Christchurch City Council

Cresselly Place Housing Complex PRO 0980

Detailed Engineering Evaluation

Quantitative Assessment Report

Christchurch City Council

Cresselly Place Housing Complex

Quantitative Assessment Report

Wilsons Road, St Martins, Christchurch

Prepared By

Claire Ford
Building Technician

Reviewed By

Lachlan Howat
Graduate Structural Engineer

Approved for Release By

Mary Ann Halliday
Senior Structural Engineer

Opus International Consultants Ltd
Christchurch Office
20 Moorhouse Avenue
PO Box 1482, Christchurch Mail Centre, Christchurch 8140
New Zealand

Telephone: +64 3 363 5400
Facsimile: +64 3 365 7858

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Summary

Cresselly Place Housing Complex
PRO 0980

Detailed Engineering Evaluation
Quantitative Report - Summary
Final

Background

This is a summary of the quantitative report for the Cresselly Place Housing Complex, and is based on the Detailed Engineering Evaluation Procedure document (draft) issued by the Structural Advisory Group on 19 July 2011. This assessment covers the 30 residential units.

Key Damage Observed

The residential units suffered moderate-to-major damage to both structural and non-structural elements. This included cracking of brick veneers, wall and ceiling linings, and the concrete ring foundation in some units. The timber floors throughout the units were out of level to varying degrees. There was also varying amounts of damage to the site with concrete paths out of level and differential settlement.

Critical Structural Weaknesses

No critical structural weaknesses were found in any of the buildings.

Indicative Building Strength

No buildings on the site are considered to be earthquake prone.

Block	NBS%	Floor Levels	Plasterboard Nail Spacings
PRO 0980 B001 (Block A)	72%	10.8mm/m	Pass
PRO 0980 B002 (Block B)	72%	5.8mm/m	Pass
PRO 0980 B003 (Block C)	72%	14.7mm/m	Pass
PRO 0980 B004 (Block D)	72%	18.9mm/m	Pass
PRO 0980 B005 (Block E)	72%	20.8mm/m	Pass
PRO 0980 B006 (Block F)	72%	17.9mm/m	Pass
PRO 0980 B007 (Block G)	62%	34.7mm/m	Pass
PRO 0980 B008 (Block H)	72%	27.4mm/m	Pass

The residential units have capacities ranging from 62% to 72% NBS and are limited by the in-plane shear capacity of the lined timber-framed shear walls in the longitudinal direction. Block G has a

lower %NBS due to the damage suffered from racking of the timber framed walls under earthquake action.

Recommendations

It is recommended that;

- Blocks A and B are cosmetically repaired and have their veneer ties checked, especially in the gable ends.
- Blocks C, D and F are re-levelled, cosmetically repaired as required under the MBIE guidelines and have their veneer ties checked, especially in the gable ends.
- Blocks E, G and H are demolished.

Contents

Summary i

1 Introduction 4

2 Compliance 4

3 Earthquake Resistance Standards 8

4 Background Information 10

5 Structural Damage 14

6 Detailed Seismic Assessment 15

7 Summary of Geotechnical Appraisal 18

8 Conclusions 20

9 Recommendations 20

10 Limitations 20

11 References 21

Appendix A - Photographs

Appendix B -Level Survey

Appendix C - Geotechnical Appraisal

Appendix D - Methodology and Assumptions

Appendix E - CERA DEE Spreadsheet

1 Introduction

Opus International Consultants Limited has been engaged by Christchurch City Council to undertake a detailed seismic assessment of the Cresselly Place Housing Complex, located at Wilsons Road, St Martins, Christchurch, following the Canterbury Earthquake Sequence since September 2010.

The purpose of the assessment is to determine if the buildings are classed as being earthquake prone in accordance with the Building Act 2004.

The seismic assessment and reporting have been undertaken based on the qualitative and quantitative procedures detailed in the Detailed Engineering Evaluation Procedure (DEEP) document (draft) issued by the Structural Engineering Society (SESOC) [2] [3] [4] [5].

2 Compliance

This section contains a brief summary of the requirements of the various statutes and authorities that control activities in relation to buildings in Christchurch at present.

2.1 Canterbury Earthquake Recovery Authority (CERA)

CERA was established on 28 March 2011 to take control of the recovery of Christchurch using powers established by the Canterbury Earthquake Recovery Act enacted on 18 April 2011. This act gives the Chief Executive Officer of CERA wide powers in relation to building safety, demolition and repair. Two relevant sections are:

Section 38 – Works

This section outlines a process in which the chief executive can give notice that a building is to be demolished and if the owner does not carry out the demolition, the chief executive can commission the demolition and recover the costs from the owner or by placing a charge on the owners' land.

Section 51 – Requiring Structural Survey

This section enables the chief executive to require a building owner, insurer or mortgagee to carry out a full structural survey before the building is re-occupied.

We understand that CERA require a detailed engineering evaluation to be carried out for all buildings (other than those exempt from the Earthquake Prone Building definition in the Building Act). CERA have adopted the Detailed Engineering Evaluation Procedure (DEEP) document (draft) issued by the Structural Engineering Society (SESOC) on 19 July 2011. This document sets out a methodology for both initial qualitative and detailed quantitative assessments.

It is anticipated that a number of factors, including the following, will determine the extent of evaluation and strengthening level required:

1. The importance level and occupancy of the building.

2. The placard status and amount of damage.

3. The age and structural type of the building.

4. Consideration of any critical structural weaknesses.

Christchurch City Council requires any building with a capacity of less than 34% of New Building Standard (including consideration of critical structural weaknesses) to be strengthened to a target of 67% as required under the CCC Earthquake Prone Building Policy.

2.2 Building Act

Several sections of the Building Act are relevant when considering structural requirements:

Section 112 – Alterations

This section requires that an existing building complies with the relevant sections of the Building Code to at least the extent that it did prior to the alteration. This effectively means that a building cannot be weakened as a result of an alteration (including partial demolition).

The Earthquake Prone Building policy for the territorial authority shall apply as outlined in Section 2.3 of this report.

Section 115 – Change of Use

This section requires that the territorial authority is satisfied that the building with a new use complies with the relevant sections of the Building Code 'as near as is reasonably practicable'.

This is typically interpreted by territorial authorities as being 67% of the strength of an equivalent new building or as near as practicable. This is also the minimum level recommended by the New Zealand Society for Earthquake Engineering (NZSEE).

Section 121 – Dangerous Buildings

This section was extended by the Canterbury Earthquake (Building Act) Order 2010, and defines a building as dangerous if:

1. In the ordinary course of events (excluding the occurrence of an earthquake), the building is likely to cause injury or death or damage to other property; or
2. In the event of fire, injury or death to any persons in the building or on other property is likely because of fire hazard or the occupancy of the building; or
3. There is a risk that the building could collapse or otherwise cause injury or death as a result of earthquake shaking that is less than a 'moderate earthquake' (refer to Section 122 below); or
4. There is a risk that other property could collapse or otherwise cause injury or death; or
5. A territorial authority has not been able to undertake an inspection to determine whether the building is dangerous.

Section 122 – Earthquake Prone Buildings

This section defines a building as earthquake prone (EPB) if its ultimate capacity would be exceeded in a 'moderate earthquake' and it would be likely to collapse causing injury or death, or damage to other property.

A moderate earthquake is defined by the building regulations as one that would generate loads 33% of those used to design an equivalent new building.

Section 124 – Powers of Territorial Authorities

This section gives the territorial authority the power to require strengthening work within specified timeframes or to close and prevent occupancy to any building defined as dangerous or earthquake prone.

Section 131 – Earthquake Prone Building Policy

This section requires the territorial authority to adopt a specific policy for earthquake prone, dangerous and insanitary buildings.

2.3 Christchurch City Council Policy

Christchurch City Council adopted their Earthquake Prone, Dangerous and Insanitary Building Policy in October 2011 following the Darfield Earthquake on 4 September 2010.

The policy includes the following:

1. A process for identifying, categorising and prioritising Earthquake Prone Buildings, commencing on 1 July 2012;
2. A strengthening target level of 67% of a new building for buildings that are Earthquake Prone;
3. A timeframe of 15-30 years for Earthquake Prone Buildings to be strengthened; and,
4. Repair works for buildings damaged by earthquakes will be required to comply with the above.

The council has stated their willingness to consider retrofit proposals on a case by case basis, considering the economic impact of such a retrofit.

If strengthening works are undertaken, a building consent will be required. A requirement of the consent will require upgrade of the building to comply 'as near as is reasonably practicable' with:

- The accessibility requirements of the Building Code.
- The fire requirements of the Building Code. This is likely to require a fire report to be submitted with the building consent application.

Where an application for a change of use of a building is made to Council, the building will be required to be strengthened to 67% of New Building Standard or as near as is reasonably practicable.

2.4 Building Code

The Building Code outlines performance standards for buildings and the Building Act requires that all new buildings comply with this code. Compliance Documents published by The Department of Building and Housing can be used to demonstrate compliance with the Building Code.

On 19 May 2011, Compliance Document B1: Structure, was amended to include increased seismic design requirements for Canterbury as follows:

- Increase in the basic seismic design load for the Canterbury earthquake region (Z factor increased to 0.3 equating to an increase of 36 – 47% depending on location within the region);
- Increased serviceability requirements.

2.5 Institution of Professional Engineers New Zealand (IPENZ) Code of Ethics

One of the core ethical values of professional engineers in New Zealand is the protection of life and safeguarding of people. The IPENZ Code of Ethics requires that:

Members shall recognise the need to protect life and to safeguard people, and in their engineering activities shall act to address this need.

1.1 Giving Priority to the safety and well-being of the community and having regard to this principle in assessing obligations to clients, employers and colleagues.

1.2 Ensuring that responsible steps are taken to minimise the risk of loss of life, injury or suffering which may result from your engineering activities, either directly or indirectly.

All recommendations on building occupancy and access must be made with these fundamental obligations in mind.

3 Earthquake Resistance Standards

For this assessment, the building's earthquake resistance is compared with the current New Zealand Building Code requirements for a new building constructed on the site. This is expressed as a percentage of new building standard (%NBS). The loadings are in accordance with the current earthquake loading standard NZS1170.5 [1].

A generally accepted classification of earthquake risk for existing buildings in terms of %NBS that has been proposed by the NZSEE 2006 [2] is presented in Figure 1below.

Description	Grade	Risk	%NBS	Existing Building Structural Performance	Improvement of Structural Performance	
					Legal Requirement	NZSEE Recommendation
Low Risk Building	A or B	Low	Above 67	Acceptable (improvement may be desirable)	The Building Act sets no required level of structural improvement (unless change in use) This is for each TA to decide. Improvement is not limited to 34%NBS.	100%NBS desirable. Improvement should achieve at least 67%NBS
Moderate Risk Building	B or C	Moderate	34 to 66	Acceptable legally. Improvement recommended		Not recommended. Acceptable only in exceptional circumstances
High Risk Building	D or E	High	33 or lower	Unacceptable (Improvement required under Act)	Unacceptable	Unacceptable

Figure 1: NZSEE Risk Classifications Extracted from table 2.2 of the NZSEE 2006 AISPBE Guidelines [2].

Table 1 below compares the percentage NBS to the relative risk of the building failing in a seismic event with a 10% risk of exceedance in 50 years (i.e. 0.2% in the next year).

Table 1: %NBS compared to relative risk of failure

Percentage of New Building Standard (%NBS)	Relative Risk (Approximate)
>100	<1 time
80-100	1-2 times
67-80	2-5 times
33-67	5-10 times
20-33	10-25 times
<20	>25 times

3.1 Minimum and Recommended Standards

Based on governing policy and recent observations, Opus makes the following general recommendations:

3.1.1 Occupancy

The Canterbury Earthquake Order[1] in Council 16 September 2010, modified the meaning of "dangerous building" to include buildings that were identified as being EPB's. As a result of this, we would expect such a building would be issued with a Section 124 notice, by the Territorial Authority, or CERA acting on their behalf, once they are made aware of our assessment. Based on information received from CERA to date and from the MBIE guidance document dated December 2012 [6], this notice is likely to prohibit occupancy of the building (or parts thereof), until its seismic capacity is improved to the point that it is no longer considered an EPB.

3.1.2 Cordoning

Where there is an overhead falling hazard, or potential collapse hazard of the building, the areas of concern should be cordoned off in accordance with current CERA/territorial authority guidelines.

3.1.3 Strengthening

Industry guidelines (NZSEE 2006 [2]) strongly recommend that every effort be made to achieve improvement to at least 67%NBS. A strengthening solution to anything less than 67%NBS would not provide an adequate reduction to the level of risk.

It should be noted that full compliance with the current building code requires building strength of 100%NBS.

3.1.4 Our Ethical Obligation

In accordance with the IPENZ code of ethics, we have a duty of care to the public. This obligation requires us to identify and inform CERA of potentially dangerous buildings; this would include earthquake prone buildings.

[1]This Order only applies to buildings within the Christchurch City, Selwyn District and Waimakariri District Councils authority.

4 Background Information

4.1 Building Descriptions

The site contains 30 residential units which were constructed in 1961. The units are numbered 1 to 31 (there is no unit 13) and are grouped together into one block of five units, five blocks of four units, one block of three units and one block of two units. A site plan showing the locations of the units is shown in Figure 2. Figure 3 shows the location of the site in Christchurch City. The site was visited by Opus International Consultants on 8 July 2013.

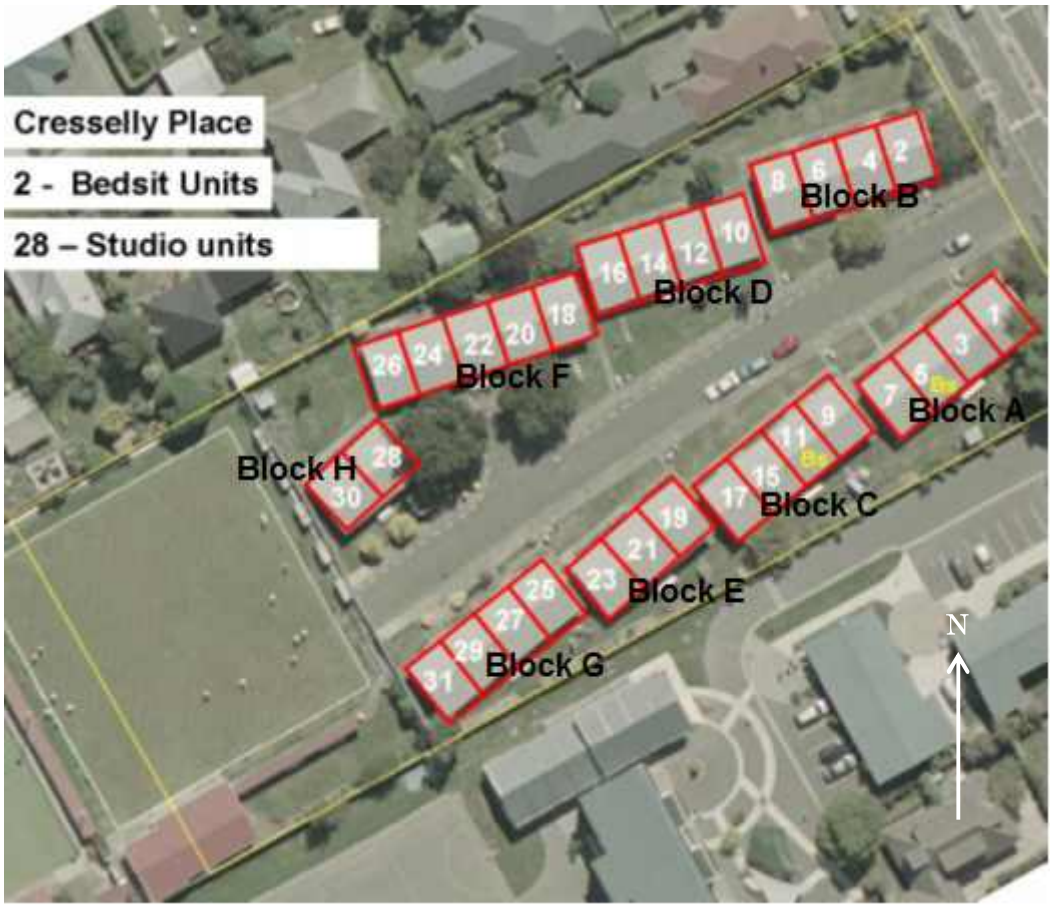


Figure 2: Site plan of Cresselly Place Housing Complex.

Figure 3: Location of site relative to Christchurch City CBD *(Source: Google Maps).*

The residential units are timber-framed buildings with diagonal timber braces. The roof structure comprises timber roof framing supporting light-weight metal cladding. The walls and ceilings are lined with plasterboard. External walls are clad with brick veneer. The timber floor is supported by ordinary timber piles and a concrete perimeter wall. The units are separated by a 200mm thick double brick fire wall with every fourth course used as a header course. The firewalls are lined with 75x50 timber framing and plasterboard each side. The screen walls, in line with the block party walls, are likely to be 2 wythes of veneer tied together.

Figure 4 shows a typical floor plan of a residential unit confirmed from site measurements by Opus.

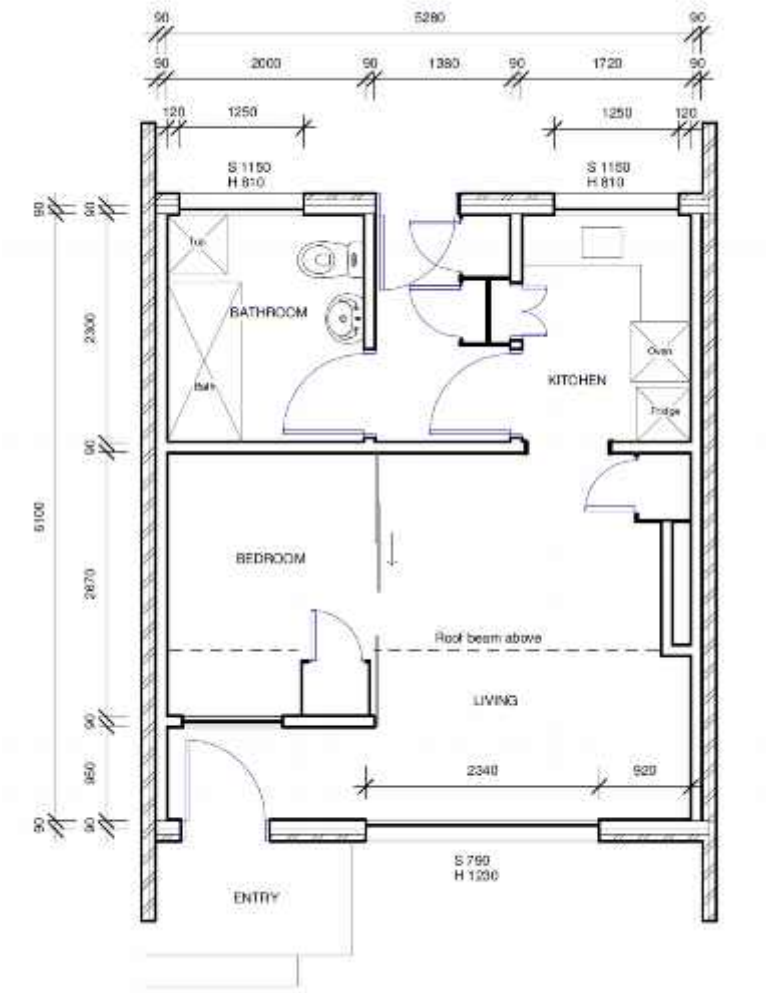


Figure 4: Partial floor plan of residential unit blocks (note that the bedsit units have a slightly different layout but are considered structurally identical).

4.2 Survey

4.2.1 Level Survey

A full level survey was deemed to be necessary at the Cresselly Place Housing Complex as it is located in a TC3 zone (Figure 7). Properties in TC3 zones suffered moderate to significant amounts of damage due to liquefaction and/or settlement. A full level survey was completed in all units which were accessible. The values from this level survey have then been used to determine the floor slope of the entire unit. Results for this level survey are summarised in Table 2. For this site, the floor slopes in twenty three units were greater than the 5mm/m limitation imposed by MBIE.

Table 2: Summary of level survey data

Block	Unit	Comment	Maximum Fall
A	1	Pass	-
	3	Fail	7.7mm/m
	5	No Access	-
	7	Fail	10.8mm/m
B	8	Pass	-
	6	No Access	-
	4	Pass	-
	2	Fail	5.8mm/m
C	9	Fail	14.7mm/m
	11	Fail	12.3mm/m
	15	Fail	5.7mm/m
	17	Fail	9.5mm/m
D	16	Fail	18.9mm/m
	14	Fail	12.6mm/m
	12	Fail	6.8mm/m
	10	Pass	-
E	19	Fail	20.8mm/m
	21	Fail	15.9mm/m
	23	Fail	16.2mm/m
F	26	Fail	18.9mm/m
	24	No Access	-
	22	Fail	17.9mm/m
	20	Fail	16.3mm/m
	18	Fail	17.3mm/m
G	25	Fail	34.7mm/m
	27	Fail	25.0mm/m
	29	Fail	5.8mm/m
	31	Fail	6.8mm/m
H	30	Fail	12.1mm/m
	28	Fail	27.4mm/m

4.2.2 Intrusive Investigations

Intrusive investigations were undertaken in Unit 27. The plasterboard linings were removed in one corner of the unit, this investigation confirmed the following;

- The brick fire wall has a header course at every fourth course.
- There are flat, cut-between, timber braces in the timber framed walls.
- There is adequate seating on the timber beam spanning the ceiling of the units.
- The fire wall has suffered minor shear cracking.
- The fireplace has not been removed and is boarded up.

4.2.3 Nail Spacing

Nail spacing was checked in a number of units and was consistently 250mm.

4.3 Original Documentation

Copies of the following construction drawings were provided by CCC:

- 122/C1 – Christchurch City Council – Pensioner's Cottages Wilson's Road – Services plan – February 1960
- A106/1-9 – Christchurch City Council – Pensioner's Cottages Wilson's Road – Plans, sections, elevations and details – 1957-1960

It is noted that the units appear to have had alterations made after its original construction; no specific drawings were provided for these changes.

The drawings have been used to confirm the structural systems, investigate potential critical structural weaknesses (CSW) and identify details which required particular attention.

Copies of the design calculations were not provided.

5 Structural Damage

This section outlines the damage to the buildings that was observed during site visits. It is not intended to be a complete summary of the damage sustained by the buildings due to the earthquakes. Some forms of damage may not be able to be identified with a visual inspection only.

Note: Any photo referenced in this section can be found in Appendix A.

Full photographic documentation of the damages observed in the site visit can be obtained from Opus International Consultants Ltd, Christchurch.

5.1 Residual Displacements

The results of the level survey indicate that significant ground settlement has occurred due to the earthquakes. This is especially prevalent in Blocks E, G and H where the changes in floor slope has caused the timber framing to be compromised due to racking. Blocks C, D and F have been subject to displacements which have caused major damage to the perimeter foundations and cladding. Blocks A and B have some units which are out of level.

