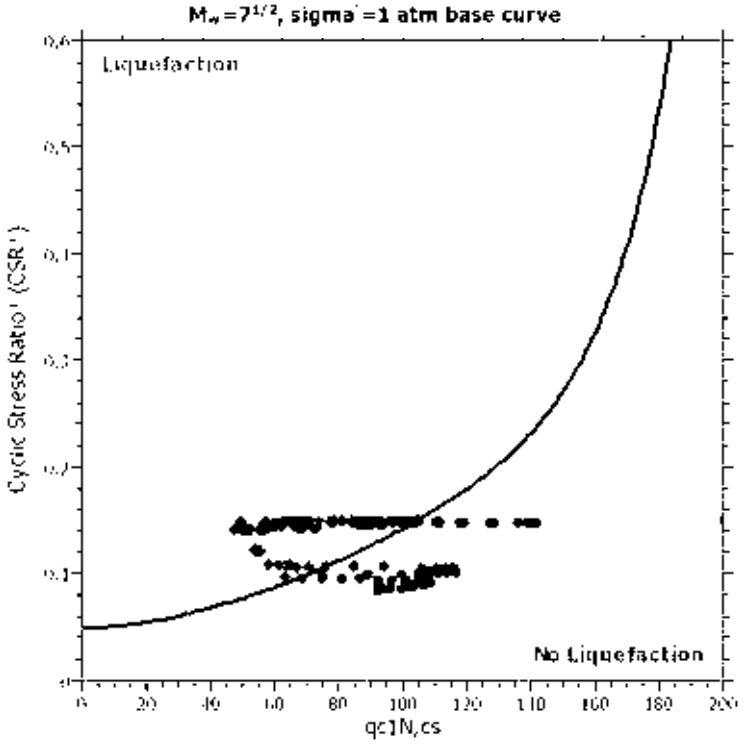
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

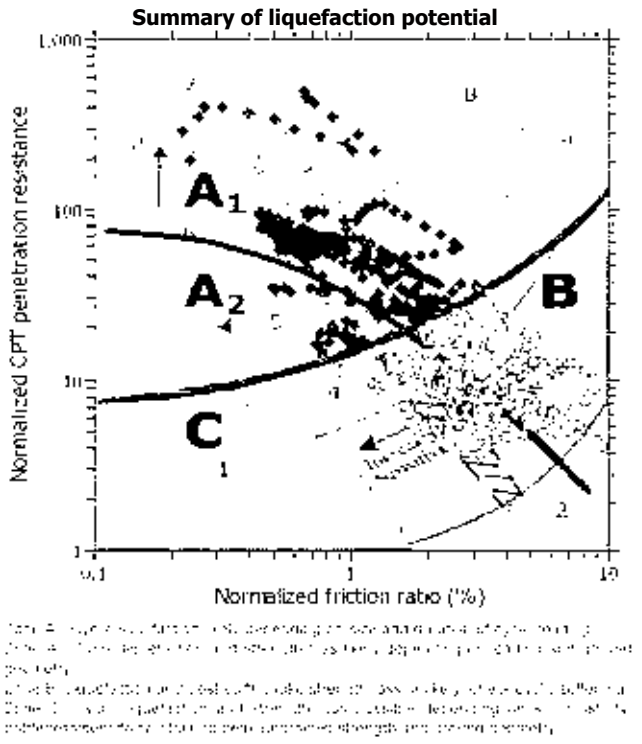
CPT file : CPT10_42QuaifesRd

Input parameters and analysis data

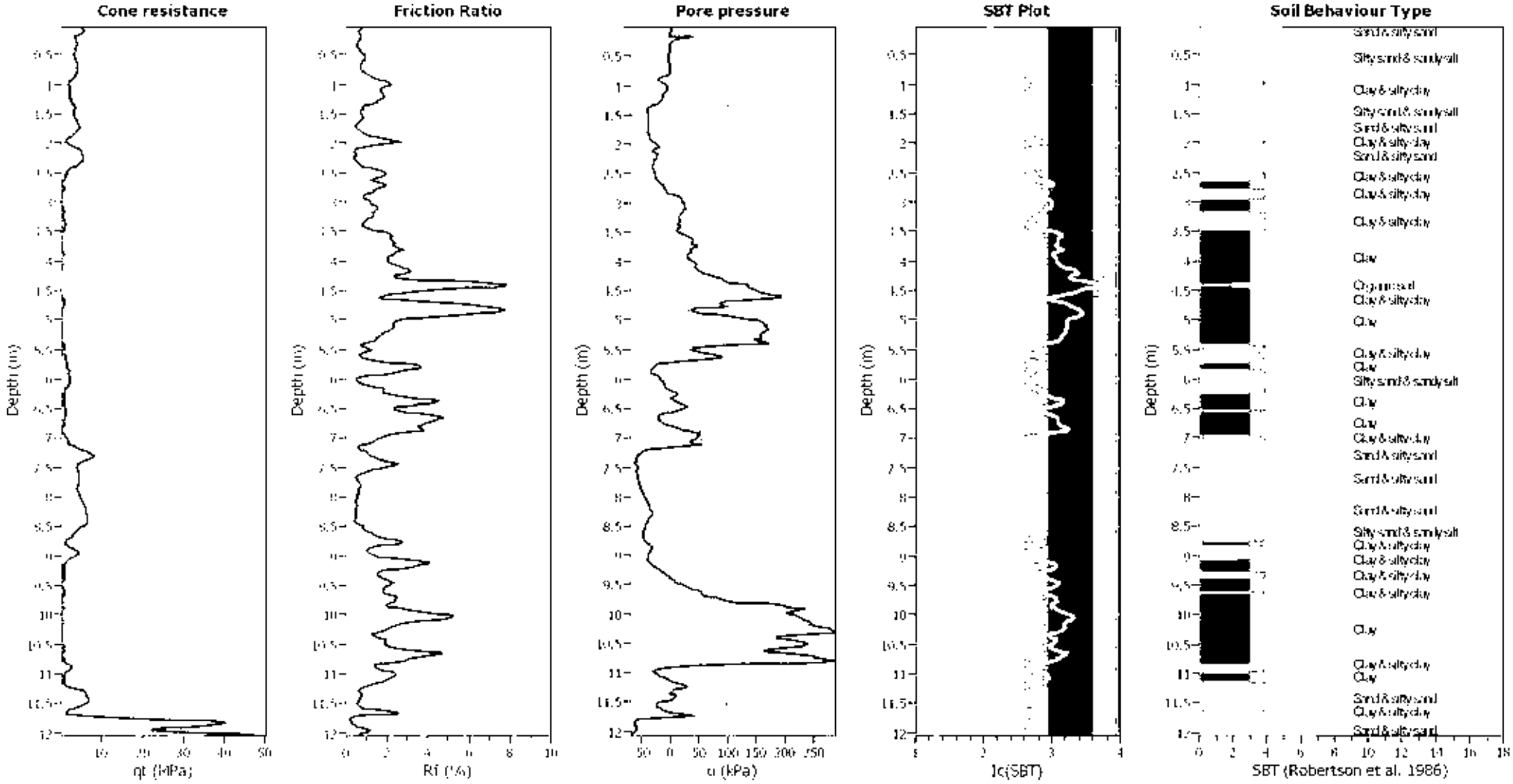
Analysis method	I&B (2008)	G.W.T. (in-situ):	1.50 m	Use fill	No	Clay like behavior applied:	Sand & Clay
Fines correction method	I&B (2008)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration	0.13	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



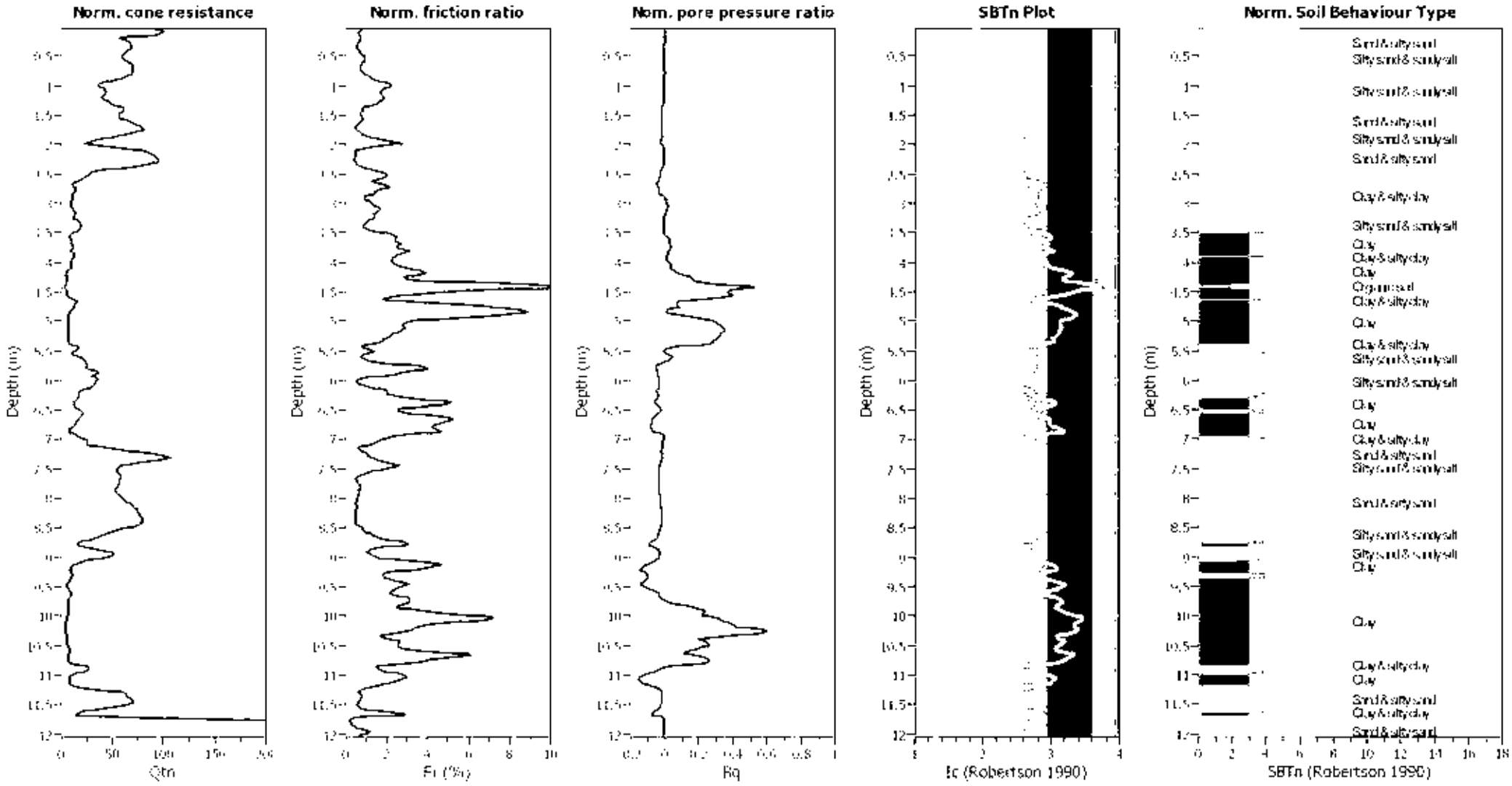
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 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

CPT basic interpretation plots (normalized)



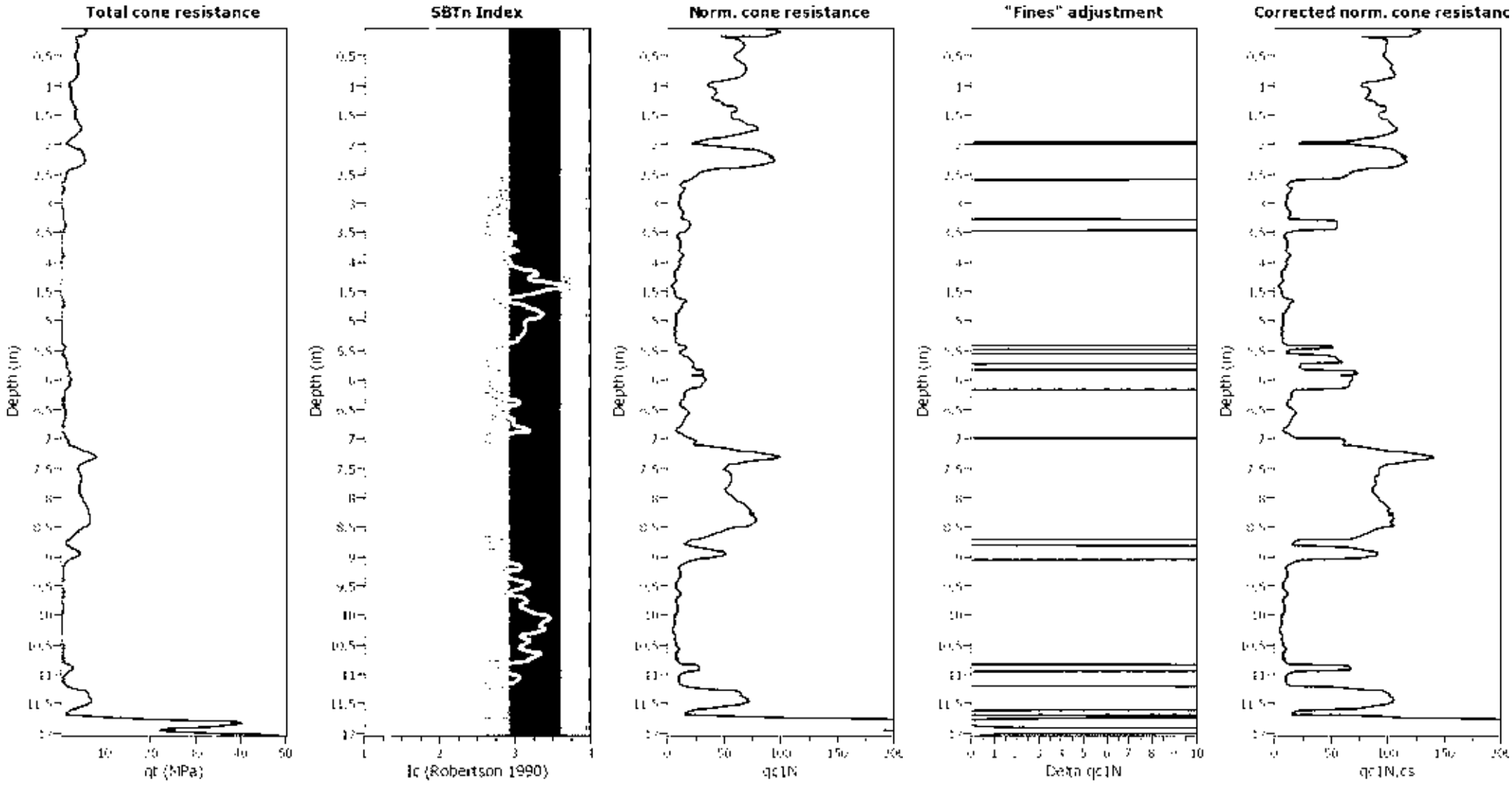
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

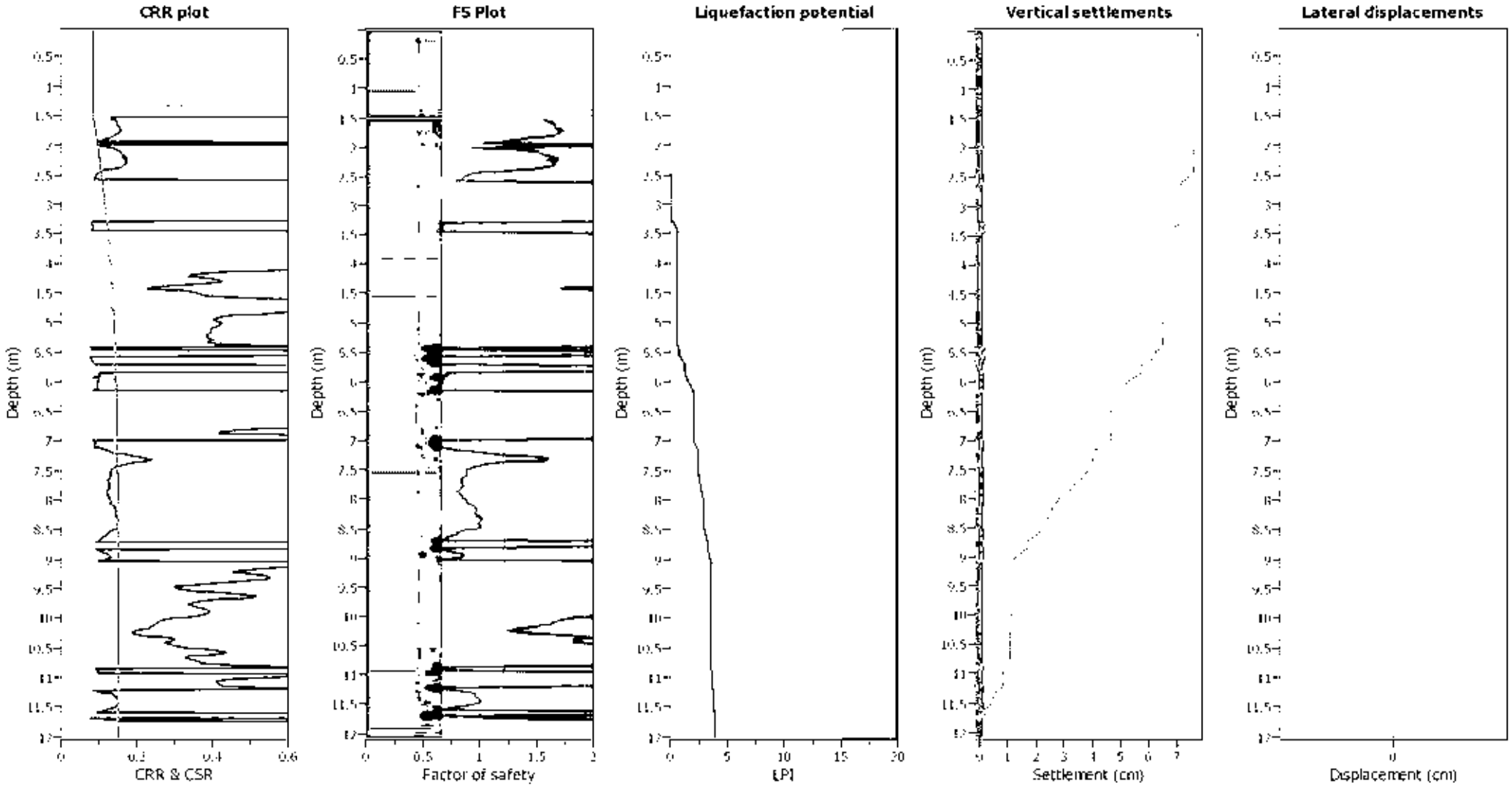
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 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.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

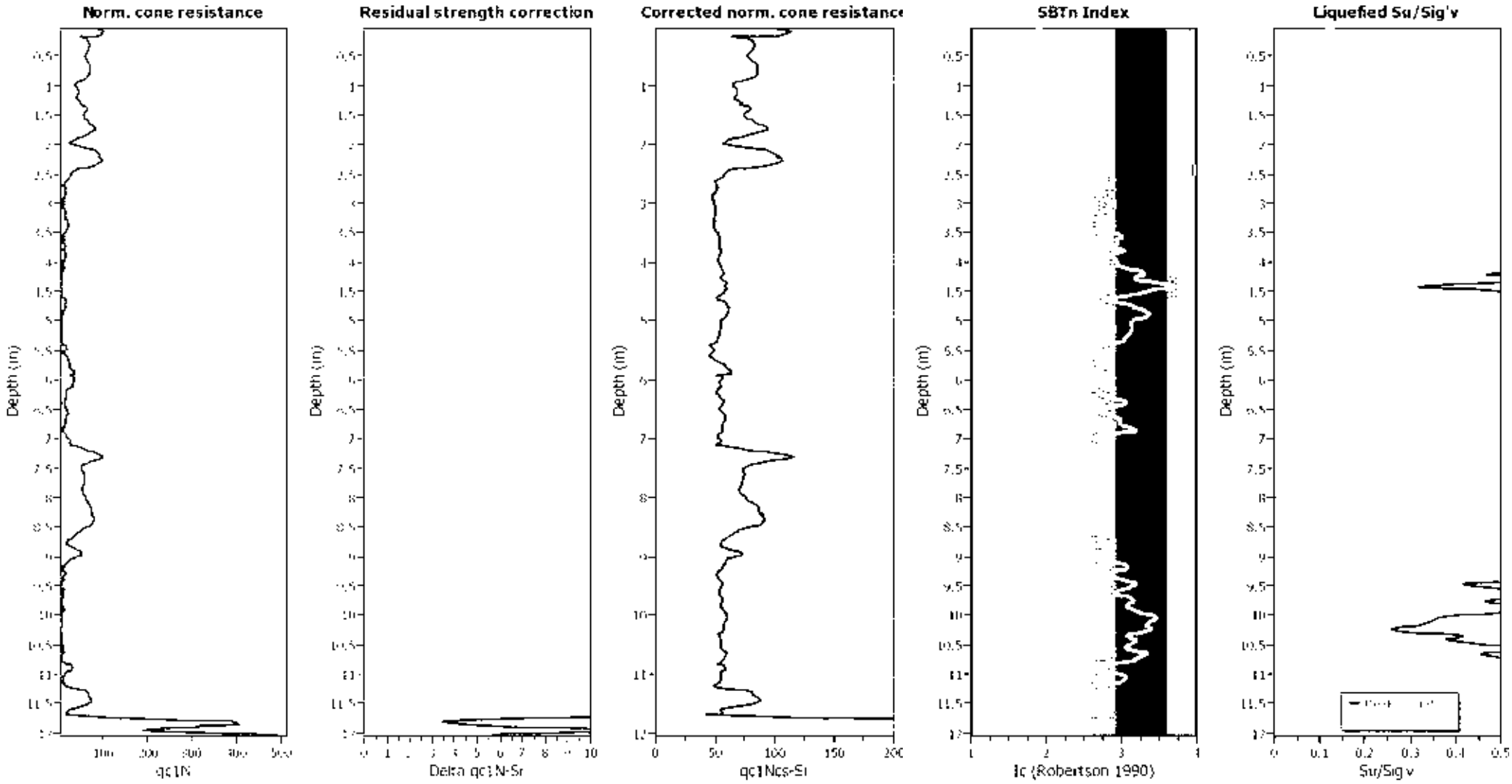
F.S. color scheme

- ☐ 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

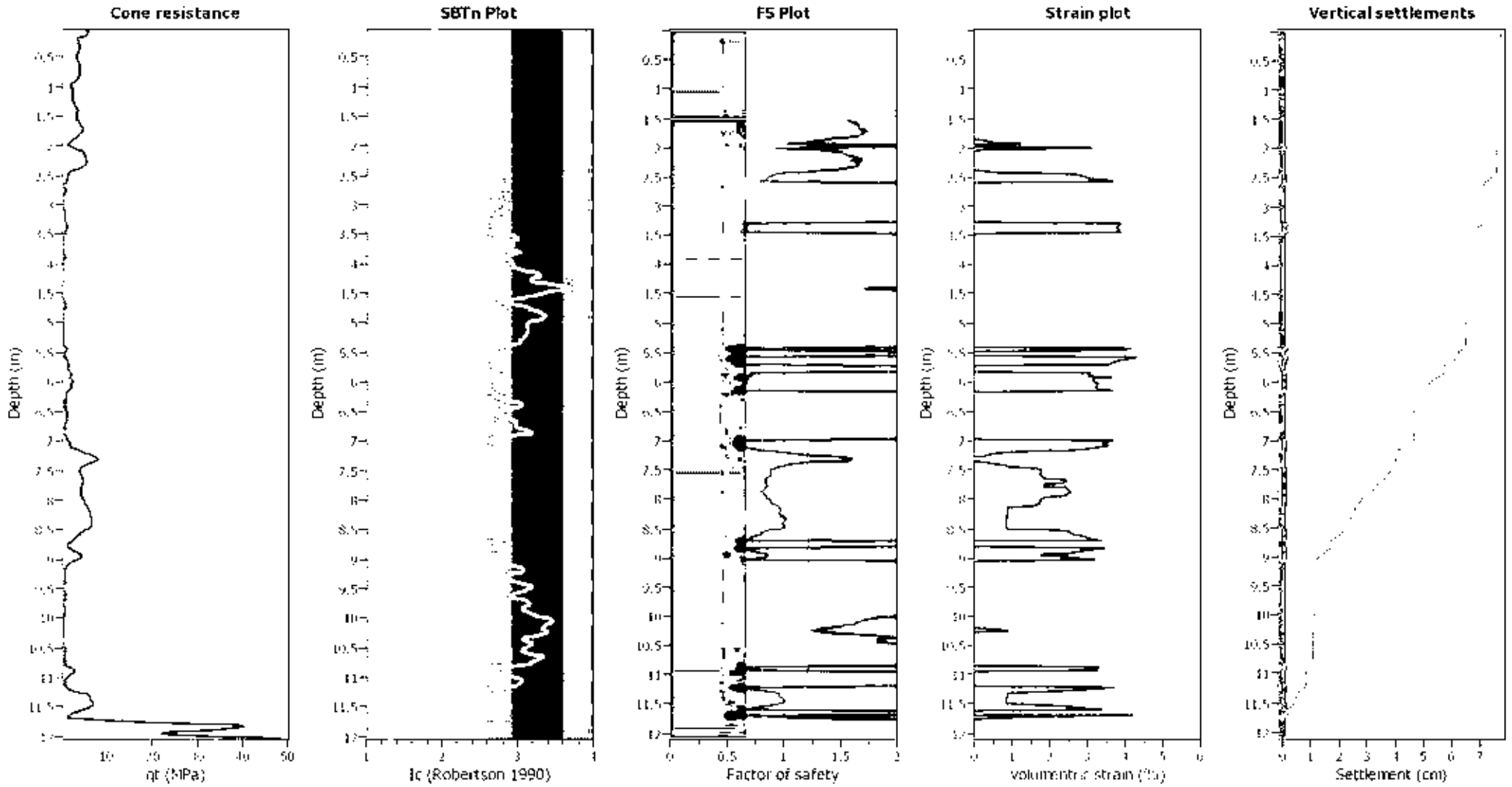
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 m	Fill height:	N/A	Limit depth	N/A

Estimation of post-earthquake settlements



Abbreviations

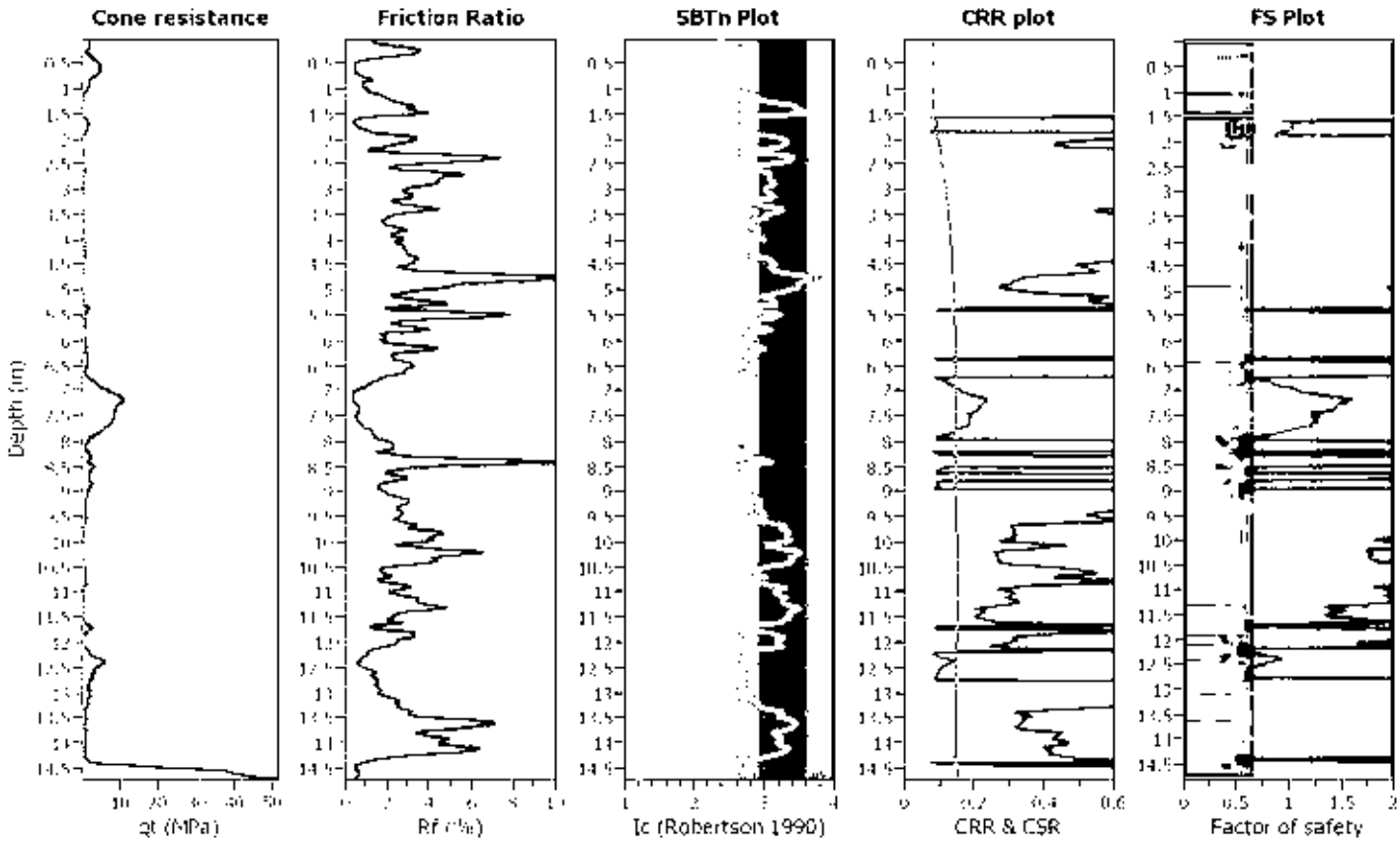
qt:	Total cone resistance (cone resistance q corrected for pore water effects)
Ic:	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumetric strain:	Post liquefaction volumetric strain

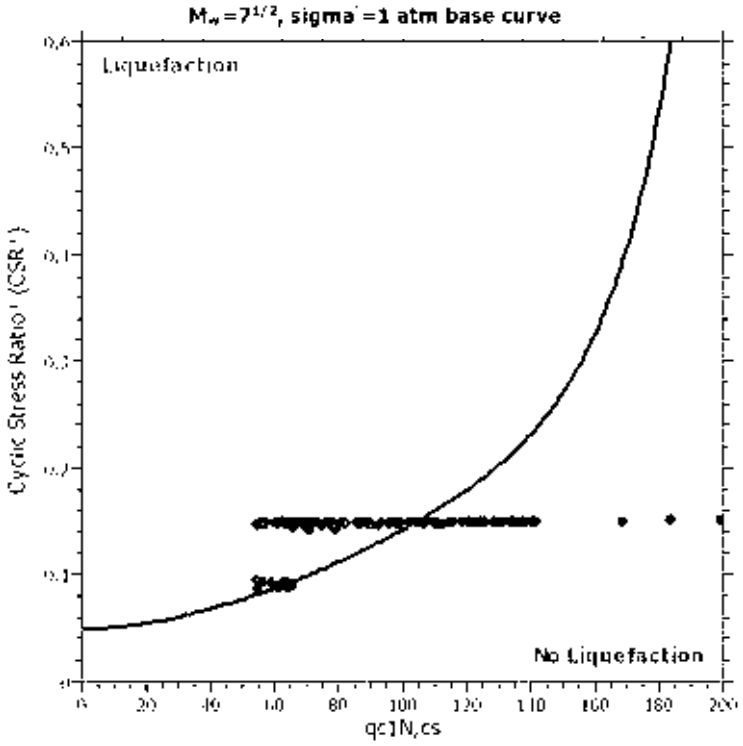
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

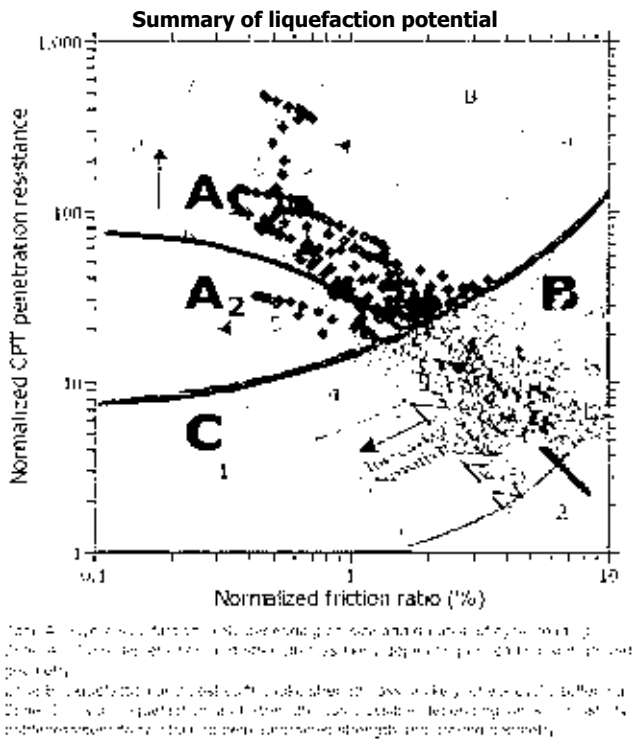
CPT file : CPT11_52QuaifesRd

Input parameters and analysis data

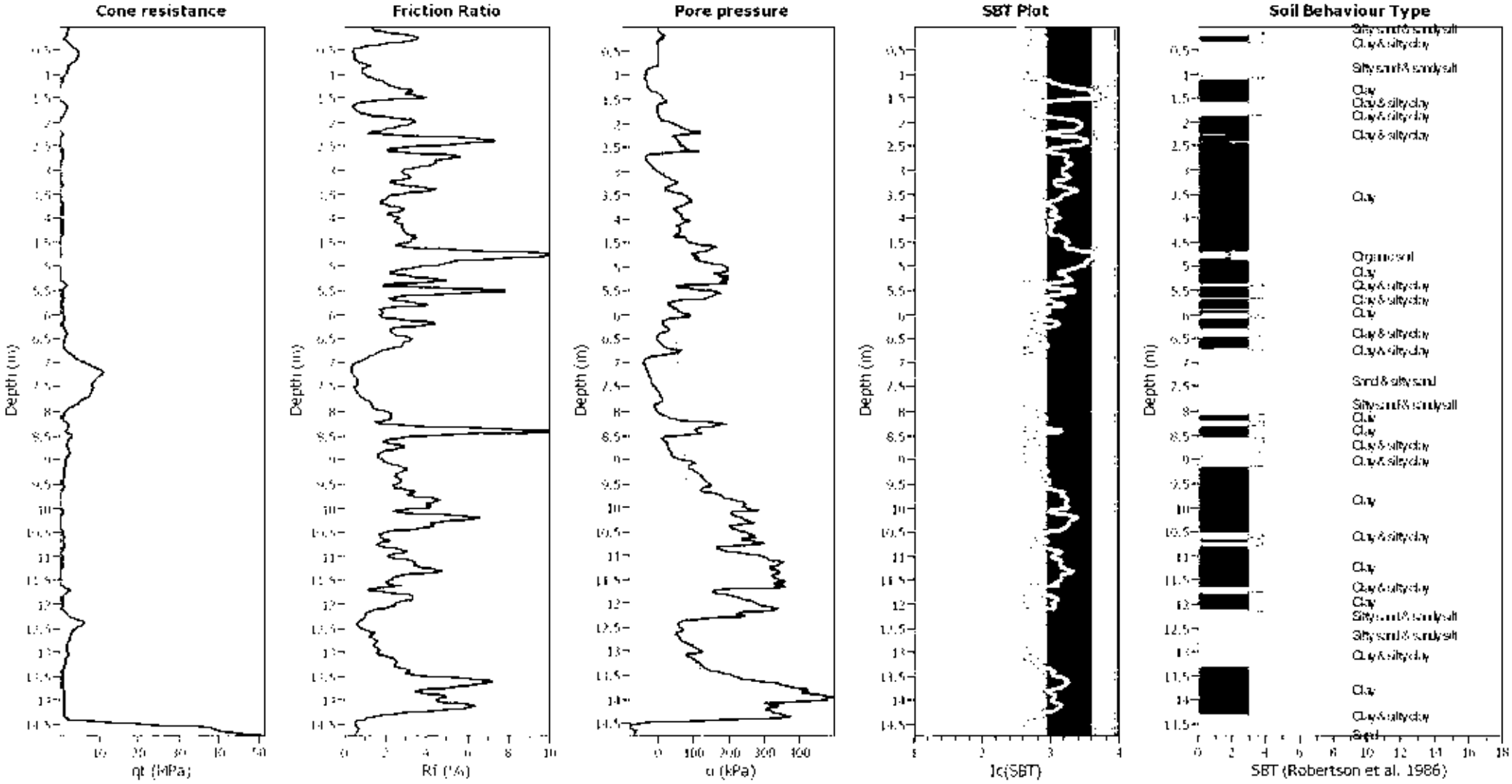
Analysis method	I&B (2008)	G.W.T. (in-situ):	1.50 m	Use fill	No	Clay like behavior applied:	Sand & Clay
Fines correction method	I&B (2008)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration	0.13	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



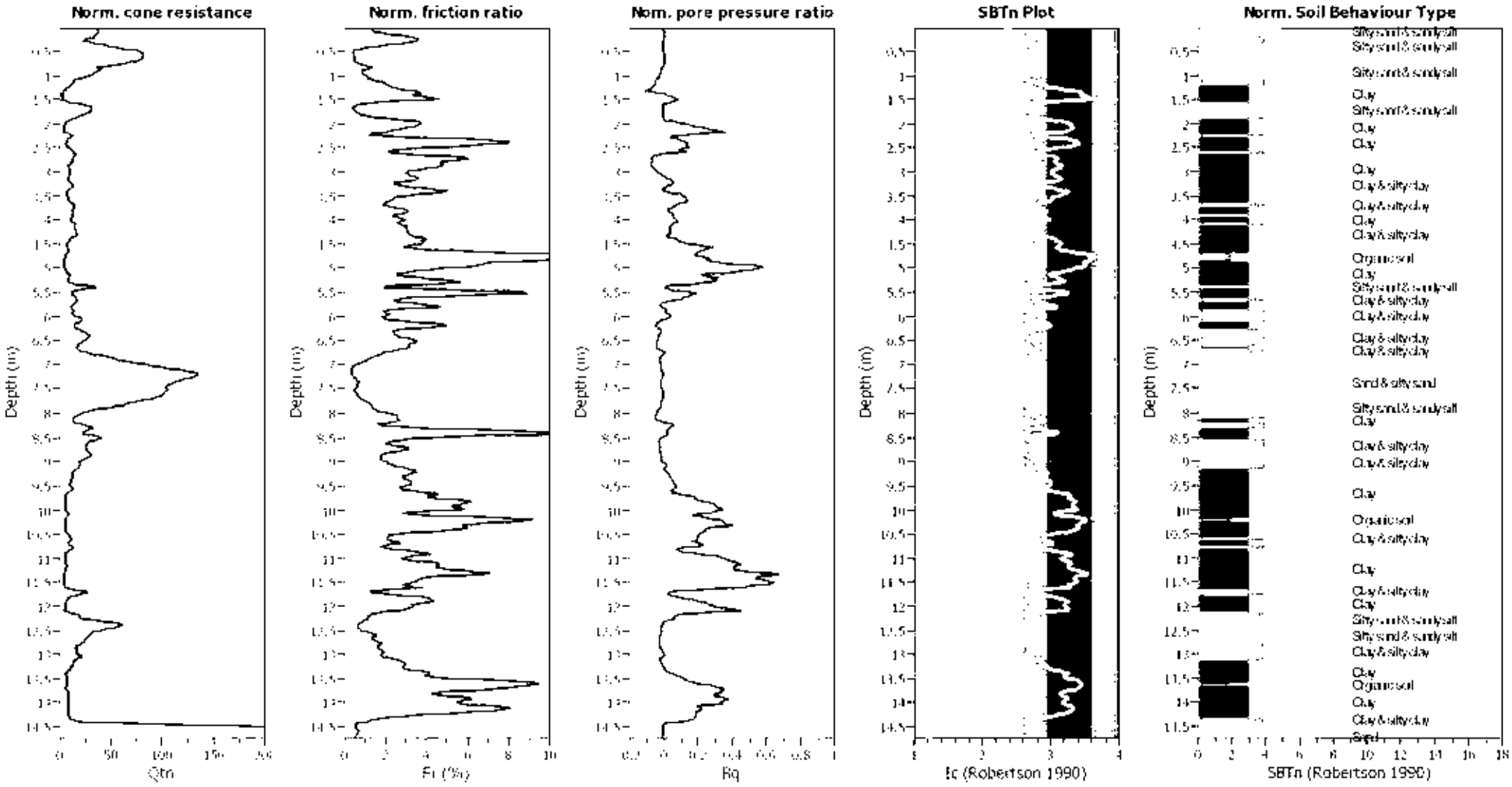
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 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

CPT basic interpretation plots (normalized)



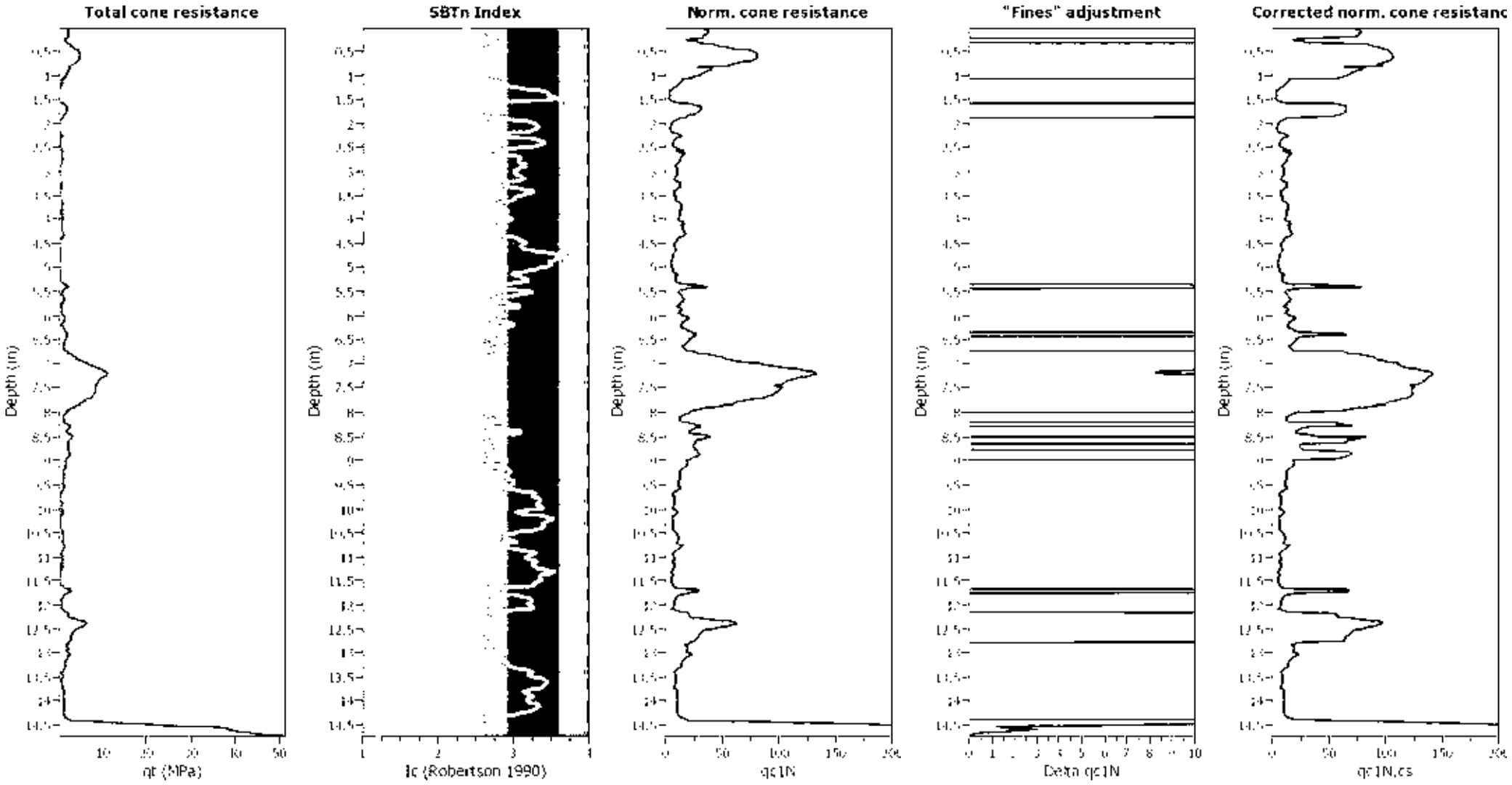
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

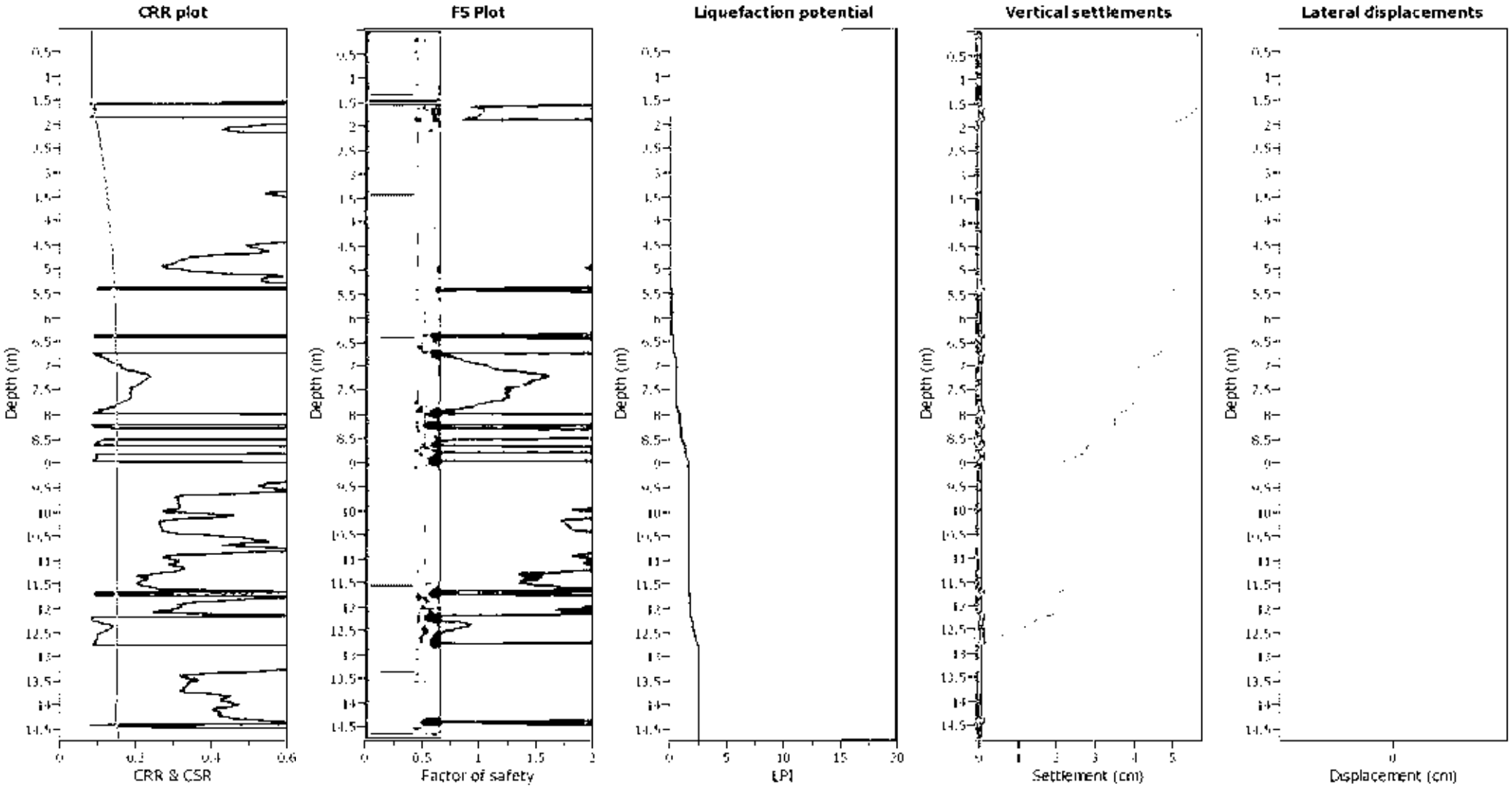
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 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.):	1.50 m	Fill weight:	N/A
Liner correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 m	Fill height:	N/A	Limit depth:	N/A

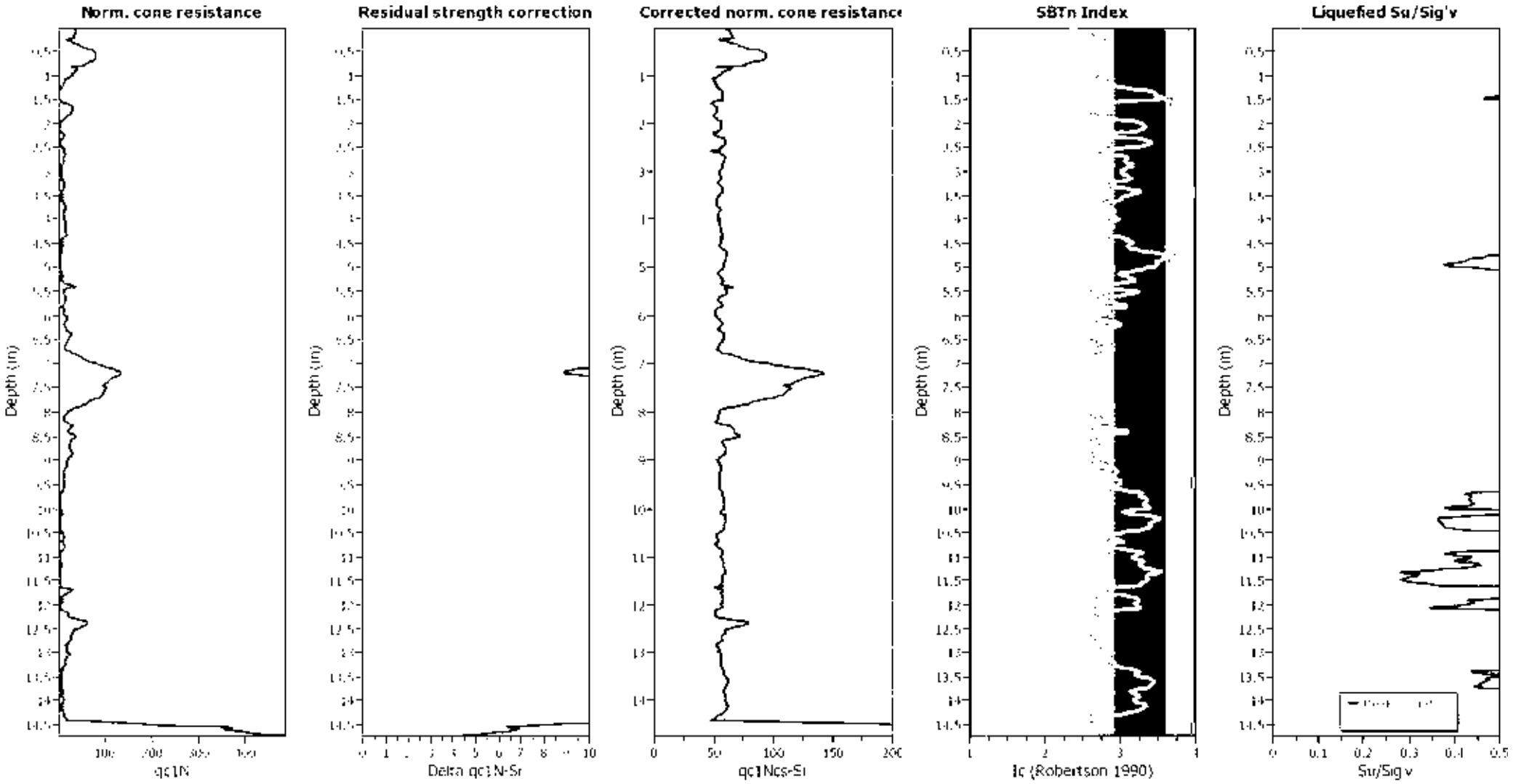
F.S. color scheme

- ☐ 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

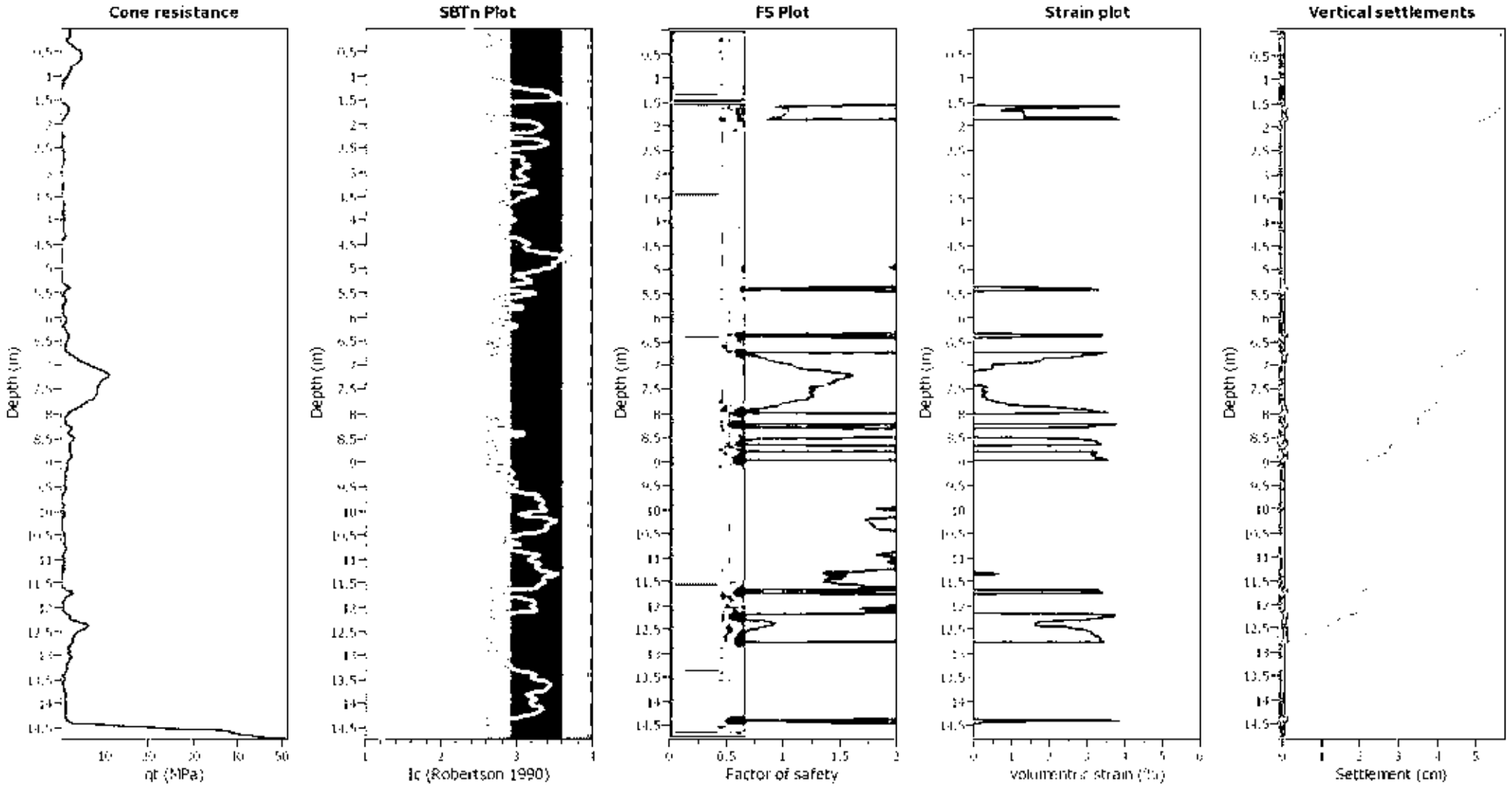
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Liner correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth	N/A

Estimation of post-earthquake settlements



Abbreviations

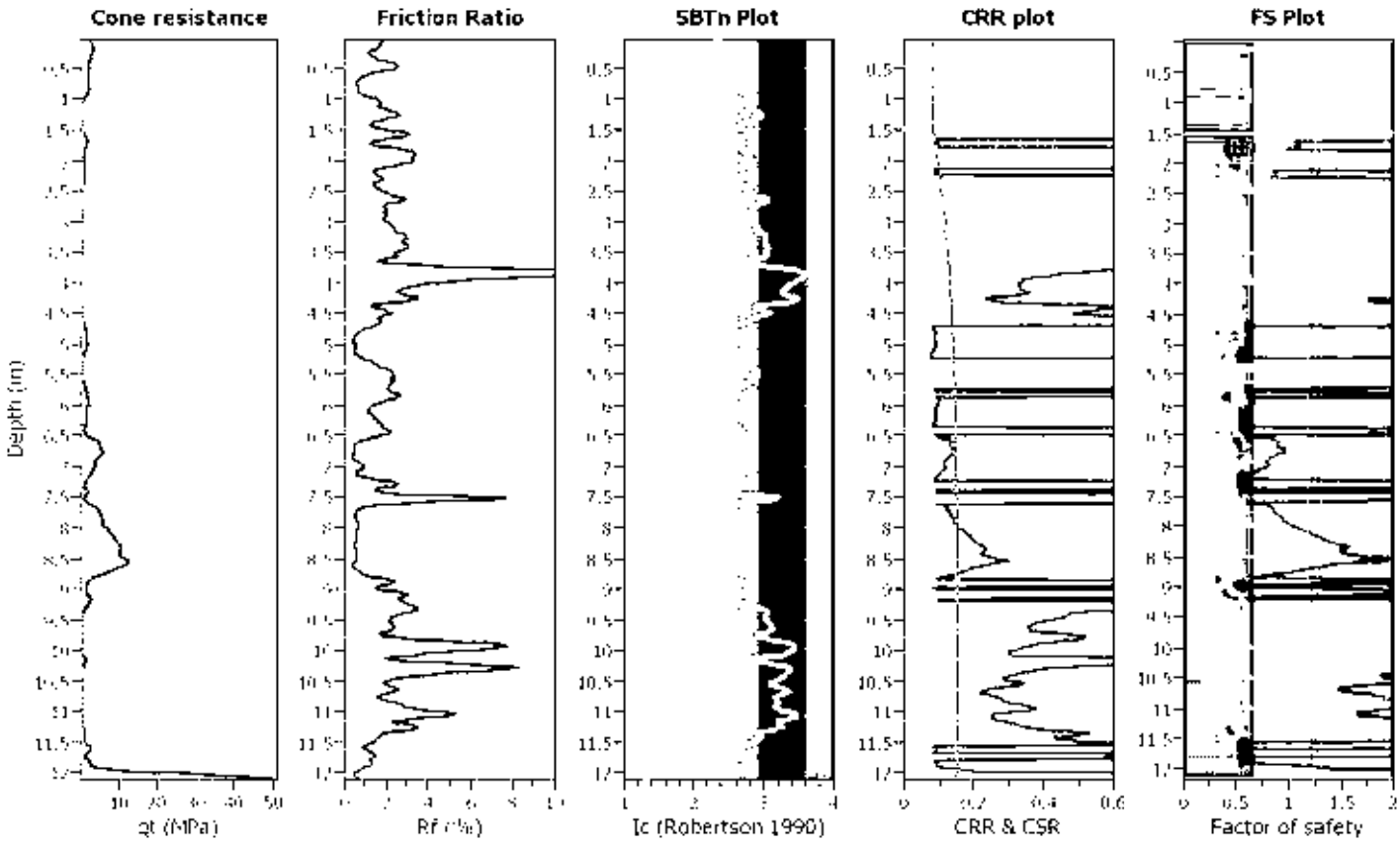
qt:	Total cone resistance (cone resistance q corrected for pore water effects)
Ic:	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumetric strain:	Post liquefaction volumetric strain

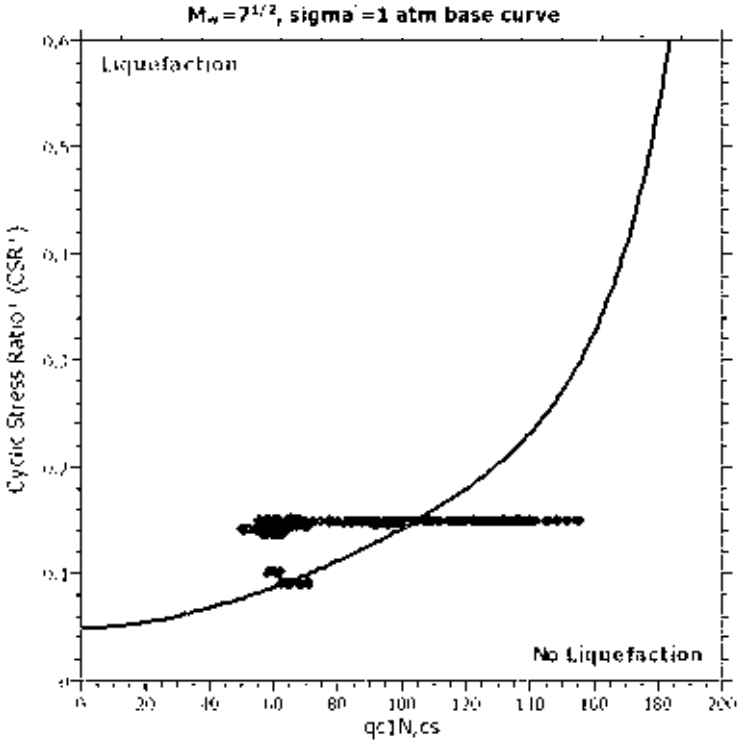
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

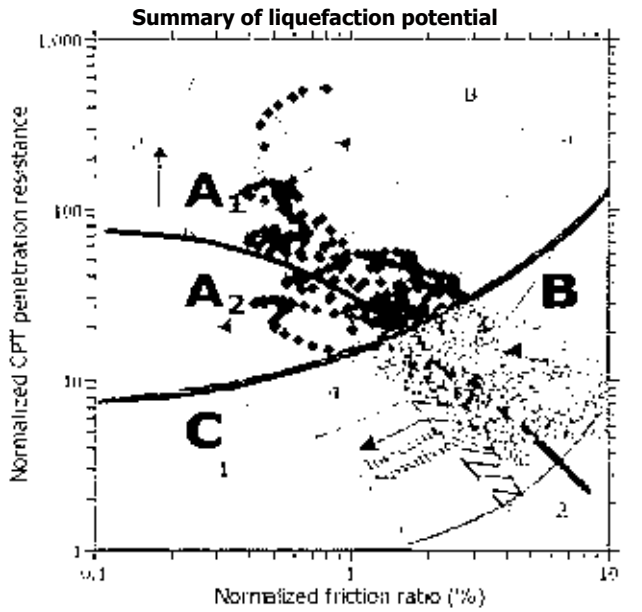
CPT file : CPT12_42QuaifesRd

Input parameters and analysis data

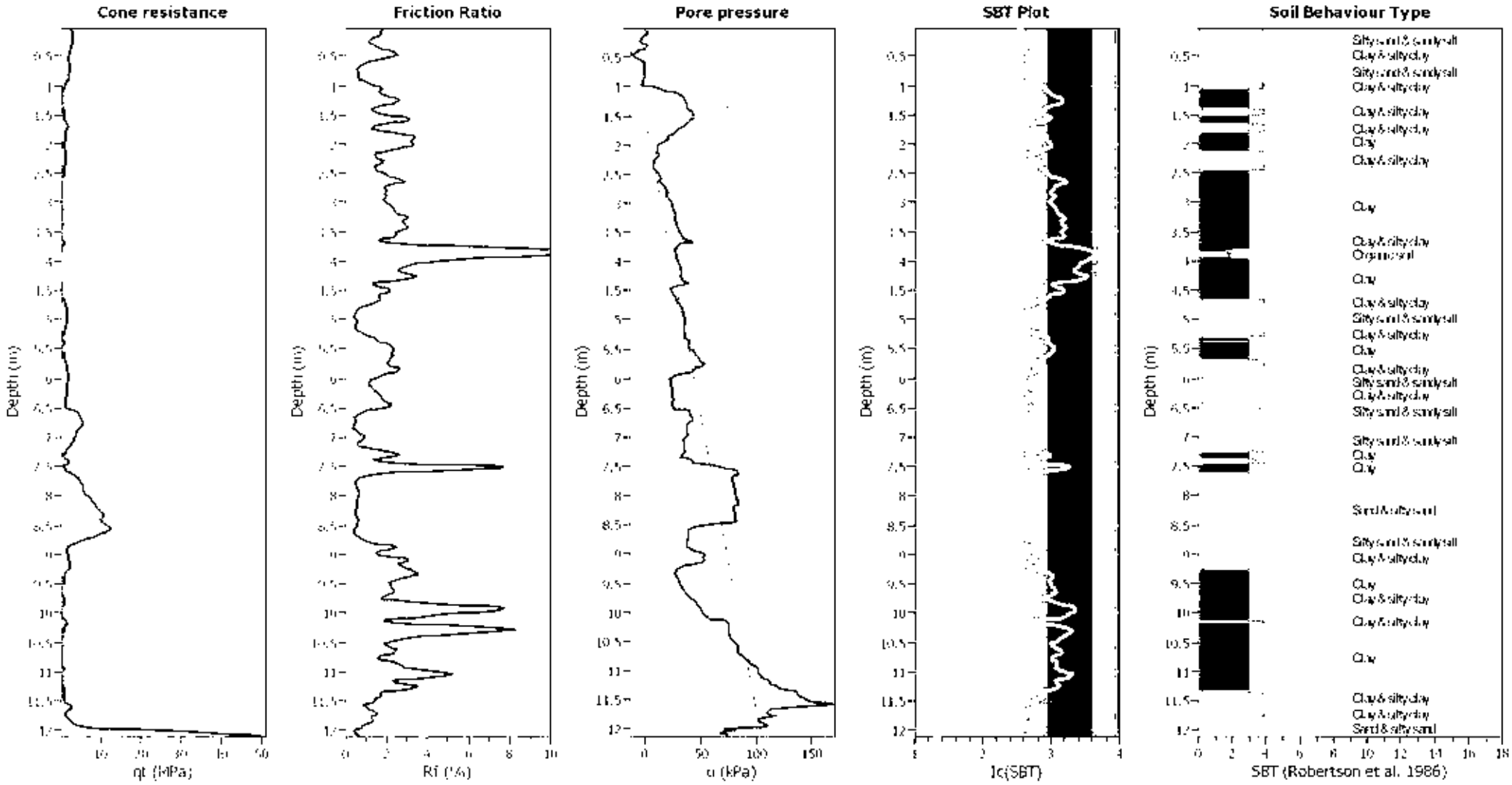
Analysis method	I&B (2008)	G.W.T. (in-situ):	1.50 m	Use fill	No	Clay like behavior applied:	Sand & Clay
Fines correction method	I&B (2008)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration	0.13	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



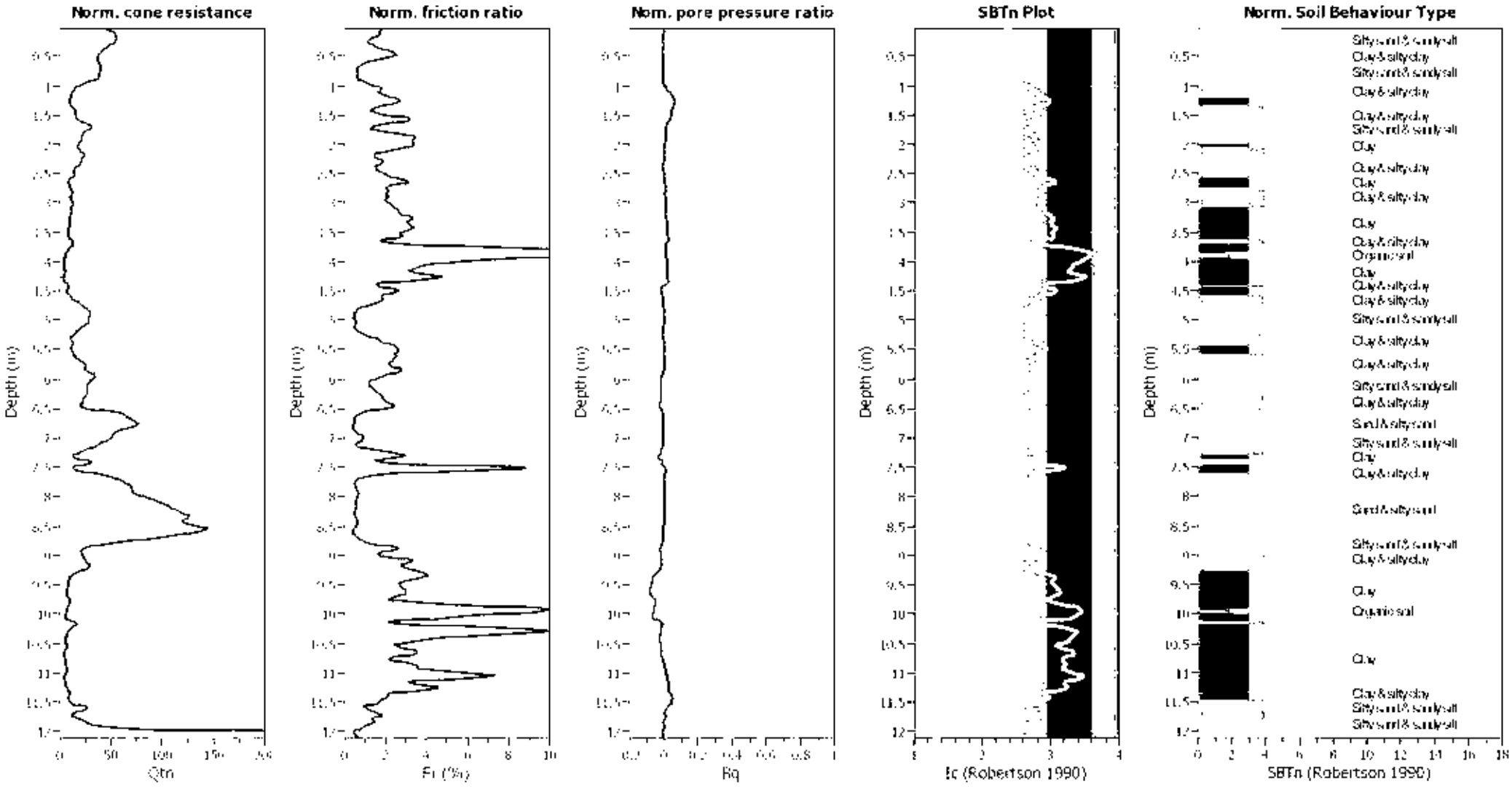
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 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