5.2 Foundations

Minor damage was observed to the perimeter foundations of all units especially around the vents (photo 3 shows typical damage).

Major cracking (photo 4) was observed to the perimeter foundations of Blocks C, D, E, F, G and H. Cracks in these blocks were up to 40mm wide and stretched the structure laterally. As highlighted in section 5.1, the foundations have suffered large displacements causing significant damage.

5.3 Primary Gravity Structure

The timber framing in Blocks E and G has been racked due to movement in the foundations (photo 5); the brick firewalls are also cracked in these blocks. No damage was observed to the gravity structures of the other units.

5.4 Primary Lateral-Resistance Structure

Minor-to-moderate damage was observed in most units to the lateral-resistance structure. Moderate to major cracking and separation of plaster wall and ceiling linings (photos 6, 7 & 8) was observed in most units.

Major shear cracking was noted in the bathroom walls of Unit 16 (photos 14 and 15).

5.5 Non Structural Elements

As well as the minor plasterboard cracking observed in all units there was also damage observed to the external brick veneer claddings. This included loose and displaced bricks in the gable end walls of all units (photo 9), varying levels of stepped cracking to the external veneers (photos 12 & 13) and in several cases diagonal and vertical cracking straight through bricks (photo 11). The most severe damage was observed in Units 19, 21, 23, 25, 27, 29 and 31.

Evidence of damage due to stretching of the building (lateral spread) was observed in the soffit and facia board of Block G (photos 17 and 18).

It was also observed that the wooden floor in Unit 26 has been affected by liquefaction and rotten floorboards.

5.6 General Observations

The site has performed poorly; this has severely affected the structures and caused increased damage due to displacement of the foundations. Most buildings have suffered distributed amounts of moderate-to-major damage which is typical of the construction type, location and age of construction.

6 Detailed Seismic Assessment

The detailed seismic assessment has been based on the NZSEE 2006 [2] guidelines for the "Assessment and Improvement of the Structural Performance of Buildings in Earthquakes" together with the "Guidance on Detailed Engineering Evaluation of Earthquake Affected Non-residential Buildings in Canterbury, Part 2 Evaluation Procedure" [3] draft document prepared by the Engineering Advisory Group on 19 July 2011, and the SESOC guidelines "Practice Note – Design of Conventional Structural Systems Following Canterbury Earthquakes" [5] issued on 21 December 2011.

As the residential units are assumed to have the same floor plan structurally, the analysis was simplified by conducting the analysis of one multi-unit block with brick cladding and using this for all multi-unit blocks.

6.1 Critical Structural Weaknesses

The term Critical Structural Weakness (CSW) refers to a component of a building that could contribute to increased levels of damage or cause premature collapse of a building.

No CSW's were identified in the buildings.

6.2 Quantitative Assessment Methodology

The assessment assumptions and methodology have been included in Appendix D. A brief summary follows:

Hand calculations were performed to determine seismic forces from the current building codes. These forces were applied globally to the structure and the capacities of the walls were calculated and used to estimate the %NBS. The walls, highlighted in Figure 5 and

Figure 6, were used for bracing in their respective directions.

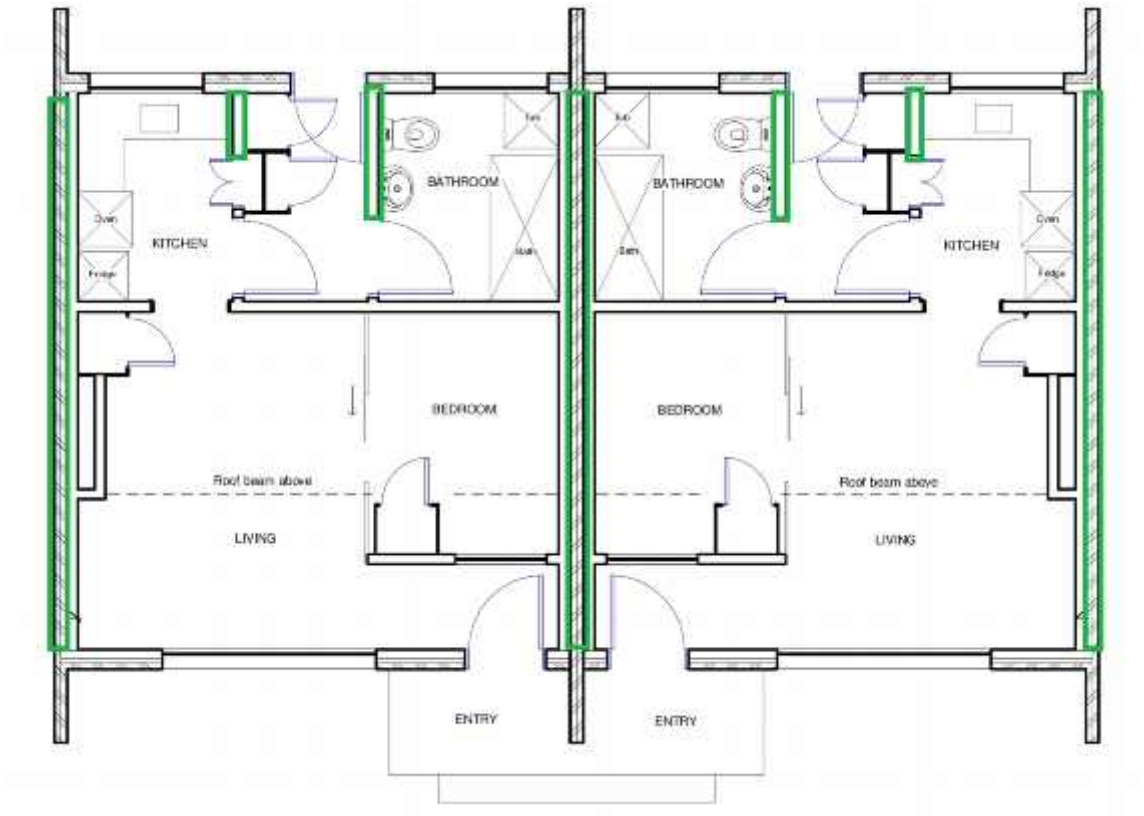


Figure 5: Walls used for bracing in the transverse direction.

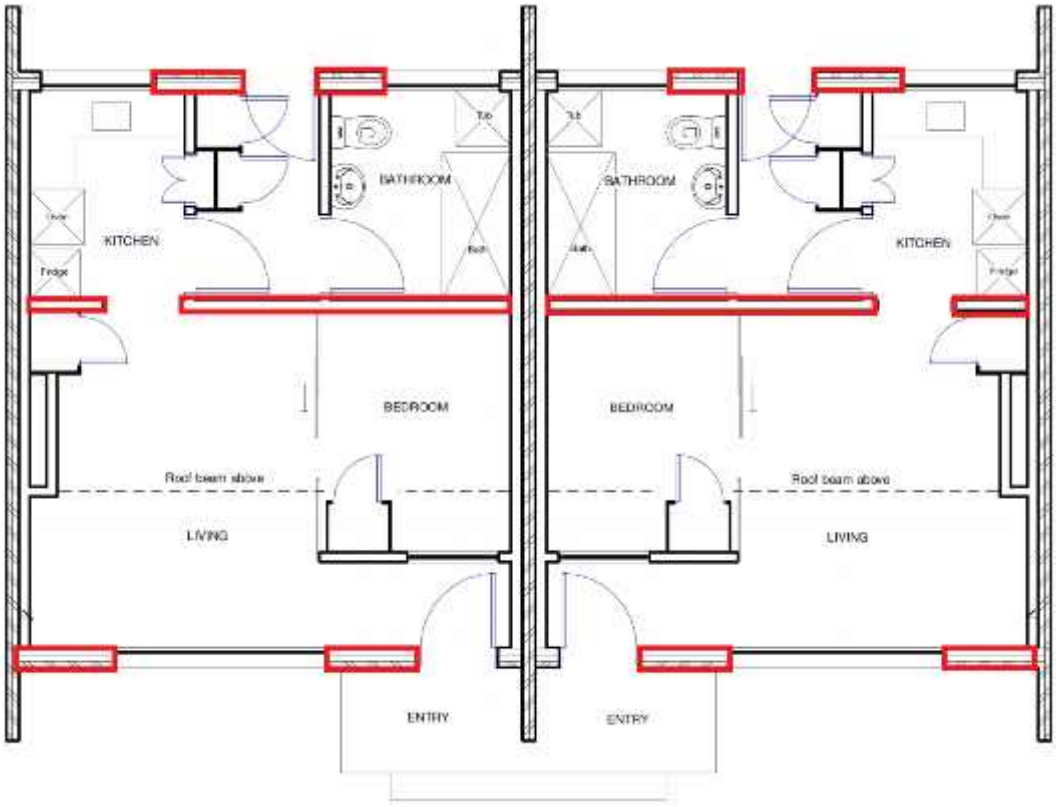


Figure 6: Walls used for bracing in the longitudinal direction.

6.3 Limitations and Assumptions in Results

Apart from Block G, the observed level of damage suffered by the buildings was deemed low enough to not affect their capacity. Therefore the analysis and assessment of the buildings was based on them being in an undamaged state. There may have been damage to the buildings that was unable to be observed that could cause the capacity of the buildings to be reduced; therefore the current capacity of the buildings may be lower than that stated.

The results have been reported as a %NBS and the stated value is that obtained from our analysis and assessment. Despite the use of best national and international practice in this analysis and assessment, this value contains uncertainty due to the many assumptions and simplifications which are made during the assessment. These include:

- Simplifications made in the analysis, including boundary conditions such as foundation fixity.
- Assessments of material strengths based on limited drawings, specifications and site inspections.
- The normal variation in material properties which change from batch to batch.
- Approximations made in the assessment of the capacity of each element, especially when considering the post-yield behaviour.

6.4 Assessment

A summary of the structural performance of the buildings is shown in Table 3. Note that the values given represent the worst performing elements in the building, where these effectively define the building's capacity. Other elements within the building may have significantly greater capacity when compared with the governing elements.

Table 3: Summary of Seismic Performance

Building Description	Critical element	% NBS based on calculated capacity in longitudinal direction	% NBS based on calculated capacity in transverse direction.
Blocks A-F, & H	Bracing capacity of structural walls	72%	100%
Block G	Out of plane capacity of firewalls	62%	100%

7 Summary of Geotechnical Appraisal

7.1 General

CERA indicates that Cresselly Place Housing Complex is located in a TC3 zone (as shown in Figure 7). This classification suggests future significant earthquakes will cause moderate to considerable land damage due to liquefaction and/or settlement. Due to this risk, a separate geotechnical desktop study was undertaken by Opus.

Figure 7 : CERA Technical Categories map (loc. starred).

7.2 Aurecon Geotechnical Assessment

In addition to the CERA TC map, a geotechnical assessment has been completed by Aurecon for Christchurch City Council [7] at the site which has been provided for review. The following bullet points have been copied from the executive summary of their report. A full copy of the report can be found in Appendix C.

- In the inferred zone of the infilled river channel, liquefaction could occur in thick layers even in an SLS event from the groundwater table down to depth. In contrast in the eastern side of the site, the dense gravelly layer is unlikely to liquefy in any design level event.

- Liquefaction induced index settlements have been calculated to be 20-120mm and 60-210mm in a SLS and ULS events respectively.

- Ishihara and LSN, indicate that extensive ground damage could occur even in low levels of shaking which is broadly consistent with observed damage.

- Based on the MBIE guidelines, the calculated index settlements of the CPTs undertaken in the zone of the inferred infilled river channel are consistent with a TC3 classification, and predominantly have a "Potentially Significant" vertical settlement potential. The calculated index settlement of the CPTs undertaken in the zone inferred with a dense gravel layer is consistent with a TC2 classification. The calculated index settlements of the CPTs undertaken in the transitional Project 238474 File 238474 -Cresselly Place Geotech Report.docx 11 November 2013 Revision 1 Page 4 zone, between these two zones, is consistent with a TC3 classification, and have a "Minor to Moderate" vertical settlement potential. This appears to be relatively consistent with observed damage and MBIE zonings of the surrounding residential properties.

- Building 1 is within an area consistent with a TC2 classification, Building 2 is within a transitional zone between a TC2 and TC3 classification, and Buildings 3, 4, 5, 6, 7 and 8 are within an area consistent with a TC3 classification. Refer to figure 8 of the Aurecon report.

- Based on the MBIE guidelines the site is assessed to have "Minor to Moderate" global movement potential (less than 300mm of global lateral movement) and "Minor to Moderate" lateral stretch potential (less than 200mm of lateral stretch across the building footprint).

- The damage from an SLS event is likely to be similar to the 23 December 2011 Aftershock; the damage from an Intermediate event is likely to be similar to the damage from the 4 September 2010 Darfield Earthquake and 13 June 2011 Aftershock. The damage from a ULS event is likely to be similar to the damage from the 22 February 2011 Christchurch Earthquake.

- It should be noted that the recent earthquakes were of relatively short duration (typically less than 20 seconds). An SLS event caused by a large but distant earthquake, such as on the Alpine or Hope faults could have 60 seconds or more of significant shaking. Therefore, the ground damage observed in recent earthquakes should be considered to be only a broad indicator of likely future damage.

8 Conclusions

- None of the buildings on site are considered to be Earthquake Prone.
- Blocks A-F and H have capacities of 72% NBS as limited by the in-plane shear capacity lined shear walls. They are deemed to be a 'low risk' in a design seismic event according to NZSEE guidelines. Their level of risk is 2-5 times that of a 100% NBS building (Figure 1).
- Block G has a capacity of 62% based on the out of plane capacity of the brick and plasterboard firewall. It is deemed to be a 'moderate risk' in a design seismic event according to NZSEE guidelines. The level of risk is 5-10 times that of a 100% NBS building (Figure 1).
- Based on the geotechnical appraisal, differential settlement as a result of liquefaction could result in further damage, similar in nature to that which has occurred in the recent earthquake sequence. The prediction of future settlement across the site is consistent with the damage already recorded.

9 Recommendations

It is recommended that;

- Blocks A and B are cosmetically repaired and have their veneer ties checked, especially in the gable ends.
- Blocks C, D and F are re-levelled, cosmetically repaired as required under the MBIE guidelines and have their veneer ties checked, especially in the gable ends.
- Blocks E, G and H are demolished.

10 Limitations

- This report is based on an inspection of the buildings and focuses on the structural damage resulting from the Canterbury Earthquake sequence since September 2010. Some non-structural damage may be described but this is not intended to be a complete list of damage to non-structural items.
- Our professional services are performed using a degree of care and skill normally exercised, under similar circumstances, by reputable consultants practicing in this field at this time.
- This report is prepared for the Christchurch City Council to assist in the assessment of any remedial works required for the Cresselly Place Housing Complex. It is not intended for any other party or purpose.

11 References

[1] NZS 1170.5: 2004, Structural design actions, Part 5 Earthquake actions, Standards New Zealand.

[2] NZSEE (2006), Assessment and improvement of the structural performance of buildings in earthquakes, New Zealand Society for Earthquake Engineering.

[3] Engineering Advisory Group, Guidance on Detailed Engineering Evaluation of Earthquake Affected Non-residential Buildings in Canterbury, Part 2 Evaluation Procedure, Draft Prepared by the Engineering Advisory Group, Revision 5, 19 July 2011.

[4] Engineering Advisory Group, *Guidance on Detailed Engineering Evaluation of Non-residential buildings, Part 3 Technical Guidance*, Draft Prepared by the Engineering Advisory Group, 13 December 2011.

[5] SESOC (2011), Practice Note – Design of Conventional Structural Systems Following Canterbury Earthquakes, Structural Engineering Society of New Zealand, 21 December 2011.

[6] MBIE (2012), Repairing and rebuilding houses affected by the Canterbury earthquakes, Ministry of Building, Innovation and Employment, December 2012.

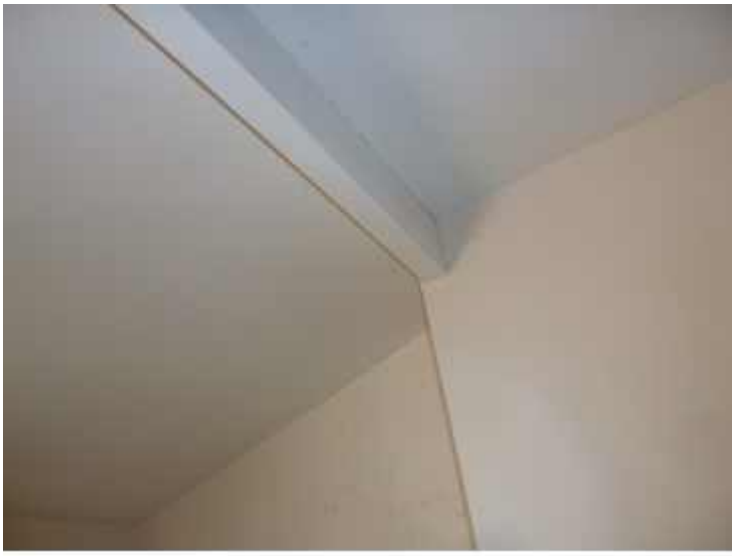
[7] CCC PRO 0980 – Cresselly Place, St Martins, Christchurch – Geotechnical Assessment, Revision 1, 11 November 2013.

Appendix A- Photographs

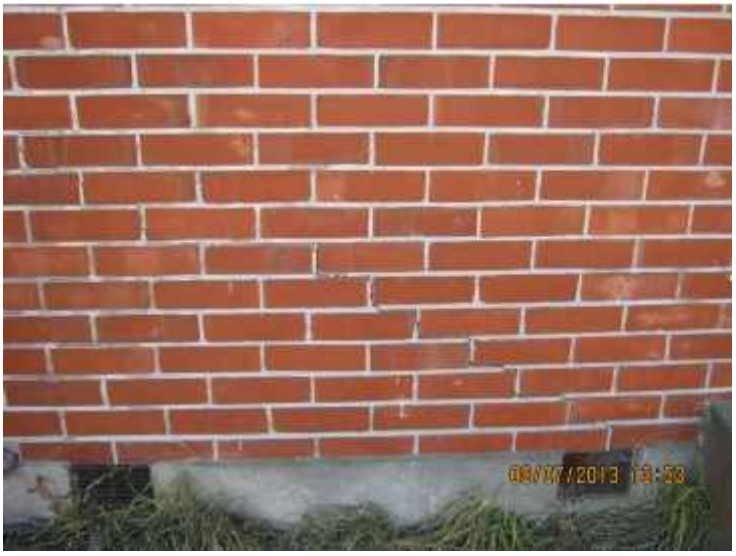
Cresselly Courts Housing Complex		
Residental Units		
1	Typical exterior, front view.	
2	Typical exterior, side wall.	

3	Typical foundation cracking, observed in all units.	
4	Major foundation cracking, observed in Units 25 and 27 (Block G). Cracking up to 40mm.	

5	Interface of brick and window showing warping in timber framing in Units 19, 21, 23, 25, 27, 29 and 31.	
6	Typical plasterboard cracking, observed in all units.	

7	Typical cracking along ceiling beam, observed in all units.	
8	Typical GIB cracking from corners of windows and doors, observed in all units.	
9	Loose bricks in gable end walls, observed at both ends of all blocks of units.	

10	Example of the severe cracking observed to veneers around Units 19, 21, 23, 25, 27, 29 and 31.	
11	Typical diagonal cracking, observed in the exterior cladding of several units.	

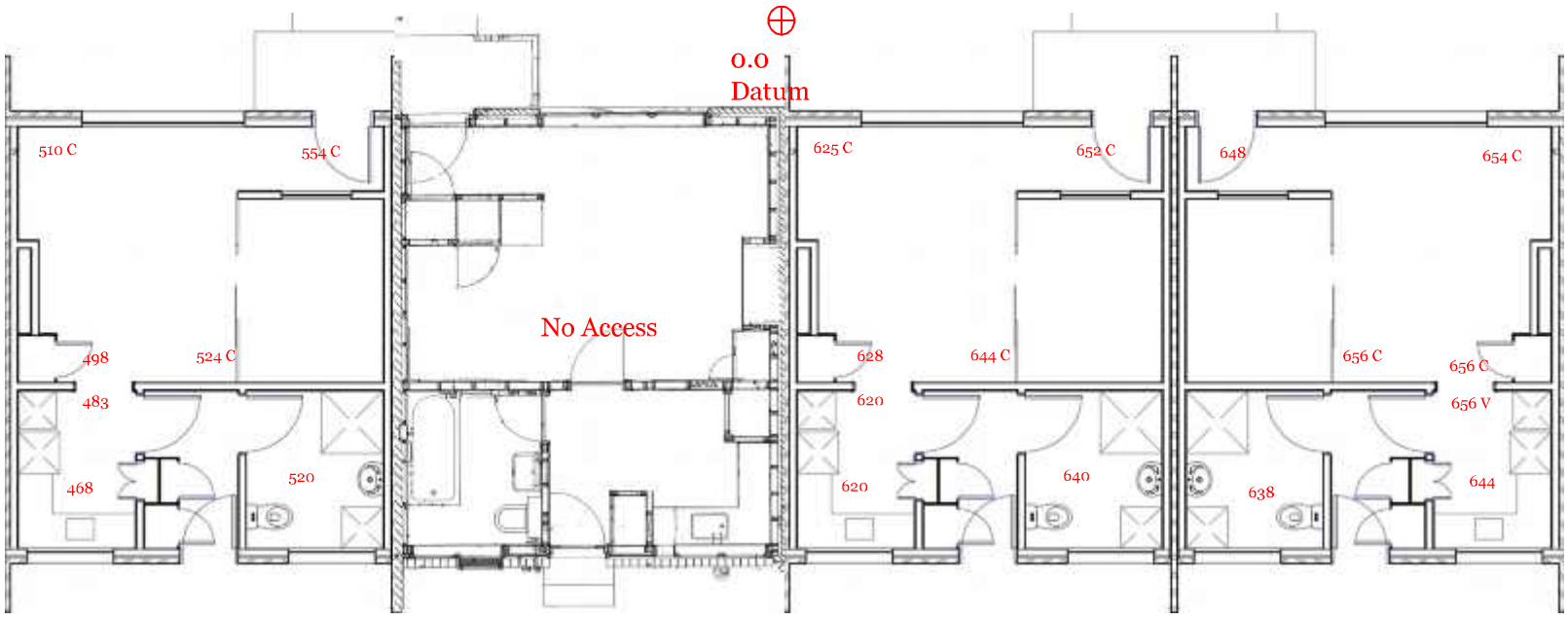
12	Severe stepped cracking in veneers, observed in Units 19, 21, 23, 25, 27, 29 and 31.	
13	Typical stepped cracking, observed in the veneers of all units.	

14	Shear cracking of the GIB lining in Unit 16.	
15	Shear cracking of the GIB lining in Unit 16.	

16	Major cracking and separation of walls and veneers.	
17	Separation of the soffit in Block G due to lateral stretching of the structure.	

18	Separation of the facia board in Block G due to lateral stretching of the structure.	

Appendix B - Level Survey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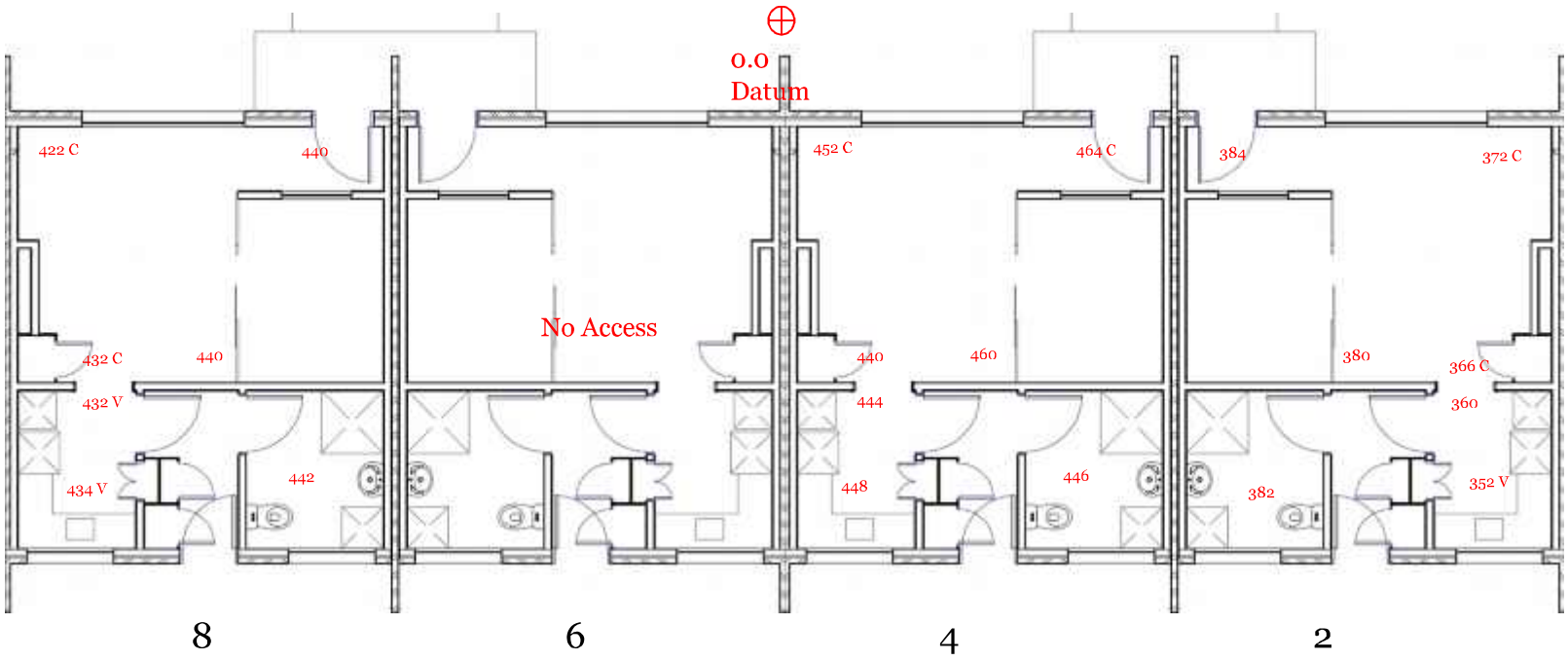
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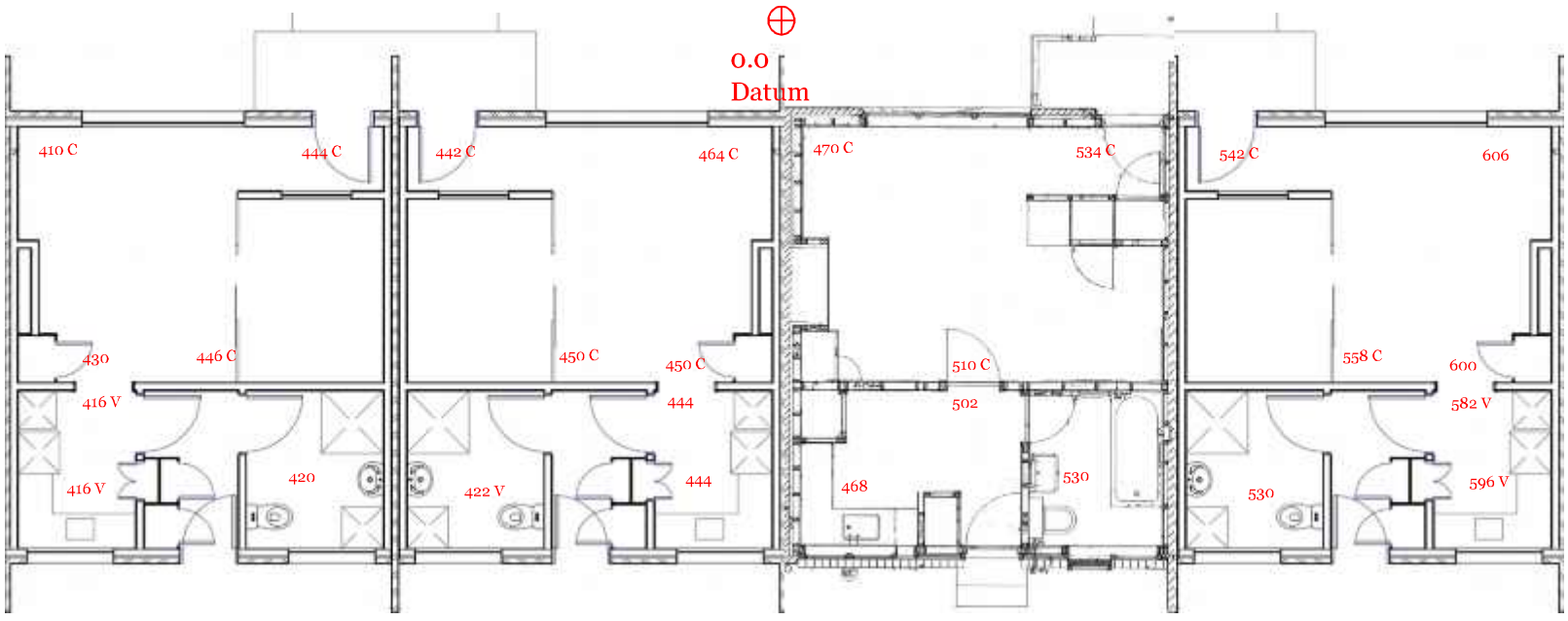
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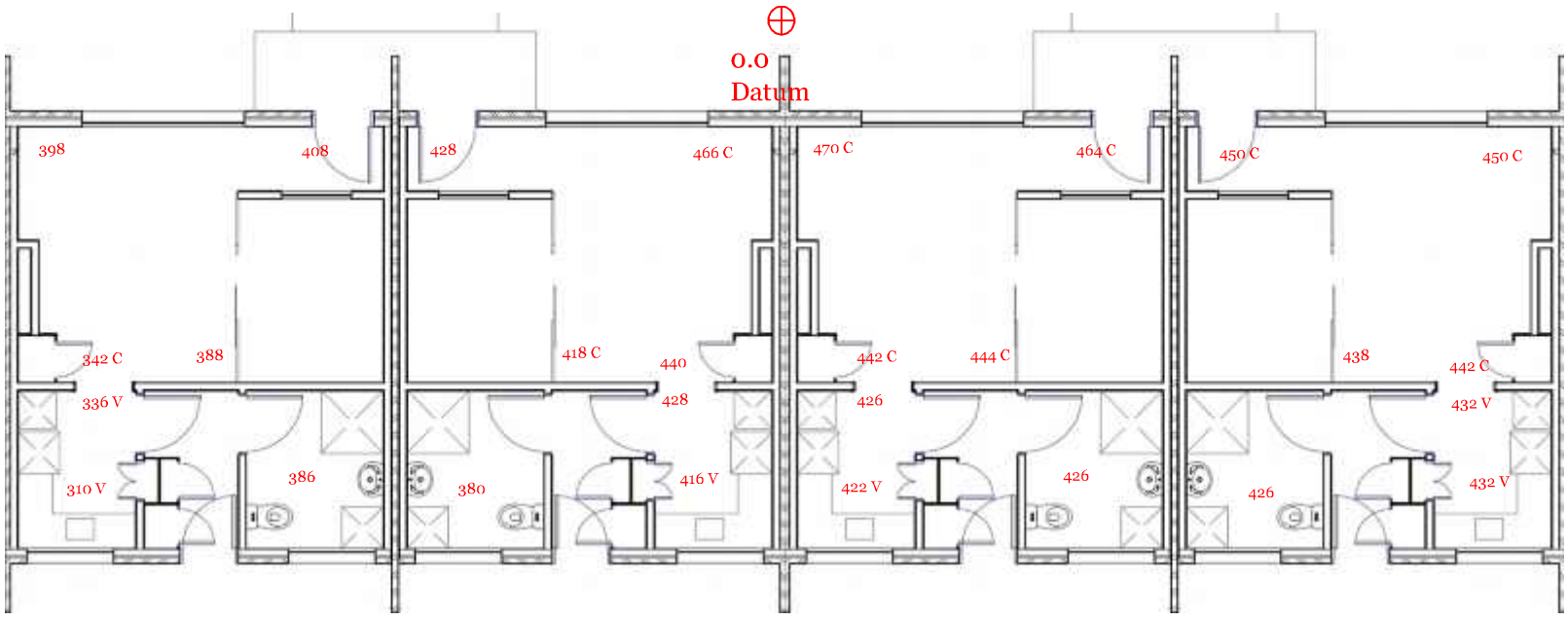
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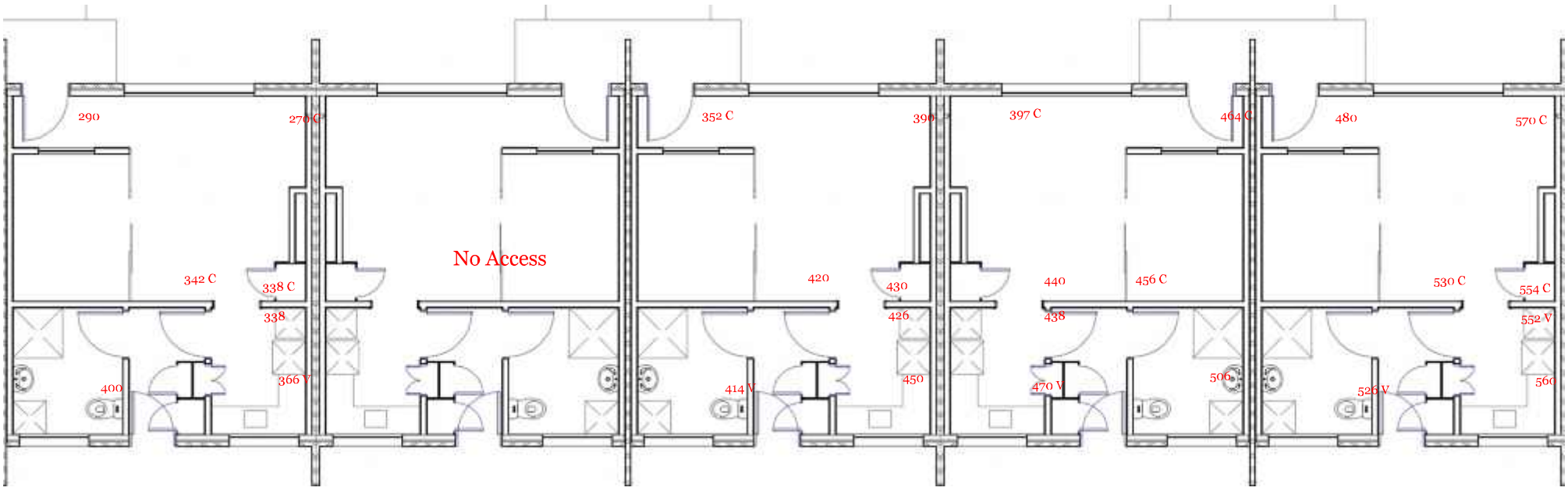
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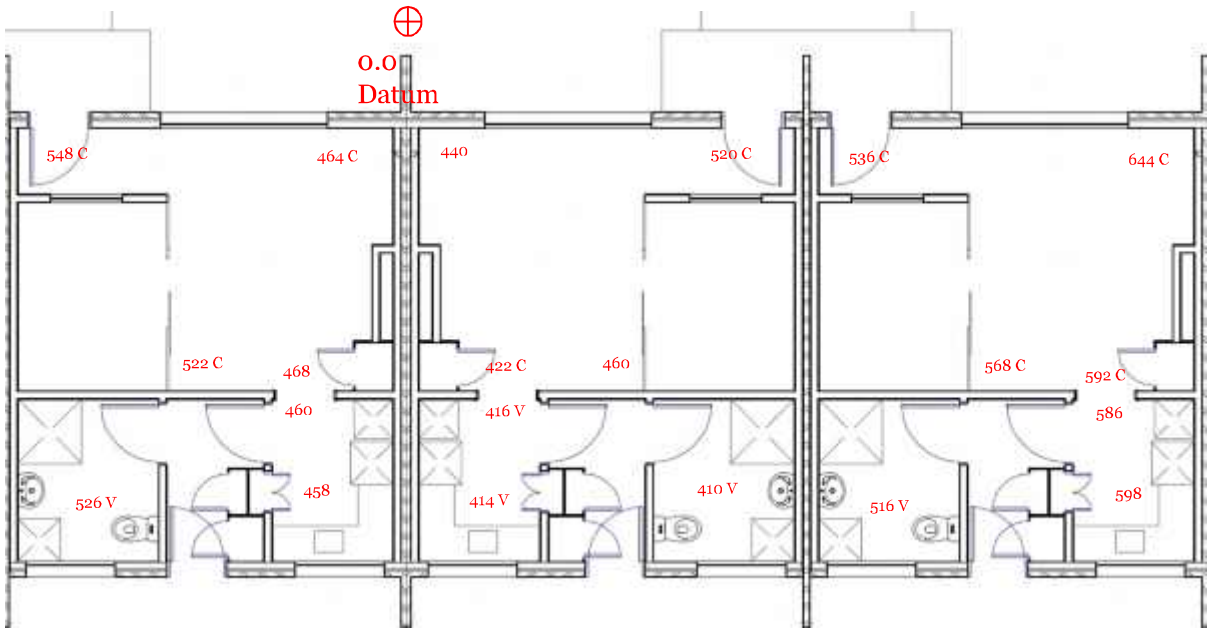
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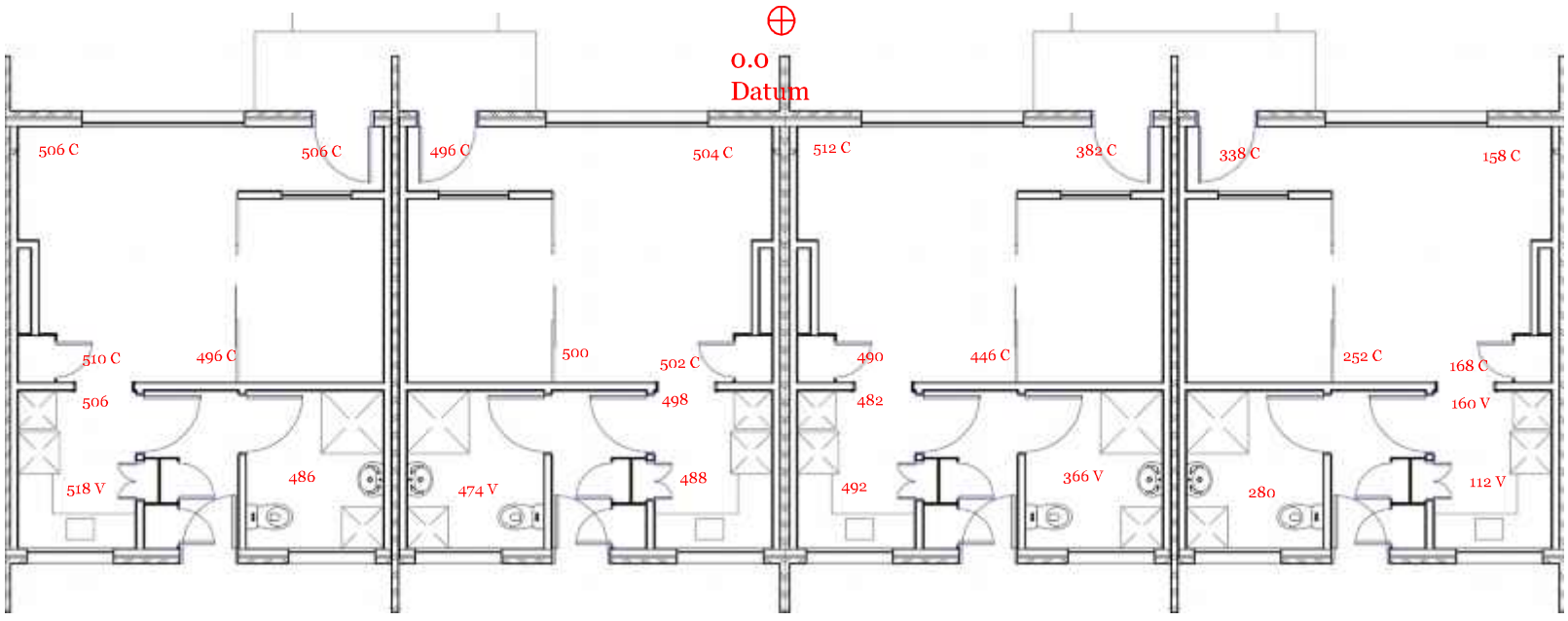
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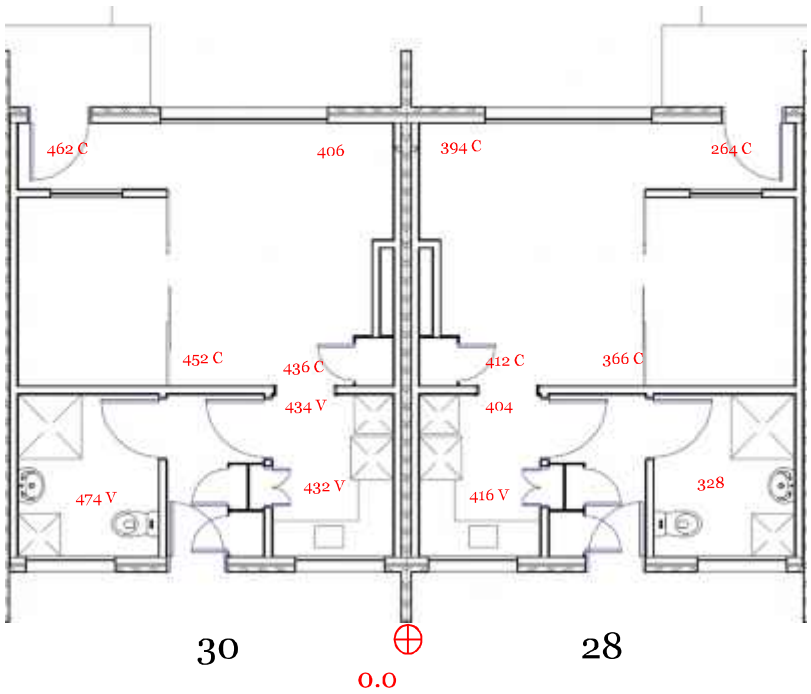
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Appendix C - Geotechnical Appraisal

Opus International Consultants Ltd
Christchurch Office
20 Moorhouse Avenue
PO Box 1482, Christchurch Mail Centre, Christchurch 8140
New Zealand

t: +64 3 363 5400
f: +64 3 365 7858
w: www.opus.co.nz

4 November 2013

Christchurch City Council
c/- Opus International Consultants Ltd
Attention: Geoff Bawden
PO Box 1482
Christchurch 8140

6-QC335.00

Dear Geoff

Geotechnical Desk Study - Cresselly Place

1 Introduction

Christchurch City Council (CCC) has commissioned Opus International Consultants (Opus) to undertake a Geotechnical Desk Study and site walkover inspection of the CCC Cresselly Place housing complex in Saint Martins. Refer to Figure 01 for the Site Locality Map. The purposes of this study are to collate the existing subsoil information, prepare an interpretive geotechnical ground model, undertake an appraisal of the potential geotechnical hazards at this site and determine whether further investigations are required.

This Geotechnical Desk Study has been prepared in accordance with Part 2 of the "Guidance on Detailed Engineering Evaluation of Earthquake Affected Non-residential Buildings in Canterbury" [1] publication. Whilst not specifically prepared to provide guidance on the preparation of Detailed Engineering Evaluations of residential buildings, this publication provides guidance that is considered generally applicable to this study.

This Geotechnical Desk Study has been undertaken without the benefit of any site specific investigations and is, therefore, preliminary in nature.

[1] Engineering Advisory Group, "Guidance on Detailed Engineering Evaluation of Earthquake Affected Non-residential Buildings in Canterbury", Part 2, Evaluation Procedure, Reference ENG.EAG.0001.2, Draft Revision 5, 19 July 2011.

2 Desktop Study

2.1 Site Location

The CCC Cresselly Place housing complex is at Cresselly Place, which is located west of Wilsons Road in Saint Martins. The complex is bounded by residential areas to the north, Wilsons Road to the east, Hillview Christian School Senior School to the south, Saint Martins Park to the southwest and St Martins Bowling Club to the west. The site is located within a loop of the Heathcote River, which is located approximately 350 m to the west, 390 m to the north, 560 m to the east and 450 m to the southeast. Refer to Figure 02 for the Site Vicinity Map for the location of the site.

2.2 Site Description

The Cresselly Place housing complex was built circa 1960 and comprises 31 residential units within eight buildings (i.e. "Blocks"). Refer to Figure 03 for the Site Plan and to Appendix A for copies of the Construction Drawings. Each building has a simple rectangular floor plan and comprises a single-storey timber-framed structure with brick veneer cladding and a corrugated iron roof. Refer to Photos 1 through 6 in Appendix B for typical elevation views of the buildings. Concrete perimeter footings with interior isolated pier footings support the suspended timber (i.e. joist and bearer) floors of the buildings. The foundations are considered to be equivalent to "Type B2" in accordance with the "Repairing and rebuilding houses affected by the Canterbury Earthquakes"[2] publication.

The ground profile is relatively flat and low lying. However, the land in the western portion of the site appears to be about 500 to 1000 mm higher than the eastern portion of the site, and a depression is located in the vicinity of units 19, 21 and 23. The raised topography in the western portion of the site generally coincides with a "grassy mound" area noted on Drawing No. A.106/4 that is presented in Appendix A. The depression coincides with an area of liquefaction that was observed during the June 2011 earthquakes (refer to Photos 10 and 51 in Appendix B for views of the "grassy mound" area; refer to Photos 8, 9, and 50 through 54 in Appendix B for views of the depression and of liquefaction after the June 2011 earthquakes).