CPT basic interpretation plots (normalized)



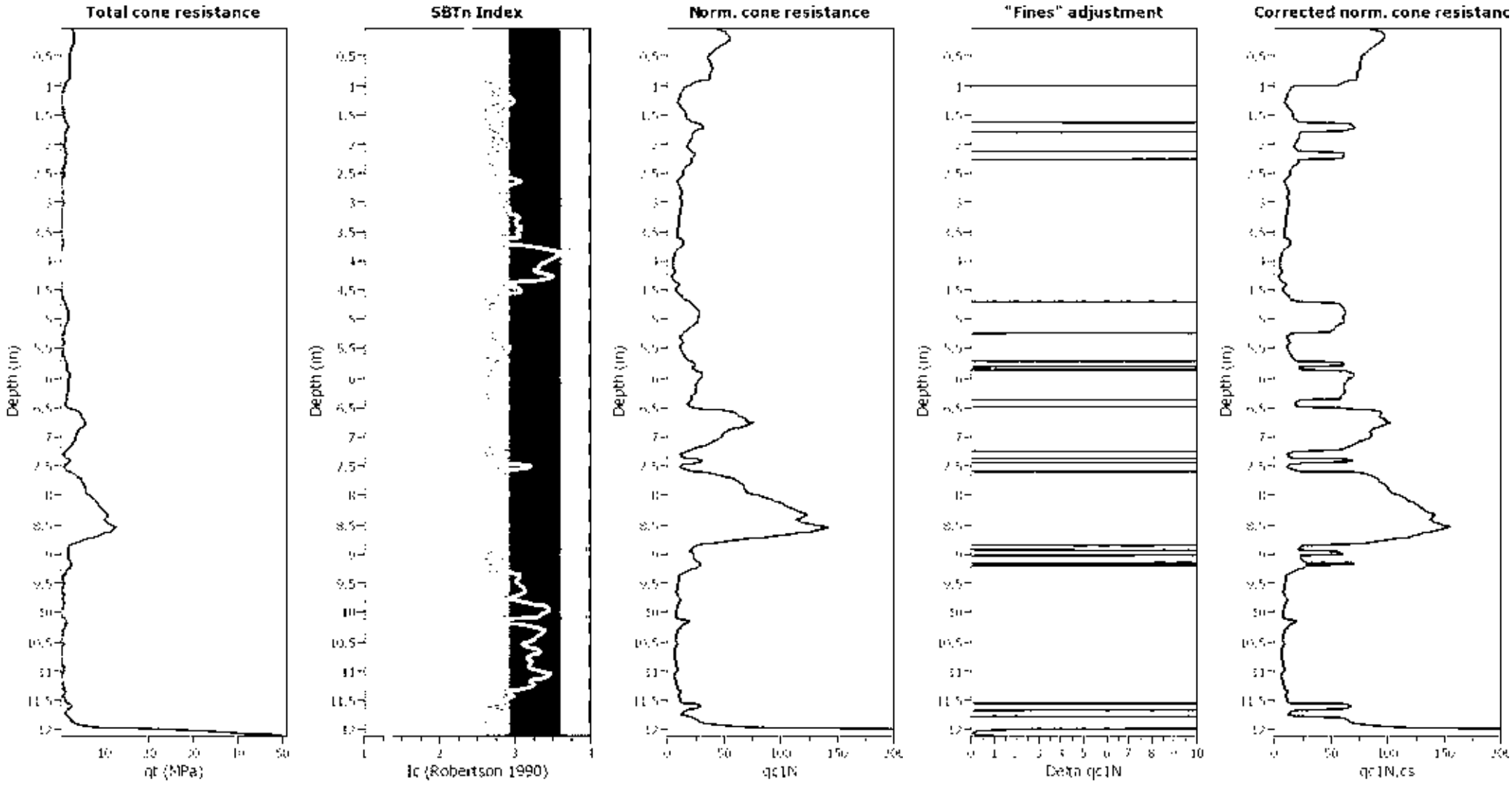
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

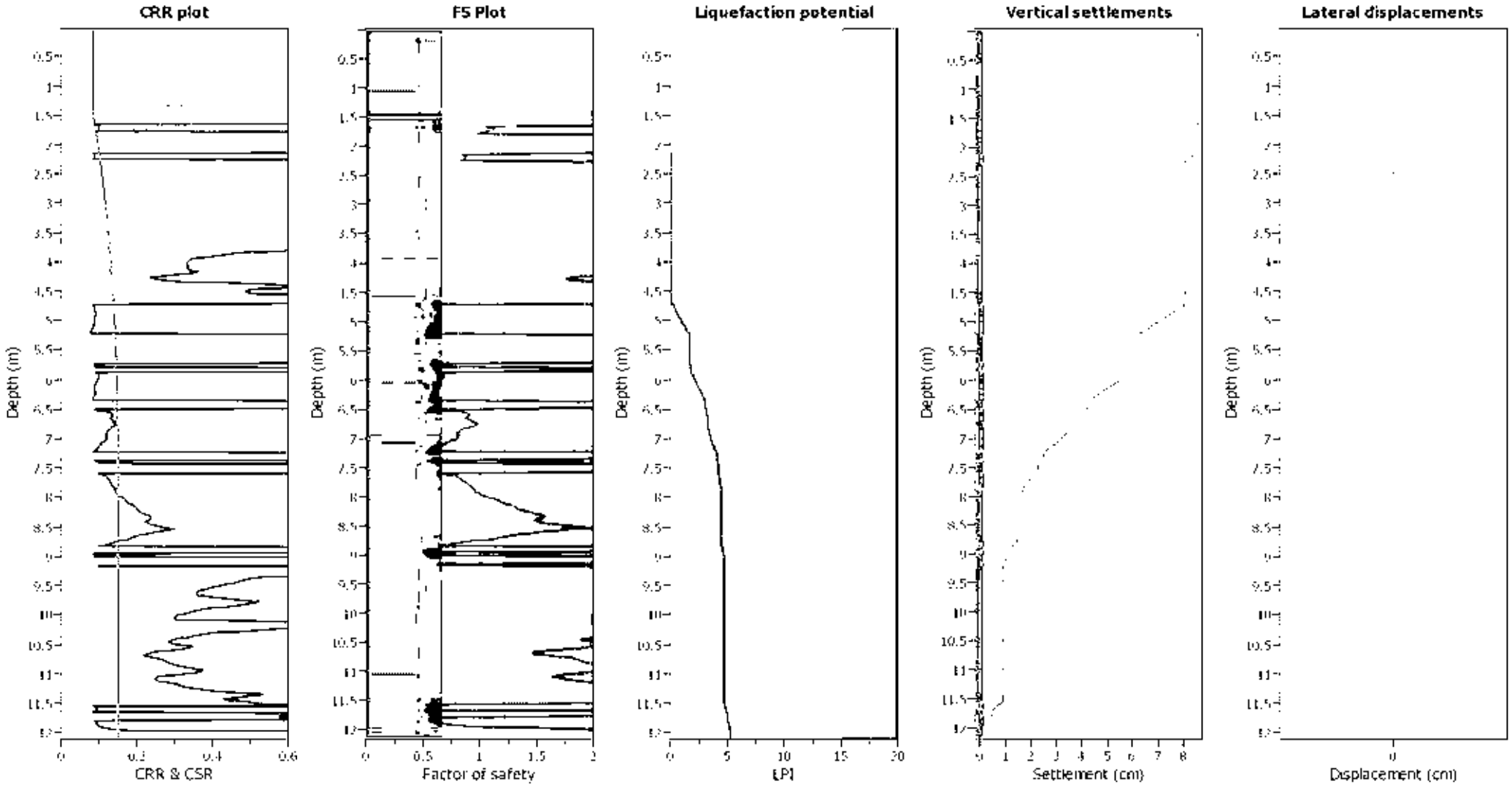
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 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.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

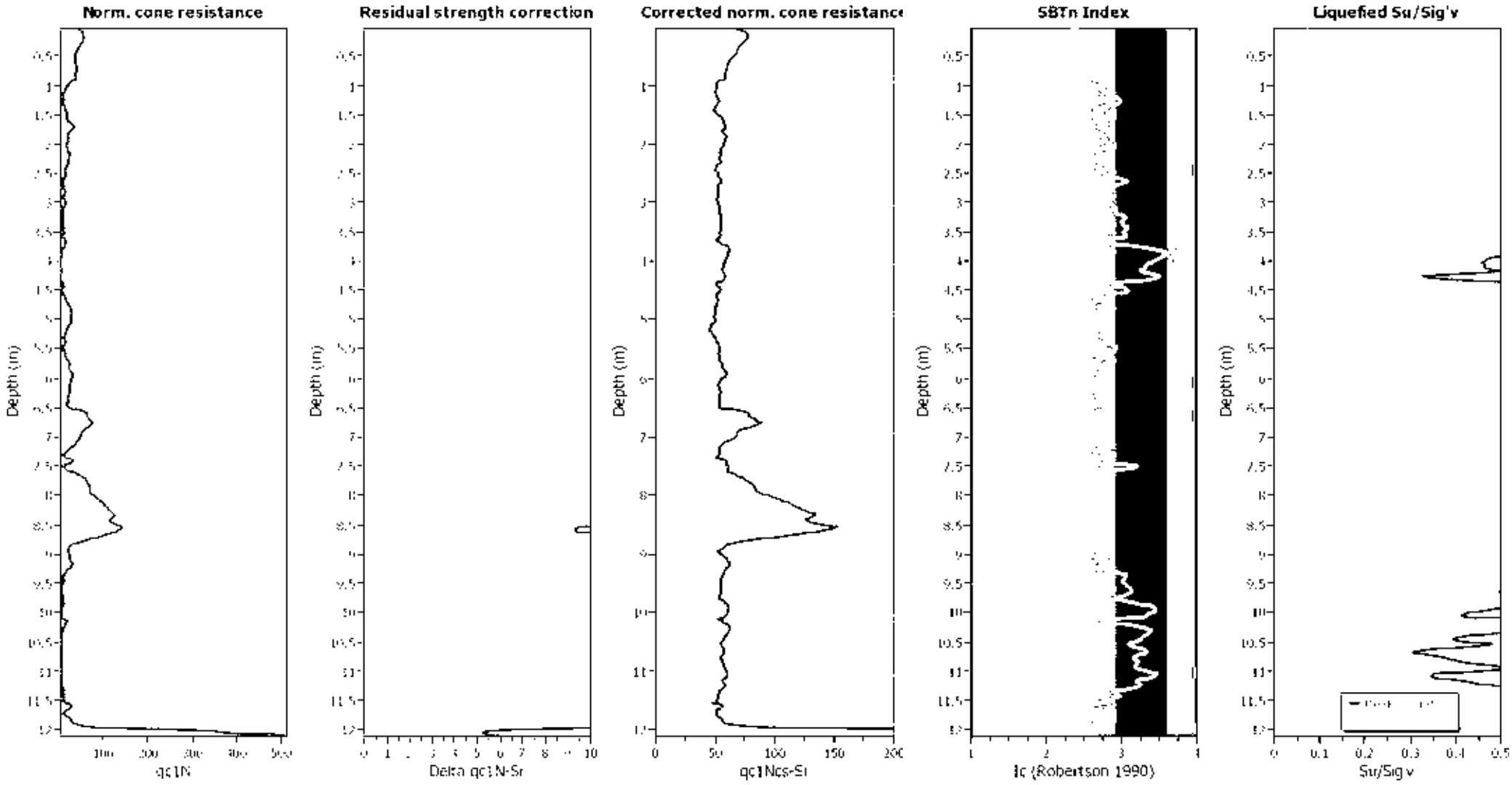
F.S. color scheme

- ☐ 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

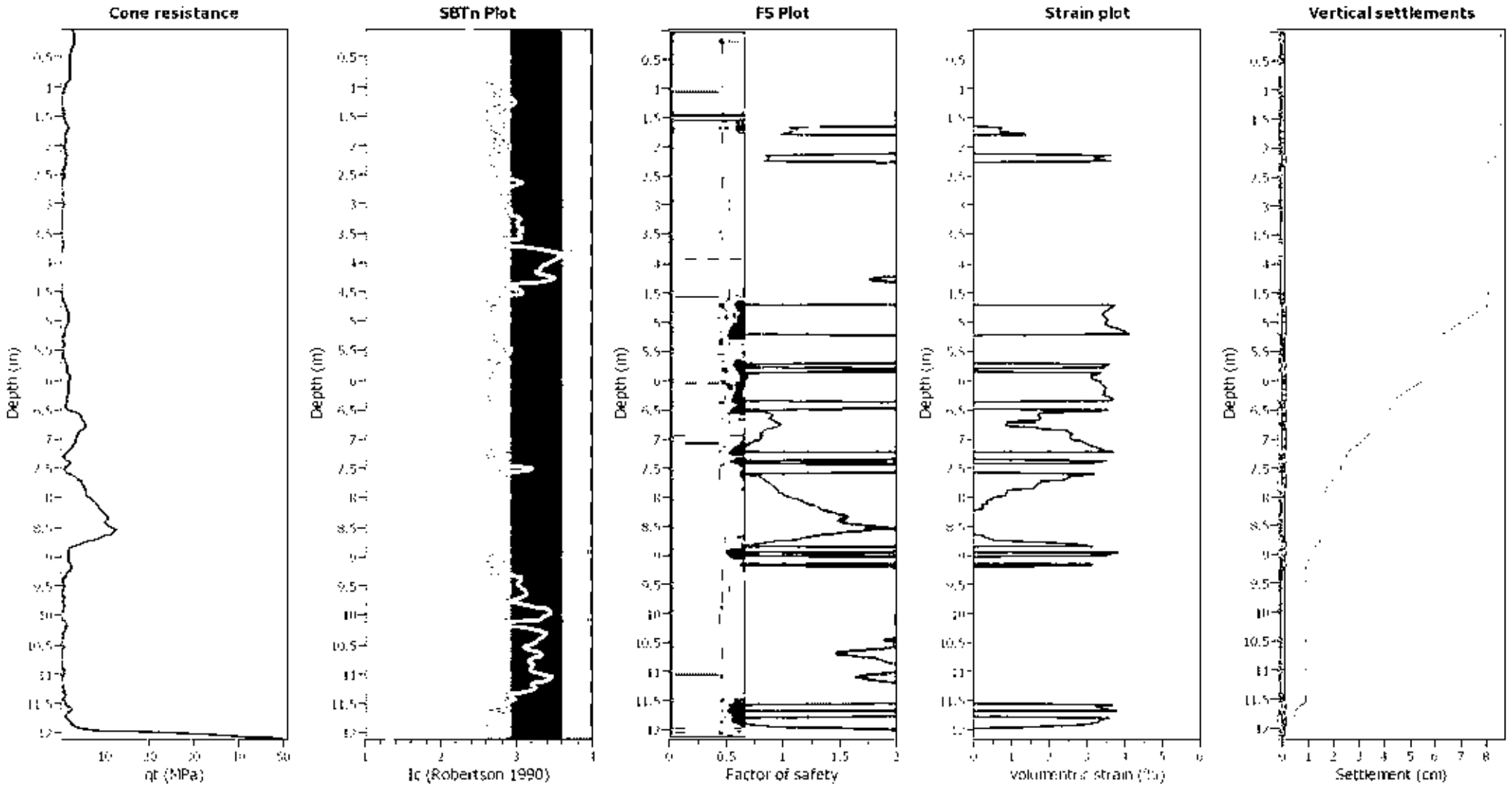
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Liquefaction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth	N/A

Estimation of post-earthquake settlements



Abbreviations

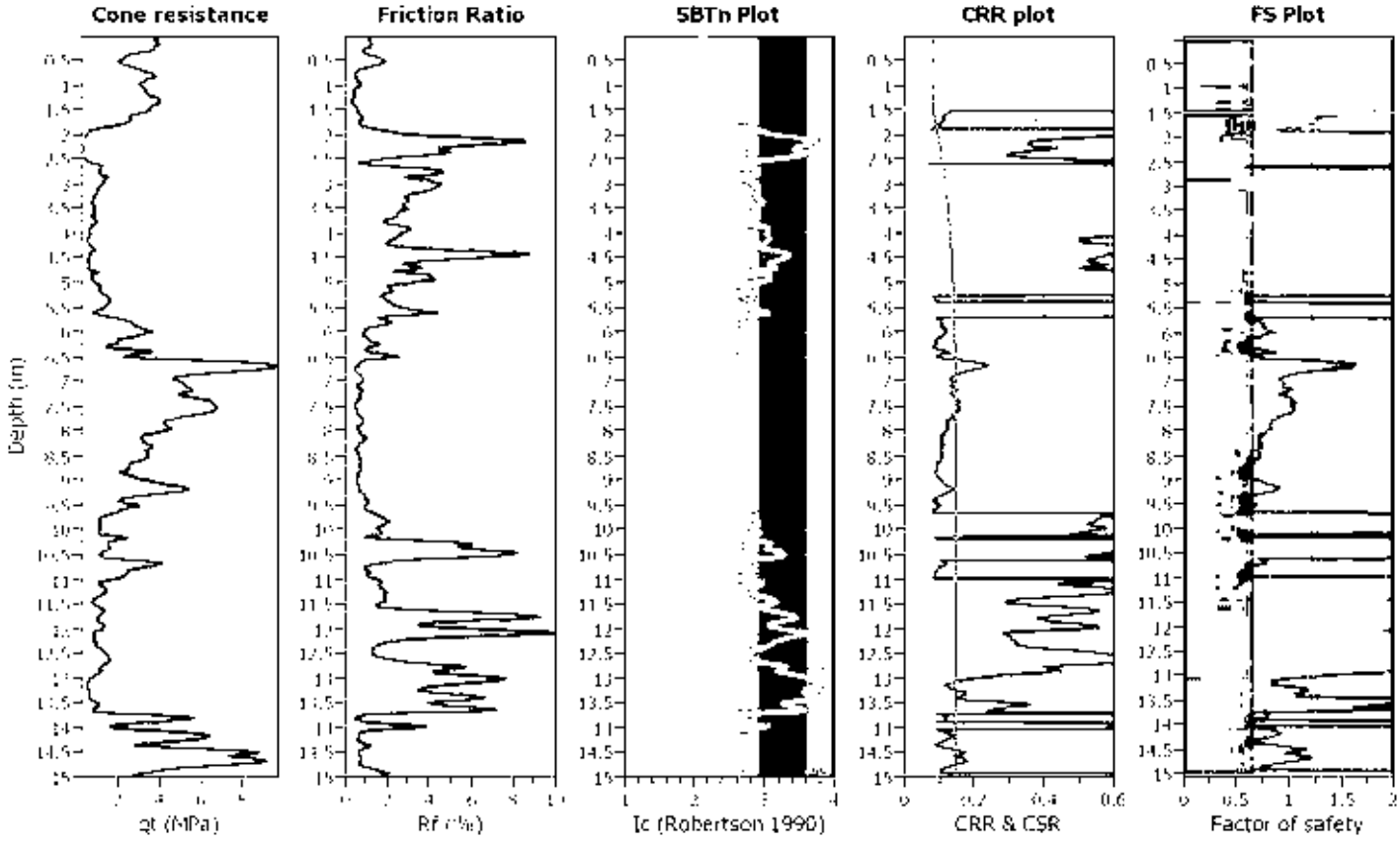
qt:	Total cone resistance (cone resistance q corrected for pore water effects)
Ic:	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumetric strain:	Post liquefaction volumetric strain

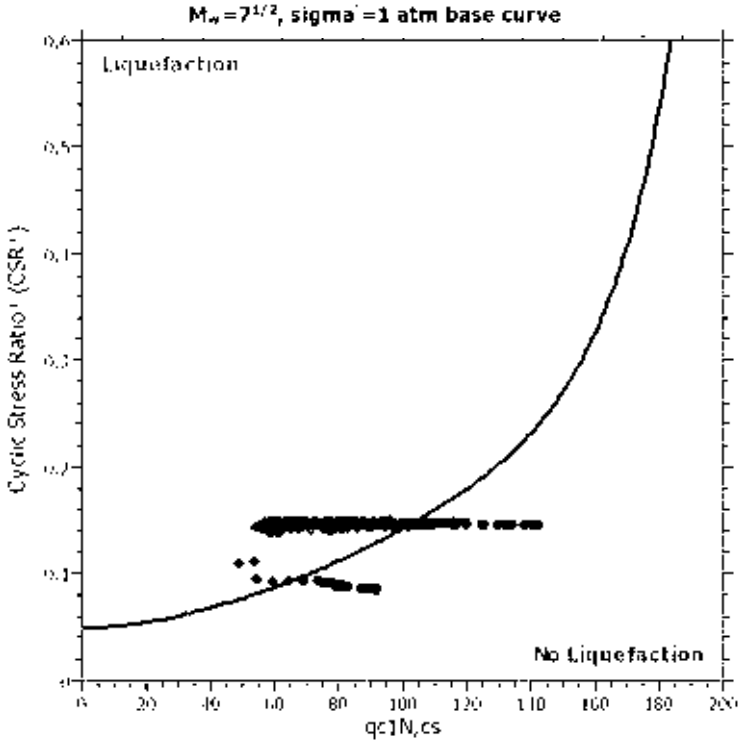
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

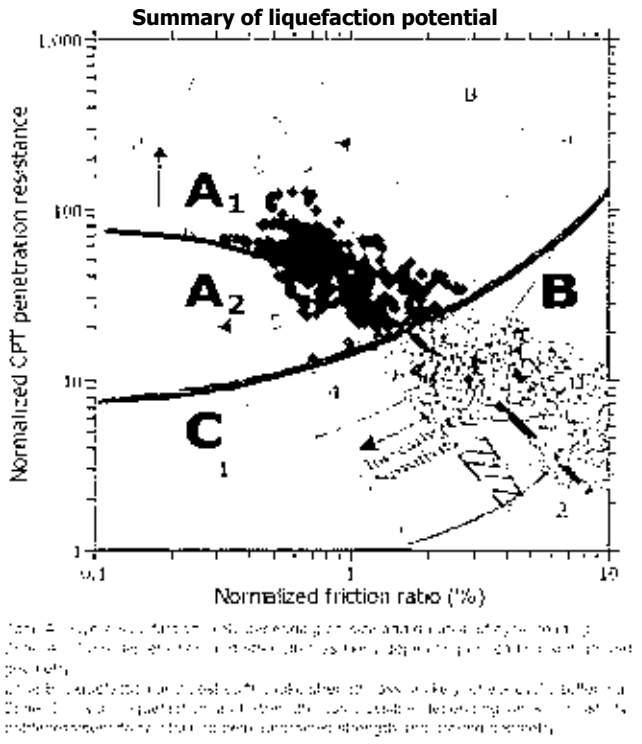
CPT file : CPT13_84SabysRd

Input parameters and analysis data

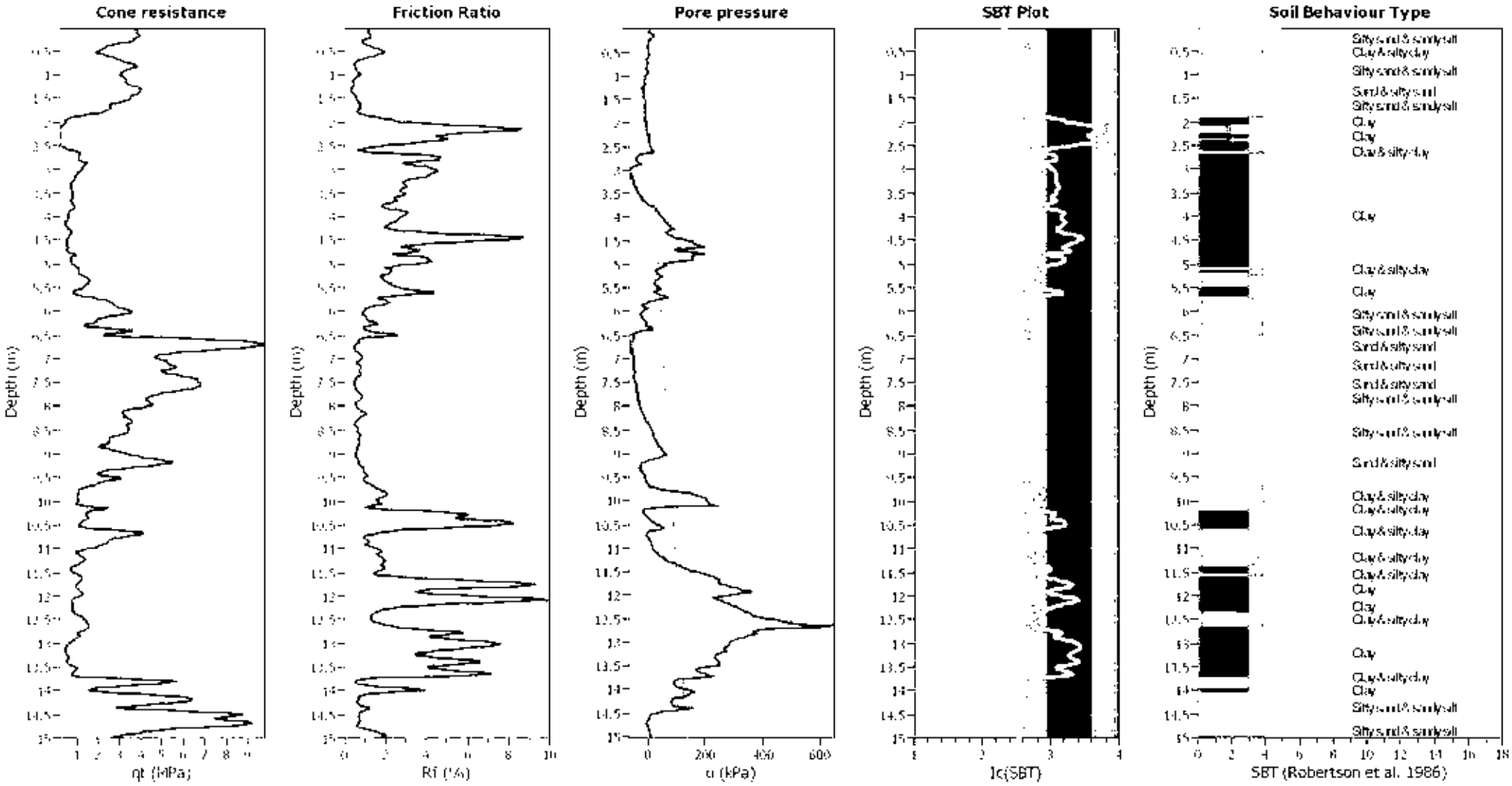
Analysis method	I&B (2008)	G.W.T. (in-situ):	1.50 m	Use fill	No	Clay like behavior applied:	Sand & Clay
Fines correction method	I&B (2008)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration	0.13	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



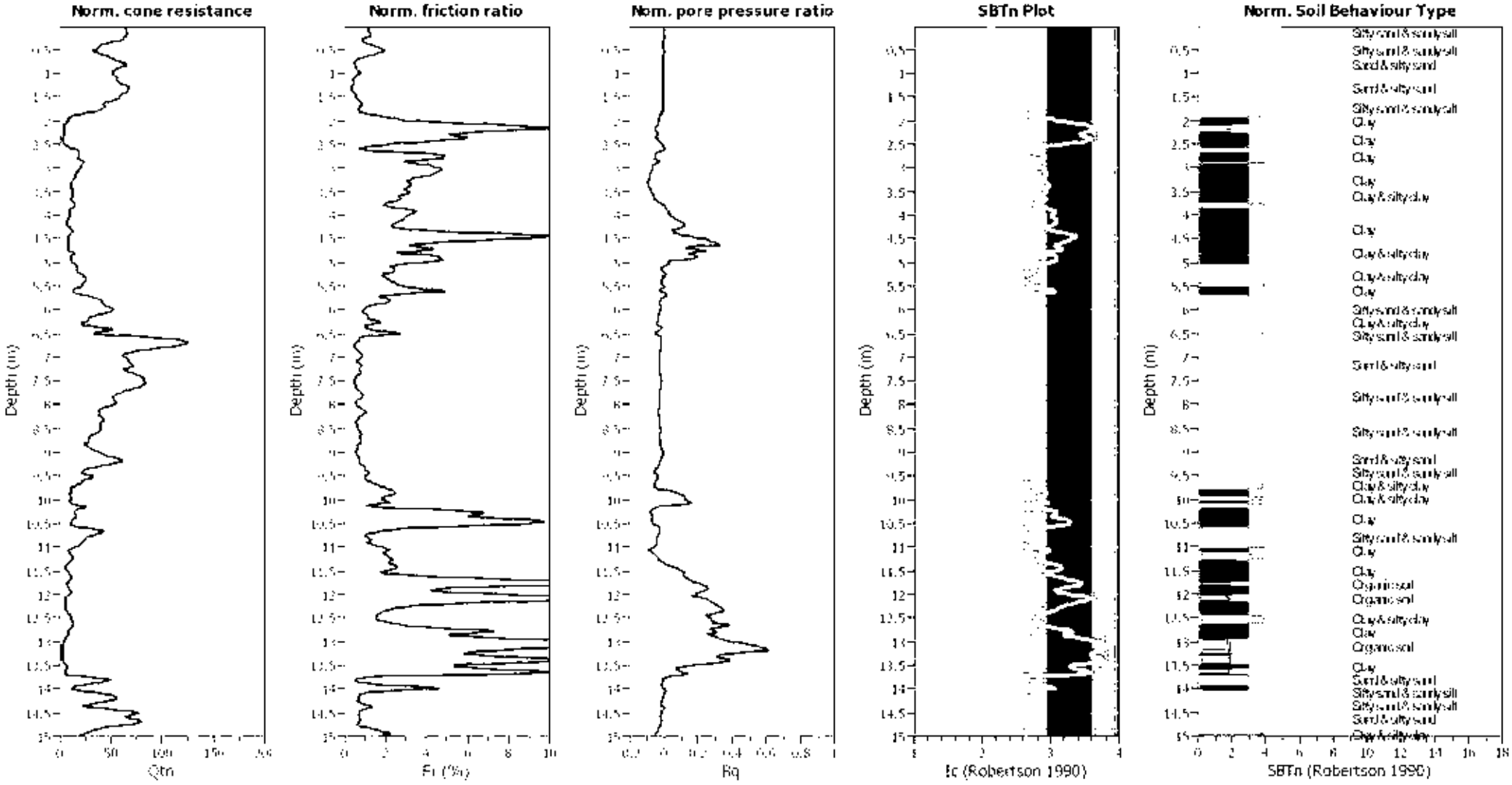
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 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

CPT basic interpretation plots (normalized)



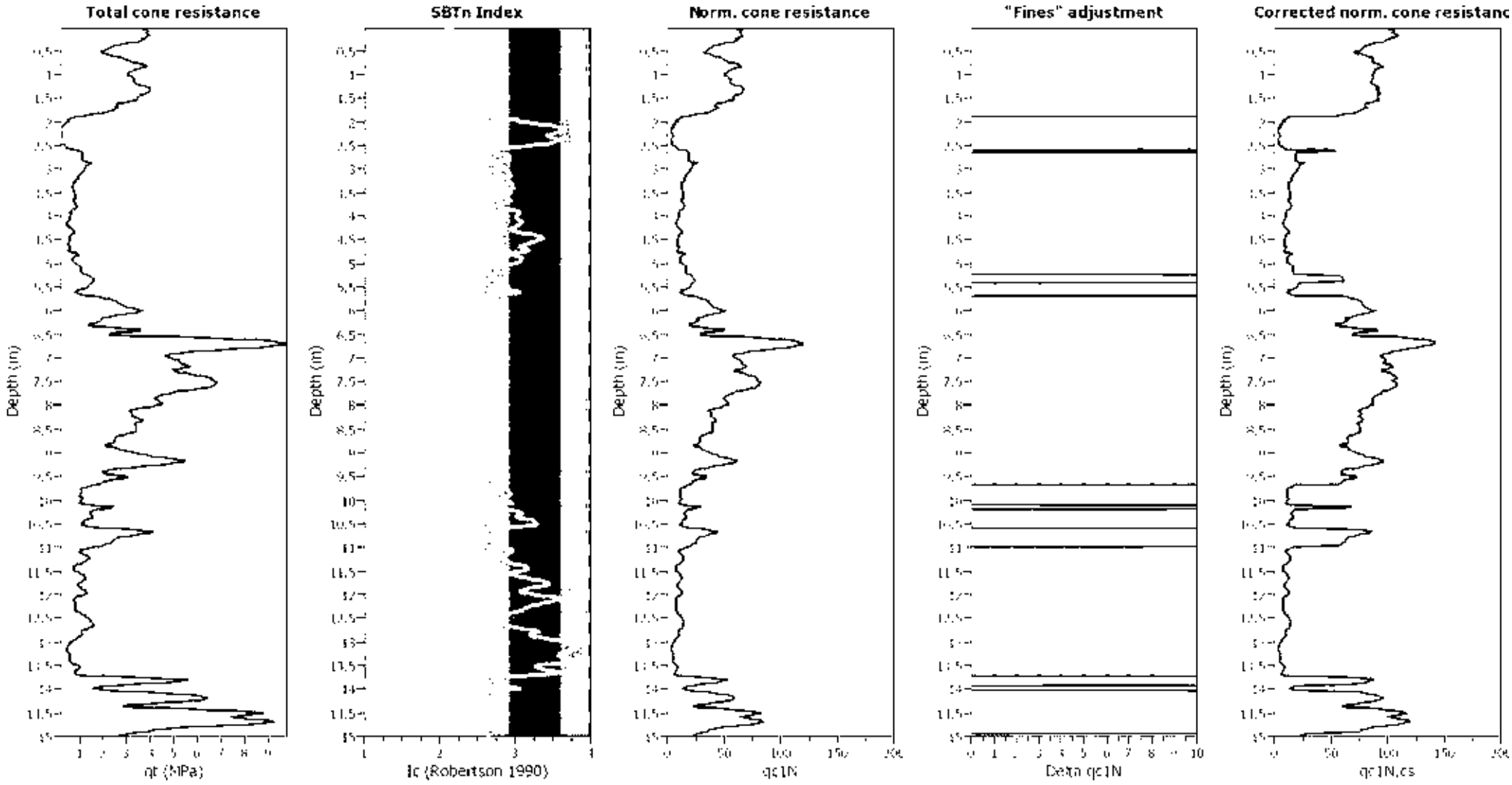
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

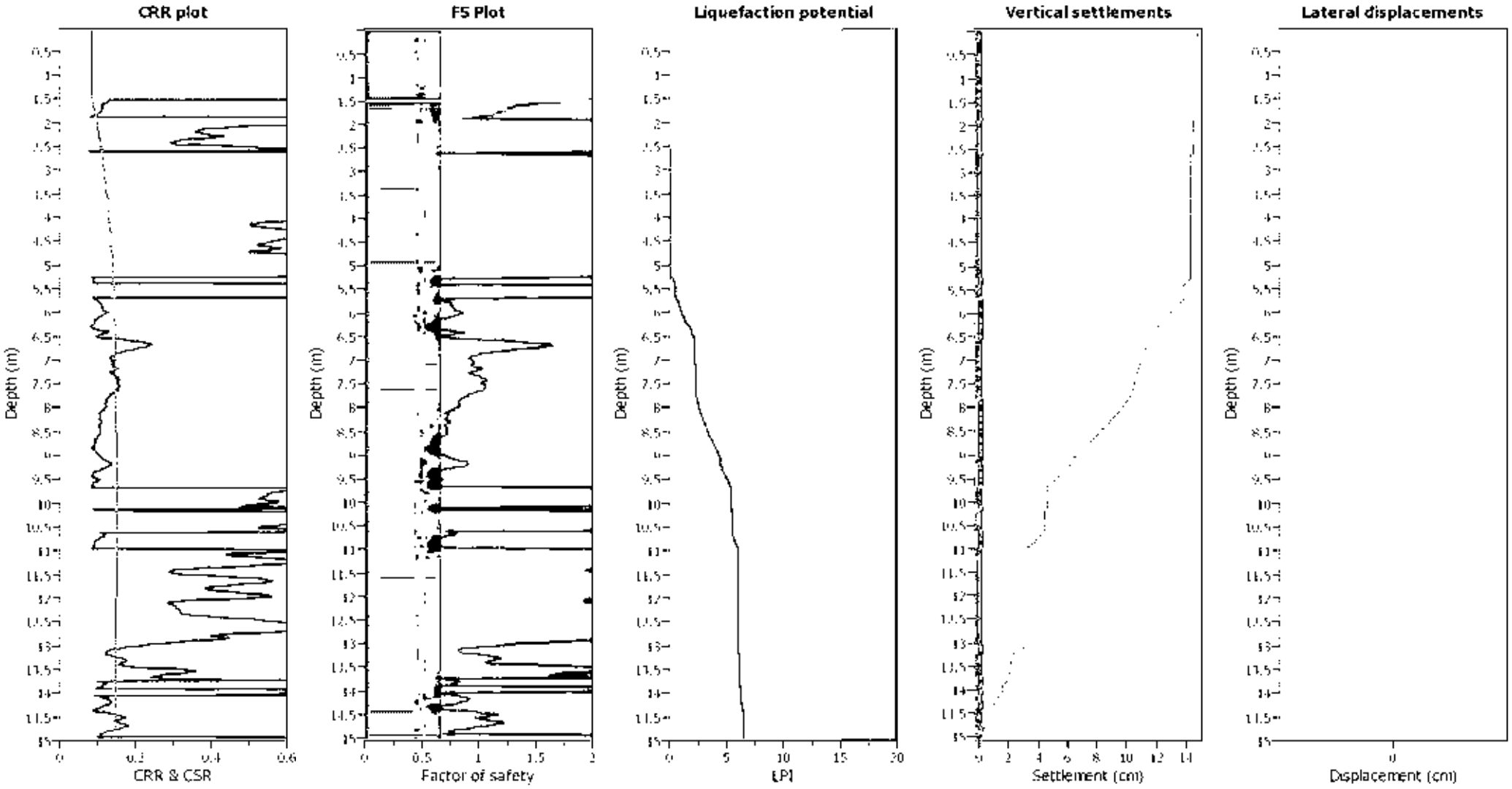
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 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.):	1.50 m	Fill weight:	N/A
Liner correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 m	Fill height:	N/A	Limit depth:	N/A

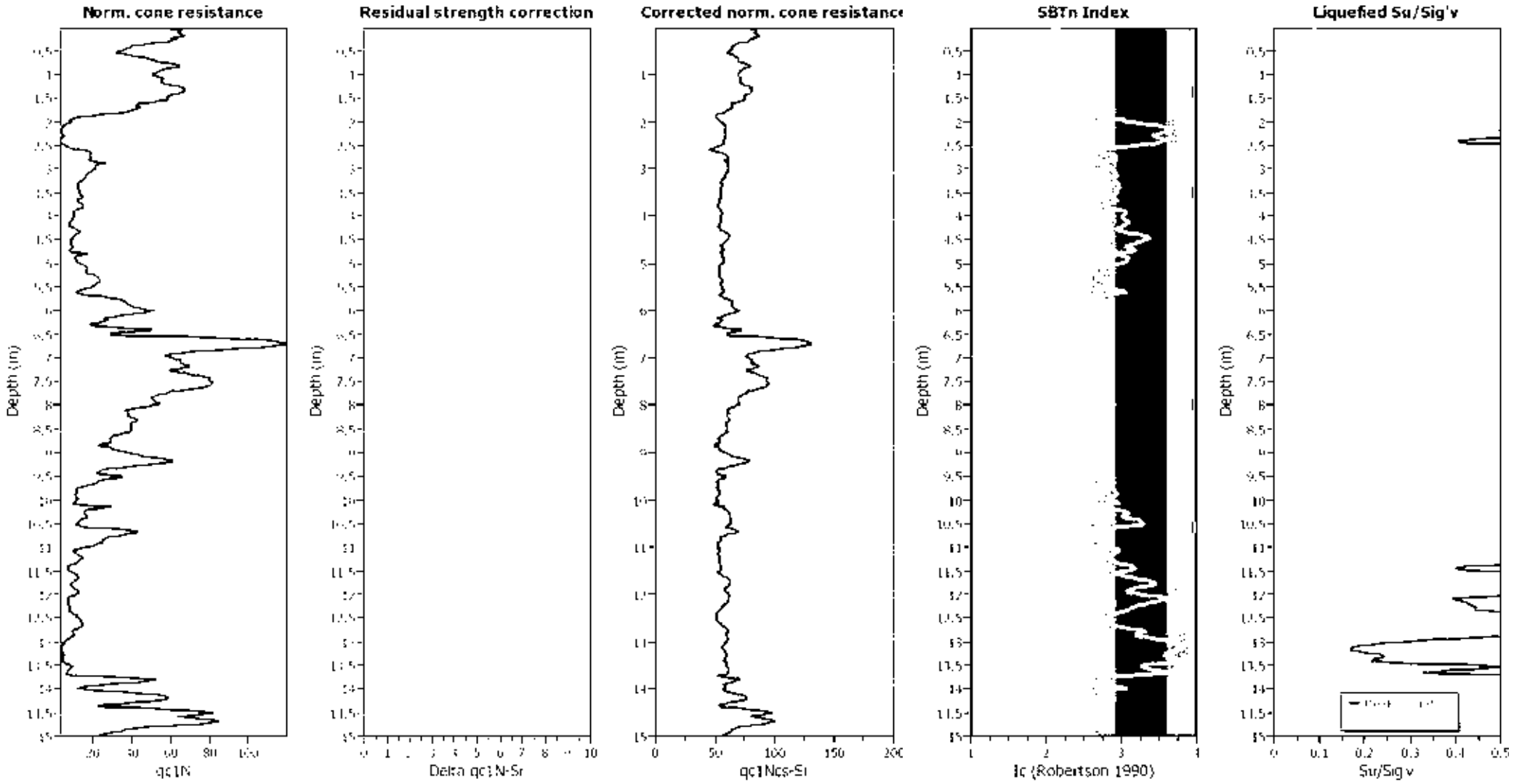
F.S. color scheme

- ☐ 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

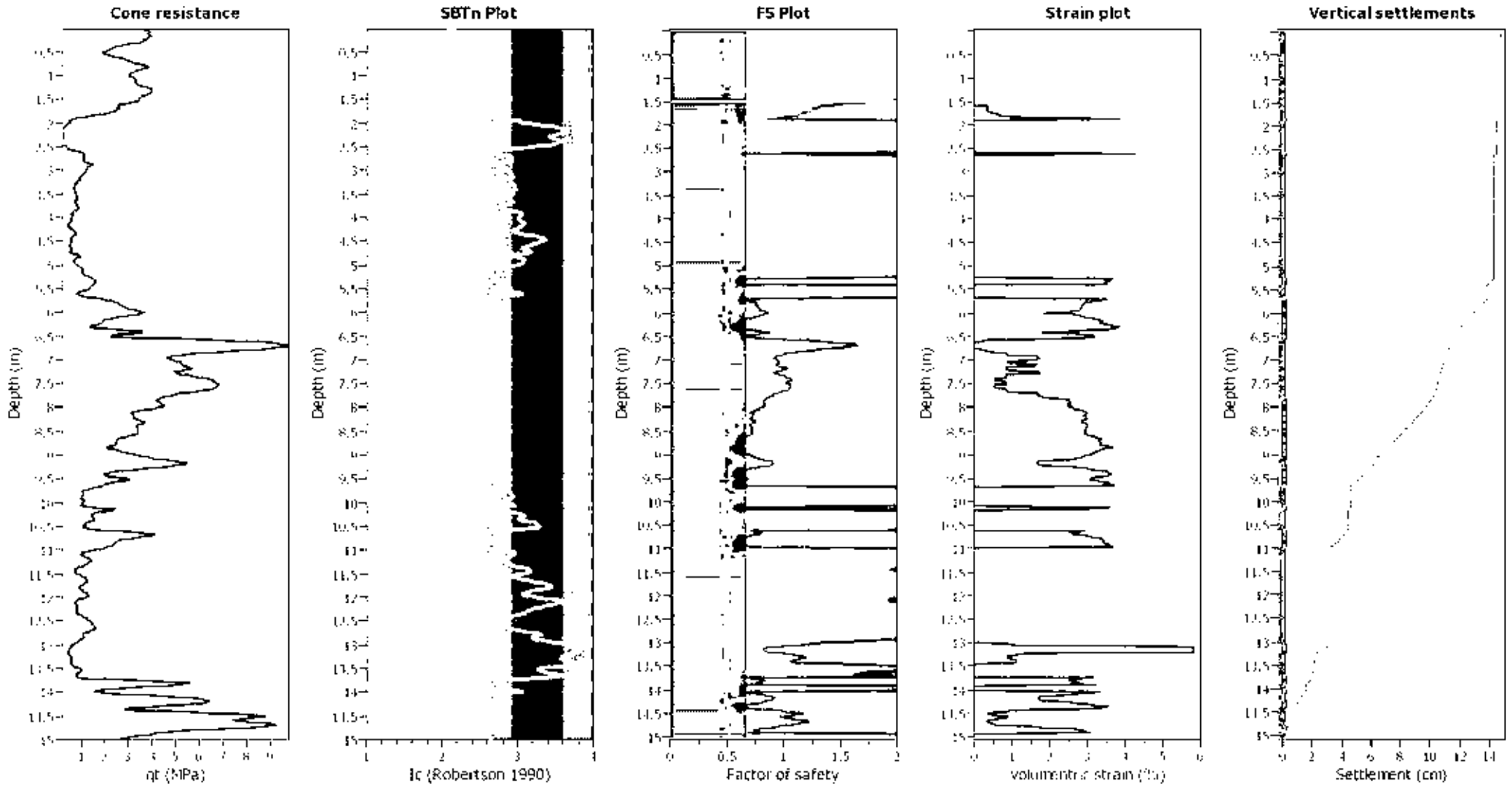
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 m	Fill height:	N/A	Limit depth	N/A

Estimation of post-earthquake settlements



Abbreviations

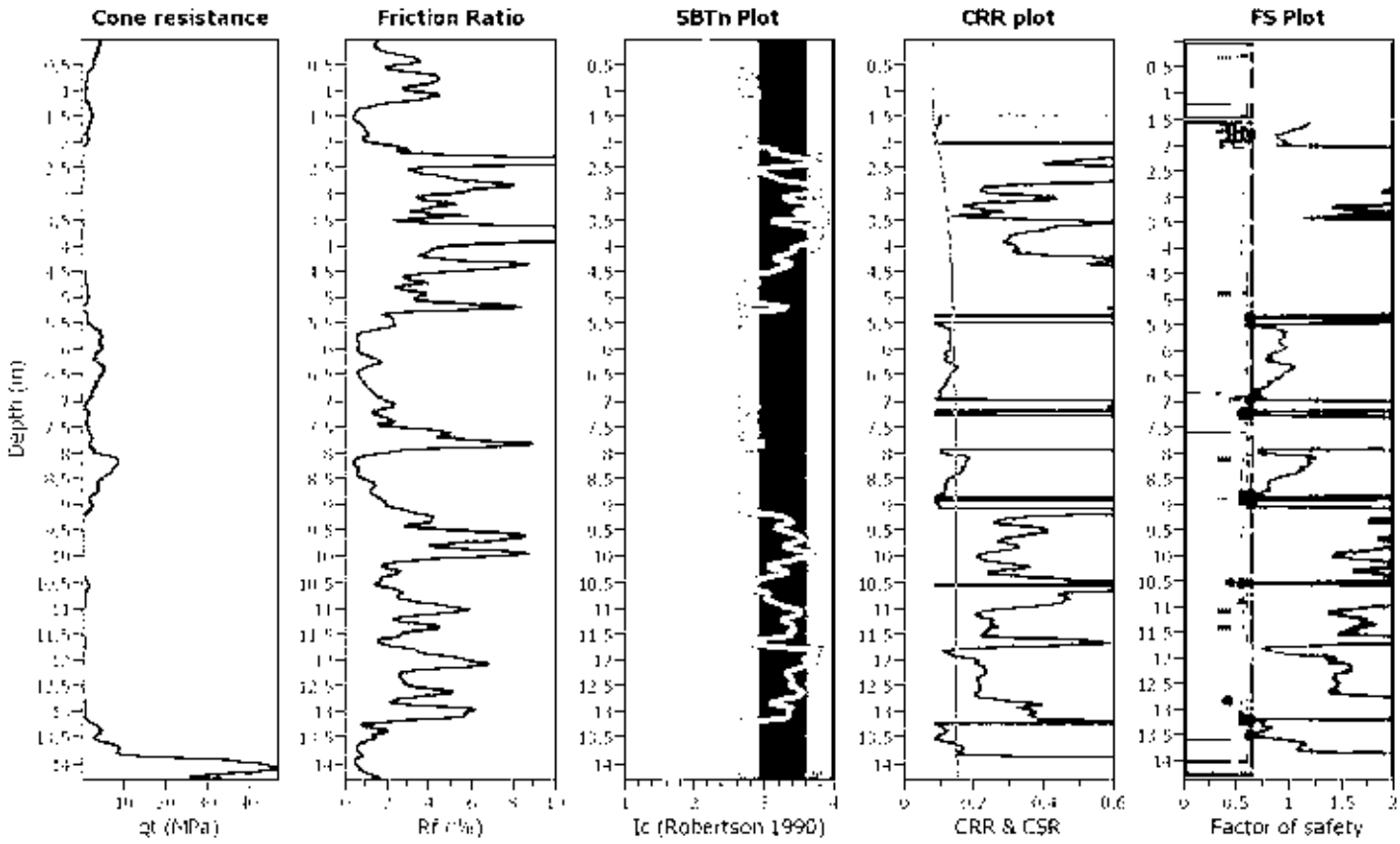
qt	Total cone resistance (cone resistance q corrected for pore water effects)
Ic	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumetric strain:	Post liquefaction volumetric strain

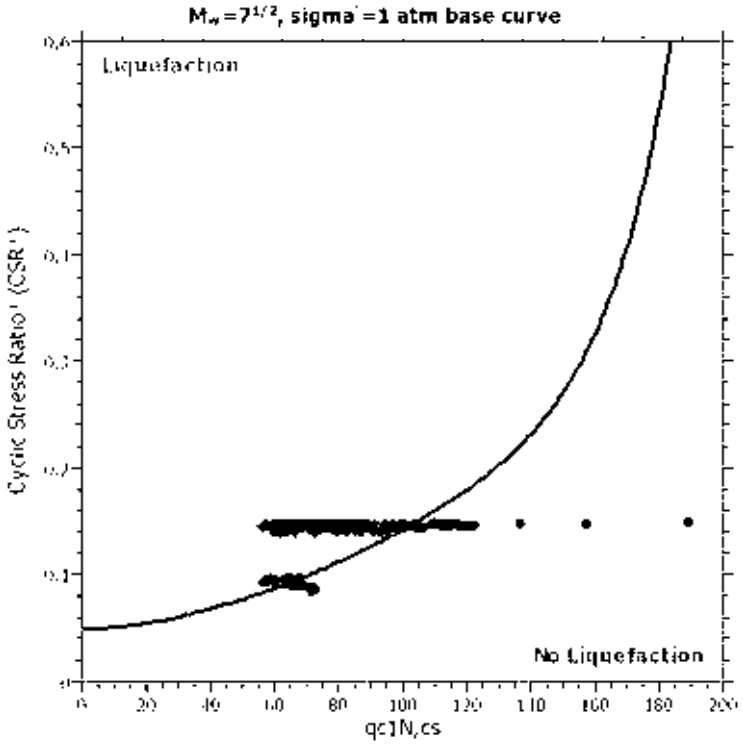
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

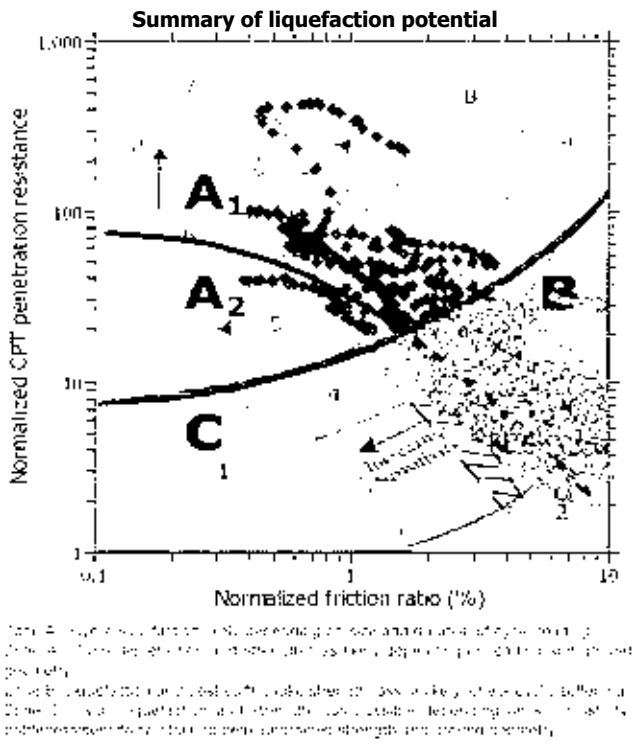
CPT file : CPT14_23QuaifesRd

Input parameters and analysis data

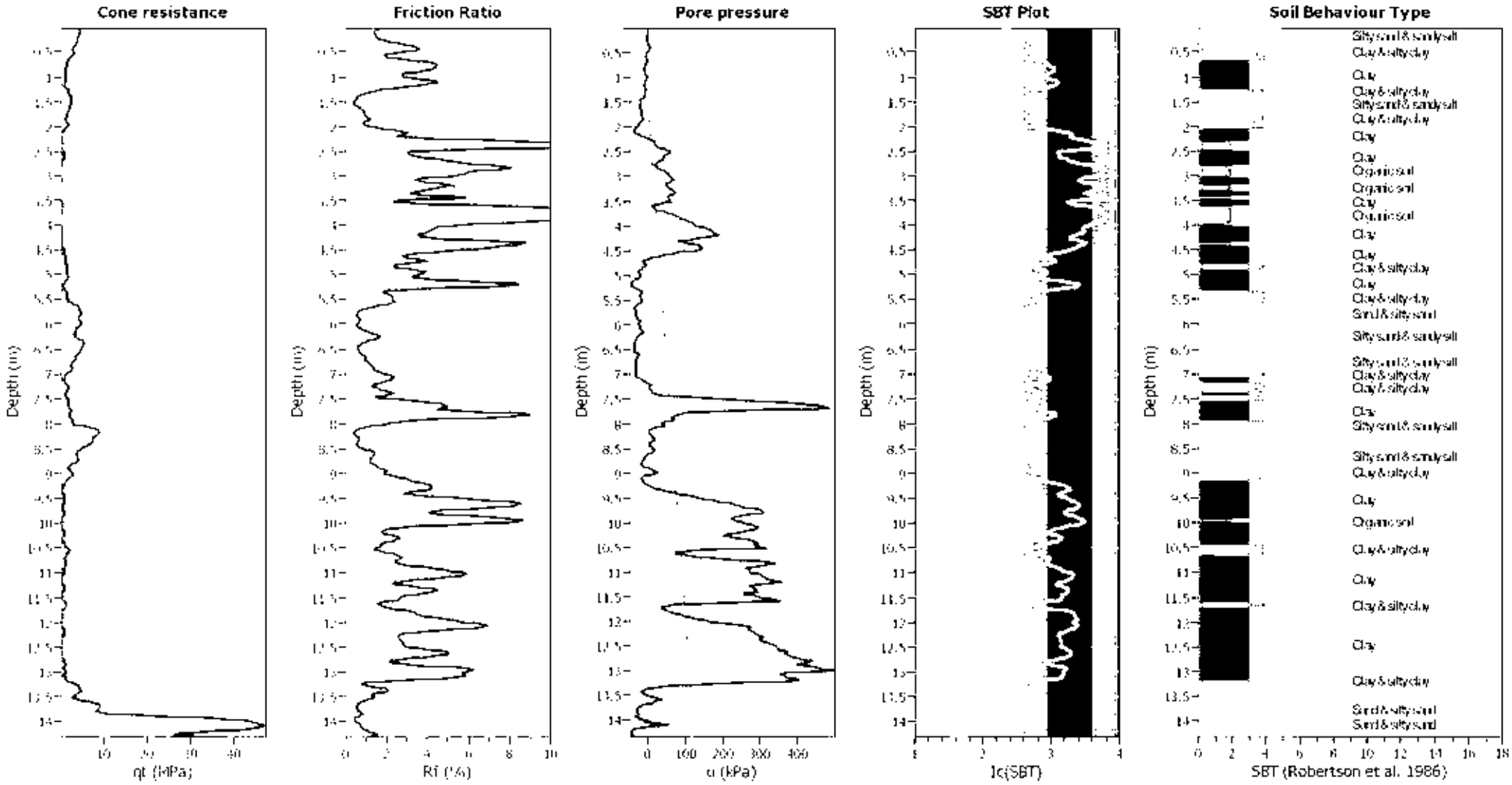
Analysis method:	I&B (2008)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	I&B (2008)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration:	0.13	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



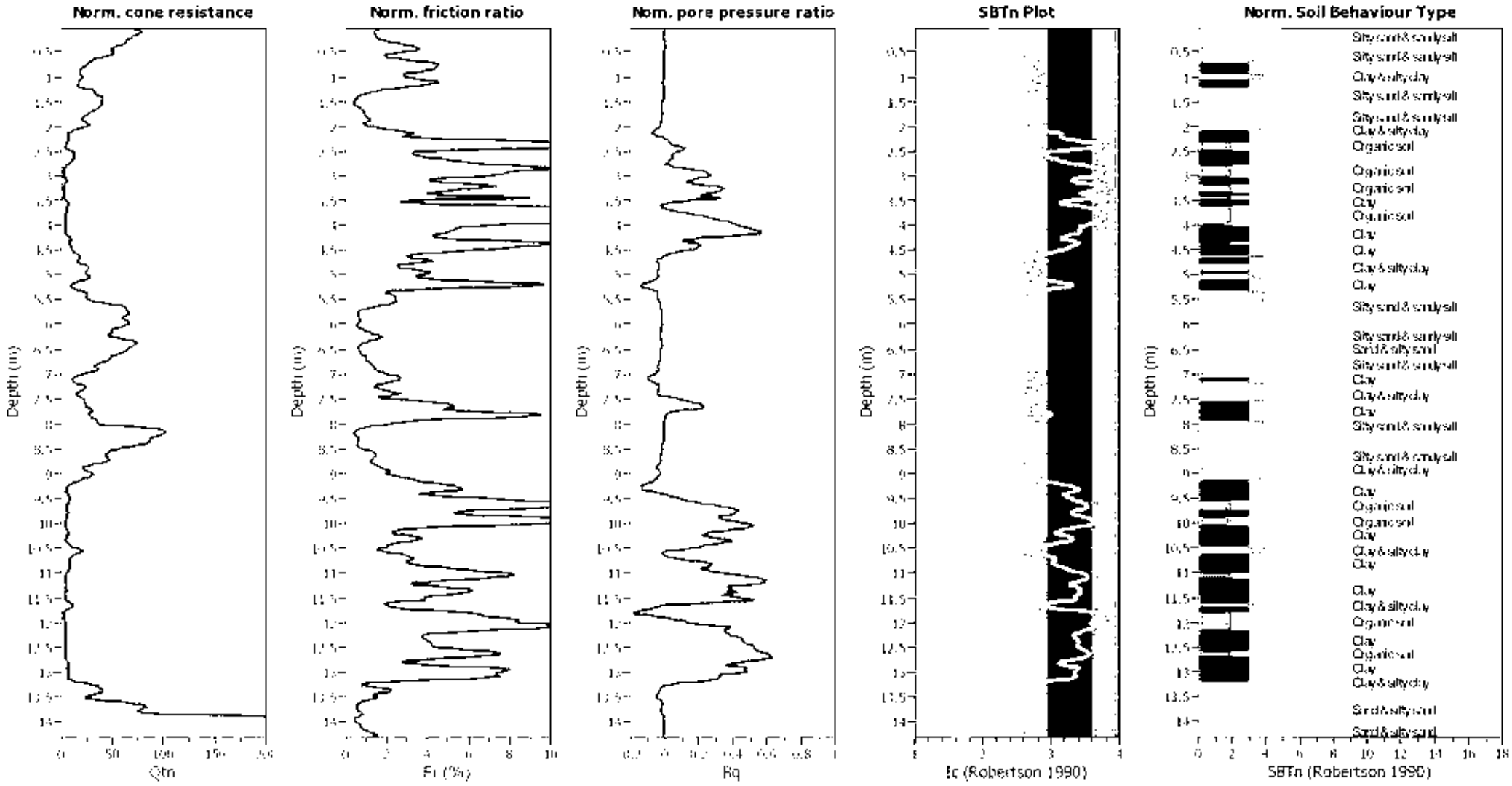
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 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

CPT basic interpretation plots (normalized)



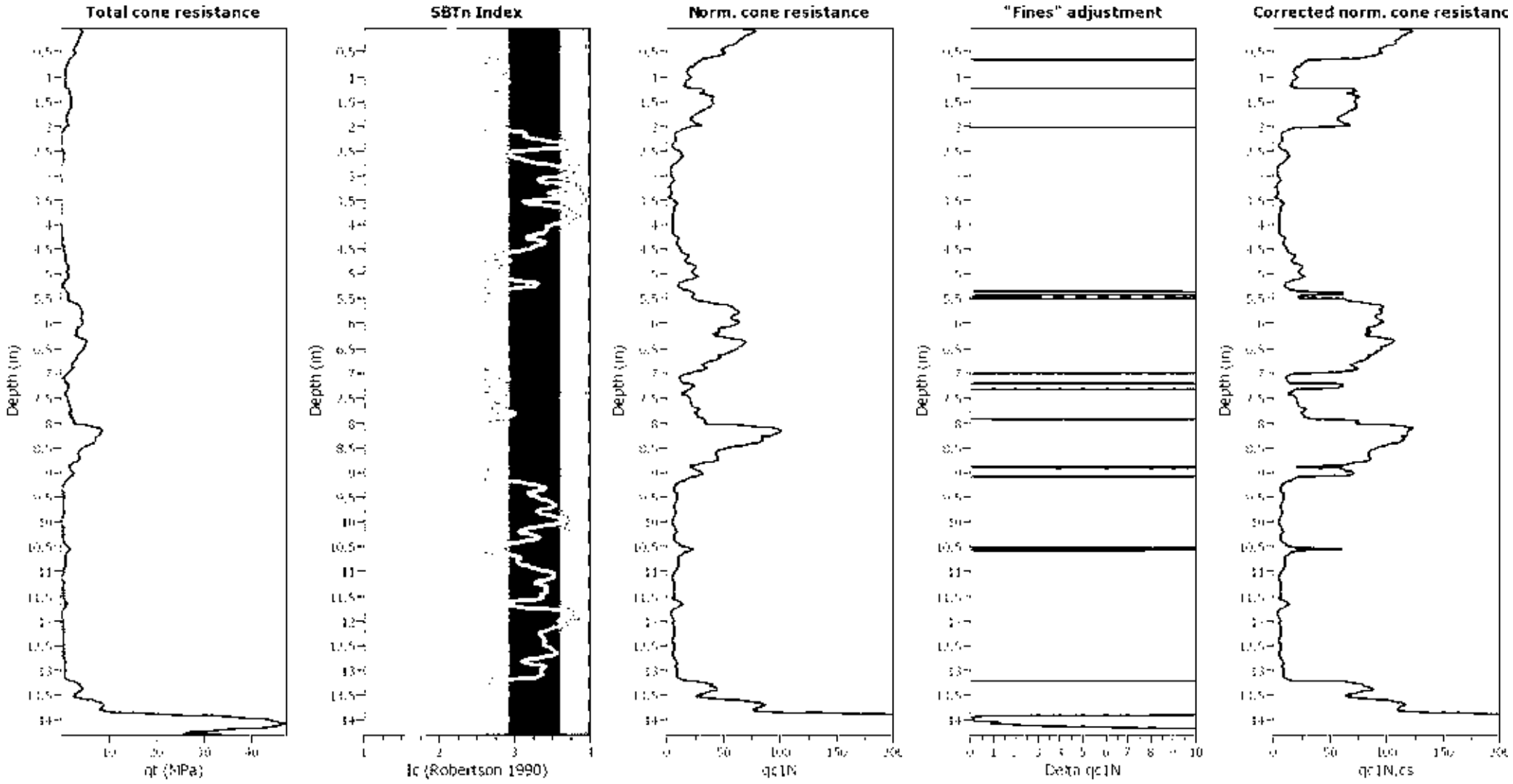
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

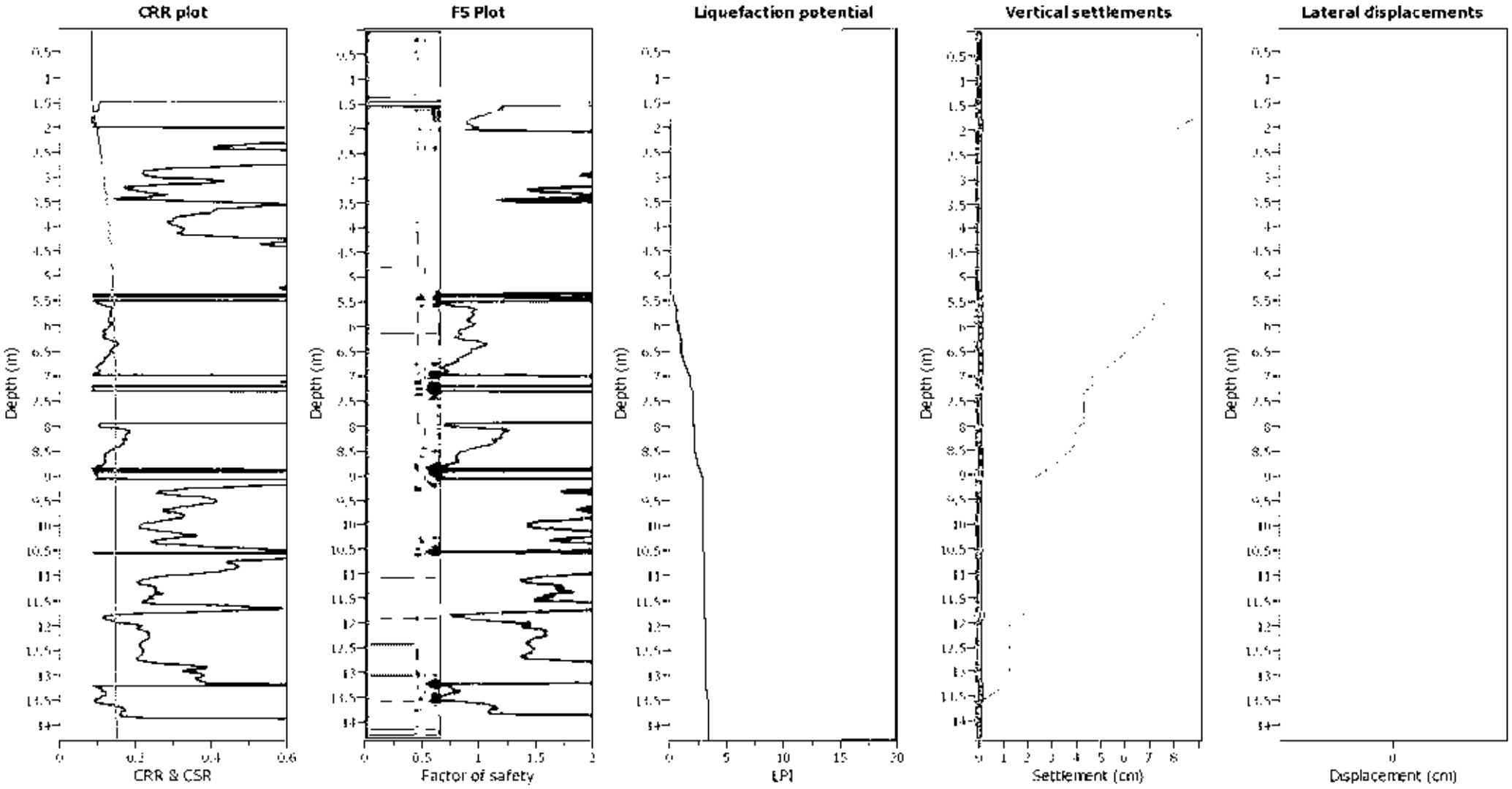
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 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.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 m	Fill height:	N/A	Limit depth:	N/A