The ground surrounding the buildings is predominantly grassed surfaces with a newly-sealed road surface.

2.3 Regional Geology

Published geological maps of the area[3,4] indicate that the site is underlain by near-surface sand and silt plains alluvium of the Yaldhurst Member (spy) of the Springston Formation (sp). At depths of approximately 200 to 400 m, Section B-B' of Forsyth, Barrell and Jongens (2008) indicates that these near-surface deposits may be underlain by Pliocene

2 Ministry of Business, Innovation and Employment (MBIE), "Repairing and rebuilding houses affected by the Canterbury Earthquakes", Version 3, December 2012.
3 Brown and Weeber, "Geology of the Christchurch urban area", Scale 1:25 000, Institute of Geological & Nuclear Sciences, geological map 1, 1992.
4 Forsyth, Barrell and Jongens, "Geology of the Christchurch area", Scale 1:250 000, Institute of Geological & Nuclear Sciences, geological map 16, 2008.

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age Kowhai Formation greywacke conglomerate underlain by various older sedimentary rocks and volcanic rocks.

2.4 Expected Ground Conditions

Logs of Boreholes and Cone Penetrometer Tests (CPTs) undertaken/compiled by the Earthquake Commission (EQC) and/or by Canterbury Earthquake Recovery Authority (CERA) have been reviewed as part of this study. Seven CPTs have been conducted within approximately 50 m of the site boundary, while 17 CPTs and three machine boreholes have been conducted within approximately 150 m of the site boundary. Refer to Figure 02 for a presentation of the surrounding site investigation locations. Copies of the referenced site investigation logs are included in Appendix C.

Using the available referenced data, a sub-surface interpretive ground model has been prepared for the site. The inferred ground conditions comprise sub-surface soil stratigraphy interpreted from the available data and from experience with comparable soils in similar geological settings. The inferred ground conditions are presented in Table 1.

Table 1: Inferred Ground Conditions

Layer Description: Stratigraphy (Consistency)	Approximate Thickness (m)	Depths Encountered (m)
Interbedded Fine to medium SAND, Silty SAND and SILT (Loose)	1.0-5.5	Surface
Fine to medium SAND to Silty SAND (Medium Dense to Dense)	1.5 to 4.5	4.0 to 9.5
Interbedded Sandy SILT and Silty SAND (Soft; Loose to Medium Dense)	3.5 to 4.0	9.0 to 13.5
Interbedded fine to medium SAND and Sandy SILT (Medium Dense to Dense; Stiff to Very Stiff)	1.5 to 3.0	13.0 to 16.5
Sandy GRAVEL (Dense to Very Dense)	-	17.0+

No existing machine borehole records were available within 50 m of the site. Existing CPTs in the vicinity of the site generally extended to 15 to 17.5 m below ground level.

It is noted that logs of machine boreholes and CPTs approximately 150 m north of and south of the site encountered different ground conditions than those presented in Table 1. These logs indicate that the ground conditions farther from the site typically comprise interbedded fine to medium SAND (Loose), Sandy GRAVEL (Medium Dense to Very Dense) and occasional SILT (Soft) to approximately 15 m overlying Sandy fine to coarse GRAVEL (Medium Dense to Very Dense).

Groundwater depths of approximately 1.5 to 3.0 m below ground level have been interpreted from the referenced machine borehole and CPT logs. Maps available within

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Project Orbit[5] indicate that the median depth to the groundwater surface at the site as 0 to 2.0 m.

2.5 Liquefaction Hazard

2.5.1 Existing Studies

A liquefaction hazard study was conducted by the Canterbury Regional Council (ECan) in 2004 to identify areas of Christchurch that are susceptible to liquefaction during an earthquake. Maps prepared through this study identify the site as having a "high liquefaction potential" for both the high groundwater and the low groundwater scenarios.

The same ECan study classified the ground damage potentials of Christchurch areas, and the study identified the site as having a "moderate liquefaction ground damage potential" for the low groundwater scenario.

Working for the EQC, Tonkin and Taylor Ltd (T&T) prepared maps showing areas of liquefaction interpreted from high resolution aerial photos for the September 2010 earthquake and the aftershocks of February 2011, June 2011 and December 2011. No data was available for the site with respect to the September 2010 event. However, the maps indicate

- Moderate to severe observed liquefaction on and around the site after the February 2011 seismic event;
- Minor observed liquefaction on and around the site after the June 2011 seismic events; and
- No observed liquefaction on and around the site after the December 2011 seismic event.

Although there are no open watercourses or free surfaces close (e.g. <200 m) to the site, the EQC maps showing observed cracks (refer to Appendix D) after the February 2011 seismic event indicate that minor to major ground cracking (<10 to >200 mm wide) occurred on and near the site. The orientation of cracks is generally parallel with Wilsons Road. This suggests that there is a potential risk of ground movement in a future seismic event.

2.5.2 Technical Category

Following the recent strong earthquakes in Canterbury, CERA zoned land in the Greater Christchurch area according to its expected ground performance in future large earthquakes. The site was listed in the "Green" residential recovery zone.

MBIE further classified the CERA "Green" zone on the flat in Christchurch into technical categories (TCs). The three TCs are summarised in Table 2, which has been adapted from the referenced Guidance document (MBIE, 2012).

MBIE classified Cresselly Place as "N/A-Urban Non-residential". However, the neighbouring residential properties have been zoned TC2 and TC3, which indicates that

[5] Project Orbit, Canterbury Geotechnical Database, Interagency/organisation collaboration portal for Christchurch recovery effort, https://canterburygeotechnicaldatabase.projectorbit.com/, accessed July 2013.

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minor to moderate land deformations are expected in future small to medium sized earthquakes and that moderate to significant land deformations in a future moderate to large earthquake.

Table 2: Technical Categories based on Expected Land Performance

Foundation Technical Category	Future land performance expected from liquefaction	Expected SLS land settlement	Expected ULS land settlement
TC 1	Negligible land deformations expected in a future small to medium sized earthquake and up to minor land deformations in a future moderate to large earthquake.	0-15 mm	0-25 mm
TC 2	Minor land deformations possible in a future small to medium sized earthquake and up to moderate land deformations in a future moderate to large earthquake.	0-50 mm	0-100 mm
TC 3	Moderate land deformations possible in a future small to medium sized earthquake and significant land deformations in a future moderate to large earthquake.	>50 mm	>100 mm

2.5.3 CPT Liquefaction Assessment

2.5.3.1 Analyses

A preliminary liquefaction assessment has been completed using the computer software CLiq[6]. The preliminary liquefaction assessment was conducted using existing data from ten CPTs located within approximately 75 m of the site boundary. These CPT locations are identified in Figure 02, and the raw CPT data was obtained from Project Orbit.

In accordance with Technical Specification 01, "Liquefaction Evaluation of CPT Investigations"[7], the method presented by Idriss & Boulanger (2008)[8] with settlements calculated using the method presented by Zhang et al. (2002)[9] were utilised in the preliminary liquefaction assessment together with a Magnitude 7.5 earthquake and Peak Ground Accelerations of 0.13 g and 0.35 g for the SLS1 and ULS design events, respectively. An Importance Level of 2 has been applied to the site. Also in accordance with (CGD, 2013) for Investigative Analyses, the GNS Science Median Groundwater Surface Elevation[10] of 3.0 m (approximately 2.5 m below ground level) was utilised in the preliminary liquefaction assessment.

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6 GeoLogismiki, *CLiq*, version 1.6.1.17. Computer software, 2006.

7 Canterbury Geotechnical Database, "Liquefaction Evaluation of CPT Investigations", Technical Specification 01, 21 May 2013.

8 Idriss and Boulanger, *Soil Liquefaction During Earthquakes*, MNO-12, Earthquake Engineering Research Institute, 242p, 2008.

9 Zhang, G., Robertson, P.K. and Brachman, R.W.I., "Estimating Liquefaction induced Ground Settlements From CPT for Level Ground", *Canadian Geotechnical Journal*, 39(5): 1168-1180. 2002.

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

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In addition to the Idriss & Boulanger (2008) method, the 1998 NCEER[11] method was applied together with the Zhang et al. (2002) method to estimate the free field liquefaction-induced vertical subsidence at the site. The free field liquefaction-induced vertical subsidences were estimated over the complete CPT depth (typically 15 to 18 m) as well as in the top 10 m of the soil profile. These estimates and are presented in Table 3, and the CLiq output is presented in Appendix E.

Table 4 presents the Liquefaction Potential Index (LPI), which is calculated using the existing CPT data within CLiq, and the Liquefaction Severity Number (LSN), which was calculated utilising the CLiq output at each CPT location. The LPI is an indicator originally developed by Iwasaki et al. (1978, 1981 and 1982)[12,13,14] that aims to predict the performance of a soil column and the consequence of liquefaction at the ground surface. LPI is correlated to the depth of a liquefiable layer and its factor of safety against liquefaction. Table 5 summarises the relationship between LPI and the risk of liquefaction occurring at a site.

The LSN is an indicator that was developed to compare test data with the observed liquefaction-induced ground damage attributes caused by the Canterbury Earthquake Sequence[15]. T&T correlated LSN to the predominant observed land performance and damage attributes. Table 13.1 within the referenced Liquefaction Vulnerability Study presented the results of this correlation, and this table is reproduced in Table 6 herein.

2.5.3.2 Results

Review of the liquefaction assessment results indicates that the site is likely to have a high to very high risk of liquefaction and is likely to be affected by liquefaction-induced vertical ground settlements during a design earthquake.

During a ULS design event, liquefaction-induced free field vertical subsidence of the order of 150 to 350 mm (with maximum and minimum values of 75 and 400 mm, respectively), moderate to severe expression of liquefaction and some to moderate structural damage are typically estimated for areas near the site. Due to the variable thicknesses of the encountered liquefiable layers, liquefaction-induced differential settlements would be expected to occur at the site during the design ULS event. Magnitudes of these differential settlements are anticipated to be of the order of 75 to 300 mm for a ULS earthquake event.

Based solely on the liquefaction-induced free field vertical subsidences predicted to occur within the top 10 m and in accordance with Section 16.5 of the MBIE (2012) guidelines, the site would likely correspond to a Technical Category 3 (TC3) classification due to the

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11 Youd et al. (20 co-authors) (2001), "Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils", *ASCE Journal of Geotechnical and Geoenvironmental Engineering*, Vol. 127, No 4. pp 297-313. 2001.

12 Iwasaki, Tatsuoka, Tokida and Yasuda, "A practical method for assessing soil liquefaction potential based on case studies at various sites in Japan", *Proc. 2nd Int. Conf. on Microzonation*, San Francisco, pp. 885-896, 1978.

13 Iwasaki, Tokida and Tatsuoka, "Soil liquefaction potential evaluation with use of the simplified procedure", *Intl. Conf. on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics*, St. Louis, pp. 209-214, 1981.

14 Iwasaki, Arakawa and Tokida, "Simplified procedures for assessing soil liquefaction during earthquakes", *Proc. Conf. on Soil Dynamics and Earthquake Engineering*, Southampton, UK, pp. 925-939, 1982.

15 Tonkin & Taylor Ltd, "Liquefaction Vulnerability Study", Prepared for the Earthquake Commission, T&T reference 52020.0200/v1.0, February 2013.

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potentially large magnitudes (e.g. of the order of 100 to 260 mm) of liquefaction-induced free field vertical subsidence's in an ULS design event.

Table 3: Estimated Free Field Liquefaction-Induced Vertical Subsidence

Project Orbit CPT No. (Test Depth)	Event	Mag / PGA	Depth to Groundwater (m)	Estimated Free Field Liquefaction-Induced Vertical Subsidence (mm*)			
				Complete CPT Depth		Top 10 m of Soil Profile	
				NCEER$	I&B^	NCEER$	I&B^
CPT_17309 (18.41 m)	ULS	M7.5 / 0.35g	2.5	75	120	35	45
	SLS	M7.5 / 0.13g	2.5	N	N	N	N
CPT_19298 (18.26 m)	ULS	M7.5 / 0.35g	2.5	220	400	110	165
	SLS	M7.5 / 0.13g	2.5	35	20	N	N
CPT_23981 (17.88 m)	ULS	M7.5 / 0.35g	2.5	175	305	125	230
	SLS	M7.5 / 0.13g	2.5	25	15	10	N
CPT_19300 (17.77 m)	ULS	M7.5 / 0.35g	2.5	240	310	140	210
	SLS	M7.5 / 0.13g	2.5	25	15	10	N
CPT_23983 (20.31 m)	ULS	M7.5 / 0.35g	2.5	155	165	105	90
	SLS	M7.5 / 0.13g	2.5	20	N	N	N
CPT_818 (15.13 m)	ULS	M7.5 / 0.35g	2.5	85	135	30	50
	SLS	M7.5 / 0.13g	2.5	45	15	N	N
CPT_23411 (15.28 m)	ULS	M7.5 / 0.35g	2.5	210	355	155	260
	SLS	M7.5 / 0.13g	2.5	80	25	55	15
CPT_23412 (17.08 m)	ULS	M7.5 / 0.35g	2.5	145	195	85	110
	SLS	M7.5 / 0.13g	2.5	45	15	20	N
CPT_15814 (15.00 m)	ULS	M7.5 / 0.35g	2.5	160	185	115	130
	SLS	M7.5 / 0.13g	2.5	65	15	50	N

* Rounded up to nearest 5 mm
^ Subsidence estimated utilising Idriss & Boulanger (2008) method
$ Subsidence estimated utilising NCEER (1998) method
N = Negligible (e.g. <10 mm)

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Table 4: Calculated LPI and LSN for Design Seismic Event

Project Orbit CPT No.	Event	Mag / PGA	Depth to Groundwater (m)	Liquefaction Potential Index*		Liquefaction Severity Number*
				NCEER$	I&B^	NCEER$
CPT_17309 (18.41 m)	ULS	M7.5 / 0.35g	2.5	6	6	11
	SLS	M7.5 / 0.13g	2.5	0	0	1
CPT_19298 (18.26 m)	ULS	M7.5 / 0.35g	2.5	21	>20	29
	SLS	M7.5 / 0.13g	2.5	0	0	3
CPT_23981 (17.88 m)	ULS	M7.5 / 0.35g	2.5	19	18	23
	SLS	M7.5 / 0.13g	2.5	0	0	2
CPT_19300 (17.77 m)	ULS	M7.5 / 0.35g	2.5	24	>20	29
	SLS	M7.5 / 0.13g	2.5	0	0	3
CPT_23983 (20.31 m)	ULS	M7.5 / 0.35g	2.5	15	15	22
	SLS	M7.5 / 0.13g	2.5	0	0	1
CPT_818 (15.13 m)	ULS	M7.5 / 0.35g	2.5	7	7	9
	SLS	M7.5 / 0.13g	2.5	1	0	4
CPT_23411 (15.28 m)	ULS	M7.5 / 0.35g	2.5	24	>20	33
	SLS	M7.5 / 0.13g	2.5	2	2	13
CPT_23412 (17.08 m)	ULS	M7.5 / 0.35g	2.5	14	19	21
	SLS	M7.5 / 0.13g	2.5	1	1	5
CPT_15814 (15.00 m)	ULS	M7.5 / 0.35g	2.5	16	16	30
	SLS	M7.5 / 0.13g	2.5	2	2	18

* Rounded to nearest whole number
^ Estimated utilising Idriss & Boulanger (2008) method
$ Estimated utilising NCEER (1998) method

Table 5: Correlation between LPI and Liquefaction Risk

LPI Range	Liquefaction Risk
LPI = 0	Very Low
0 < LPI ≤ 5	Low
5 < LPI ≤ 15	High
15 < LPI	Very High

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Table 6: LSN Ranges and Observed Land Effects

LSN Range	Predominant Performance	Photographs in T&T (2013) Appendix N
0-10	Little to no expression of liquefaction, minor effects	Figure N7a-y
10-20	Minor expression of liquefaction, some sand boils	Figure N8a-y
20-30	Moderate expression of liquefaction, with sand boils and some structural damage	Figure N9a-t
30-40	Moderate to severe expression of liquefaction, settlement can cause structural damage	Figure N10a-v
40-50	Major expression of liquefaction, undulations and damage to ground surface; severe total and differential settlement of structures	Figure N11a-p
>50	Severe damage, extensive evidence of liquefaction at surface, severe total and differential settlements affecting structures; damage to services	Figure N12a-x

Note: Table from Tonkin & Taylor Ltd (2013); LSN derived from Canterbury Earthquake Sequence observations

3 Site Walkover Inspection

A site walkover inspection of the Cresselly Place housing complex was carried out by an Opus Geotechnical Engineer on 8 July 2013. Photographs of significant observations were taken during the site walkover inspection with selected photographs presented in Appendix B and their locations and directions of view approximated on Figure 03. The following observations were made during the site walkover:

- Thin stepped cracking within the brick veneer of Flats 1, 3, 5, 6, 7, 15, 17 , 26, 30 (typified by Photo 11 in Appendix B)
- Moderate stepped cracking within the brick veneer of Flats 5, 16, 22, 30, 31 (typified by Photos 12 and 13 in Appendix B)
- Wide stepped cracking within the brick veneer of Flats 7, 14, 18 (typified by Photo 14 in Appendix B)
- Severe stepped cracking within exterior veneers of Flats 19, 27, 28 (typified by Photos 15 and 16 in Appendix B)
- Moderate foundation cracking of Flats 1, 3, 5, 6, 7, 10, 14, 16, 19, 20, 22, 23, 28, 30 (typified by Photo 17 in Appendix B)
- Severe foundation cracking at Flats 27, 29 (typified by Photo 16 in Appendix B)
- Stretching separation of the fascia boards at Flats 1, 3, 5, 6, 12, 14, 25, 27, 29 (typified by Photos 18 and 19 in Appendix B)
- Shearing through bricks in exterior veneers at Flats 5, 12, 27, 28 (typified by Photos 21, 22 and 23 in Appendix B)
- Moderate vertical cracking through bricks in corner exterior wall veneers at Flats 16, 17, 30 (typified by Photo 22 in Appendix B)
- Moderate vertical cracking through bricks in centre of exterior wall veneers at Flats 7, 28, 30 (typified by Photos 24 through 28 in Appendix B)

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- Severe stretching of walls at Flats 27, 28, 29 (typified by Photos 30 and 31 in Appendix B)
- Separation of downspout connections from the pilasters between Flats 3 & 5, 5 & 7, 10 & 12, 25 & 26 (typified by Photos 32 and 33 in Appendix B)
- Shearing through grout within exterior wall veneers of Flats 1, 7, 23, 26, 28, 30 (typified by Photos 35 and 36 in Appendix B)
- Distortion of fencing along the perimeter site boundary behind Flats 9, 11, 25, 27, 28, 30 (typified by Photos 37, 38, 39 and 40 and 16 in Appendix B)
- Differential movement of concrete footpaths behind Flats 16, 17, 18, 19, 20, 26, 28; in front of Flats 8, 10, 14, 20, 25, 26, 27, 28; and to the side of Flats 8, 10, 16, 18, 26, 28 (typified by Photos 44, 45 and 53 in Appendix B)
- Grey SILT/SAND ejecta behind Flats 6, 14, 16, 18, 20, 21, 22, 24, 26, 28, 30, 31; in front of Flats 12, 14, 25; and beside Flats 18, 26 (typified by Photos 46, 47 and 48 in Appendix B)
- Differential settlement of Flats 18, 21, 23, 25, 27, 28, 29 (typified by Photos 49, 50, 51 and 52 in Appendix B)
- Ground settlement in Front of Flats 15, 17, 19 (refer to Photos 50 and 54 in Appendix B)
- Tilting of exterior walls at Flats 16, 28 (typified by Photo 56 in Appendix B)
- Cracking in concrete porch at Flats 20, 22 & 24, and 28 (refer to Photos 57, 58 and 59 in Appendix B)

Due to the amount of time since the Canterbury Earthquake Sequence events, signs lof land damage, which may have existed immediately after the earthquakes, may have been cleared or become less apparent by the time the Opus site walkover inspections were conducted.

4 Level Survey

A summary of the level survey undertaken by Opus Christchurch Surveyors on 8 July 2013 at the Cresselly Place housing complex is given in Table 7.

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Table 7: Summary of Level Survey Results

Block	Flat No.	Maximum Fall (mm/m)
A	1	< 5
	3	7.7
	5	No Access
	7	10.8
C	9	14.7
	11	12.3
	13	12.6
	15	5.7
E	17	9.5
	19	20.8
	21	15.9
	23	16.2
G	25	34.7
	27	25.0
	29	5.8
	31	6.8

Block	Flat No.	Maximum Fall (mm/m)
B	2	5.8
	4	< 5
	6	No Access
	8	< 5
D	10	< 5
	12	6.8
	14	12.6
	16	18.9
F	18	17.3
	20	16.3
	22	17.9
	24	No Access
	26	18.9
H	28	27.4
	30	12.1

Foundations are considered to be equivalent to Type B as defined by the MBIE guidance. Most of the units also exhibited total floor level variations greater than 100 mm. In accordance with Table 2.3 of the MBIE (2012) guidance, the majority of units would require foundation rebuild and/or re-level, because their maximum fall is greater than 5mm/m and/or their total floor level variations are greater than 100 mm.

5 Discussion

All flats at the Cresselly Place housing complex are supported on concrete perimeter footings with interior isolated pier footings with suspended timber (i.e. joist and bearer) floors. These buildings are considered to be equivalent to "Type B2" in accordance with the MBIE (2012) guidance.

Moderate to major liquefaction damage occurred at the Cresselly Place housing complex as a result of the 2010 and 2011 earthquake sequence. At the time of the 8 July 2013 inspection, evidence of ejected material and ground settlement was observed. The damage to pavements appears to be a result of differential settlement and uplift due to liquefaction heave. Minor to major cracking within the building footings and walls was observed. The EQC maps showing areas of liquefaction interpreted from high resolution aerial photos indicate evidence of moderate to severe observed liquefaction on the site and in the vicinity after the February 2011 seismic event, while minor observed liquefaction was noted and confirmed by Opus inspection after the June 2011 seismic

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events. No mapping was completed in this area after the September 2010 seismic event, while no observed liquefaction was reported after the December 2011 seismic event.

The level survey results have been assessed and indicate large floor level variations (i.e. maximum falls greater than 5 mm/m) in all but a few flats at Cresselly Place housing complex. In accordance with the MBIE (2012) guidance, the flats with maximum falls greater than 5 mm/m will require a foundation re-level. For units with floor variations of greater than 100 mm a foundation rebuild is indicated.

CPTs undertaken for EQC indicate the residential complex is likely to be founded on interbedded layers of loose to dense SAND, Silty SAND and Sandy SILT overlying dense to very dense Sandy GRAVEL located at a depth of approximately 15.0 to 16.5 m. Groundwater depths are expected to range from 1.5 to 3.0 m below ground level.

Liquefaction typically occurs in recent (i.e. less than 10,000 years old), normally consolidated silts and sands beneath groundwater and is dependent on material density, grain size and soil composition. The liquefaction assessment utilising data from nearby CPT's identified liquefiable layers throughout the sub-surface profile. The sub-surface ground profile, together with the ground damage reported at the site during the recent earthquakes of 2010 and 2011, confirms that the site has a high to very high risk of liquefaction and that further ground subsidence and differential settlement are likely at the site during a future design seismic event.

GNS Science and the EQC indicate on GeoNet[16] that there is an elevated risk of seismic activity in the Canterbury region as a result of the earthquake sequence following the September 2010 earthquake. Recent advice on GeoNet indicates there is currently an 11% probability of another Magnitude 6 or greater earthquake occurring in the next 12 months in the Canterbury region. Depending on the location of the epicentre, such an event could cause liquefaction-induced land damage at the site similar to what was experienced in 2010 and 2011.

Based on our liquefaction assessment the site is considered to be equivalent to a TC3 site. Due to the presence of existing ground cracking, the site is considered to have a moderate risk of lateral spread.

6 Recommendations

In order to determine foundation repair options at the Cresselly Place housing complex, it is recommended that a site specific investigation is undertaken at the site comprising CPTs, hand auger boreholes and Dynamic Cone Penetrometer (DCP) tests (i.e. "Scalas"). Due to the absence of deep (e.g. of the order of 20 m deep) machine boreholes near the site and to the significant extent of ground damage recorded, it would be beneficial for a deep sonic machine borehole to be conducted at the site as part of the site investigation. The site investigation will enable a site specific liquefaction assessment to be undertaken to identify the liquefiable layers and to help determine conceptual foundation repair and

[16] GNS Science and the Earthquake Commission, "Canterbury region long-term probabilities" in "Aftershocks" on "GeoNet", available online at http://info.geonet.org.nz/display/home/Aftershocks, accessed 12 July 2013.

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re-levelling options. The recommended scope of the proposed site specific geotechnical investigations comprises the following:

- One sonic machine borehole adjacent to one of the CPTs on the site;
- 4 CPTs to depths of 20 m;
- Several hand auger boreholes and DCP tests carried out to depths of 3 m or refusal; and
- Assessment and reporting.

7 Limitation

This report has been prepared solely for the benefit of the Christchurch City Council as our client with respect to the particular brief given to us. Data and/or opinions in this desk study may not be used in other contexts, by any other party or for any other purpose.

It is recognised that the passage of time affects the information and the assessments provided in this Document. Opus' opinions are based upon information that existed at the time of the production of this Desk Study. It is understood that the Services provided allowed Opus to form no more than an opinion on the actual conditions of the site at the time the site was visited and cannot be used to assess the effect of any subsequent changes in the quality of the site, its surroundings or any laws or regulations.

For and on behalf of Opus International Consultants Ltd,

Prepared By:

Riley Gerbrandt
Geotechnical Engineer

Reviewed By:

Graham Brown
Senior Geotechnical Engineer

Figures:

Figure 01 Site Locality Map
Figure 02 Site Vicinity Map
Figure 03 Site Plan

Appendices:

Appendix A Construction Details
Appendix B Selected Site Walkover Photographs
Appendix C Surrounding Site Investigation Data
Appendix D EQC Map Output
Appendix E CLiq Liquefaction Analysis Output

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Figures

Figure 01 Site Locality Map

Figure 02 Site Vicinity Map

Figure 03 Site Plan

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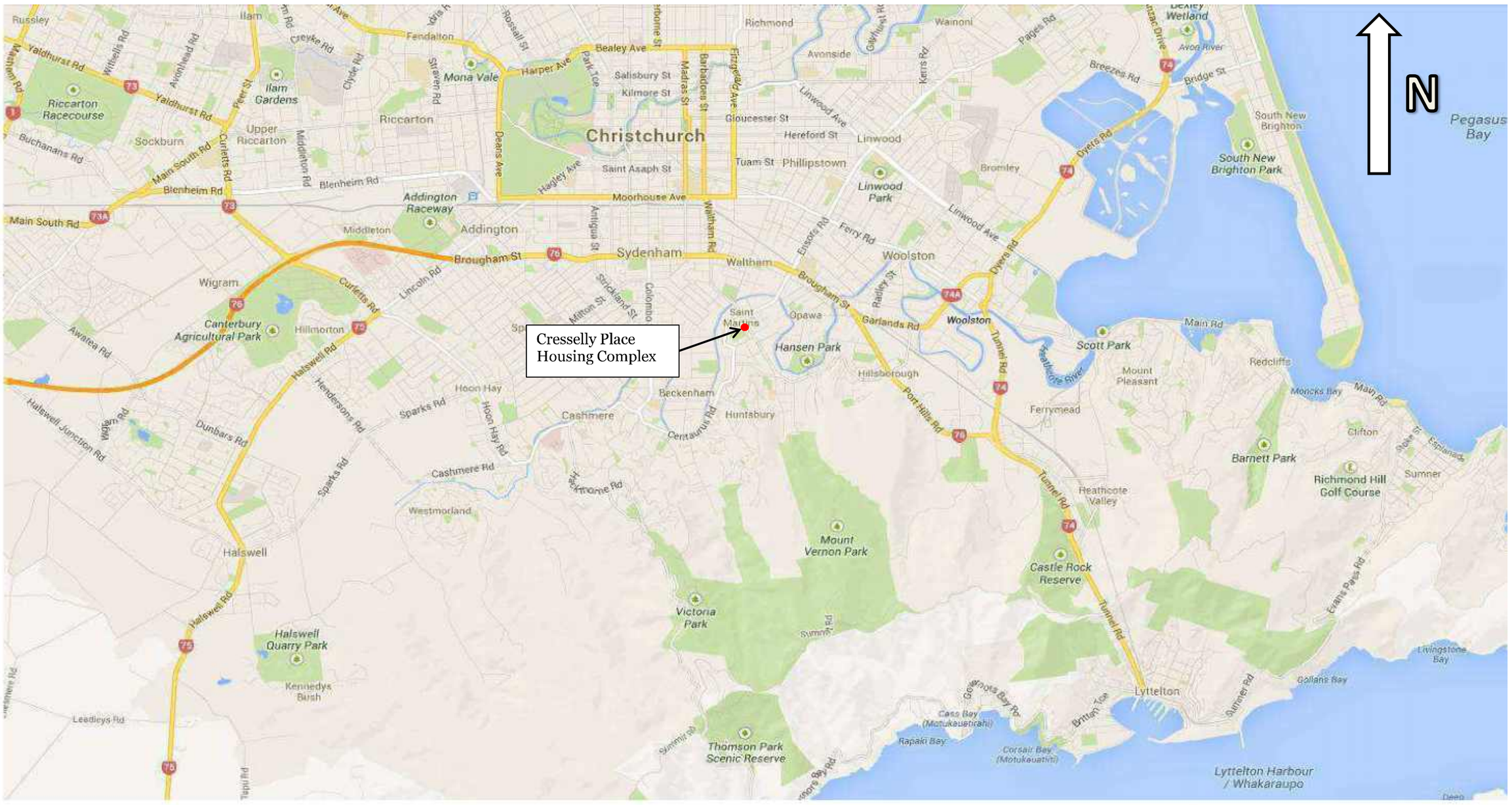

SOURCE: Google Maps (Accessed on 12/7/2013)

OPUS

Opus International Consultants Ltd
Christchurch Office
20 Moorhouse Ave
PO Box 1482
Christchurch, New Zealand
Tel: +64 3 363 5400 Fax: +64 3 365 7857

Project:	Cresselly Place, Saint Martins, Christchurch
Project No.:	6-QC335.00
Client:	Christchurch City Council

Figure 01: Site Locality Map

Drawn:	Opus Geotechnical Engineer
Scale:	Not to Scale
Date:	12-Jul-13

Legend:

CPTs assessed for liquefaction potential

SOURCE: https://canterburygeotechnicaldatabase.projectorbit.com/ (Accessed on 8/7/2013)

OPUS

Opus International Consultants Ltd
Christchurch Office
20 Moorhouse Ave
PO Box 1482
Christchurch, New Zealand
Tel: +64 3 363 5400 Fax: +64 3 365 7857

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Project No.:	6-QC335.00
Client:	Christchurch City Council

Figure 02: Site Vicinity Map

Drawn:	Opus Geotechnical Engineer
Scale:	Not to Scale
Date:	12-Jul-13

SOURCE: Google Maps (Accessed on 8/7/2013)

OPUS
Opus International Consultants Ltd
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20 Moorhouse Ave
PO Box 1482
Christchurch, New Zealand
Tel: +64 3 363 5400 Fax: +64 3 365 7857

Project: Cresselly Place, Saint Martins, Christchurch
Project No.: 6-QC335.00
Client: Christchurch City Council

Figure 03: Site Plan

Drawn: Opus Geotechnical Engineer
Scale: No Scale
Date: 12-Jul-13

Appendix A

Construction Details

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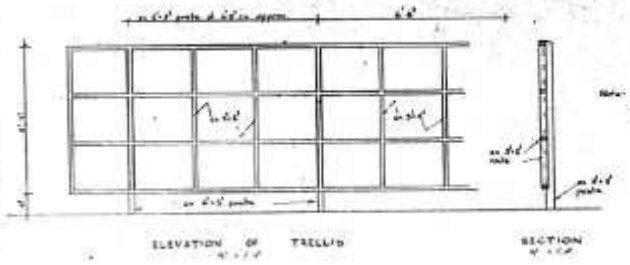
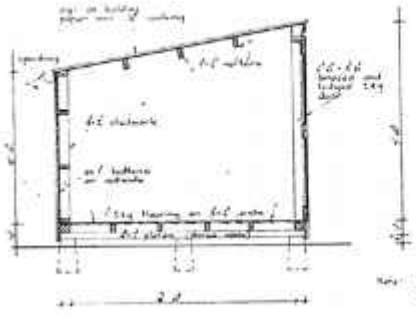


ELEVATION OF TRELLIS

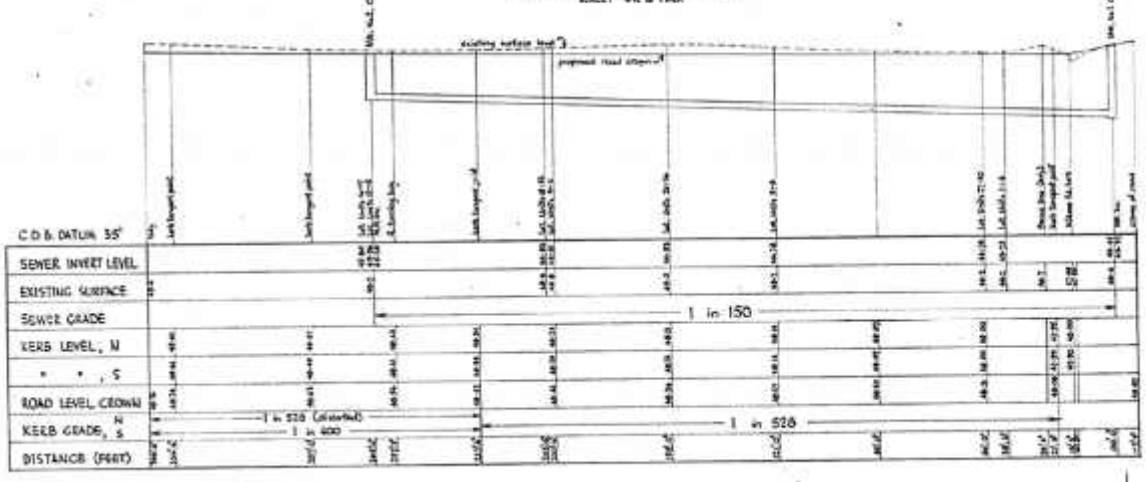
SECTION

TYPICAL ROAD CROSS SECTION



SECTION THROUGH SHED

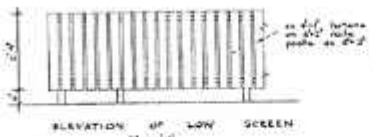
DETAIL OF BATTENING



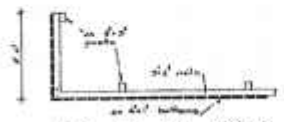
LONGITUDINAL SECTIONS - SEWER AND ROADING

SCALES: Horizontal = 50 ft. to 1 inch
Vertical = 5 ft. to 1 inch

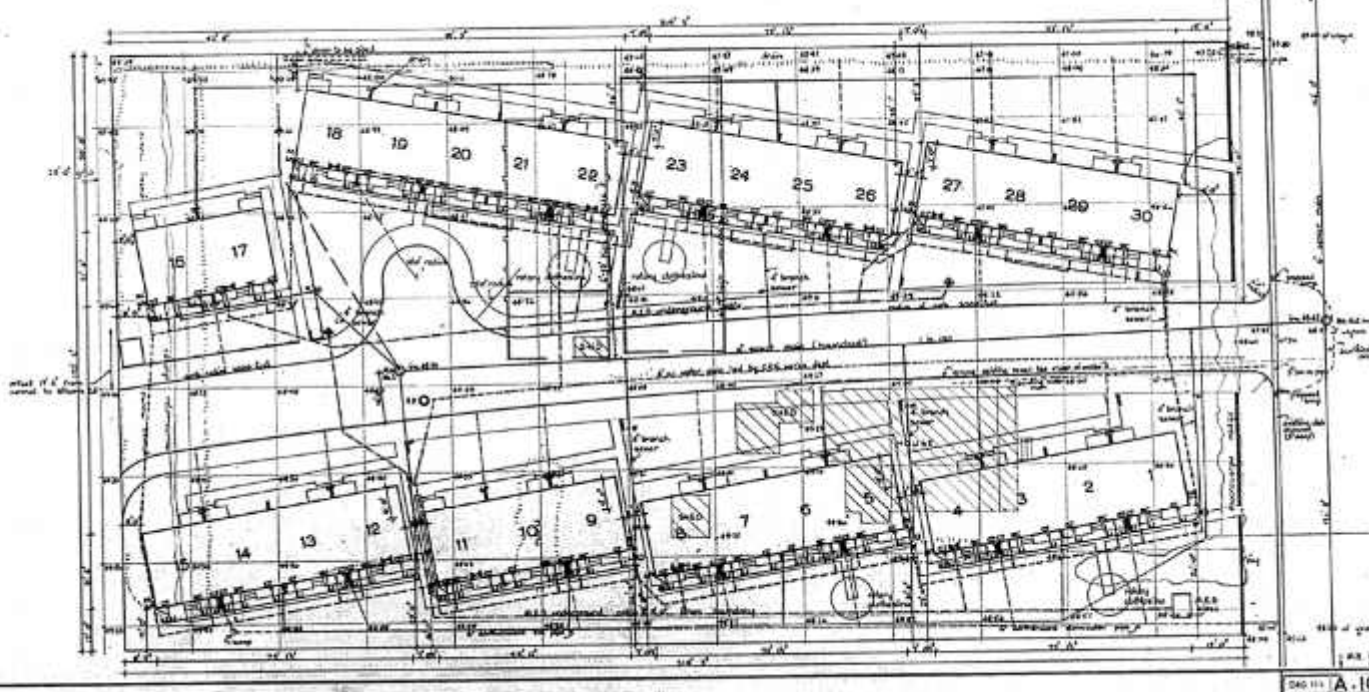
MAIN SEWER AND BRANCHES
4" GLAZED EARTHENWARE STORMWATER
WATER SUPPLY
ELECTRICITY SUPPLY UNDERGROUND CABLE
SEWER MANHOLE
VENT
GULLY TRAP
INSPECTION JUNCTION
INSPECTION PIPE
BLIND END
WATER CLOSET
RAINWATER DOWNPIPE
½" PILLAR BIBB
METER CABINET
LETTER AND MILK BOX
STREET LIGHT
FIRE PLUG
Y JUNCTION



ELEVATION OF LOW SCREEN



PLAN OF LOW SCREEN



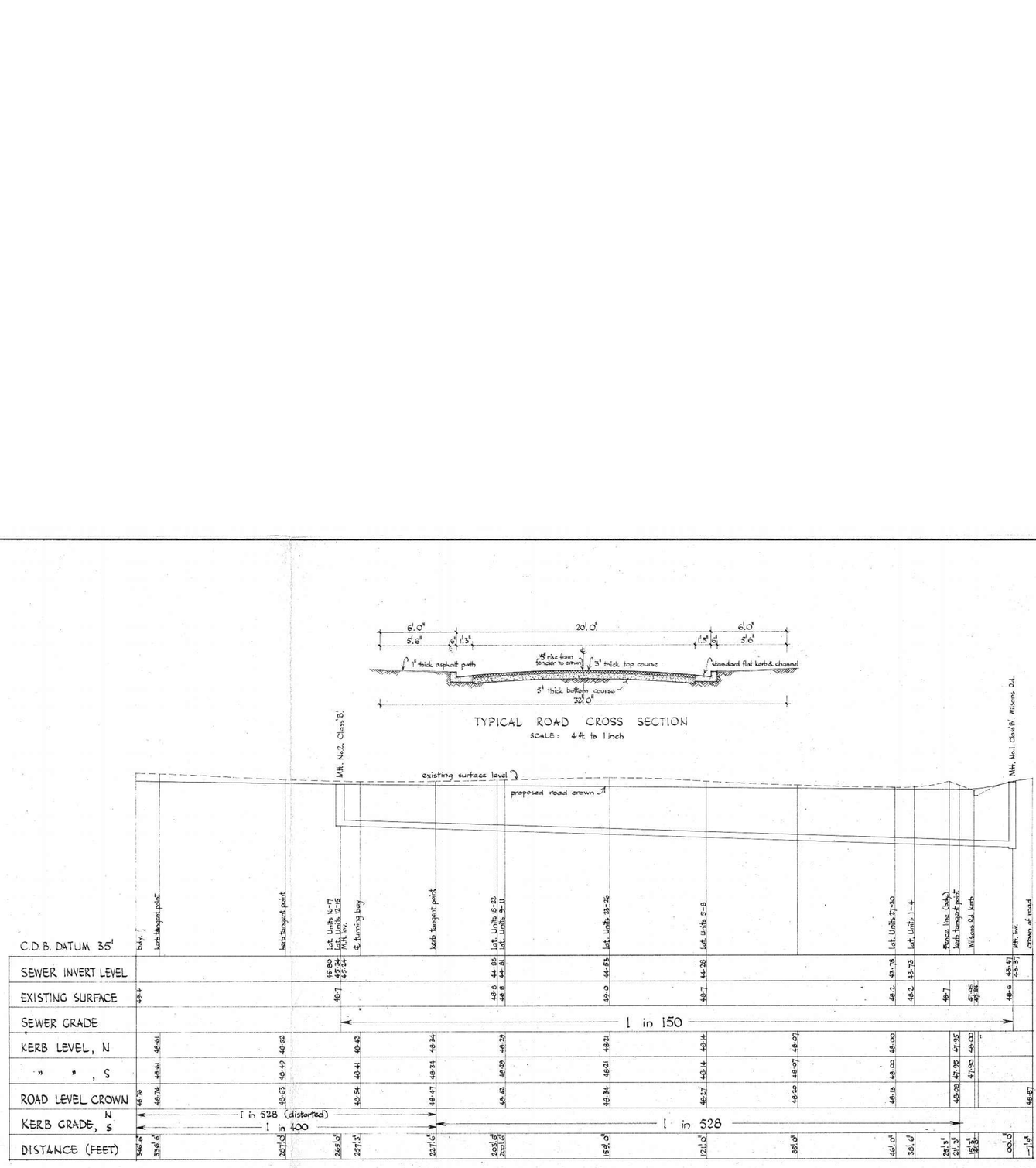
CHRISTCHURCH CITY COUNCIL
CITY ENGINEER'S DEPARTMENT

PENSIONERS' COTTAGES WILSONS ROAD

DWG No. A.106/4.
SCALE 1/8" = 1'0"
DATE FEBRUARY 1960

TYPICAL ROAD CROSS SECTION

SCALE : 4 ft. to 1 inch



LONGITUDINAL SECTIONS - SEWER AND ROADING

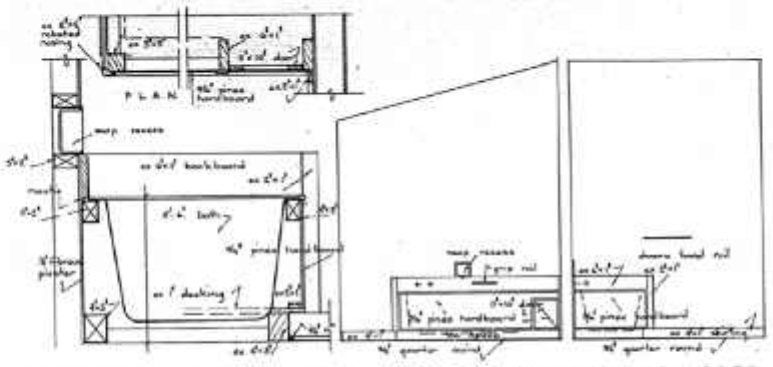
SCALES : Horizontal – 20 ft. to 1 inch
Vertical – 4 ft. to 1 inch

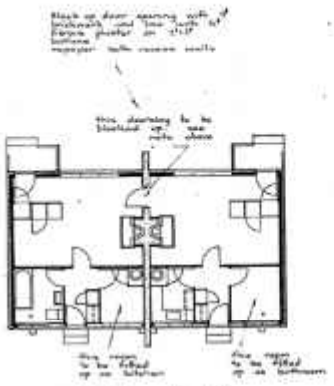
MAIN SEWER AND BRANCHES
4" GLAZED EARTHENWARE STORMWATER
WATER SUPPLY
ELECTRICITY SUPPLY UNDERGROUND CABLE
SEWER MANHOLE
M.V. MAIN VENT
G.T. GULLY TRAP
I.J. INSPECTION JUNCTION
I.P. INSPECTION PIPE
B.E. BLIND END
W.C. WATER CLOSET
D.P. RAINWATER DOWNPIPE
P.C. ½" PILLAR COCK
METER CABINET
LETTER AND MILK BOX
STREET LIGHT
FIRE PLUG
Y.J. Y JUNCTION