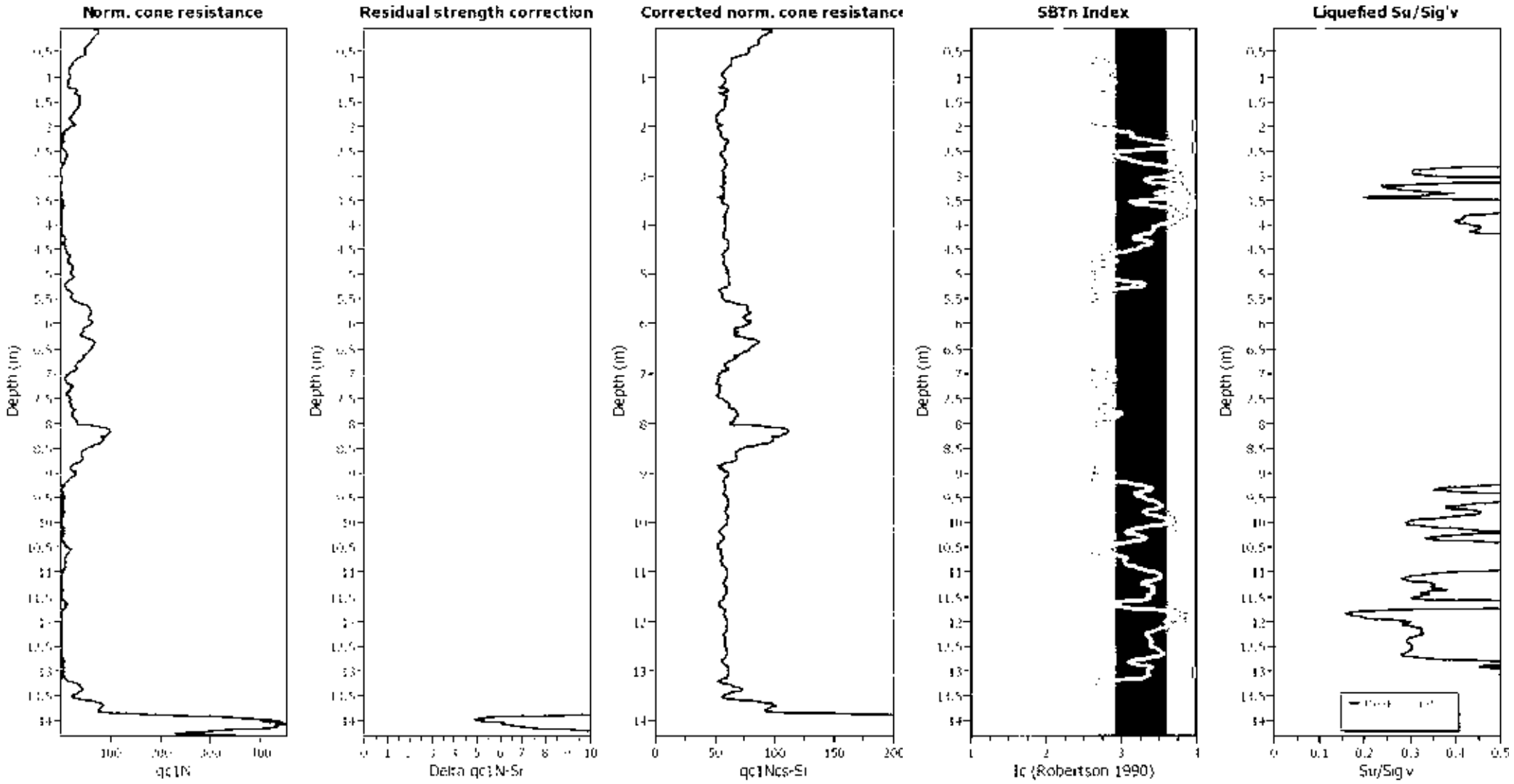
F.S. color scheme

- ☐ 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

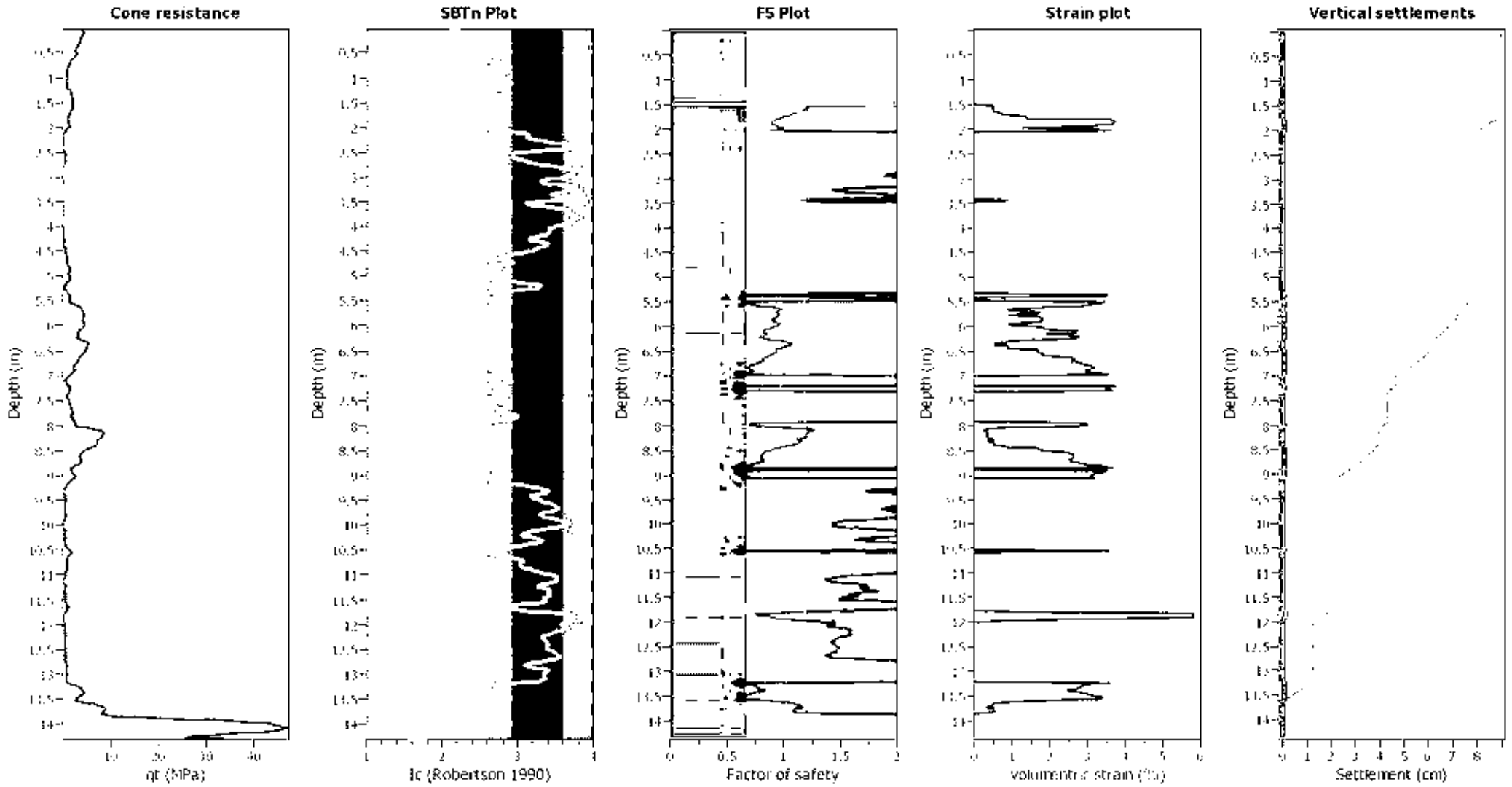
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Liner correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth	N/A

Estimation of post-earthquake settlements



Abbreviations

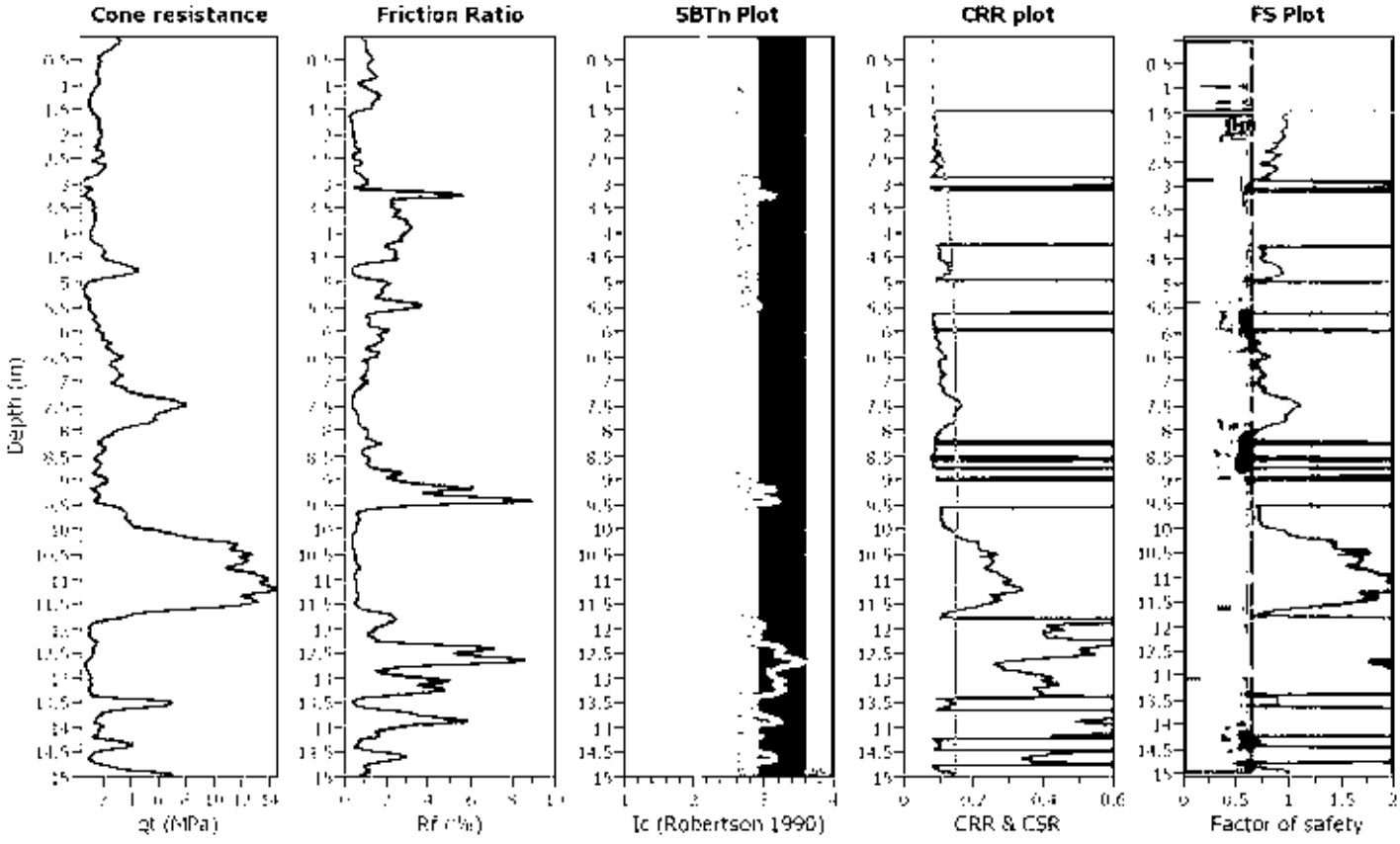
qt:	Total cone resistance (cone resistance q corrected for pore water effects)
Ic:	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumentric strain:	Post liquefaction volumentric strain

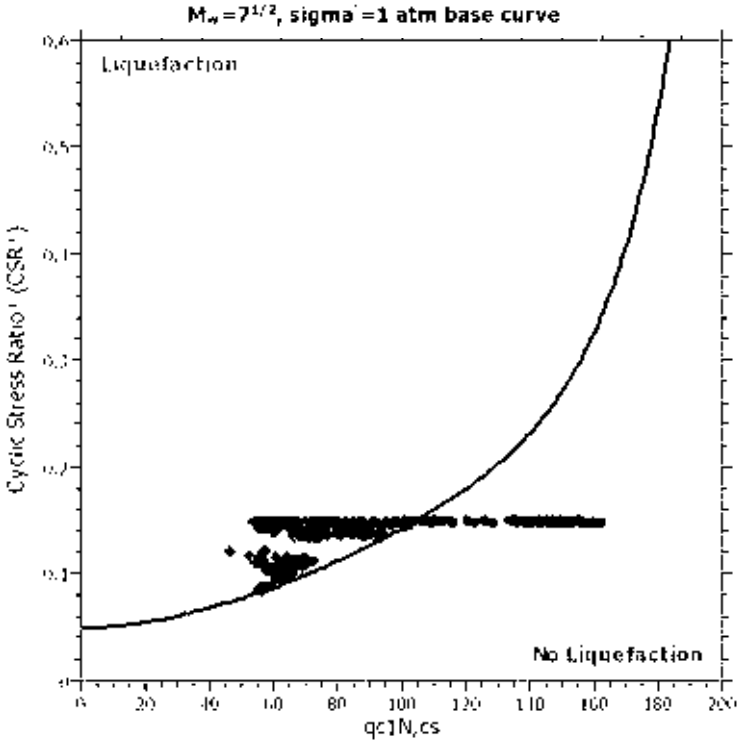
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

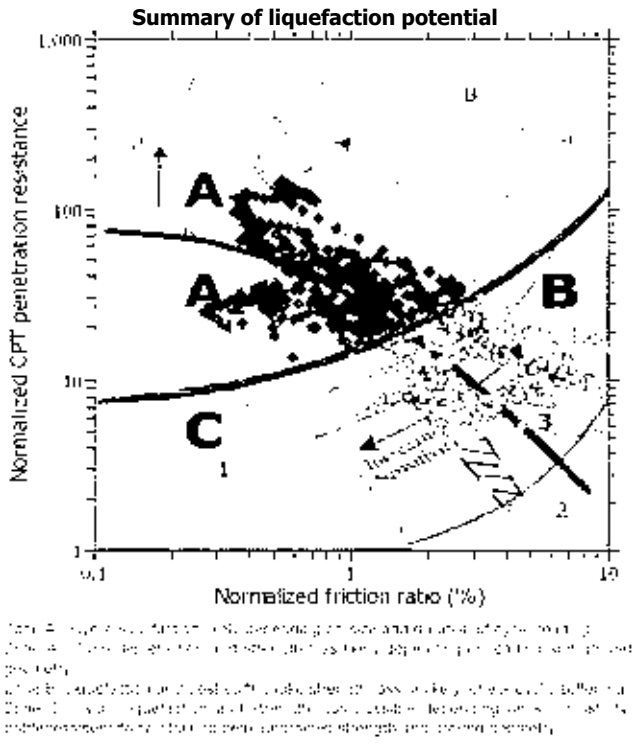
CPT file : CPT15_101SabysRd

Input parameters and analysis data

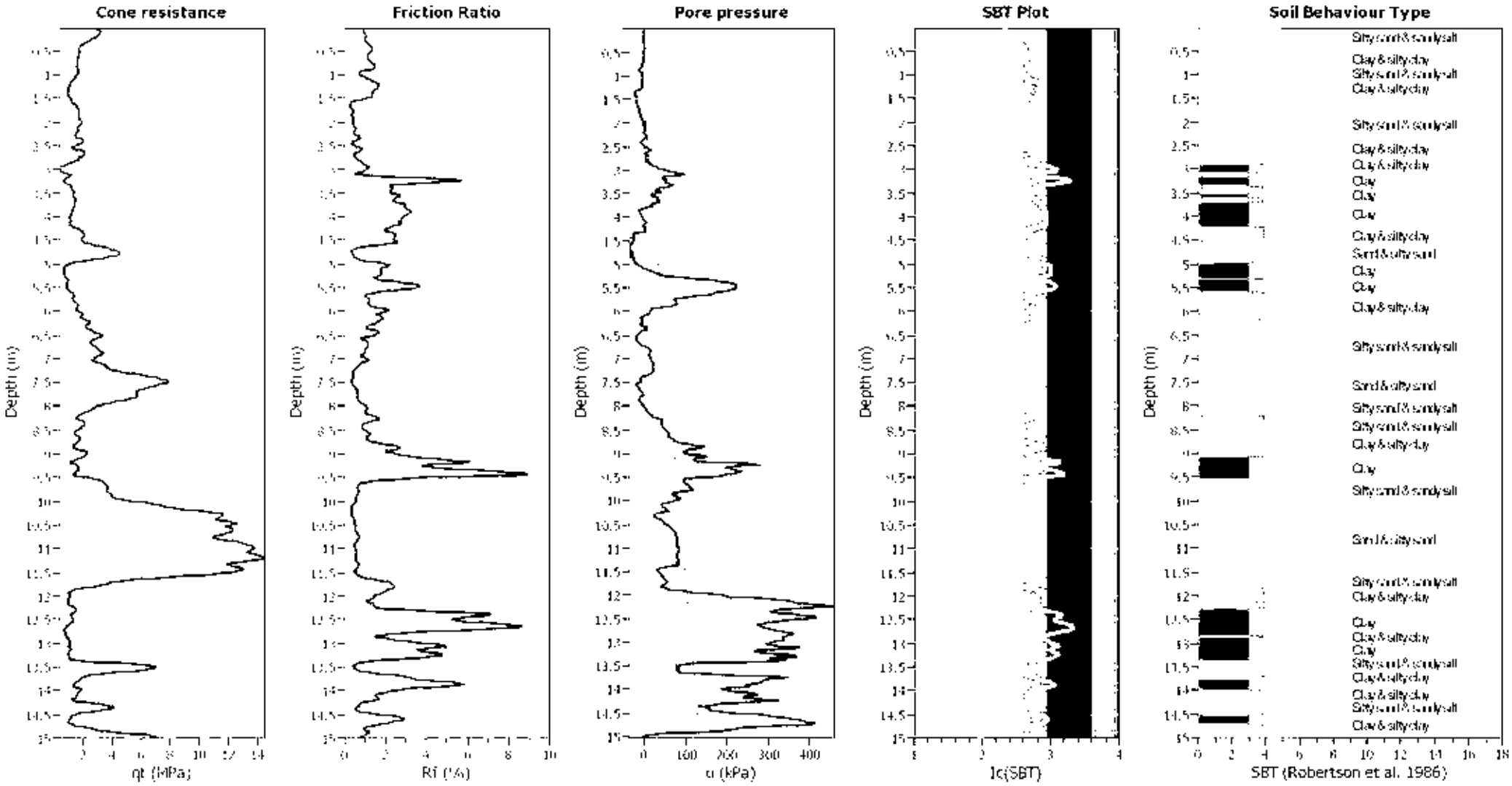
Analysis method:	I&B (2008)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	I&B (2008)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration:	0.13	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



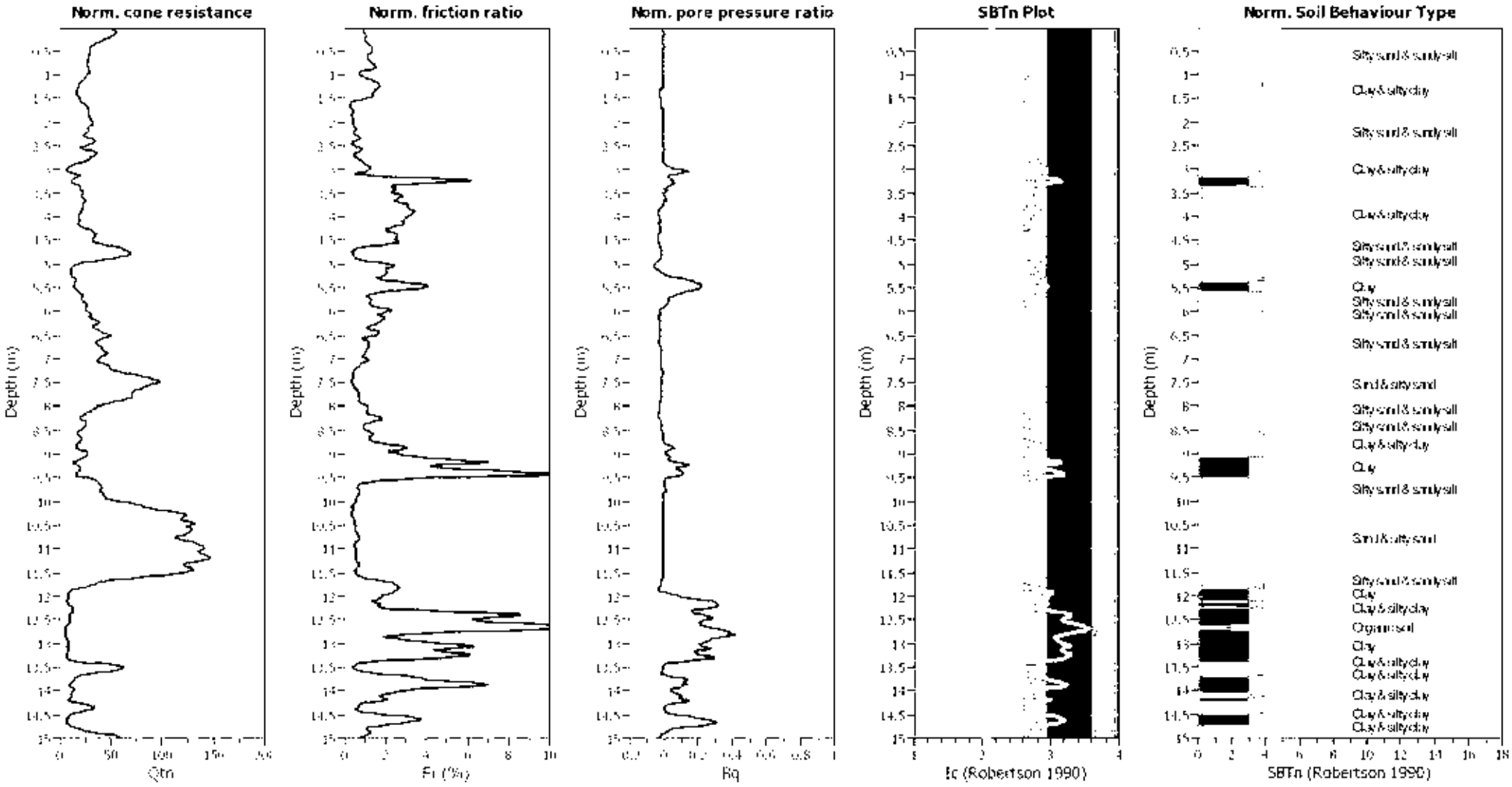
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 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

CPT basic interpretation plots (normalized)



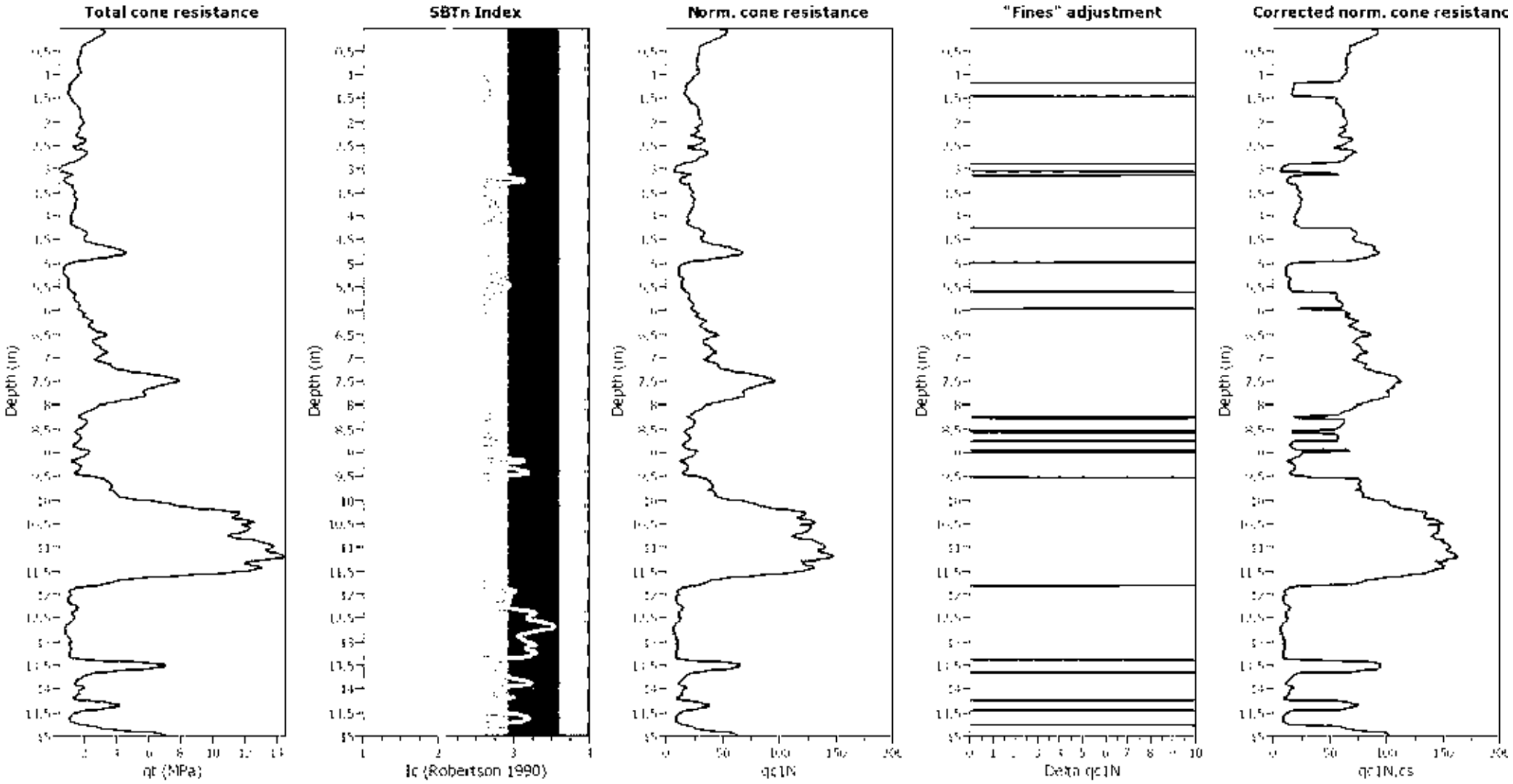
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

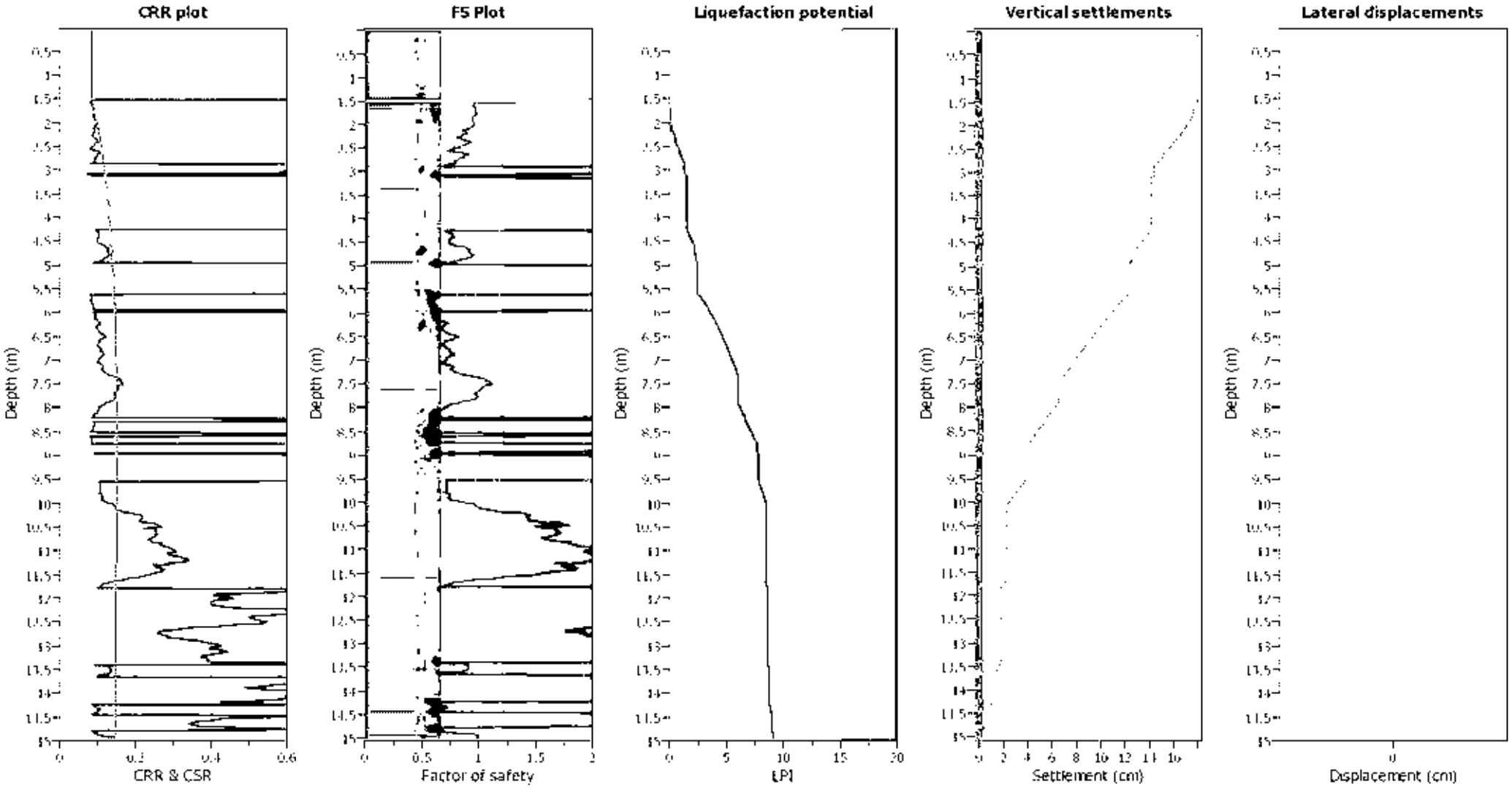
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 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.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 m	Fill height:	N/A	Limit depth:	N/A

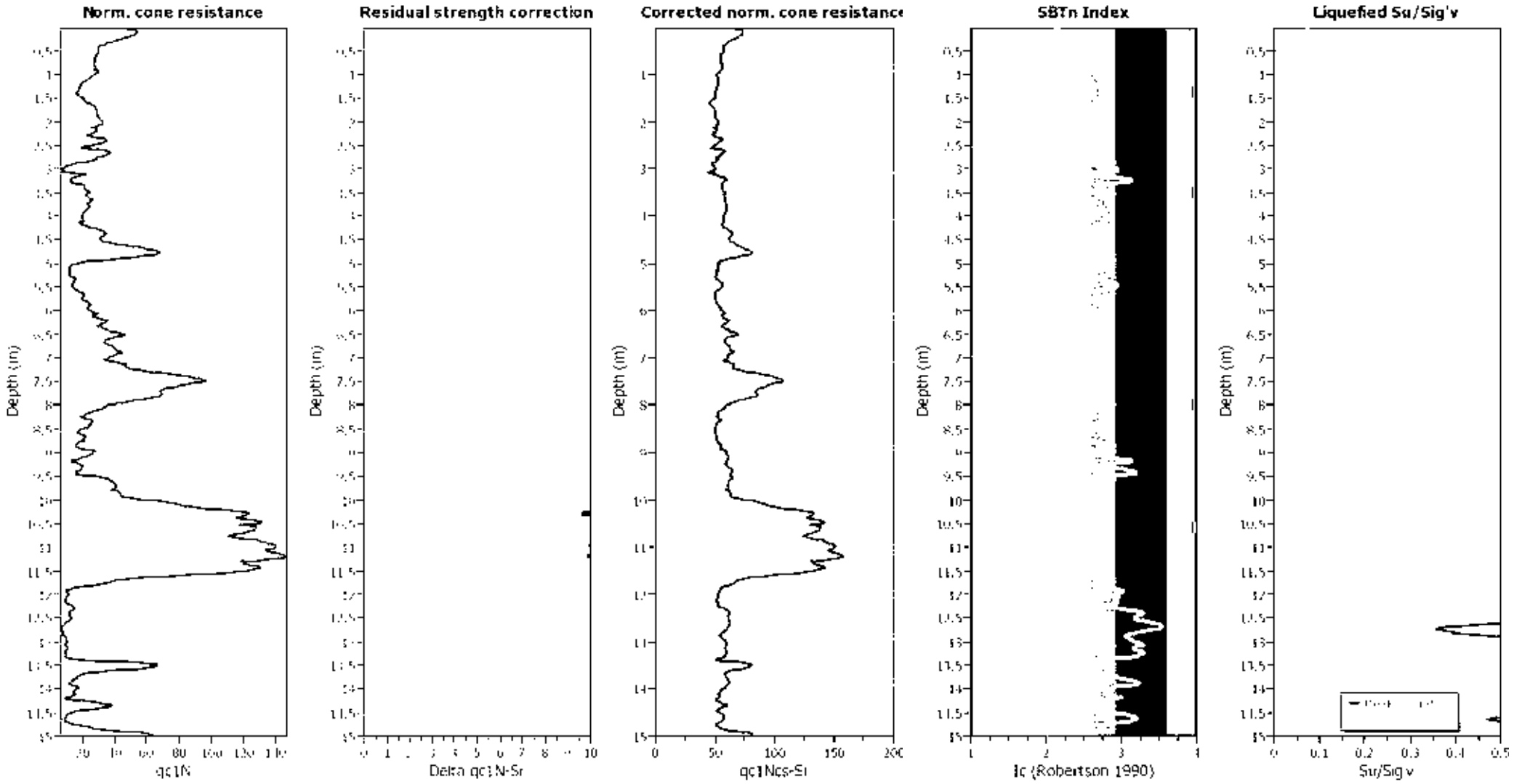
F.S. color scheme

- ☐ 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

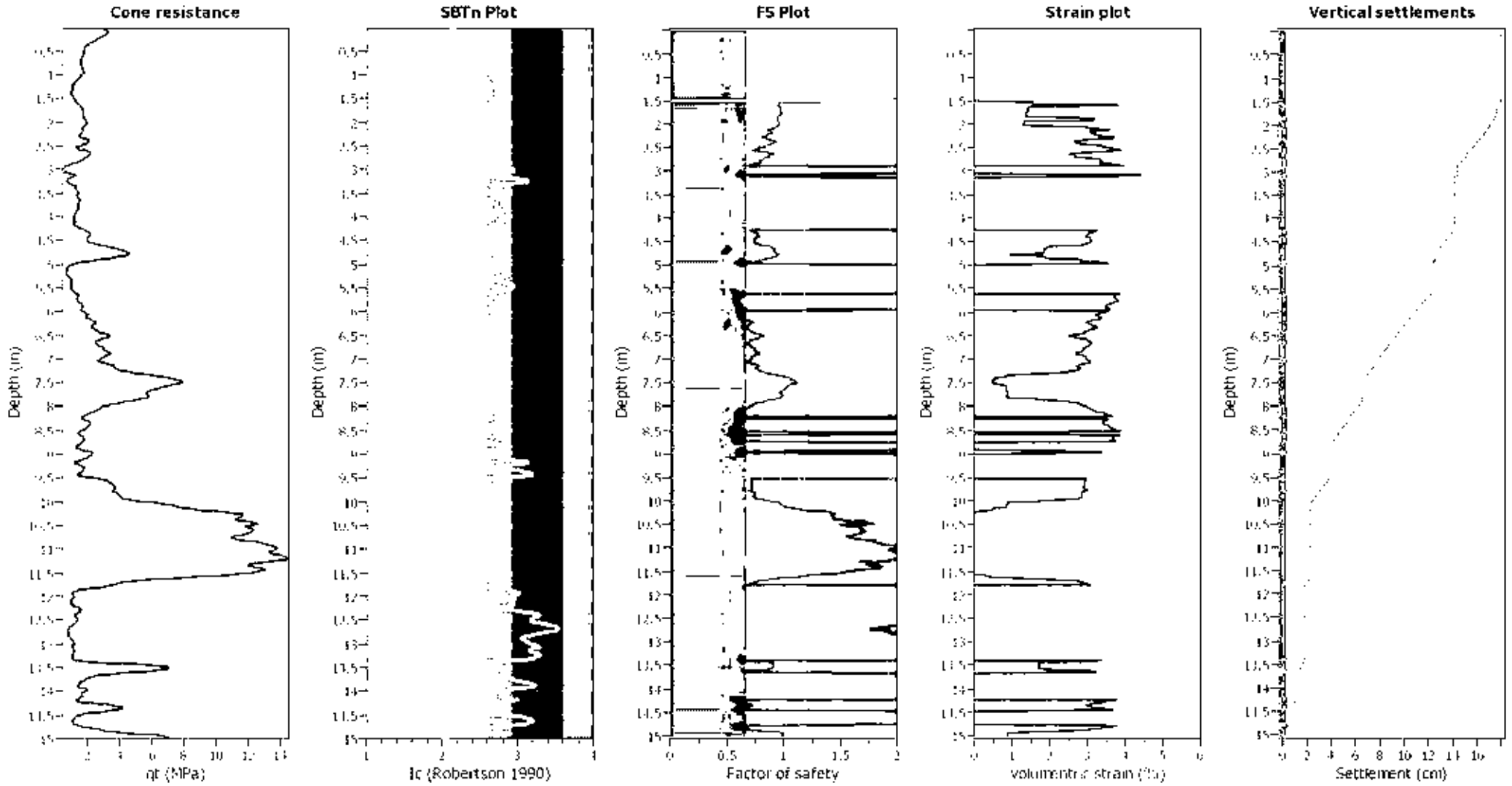
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Liquefaction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth	N/A

Estimation of post-earthquake settlements



Abbreviations

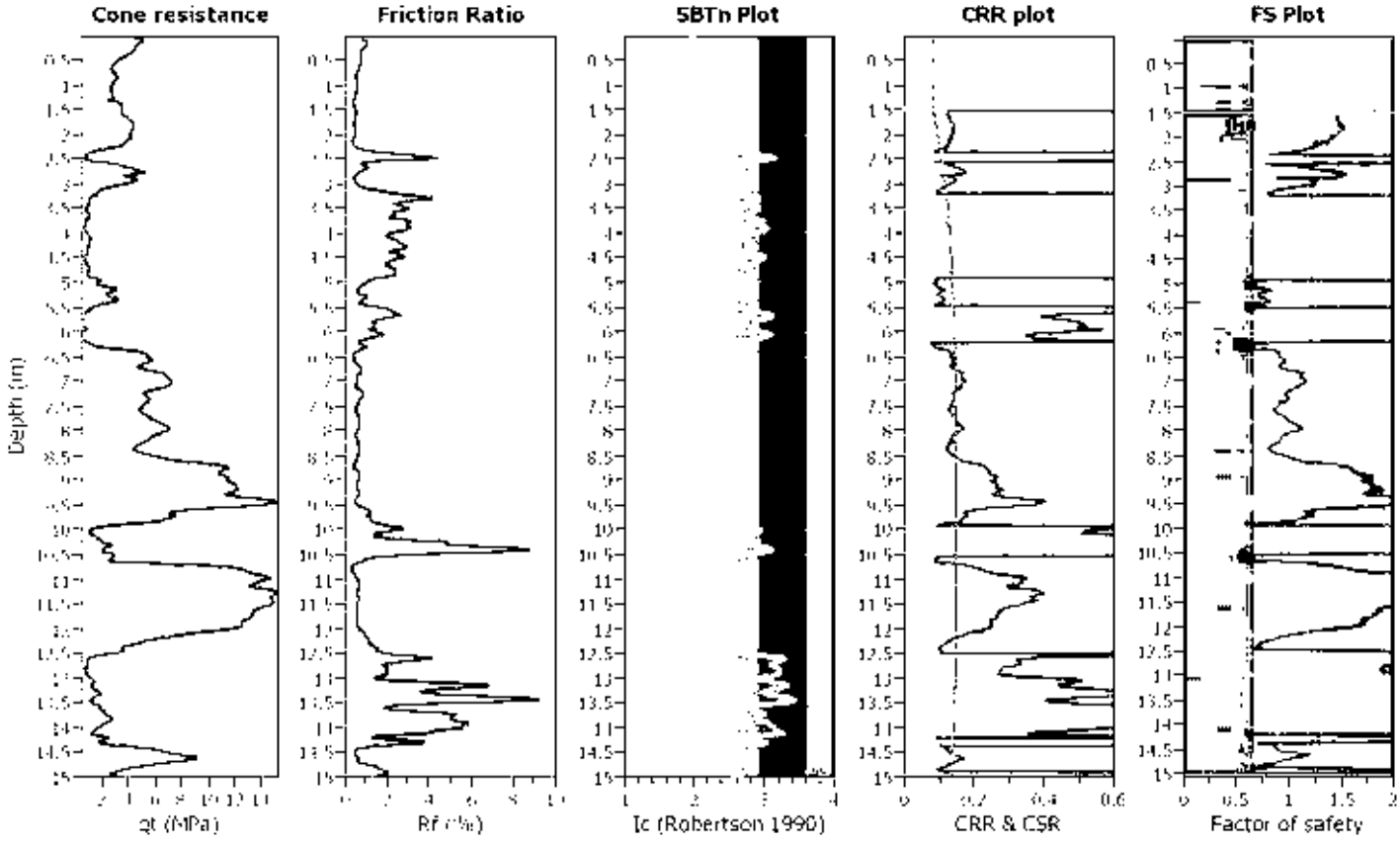
qt:	Total cone resistance (cone resistance q corrected for pore water effects)
Ic:	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumetric strain:	Post liquefaction volumetric strain

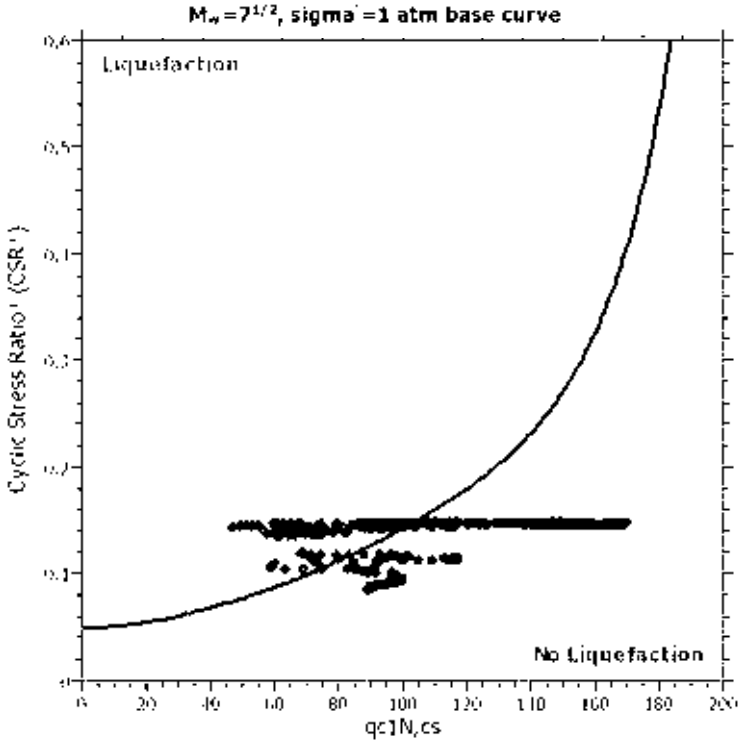
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

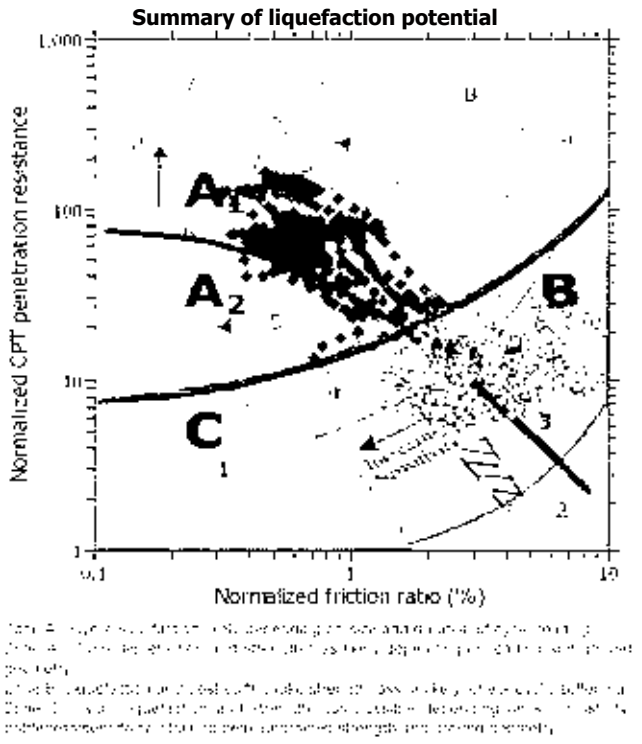
CPT file : CPT16_101SabysRd

Input parameters and analysis data

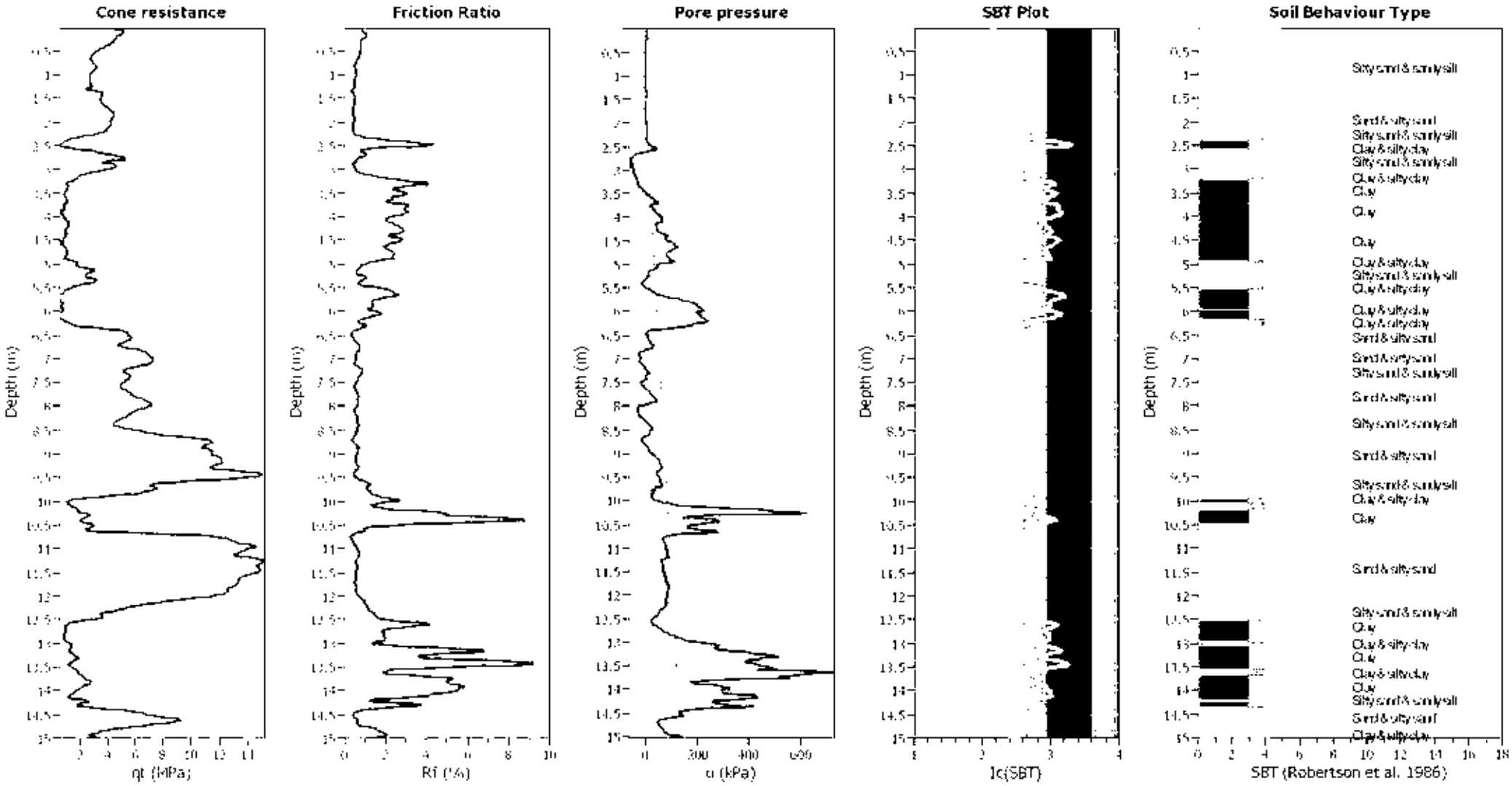
Analysis method:	I&B (2008)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	I&B (2008)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration:	0.13	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



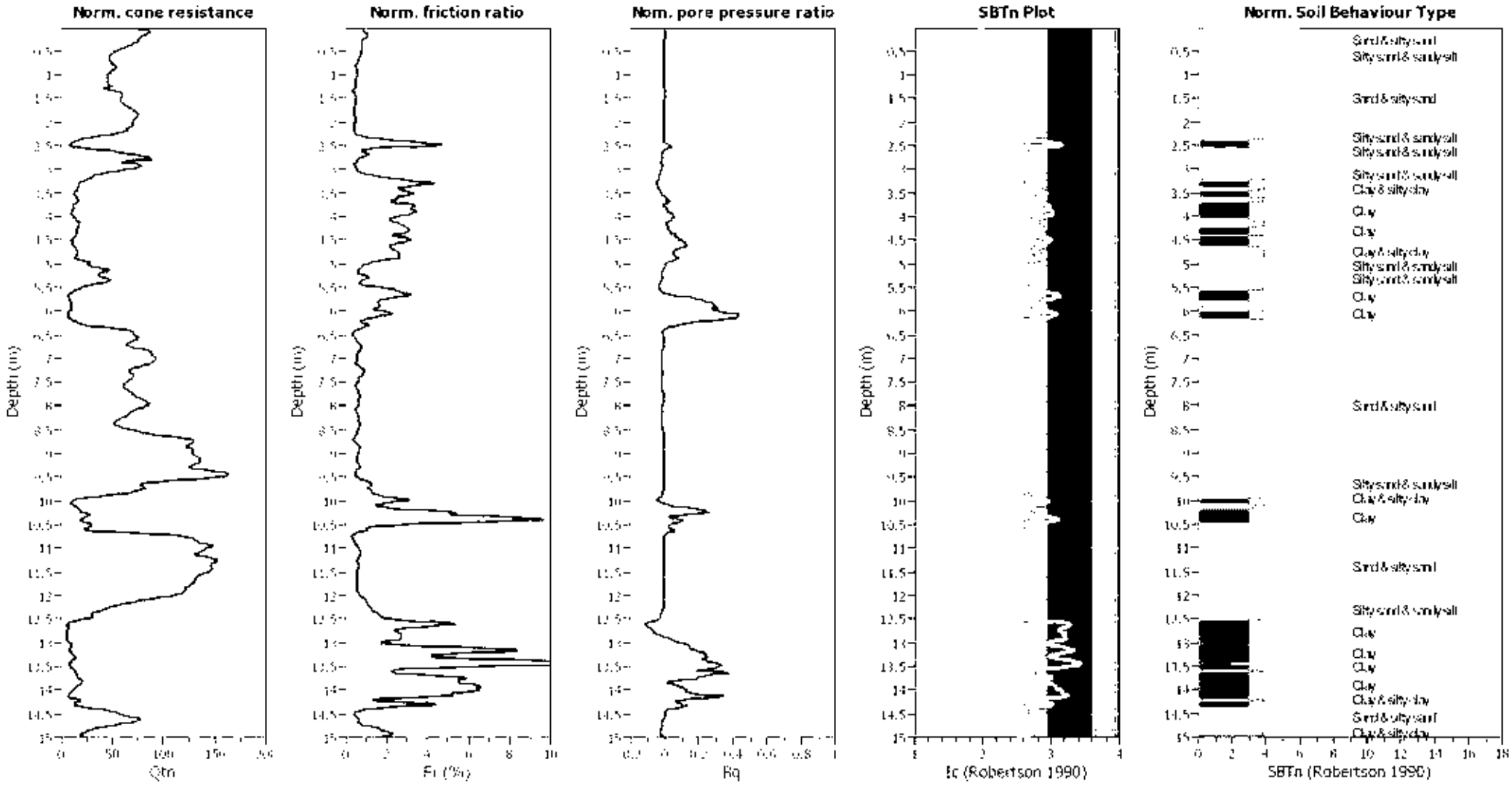
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 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

CPT basic interpretation plots (normalized)



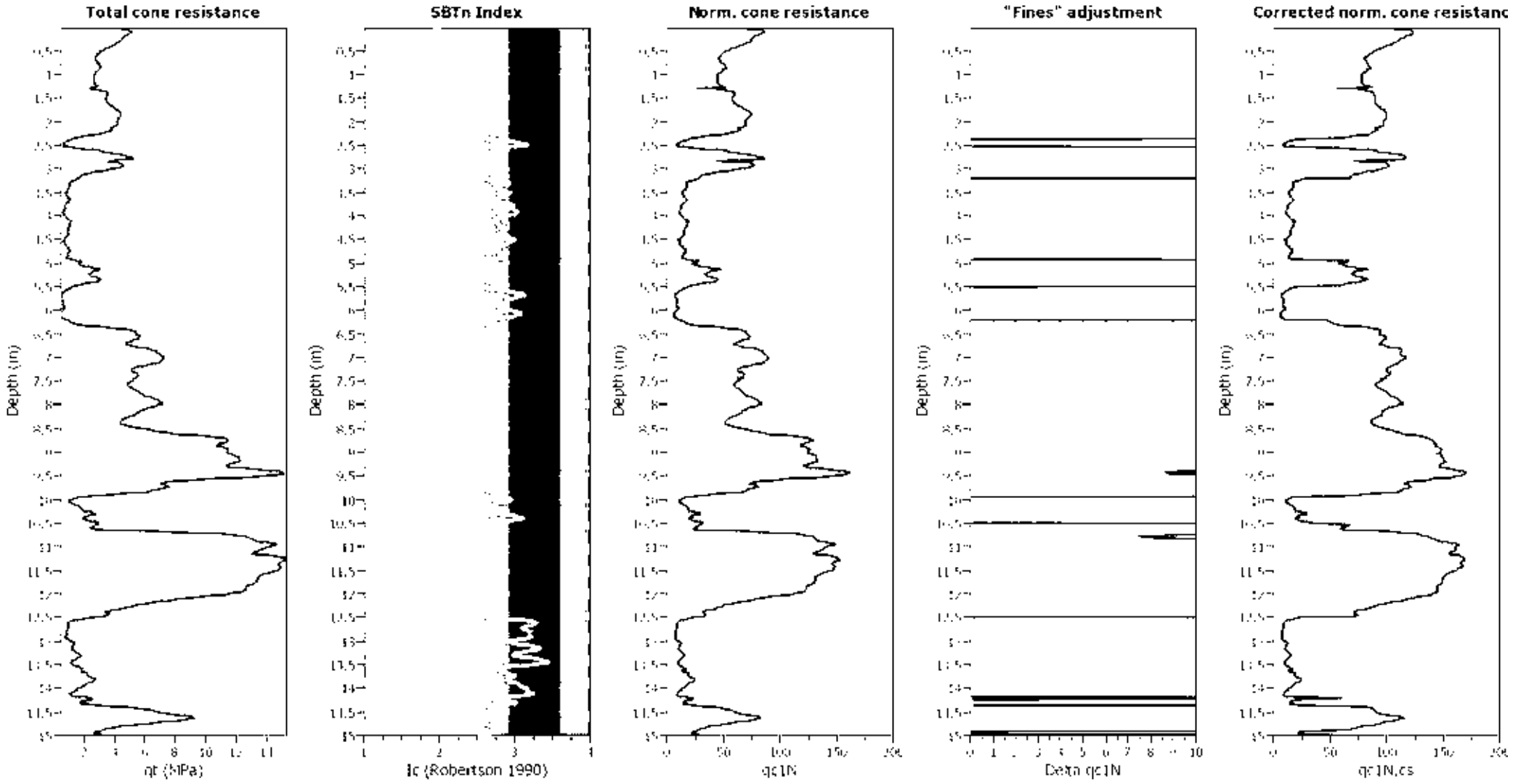
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Unit weight:	N/A
Liquefaction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

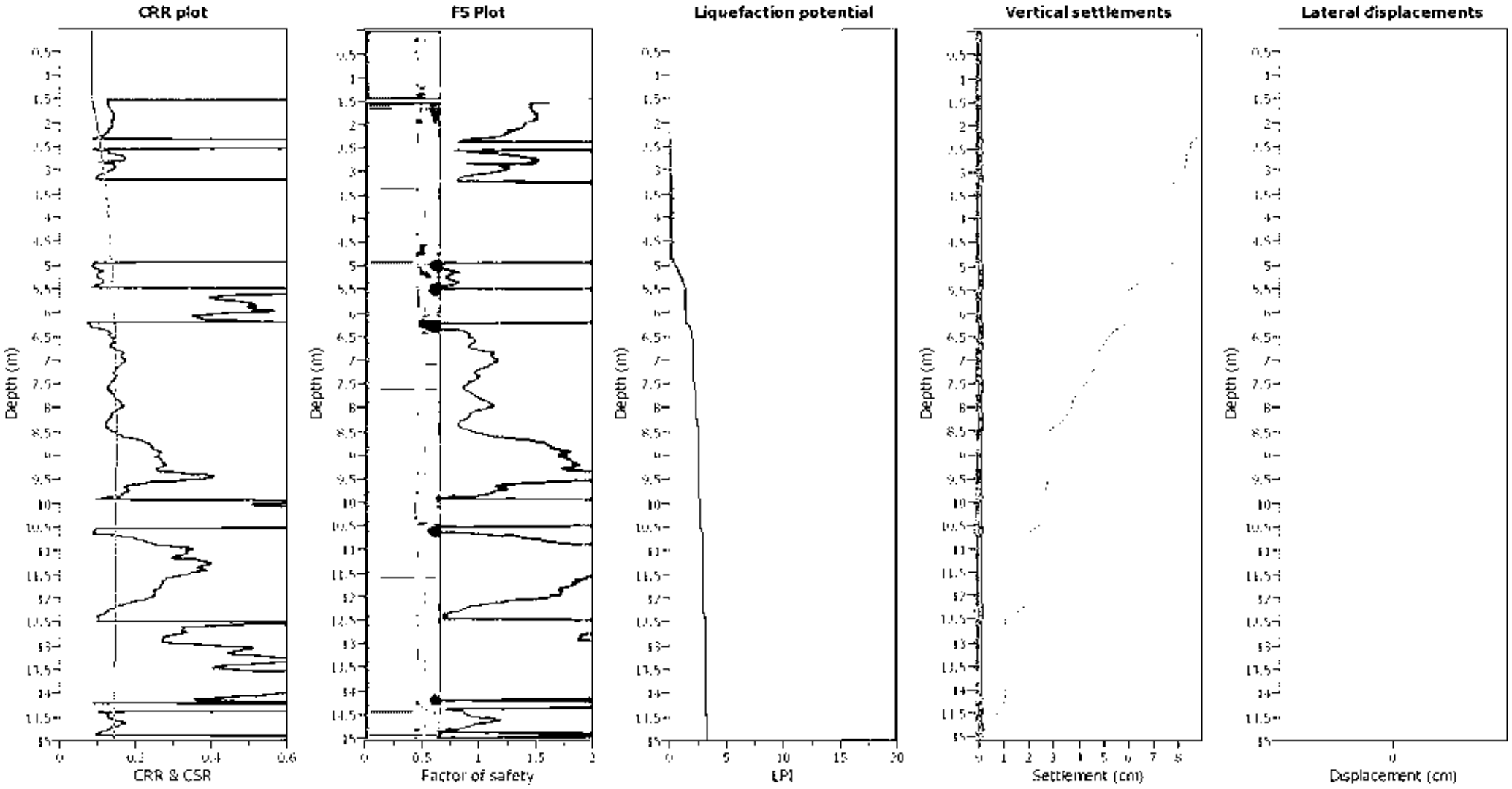
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 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.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

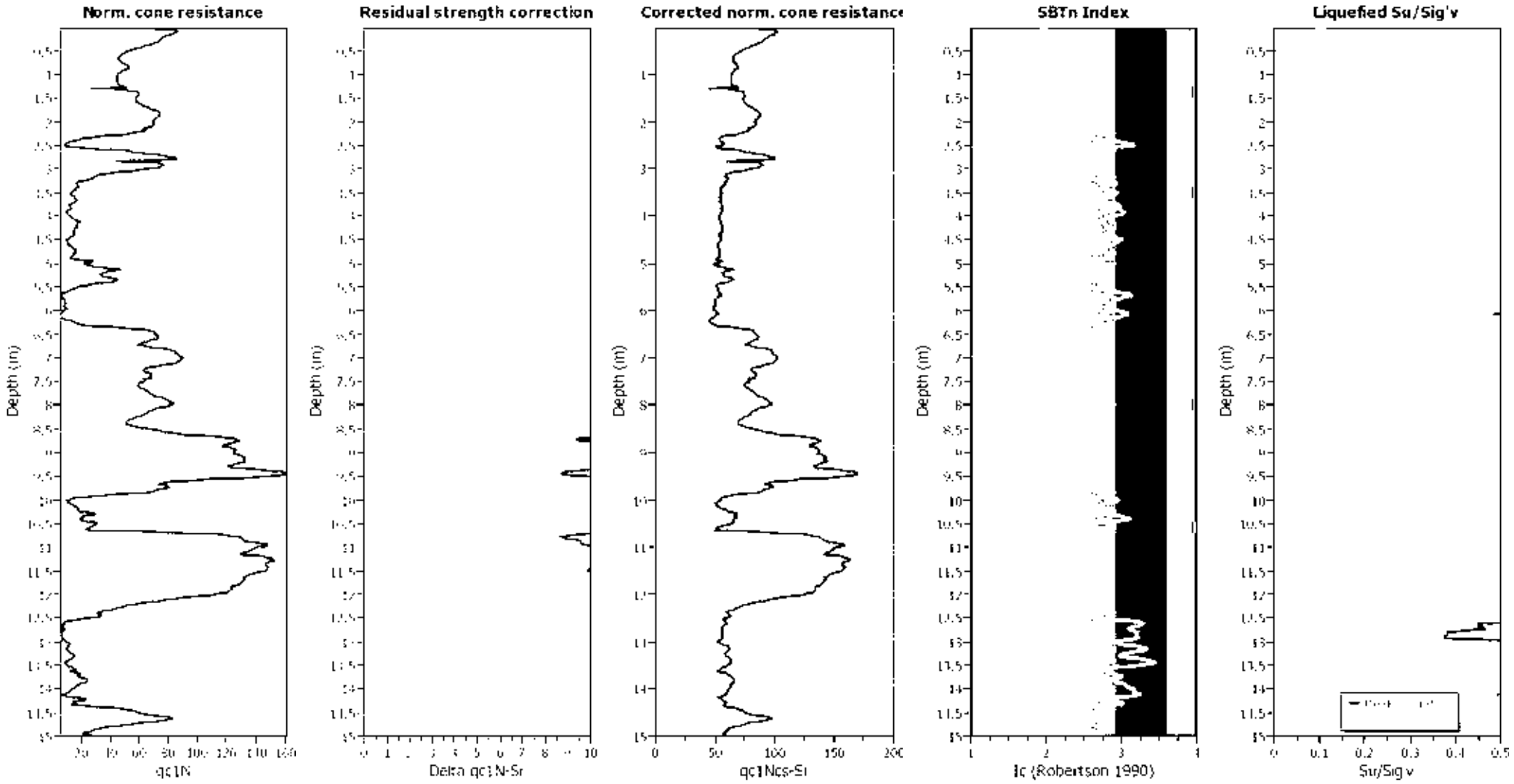
F.S. color scheme

- ☐ 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

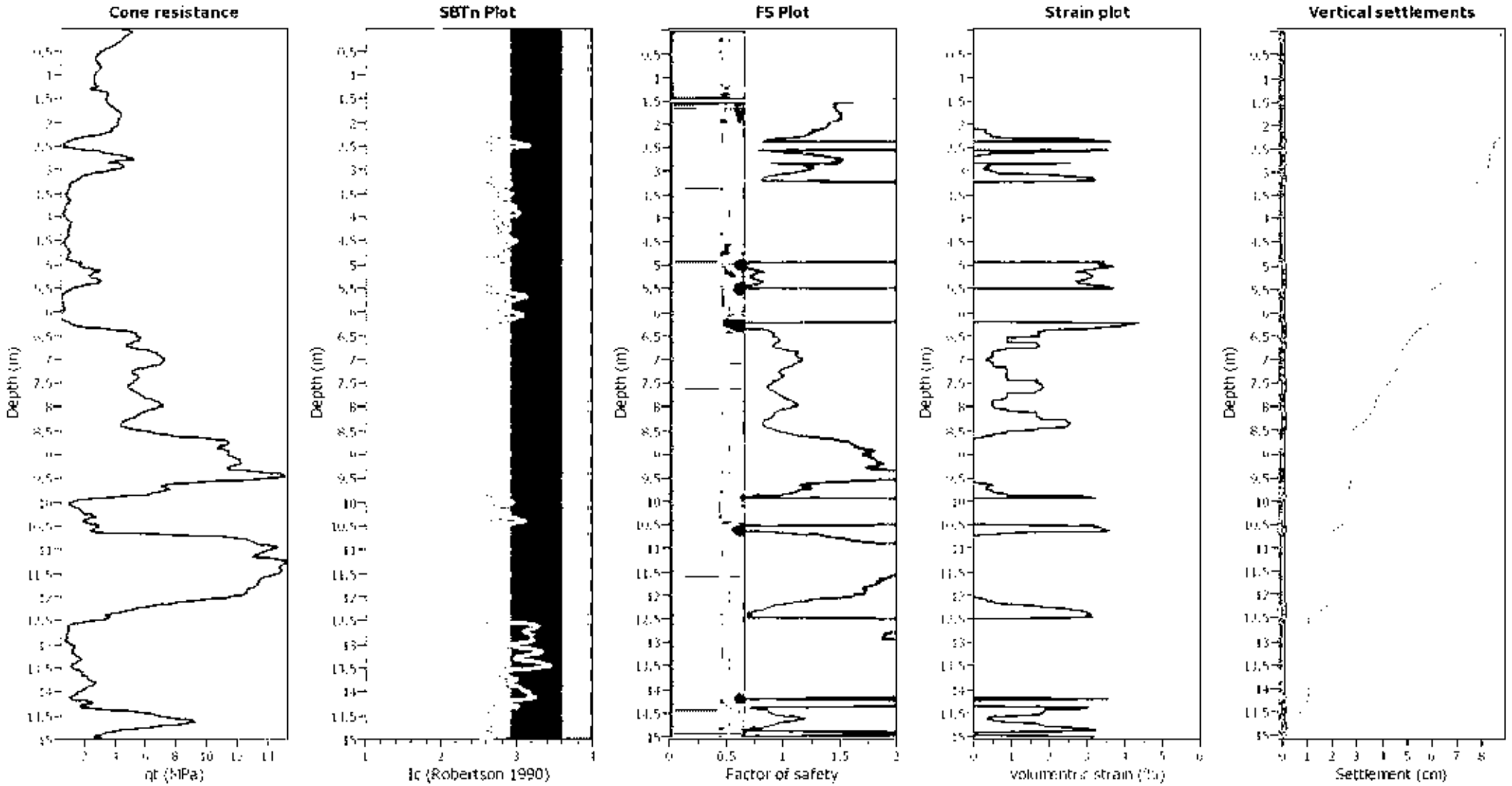
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Liquefaction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth	N/A

Estimation of post-earthquake settlements



Abbreviations

qt:	Total cone resistance (cone resistance q corrected for pore water effects)
Ic:	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumetric strain:	Post liquefaction volumetric strain

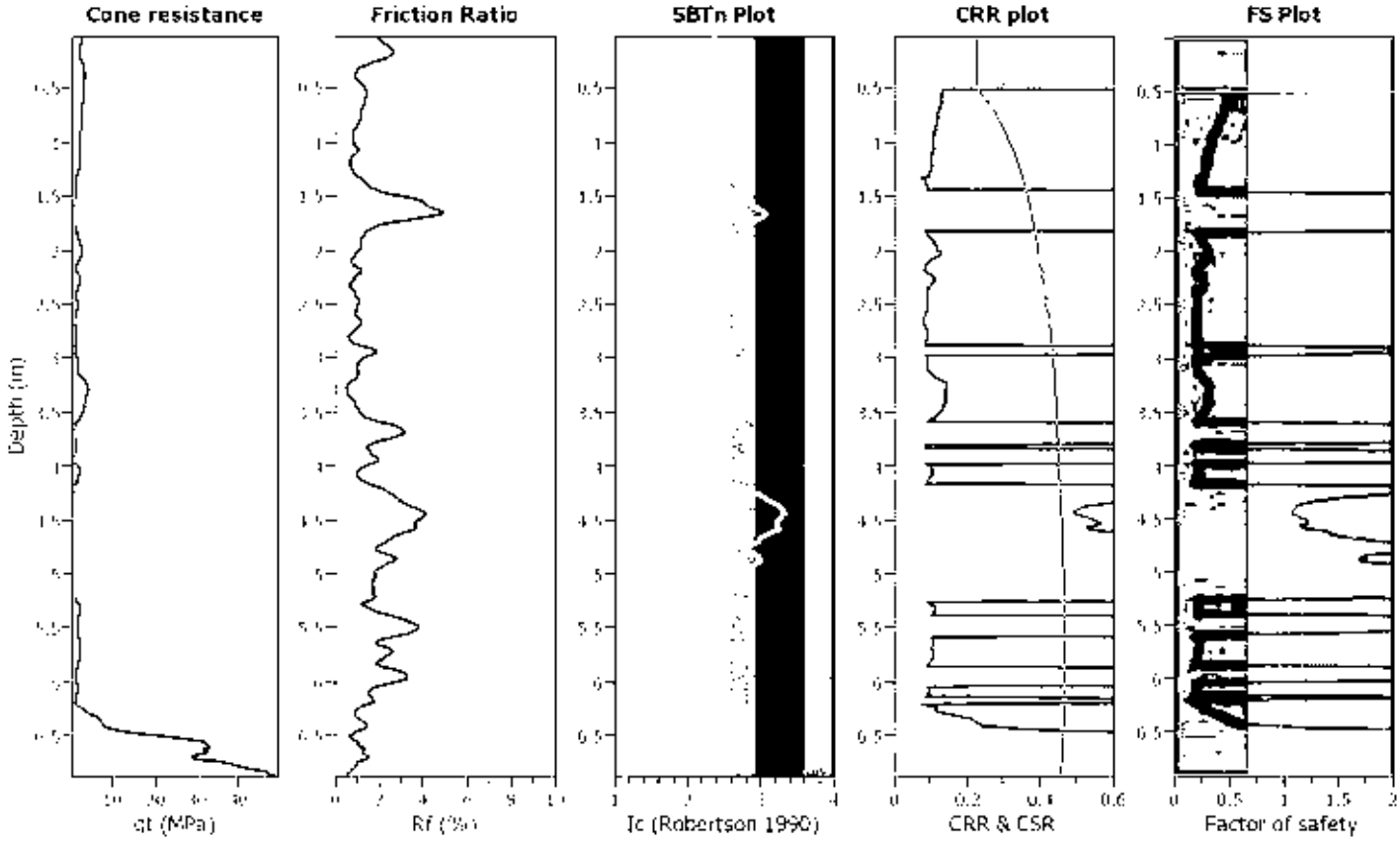
Beca Ltd
Geotechnical Engineers
www.beca.com

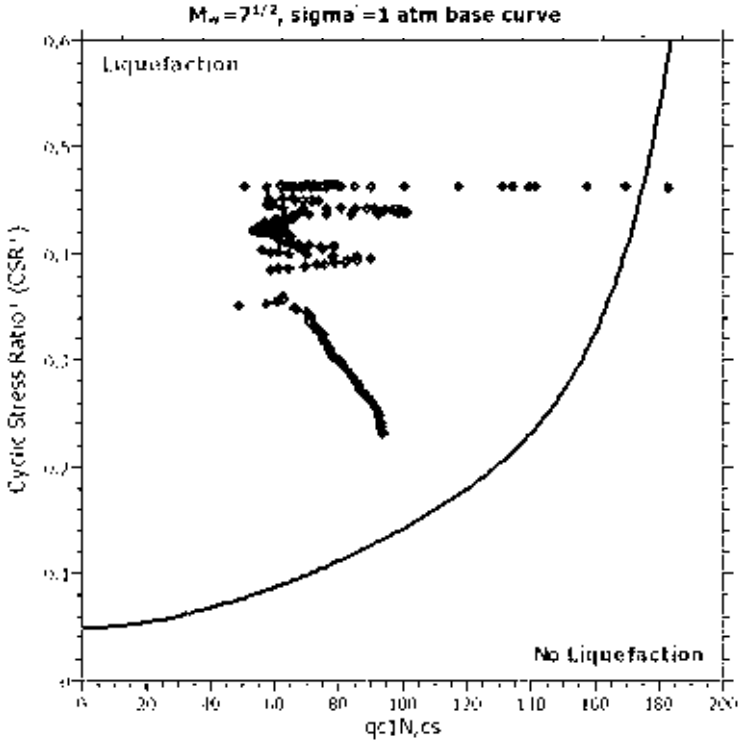
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