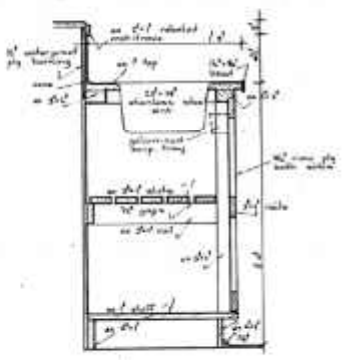
Checked on K.P. 28 March 4

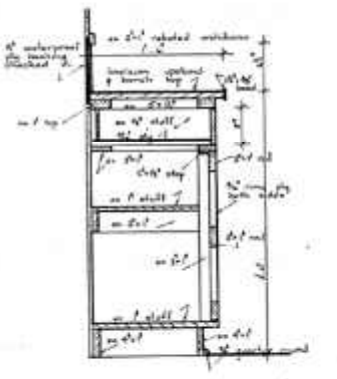
PENSIONERS' COTTAGES WILSONS ROAD

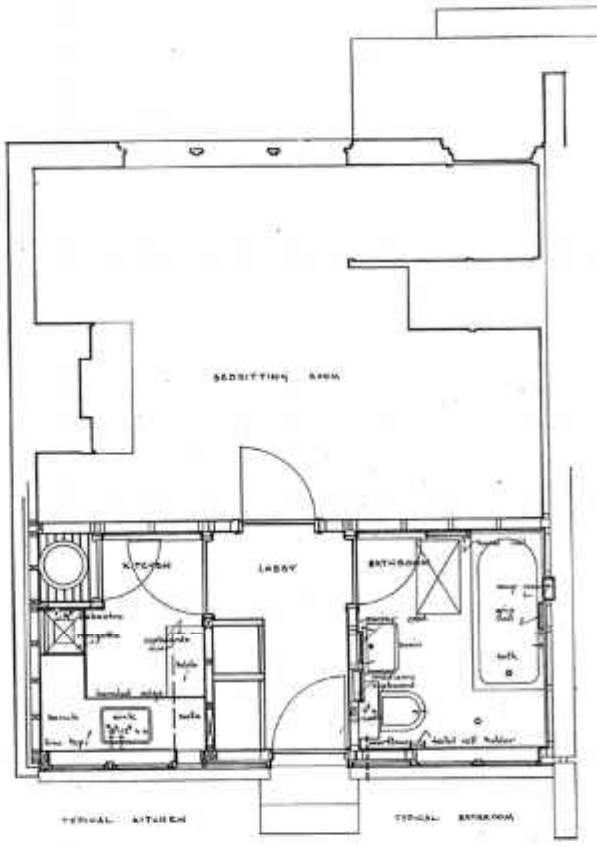
122/C1
1/16" = 1'. 0"
FEBRUARY 1960

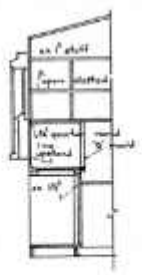


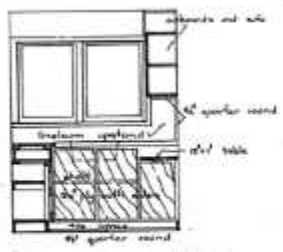


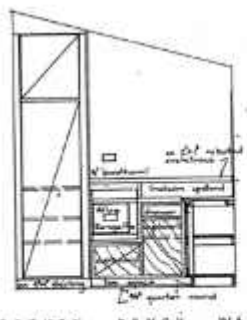


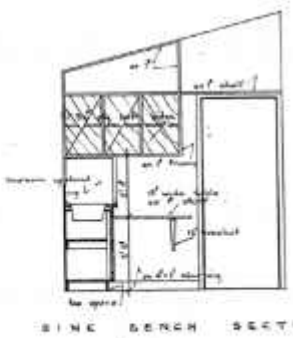








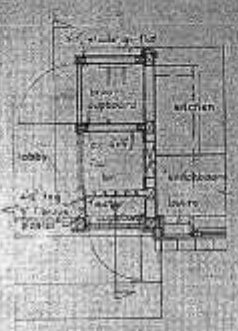




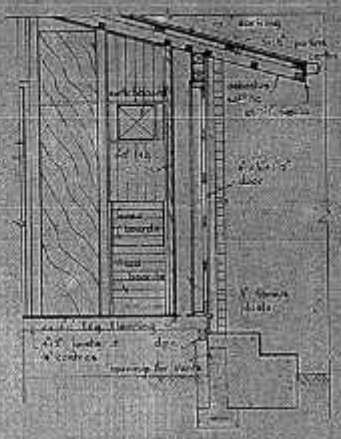
CHRISTCHURCH CITY COUNCIL

CONVERSION OF PENSIONERS COTTAGES

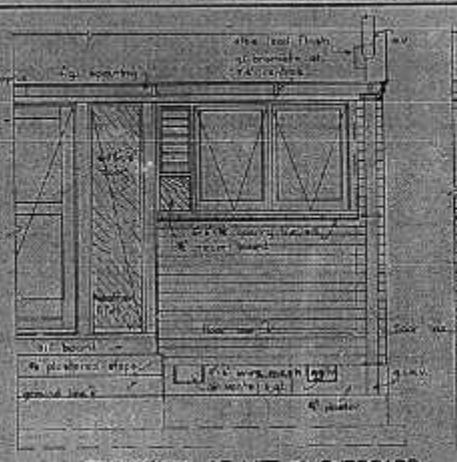
DWG NO. A·106·172.
SCALE



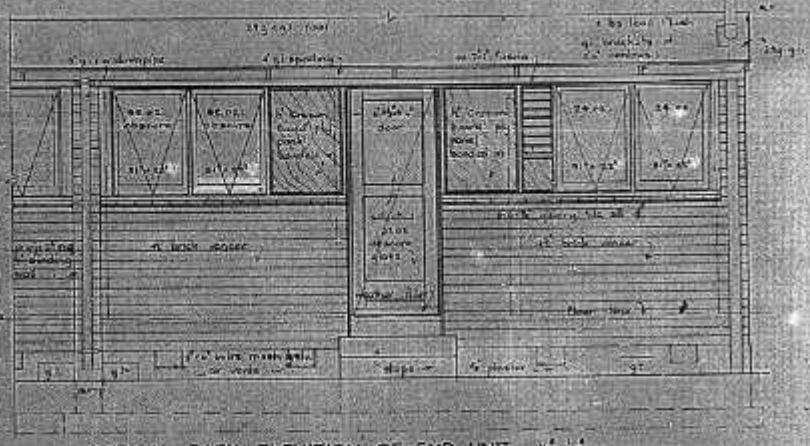
PLAN OF METER CUPBOARD ½"=1'0"



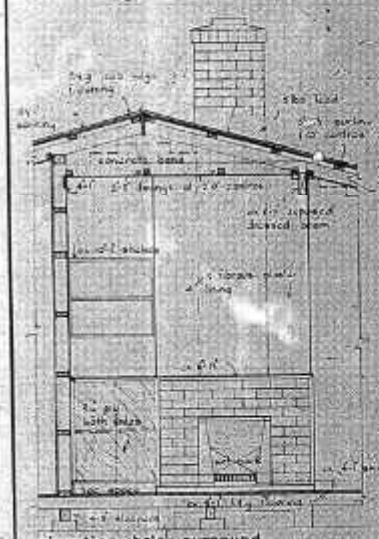
SECTION THROUGH METER CUPBOARD



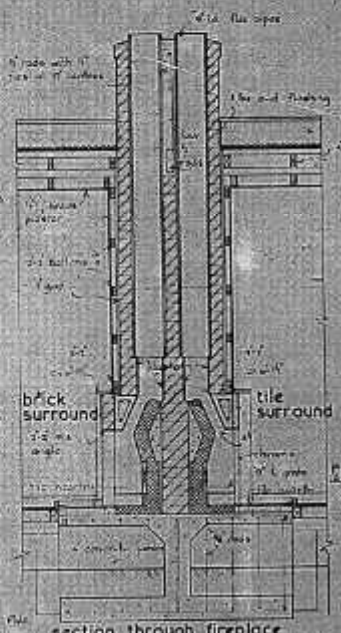
ELEVATION OF METER CUPBOARD



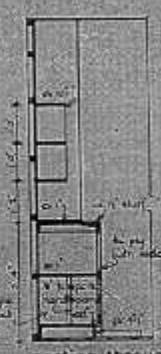
TYPICAL BACK ELEVATION OF END UNIT ½"=1'0"



elevation brick surround

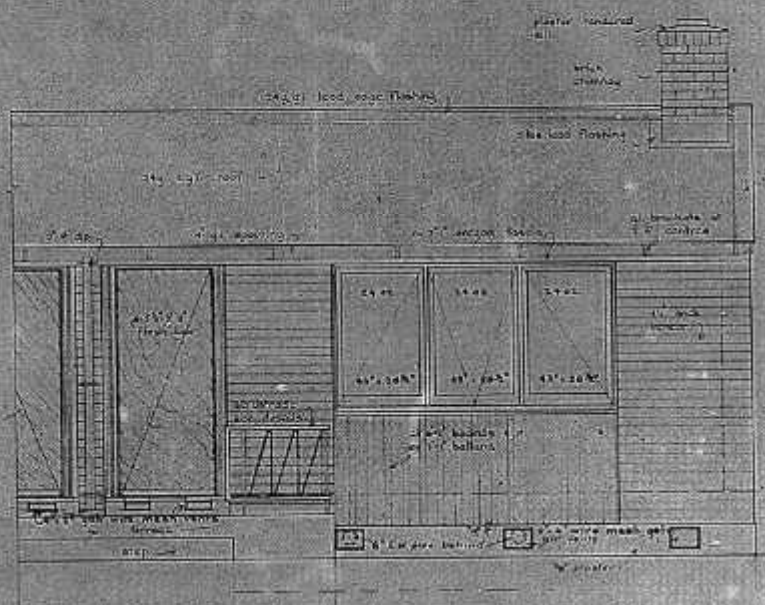


section through fireplace

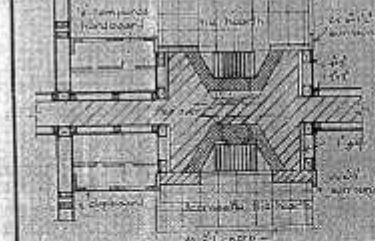


section through cupboard

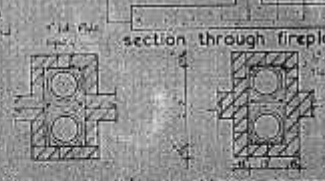
elevation of tile surround



TYPICAL ELEVATION OF END UNIT ½"=1'0"



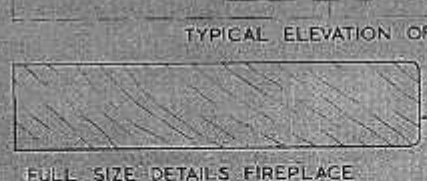
plans of fireplaces



plans of alternate chimney courses

top course

rendered sill



FULL SIZE DETAILS FIREPLACE SURROUND & HEARTH KERB

FIREPLACE & CHIMNEY DETAILS ½"=1'0"

CHRISTCHURCH CITY COUNCIL
CITY ENGINEER'S DEPARTMENT

FIRE PLACE DETAILS, FRONT & REAR ELEVATIONS
PENSIONERS COTTAGES [redacted] ROAD

A.106/6
½"=1'0"
FULL SITE
FEBRUARY 1960

Appendix B

Selected Site Walkover Photographs

© Opus International Consultants Ltd

Photo 1: View of Even-Numbered Flats 2-8 Looking Southwest

Photo 2: View of Cresselly Place and Even-Numbered Flats 2-8 Looking Northwest

Photo 3: View of Cresselly Place and Odd-Numbered Flats 1-19 Looking East

Photo 4: View of Cresselly Place Looking Northeast

OPUS	Christchurch City Council		**Site Walkover Photographs**
	12/07/2013	**6-QC335.00**	**Geotechnical Desktop Study** **Cresselly Place, St Martins, Christchurch**

Photo 5: View of Flats 14 and 16 Looking Northwest

Photo 6: View of Cresselly Place and Even-Numbered Flats 14-20 Looking North-Northwest

Photo 7: View Cresselly Place and Odd-Numbered Flats 23-31 Looking Southwest;
Note that Odd-Numbered Flats 27-31 are in the General Area of the "Grassy Mound"

Photo 8: View of Cresselly Place and Odd-Numbered Flats 19-23 Looking South;
Note Depression in Centre of Photo

OPUS	Christchurch City Council		**Site Walkover Photographs**
	12/07/2013	6-QC335.00	**Geotechnical Desktop Study** **Cresselly Place, St Martins, Christchurch**

Photo 9: View Liquefaction at Cresselly Place and Even-Numbered Flats 20-26 Looking North-Northeast; Photo taken 14 June 2011

Photo 10: View of "Grassy Mound" Area behind Even-Numbered Flats 28-30 Looking Northwest

Photo 11: Small Stepping Crack in Brick Veneer behind Flat 3 Looking North

Photo 12: Bottom Portion of Medium Stepping Crack in Brick Veneer behind Flat 5 Looking North

OPUS	Christchurch City Council		**Site Walkover Photographs**
	12/07/2013	6-QC335.00	**Geotechnical Desktop Study** **Cresselly Place, St Martins, Christchurch**

Photo 13: Top Portion of Medium Stepping Crack in Brick Veneer behind Flat 5

Photo 14: Major Stepping Crack in Brick Veneer in the Back Portion of the Right Wall of Flat 7 Looking East

Photo 15: Severe Step Cracking in Brick Veneer at Back of Flat 21 Looking North

Photo 16: Severe Stepping Crack, Shearing Through Brick in Exterior Veneer and Cracking through Foundation at Front of Flat 27 Looking South

OPUS	Christchurch City Council		**Site Walkover Photographs**
	12/07/2013	**6-QC335.00**	**Geotechnical Desktop Study** **Cresselly Place, St Martins, Christchurch**

Photo 17: Moderate Crack in Foundation behind Flat 5 Looking North

Photo 18: Stretching Separation of Fascia Boards at Back of Flats 1 and 3Looking Northwest

Photo 19: Stretching Separation of Fascia Boards and Movement of Gutter in its Hangar at Front of Flat 27 Looking South

Photo 20: Separation of Doorjamb from Brick Veneer at Back of Flat 5 Looking North-Northwest

OPUS	Christchurch City Council		Site Walkover Photographs
	12/07/2013	6-QC335.00	Geotechnical Desktop Study Cresselly Place, St Martins, Christchurch

Photo 21: Shearing through Bricks of Exterior Veneer at Back of Flat 5 Looking Northwest

Photo 22: Shearing through Bricks of Exterior Veneer and Minor Vertical Cracking through Bricks in Corner Exterior Wall at Back of Flat 23 Looking West

Photo 23: Shearing through Bricks of Exterior Veneer and Minor Vertical Cracking through Bricks in Corner Exterior Wall at Back of Right Wall of Flat 7 Looking East

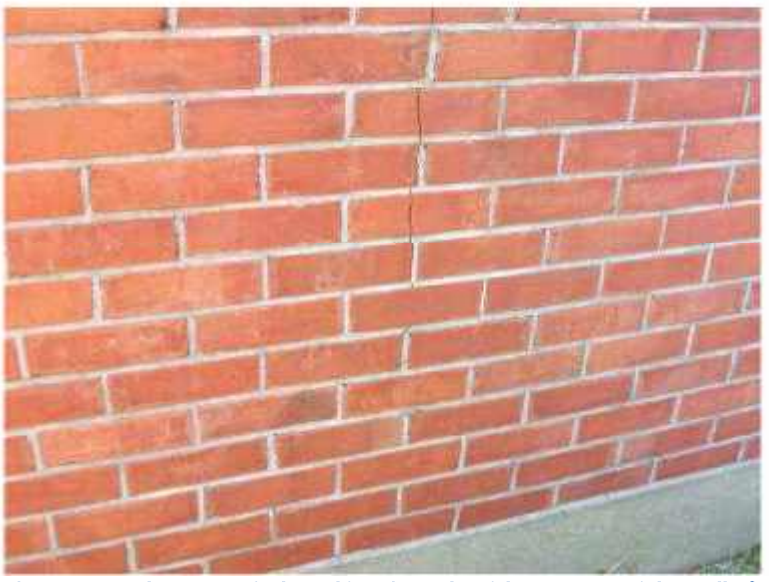


Photo 24: Moderate Vertical Cracking through Brick Veneer at Right Wall of Flat 7 (Photo 1 of 5) Looking Southeast

OPUS	Christchurch City Council		**Site Walkover Photographs**
	12/07/2013	6-QC335.00	**Geotechnical Desktop Study** **Cresselly Place, St Martins, Christchurch**

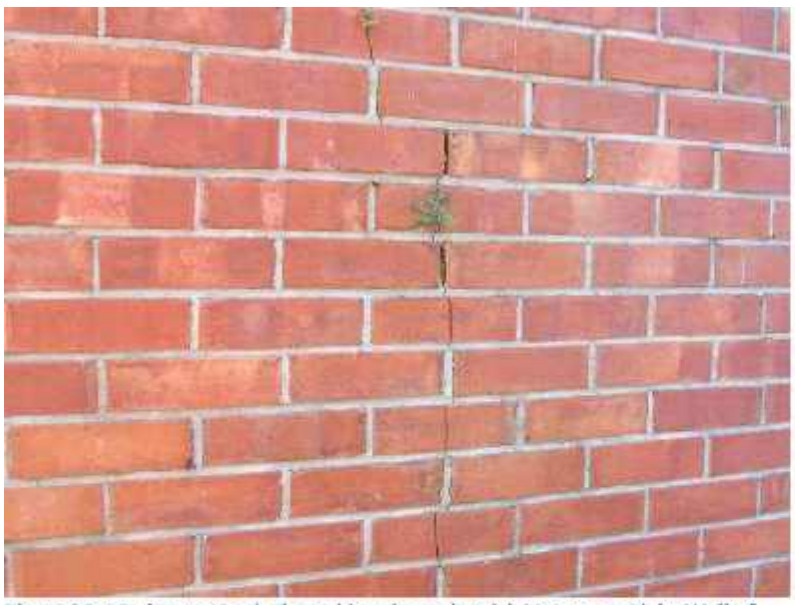


Photo 25: Moderate Vertical Cracking through Brick Veneer at Right Wall of Flat 7 (Photo 2 of 5) Looking Southeast

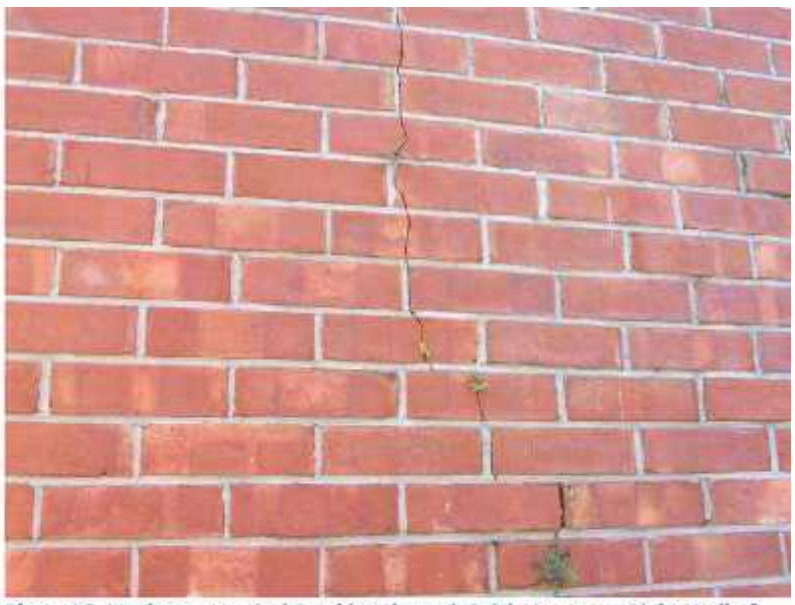


Photo 26: Moderate Vertical Cracking through Brick Veneer at Right Wall of Flat 7 (Photo 3 of 5) Looking Southeast

Photo 27: Moderate Vertical Cracking through Brick Veneer at Right Wall and Failing of Gable Bricks of Flat 7 (Photo 4 of 5) Looking Southeast

Photo 28: Moderate Vertical Cracking through Brick Veneer at Right Wall and Failing of Gable Bricks of Flat 7 (Photo 5 of 5) Looking East

OPUS	Christchurch City Council		**Site Walkover Photographs**
	12/07/2013	6-QC335.00	**Geotechnical Desktop Study** **Cresselly Place, St Martins, Christchurch**

Photo 29: Tension Cracking of Pilaster between Rear of Flats 5 and 7 Looking East

Photo 30: Severe Stretching of Walls at Rear of Flats 27 and 29 Looking North (Photo 1 of 2)

Photo 31: Severe Stretching of Walls at Rear of Flats 27 and 29 Looking North (Photo 2 of 2)

Photo 32: Separation of Downspout Connector from Pilaster at Rear of Flats 5 and 7 Looking East

OPUS	Christchurch City Council	Site Walkover Photographs
	12/07/2013 6-QC335.00	Geotechnical Desktop Study Cresselly Place, St Martins, Christchurch

Photo 33: Separation of Downspout Connector from Pilaster and Separation of Gutter Sections at Front of Flats 1 and 3 Looking Southeast

Photo 34: Shearing of Downspout at Rear of Flat 7 Looking Northwest

Photo 35: Shearing through Grout between Bricks of Exterior Veneer at Back of Flat 7 Looking North

Photo 36: Shearing through Grout between Bricks of Exterior Veneer at Back of Flat 1 Looking Northeast

OPUS	Christchurch City Council		**Site Walkover Photographs**
	12/07/2013	6-QC335.00	**Geotechnical Desktop Study** **Cresselly Place, St Martins, Christchurch**

Photo 37: Distortion of Fence along Southern Property Boundary behind Flats 9 and 11 Looking Southwest

Photo 38: Distortion of Fence along Southern Property Boundary behind Flats 9 and 11 Looking Southeast

Photo 39: Distortion of Fence along Southern Property Boundary behind Flats 9 and 11 Looking Southwest

Photo 40: Distortion of Fence along Southern Property Boundary behind Flats Looking Northeast from behind Flat 31

OPUS	Christchurch City Council		**Site Walkover Photographs**
	12/07/2013	6-QC335.00	**Geotechnical Desktop Study** **Cresselly Place, St Martins, Christchurch**

Photo 41: Movement of Gutter in its Hangar at Back of Flat 1 Looking Northwest

Photo 42: Movement of Gutter in its Hangar and Separation of Eave Joint at Front of Flat 29 Looking South-Southwest

Photo 43: Cracking of Gable at Top of Right Wall of Flat 7 Looking Northeast

Photo 44: Differential Movement of Concrete Footpaths behind Flat 19 Looking Northeast

OPUS	Christchurch City Council		**Site Walkover Photographs**
	12/07/2013	6-QC335.00	**Geotechnical Desktop Study** **Cresselly Place, St Martins, Christchurch**

Photo 45: Differential Movement of Concrete Footpaths in front of Flat 25 Looking Northeast

Photo 46: SILT/SAND Ejecta behind Flat 21 Looking Southwest

Photo 47: SILT/SAND Ejecta behind Flat 26 Looking Northwest

Photo 48: SILT/SAND Ejecta behind Flat 26 Looking West

OPUS	Christchurch City Council		**Site Walkover Photographs**
	12/07/2013	6-QC335.00	**Geotechnical Desktop Study** **Cresselly Place, St Martins, Christchurch**

Photo 49: Differential Settlement at Back of Flat 21 Looking Northwest

Photo 50: Depression and Differential Settlement at Front of Flats 21 and 23 Looking Southeast

Photo 51: Depression and Differential Settlement at Front of Flats 23, 25, 27 and 29 Looking South-Southwest

Photo 52: Differential Settlement at Back of Flat 28 Looking Southeast

OPUS	Christchurch City Council		Site Walkover Photographs
	12/07/2013	6-QC335.00	Geotechnical Desktop Study Cresselly Place, St Martins, Christchurch

Photo 53: Depression, Differential Settlement and Distortion of Concrete Footpath in Front of Flats 23 and 25 Looking Northeast

Photo 54: Depression, Differential Settlement and Distortion of Concrete Footpath and in Cresselly Place in Front of Flats 19, 21, 23 and 25 Looking Southwest

Photo 55: Leaning Letterboxes and New Asphalt Footpath in Front of Flats 5, 7 and 9 Looking Southeast

Photo 56: Shear Cracking of Downspout and Tilting of Exterior Wall at Flat 16 Looking Northwest

OPUS	Christchurch City Council		**Site Walkover Photographs**
	12/07/2013	6-QC335.00	**Geotechnical Desktop Study** **Cresselly Place, St Martins, Christchurch**

Photo 57: Cracking of Concrete Porch at Back of Flat 28 Looking Southeast

Photo 58: Cracking of Concrete Porch at Back of Flats 22 and 24 Looking Southeast

Photo 59: Cracking of Concrete Porch at Back of Flat 20 Looking Southeast

OPUS	Christchurch City Council		Site Walkover Photographs
	12/07/2013	6-QC335.00	Geotechnical Desktop Study Cresselly Place, St Martins, Christchurch

Appendix C

Surrounding Site Investigation Data

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BOREHOLE No **350/2**

MACHINE BOREHOLE LOG

SHEET 1 of 2

PROJECT	MAS Geotechnical Investigation	JOB NUMBER	4370295
SITE LOCATION	Christchurch	CLIENT	MAS
BOREHOLE LOCATION	79 St Martins Road	CIRCUIT	NZTM
COORDINATES	N 5,177,446 m	R L	6.5 m
	E 1,571,805 m	DATUM	MSL

DRILLING: FLUID LOSS (%)	WATER LEVEL	TOTAL CORE RECOVERY	METHOD / SAMPLER	CASING	RQD (%) 20 40 60 80	DEPTH (m)	GRAPHIC LOG	SOIL / ROCK DESCRIPTION	DISCONTINUITIES	IN-SITU TESTS: SV (peak/res.) (kPa)	IN-SITU TESTS: SPT 'N'	SAMPLES	INSTRUMENTATION	GEOLOGICAL UNIT	R L (m)
								Asphalt.						Fill	
								Dense, silty, fine to coarse GRAVEL, minor fine to medium sand; greyish brown; moist, non plastic. Gravel: SW, subrounded, greywacke, matrix supported.							
		60%	Sonic70					'Loose', SILT, some fine sand; light brown; wet, non plastic.							
								Loose, fine to medium SAND, trace silt; light brown; wet, non plastic.							
		89%	SPT			1									
								1.95 - 2.40 Saturated.						Springston Formation	
	2.4m @ 16/07/2012 7 00 00 a.m.	86%	Sonic70			2		Very soft, SILT, trace clay; grey; saturated, low plasticity.							
								Loose, fine to medium SAND, trace silt; light grey; saturated, non plastic.							
		67%	SPT			3									
		95%	Sonic70					4.00 - 4.20 Medium to coarse sand.							
		78%	SPT			4		Dense, medium to coarse sandy, fine to coarse GRAVEL; grey; saturated, non plastic. Gravel: SW, subrounded, greywacke, matrix supported.							
		95%	Sonic70			5		Dense, medium to coarse SAND; grey; saturated, non plastic. (sand heave to top of run)							
								Very dense, medium to coarse sandy, fine to coarse GRAVEL, trace cobbles; grey; saturated, non plastic. Gravel/cobbles: SW, subrounded, greywacke, matrix supported.							
		78%	SPT			6		Dense, medium to coarse SAND, some fine to coarse gravel; brownish grey; saturated, non plastic. Gravel: SW, subrounded, greywacke.							
		86%	Sonic70					6.00 - 6.45 Sand heave 0.55m to 1 m.						Springston Gravels	
		34%	SPT			7		Very dense, medium to coarse sandy, fine to medium GRAVEL, trace coarse gravel, trace cobbles; grey; saturated, non plastic. Gravel/cobbles: SW, subrounded, greywacke, matrix supported.			N=50+ (5,6/9,12,15,14 for 60mm)				
		90%	Sonic70			8		7.50 - 7.94 Sand heave 0.55m to 1 m.							
		67%	SPT			9		9.00 - 9.45 Sand heave 0.55m to 1 m.			N=50+ (10,10/13,15,22 for 75mm)				
		80%	Sonic70					9.50 - 9.60 Minor decomposing wood fragments.							
								Medium dense, fine to medium SAND, some organics, trace silt;							

DATE STARTED	16/7/12	DRILLED BY	DCN Drilling Ltd. (Evan)
DATE FINISHED	16/7/12	EQUIPMENT	YDX-3L
LOGGED BY	Ryan Everiss	DRILL METHOD	SNC
SHEAR VANE No		DRILL FLUID	
SHEAR VANE C.F.		INCLINATION	90°

COMMENTS
SPT recovery estimated from bag samples.
Disturbed Sample from 0 to 6.9m due to CPT.

FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS SEE KEY SHEET

FINAL

MACHINE_BOREHOLE_UPDATED P:\320\320000\MAS TGE\MAS AGS4_PROTOTYPE.GPJ BECA.GDT 26/10/12

A4 Scale 1:50

BOREHOLE No **350/2**

MACHINE BOREHOLE LOG

SHEET 2 of 2

PROJECT	MAS Geotechnical Investigation	JOB NUMBER	4370295
SITE LOCATION	Christchurch	CLIENT	MAS
BOREHOLE LOCATION	79 St Martins Road	CIRCUIT	NZTM
COORDINATES	N 5,177,446 m	R L	6.5 m
	E 1,571,805 m	DATUM	MSL

DRILLING: FLUID LOSS (%)	WATER LEVEL	TOTAL CORE RECOVERY	METHOD / SAMPLER	CASING	RQD (%) 20 40 60 80	DEPTH (m)	GRAPHIC LOG	SOIL / ROCK DESCRIPTION	DISCONTINUITIES	IN-SITU TESTS: SV (peak/res.) (kPa)	IN-SITU TESTS: SPT 'N'	SAMPLES	INSTRUMENTATION	GEOLOGICAL UNIT	R L (m)
		80%	Sonic70					greyish brown; saturated, non plastic. Organics: fibrous, decomposing wood fragments.							-4
		56%	SPT					10.50 - 10.95 Sand heave 0.55m to 1 m. No organics.			N=27 (3,4/6,6,7,8)				
						11		10.95 - 11.40 Some silt, trace clay, trace shells; low plasticity.							-5
		86%	Sonic70					Soft, SILT, minor clay; grey; saturated, high plasticity.							
		78%	SPT			12		Medium dense, fine to medium SAND, trace silt; grey; saturated, non plastic. 12.00 - 12.45 Sand heave 0.55m to 1 m.			N=22 (3,4/5,5,5,7)			**Springston Formation** *(Contd.)*	
								END OF LOG @ 12.45m							-6
						13									-7
						14									-8
						15									-9
						16									-10
						17									-11
						18									-12
						19									-13

				COMMENTS
DATE STARTED	16/7/12	DRILLED BY	DCN Drilling Ltd. (Evan)	SPT recovery estimated from bag samples.
DATE FINISHED	16/7/12	EQUIPMENT	YDX-3L	Disturbed Sample from 0 to 6.9m due to CPT.
LOGGED BY	Ryan Everiss	DRILL METHOD	SNC	
SHEAR VANE No		DRILL FLUID		
SHEAR VANE C.F.		INCLINATION	90°	

FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS SEE KEY SHEET

FINAL

MACHINE_BOREHOLE_UPDATED P:\320\320000\MAS TGE\MAS AGS4_PROTOTYPE.GPJ BECA.GDT 26/10/12

A4 Scale 1:50

HAND AUGER No: **350/4**

HAND AUGER LOG

SHEET 1 of 1

PROJECT: MAS Geotechnical Investigation
JOB NUMBER: 4370295
SITE LOCATION: Christchurch
CLIENT: MAS

CIRCUIT: NZTM
AUGER LOCATION: 79 St Martins Road
COORDINATES: N 5,177,452 m
E 1,571,792 m
R L: 6.6 m
DATUM: MSL

DEPTH (m)	WATER LEVEL	GRAPHIC LOG	SOIL / ROCK DESCRIPTION	GEOLOGICAL UNIT	SV (peak/res.) (kPa)	S ala (Blows/mm) (depth)	SAMPLES	INSTRUMENTATION	R L (m)
0			Very loose, Fine to coarse SAND, minor silt; dark grey; moist, non plastic.	Springston Formation	38/19	1/50 (0m) 0/50 (0.05m) 1/50 (0.1m) 0/50 (0.15m) 1/50 (0.2m) 1/50 (0.25m) 0/50 (0.3m) 1/50 (0.35m) 0/50 (0.4m) 1/50 (0.45m) 0/50 (0.5m) 1/50 (0.55m) 2/50 (0.6m) 1/50 (0.65m) 2/50 (0.7m) 1/50 (0.75m) 2/50 (0.8m) 3/50 (0.85m)			6.5
0.5			Stiff, SILT, some sand, some clay; dark brown; moist, high plasticity.		150/29				6.0
1.0			Medium dense, SAND, minor silt; yellowish brown; moist, non plastic.		99/19 196/44 70/35				5.5
1.5			1.7m Brownish red.		99/41				5.0
2.0			1.9m Wet.		196/47	2/50 (2m) 2/50 (2.05m) 1/50 (2.1m) 2/50 (2.15m) 1/50 (2.2m) 1/50 (2.25m) 2/50 (2.3m) 1/50 (2.35m) 2/50 (2.4m) 2/50 (2.45m) 2/50 (2.5m) 2/50 (2.55m) 2/50 (2.6m) 2/50 (2.65m) 2/50 (2.7m) 1/50 (2.75m) 0/50 (2.8m) 1/50 (2.85m) 1/50 (3m) 0/50 (3.05m) 1/50 (3.1m) 0/50 (3.15m) 1/50 (3.2m) 1/50 (3.25m) 1/50 (3.3m) 1/50 (3.35m) 1/50 (3.4m) 0/50 (3.45m) 1/50 (3.5m) 0/50 (3.55m) 1/50 (3.6m) 0/50 (3.65m) 1/50 (3.7m) 0/50 (3.75m) 1/50 (3.8m) 1/50 (3.85m)			4.5
2.5									4.0
3.0	▽ 2.9m @ 15/05/2012 7:00:00 a.m.		Loose. Saturated. Bluish grey.				SDS/350/4/S1		3.5
3.5									3.0
4.0			3.8m Flooding sands. Hole caving in. END OF LOG @ 3.8 m						2.5
4.5									2.0

DATE AUGERED: 15/05/2012 DIAMETER:
LOGGED BY: S. Nathalapati METHOD: HA
SHEAR VANE No:

COMMENTS:
Water table inferred from saturated sample.

FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS SEE KEY SHEET

FINAL

A4 Scale 1:25

HAND_AUGER_UPDATED P:\320\320000\MAS TGE\MAS AGS4_PROTOTYPE.GPJ BECA.GDT 6/9/12

DEPTH 0.0m to 3.8m

Soil Borehole Log

Location: 75a St Martins Rd, St Martins, Christchurch

Reference: GA_RO_7245

North (m): 5177418
East (m): 1571775
Elevation (m): 2
Hole Depth (m): 15.95
Orientation (°): -
Inclination (°): 90

Grid: NZTM **Datum:** MSL

Formation	Graphic Log	Description	USC	Moisture Condition	Consistency / Density	Water Observations	Depth	TCR (%)	SPT N-value (Uncorrected)	Samples & In-situ Testing	Backfill & Installation
		Gravelly sand (FILL); brown. Gravel, fine to medium.	SW	D							
		Fine SAND; brown with orange mottling from 0.5 m. Loose; moist; poorly graded.	SP	M			0.50				
							1.00			SPT N = 6 Depth: 1.00m Type: Raymond Split Spoon 3, 1 / 2, 1, 2, 1 450mm penetration	
		Silty fine SAND with trace gravel; grey. Loose; moist to wet; well graded; gravel, fine.	SW	M-W	L		1.50				
							2.00			SPT N = 6 Depth: 2.00m Type: Raymond Split Spoon 1, 2 / 2, 1, 2, 3 450mm penetration	
							2.50				
							3.00				
		Sandy GRAVEL; grey. Medium dense; moist; well graded; gravel, fine to coarse, subangular to subrounded; sand, medium to coarse.					3.50			SPT N = 28 Depth: 3.50m Type: Raymond Split Spoon 4, 5 / 5, 7, 8, 8 450mm penetration	
							4.00				
							4.50				
					MD		5.00			SPT N = 27 Depth: 5.00m Type: Raymond Split Spoon 6, 7 / 7, 7, 6, 7 450mm penetration	
							5.50				
							6.00				
							6.50			SPT N = 39 Depth: 6.50m Type: Raymond Split Spoon 6, 7 / 9, 9, 10, 11 450mm penetration	
		Dense below 6.5 m.	GW	M			7.00				
							7.50				
					D		8.00			SPT N = 47 Depth: 8.00m Type: Raymond Split Spoon 7, 9 / 11, 11, 12, 13 450mm penetration	
							8.50				
							9.00				
							9.50			SPT N = 50 Depth: 9.50m Type: Raymond Split Spoon 9, 14 / 17, 15, 15, 3 380mm penetration	
		Very dense below 9.5 m.			VD						

Driller	**Logger**	**Remarks**
Pro-Drill	SB	Water level was not recorded.
Drill Method / Rig		
HQ3		
Start Date	**Checked By**	
08/06/2012	MF	
End Date		
08/06/2012		

Borehole logged in accordance with NZGS guideline "Field description of soil and rock" 2005
Vane tests completed in accordance with NZGS guideline

Hole Depth 15.95m

Soil Borehole Log

Location: 75a St Martins Rd, St Martins, Christchurch

Reference: GA_RO_7245

North (m): 5177418
East (m): 1571775
Elevation (m): 2
Hole Depth (m): 15.95
Orientation (°): -
Inclination (°): 90

Grid: NZTM **Datum:** MSL

Formation	Graphic Log	Description	USC	Moisture Condition	Consistency / Density	Water Observations	Depth	TCR (%)	SPT N-value (Uncorrected)	Samples & In-situ Testing	Backfill & Installation
		Very dense below 9.5 m.	GW	M	VD		10.50 11.00 11.50 12.00 12.50 13.00 13.50 14.00 14.50 15.00 15.50	25 50 75 100	10 20 30 40	SPT N = 50 Depth: 11.00m Type: Raymond Split Spoon 8, 10 / 15, 17, 16, 2 380mm penetration SPT N = 50 Depth: 12.50m Type: Raymond Split Spoon 10, 11 / 12, 14, 18, 6 385mm penetration SPT N = 50 Depth: 14.00m Type: Raymond Split Spoon 7, 9 / 12, 13, 19, 6 380mm penetration SPT N = 50 Depth: 15.50m Type: Raymond Split Spoon 10, 12 / 15, 16, 19, 0 375mm penetration	

EOH: 15.95 m

Driller Pro-Drill	**Logger** SB	**Remarks** Water level was not recorded.
Drill Method / Rig HQ3		
Start Date 08/06/2012	**Checked By** MF	**Hole Depth** 15.95m
End Date 08/06/2012		Page 2 of 2

Borehole logged in accordance with NZGS guideline "Field description of soil and rock" 2005
Vane tests completed in accordance with NZGS guideline

METHOD OF SOIL DESCRIPTION USED IN BOREHOLE AND TEST PIT REPORTS

 FILL

 GRAVEL (GP or GW)

 SAND (SP or SW)

 SILT (ML or MH)

 CLAY (CL, CI or CH)

 ORGANIC SOILS (OL or OH or Pt)

 COBBLES or BOULDERS

CLASSIFICATION AND INFERRED STRATIGRAPHY

Soil and Rock is classified and described in Reports of Boreholes and Test Pits using the descriptions given in NZGS 2005 Field Description of Soil and Rock. The material properties are assessed by visual/tactile methods.

PARTICLE SIZE – NZGS 2005

Major Division	Sub Division	Particle Size
BOULDERS		>200 mm
COBBLES		60 to 200 mm
GRAVEL	Coarse	20 to 60 mm
	Medium	6.0 to 20 mm
	Fine	2.0 to 6.0 mm
SAND	Coarse	0.6 to 2.0 mm
	Medium	0.2 to 0.6 mm
	Fine	0.06 to 0.2 mm
SILT		0.002 to 0.006 mm
CLAY		< 0.002 mm

MOISTURE CONDITION – NZGS 2005

Symbol	Term	Description
D	Dry	Sands and gravels are free flowing. Clays and silts may be brittle or friable and powdery.
M	Moist	Soils are darker than in the dry condition and may feel cool. Sands and gravels tend to cohere.
W	Wet	Soils exude free water. Sands and gravels tend to cohere.
S	Saturated	Feels cool, darkened in colour and free water is present on the sample.

CONSISTENCY AND DENSITY – NZGS 2005

Symbol	Term	Undrained Shear Strength
VS	Very Soft	< 12 kPa
S	Soft	12 to 25 kPa
F	Firm	25 to 50 kPa
St	Stiff	50 to 100 kPa
Vst	Very Stiff	100 to 200 kPa
H	Hard	> 200 kPa

Symbol	Term	Density Index %	SPT "N" Value (blows/300 mm)	Dynamic Cone (blows/300 mm)
VL	Very Loose	< 15	< 4	< 2
L	Loose	15 to 35	4 to 10	1 to 3
MD	Medium Dense	35 to 65	10 to 30	3 to 7
D	Dense	65 to 85	30 to 50	7 to 17
VD	Very Dense	> 85	> 50	> 17

In the absence of test results, consistency and density may be assessed from correlations with the observed behaviour of the material.
SPT “N-Values” are uncorrected.
No correlation is implied between Standard Penetration Test (SPT) and Dynamic Cone Penetrometer Test values.

EXPLANATION OF METHOD OF SOIL DESCRIPTION USED IN BOREHOLE AND TEST PIT REPORTS

DRILLING/EXCAVATION METHOD

AS*	Auger Screwing	RD	Rotary Blade or Drag Bit	NQ	Diamond Core – 47 mm
AD*	Auger Drilling	RT	Rotary Tricone bit	NMLC	Diamond Core – 52 mm
*V	V-Bit	RAB	Rotary Air Blast	HQ	Diamond Core – 63 mm
*T	TC-Bit, e.g. ADT	RC	Reverse Circulation	HMLC	Diamond Core – 63 mm
HA	Hand Auger	PT	Push Tube	BH	Tractor Mounted Backhoe
ADH	Hollow Auger	CT	Cable Tool Rig	EX	Tracked Hydraulic Excavator
DTC	Diatube Coring	NDD	Non-Destructive Digging	EE	Existing Excavation
WB	Washbore or Bailer	SON	Sonic Drilling	HAND	Excavated by Hand Methods

WATER

▼ Water level at date shown

GROUNDWATER NOT OBSERVED	The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit
GROUNDWATER NOT ENCOUNTERED	The borehole/test pit was dry soon after excavation. However, groundwater could be present in less permeable strata. Inflow may have been observed had the borehole/test pit been left open for a longer period.

SAMPLING AND TESTING

SPT	Standard Penetration Test to NZS4402 Test 6.5.1:1998
2,3 / 3,4,4,4	2,3 / 3,4,4,4 = Blows per 75 mm.
N = 15	N = Blows per 300 mm penetration following 150 mm seating
30/60 mm	Where practical refusal occurs, the blows and penetration for that interval are reported
RW	Penetration occurred under rod weight only
HW	Penetration occurred under the hammer and rod weight only
HB	Hammer double bouncing on anvil
DS	Disturbed sample
BDS	Bulk disturbed sample
G	Gas sample
W	Water sample
FP	Field permeability test over section noted
FV	Field vane shear test expressed as uncorrected shear strength s_v = peak value, s_r = residual value
PID	Photoionisation Detector reading in ppm
PM	Pressuremeter test over section noted
PP	Pocket penetrometer test expressed as instrument reading in kPa
U50	Thin walled tube sample – number indicates nominal sample diameter in milimetres
WPT	Water pressure tests
DCP	Dynamic cone penetration test
CPT	Static cone penetration test
CPTu	Static cone penetration test with pore pressure (u) measurement

SAMPLING AND TESTING

TCR Total Core Recovery (%)

$$\frac{\text{Length of core recovered}}{\text{Length of core run}} \times 100$$

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: BH-05
Hole Location:
STM-POD05-BH-05
(73 Saint Martins Road)
SHEET 1 OF 2

PROJECT: CHCH TC3 GEOTECHNICAL INVESTIGATIONS | LOCATION: ST MARTINS | JOB No: 52003.000

CO-ORDINATES 5738999.57 mN 2481762.5 mE
R.L. 6.19 m
DATUM NZMG, MSL (CCC 20/01/12 Datum -9.043m)

DRILL TYPE: Roto-Sonic
DRILL METHOD: PQDT/Auto SPT
DRILL FLUID: LP2000

HOLE STARTED: 10/9/12
HOLE FINISHED: 11/9/12
DRILLED BY: Pro-Drill
LOGGED BY: MOSS-NDP CHECKED: BMcD

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	DEPTH (m)	TESTS	CORE RECOVERY (%)	METHOD	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STREN TH/DENSITY CLASSIFICATION	ENGINEERING DESCRIPTION
TOPSOIL	0				ML	M		SILT with minor rootlets and trace sand, dark brown, moist, low plasticity. Sand i fine to medium.
YALDHURST MEMBER OF THE SPRINGSTON FORMATION (ALLUVIAL)	1	*FC1.5 1/0//1/1/1/1 N=4	66	PQDT				Sandy SILT, brownish orange, moist, low plasticity. Sand is fine to medium. 1.0 to 1.5m- no recovery.
	1		100	SPT			F	1.5m- firm.
	2				SP		L	Silty fine to medium SAND, brownish grey, loose, moist, poorly graded, quick dilatancy.
	2		100	PQDT				
	3	*FC3.0 2/2//3/3/4/4 N=14	100	SPT			MD	3.0m- medium dense.
	3				GW	W		Sandy fine to coarse GRAVEL with trace silt, grey, subrounded to rounded, medium dense, wet, well graded. Sand is fine to coarse.
	4		57	PQDT				4.05 to 4.5m- no recovery.
	4	4/5//4/4/3/3 N=14	100	SPT				
	5		76	PQDT				
	5		100	SPT				5.75 to 6.0m- no recovery.
	6	3/3//3/2/3/5 N=13	100	PQDT				
	6							
	7							
	7	5/4//3/3/3/4 N=13	100	SPT				
	8		57	PQDT				8.55 to 9.0m- no recovery.
	8							
	9	*FC9.0 1/0//0/0/0/1 N=1	100	SPT	SP		VL	Fine to medium SAND with trace silt, brown, very loose, wet, poorly graded.
CHRISTCHURCH FORMATION (MARINE/ ESTUARINE)	9		100	PQDT				
	10							

SOIL DESCRIPTION
Soil type, minor components, plasticity or particle size, colour.