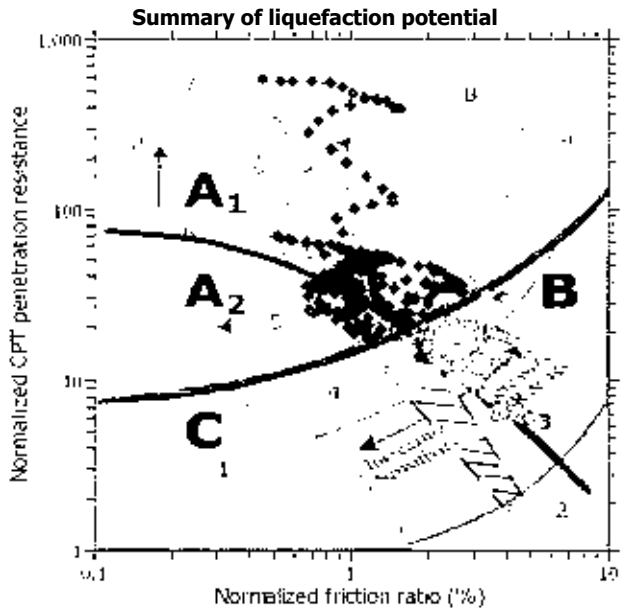
CPT file : CPT01_163bHalswellJunctionRd

Input parameters and analysis data

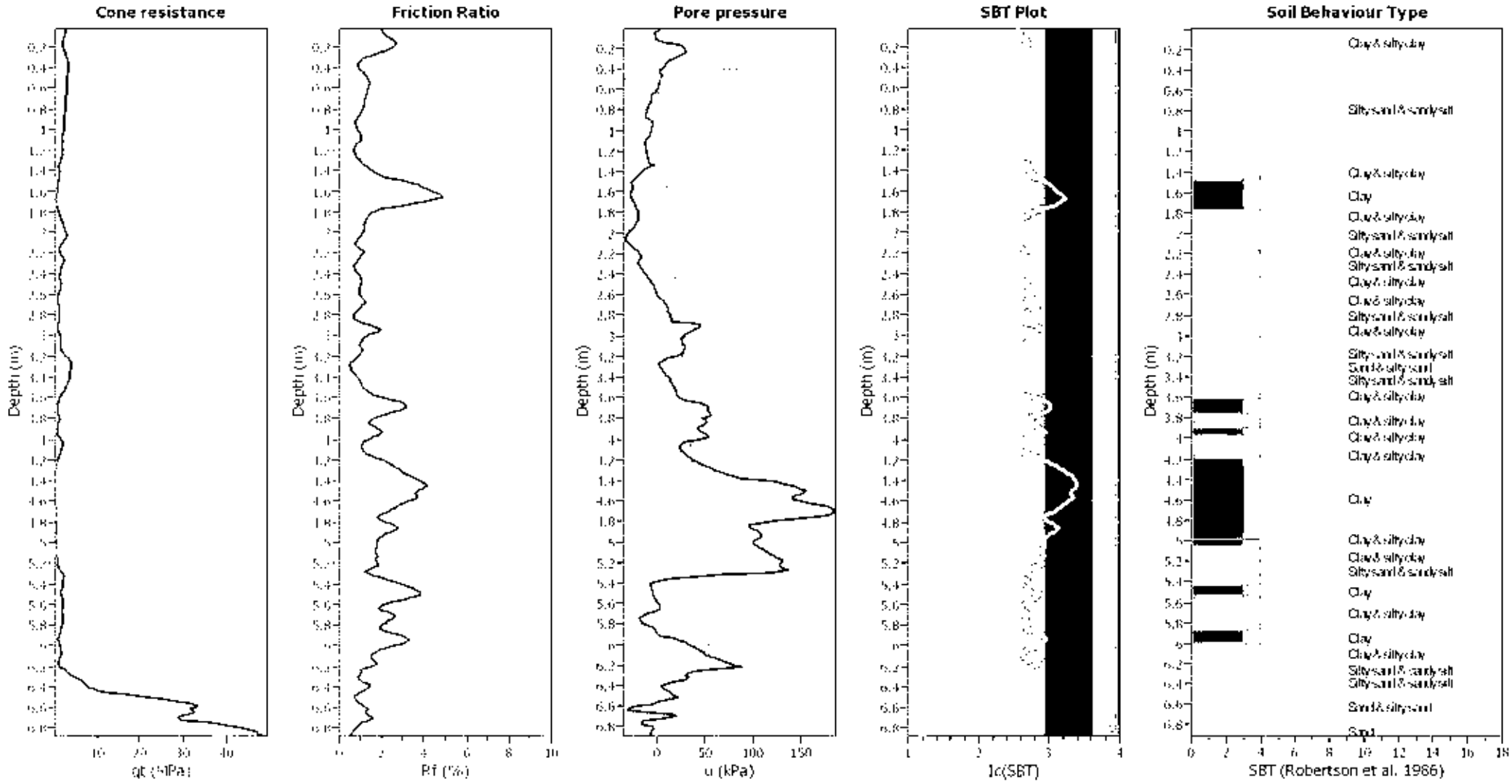
Analysis method:	I&B (2008)	G.W.T. (in-situ):	0.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	I&B (2008)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



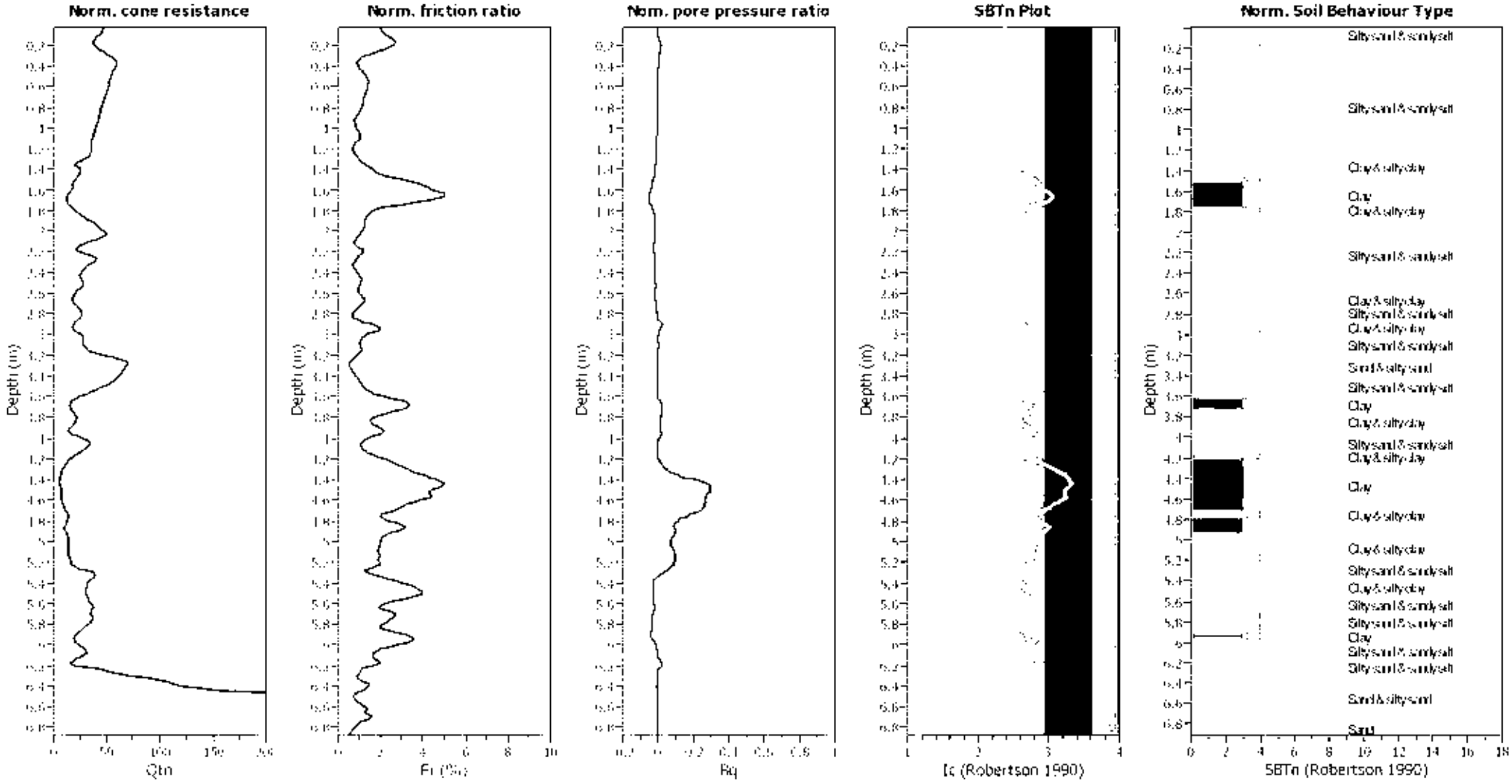
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 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

CPT basic interpretation plots (normalized)



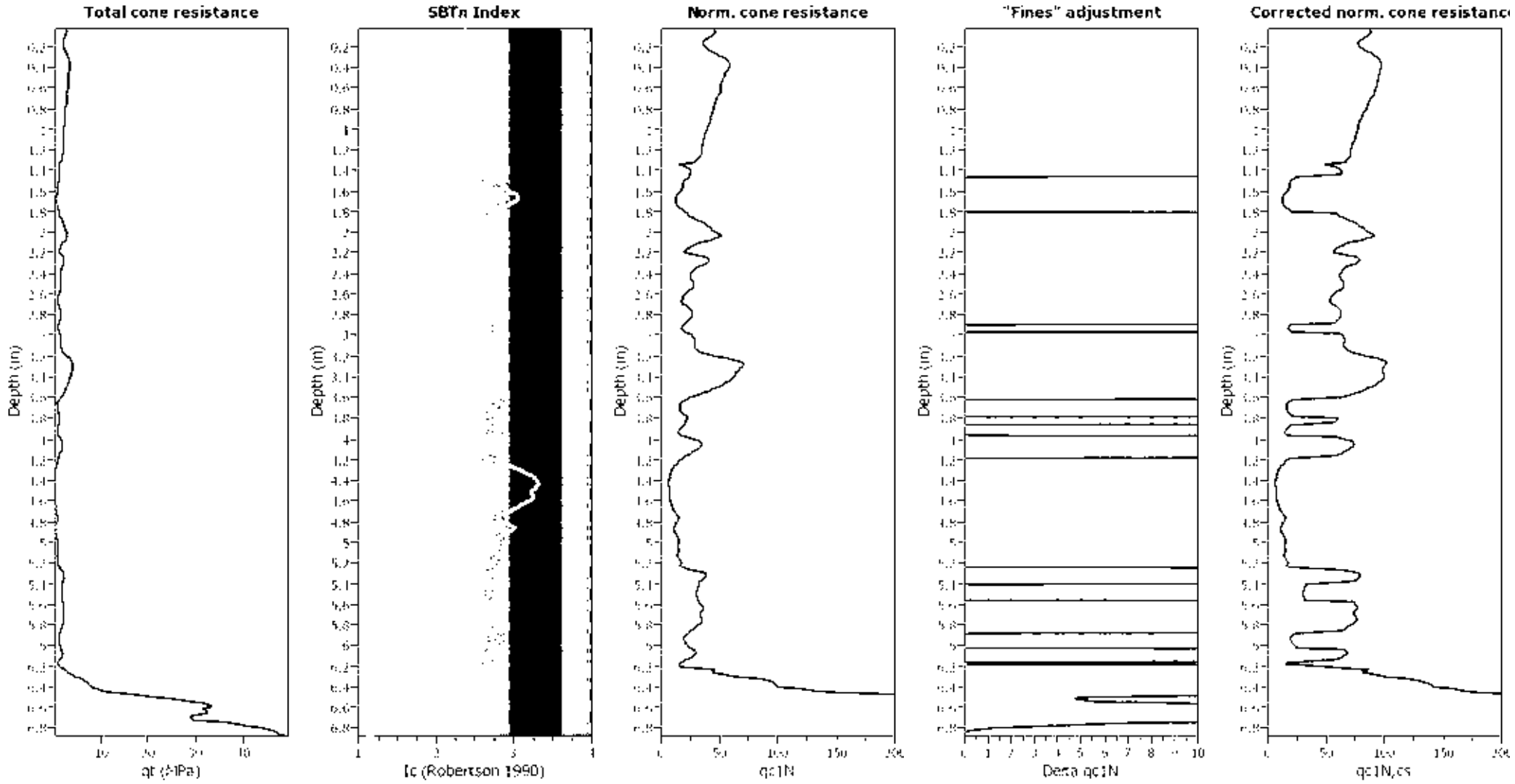
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	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	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

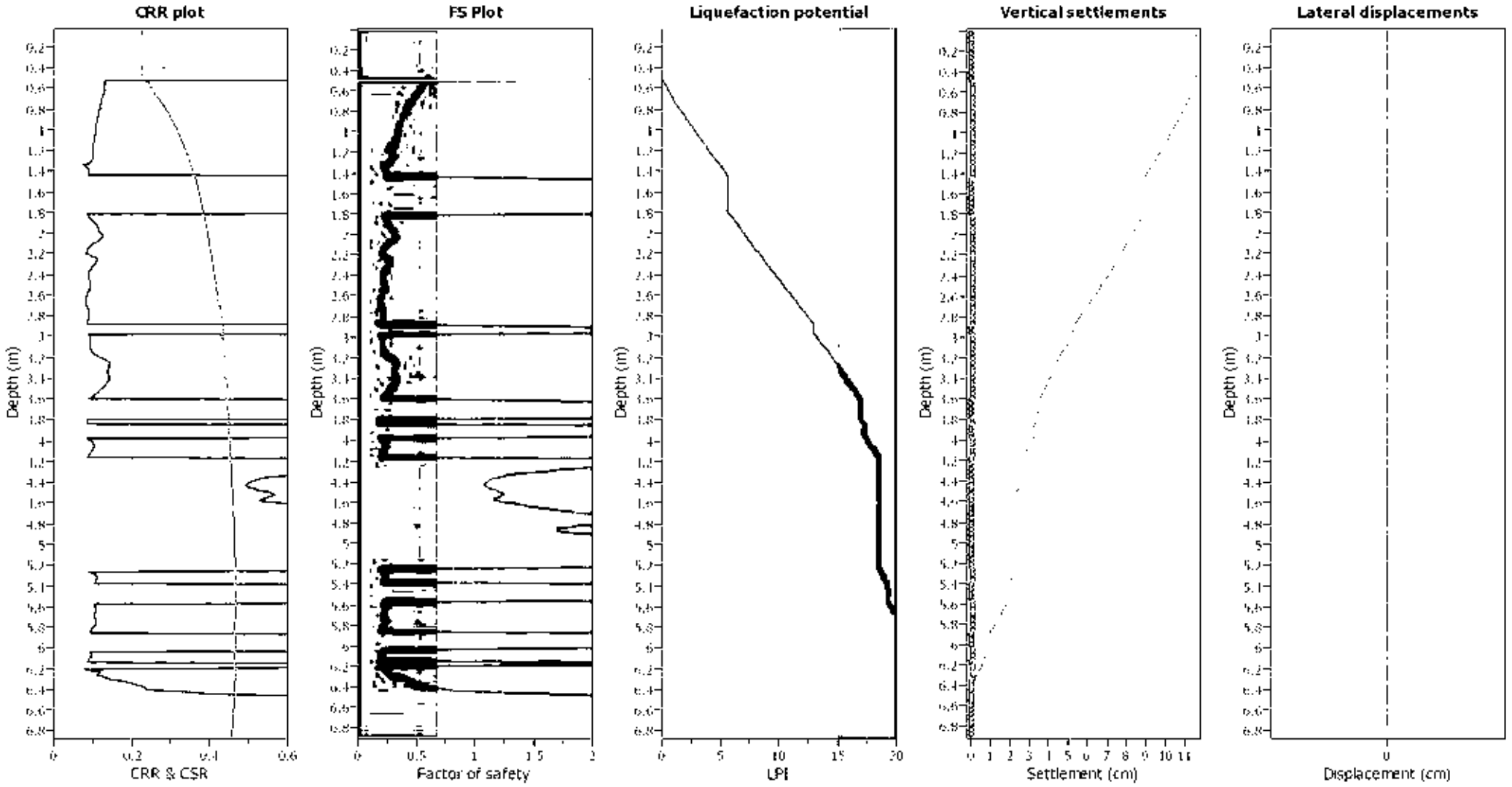
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	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:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 m	Fill height:	N/A	Limit depth:	N/A

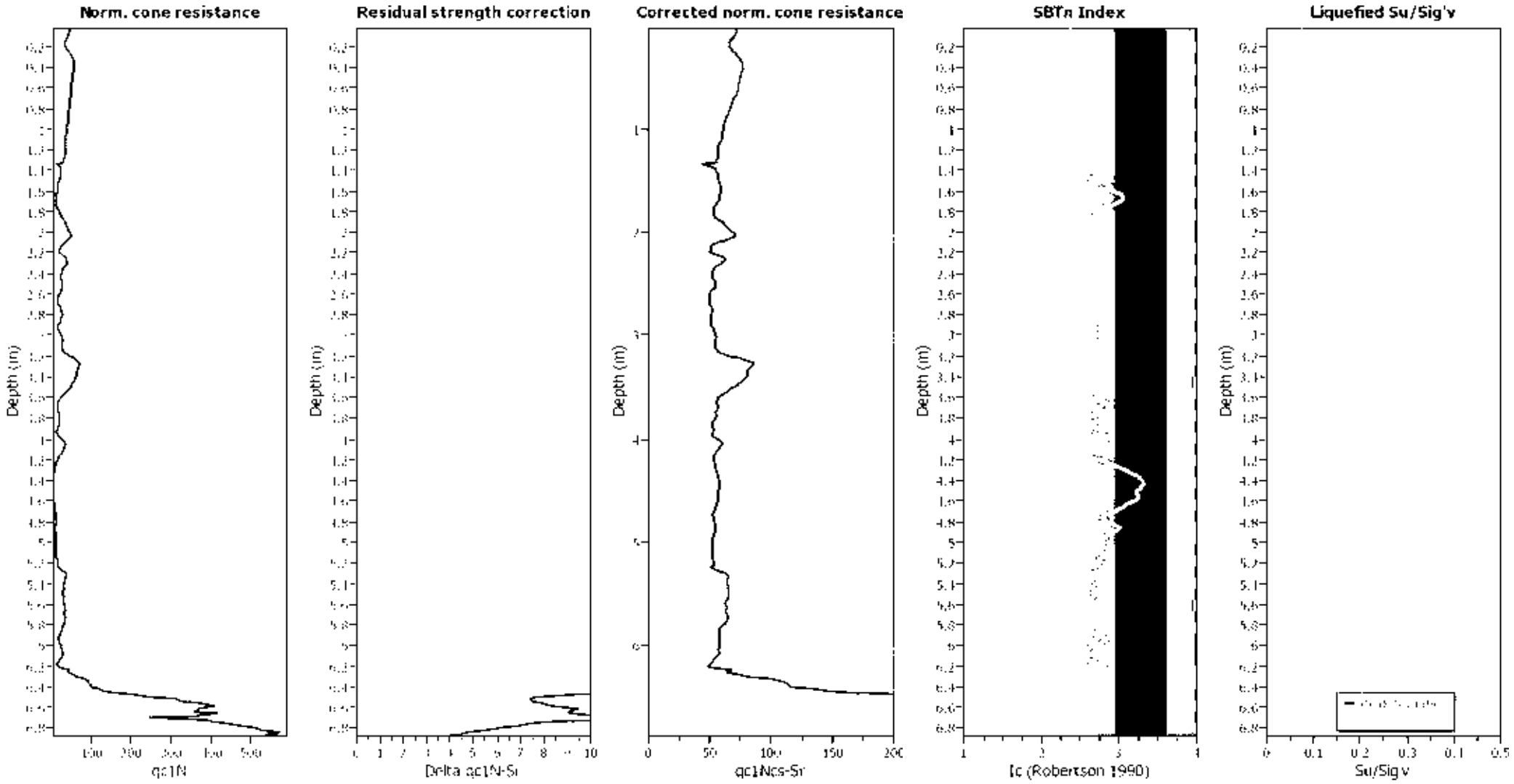
F.S. color scheme

- ☐ 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

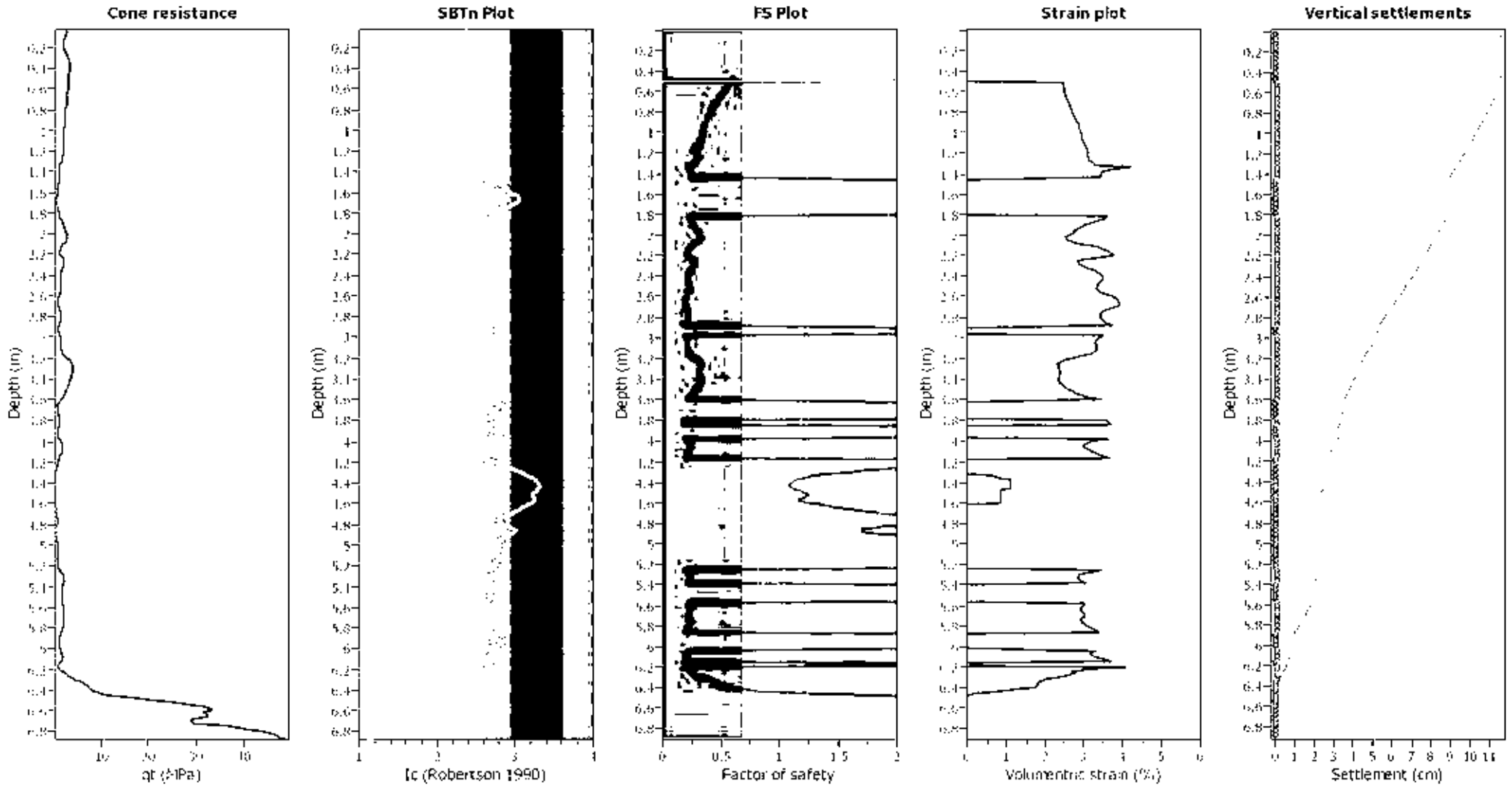
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Liquefaction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	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

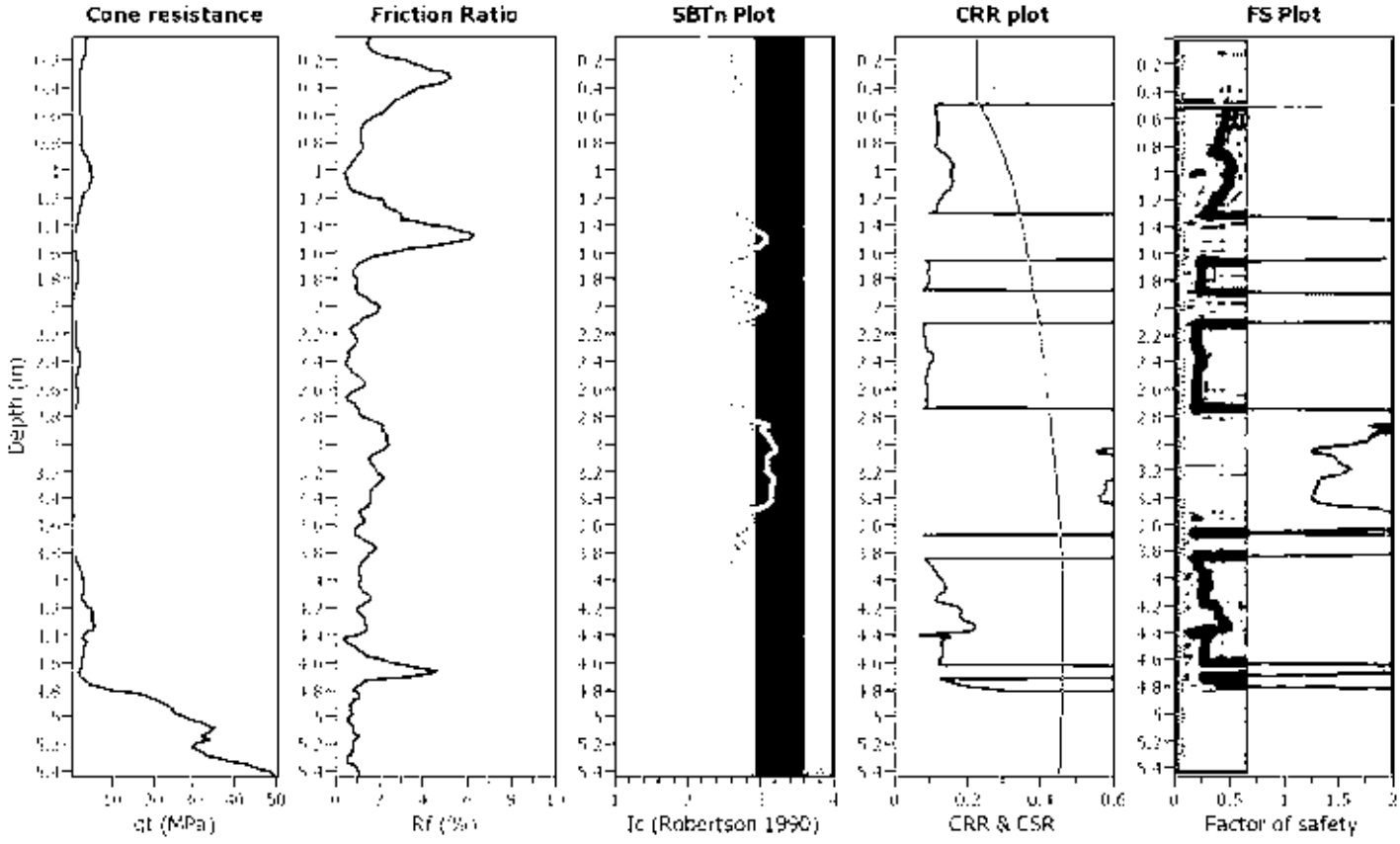
qt	Total cone resistance (cone resistance q corrected for pore water effects)
Ic	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumentric strain:	Post liquefaction volumentric strain

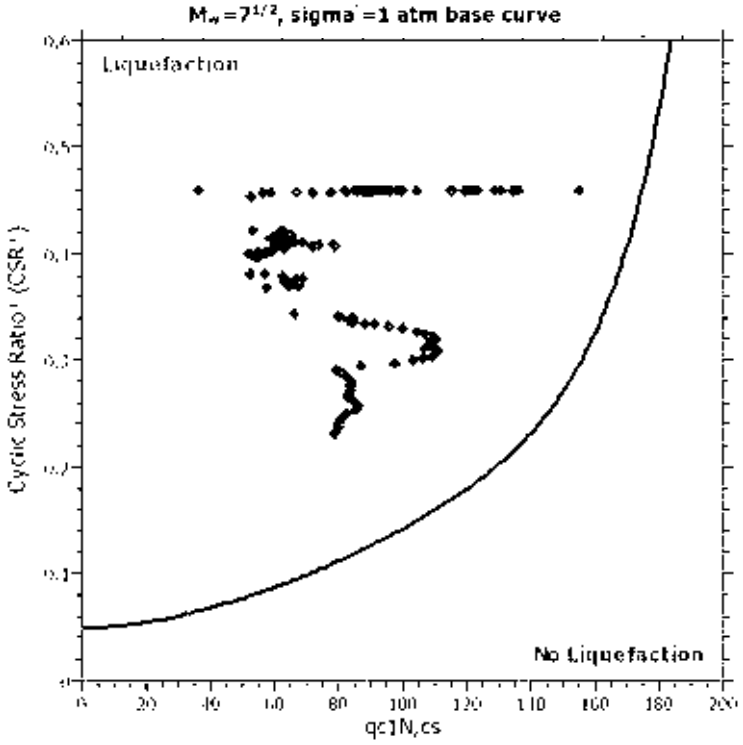
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

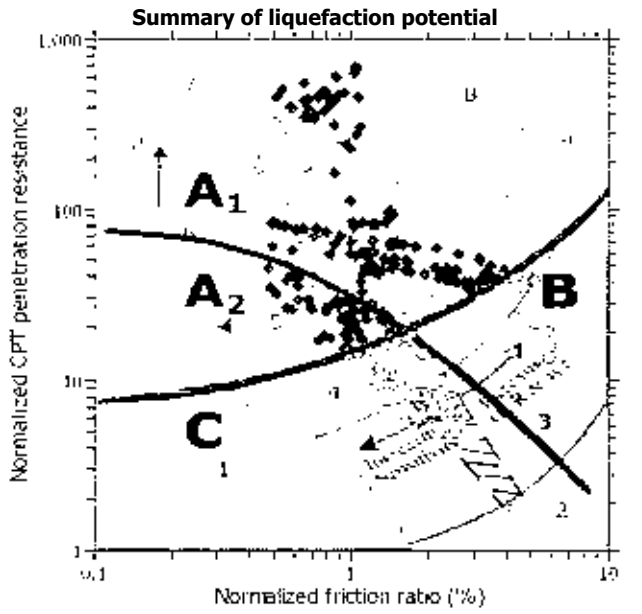
CPT file : CPT02_163bHalswellJunctionRd

Input parameters and analysis data

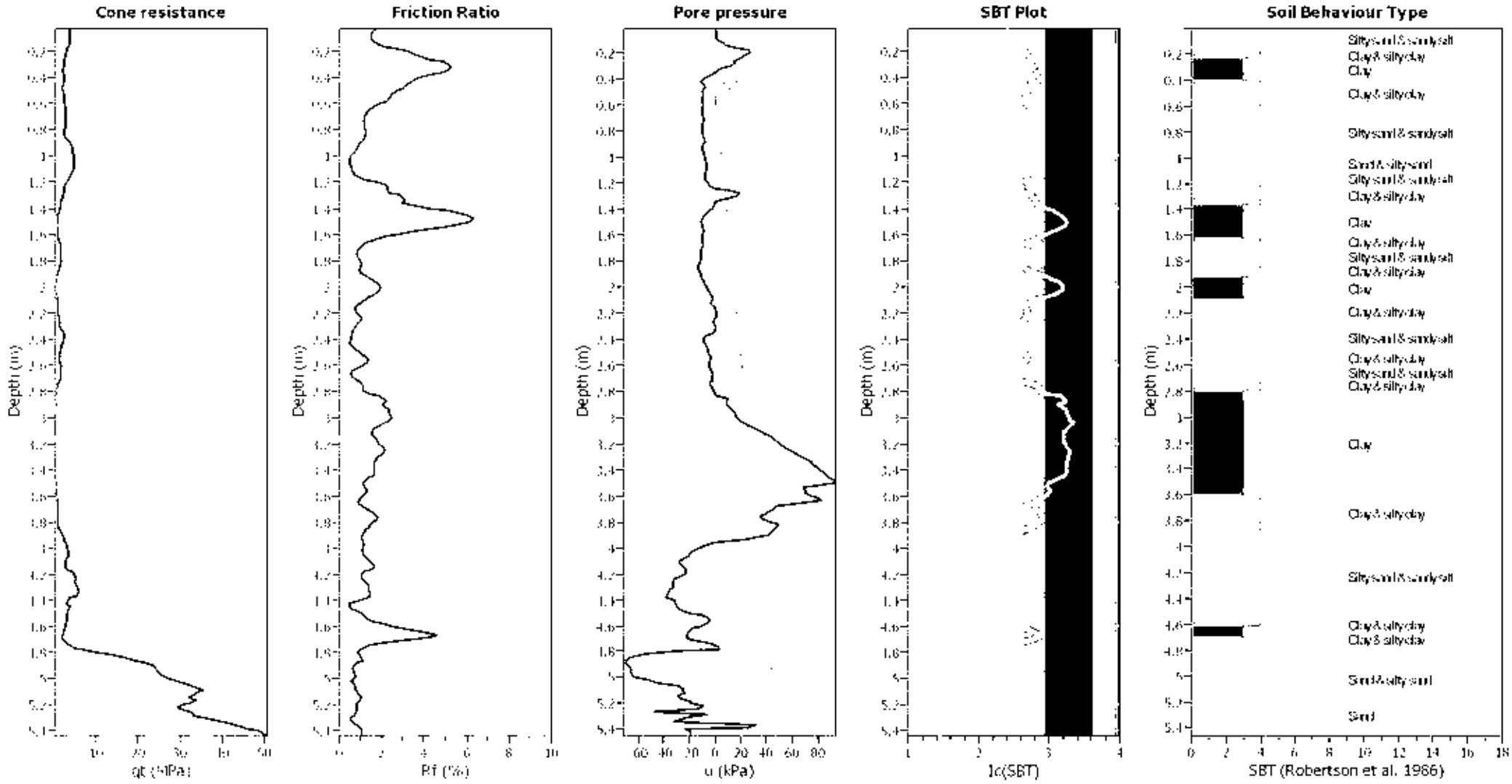
Analysis method	I&B (2008)	G.W.T. (in-situ):	0.50 m	Use fill	No	Clay like behavior applied:	Sand & Clay
Fines correction method	I&B (2008)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration	0.35	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



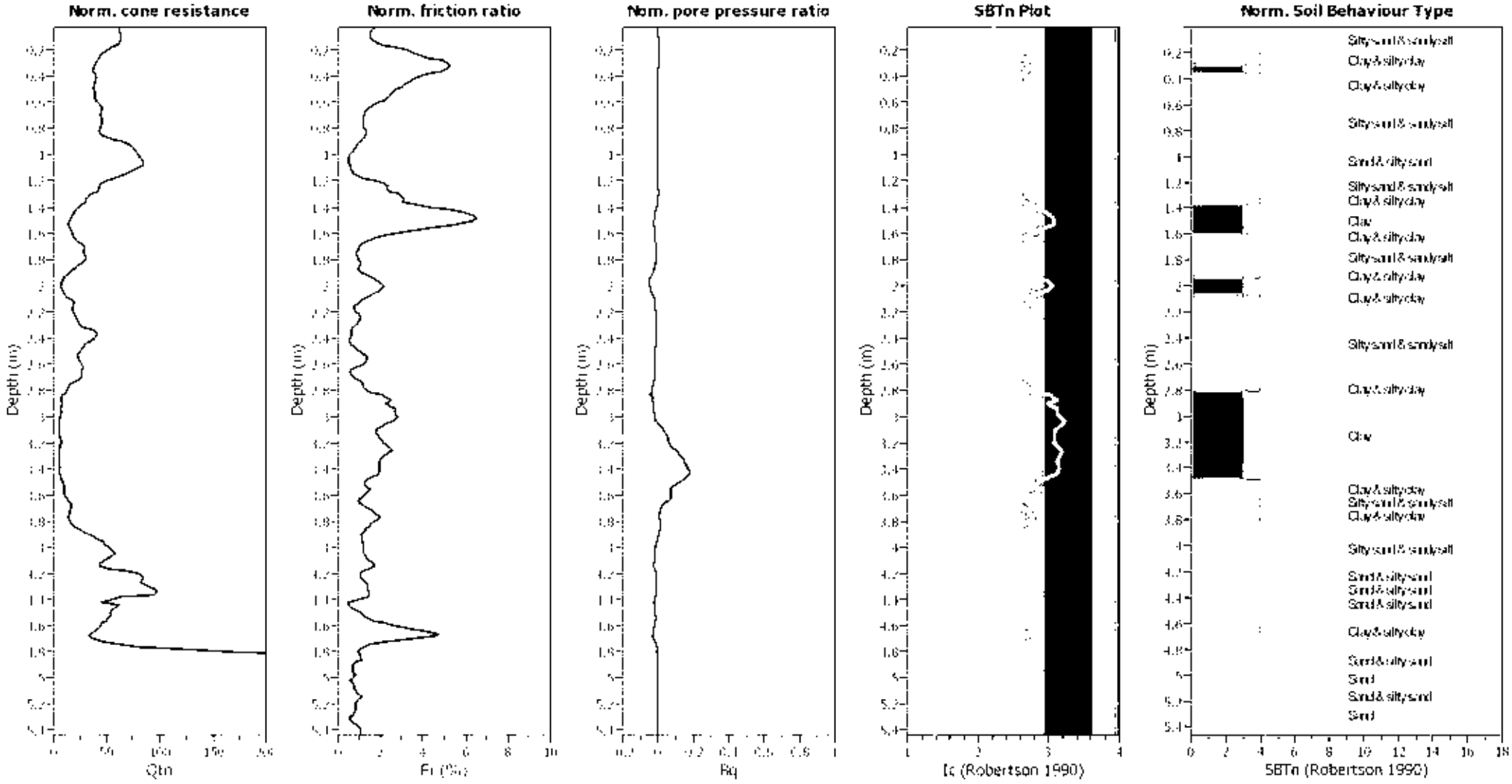
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 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

CPT basic interpretation plots (normalized)



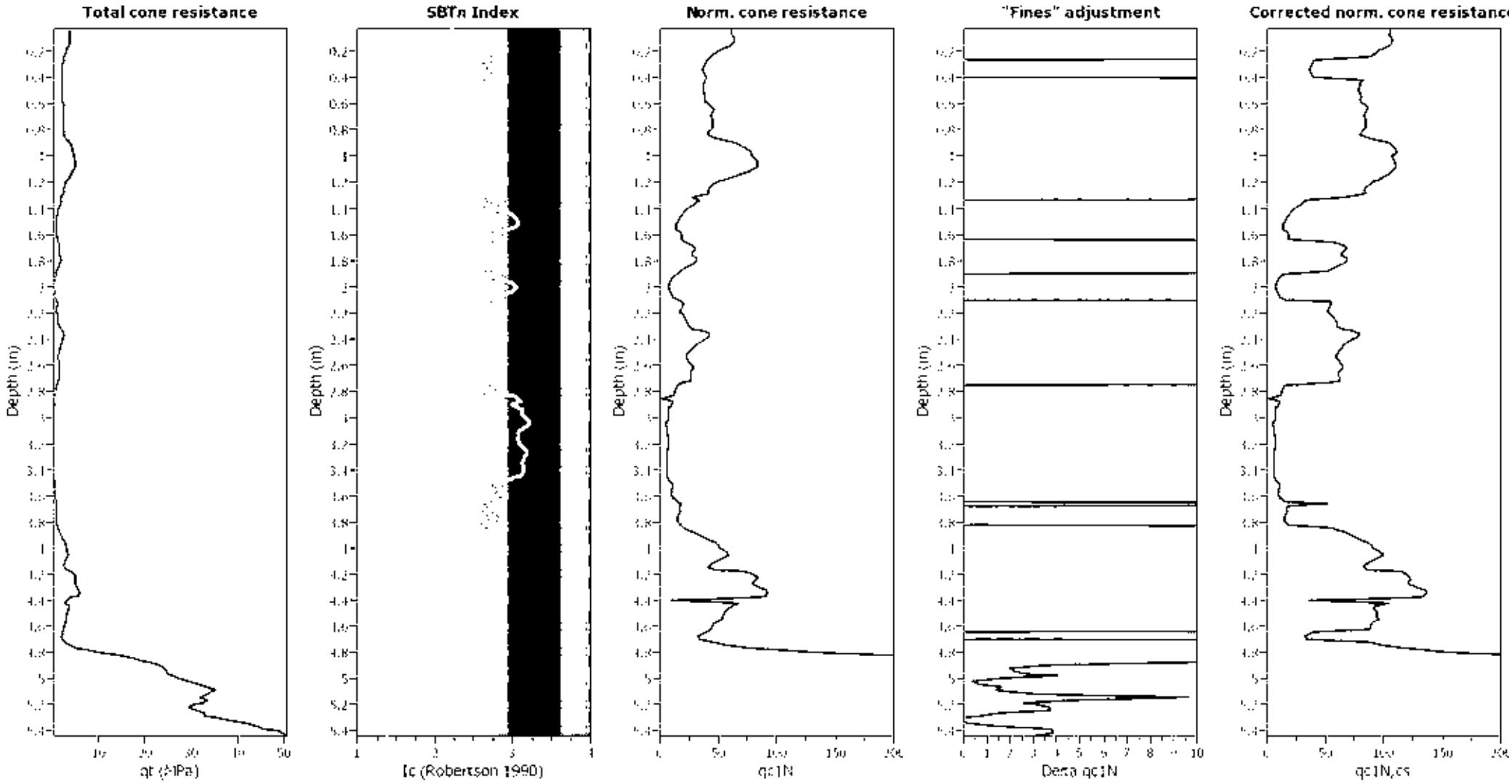
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	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	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

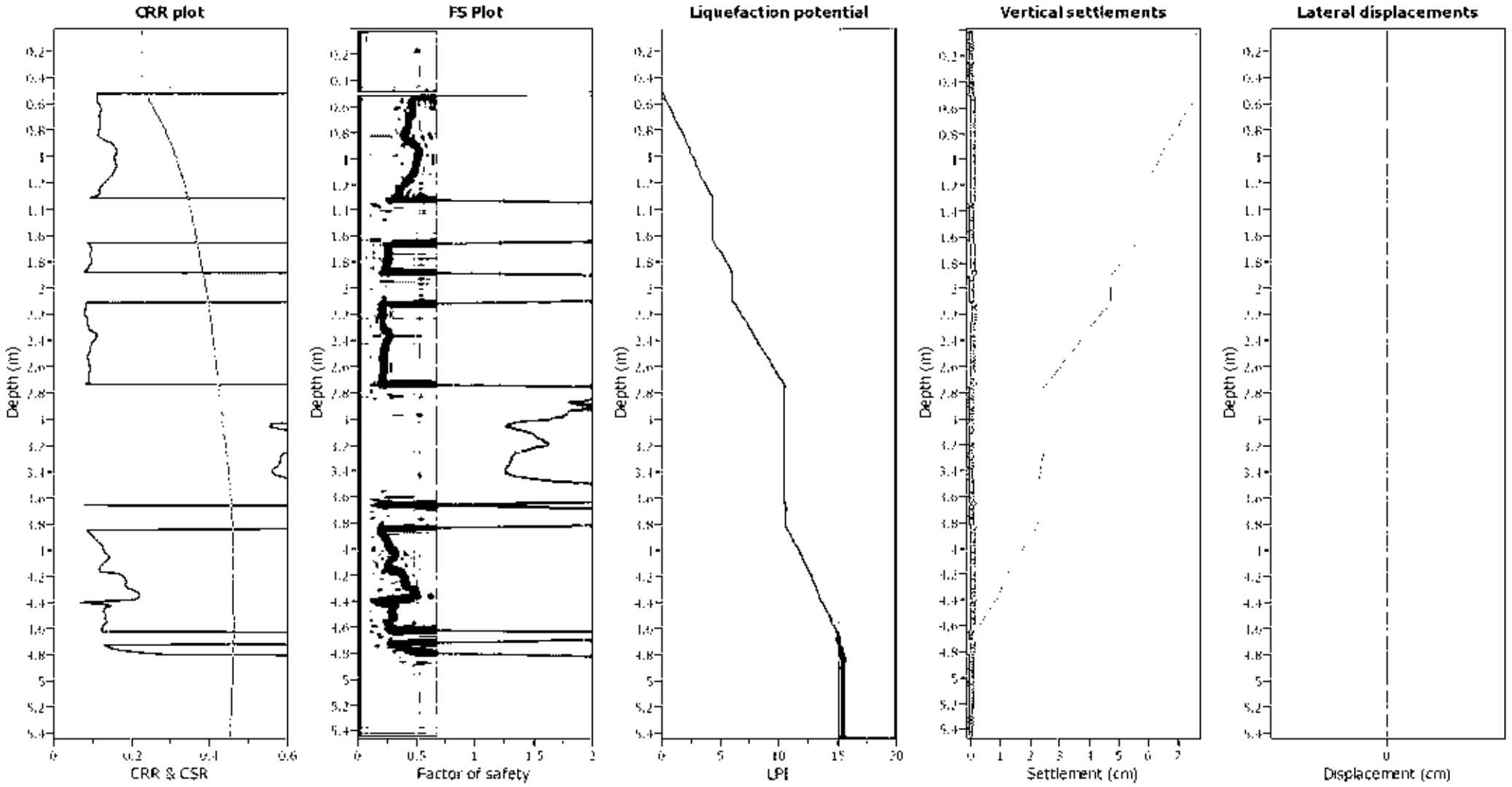
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	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
Liner correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 m	Fill height:	N/A	Limit depth:	N/A

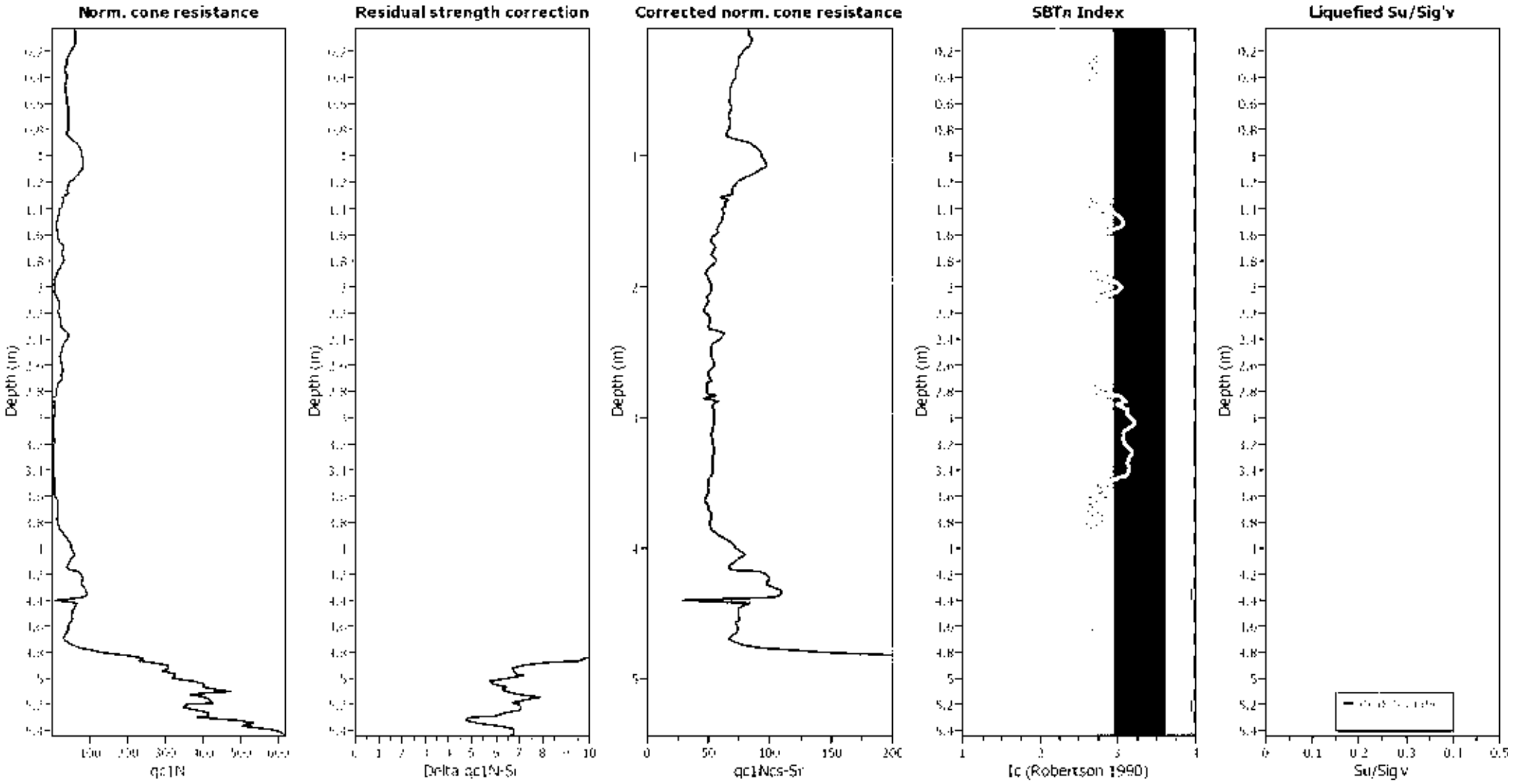
F.S. color scheme

- ☐ 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

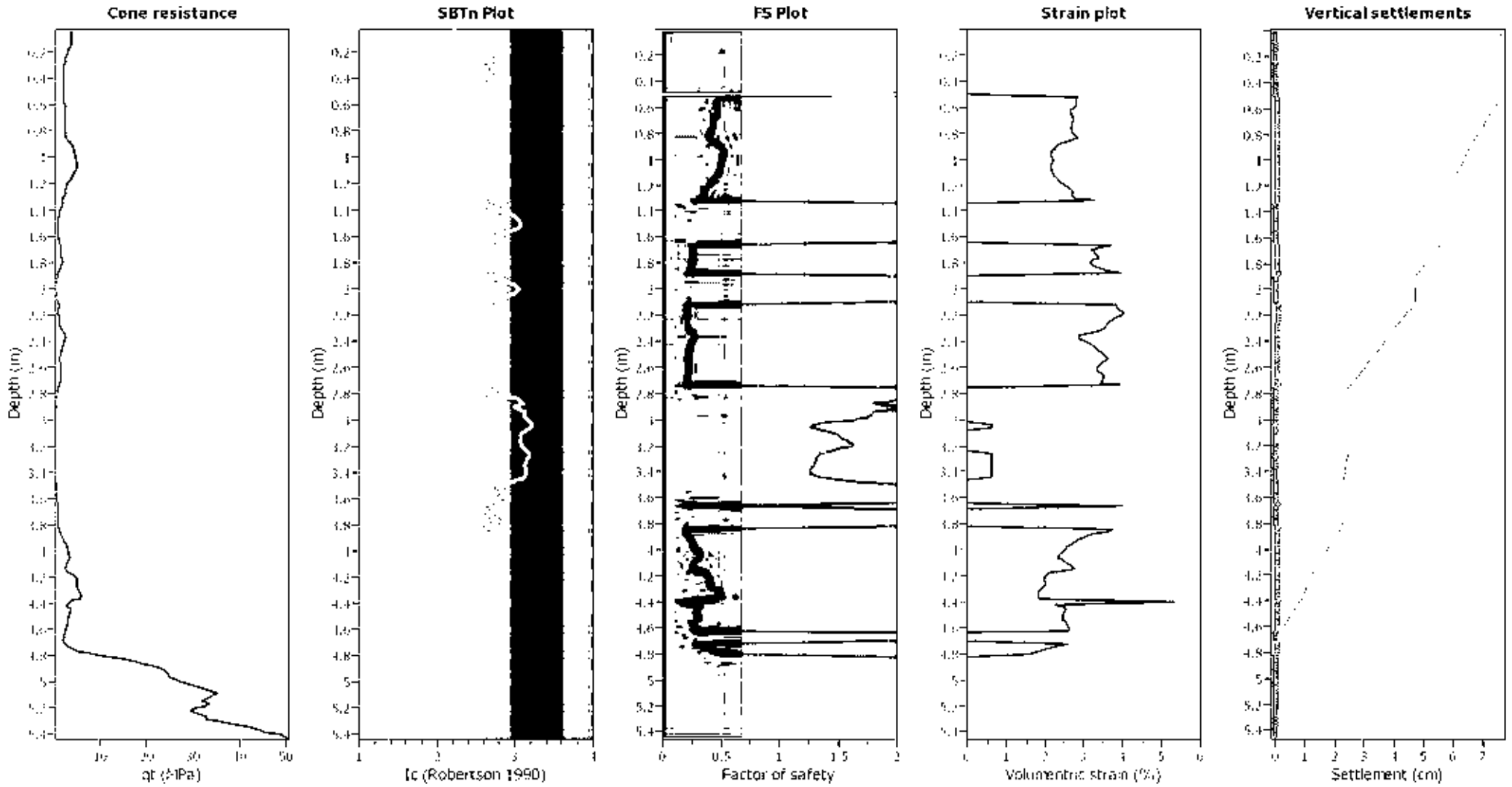
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Liner correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 m	Fill height:	N/A	Limit depth	N/A

Estimation of post-earthquake settlements



Abbreviations

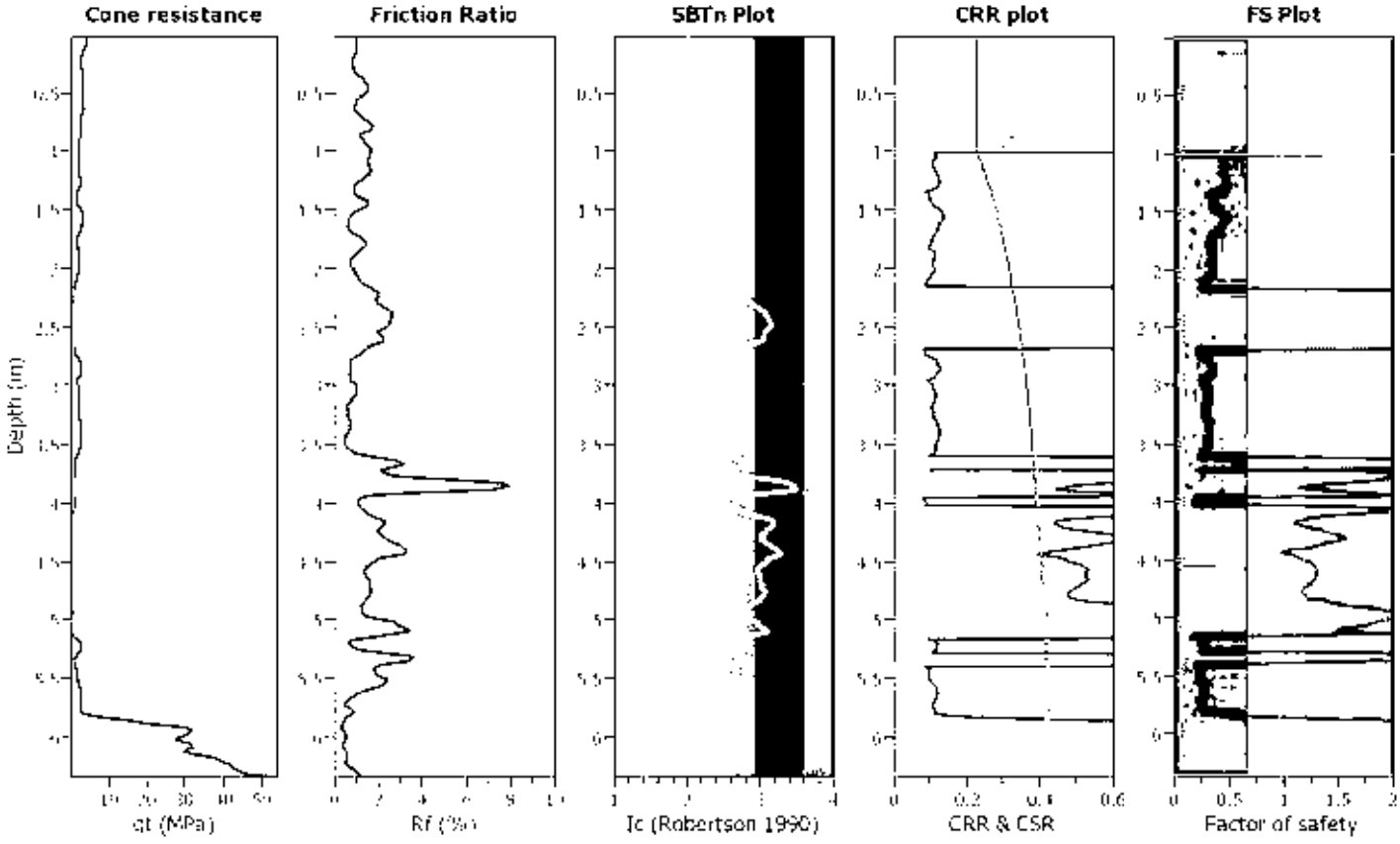
qt	Total cone resistance (cone resistance q corrected for pore water effects)
Ic	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumentric strain:	Post liquefaction volumentric strain

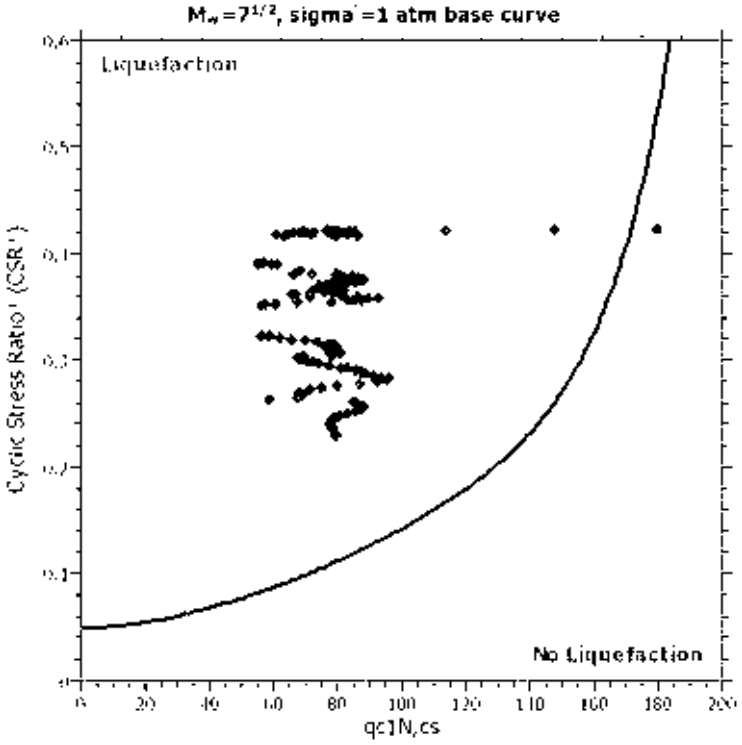
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

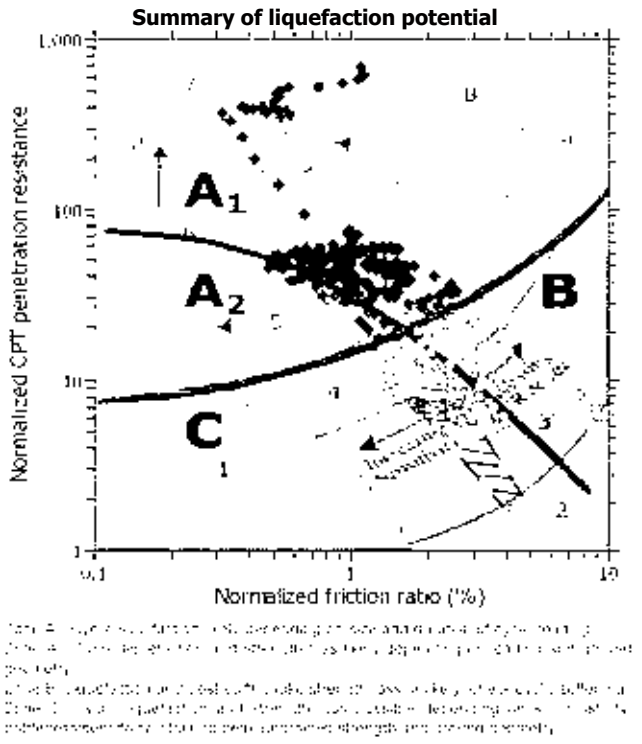
CPT file : CPT03_163bHalswellJunctionRd

Input parameters and analysis data

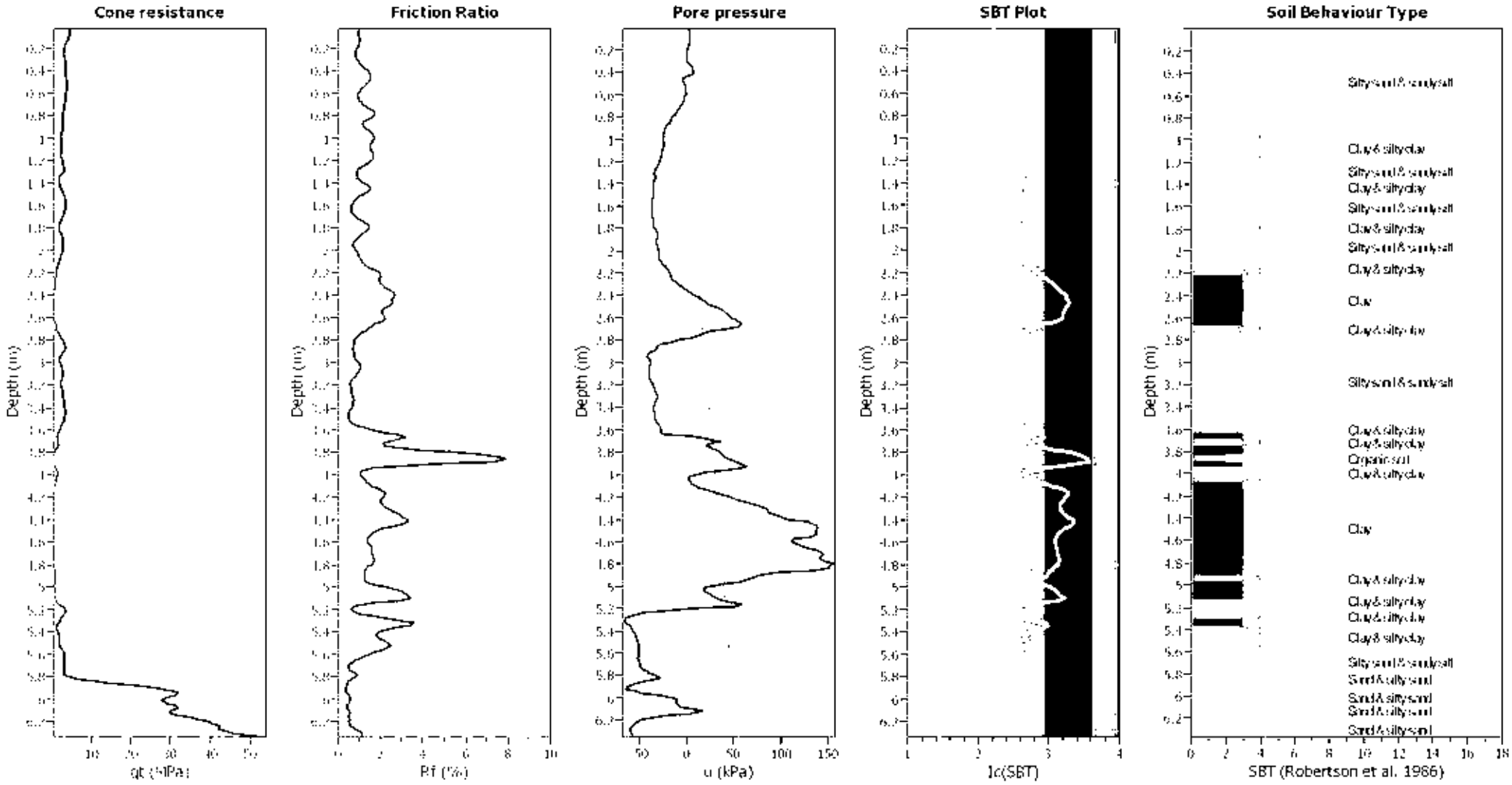
Analysis method	I&B (2008)	G.W.T. (in-situ):	1.00 m	Use fill	No	Clay like behavior applied:	Sand & Clay
Fines correction method	I&B (2008)	G.W.T. (earthq.):	1.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration	0.35	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



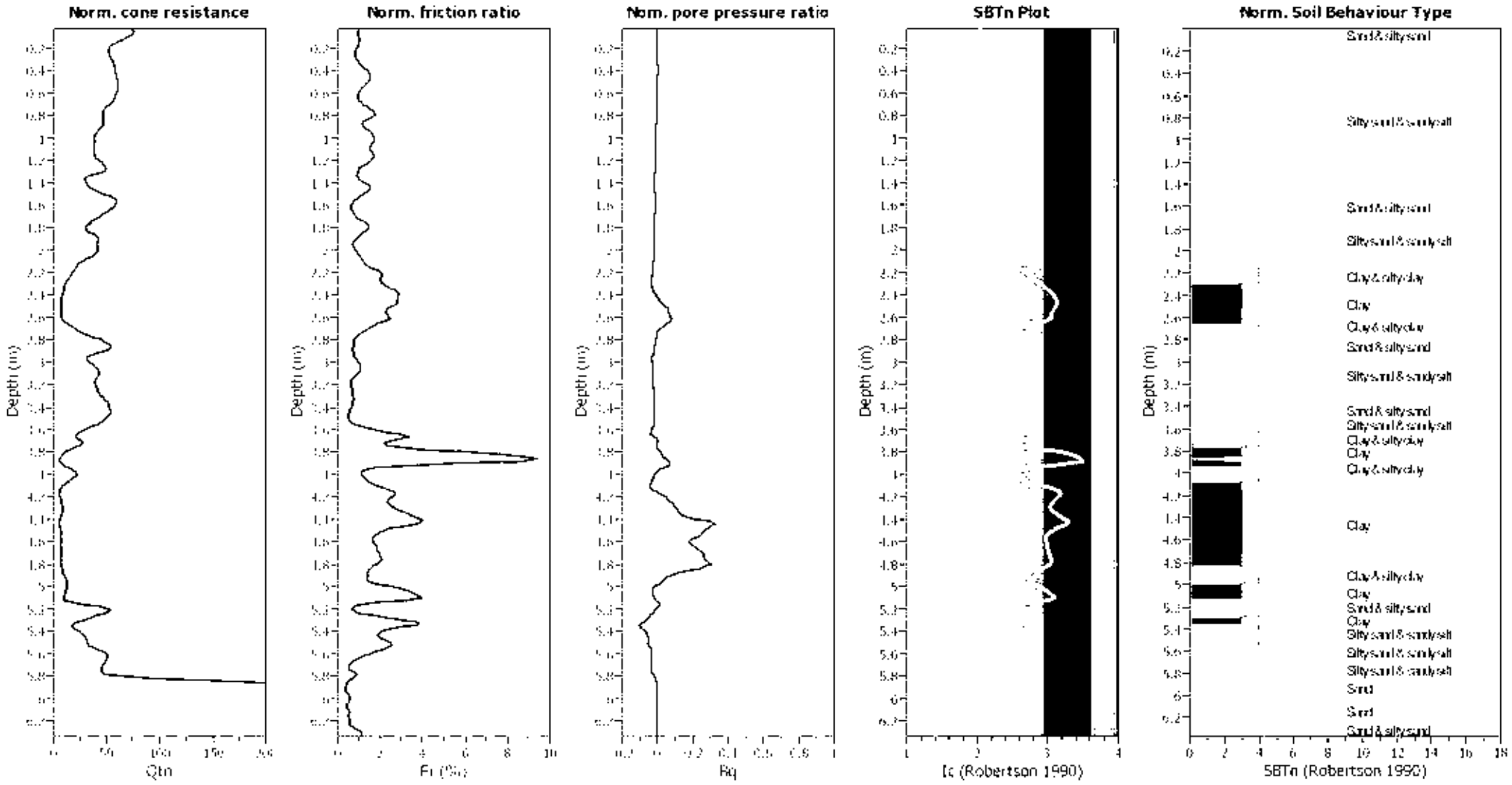
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 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

CPT basic interpretation plots (normalized)



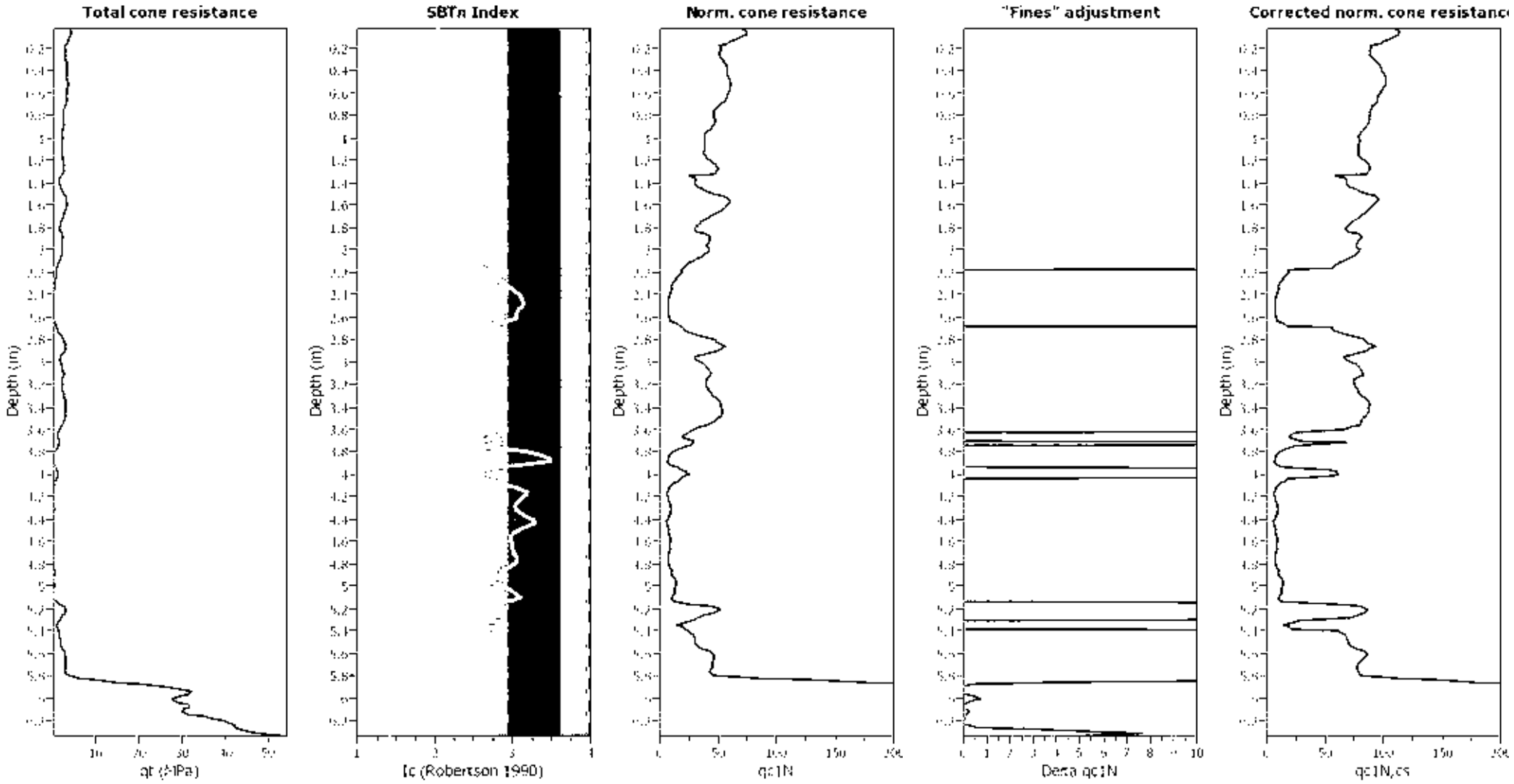
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

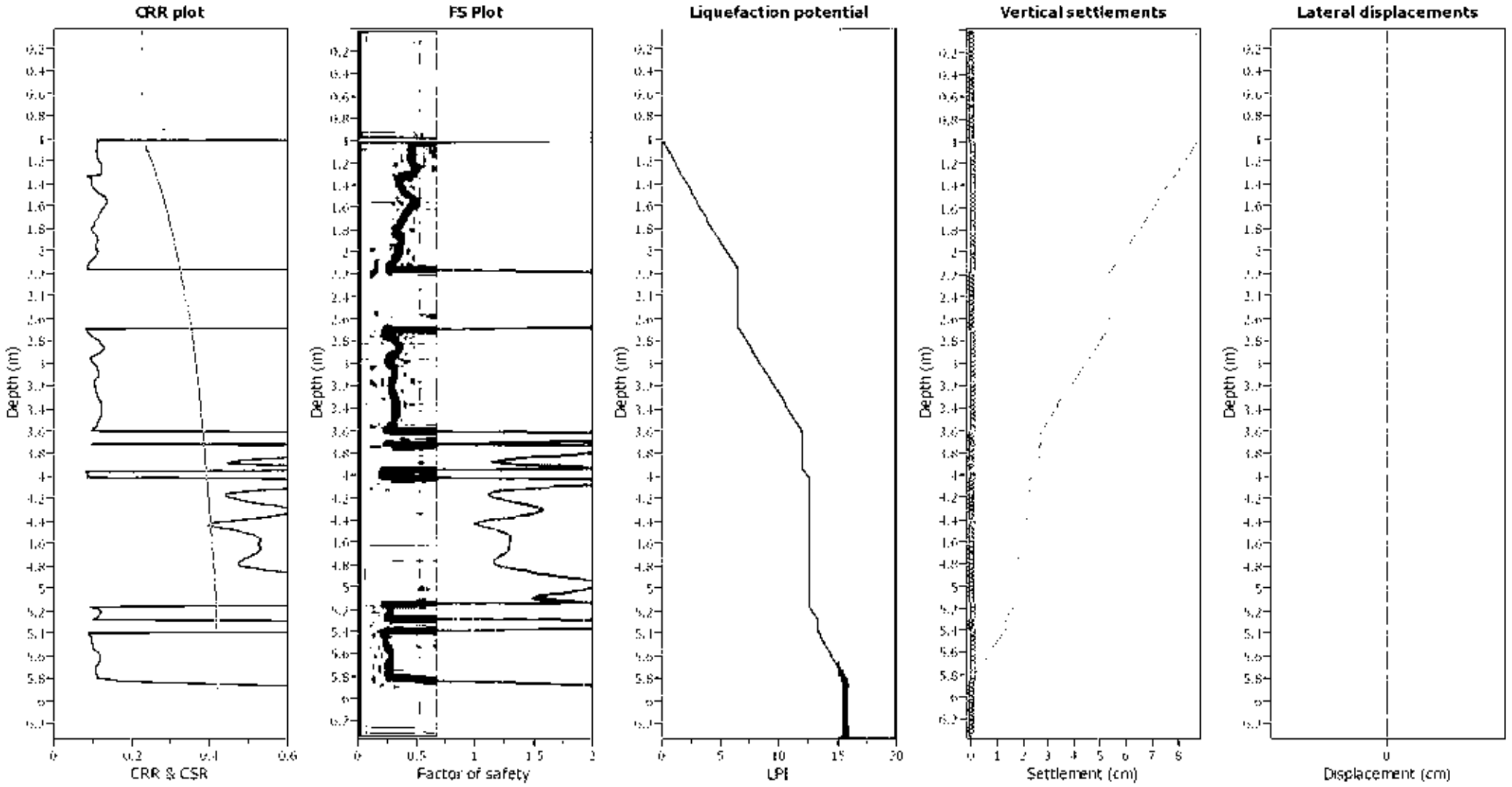
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 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.):	1.00 m	Fill weight:	N/A
Liquefaction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.00 m	Fill height:	N/A	Limit depth:	N/A

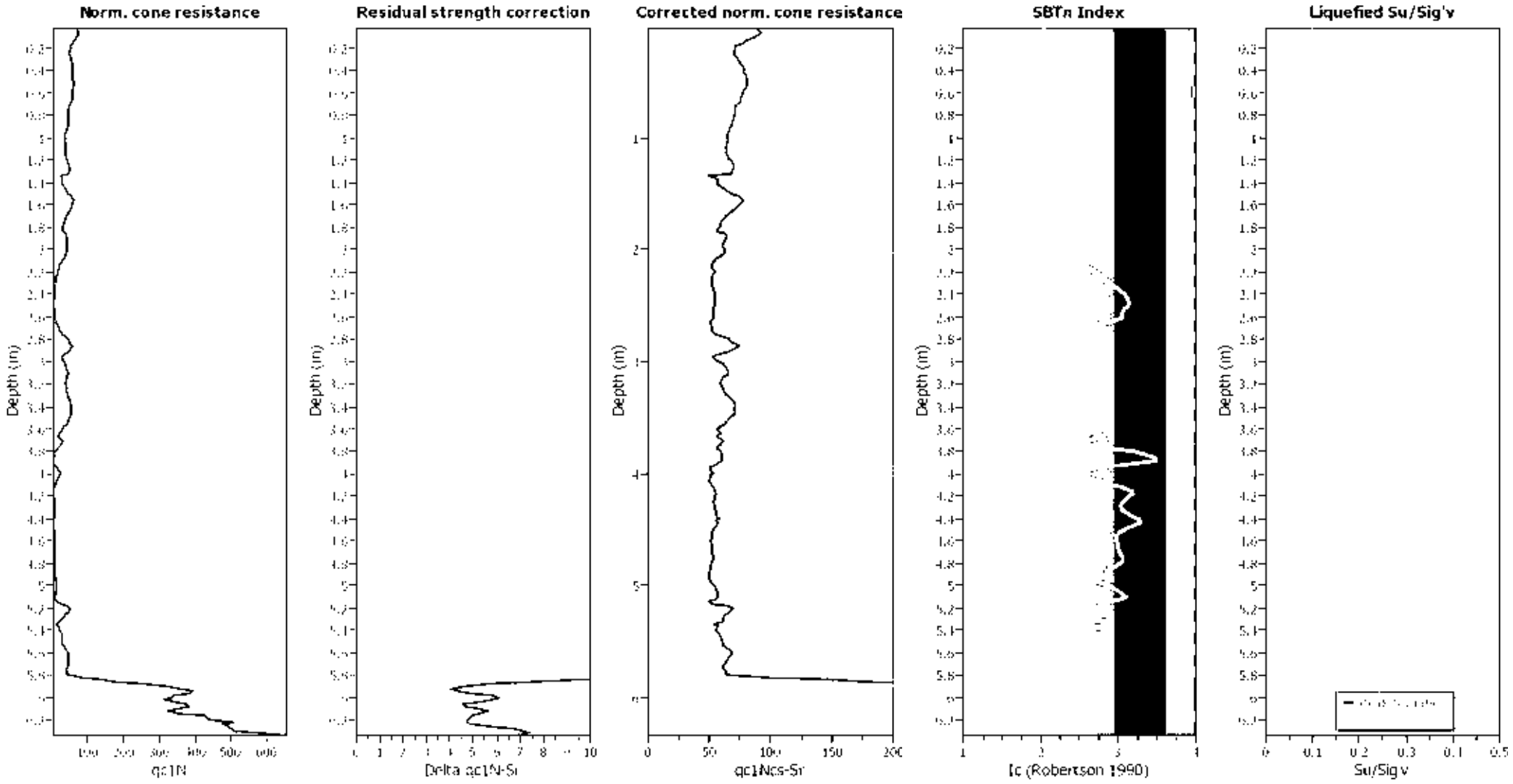
F.S. color scheme

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

LPI color scheme

- ☐ Very high risk
- ☐ High risk
- ☐ Low risk

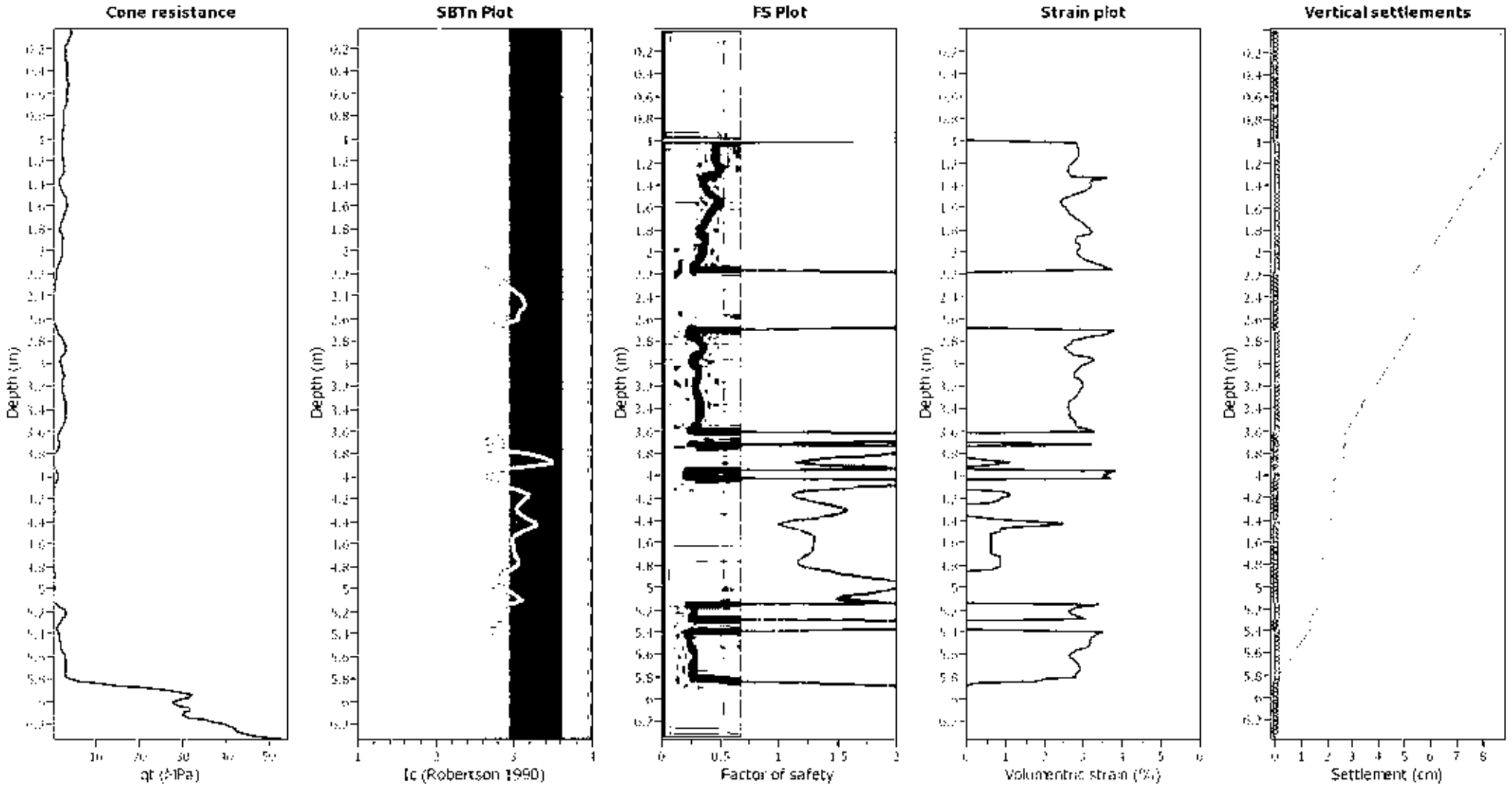
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.00 m	Fill height:	N/A	Limit depth:	N/A

Estimation of post-earthquake settlements



Abbreviations

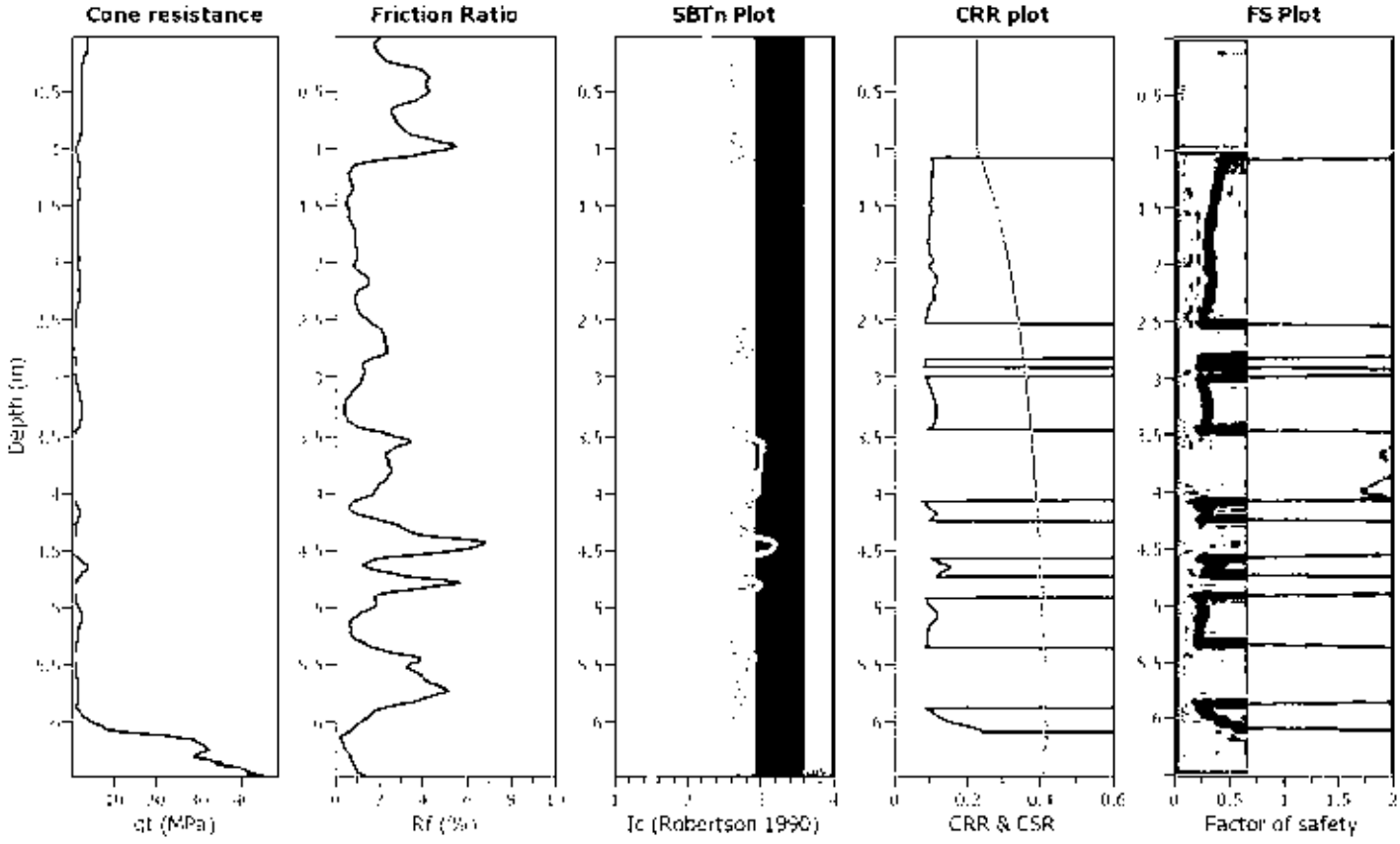
qt	Total cone resistance (cone resistance q corrected for pore water effects)
Ic	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumetric strain	Post liquefaction volumetric strain

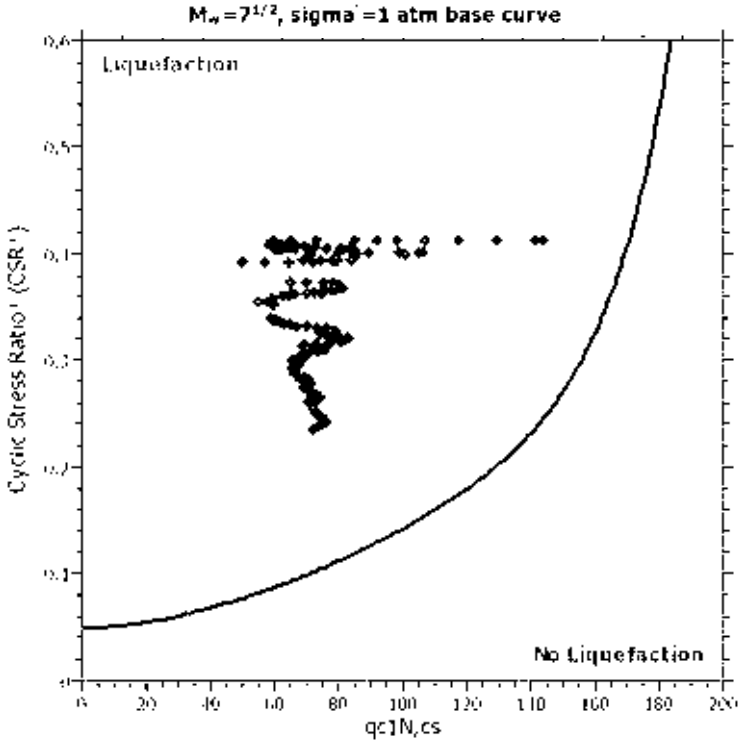
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

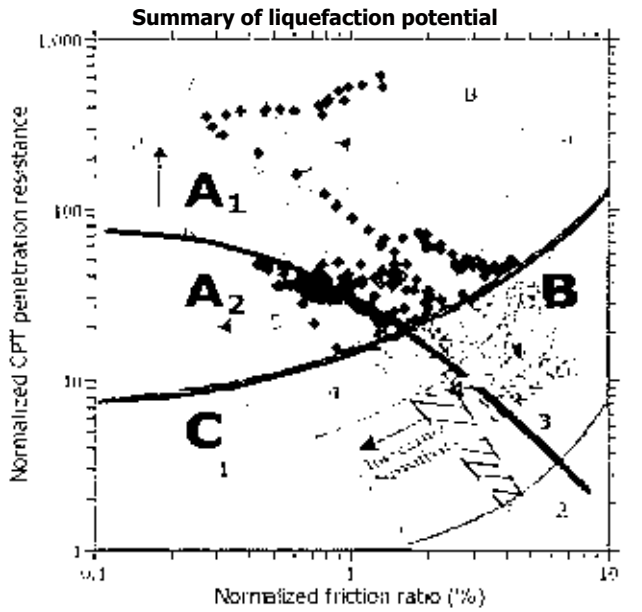
CPT file : CPT04_163bHalswellJunctionRd

Input parameters and analysis data

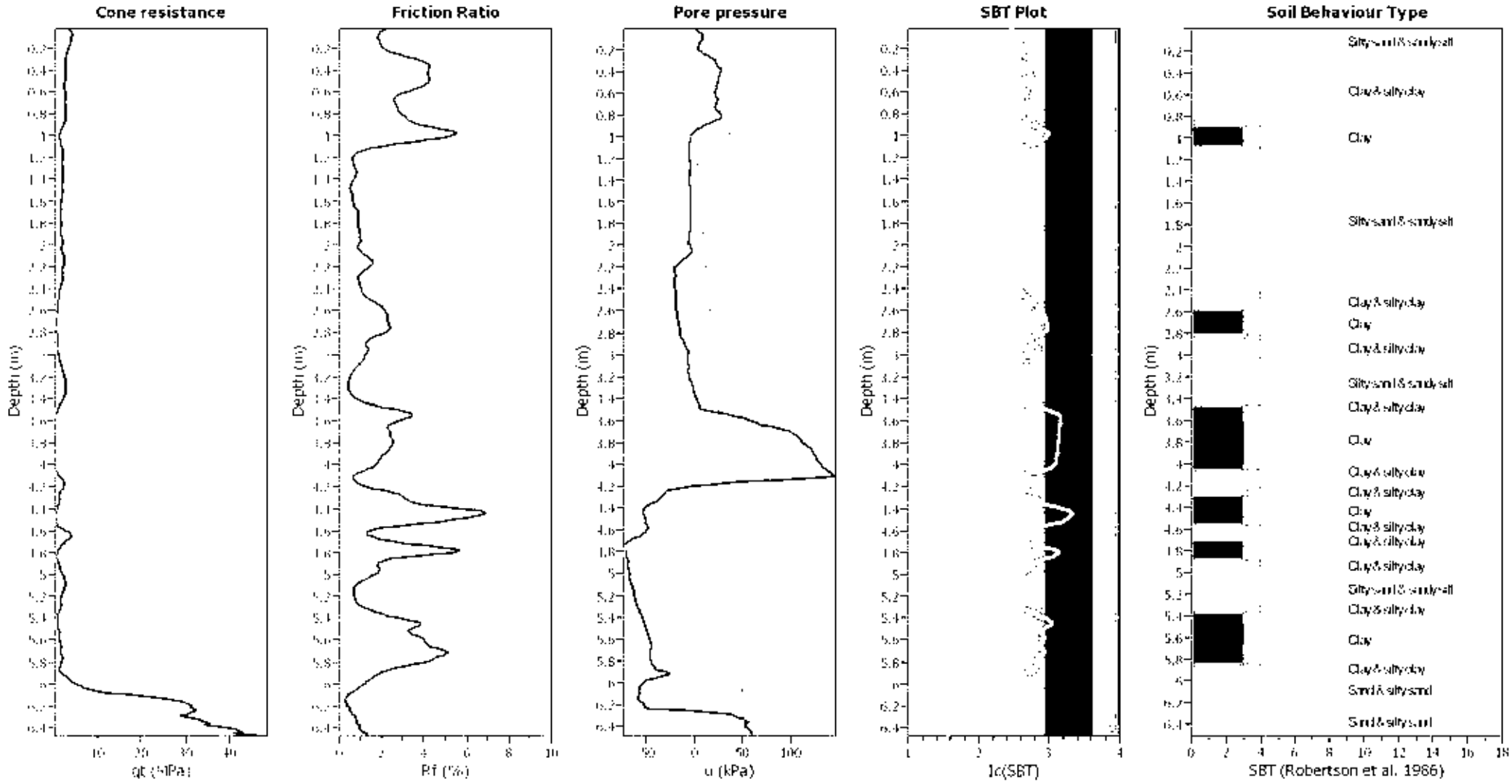
Analysis method:	I&B (2008)	G.W.T. (in-situ):	1.00 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	I&B (2008)	G.W.T. (earthq.):	1.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



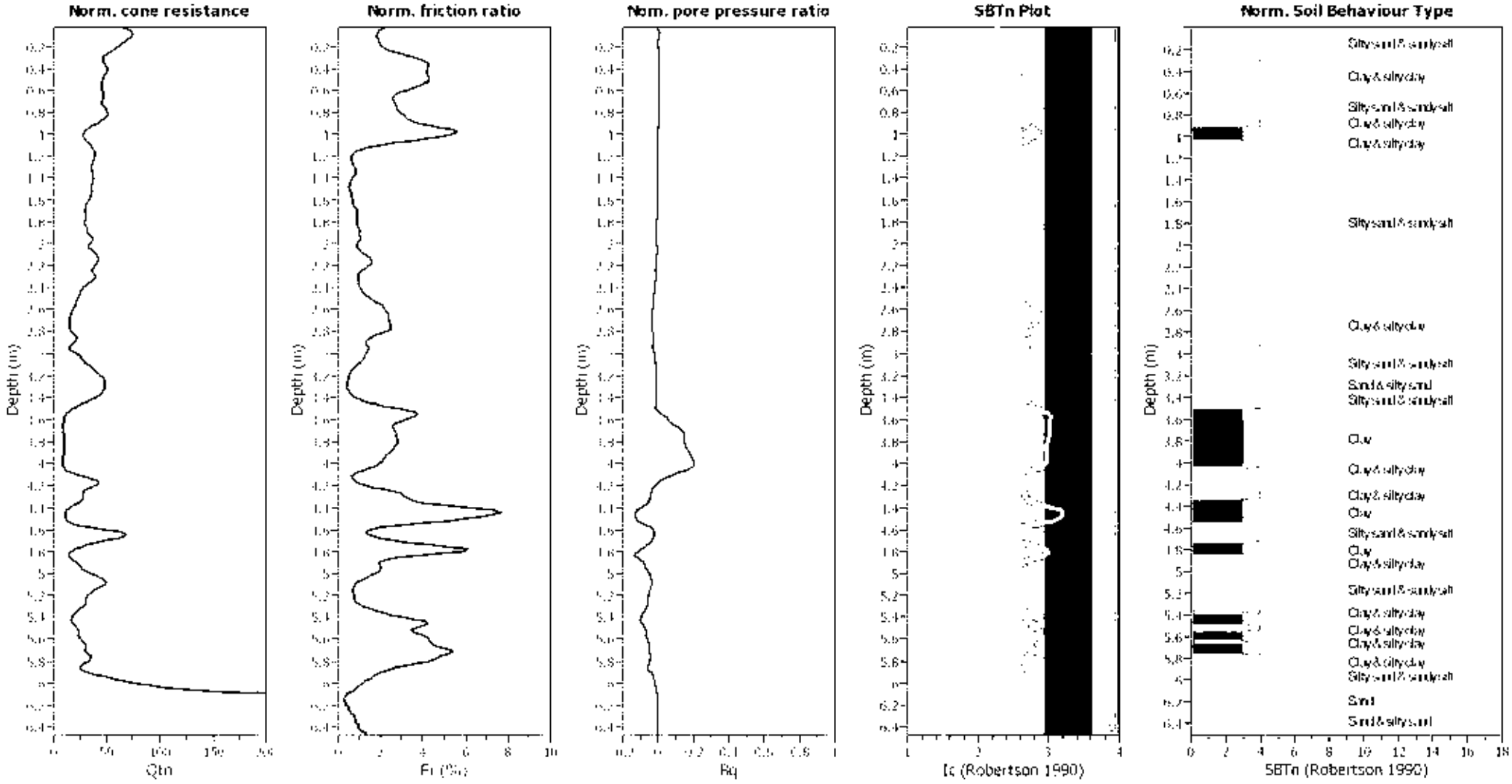
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 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

CPT basic interpretation plots (normalized)



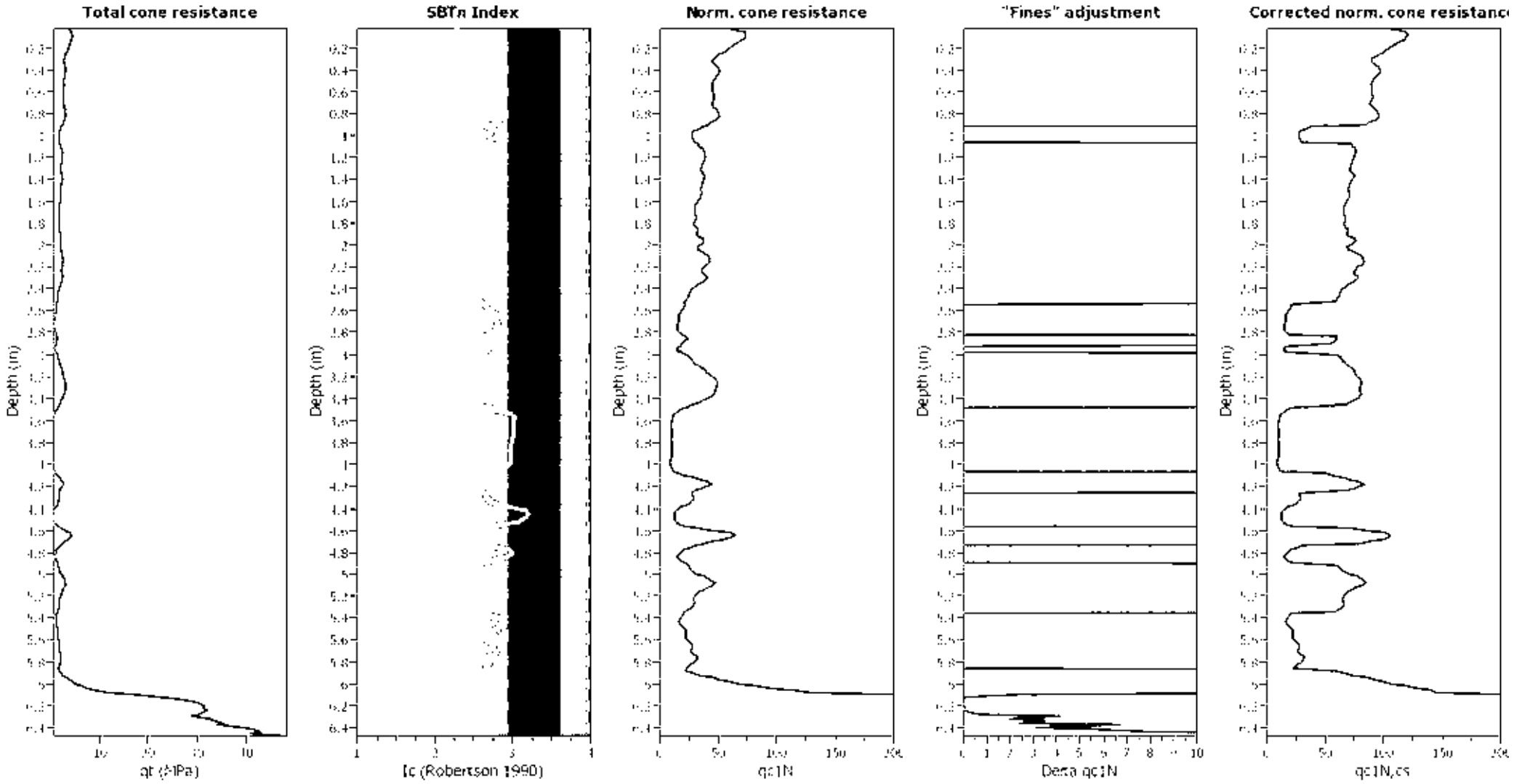
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

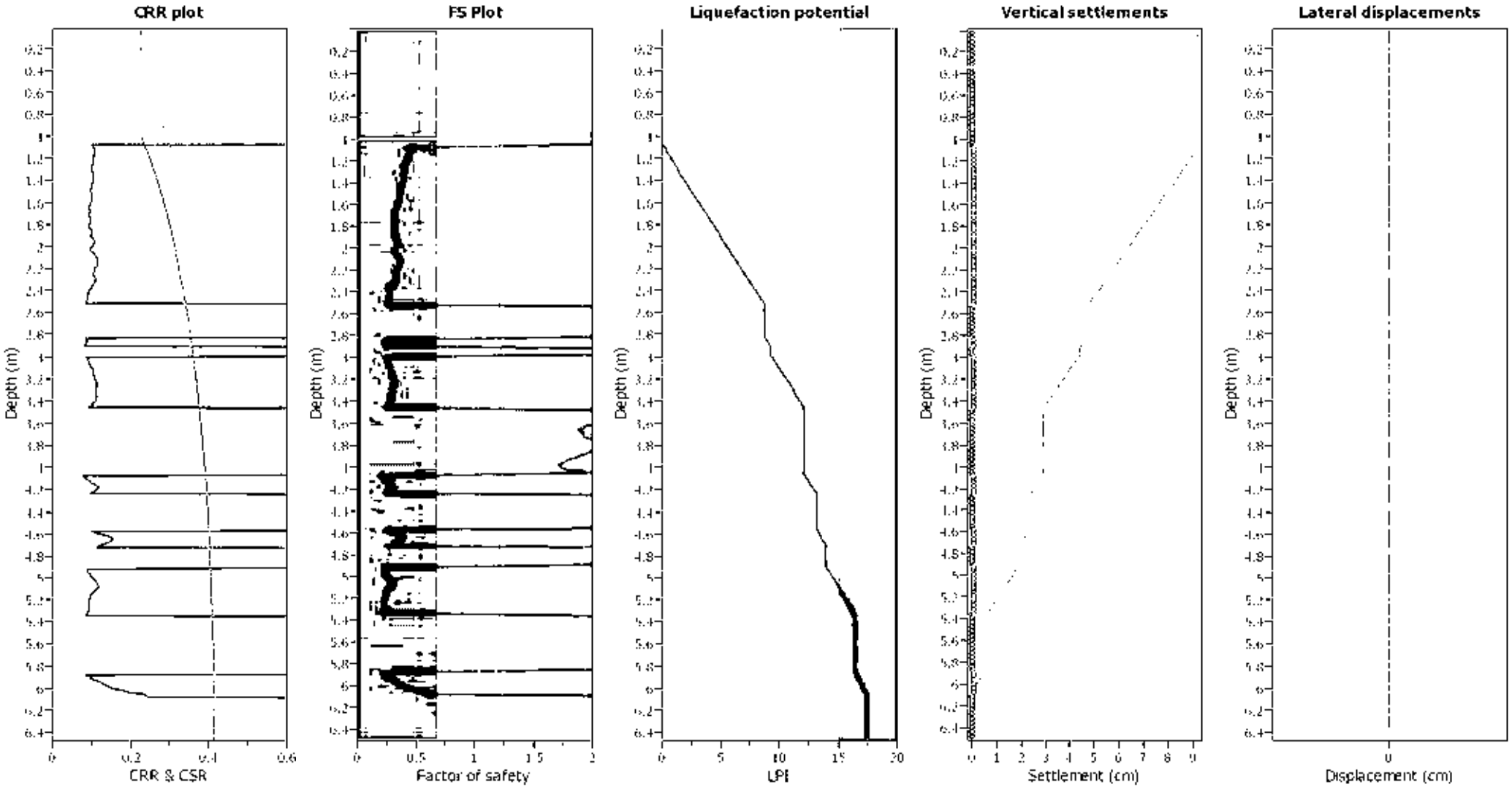
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 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.):	1.00 m	Fill weight:	N/A
Liquefaction correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 m	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

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

LPI color scheme

- ☐ Very high risk
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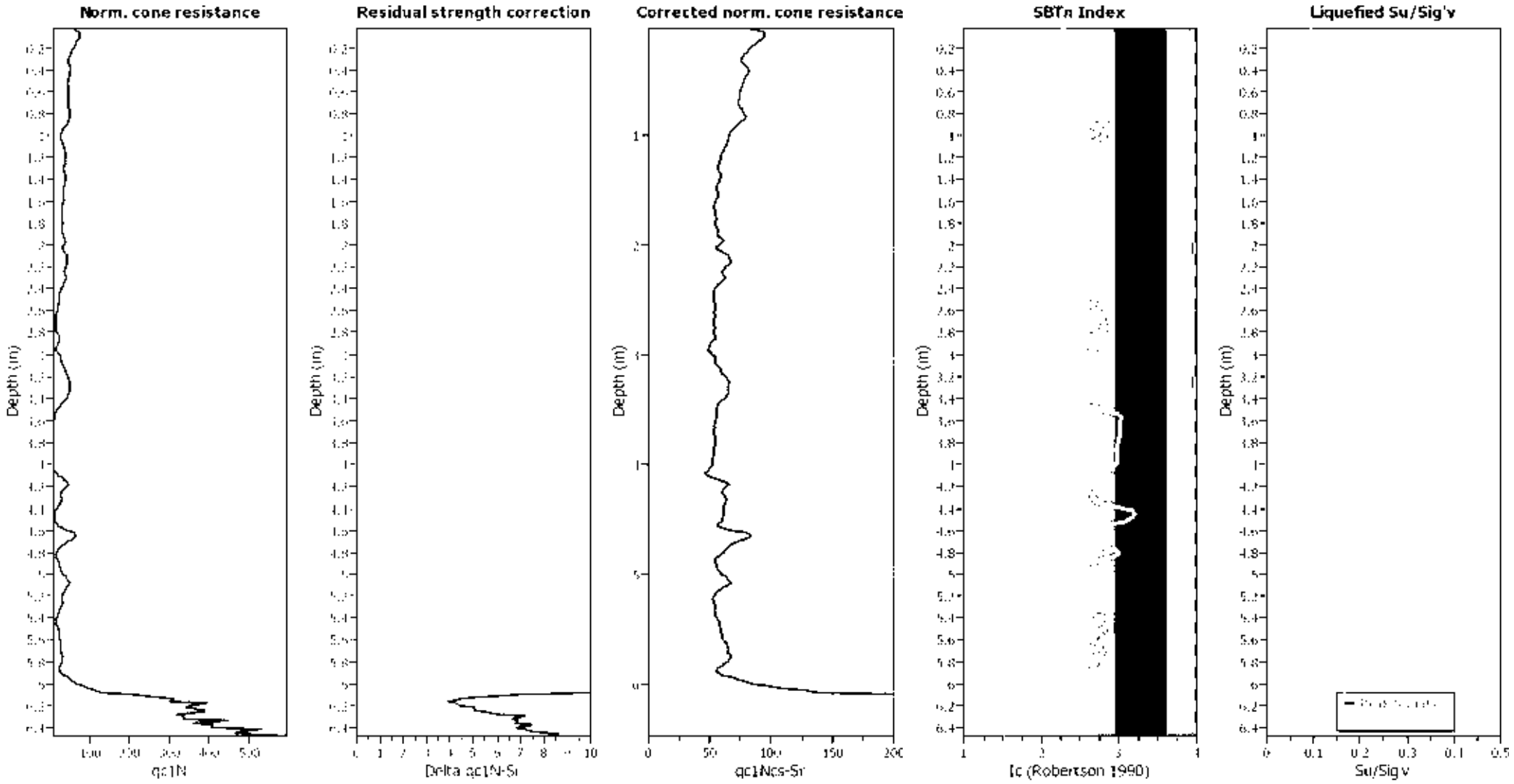
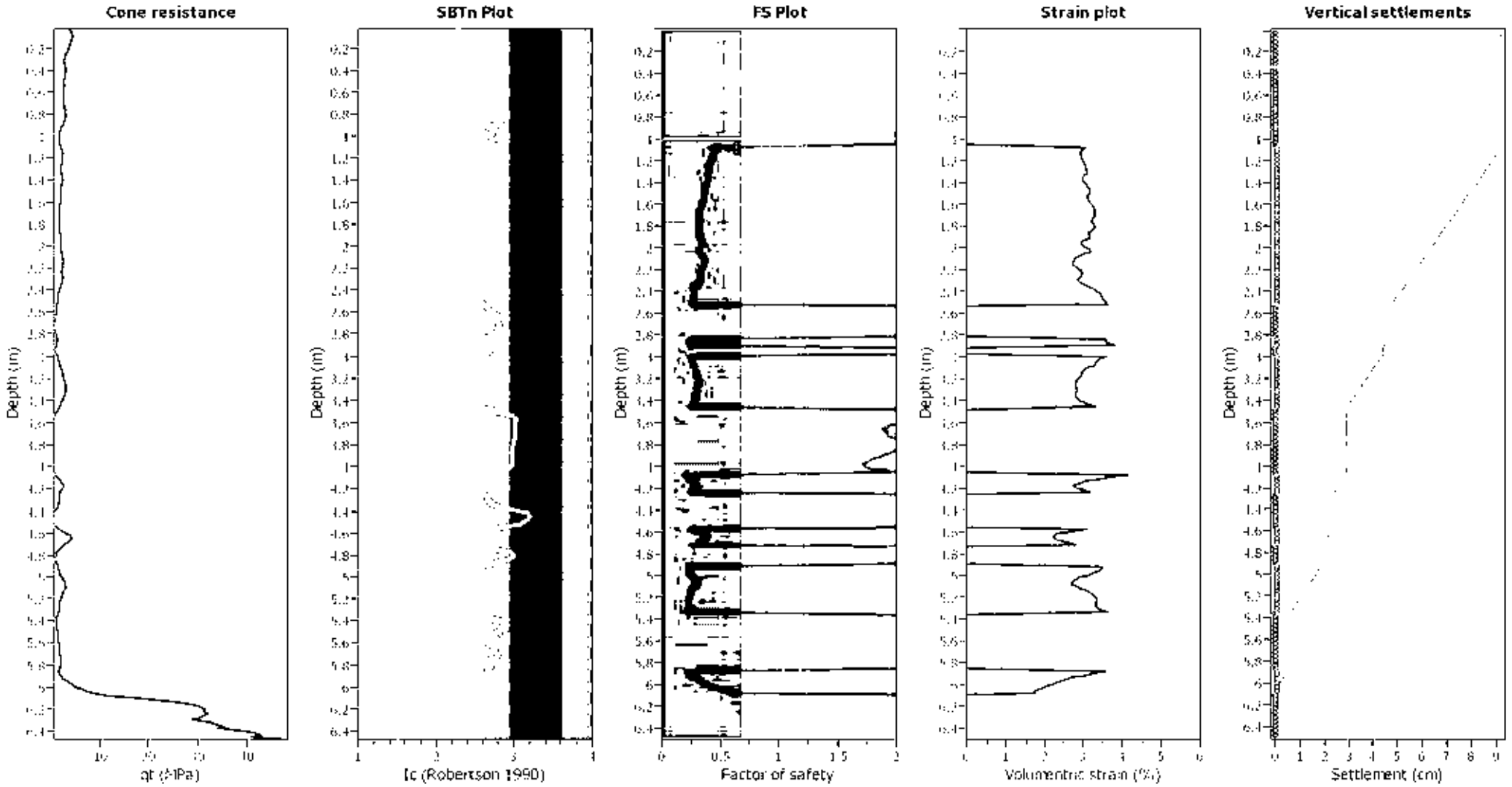
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Liquefaction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 m	Fill height:	N/A	Limit depth	N/A

Estimation of post-earthquake settlements



Abbreviations

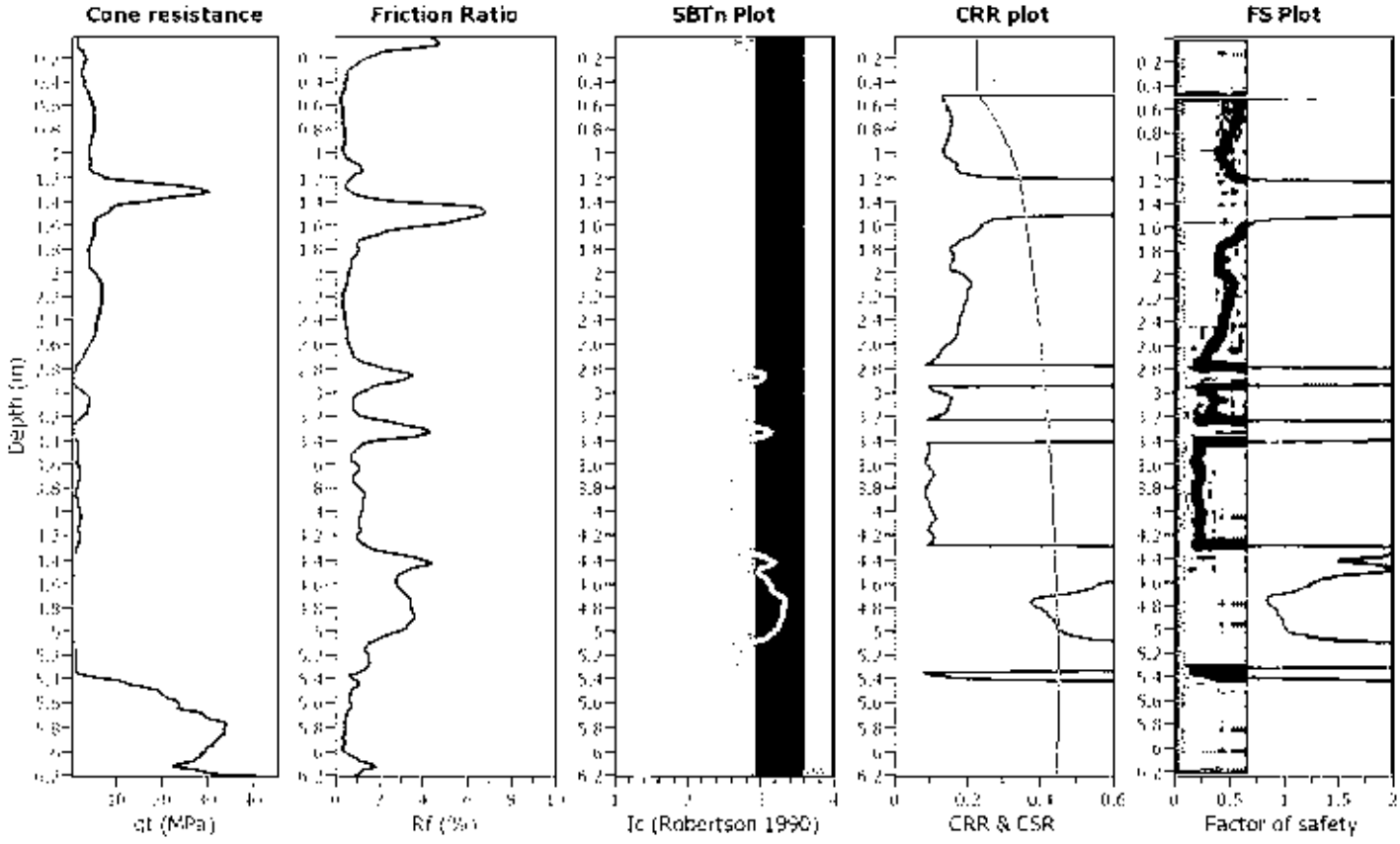
qt:	Total cone resistance (cone resistance q corrected for pore water effects)
Ic:	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumentric strain:	Post liquefaction volumentric strain

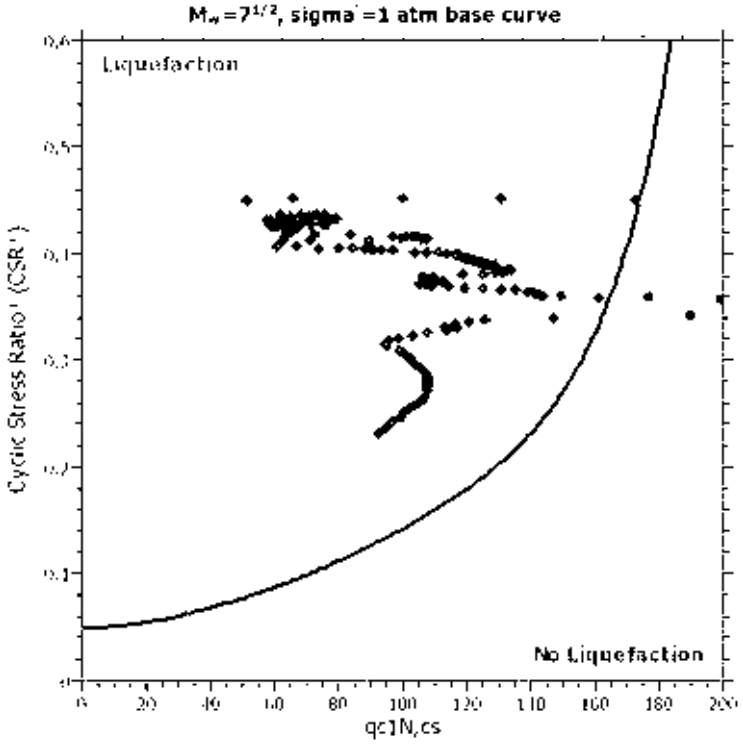
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

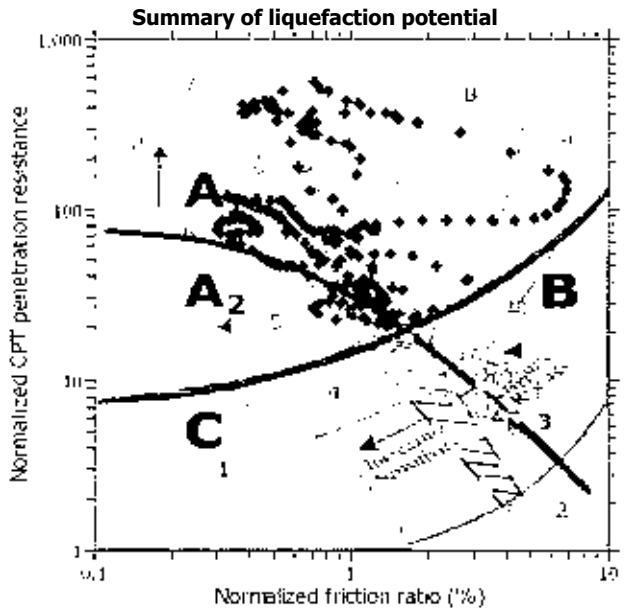
CPT file : CPT05_163bHalswellJunctionRd

Input parameters and analysis data

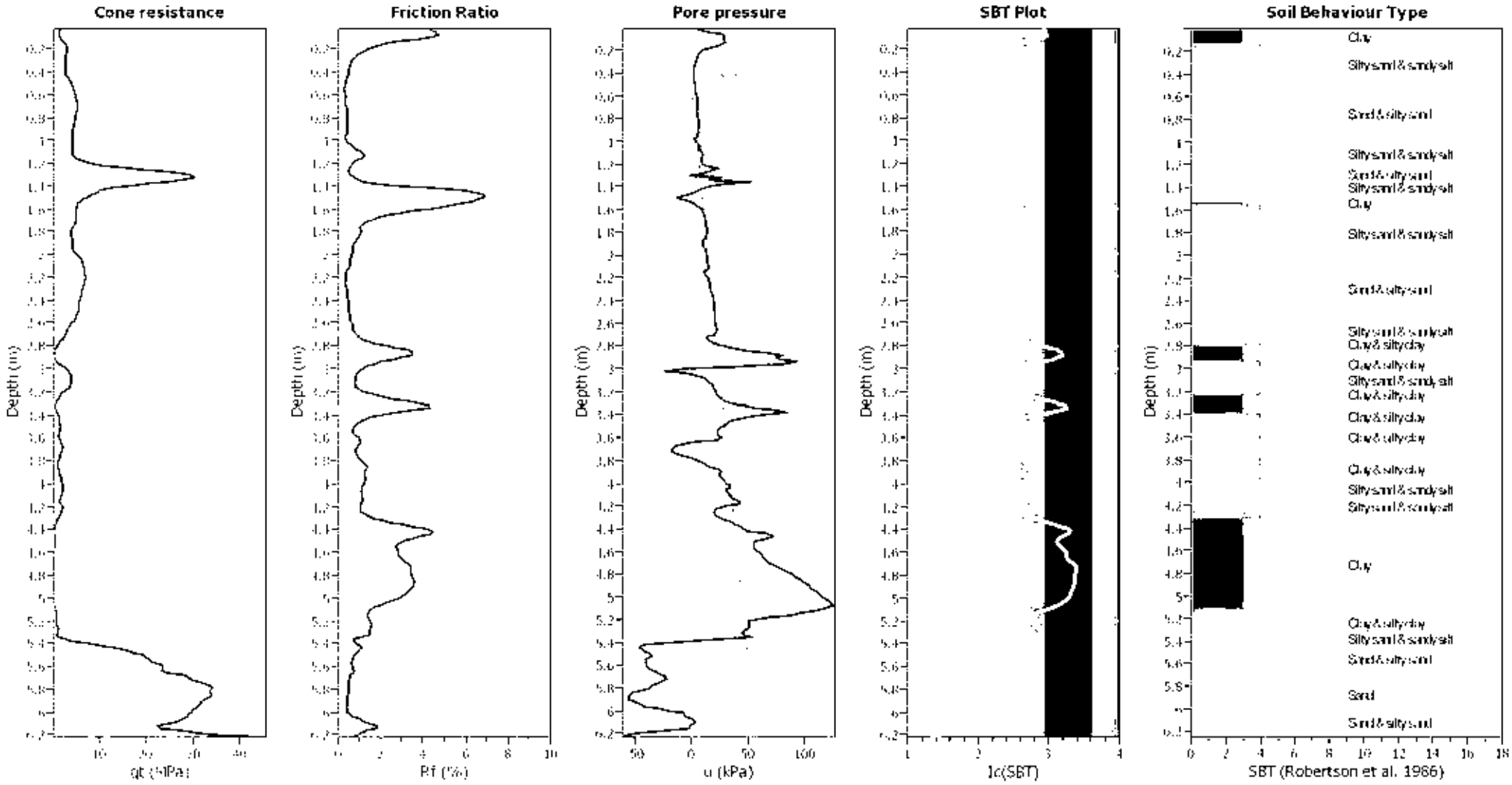
Analysis method:	I&B (2008)	G.W.T. (in-situ):	0.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	I&B (2008)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



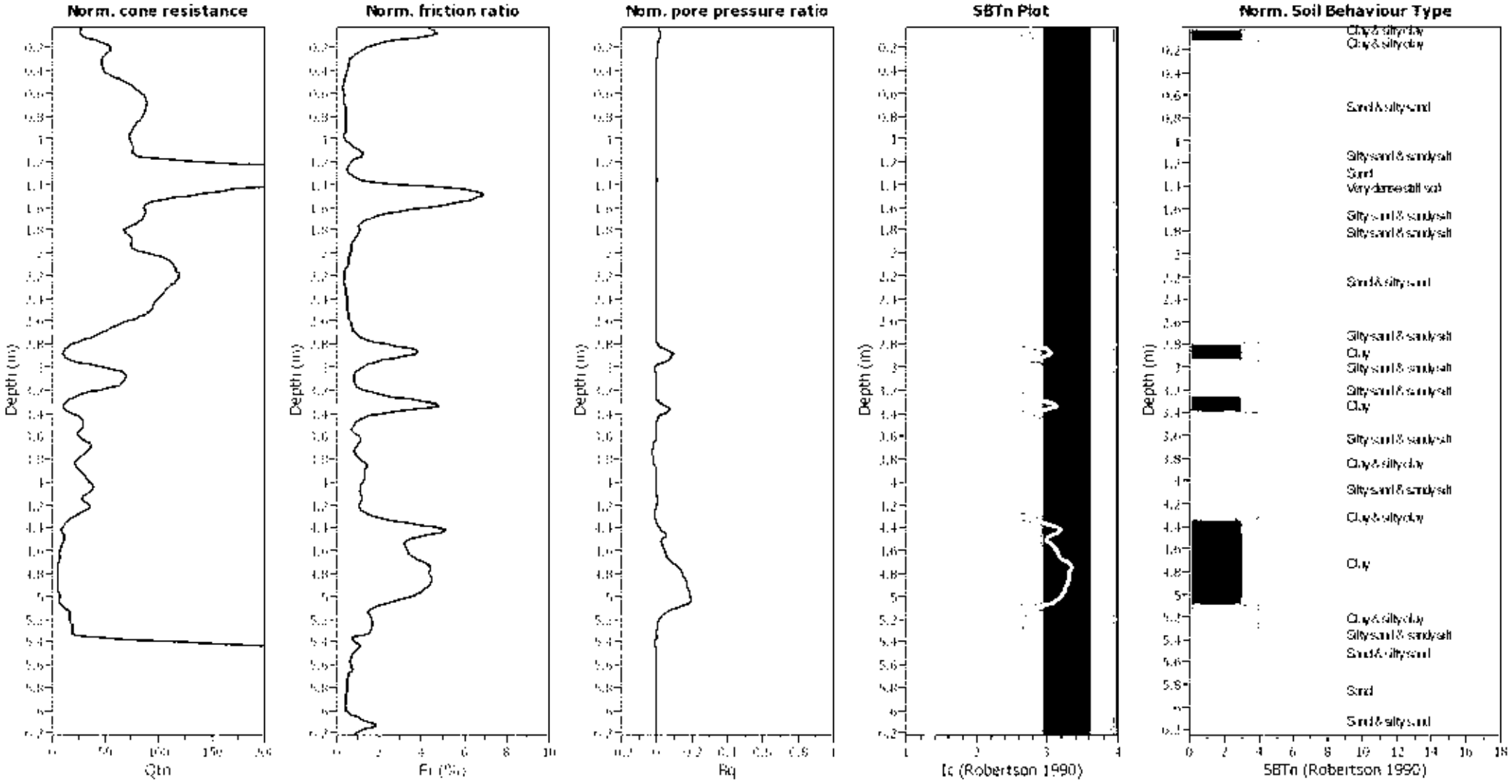
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 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

CPT basic interpretation plots (normalized)



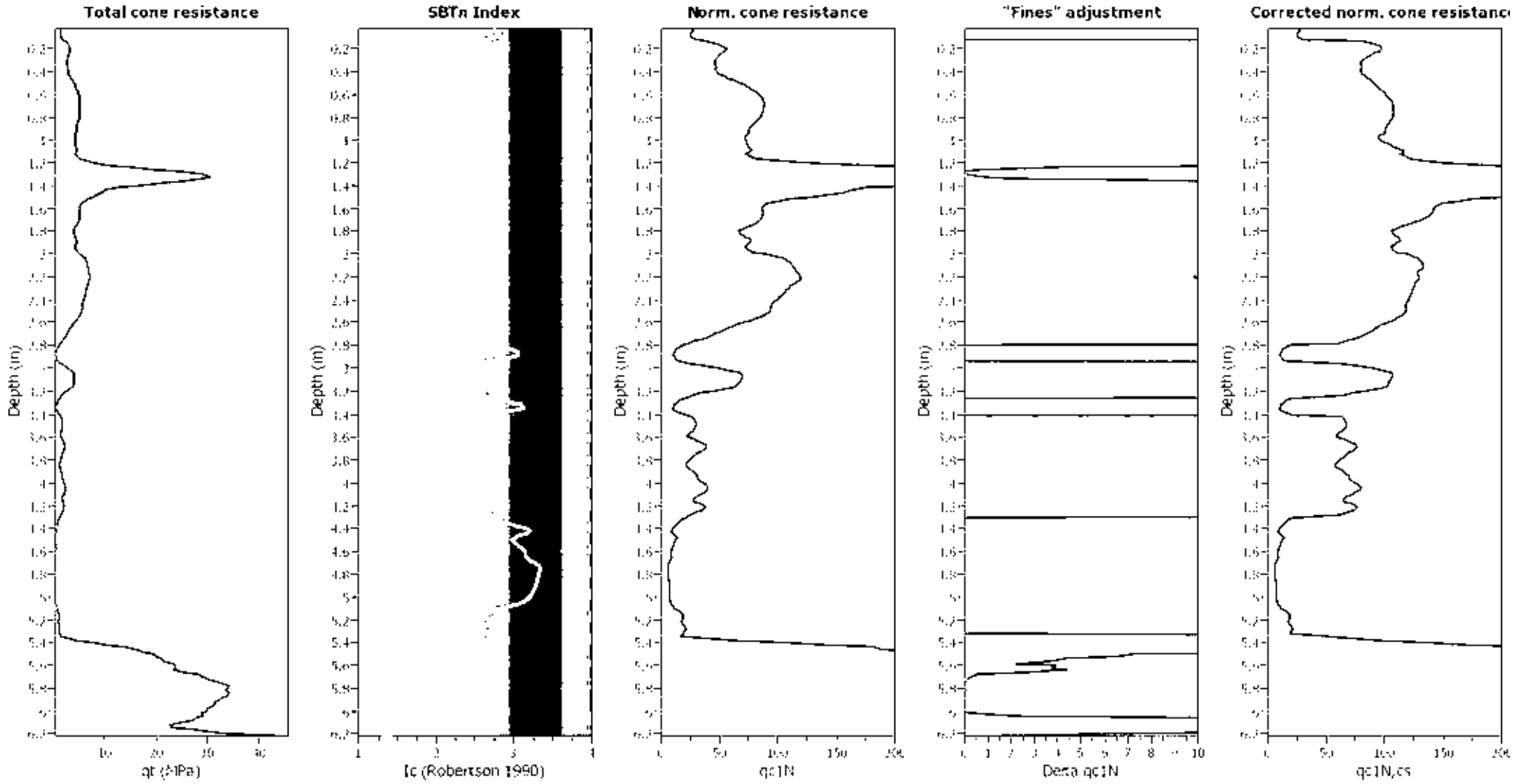
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	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	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

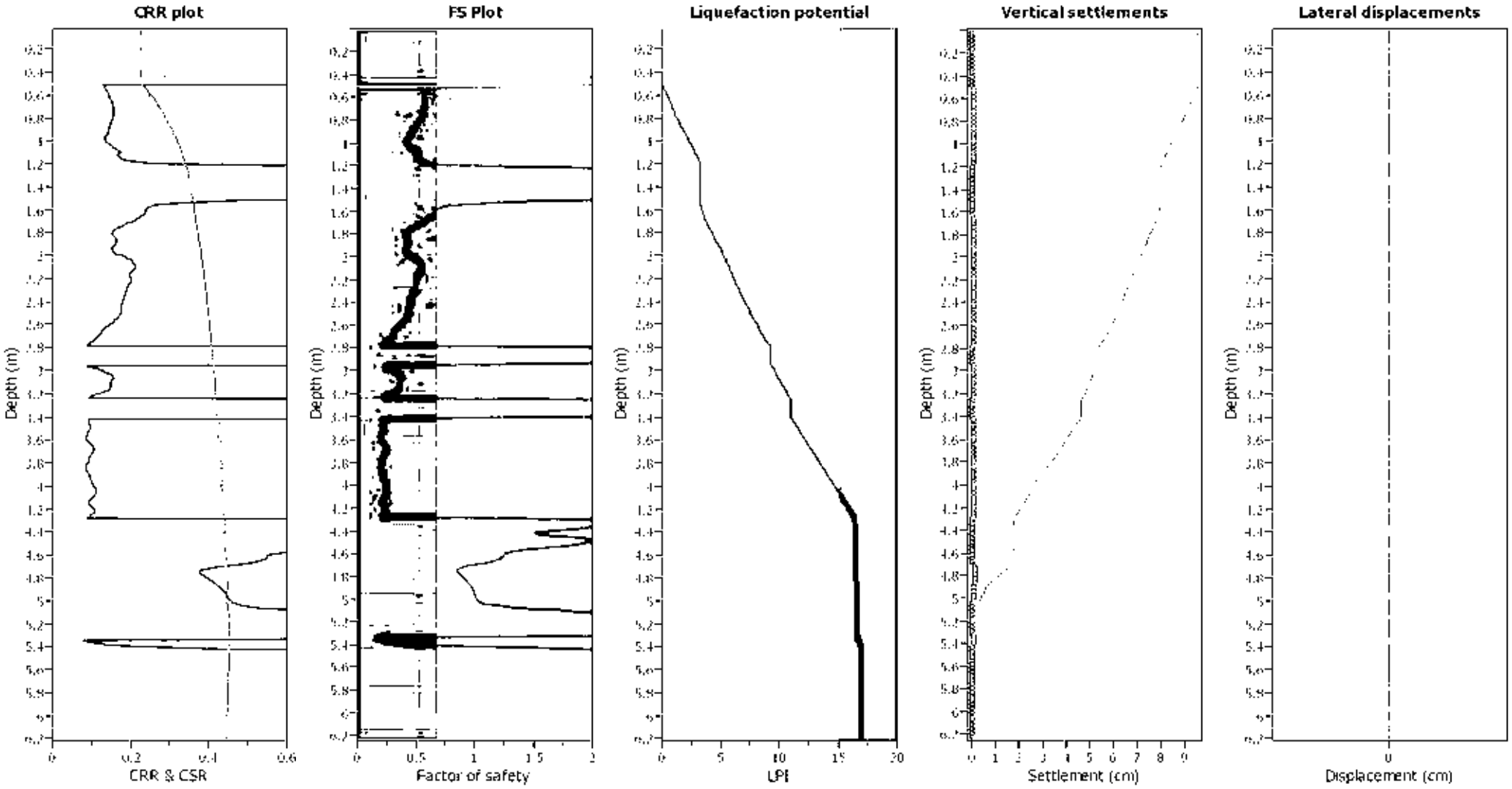
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	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
Liquefaction correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 m	Fill height:	N/A	Limit depth:	N/A

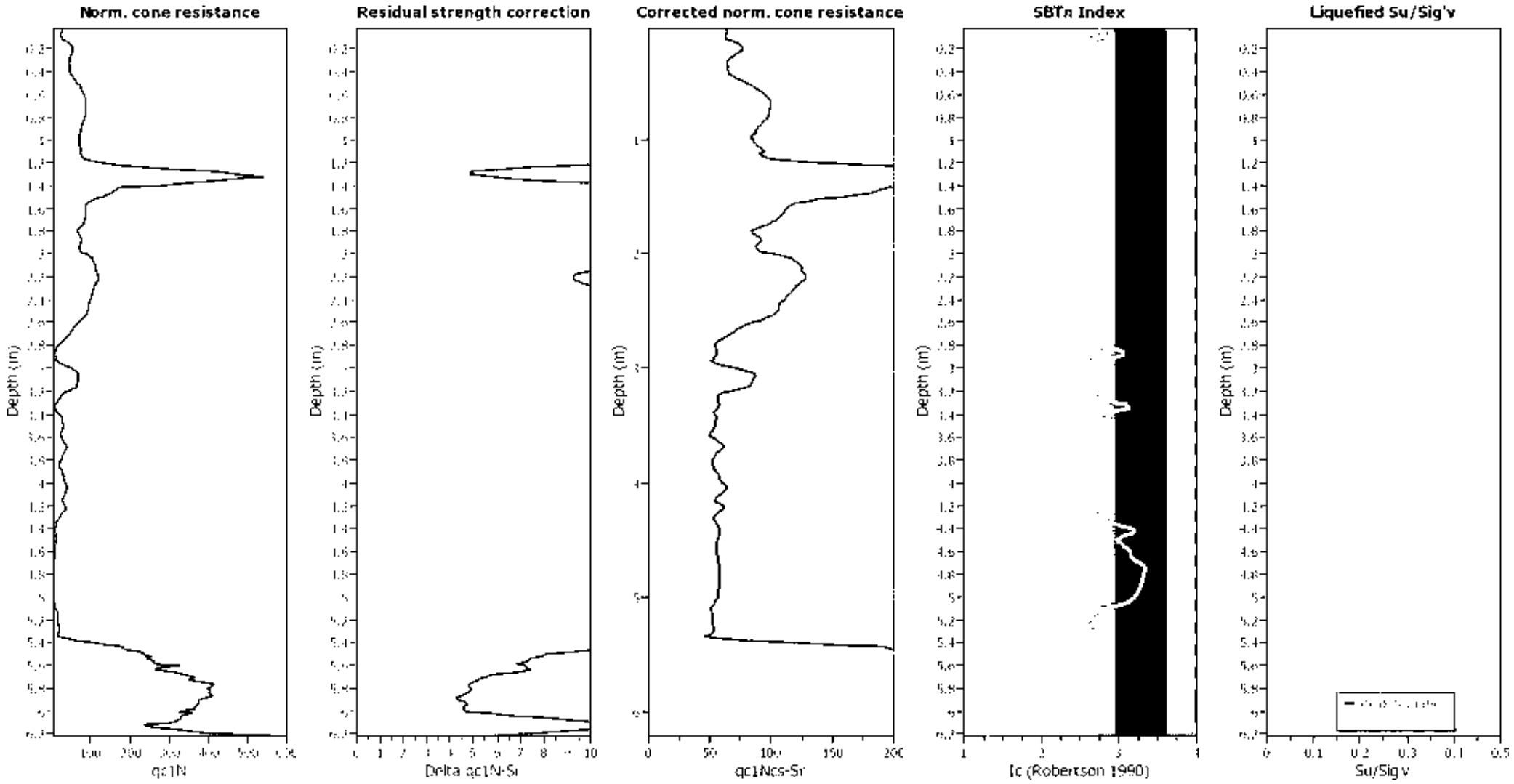
F.S. color scheme

- ☐ 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

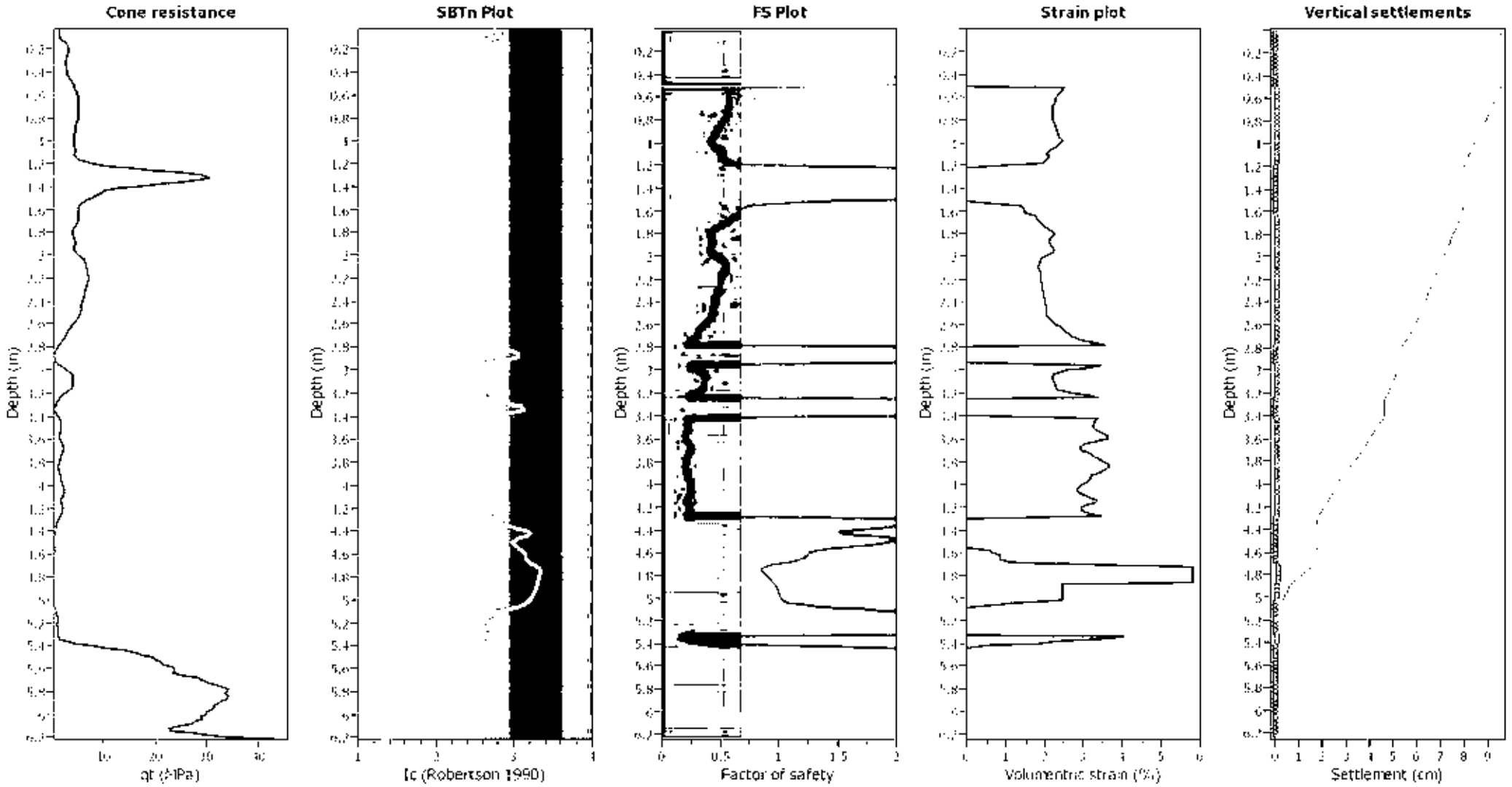
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 m	Fill height:	N/A	Limit depth:	N/A

Estimation of post-earthquake settlements



Abbreviations

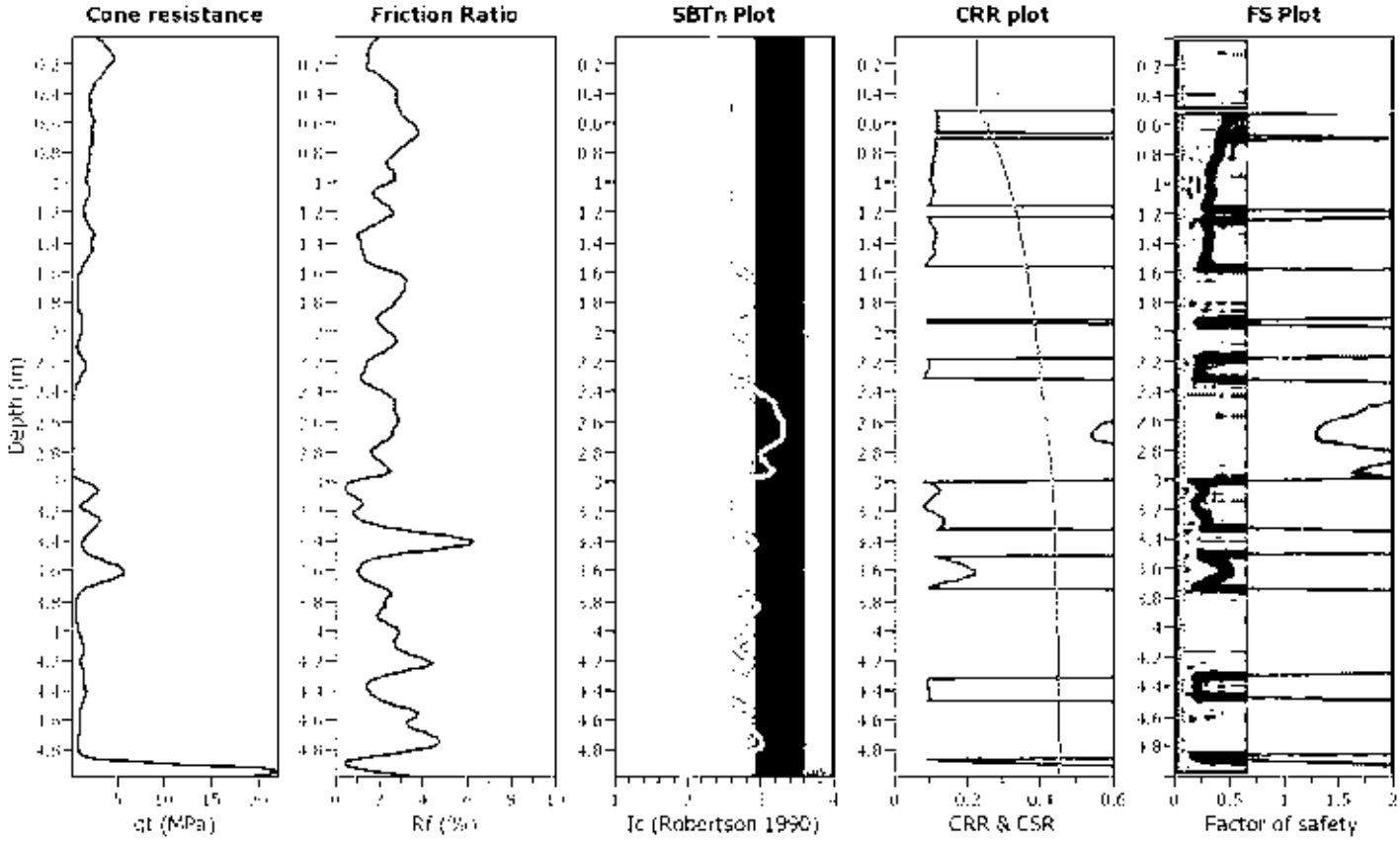
qt:	Total cone resistance (cone resistance q corrected for pore water effects)
Ic:	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumentric strain:	Post liquefaction volumentric strain

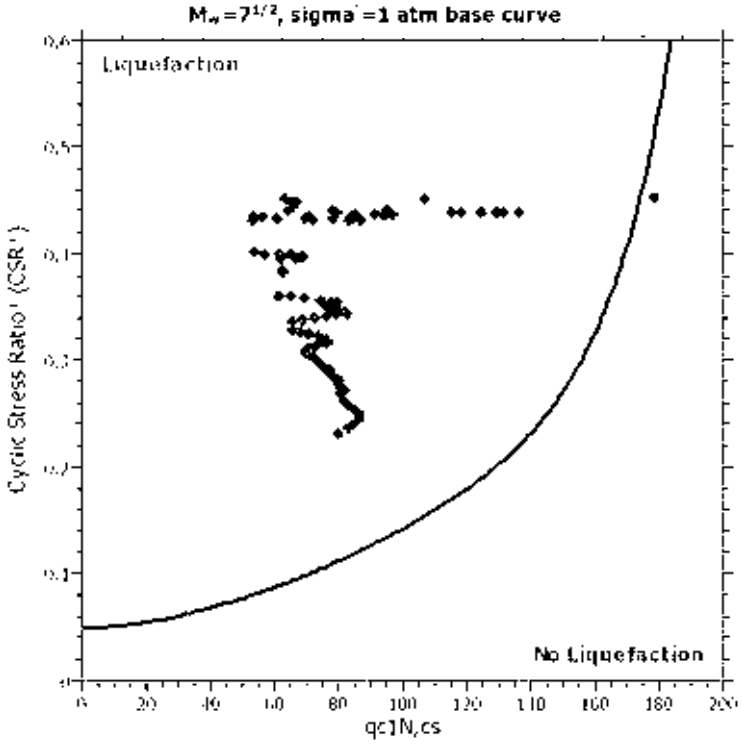
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

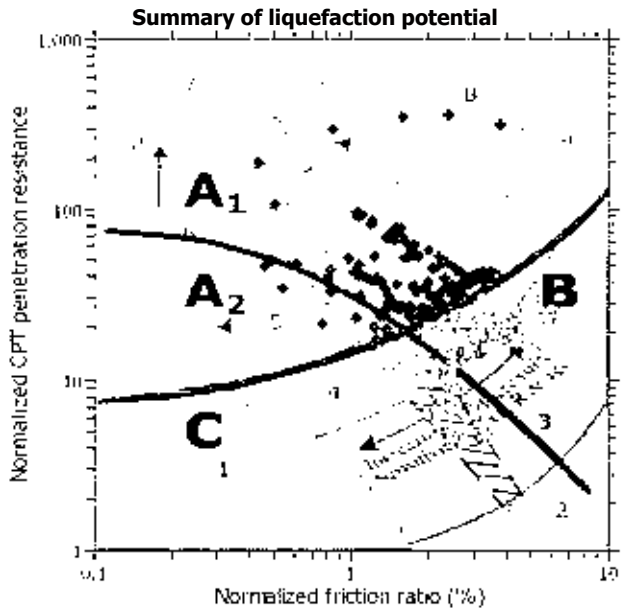
CPT file : CPT06_163bHalswellJunctionRd

Input parameters and analysis data

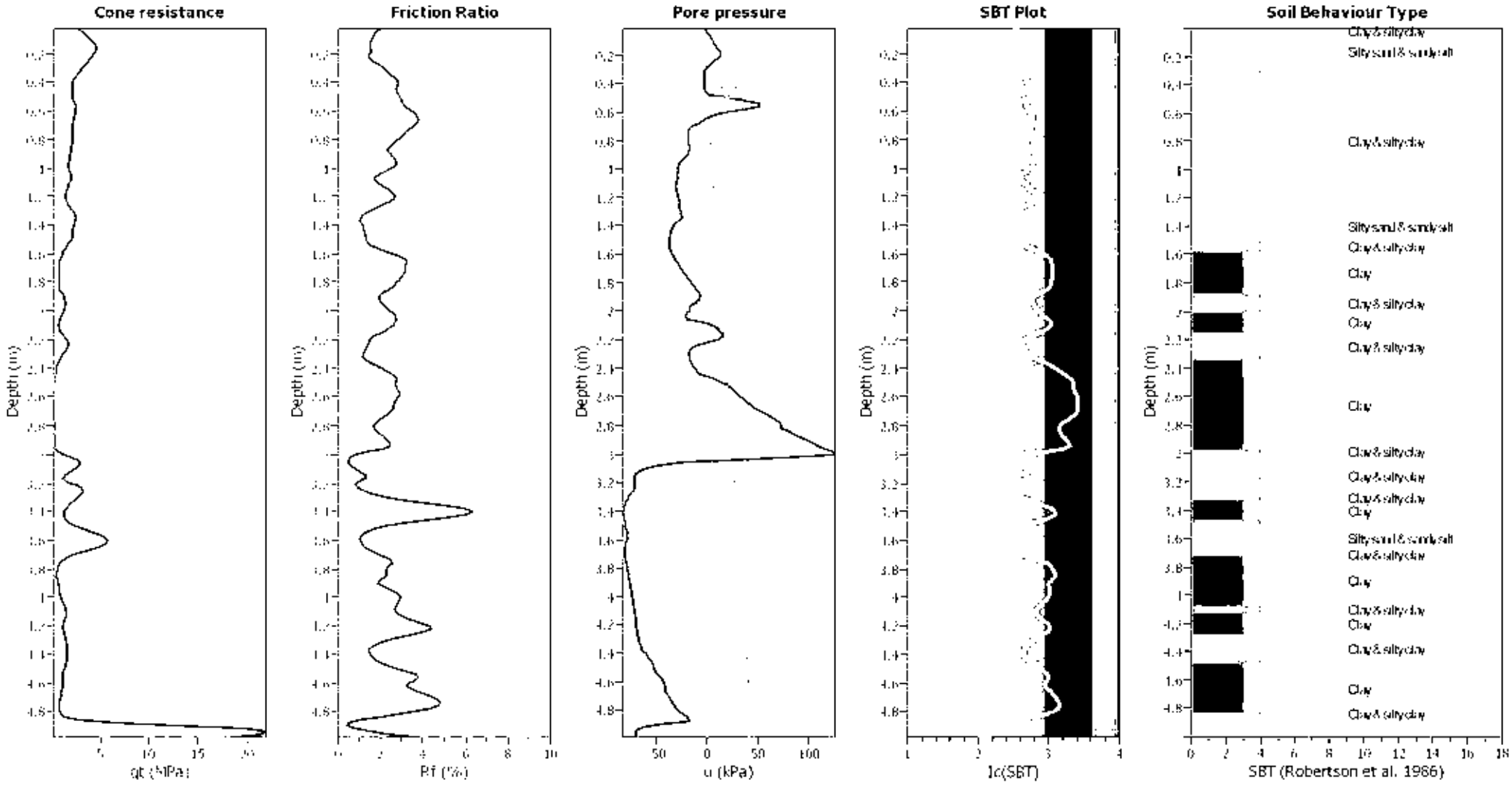
Analysis method:	I&B (2008)	G.W.T. (in-situ):	0.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	I&B (2008)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



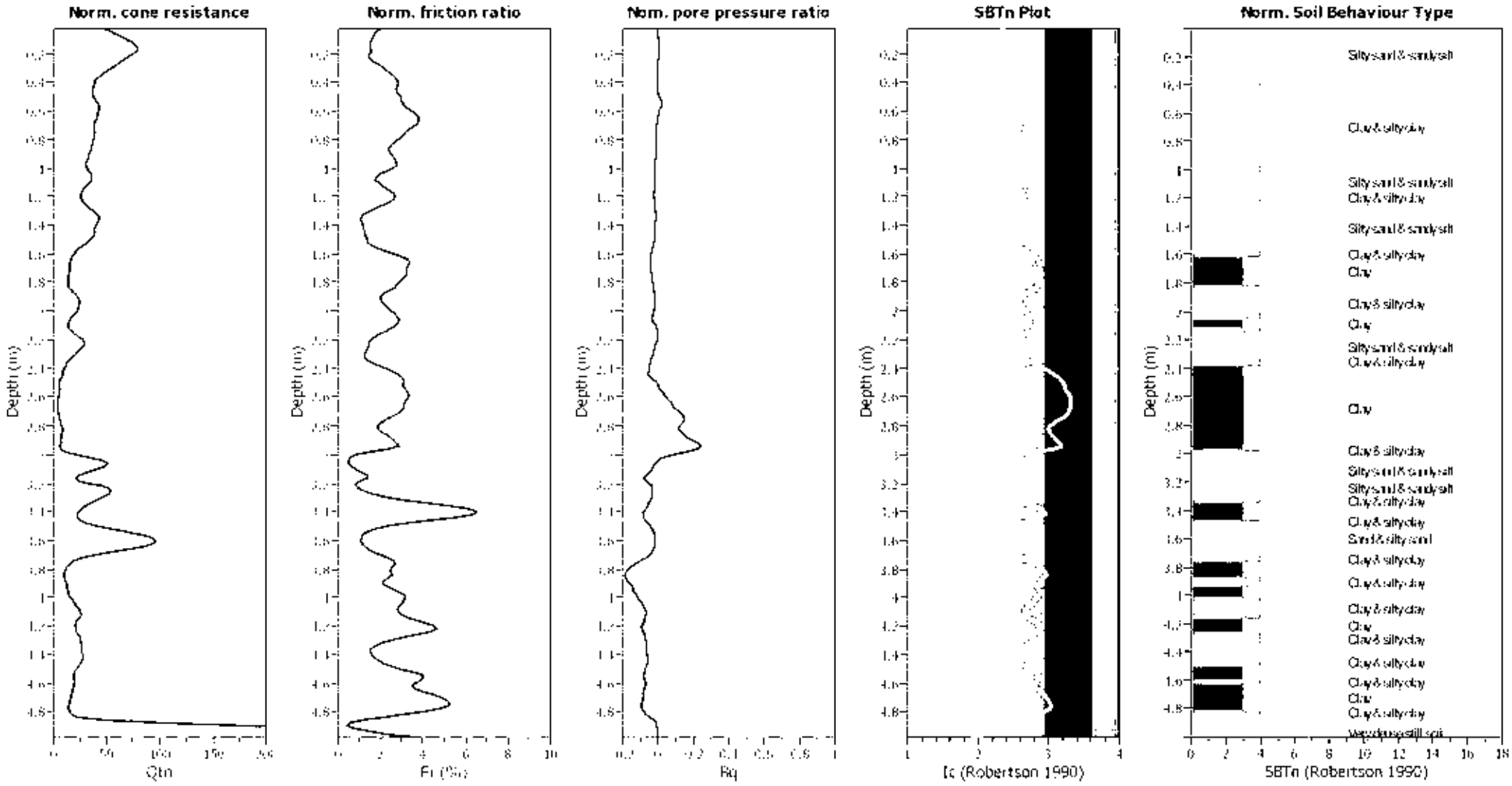
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	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	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

CPT basic interpretation plots (normalized)



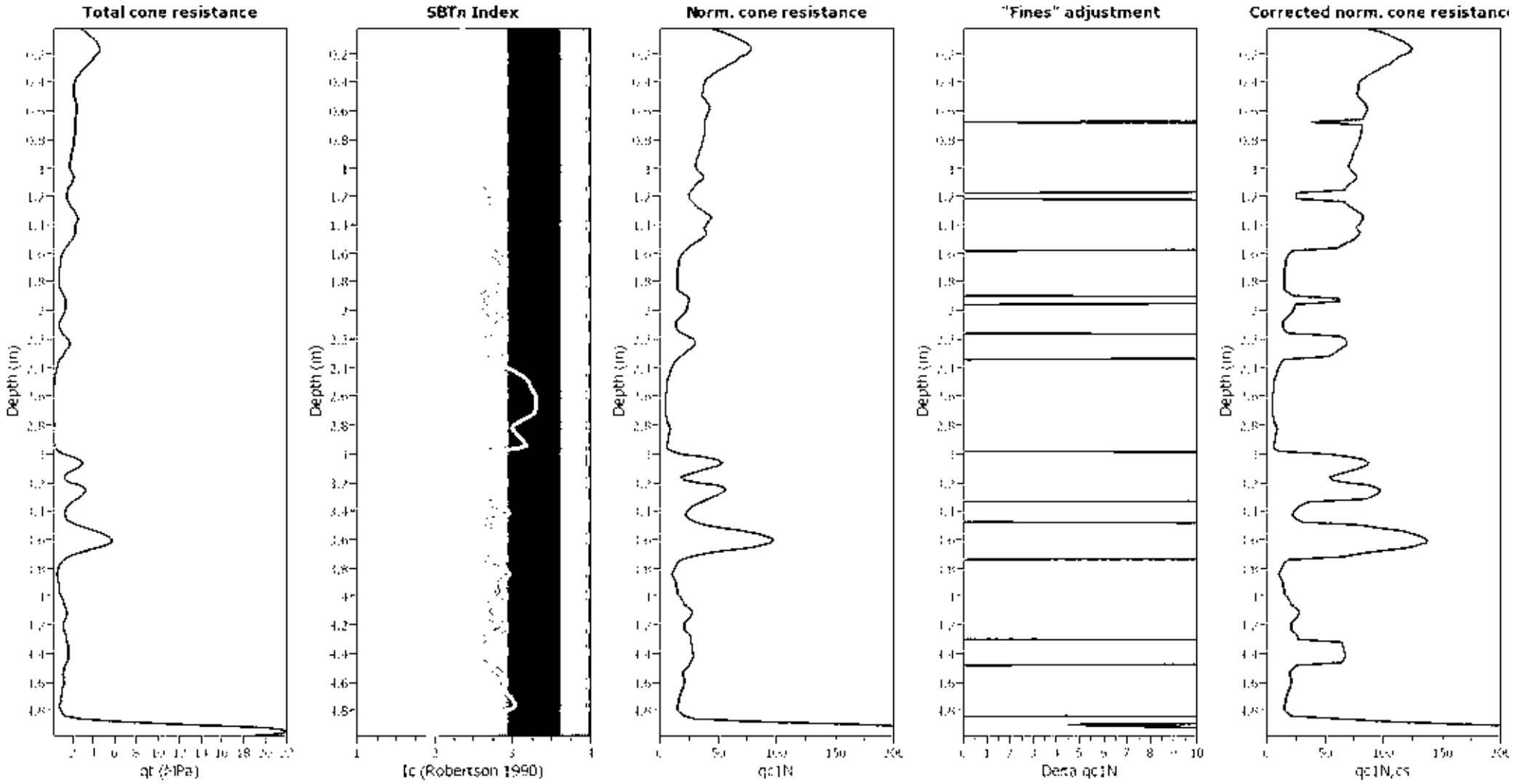
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	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	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

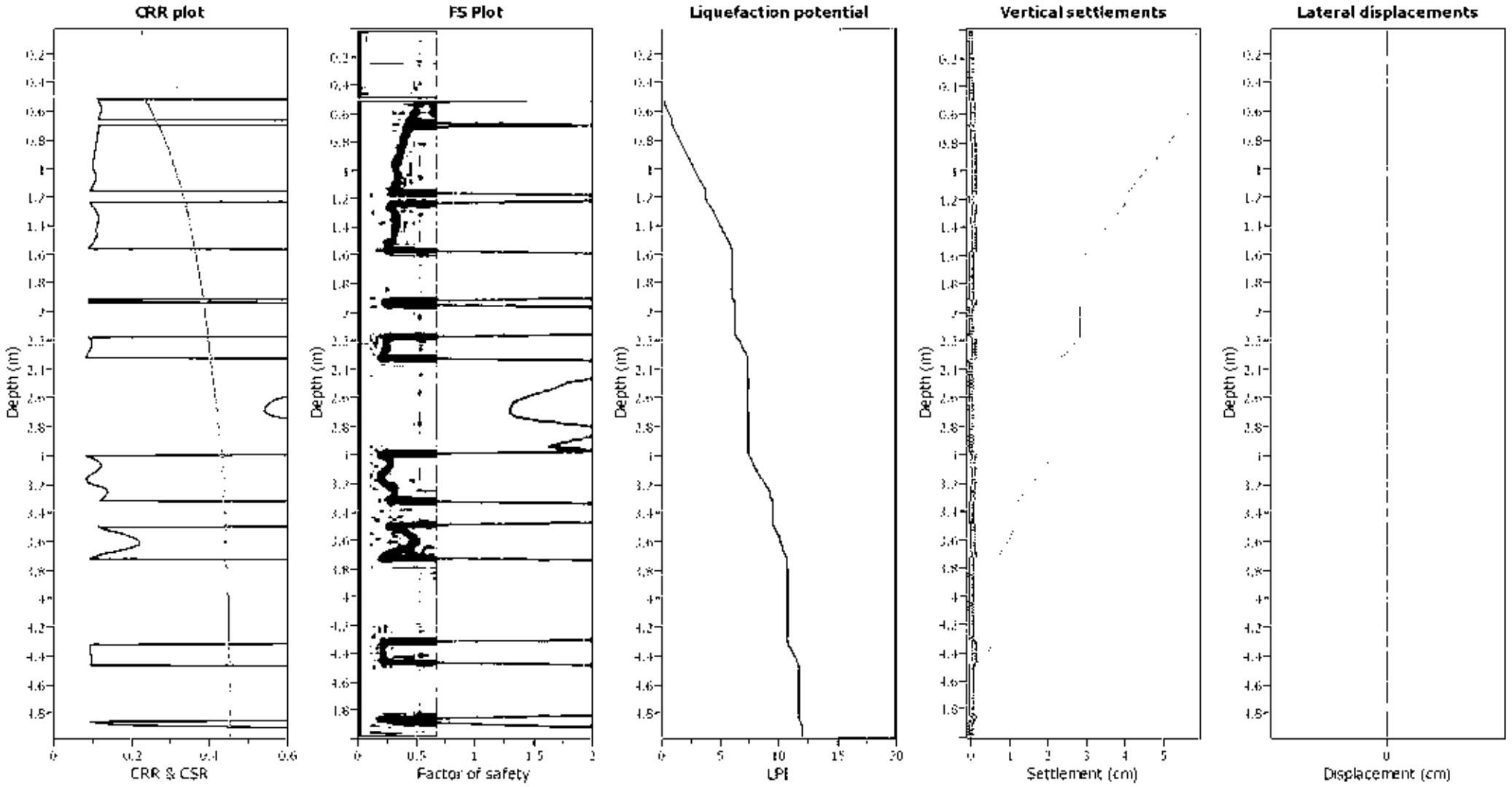
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	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
Liner correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 m	Fill height:	N/A	Limit depth:	N/A

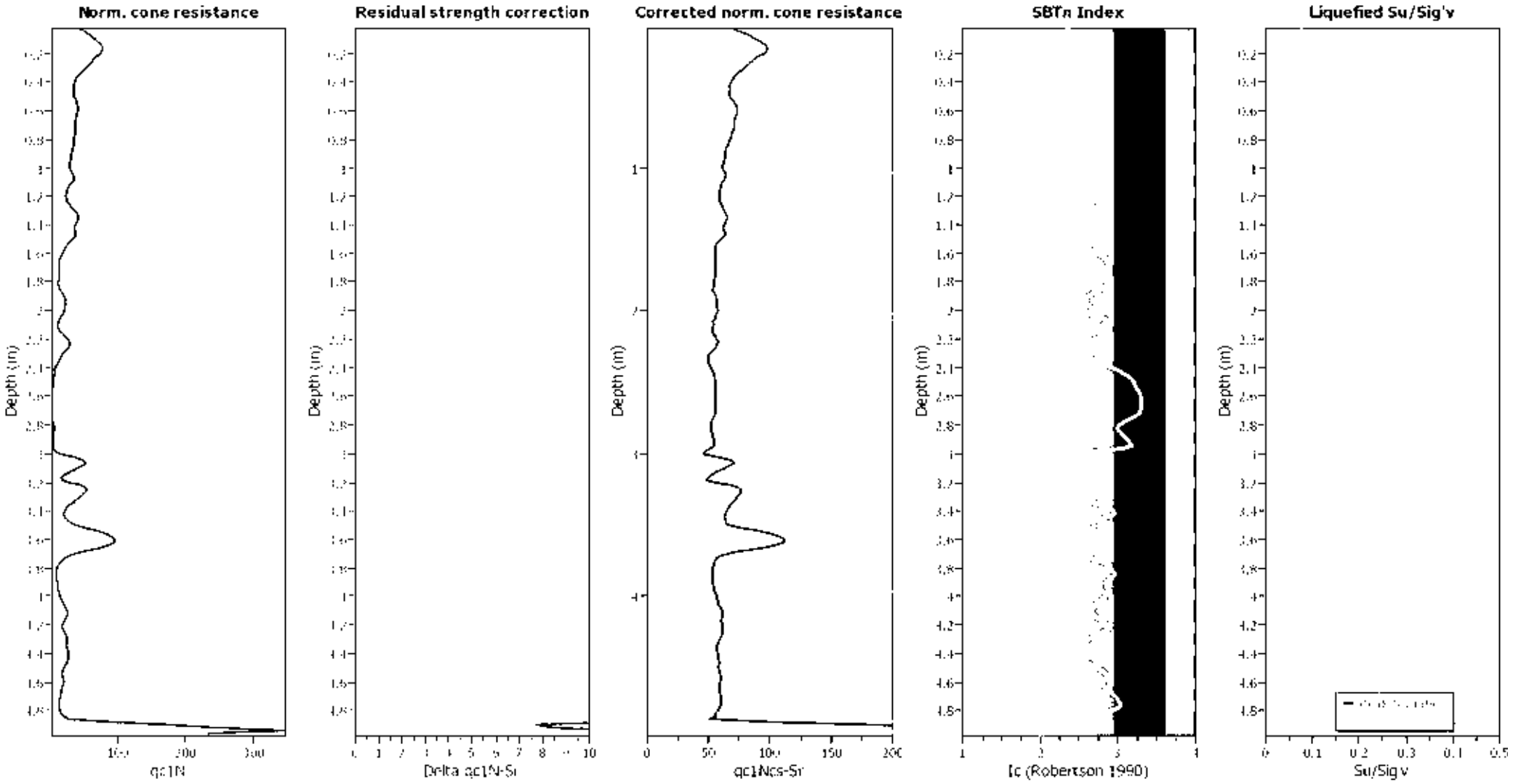
F.S. color scheme

- ☐ 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

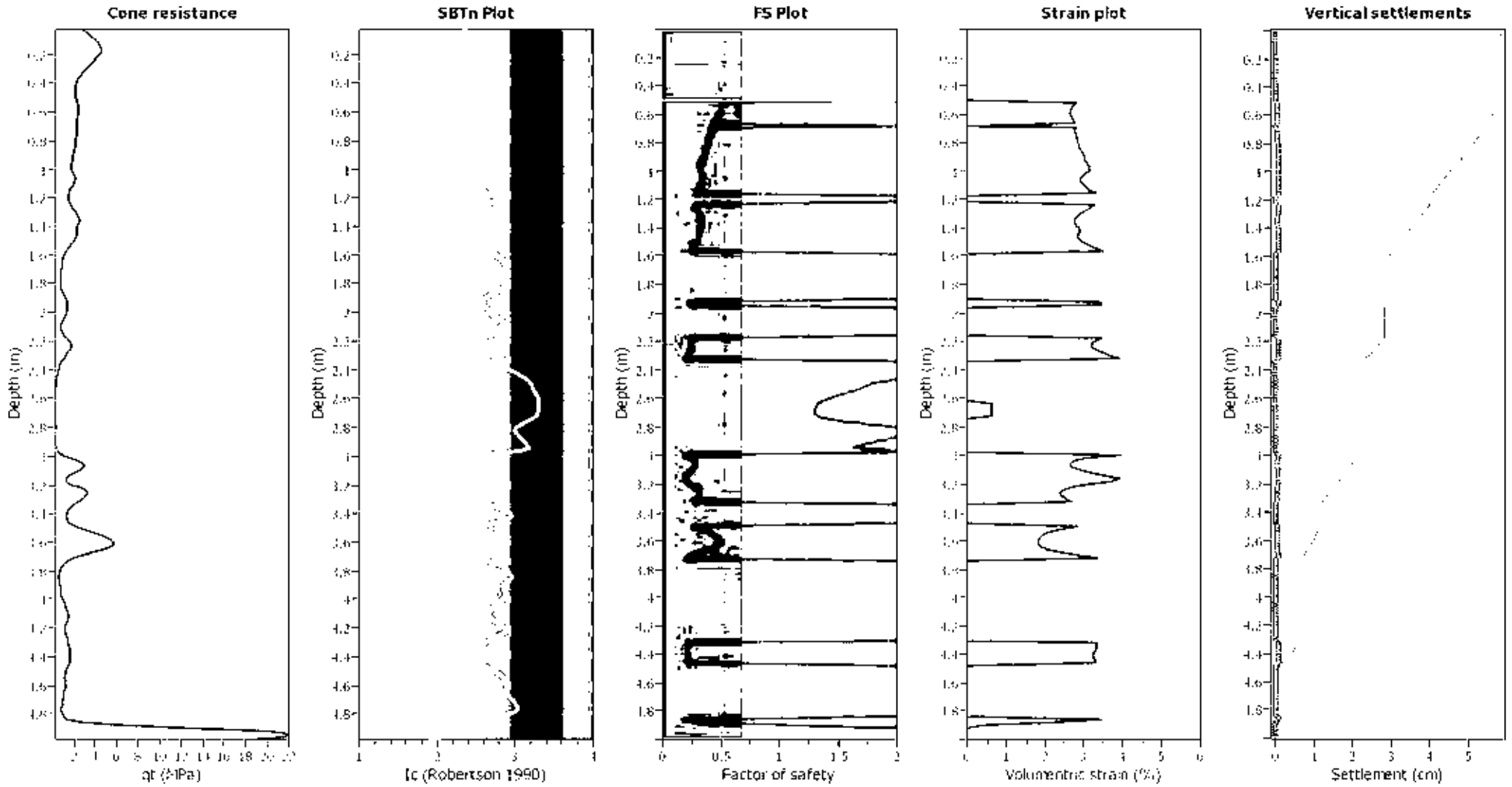
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Liquefaction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 m	Fill height:	N/A	Limit depth	N/A

Estimation of post-earthquake settlements



Abbreviations

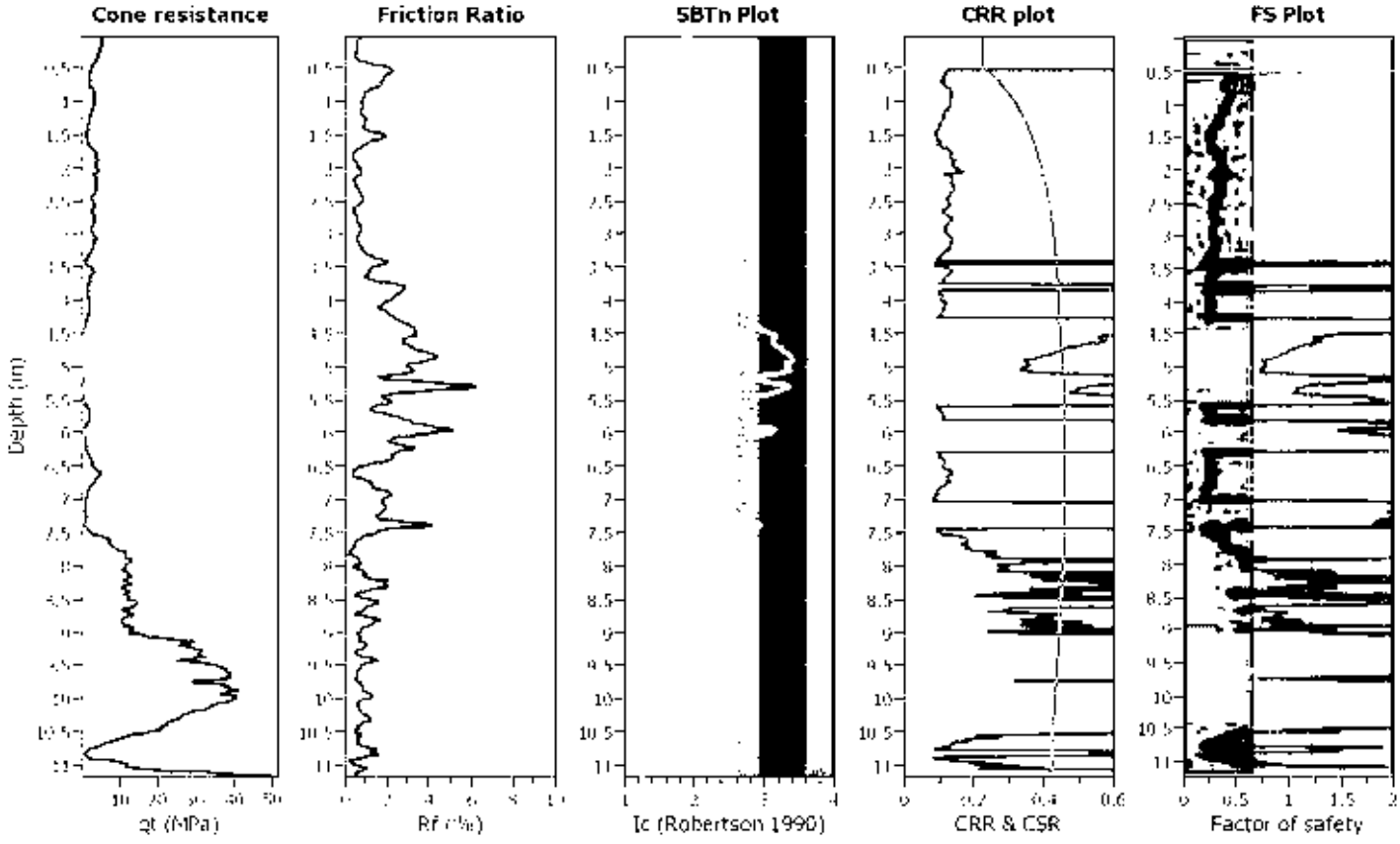
qc	Total cone resistance (cone resistance q corrected for pore water effects)
Ic	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumentric strain:	Post liquefaction volumentric strain

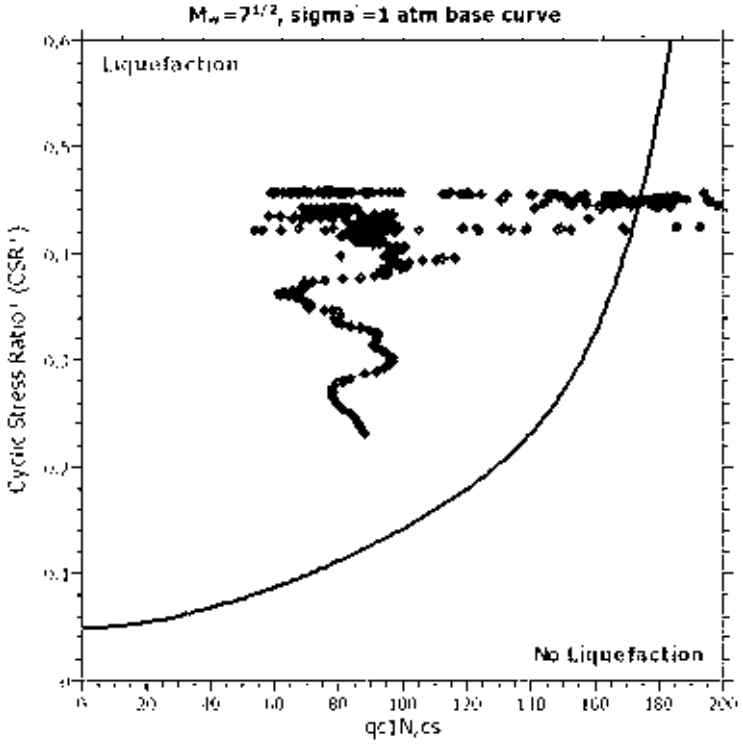
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

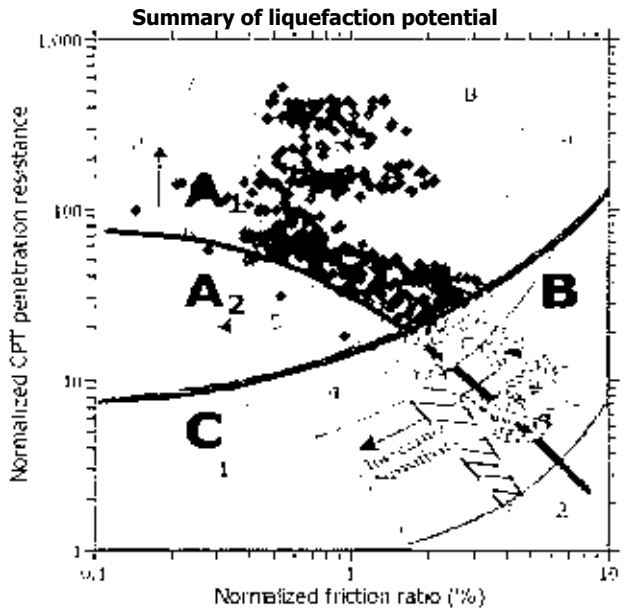
CPT file : CPT07_117HalswellJunctionRd

Input parameters and analysis data

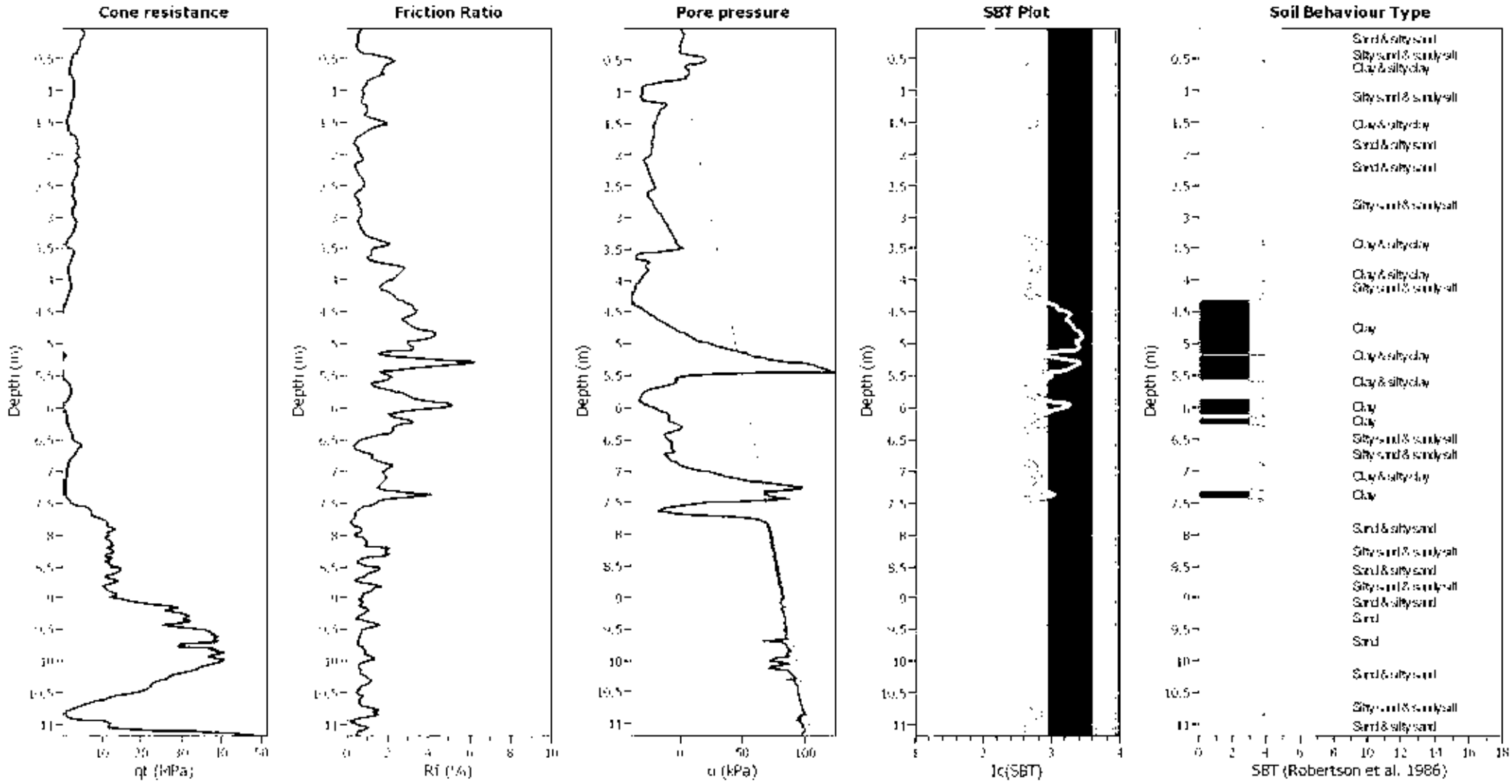
Analysis method	I&B (2008)	G.W.T. (in-situ):	0.50 m	Use fill	No	Clay like behavior applied:	Sand & Clay
Fines correction method	I&B (2008)	G.W.T. (earthq.):	0.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration	0.35	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



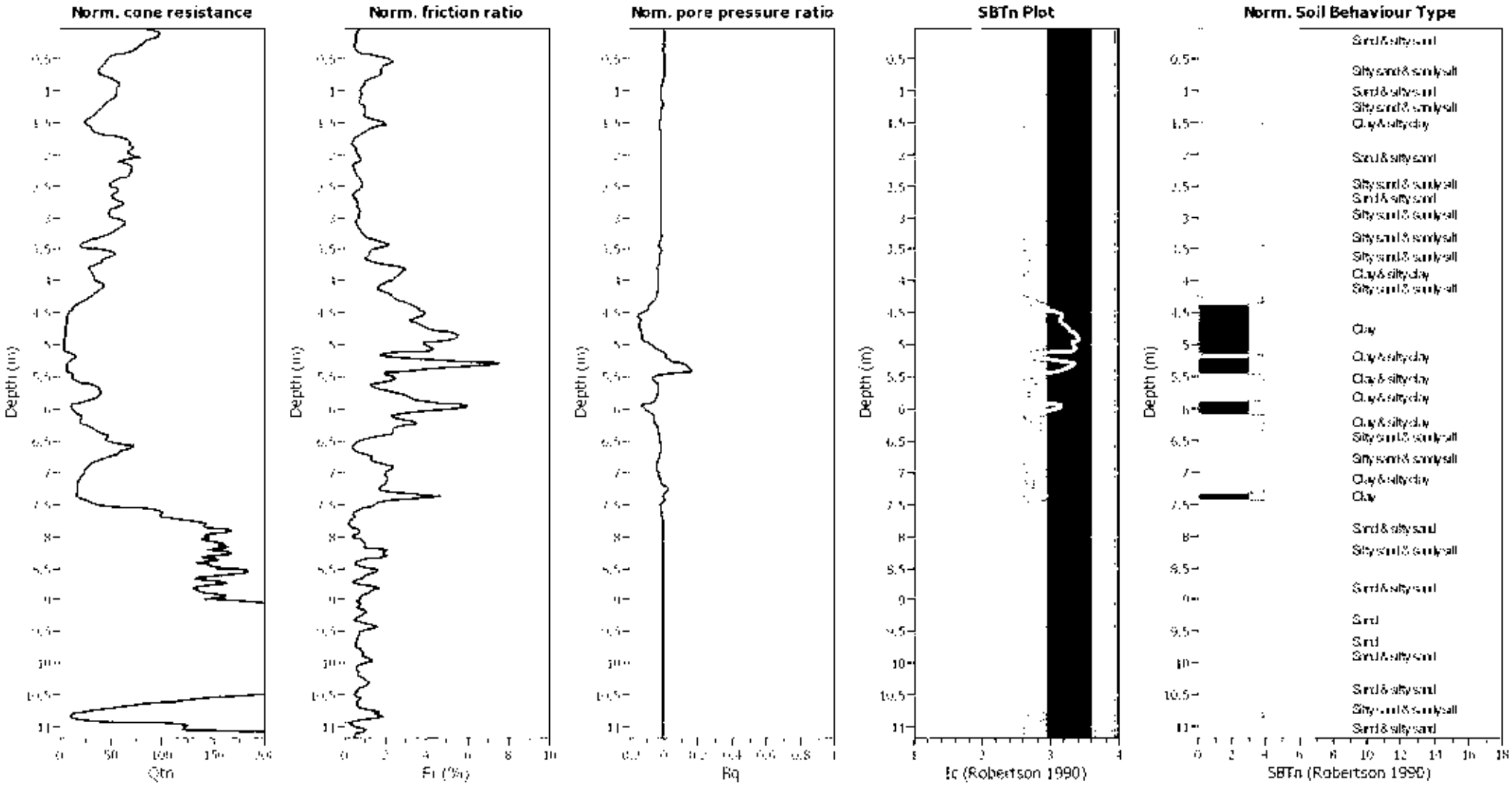
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	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	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

CPT basic interpretation plots (normalized)



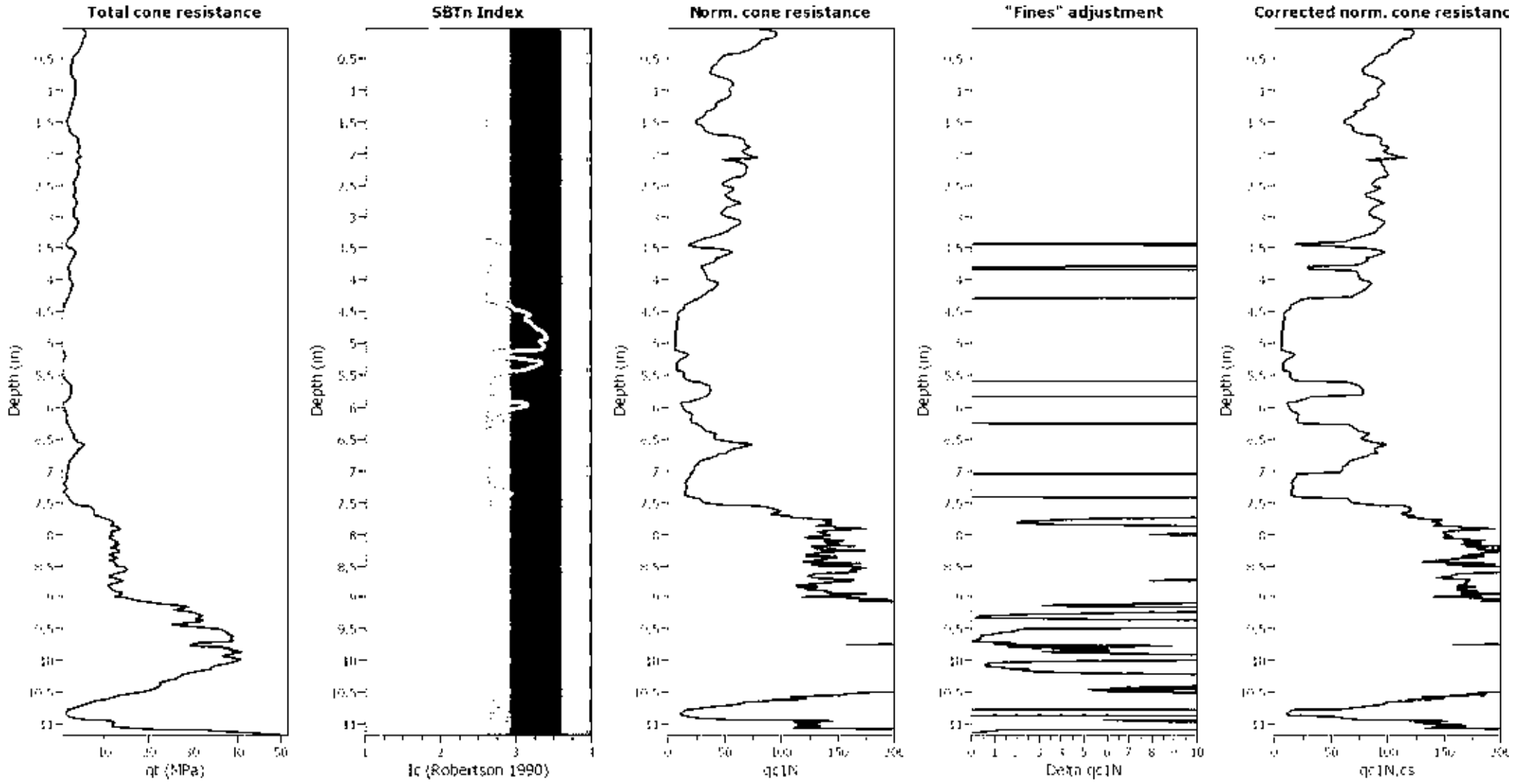
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

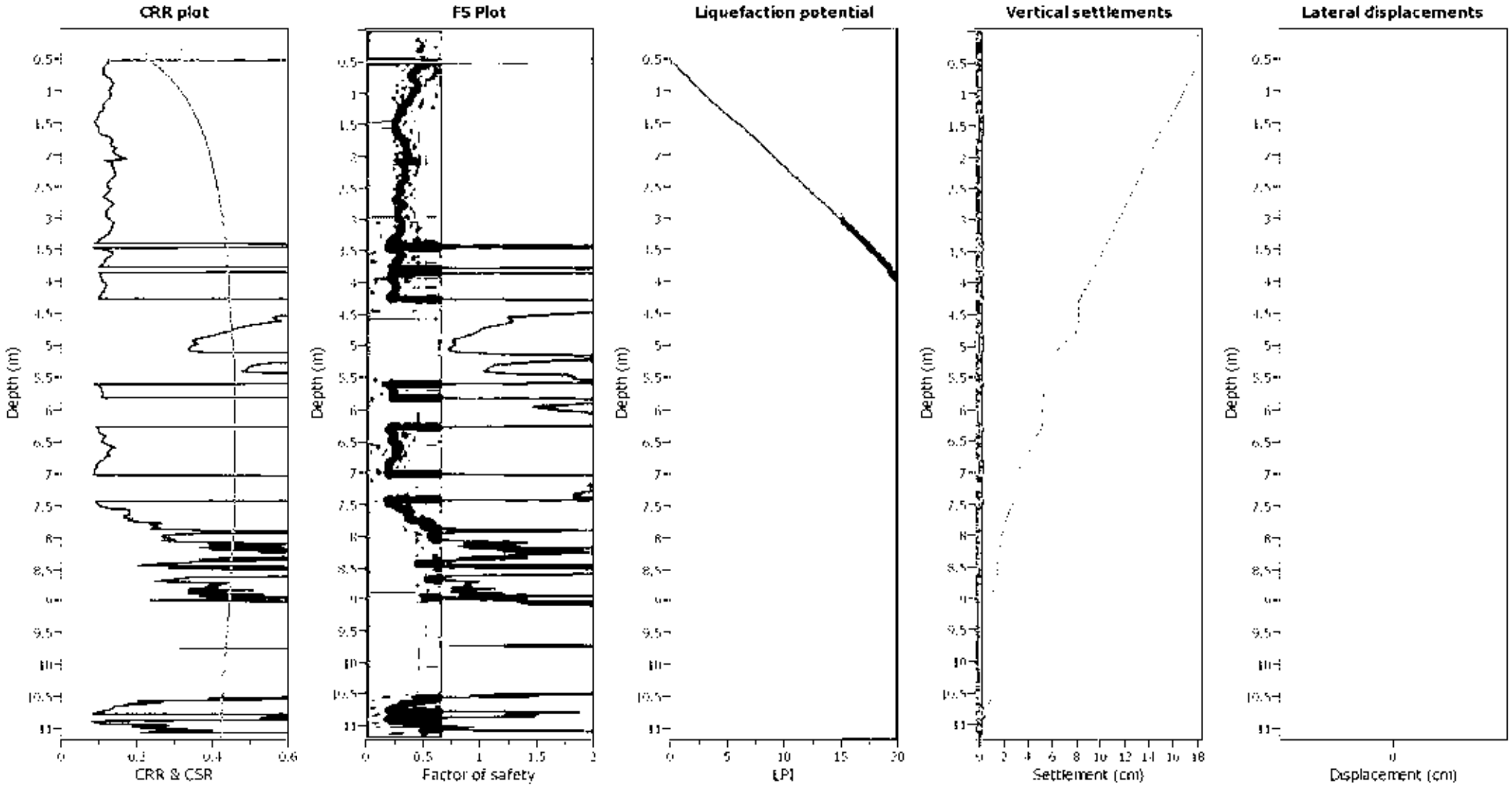
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	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
Liner correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 m	Fill height:	N/A	Limit depth:	N/A

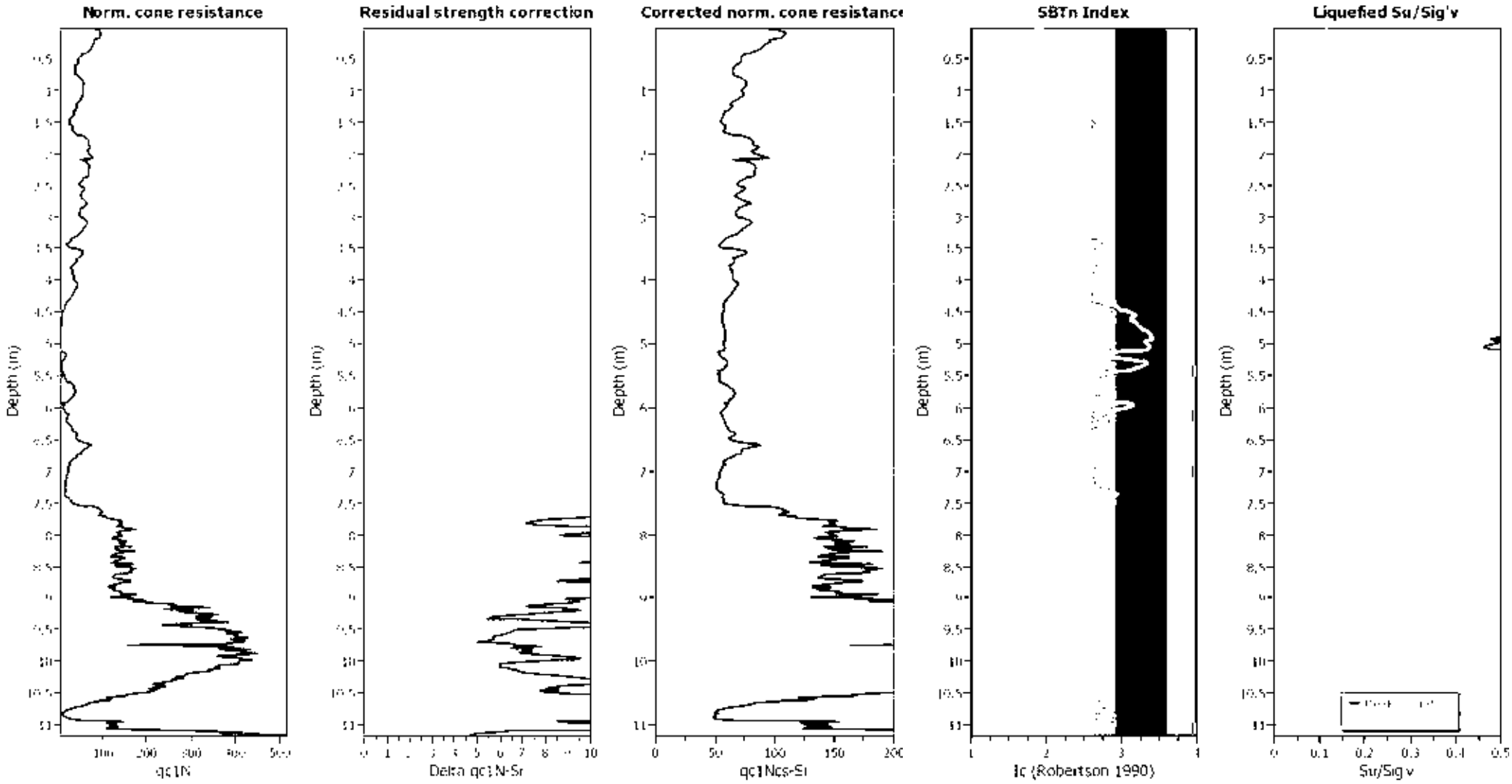
F.S. color scheme

- ☐ 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

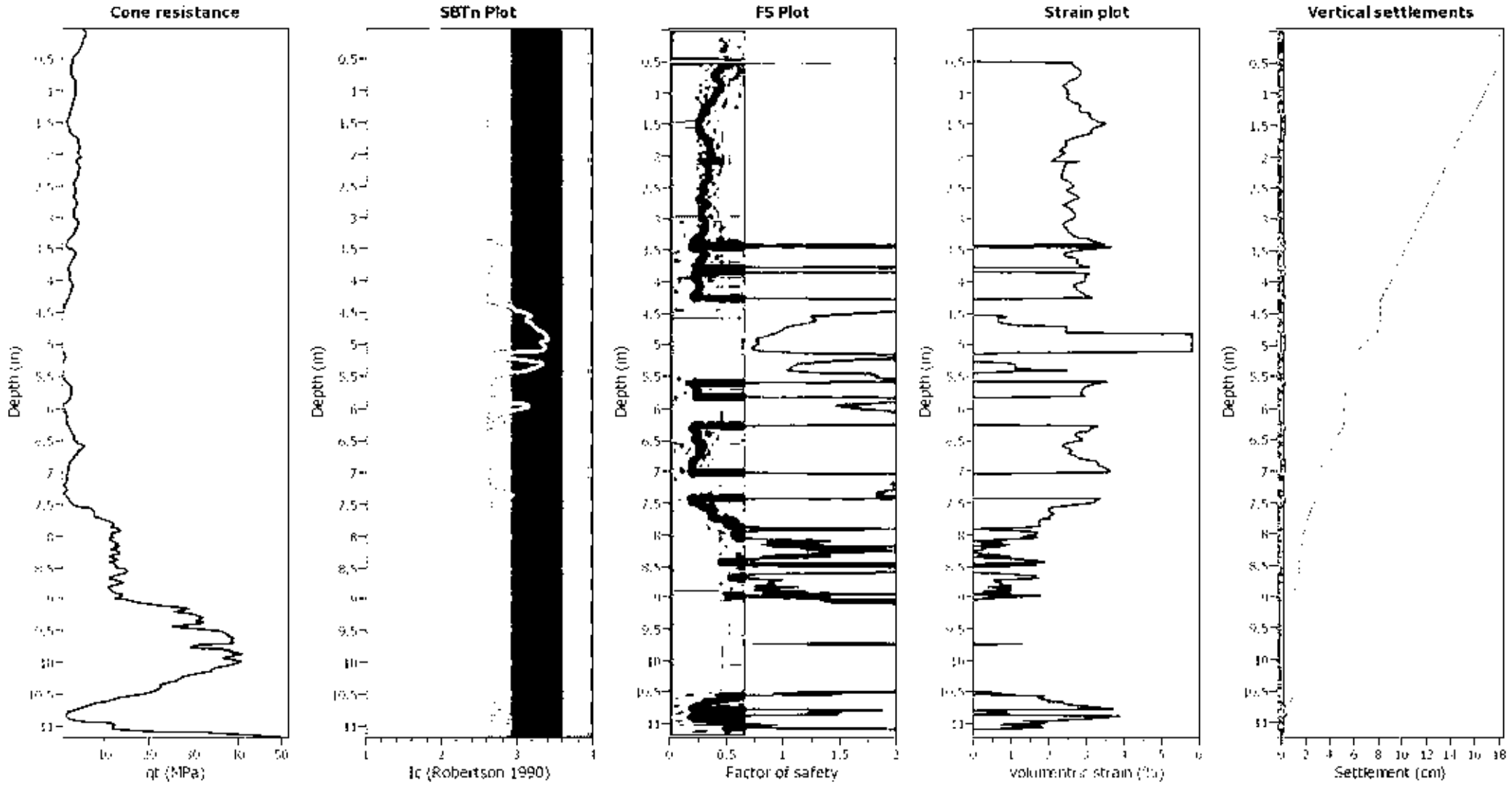
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	0.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	0.50 m	Fill height:	N/A	Limit depth:	N/A

Estimation of post-earthquake settlements



Abbreviations

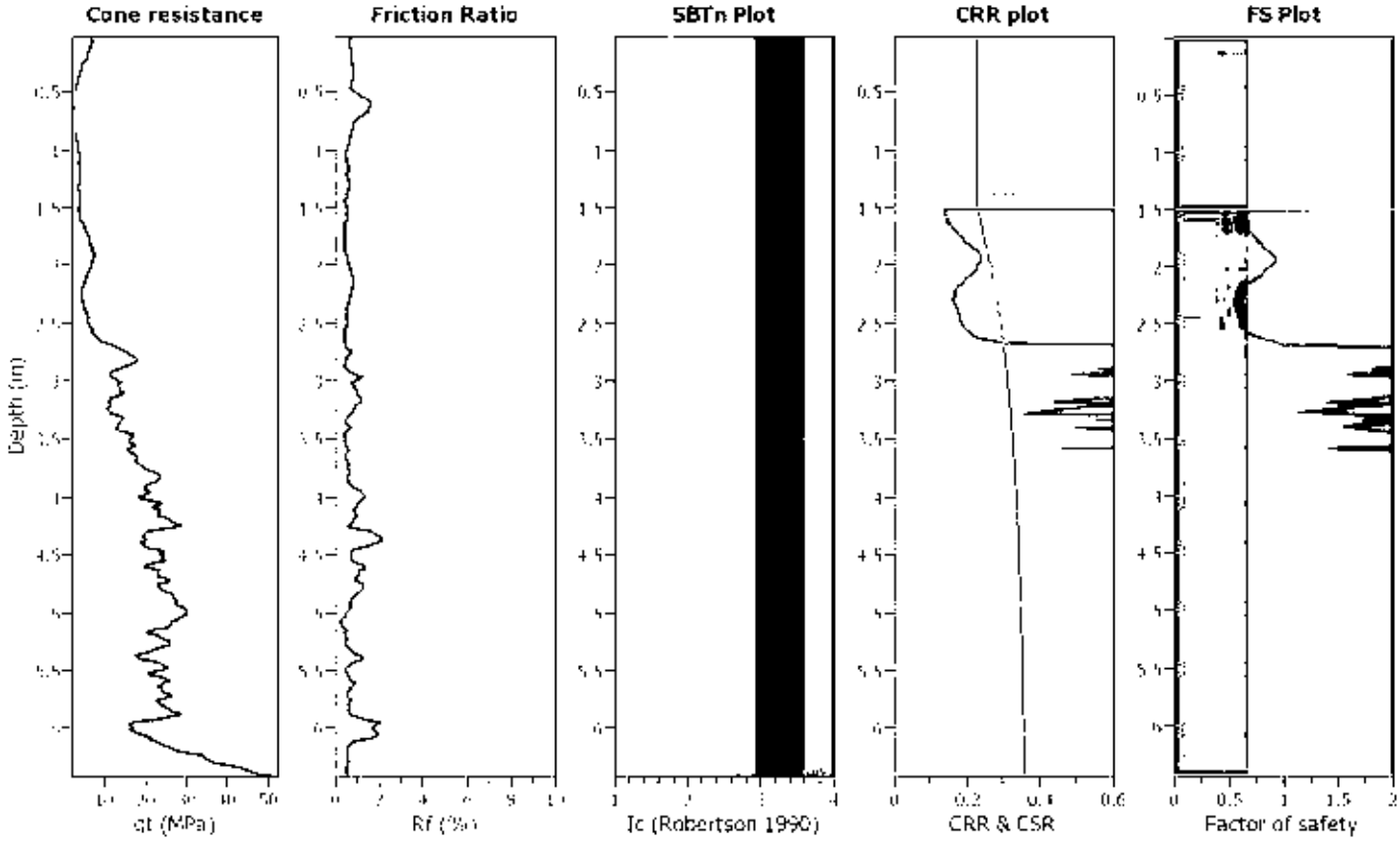
qt:	Total cone resistance (cone resistance q corrected for pore water effects)
Ic:	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumetric strain:	Post liquefaction volumetric strain

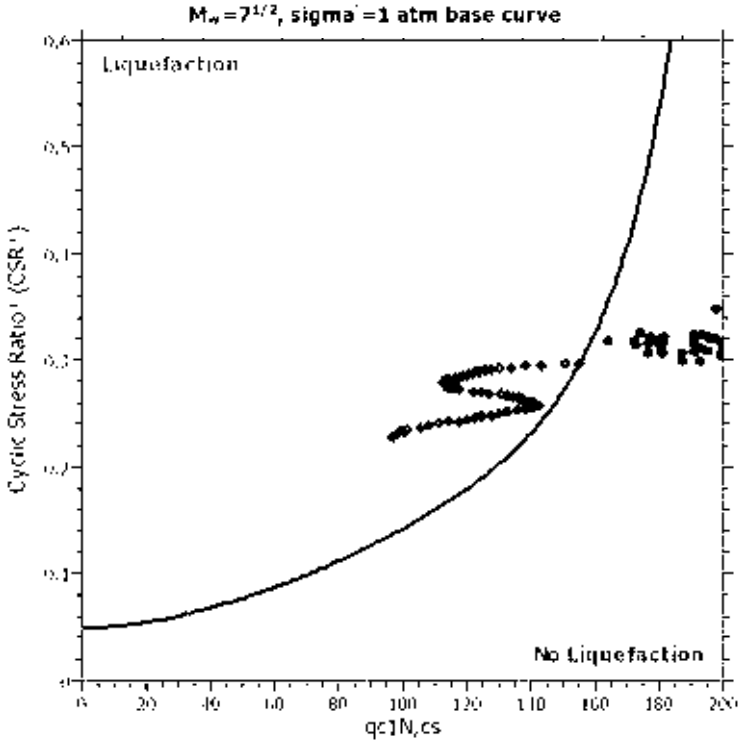
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

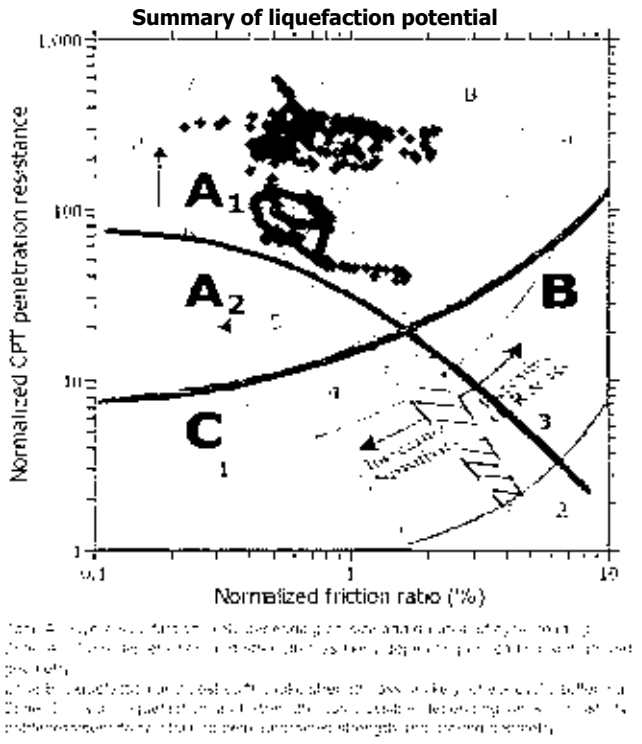
CPT file : CPT08_103HalswellJunctionRd

Input parameters and analysis data

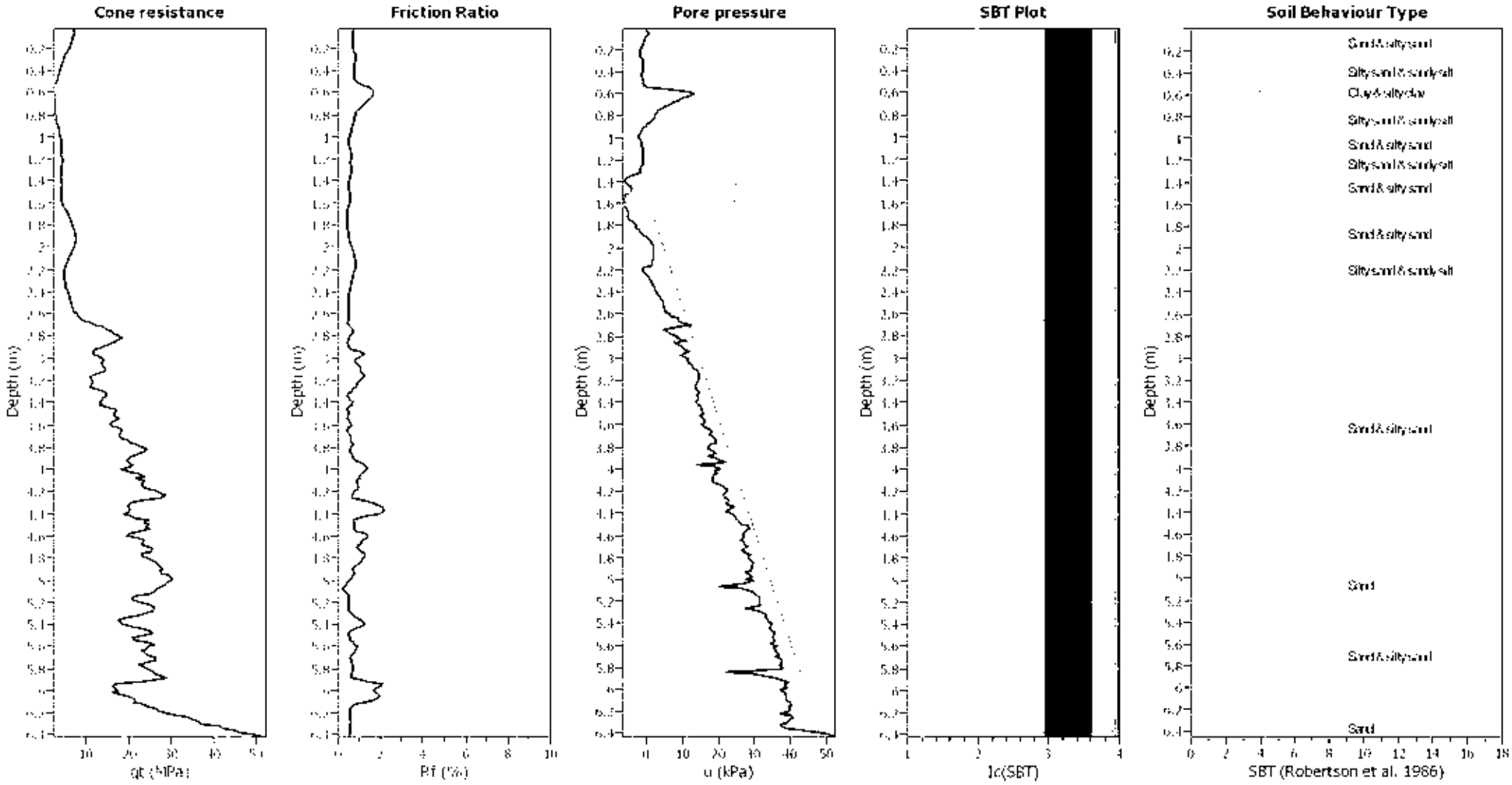
Analysis method:	I&B (2008)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	I&B (2008)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



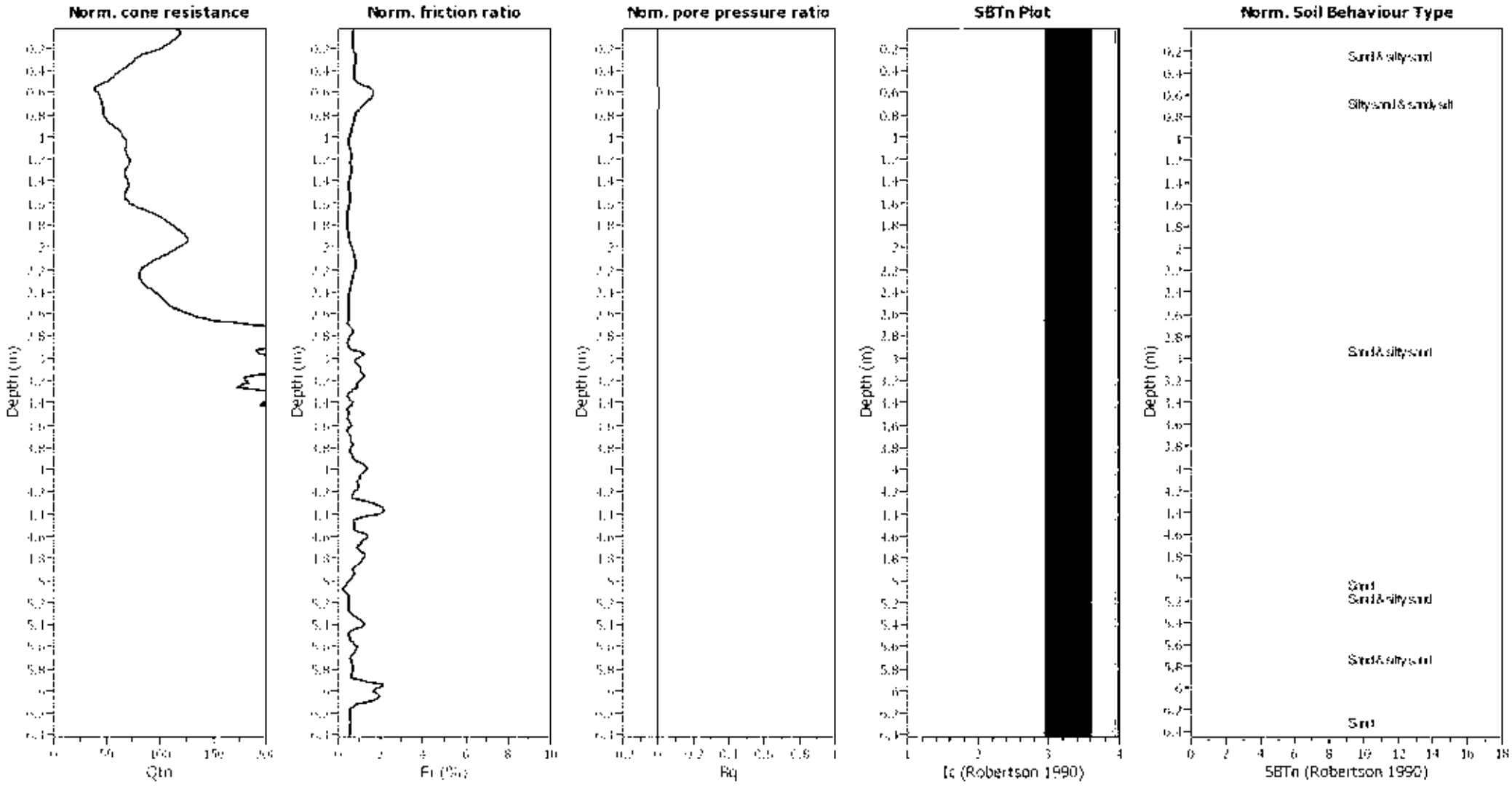
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 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

CPT basic interpretation plots (normalized)



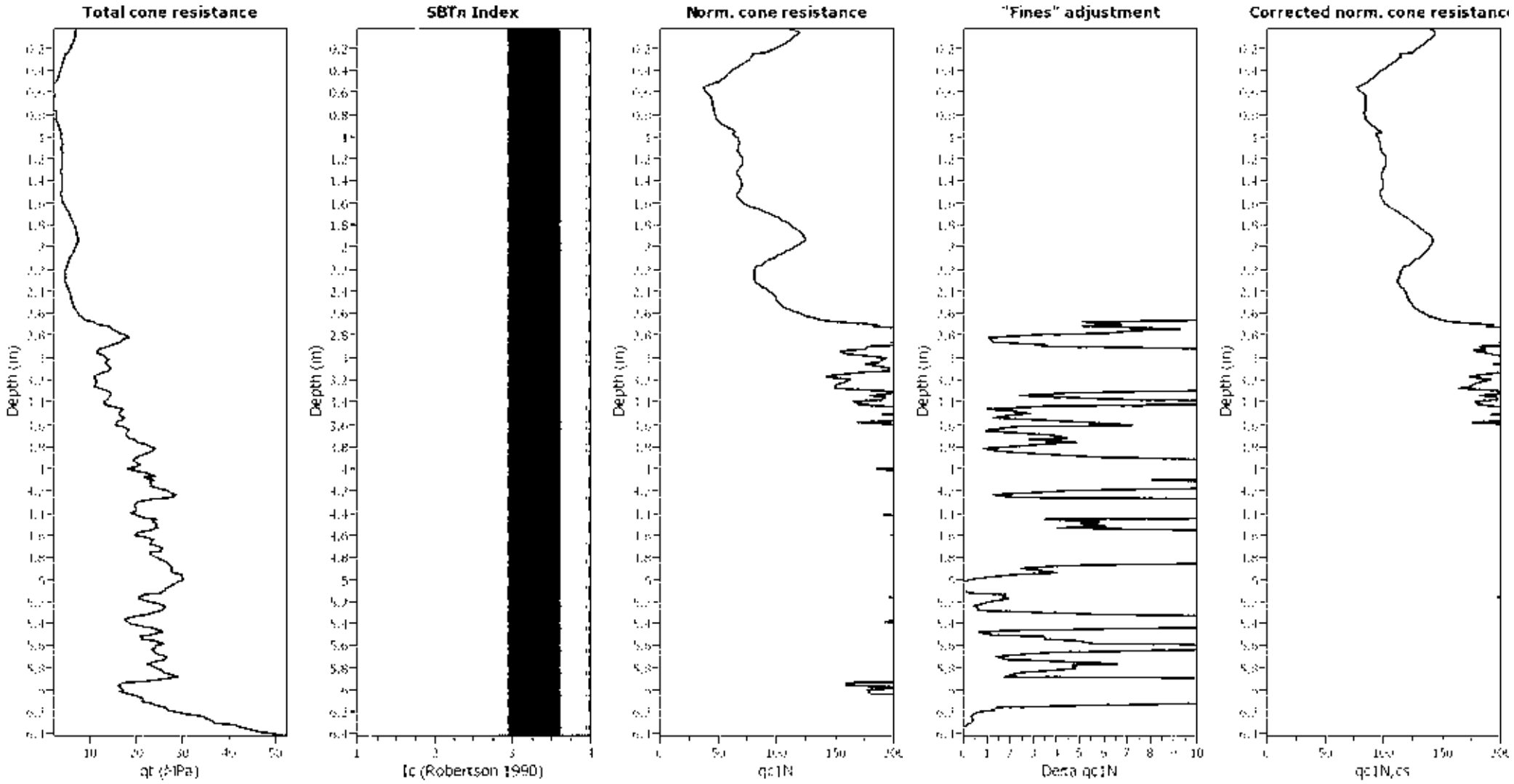
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

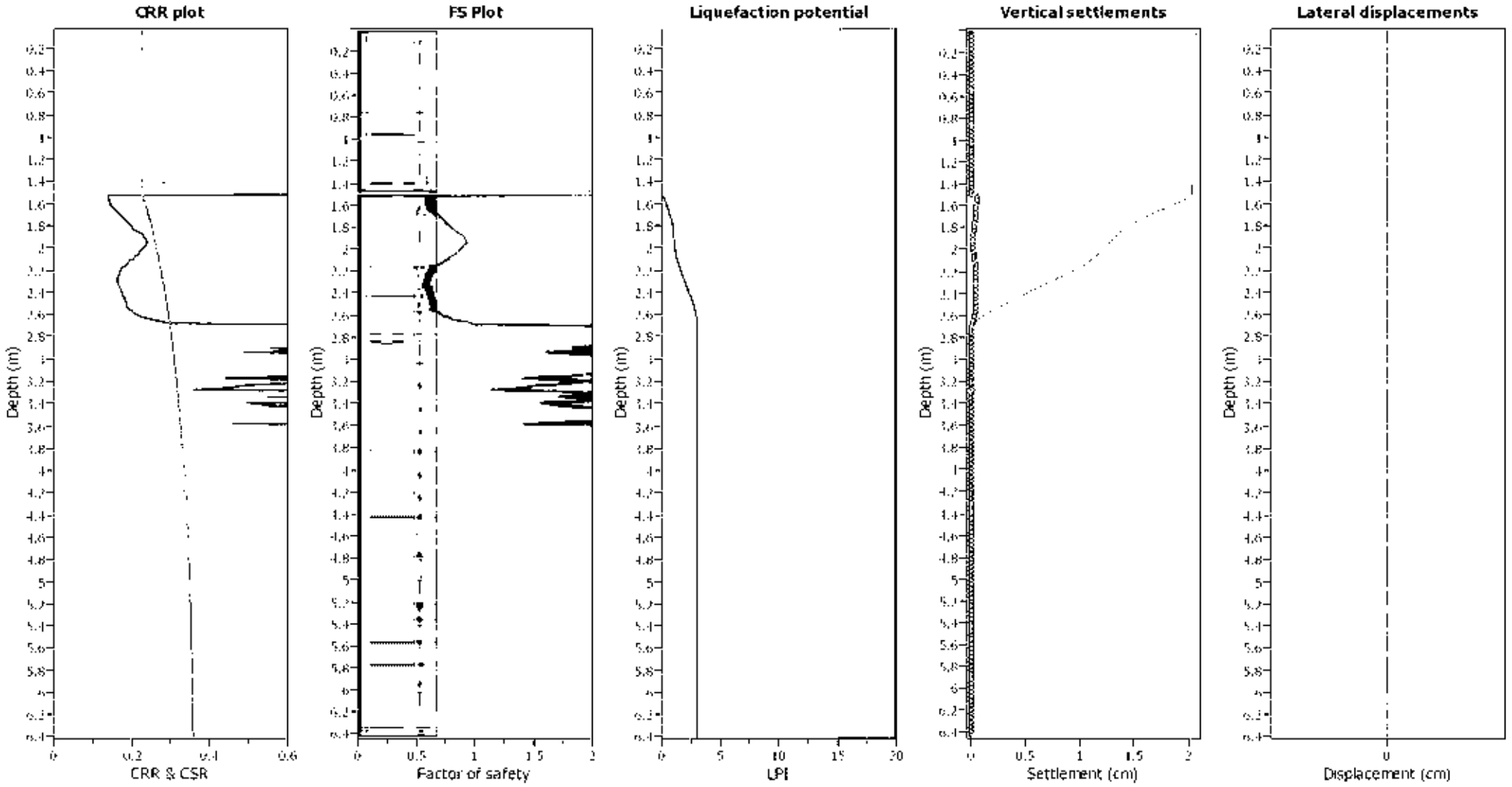
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 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.):	1.50 m	Fill weight:	N/A
Liquefaction correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 m	Fill height:	N/A	Limit depth:	N/A

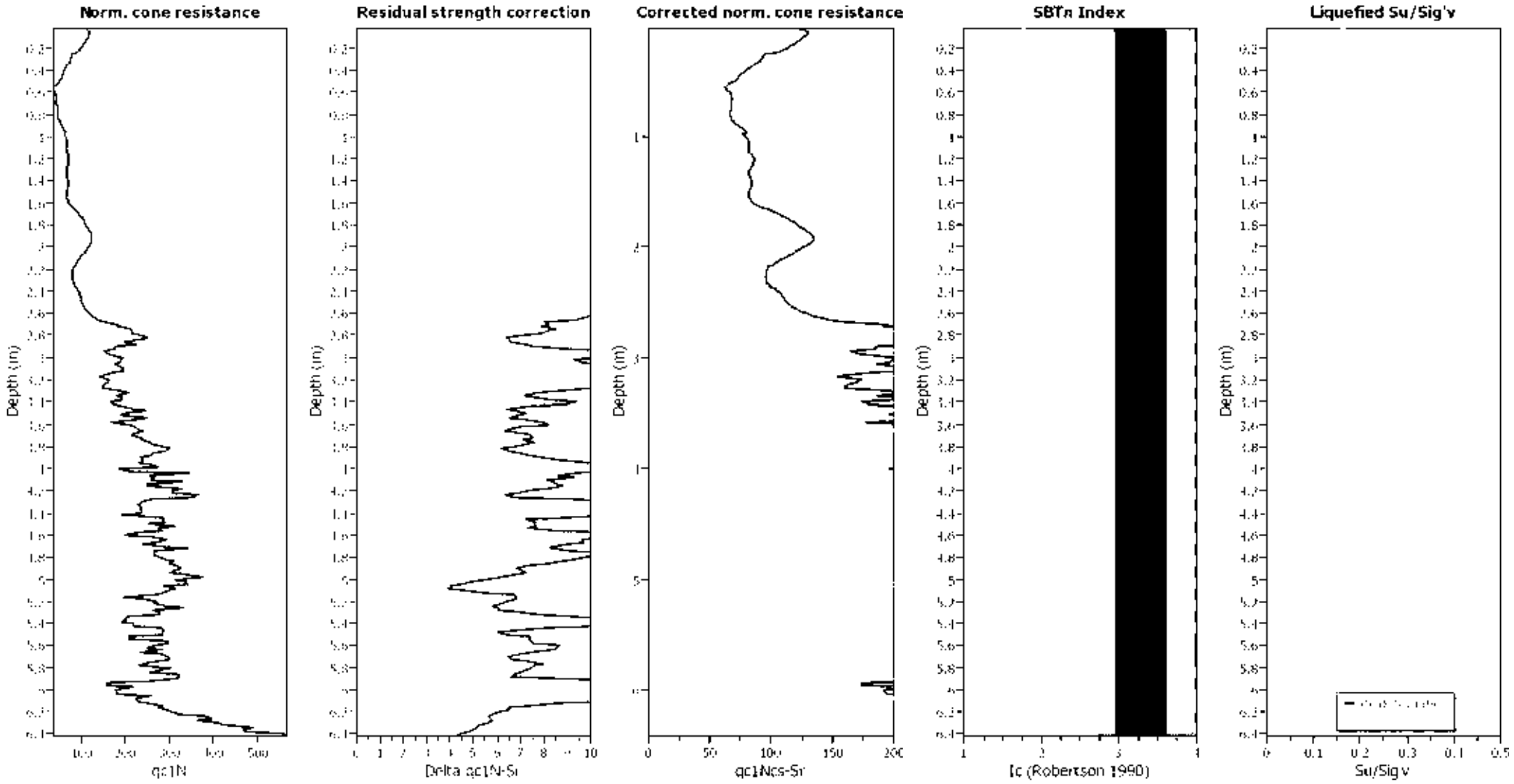
F.S. color scheme

- ☐ 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

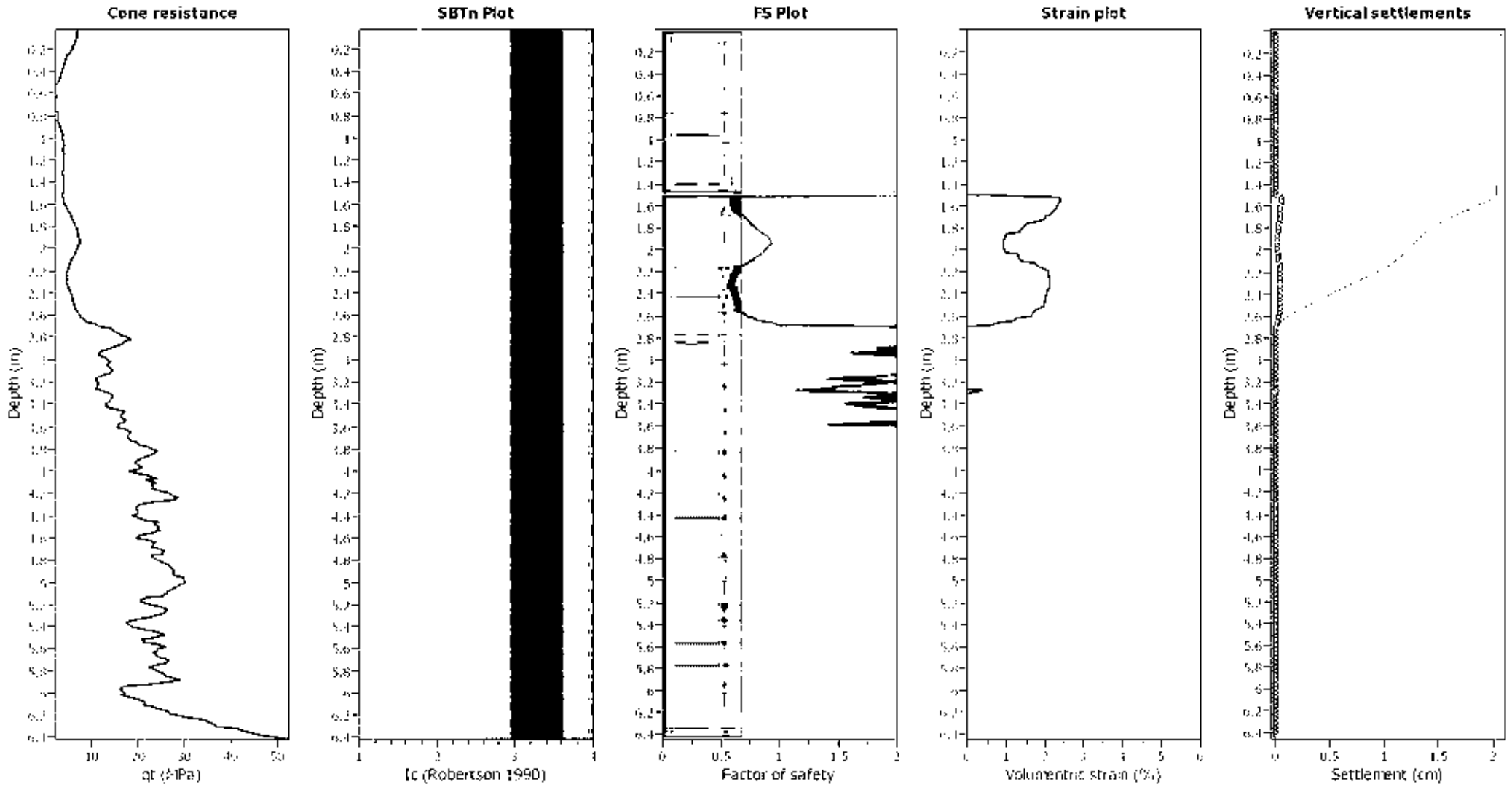
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Liquefaction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth	N/A

Estimation of post-earthquake settlements



Abbreviations

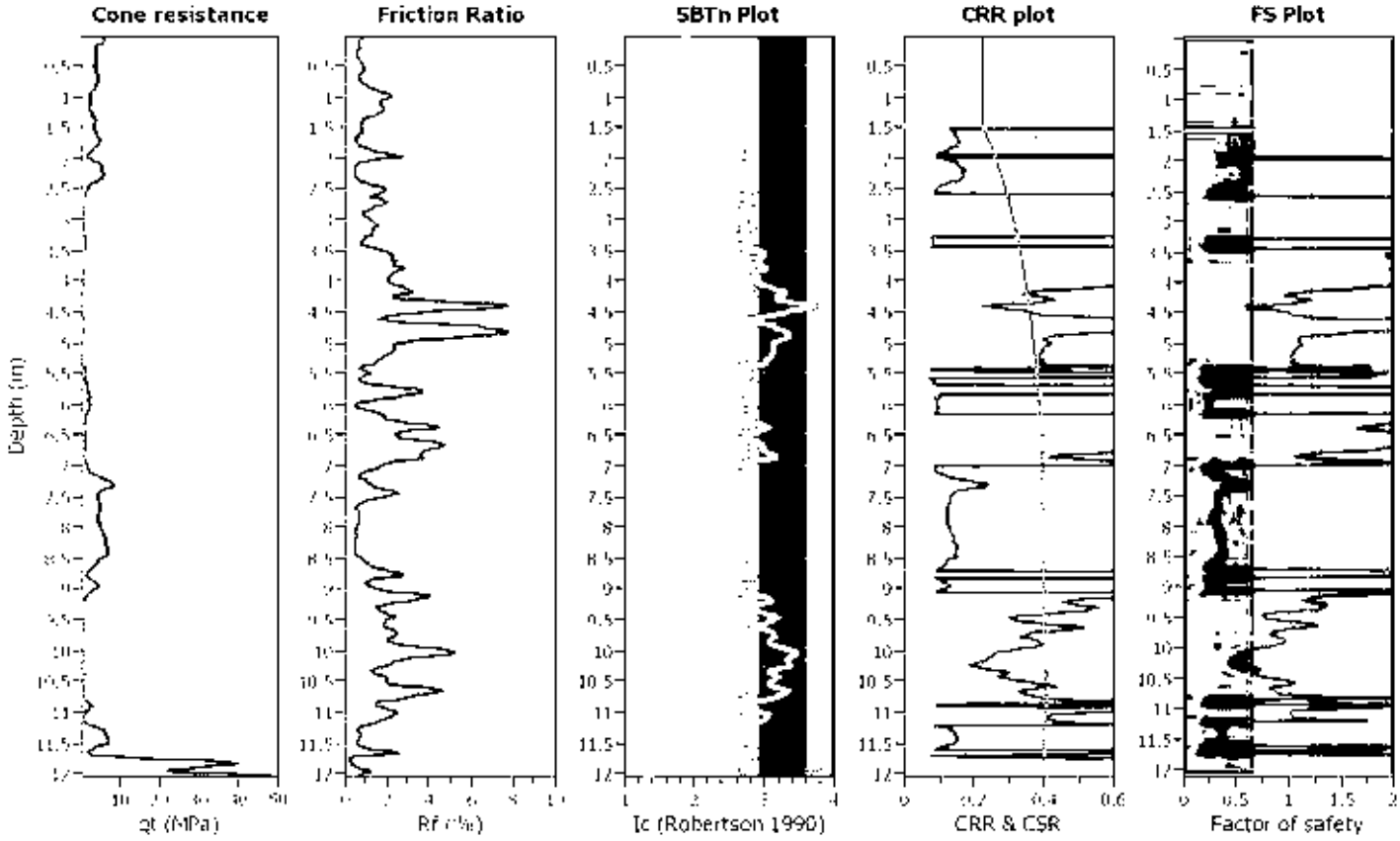
qc	Total cone resistance (cone resistance q corrected for pore water effects)
Ic	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumentric strain:	Post liquefaction volumentric strain

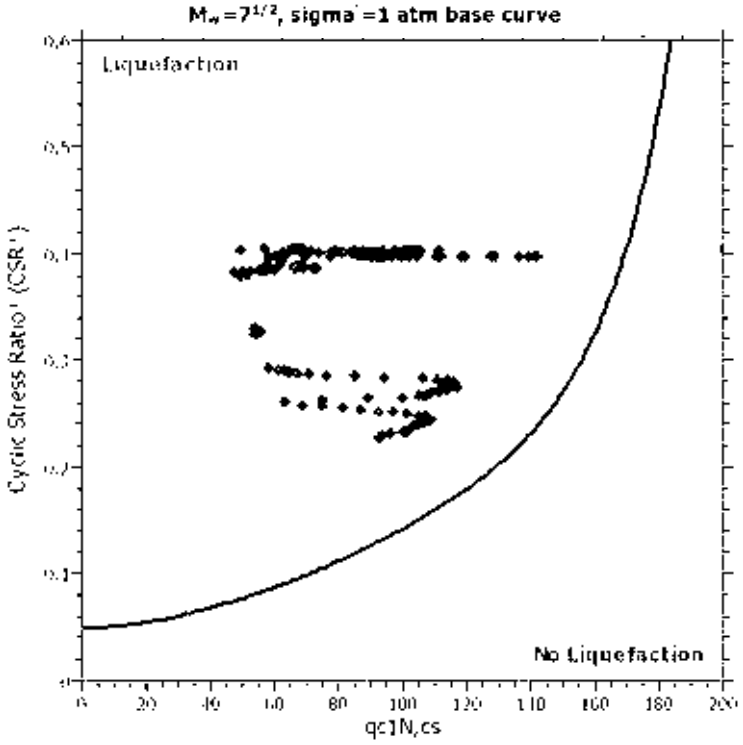
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

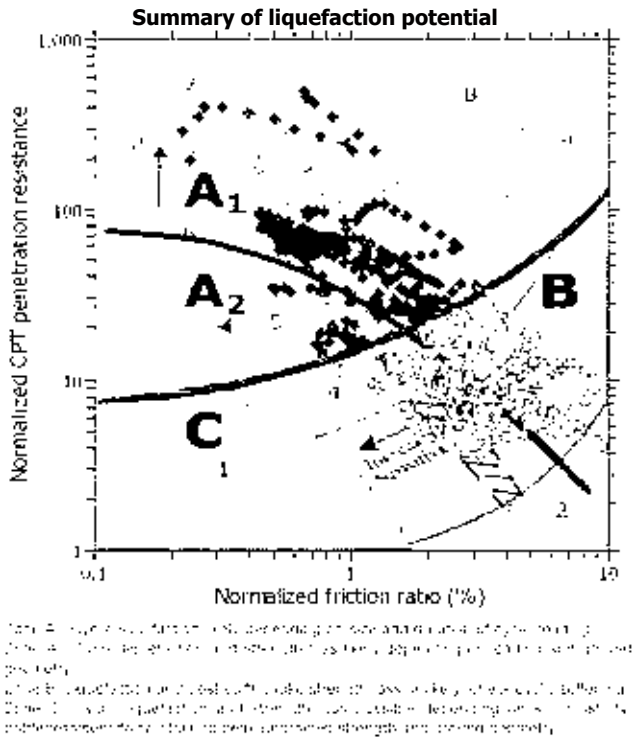
CPT file : CPT10_42QuaifesRd

Input parameters and analysis data

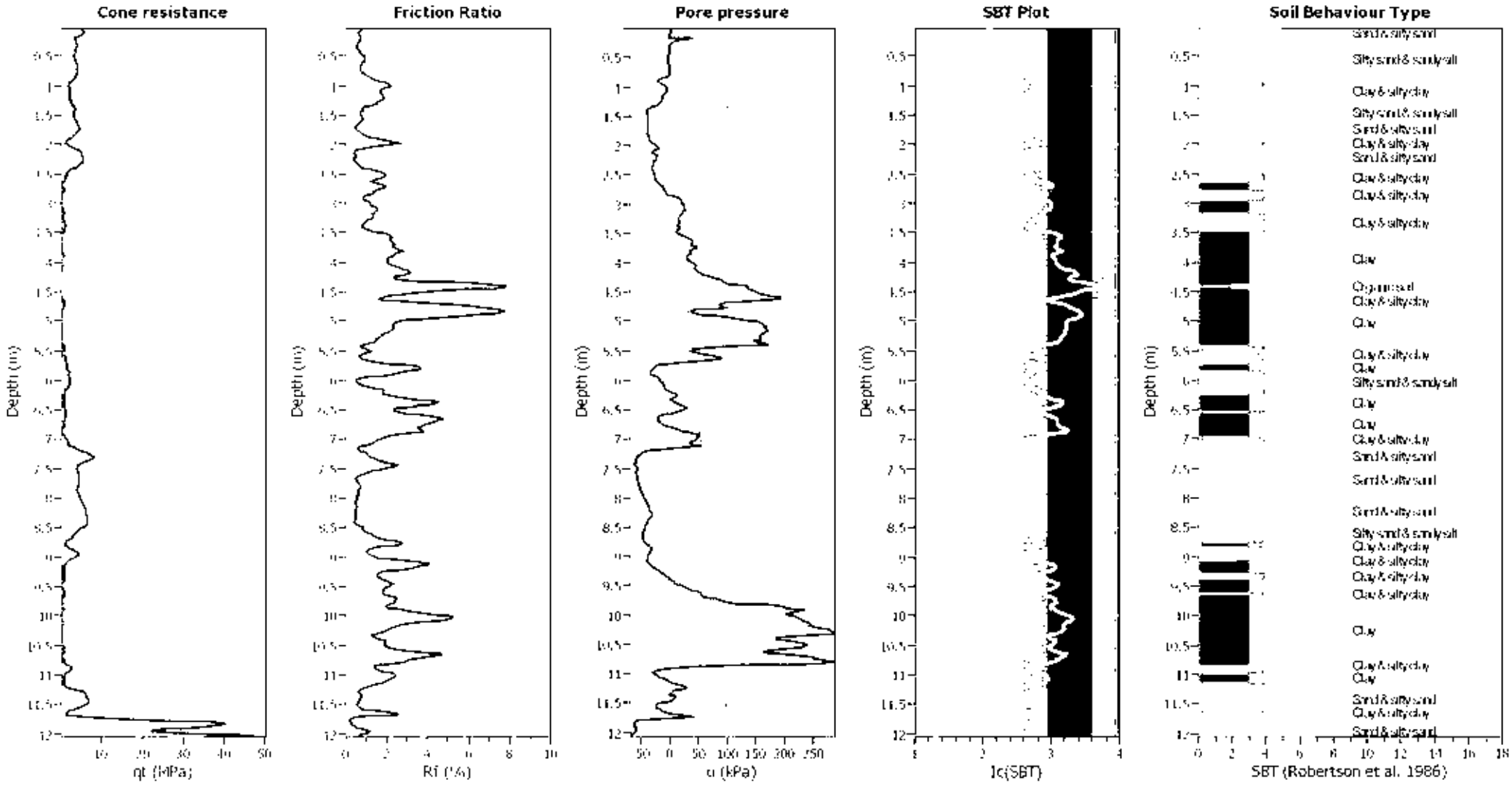
Analysis method	I&B (2008)	G.W.T. (in-situ):	1.50 m	Use fill	No	Clay like behavior applied:	Sand & Clay
Fines correction method	I&B (2008)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration	0.35	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



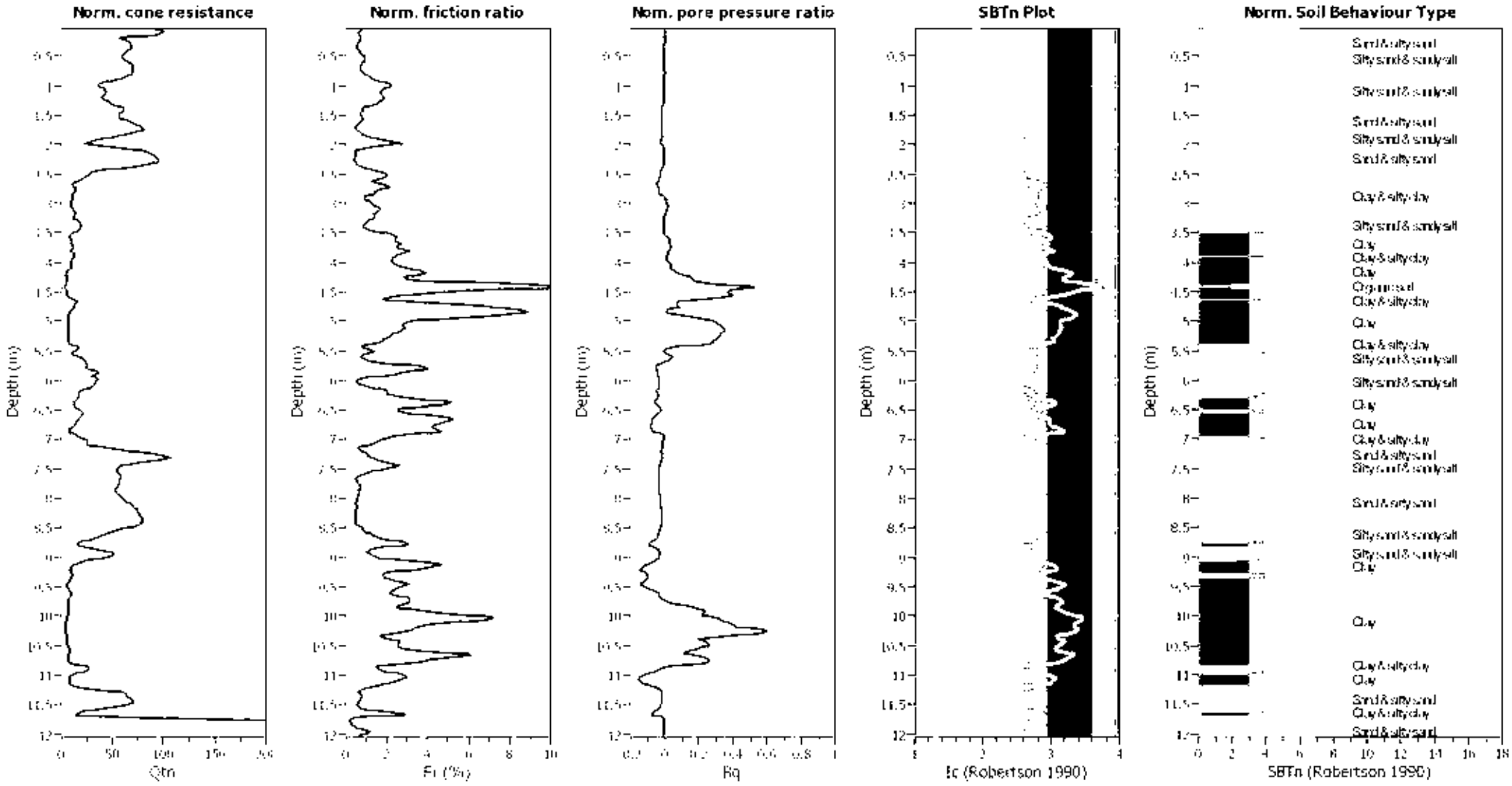
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 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

CPT basic interpretation plots (normalized)



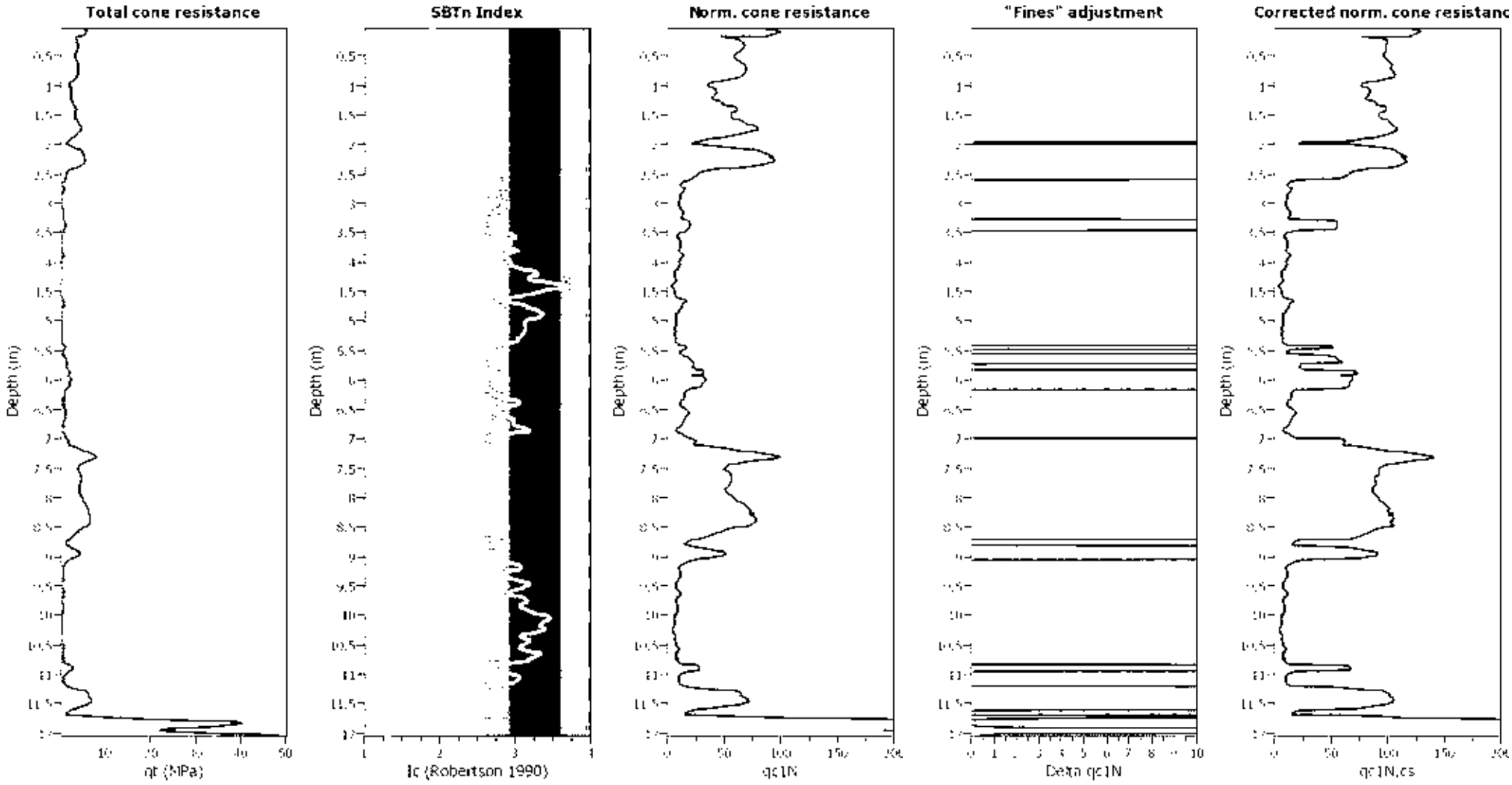
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

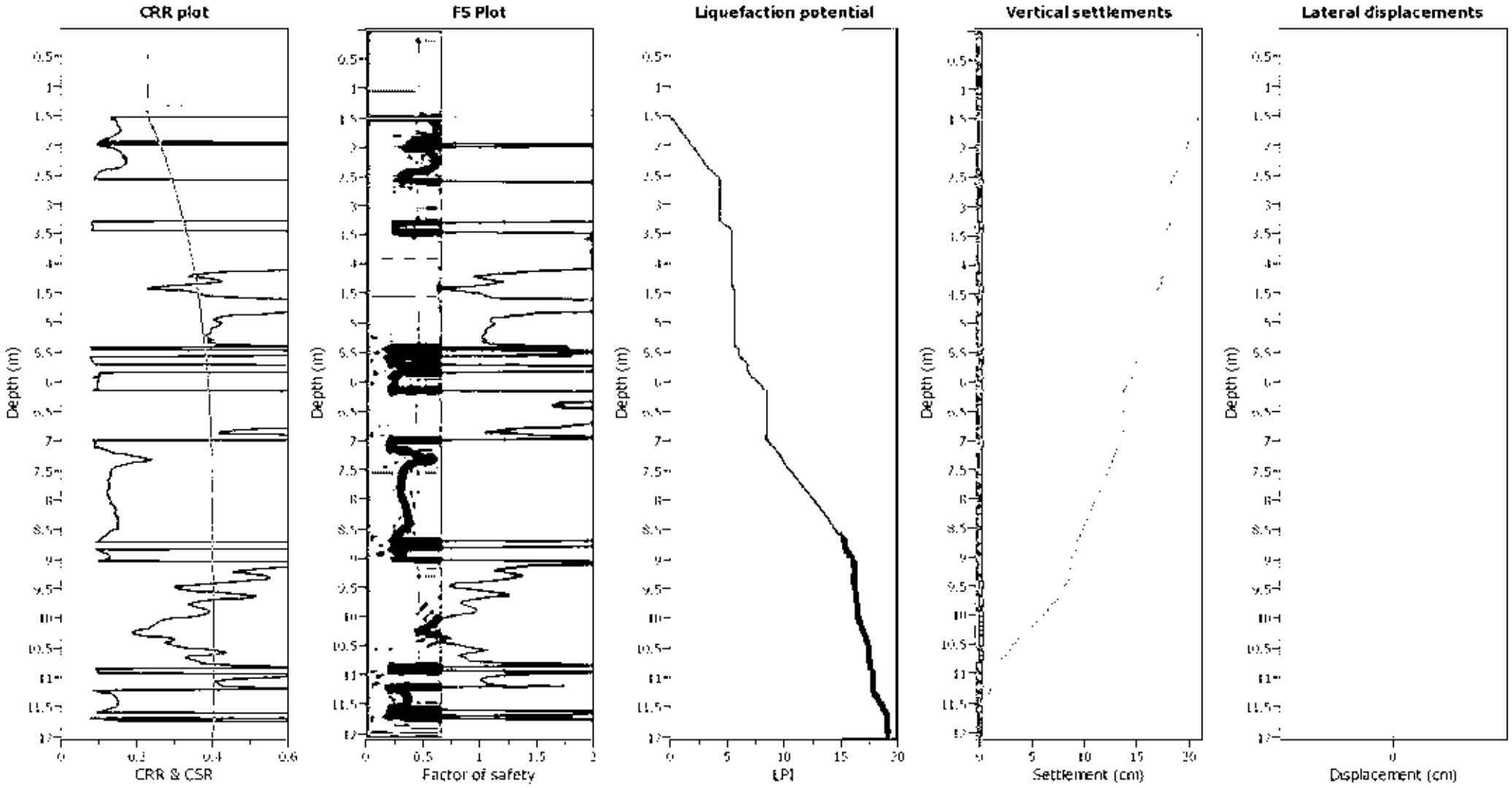
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 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.):	1.50 m	Fill weight:	N/A
Liner correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 m	Fill height:	N/A	Limit depth:	N/A

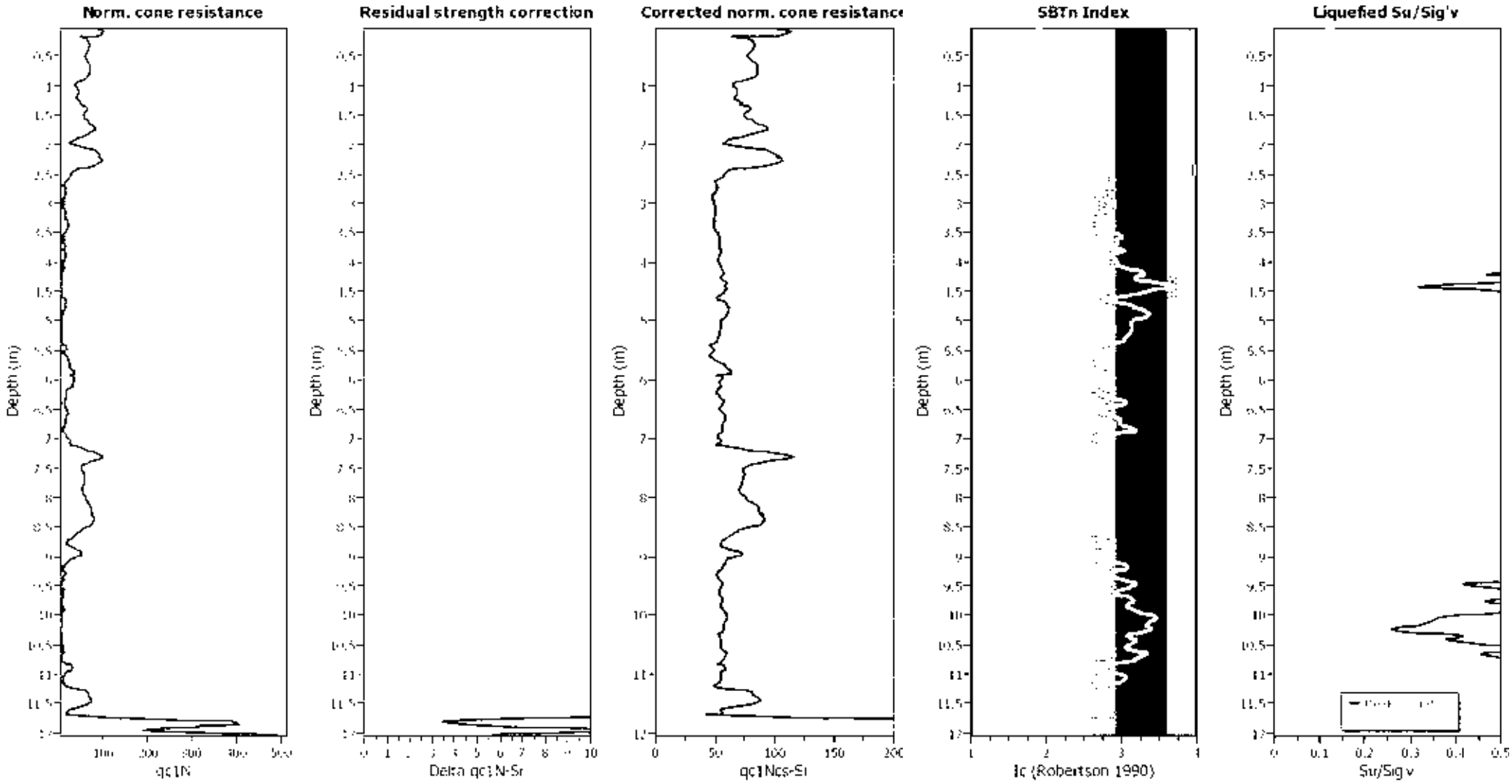
F.S. color scheme

- ☐ 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

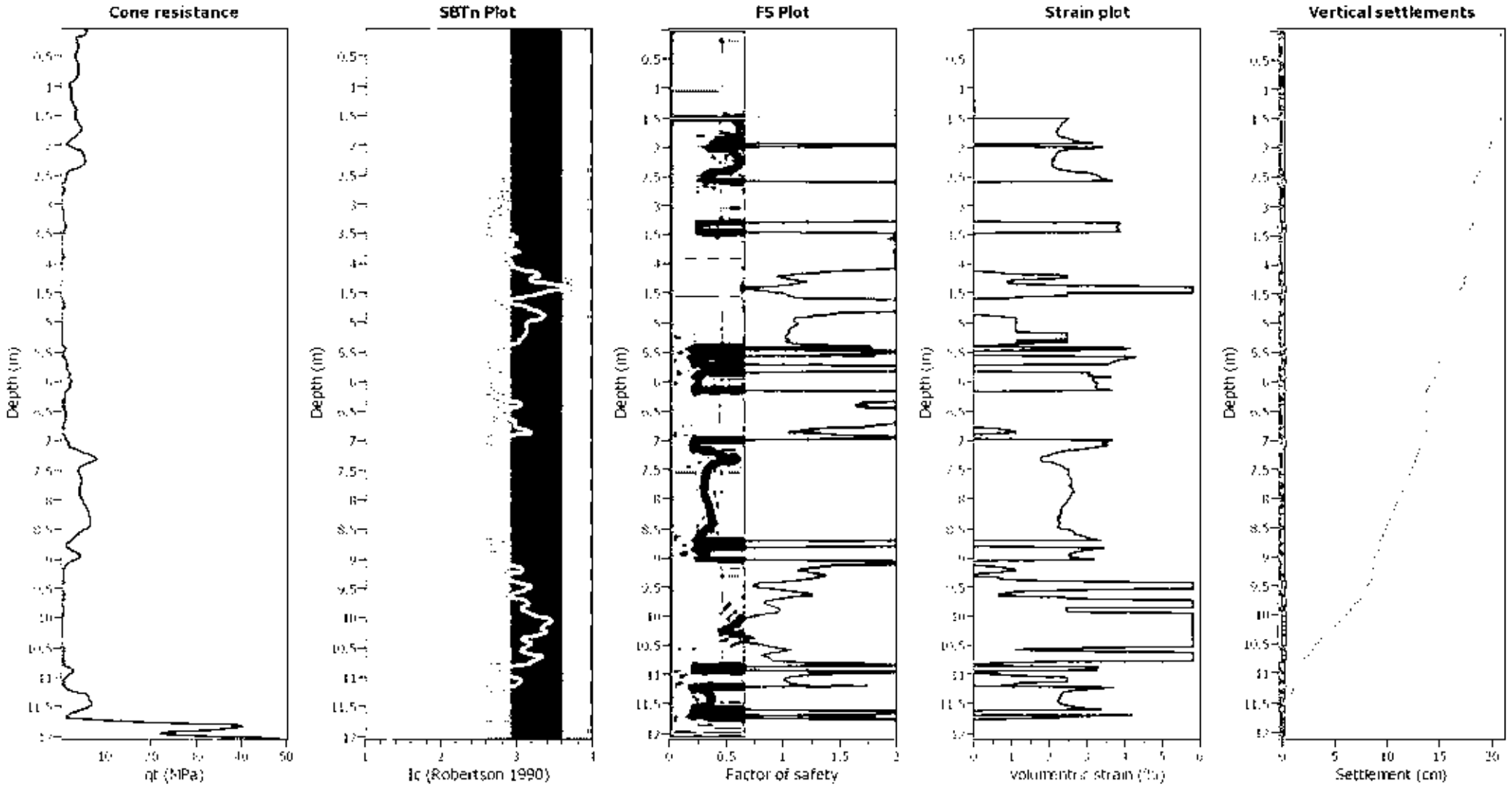
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 m	Fill height:	N/A	Limit depth	N/A

Estimation of post-earthquake settlements



Abbreviations

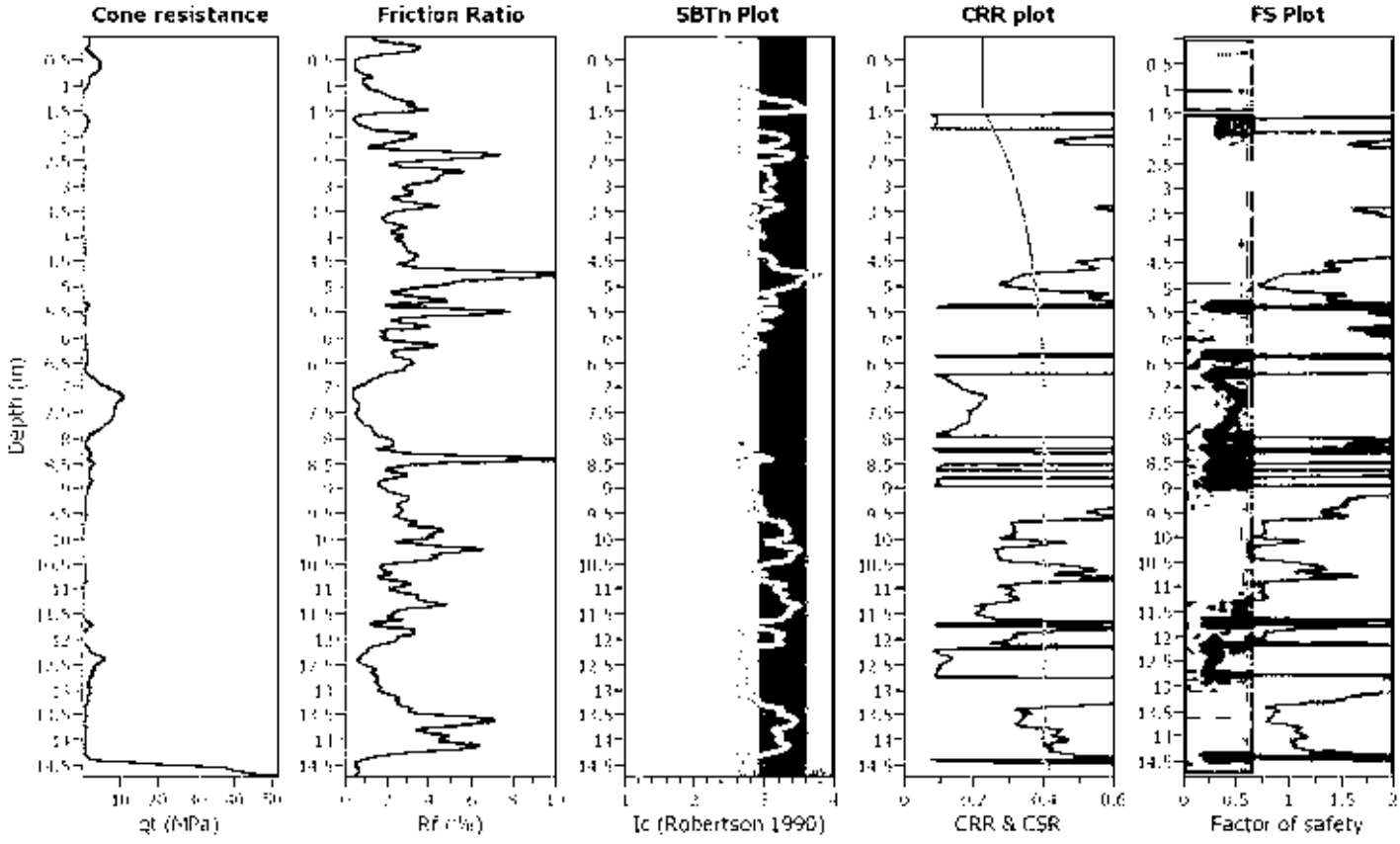
qt:	Total cone resistance (cone resistance q corrected for pore water effects)
Ic:	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumetric strain:	Post liquefaction volumetric strain

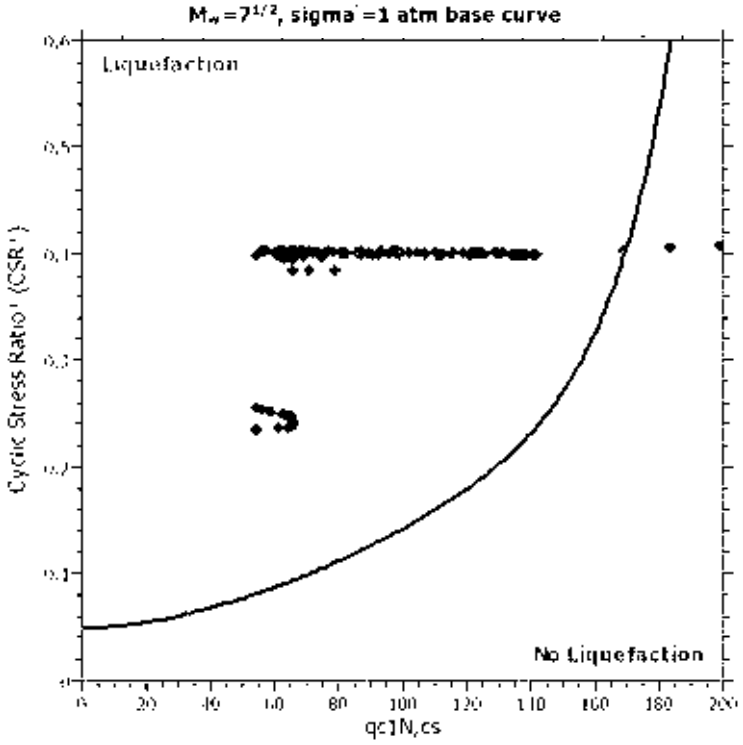
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

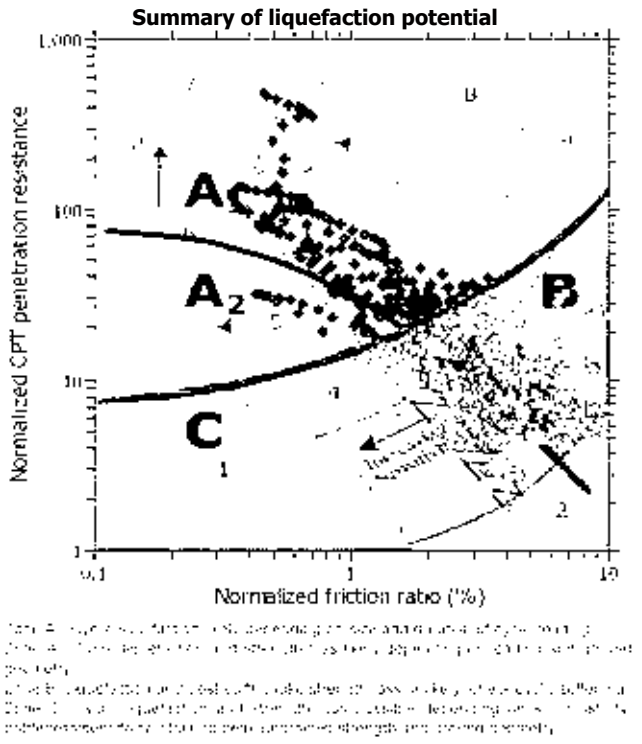
CPT file : CPT11_52QuaifesRd

Input parameters and analysis data

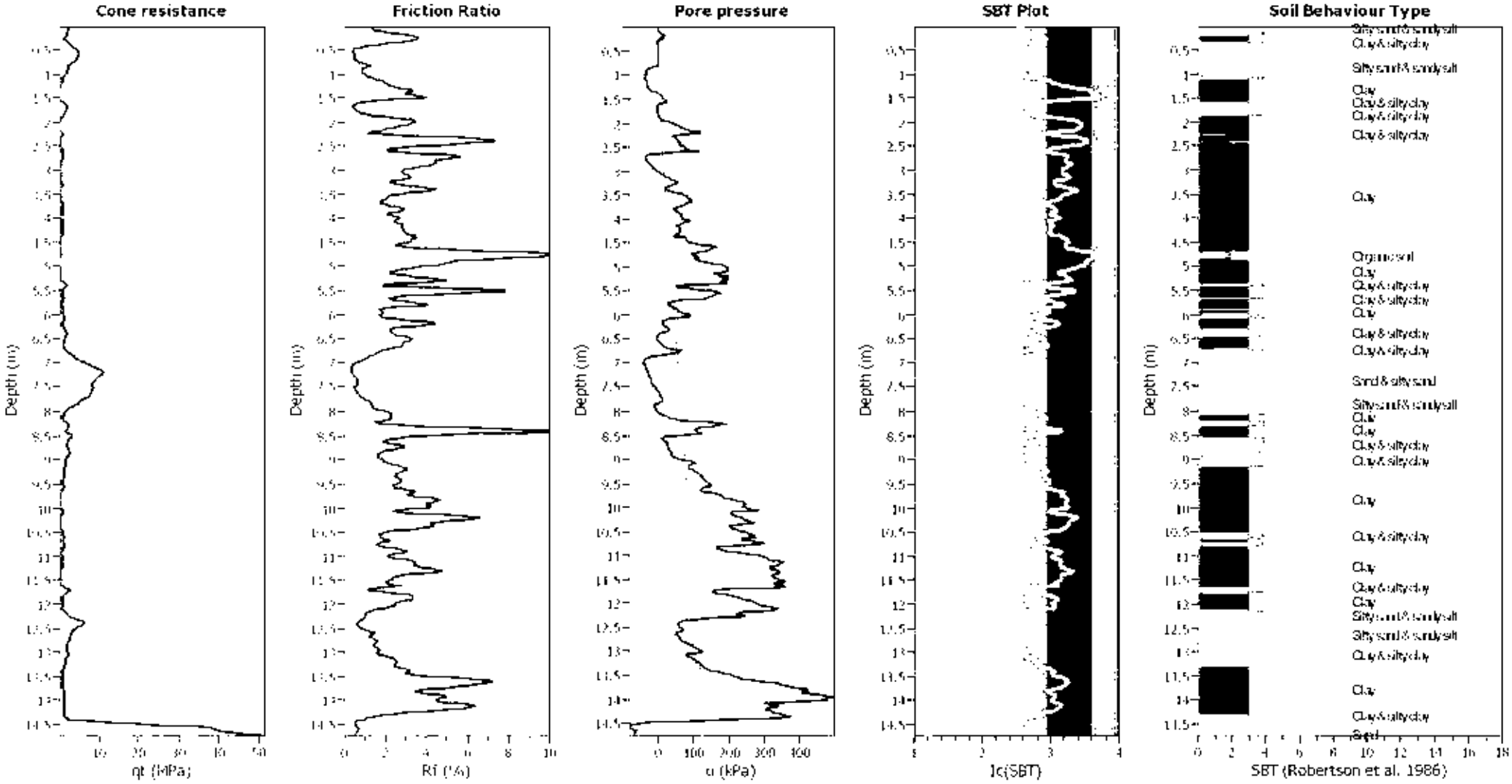
Analysis method:	I&B (2008)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	I&B (2008)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



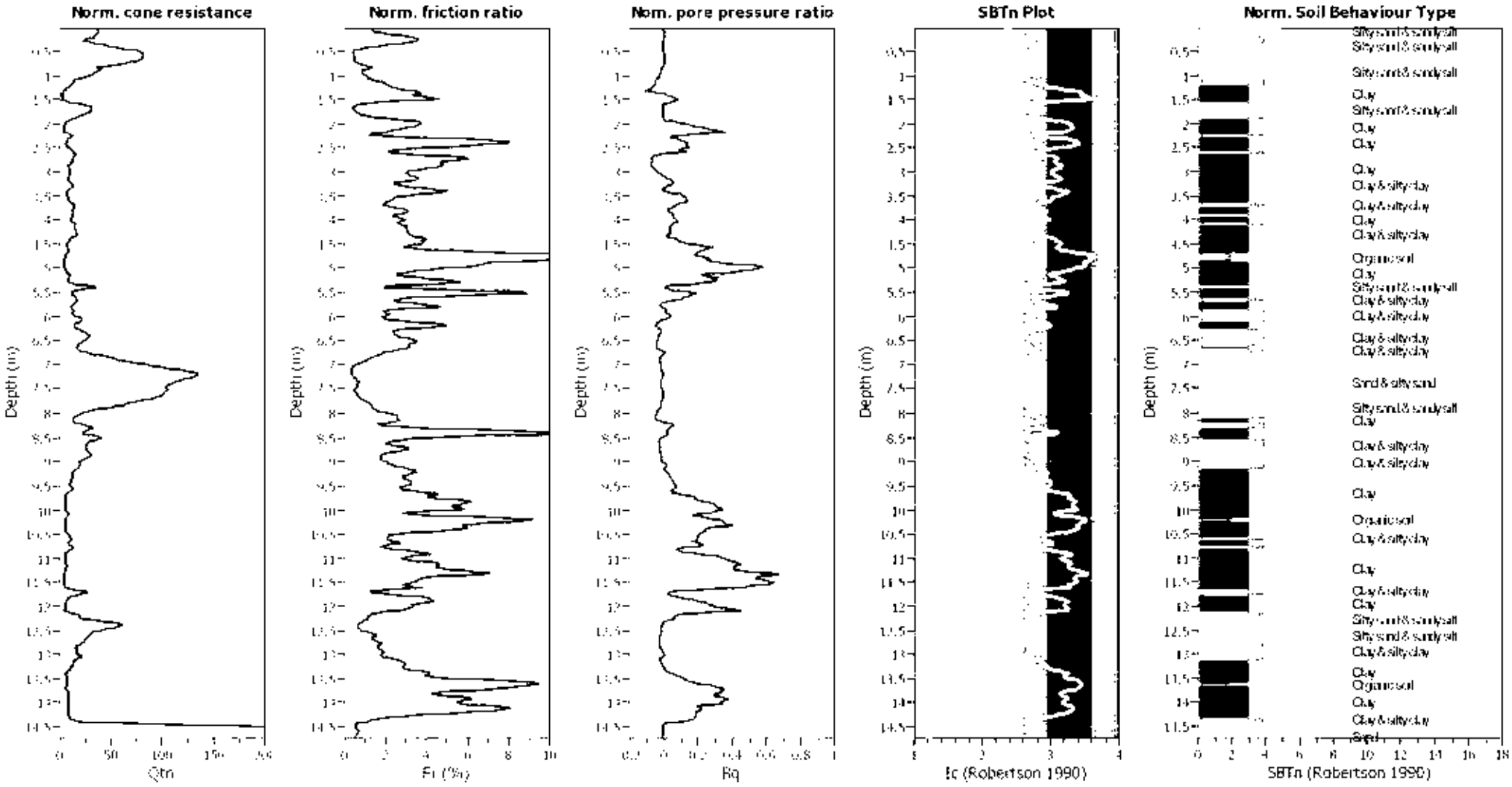
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 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

CPT basic interpretation plots (normalized)



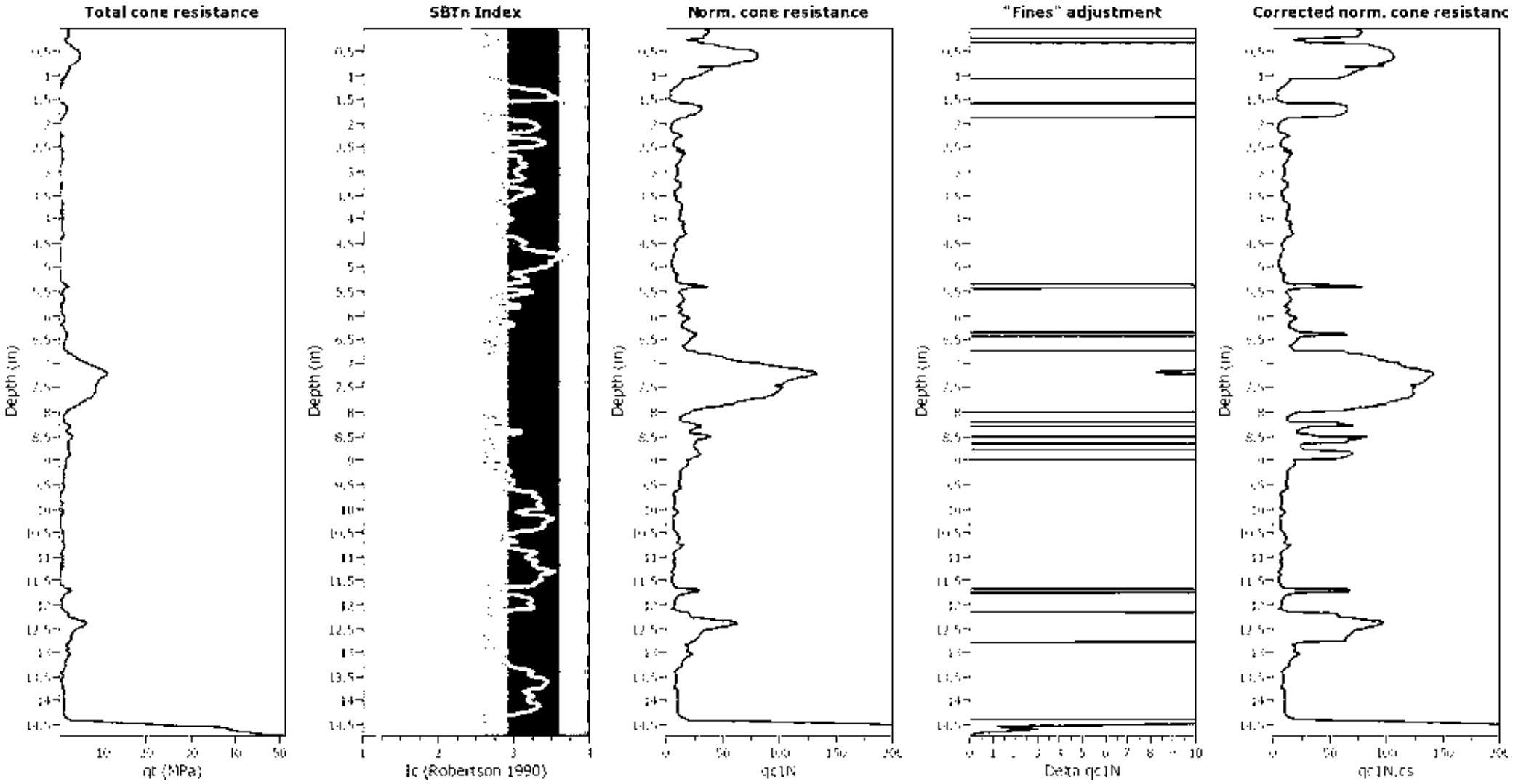
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

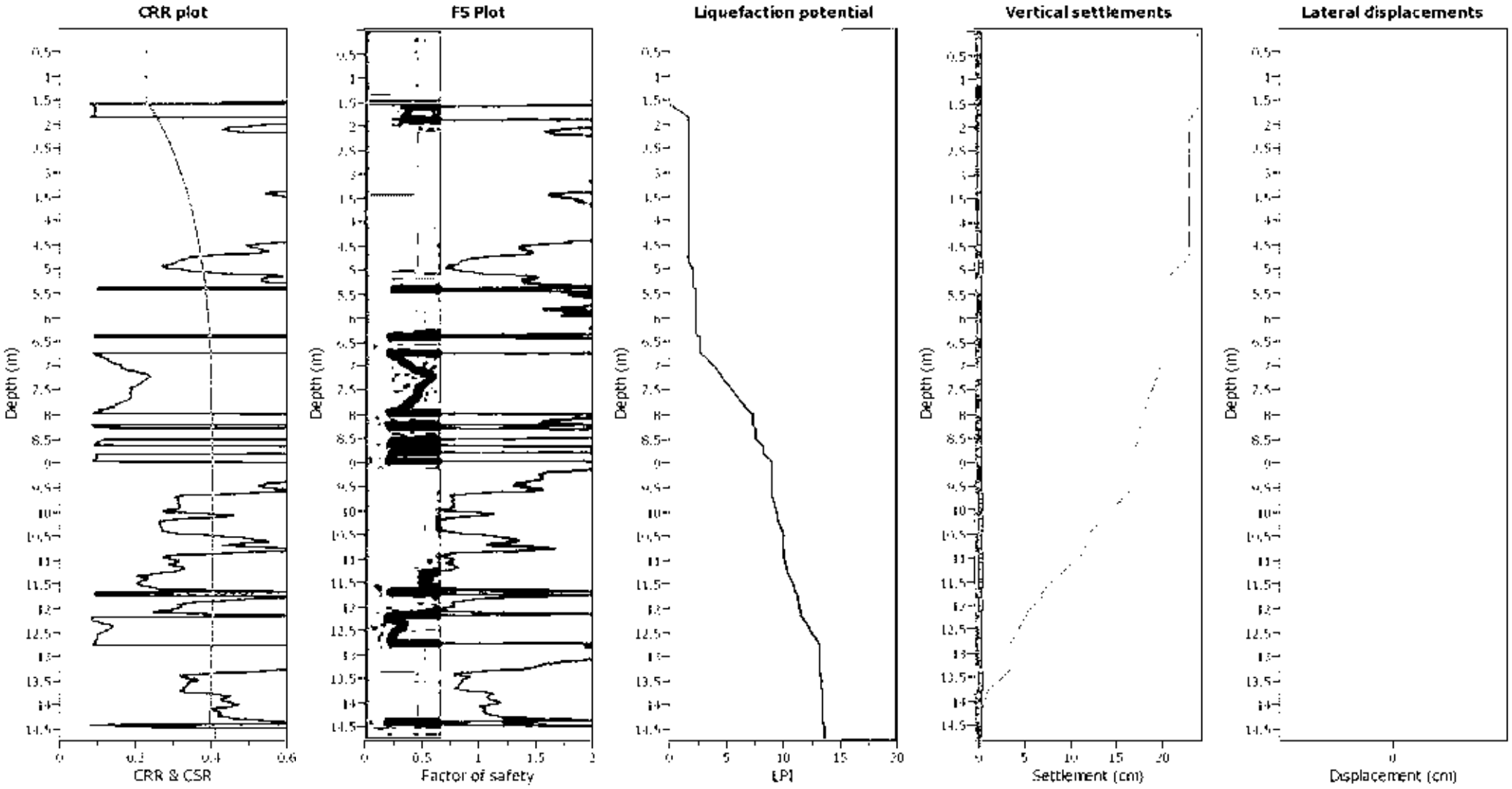
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 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.):	1.50 m	Fill weight:	N/A
Liner correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 m	Fill height:	N/A	Limit depth:	N/A

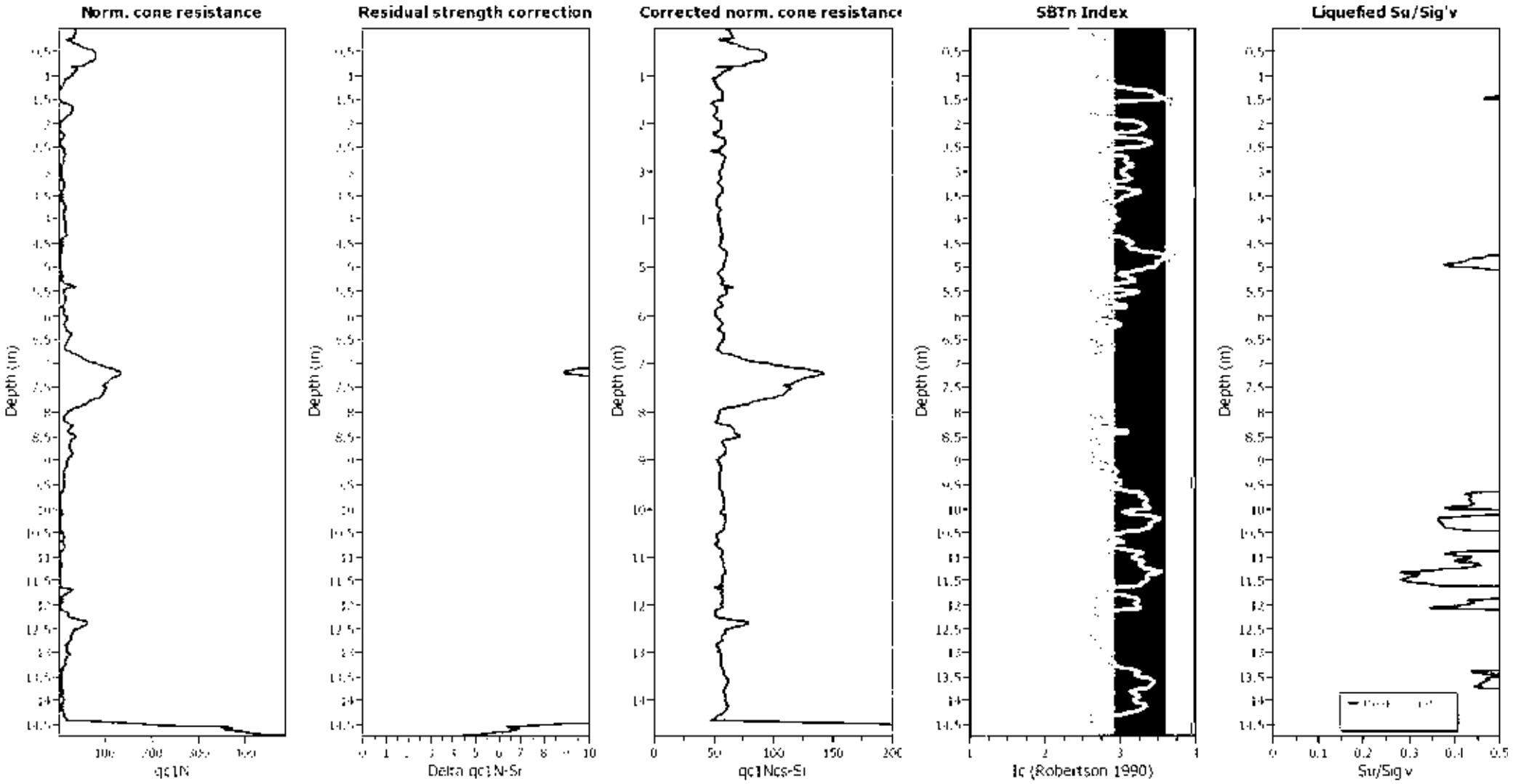
F.S. color scheme

- ☐ 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

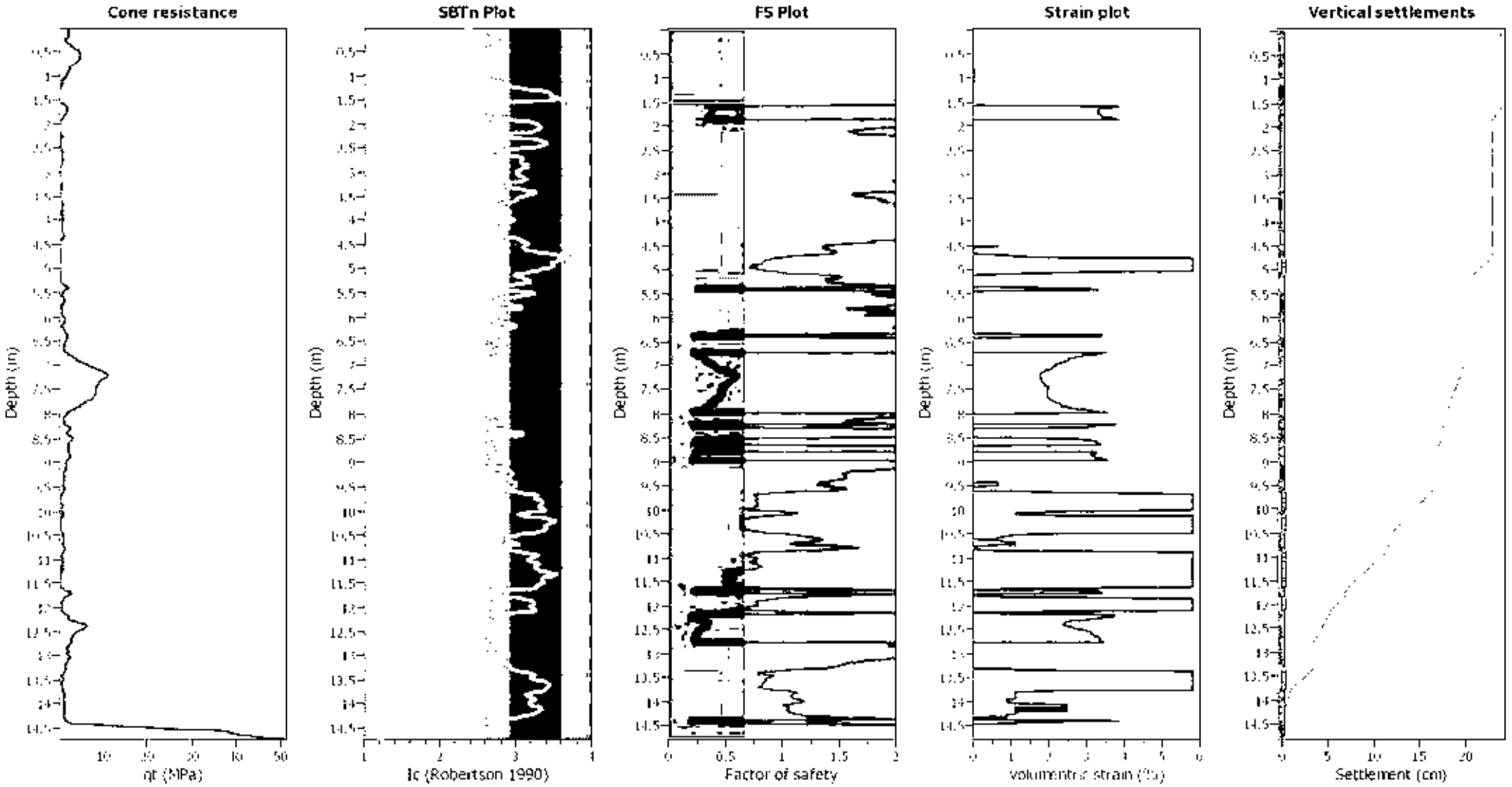
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Liquefaction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 m	Fill height:	N/A	Limit depth	N/A

Estimation of post-earthquake settlements



Abbreviations

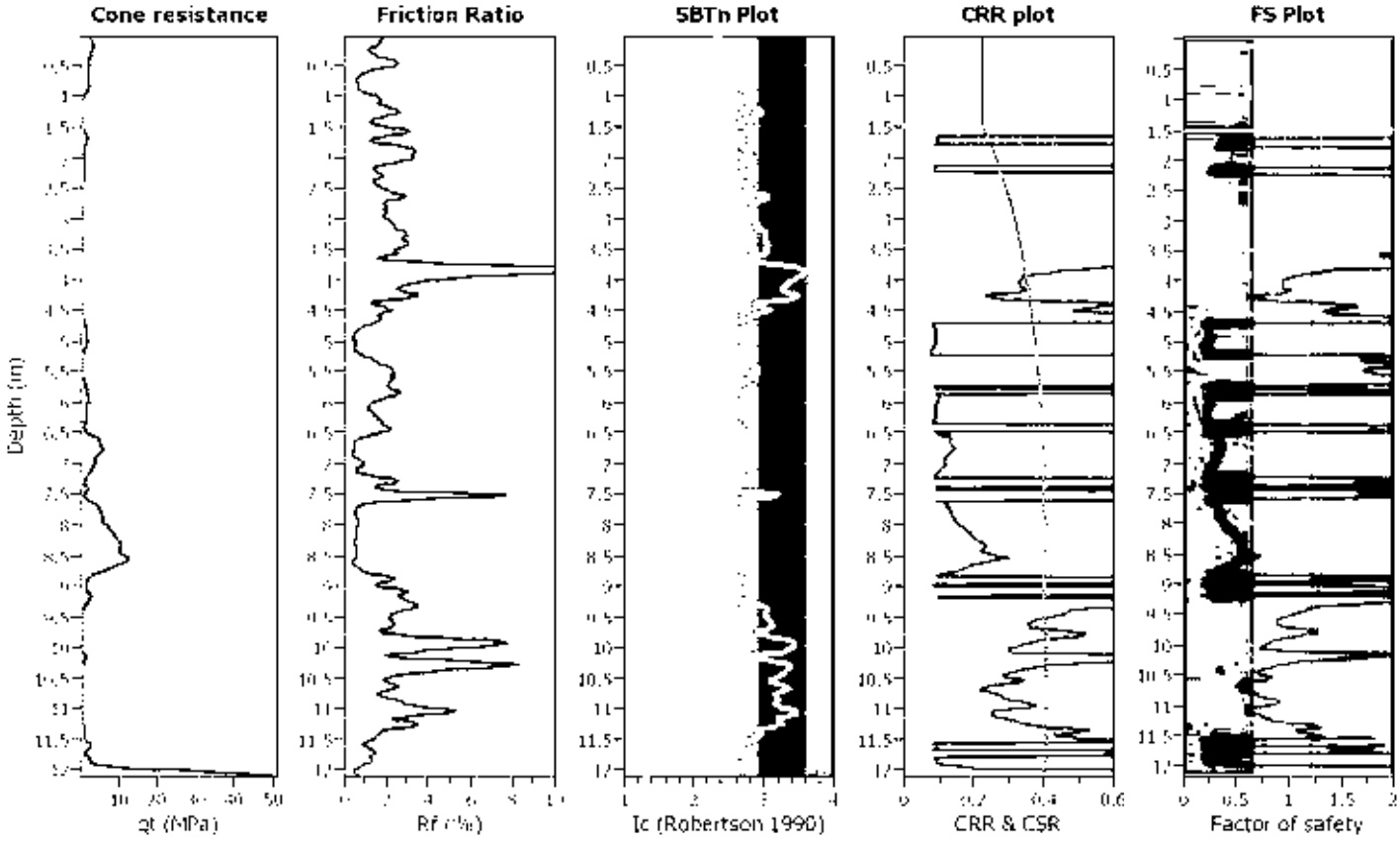
qt	Total cone resistance (cone resistance q corrected for pore water effects)
Ic	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumetric strain:	Post liquefaction volumetric strain

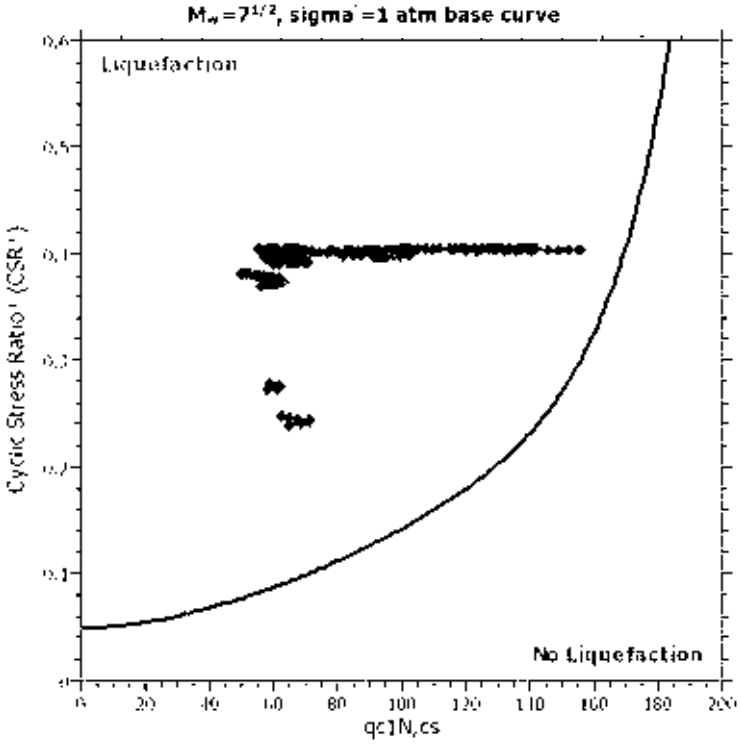
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

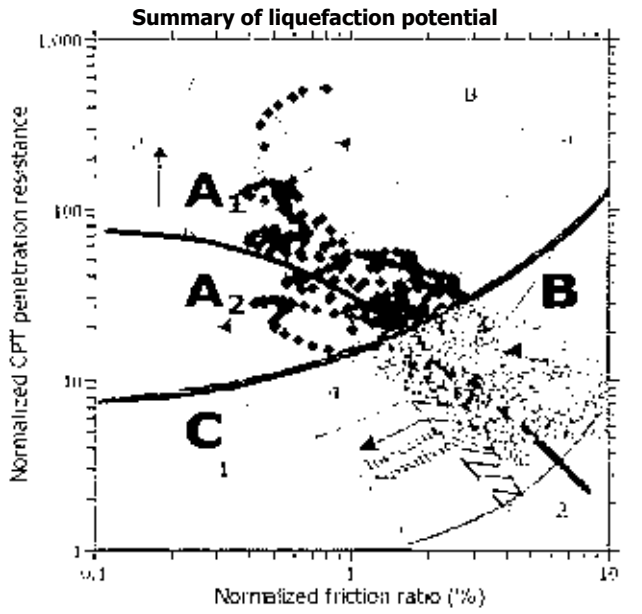
CPT file : CPT12_42QuaifesRd

Input parameters and analysis data

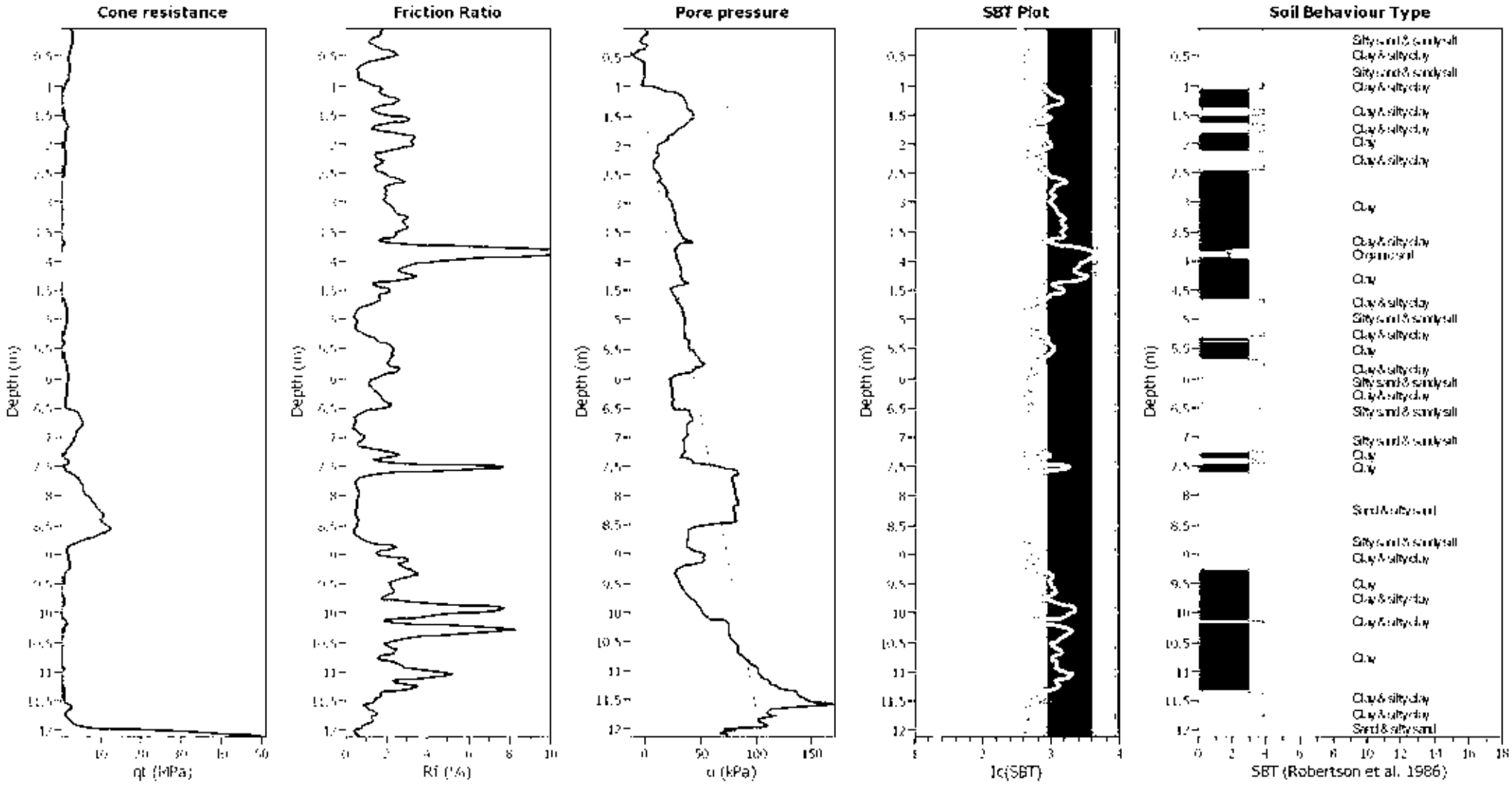
Analysis method:	I&B (2008)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	I&B (2008)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



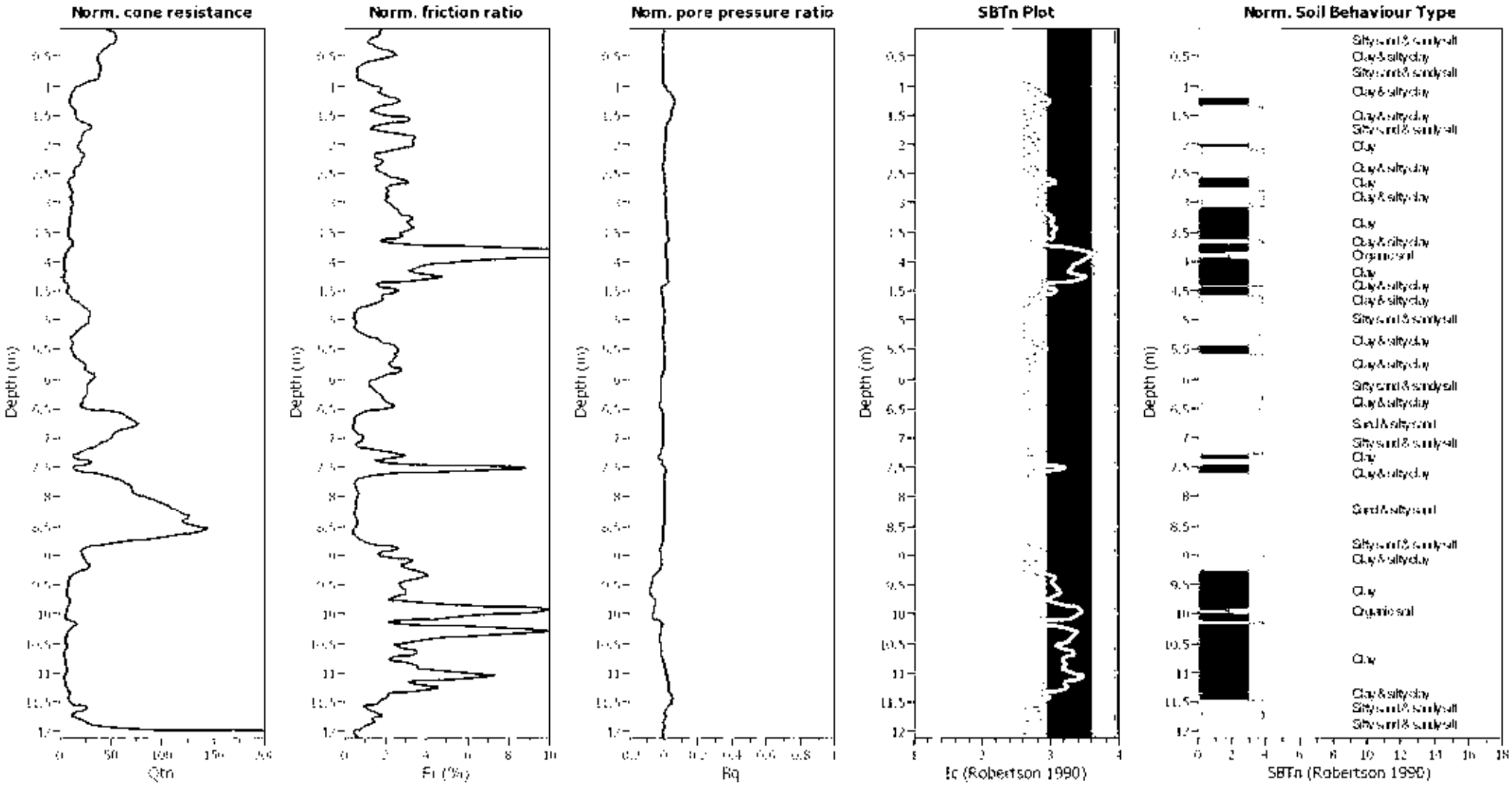
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 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

CPT basic interpretation plots (normalized)



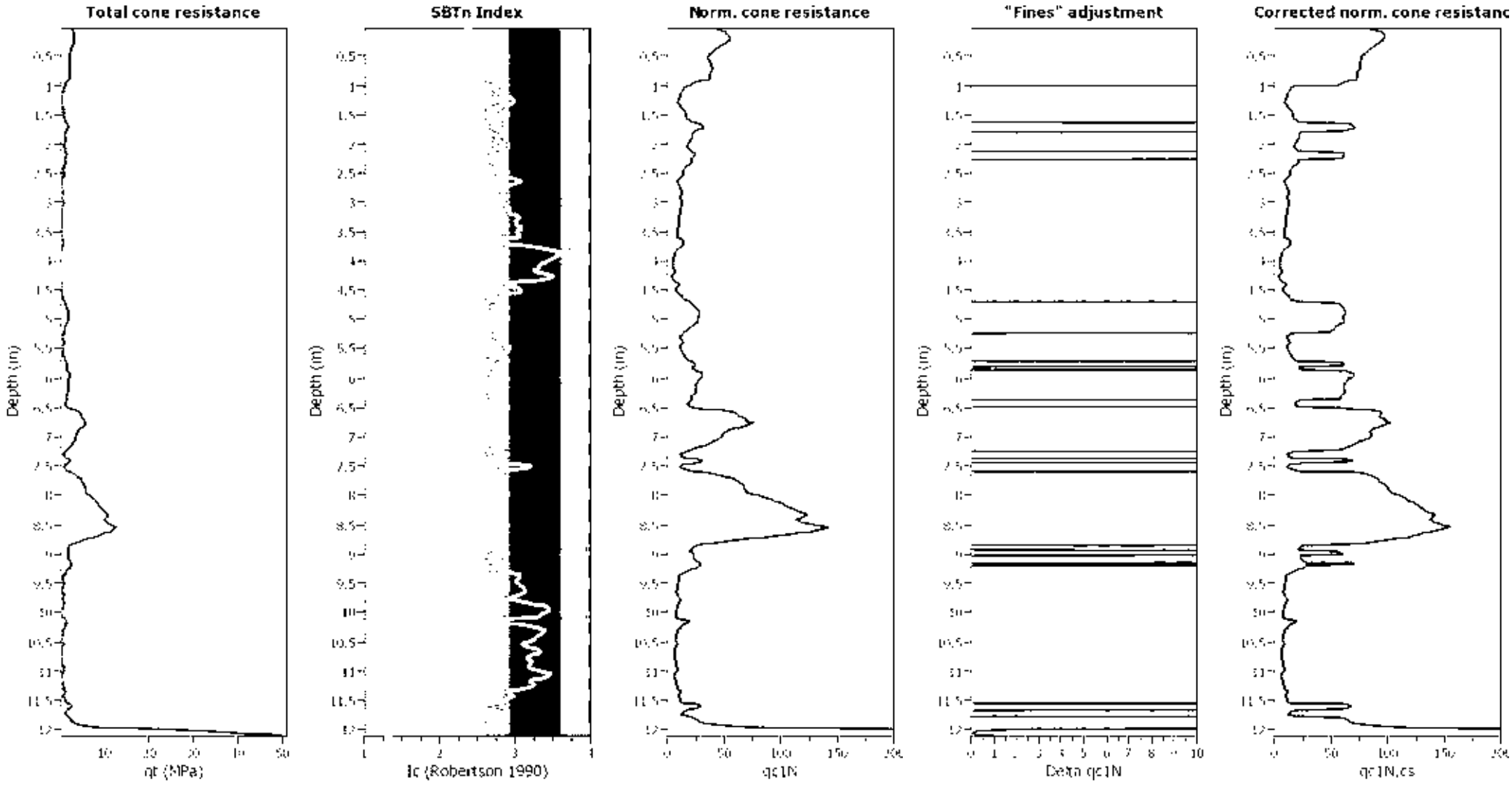
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

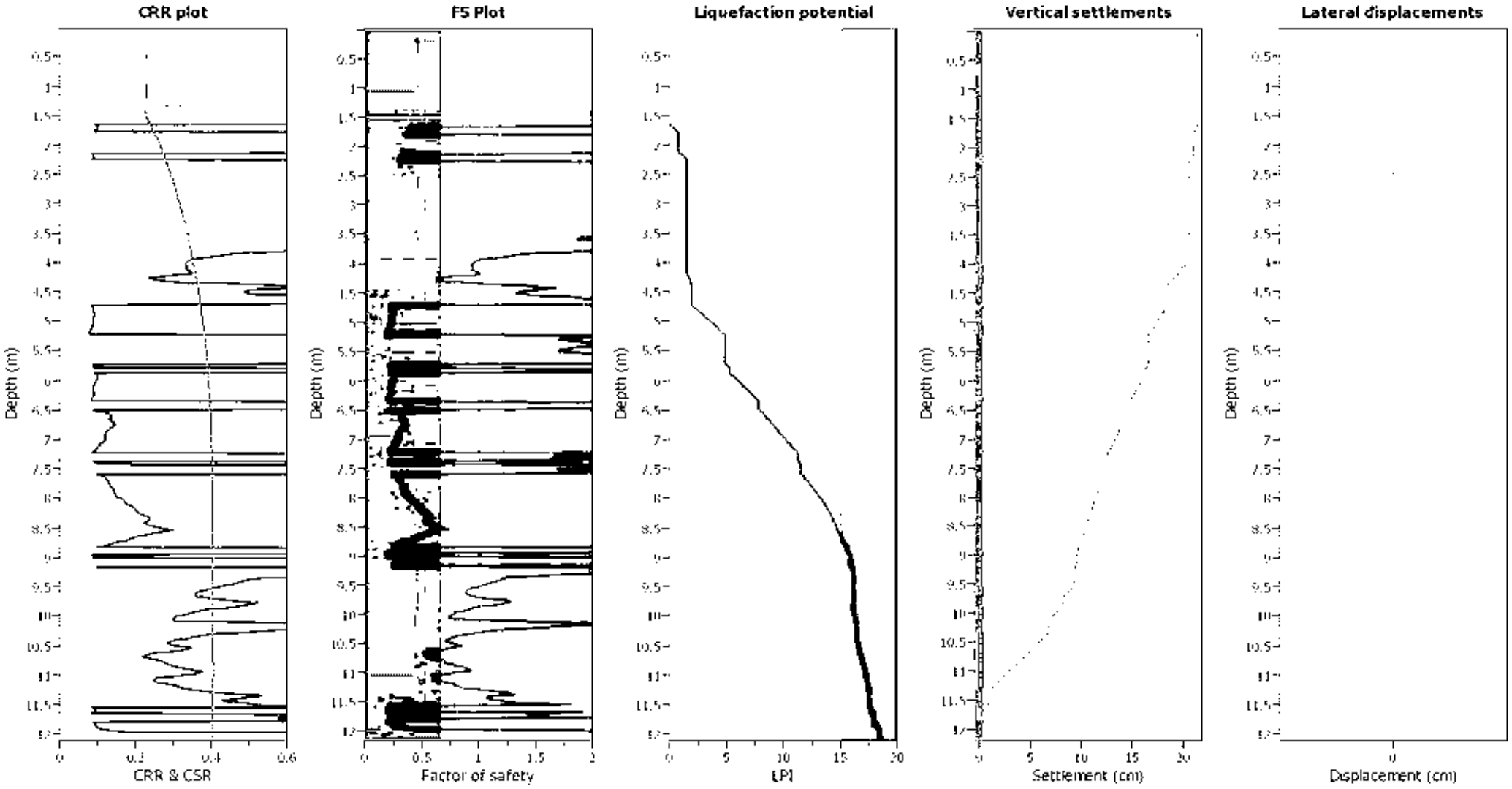
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 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.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K$_\sigma$ applied:	Yes
Earthquake magnitude M$_w$:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 m	Fill height:	N/A	Limit depth:	N/A

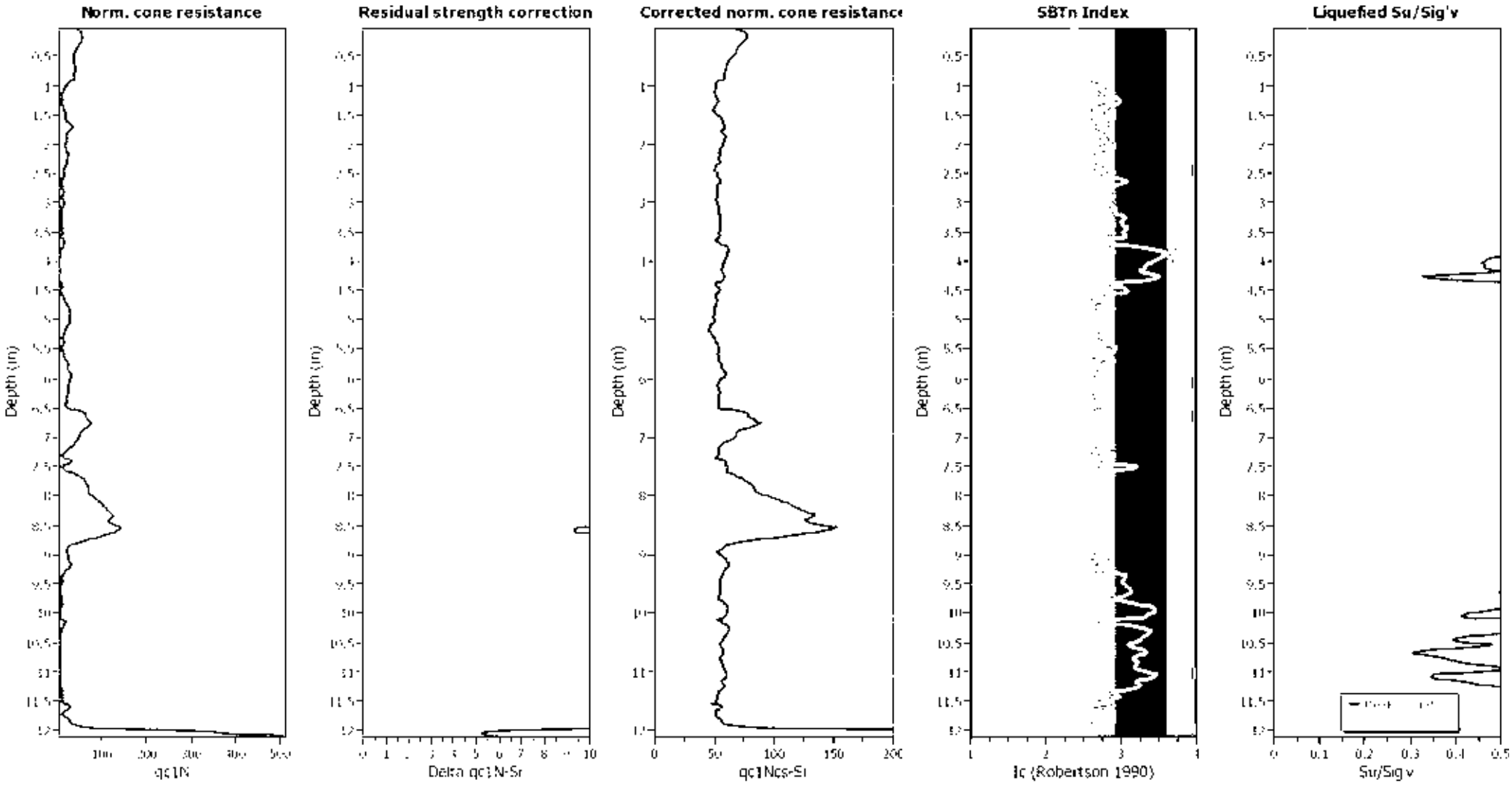
F.S. color scheme

- ☐ 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

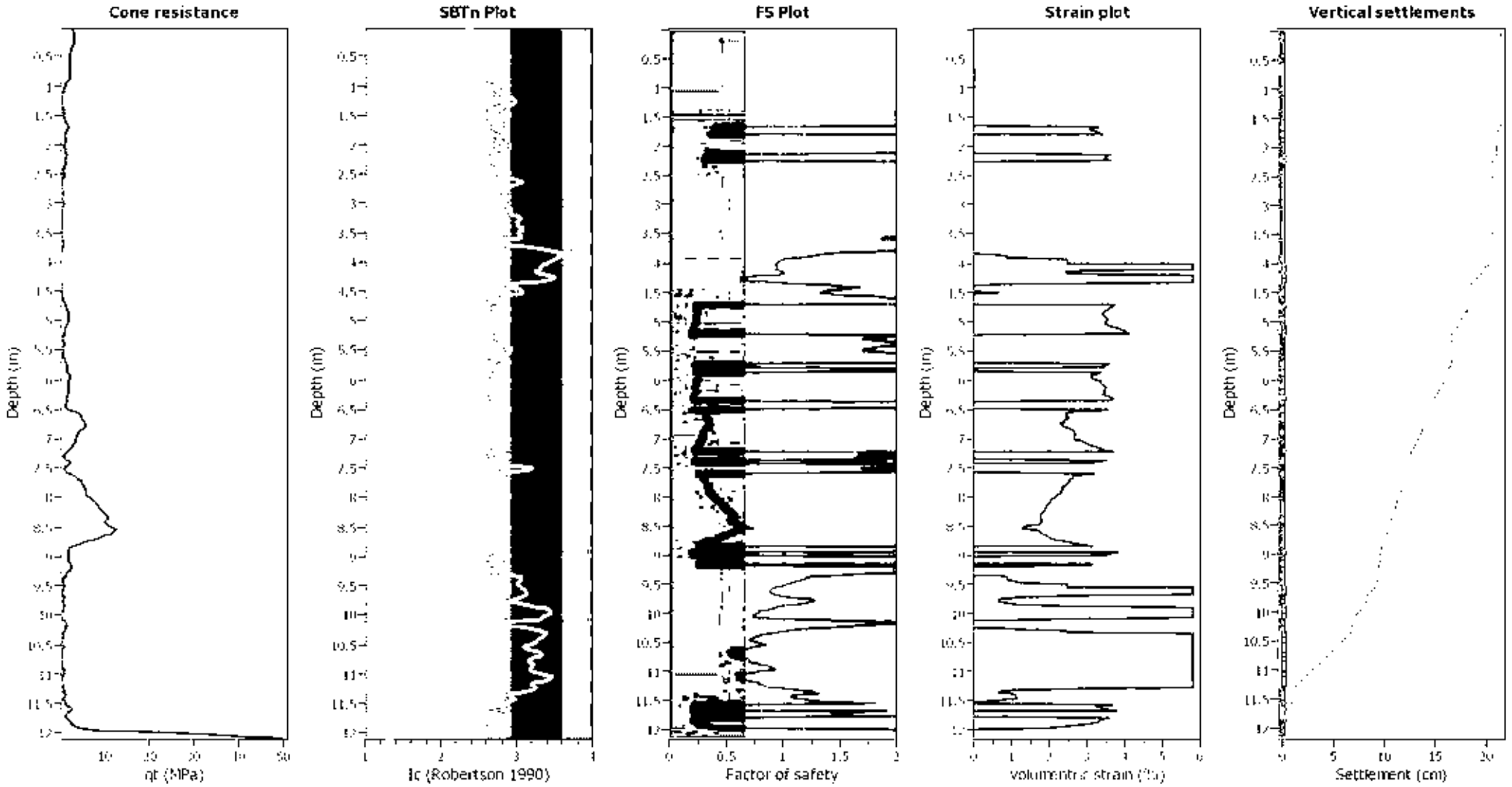
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Liquefaction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth	N/A

Estimation of post-earthquake settlements



Abbreviations

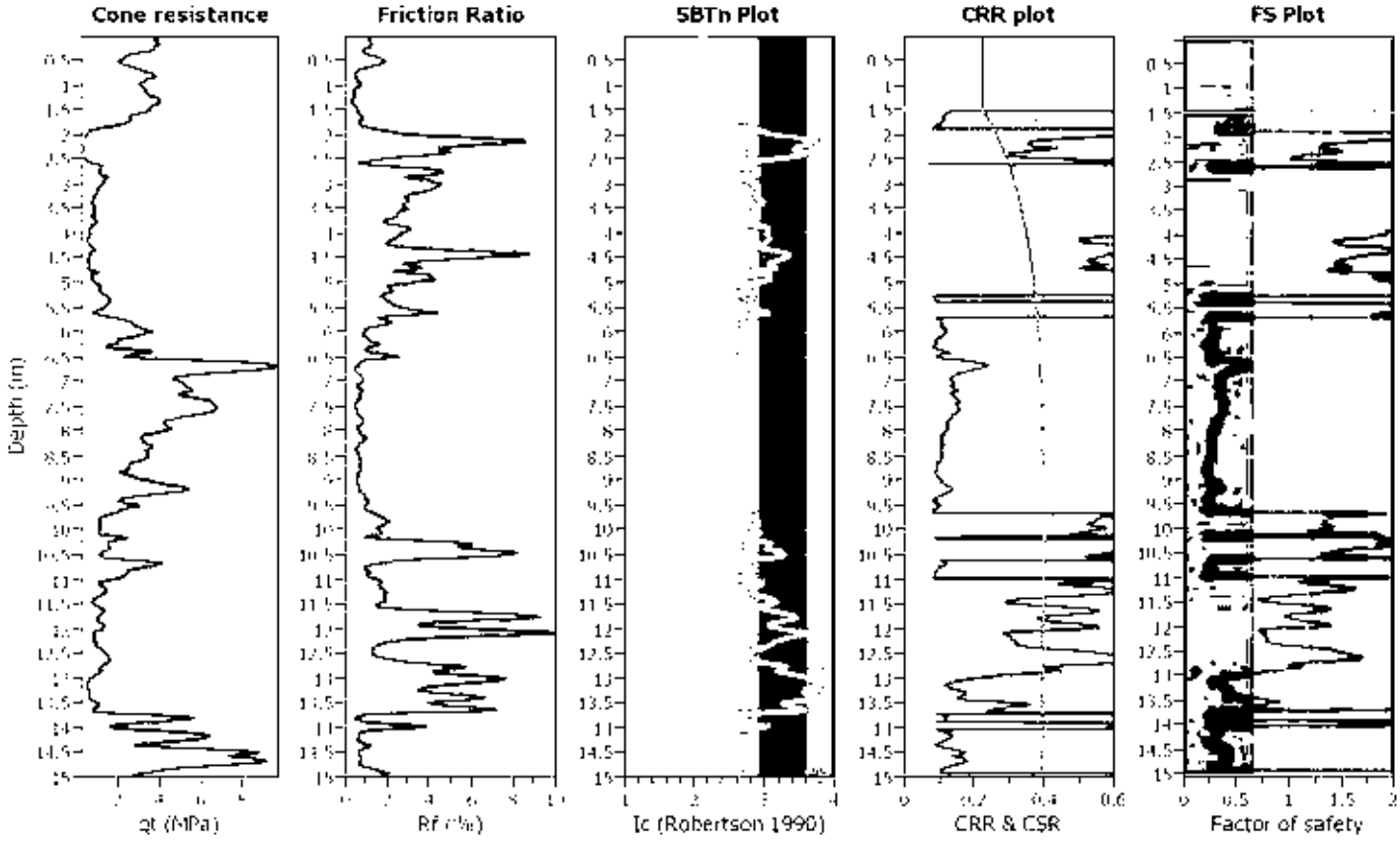
qt:	Total cone resistance (cone resistance q corrected for pore water effects)
Ic:	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumetric strain:	Post liquefaction volumetric strain

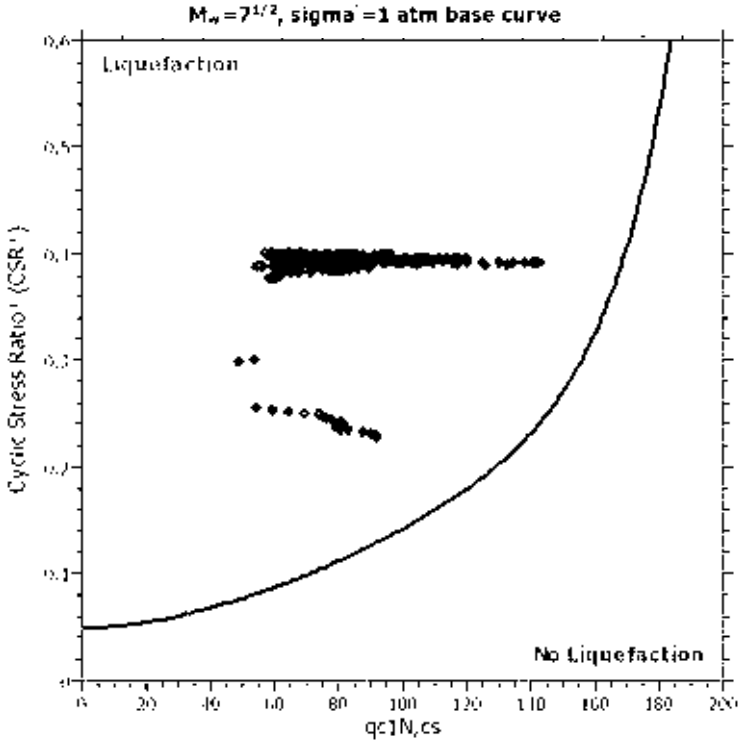
Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

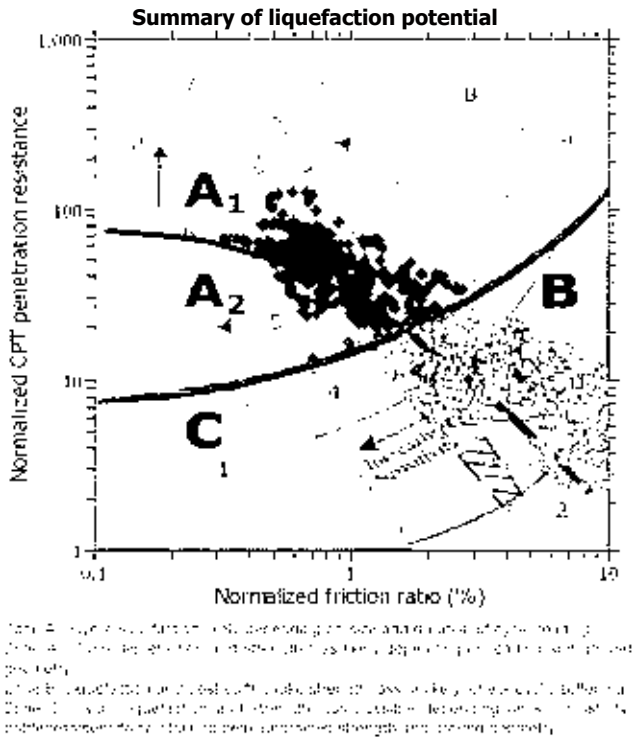
CPT file : CPT13_84SabysRd

Input parameters and analysis data

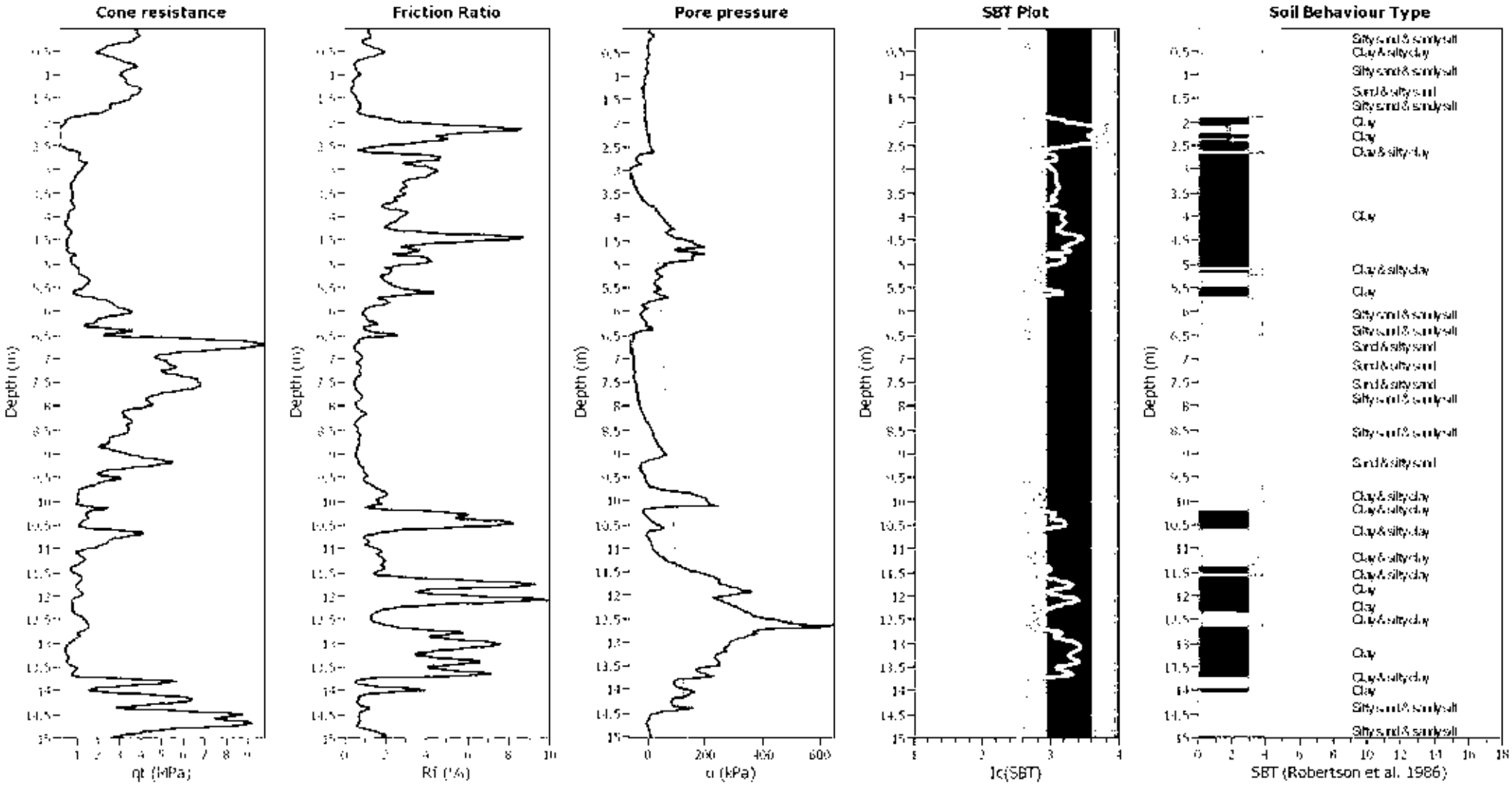
Analysis method:	I&B (2008)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	I&B (2008)	G.W.T. (earthq.):	1.50 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.50	Ic cut-off value:	2.60	Trans. detect. applied:	No		
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes		







CPT basic interpretation plots



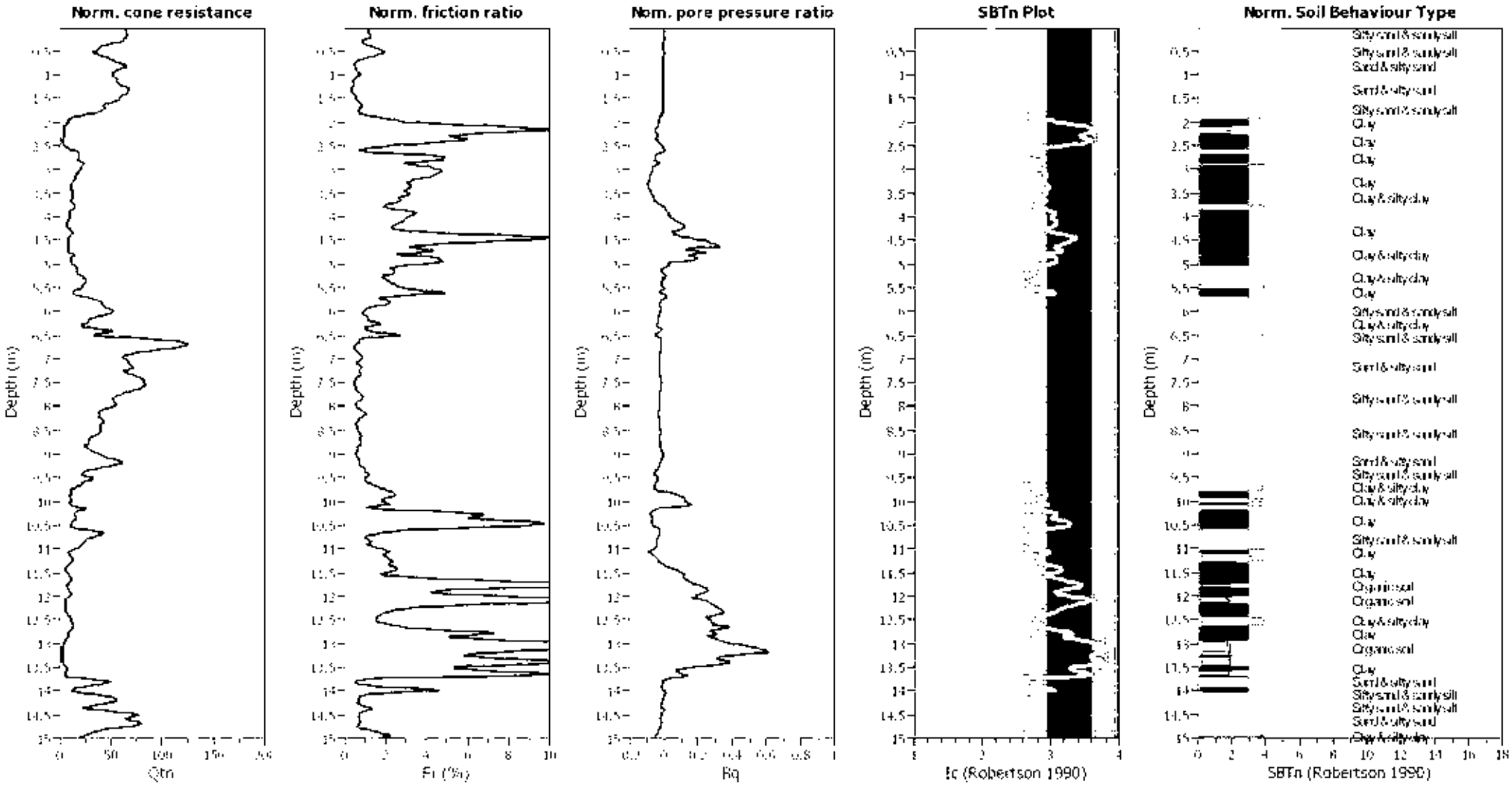
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 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

CPT basic interpretation plots (normalized)



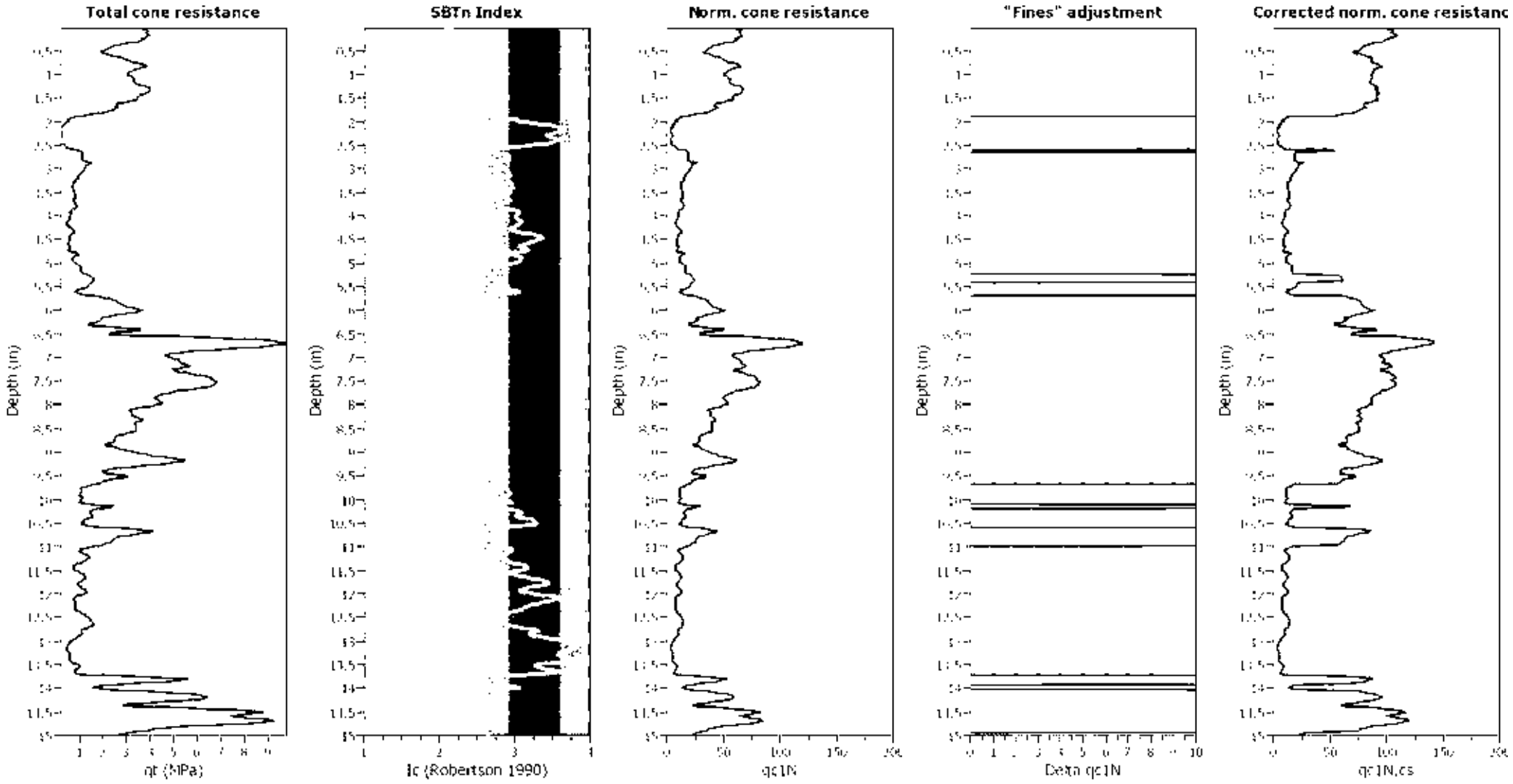
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 m	Fill height:	N/A	Limit depth:	N/A

SBTn 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

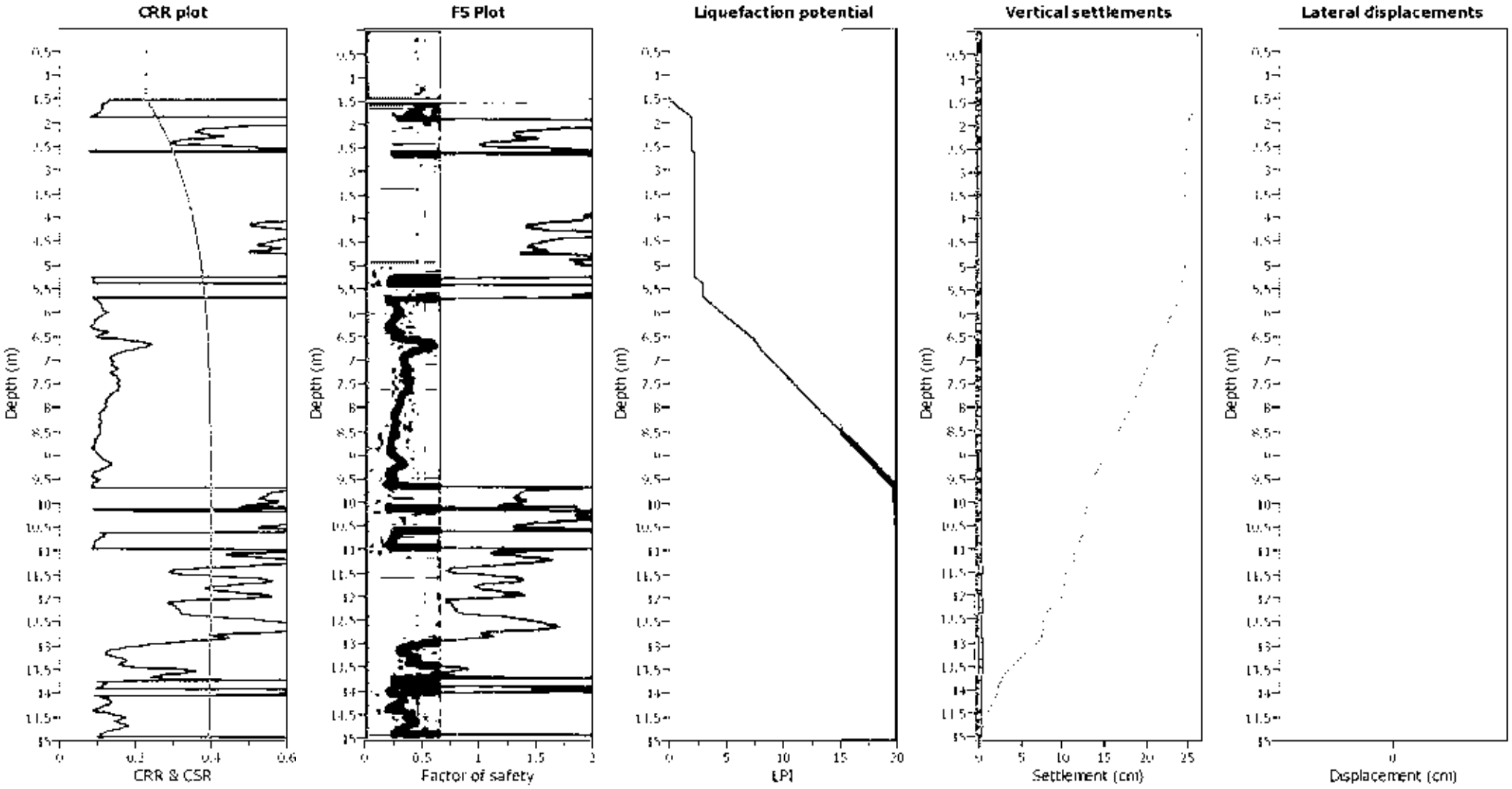
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 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.):	1.50 m	Fill weight:	N/A
Liquefaction correction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

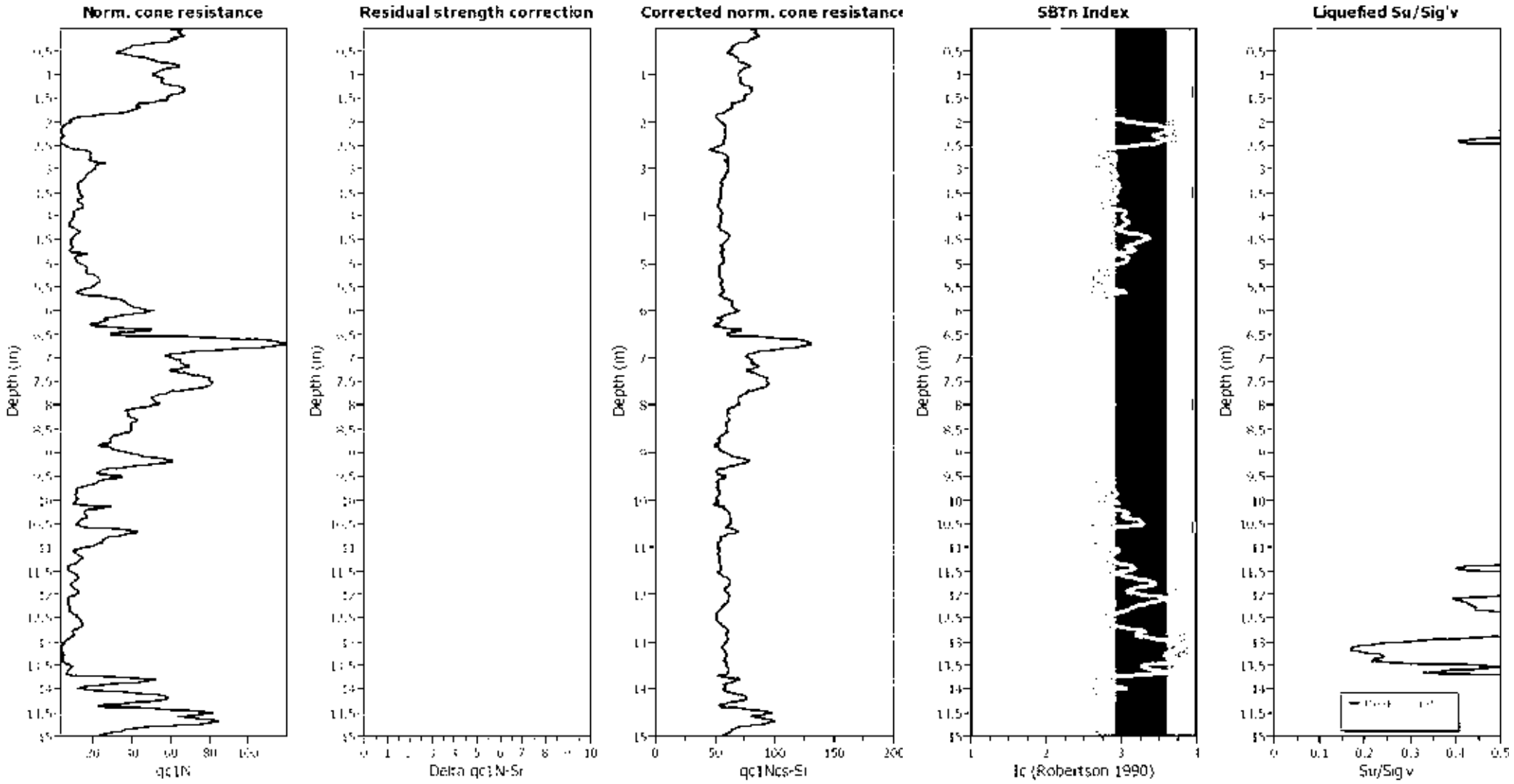
F.S. color scheme

- ☐ 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

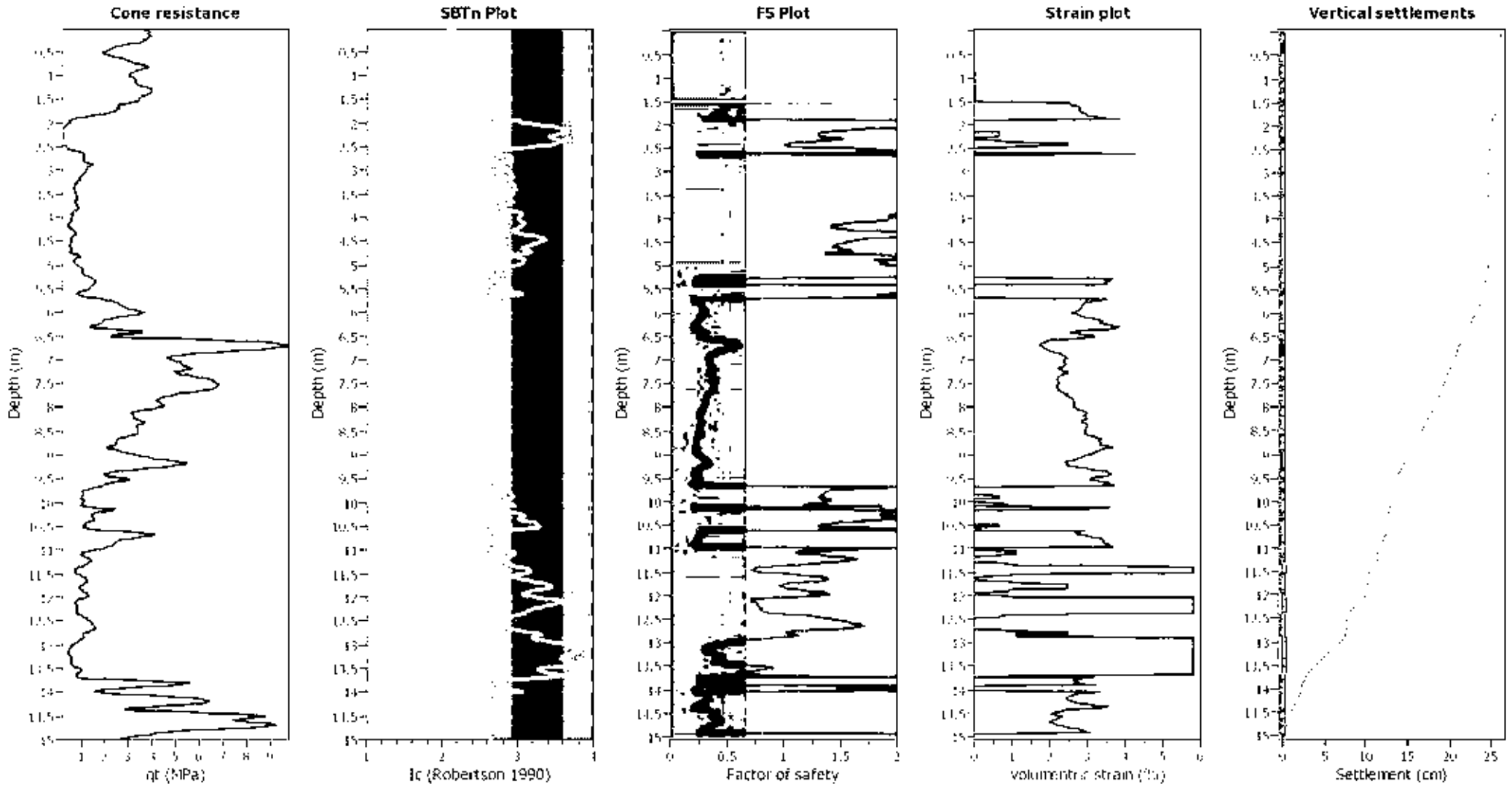
Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Liquefaction method:	I&B (2008)	Average results interval:	3	Transition detect. applied:	Sand & Clay
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behaviour applied:	.
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (erthq.):	1.50 m	Fill height:	N/A	Limit depth	N/A

Estimation of post-earthquake settlements



Abbreviations

qt:	Total cone resistance (cone resistance q corrected for pore water effects)
Ic:	Soil Behaviour Type Index
FS	Calculated Factor of Safety against Liquefaction
Volumetric strain:	Post liquefaction volumetric strain

Project title : CCC Halswell ODP Geotechnical Investigation **Location : Halswell, Christchurch**

CPT file : CPT14_23QuaifesRd

Input parameters and analysis data

Analysis method:	I&B (2008)	G.W.T. (in-situ):	1.50 m	Use fill:	No	Clay like behavior applied:	Sand & Clay
Fines correction method:	I&B (2008)	G.W.T. (earthq.):	1.50 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:	0.35	Unit weight calculation:	Based on SBT	K$_\sigma$ applied:	Yes