ROCK DESCRIPTION
Substance: Rock type, particle size, colour, minor components.
Defects: Type, inclination, thickness, roughness, filling.

T+T DATATEMPLATE-SPT.GDT rcb

Log Scale 1:50

BORELOG-TC3 720016 STM-POD05.GPJ 7-Jan-2013

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: BH-05
Hole Location:
STM-POD05-BH-05
(73 Saint Martins Road)
SHEET 2 OF 2

PROJECT: CHCH TC3 GEOTECHNICAL INVESTIGATIONS | LOCATION: ST MARTINS | JOB No: 52003.000

CO-ORDINATES 5738999.57 mN 2481762.5 mE
R.L. 6.19 m
DATUM NZMG, MSL (CCC 20/01/12 Datum -9.043m)

DRILL TYPE: Roto-Sonic
DRILL METHOD: PQDT/Auto SPT
DRILL FLUID: LP2000

HOLE STARTED: 10/9/12
HOLE FINISHED: 11/9/12
DRILLED BY: Pro-Drill
LOGGED BY: MOSS-NDP CHECKED: BMcD

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	DEPTH (m)	R.L. (m)	SAMPLES	TESTS	CASIN	METHOD	CORE RECOVERY (%)	WATER	FLUID LOSS	RAPHIC LO	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERIN	STREN TH/DENSITY CLASSIFICATION	SHEAR STREN TH (kPa)	COMPRESSIVE STREN TH (MPa)	DEFECT SPACIN (mm)	SOIL DESCRIPTION / ROCK DESCRIPTION
CHRISTCHURCH FORMATION (MARINE/ ESTUARINE)	10	-4				PQDT	100				SP	W	VL				Fine to medium SAND with trace silt, brownish grey, very loose, wet, poorly graded.
				3/5//5/7/8/7 N=27		SPT	100						MD				10.5m- trace fine gravel, rounded, medium dense.
	11	-5				PQDT	100										11.0m- minor fine to medium gravel, rounded.
				*FC12.0 3/2//2/2/3/5 N=12		SPT	100										12.0m- some silt.
	12	-6	B														
						PQDT	100										12.45m- gravel absent.
	13	-7															
				4/4//5/7/4/4 N=20		SPT	11										13.3 to 13.5m- fibrous wood fragments. 13.55 to 13.95m- no recovery.
	14	-8				PQDT	100										
				*FC15.0 1/2//2/3/3/5 N=13		SPT	100										
	15	-9	B														
						PQDT	100										
	16	-10															
				1/1//2/2/3/4 N=11		SPT	0										16.5 to 16.95m- no recovery.
	17	-11				PQDT	100										
				1/2//2/3/3/4 N=12		SPT	100										
	18	-12									GP						Sandy fine to medium GRAVEL with some silt, brownish grey, medium dense, wet, poorly graded. Sand is fine to coarse.
						PQDT	100										
	19	-13															
				2/4//6/7/7/6 N=26		SPT	100										End of borehole at 19.95mbgl (target depth)
	20																

SOIL DESCRIPTION
Soil type, minor components, plasticity or particle size, colour.

ROCK DESCRIPTION
Substance: Rock type, particle size, colour, minor components.
Defects: Type, inclination, thickness, roughness, filling.

T+T DATATEMPLATE-SPT.GDT rcb

Log Scale 1:50

BORELOG-TC3 720016 STM-POD05.GPJ 7-Jan-2013

Bore Log

McMILLAN Drilling GROUP

Client: MWH Recovery

Project: 11 Wades Avenue, Christchurch

Bore No.: BH001

Job No.: 12188

Site Location: 11 Wades Avenue, Christchurch
Grid Reference: 1572061.04mE, 5177273.68mN (NZTM)
Rig Operator: C. Nee
Rig Model & Mounting: VTR 9750 - Track

Date Commenced: 29/05/2013
Date Completed: 30/05/2013
Consent: -
Datum: 0m

Description	Method	Drivability (1 2 3 4)	Recovery (25 50 75)	Depth	Graphic Log	SPT N-value (Uncorrected) (10 20 30 40 50)	SPT Data (Uncorrected)	Samples	Installation & Resources
CONCRETE	Dual tube		60%	0.5					0.1m nt (0.2
TOPSOIL				1.0					
Sandy SILT				1.5			N = 2 (S) 1.42m 0, 1 / 0, 1, 0, 1 450mm	1.42 - 1.73m, SPTLS, 1	
Fine grey SAND				2.0					
-1.42m; trace peat			35%	2.5					Bentonite (0.5 bags)
-2.50m - 3.02m; grey silt lens				3.0			N = 4 (S) 2.92m 0, 0 / 0, 1, 1, 2 450mm	2.92 - 3.30m, SPTLS, 2	2.8m
			50%	3.5					
Sandy GRAVEL				4.0					
				4.5			N = 33 (C) 4.42m 7, 10 / 9, 8, 8, 8 450mm		
			75%	5.0					
Fine to medium brown SAND				5.5					
				6.0			N = 9 (S) 5.92m 1, 1 / 1, 2, 3, 3 450mm	5.92 - 6.32m, SPTLS, 3	
			65%	6.5					
Gravelly SAND; trace peat				7.0					
Sandy GRAVEL				7.5			N = 22 (S) 7.47m 2, 4 / 5, 5, 6, 6 450mm	7.47 - 7.83m, SPTLS, 4	
			65%	8.0					
-8.65m; peat lens				8.5					
Fine SAND; minor silt, trace rootlets				9.0			N = 5 (C) 9.02m 2, 1 / 0, 0, 1, 4 450mm		
Grey SILT			95%	9.5					
				10.0					
			95%	10.5			N = 0 (S) 10.52m 0, 0 / 0, 0, 0, 0 450mm	10.52 - 10.88m, SPTLS, 5	
				11.0					Surrounding ground collapse

Remarks

Geotechnical Investigation Borehole BH001 with SPT Testing

Static Water Levels:
-0.61m @ Casing depth of 12.00m
1500 Litres Water Added
Safety Auto Trip Hammer #396 used (energy ratio 80.8%)

Drivability

1 Easy Push - No Hammer \ Fast Penetration
2 Relatively Easy Push - Light Hammer \ Relatively Fast
3 Medium Push - Consistent Hammer \ Medium
4 Hard Push - Full Hammer \ Somewhat Slow
5 Very Hard Push - Full Hammer \ Very Slow

Additional Resources:

Plastic Liner	**m**	19.5
Flush Mounted Toby Box		
- Standard	**ea**	
- Environmental	**ea**	
Above Ground Protective Surround	**ea**	
Geotextile Sock	**m**	**0.0**
Hand Clear Location	**ea**	
Decontaminate Equipment	**ea**	

120 High Street, Southbridge 7602, Canterbury, New Zealand ph: (03) 324 2571 fax: (03) 324 2431 web: www.drilling.co.nz

Hole Depth: 20.22m

Generated by GEROC Core-GS

Created: 4/06/2013 9:38:05 a.m.

Bore Log

McMILLAN Drilling GROUP

Client: MWH Recovery

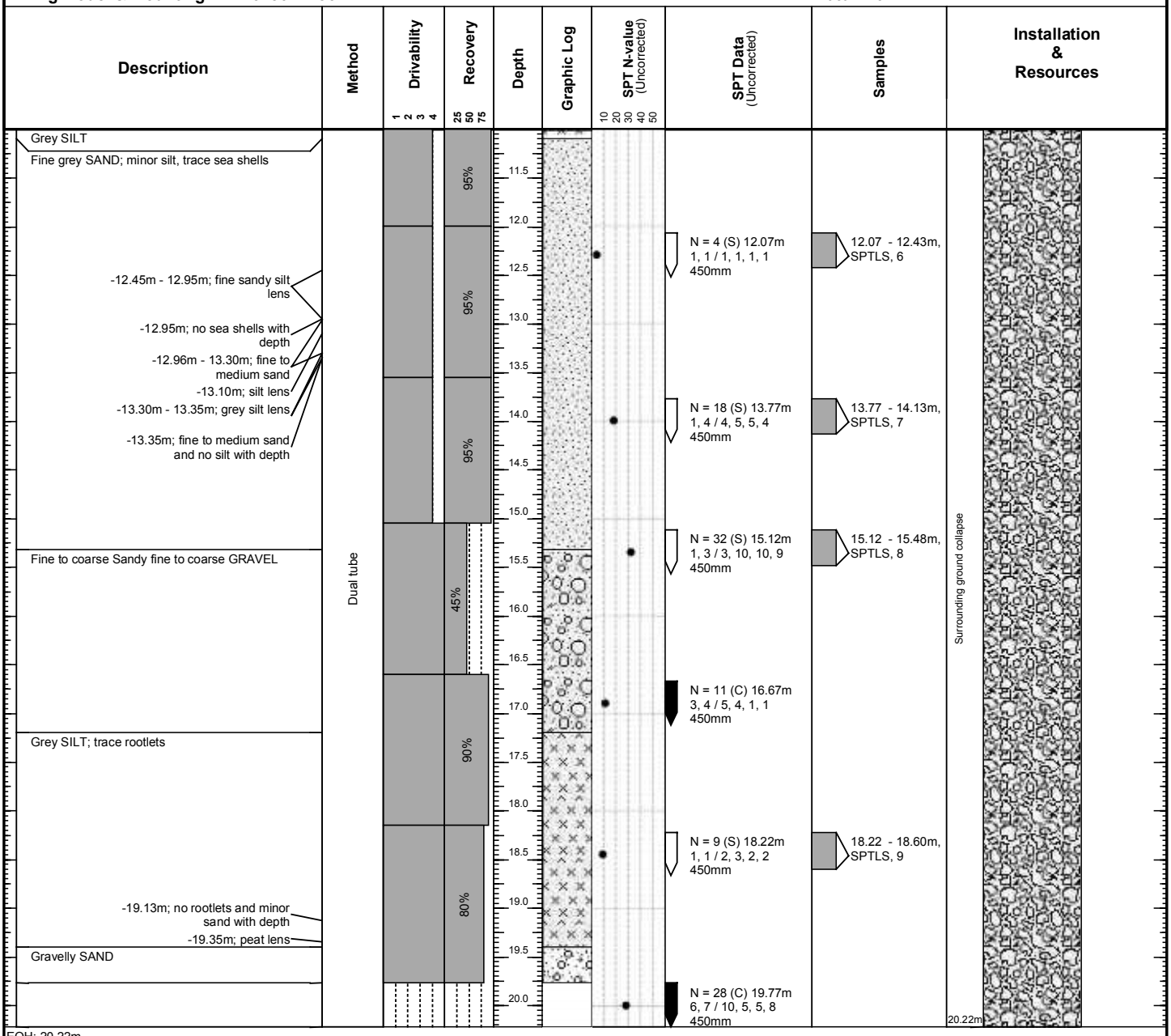
Project: 11 Wades Avenue, Christchurch

Bore No.: BH001

Job No.: 12188

Site Location: 11 Wades Avenue, Christchurch
Grid Reference: 1572061.04mE, 5177273.68mN (NZTM)
Rig Operator: C. Nee
Rig Model & Mounting: VTR 9750 - Track

Date Commenced: 29/05/2013
Date Completed: 30/05/2013
Consent: -
Datum: 0m



EOH: 20.22m

Remarks

Geotechnical Investigation Borehole BH001 with SPT Testing

Static Water Levels:
-0.61m @ Casing depth of 12.00m
1500 Litres Water Added
Safety Auto Trip Hammer #396 used (energy ratio 80.8%)

Drivability

1 Easy Push - No Hammer \ Fast Penetration
2 Relatively Easy Push - Light Hammer \ Relatively Fast
3 Medium Push - Consistent Hammer \ Medium
4 Hard Push - Full Hammer \ Somewhat Slow
5 Very Hard Push - Full Hammer \ Very Slow

Additional Resources:

Plastic Liner	**m**	19.5
Flush Mounted Toby Box		
- Standard	**ea**	
- Environmental	**ea**	
Above Ground Protective Surround	**ea**	
Geotextile Sock	**m**	**0.0**
Hand Clear Location	**ea**	
Decontaminate Equipment	**ea**	

120 High Street, Southbridge 7602, Canterbury, New Zealand ph: (03) 324 2571 fax: (03) 324 2431 web: www.drilling.co.nz

Hole Depth: 20.22m

Generated by GEROC Core-GS

Created: 4/06/2013 9:38:06 a.m.

TONKIN & TAYLOR LTD

BOREHOLE LOG

BH No: STM-POD04-BHCPT013
Hole Location: 1/26 Wades Avenue

PROJECT: CHCH TC3 GEOTECHNICAL INVESTIGATIONS | LOCATION: SAINT MARTINS | JOB No: 52003.000

CO-ORDINATES: 5738889.32 mN, 2482152.41 mE
R.L.: 5.16 m
DATUM: NZMG, MSL (CCC 20/01/12 Datum -9.043m)

DRILL TYPE: Roto-Sonic
DRILL METHOD: PQDT/Auto SPT
DRILL FLUID: LP2000

HOLE STARTED: 16/1/13
HOLE FINISHED: 16/1/13
DRILLED BY: Pro-Drill
LOGGED BY: T&T-JG CHECKED: DAA

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	TESTS	DEPTH (m)	R.L. (m)	CLASSIFICATION SYMBOL	STRENGTH/DENSITY CLASSIFICATION	ENGINEERING DESCRIPTION
ASHPHALT		0	5	GW		ASPHALT.
FILL						Sandy fine to coarse GRAVEL with trace silt, brown, angular to subrounded, moist, well graded. Sand is fine to coarse. 0.3m- subangular to subrounded gravel.
YALDHURST MEMBER OF THE SPRINGSTON FORMATION (ALLUVIAL)	*FC@1.5m 3/3//2/4/4/5 N=15	1	4	SP		Fine to medium SAND with minor silt, grey, moist, poorly graded.
		2	3		MD	1.5m- medium dense, wet.
		3	2	GW		Sandy fine to coarse GRAVEL with trace silt, grey, subangular to subrounded, medium dense, wet, well graded. Sand is fine to coarse.
	1/2/2/2/2/2// 1/2/2/1/1/2/ 2/1/2/2/2/2 N=20	4	1	SP		Fine to medium SAND with minor silt, grey, medium dense, wet, poorly graded.
		5	0	GW		Sandy fine to coarse GRAVEL with trace silt, grey, subangular to subrounded, medium dense, wet, well graded. Sand is fine to coarse.
	1/1/2/2/2/2// 2/2/2/2/2/2/ 2/1/2/2/1/2/ N=22	6	-1			5.8m- minor silt. 6.0 to 6.45m- sample obtained from overcore.
	1/1/1/2/3/2// 3/2/2/2/3/3/ 2/2/2/2/2/2 SOLID N=27	7	-2			
	1/1/1/1/1/2// 1/2/1/2/2/3/ 4/4/4/4/4/4 SOLID N=35	8	-3		D	7.5 to 7.95m- sample obtained from overcore. 7.5m- dense.
CHRISTCHURCH FORMATION (MARINE/ ESTUARINE)	*ATP@9.0m *FC@9.0m 0/2//0/0/0/0 N=0	9	-4	ML	H VS	8.8m- trace amorphous organics. SILT with some sand and trace broken shells, grey, hard, wet, low plasticity. Sand is fine to medium. 9.0m- very soft. 9.1m- trace fine to medium sand.
		10				

T+T DATATEMPLATE-SPT.GDT rcb

TONKIN & TAYLOR LTD

BOREHOLE LOG

BH No: STM-POD04-BHCPT013
Hole Location: 1/26 Wades Avenue

PROJECT: CHCH TC3 GEOTECHNICAL INVESTIGATIONS | LOCATION: SAINT MARTINS | JOB No: 52003.000

CO-ORDINATES: 5738889.32 mN, 2482152.41 mE
R.L.: 5.16 m
DATUM: NZMG, MSL (CCC 20/01/12 Datum -9.043m)

DRILL TYPE: Roto-Sonic
DRILL METHOD: PQDT/Auto SPT
DRILL FLUID: LP2000

HOLE STARTED: 16/1/13
HOLE FINISHED: 16/1/13
DRILLED BY: Pro-Drill
LOGGED BY: T&T-JG CHECKED: DAA

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	CLASSIFICATION SYMBOL	MOIST CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION / ROCK DESCRIPTION
CHRISTCHURCH FORMATION (MARINE/ ESTUARINE)	1/4//3/4/3/4 N=14		-5	11	ML	W	VS	SILT with trace broken shells and trace sand, grey, very soft, wet, low plasticity. Sand is fine to medium.
			-6		SM		VL	Silty fine to medium SAND with trace broken shells, grey, very loose, wet, poorly graded.
							MD	10.5m- medium dense.
					ML		St	SILT with some sand, grey, stiff, wet, low plasticity.
	*FC@12.0m 2/2//4/3/3/3 N=13	B	-7	12				Sandy SILT with trace broken shells, grey, stiff, wet, low plasticity. Sand is fine to medium.
			-8	13	SW		MD	Fine to coarse SAND with some silt, grey medium dense, wet, well graded.
	2/4//4/5/10/12 N=31		-9	14			D	13.5m- dense.
RICCARTON GRAVEL	7/9//10/8/6/5 N=29		-10	15	GP		MD	Sandy fine to coarse GRAVEL with trace silt, greyish brown, subrounded, medium dense, wet, poorly graded. Sand is fine to medium. 15.15 to 15.45m- no recovery.
	3/2/5/4/3/4// 4/3/3/3/3/3/ 3/4/4/4/3/4 SOLID N=41		-11	16			D	16.5m- dense. 16.5 to 16.95m- sample obtained from overcore. 16.7m- grey.
			-12	17	ML		H	SILT with trace sand, grey, hard, wet, low plasticity. Sand is fine to medium.
	4/5//4/6/6/6 N=22		-13	18	SM		MD	Silty fine to medium SAND, grey, medium dense, wet, poorly graded. 18.25 to 18.345m- no recovery.
			-14	19				
	9/8//8/8/8/8 N=32			20	GW		D	Sandy fine to coarse GRAVEL with trace silt, greyish brown, subangular to subrounded, medium dense, wet, well graded. Sand is fine to coarse.

CORE RECOVERY (%)	METHOD	CASING
100	PQDT	
100	SPT	
100	PQDT	
100	SPT	
100	PQDT	
100	SPT	
33	SPT	
100	PQDT	
100	SPT	
56	SPT	
100	PQDT	
22	SPT	

FL ID LOSS | WATER | GRAPHIC LOG | WEATHERING | SHEAR STRENGTH (kPa) | COMPRESSIVE STRENGTH (MPa) | DEFECT SPACING (mm)

Soil type, minor components, plasticity or particle size, colour.

Substance: Rock type, particle size, colour, minor components.

Defects: Type, inclination, thickness, roughness, filling.

TONKIN & TAYLOR LTD

BOREHOLE LOG

BH No: STM-POD04-BHCPT013
Hole Location: 1/26 Wades Avenue

PROJECT: CHCH TC3 GEOTECHNICAL INVESTIGATIONS		LOCATION: SAINT MARTINS	JOB No: 52003.000
CO-ORDINATES:	5738889.32 mN 2482152.41 mE	DRILL TYPE: Roto-Sonic	HOLE STARTED: 16/1/13 HOLE FINISHED: 16/1/13
R.L.:	5.16 m	DRILL METHOD: PQDT/Auto SPT	DRILLED BY: Pro-Drill
DATUM:	NZMG, MSL (CCC 20/01/12 Datum -9.043m)	DRILL FLUID: LP2000	LOGGED BY: T&T-JG CHECKED: DAA

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FL ID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOIST RE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 200	DEFECT SPACING (mm) 60 250 600 2000	SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
								-15	21								19.5m- dense. 19.6 to 19.95m- no recovery. End of borehole at 19.95mbgl (target depth)
								-16	22								
								-17	23								
								-18	24								
								-19	25								
								-20	26								
								-21	27								
								-22	28								
								-23	29								
								-24	30								

T+T DATATEMPLATE-SPT.GDT rcb

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: STM 08
Hole Location: 17 Wades Ave

SHEET 1 OF 5

PROJECT: CHRISTCHURCH 2011 EARTHQUAKE | LOCATION: ST MARTINS | JOB No: 52000.3200

CO-ORDINATES 5738869.98 mN, 2482120.82 mE
R.L. 5.15 m
DATUM NZMG

DRILL TYPE: Rotary
DRILL METHOD: Triple Tube/Wash Drilling
DRILL FLUID: Mud

HOLE STARTED: 15/6/11
HOLE FINISHED: 16/6/11
DRILLED BY: Pro-Drill
LOGGED BY: RKH CHECKED: RAP

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	ENGINEERING DESCRIPTION
HAND DIG FILL. (Potholed for services check and backfilled.)			0	PRE-DUG				5.0	0								Fill: Borehole drilled through pre-dug and backfilled pothole.
			0	Wash Drill				4.5	0.5								1.5 to 3.0m no recovery
								4.0	1.0								
								3.5	1.5								
								3.0	2.0								
								2.5	2.5								
YALDHURST MEMBER OF THE SPRINGSTON FORMATION (ALLUVIAL)				SPT		2/3/3/ 4/4/4 N=15		2.0	3.0		SP	M	MD				Medium SAND, brownish grey. Medium dense, moist.
			71	HQTT		*FC	B	1.5	3.5								3.45m to 3.9m no recovery
								1.0	4.0								- becoming grey
								0.5	4.5								
									5								

SOIL DESCRIPTION
Soil type, minor components, plasticity or particle size, colour.

ROCK DESCRIPTION
Substance: Rock type, particle size, colour, minor components.
Defects: Type, inclination, thickness, roughness, filling.

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: STM 08
Hole Location: 17 Wades Ave

SHEET 2 OF 5

PROJECT: CHRISTCHURCH 2011 EARTHQUAKE		LOCATION: ST MARTINS	JOB No: 52000.3200
CO-ORDINATES	5738869.98 mN 2482120.82 mE	DRILL TYPE: Rotary	HOLE STARTED: 15/6/11 HOLE FINISHED: 16/6/11
R.L.	5.15 m	DRILL METHOD: Triple Tube/Wash Drilling	DRILLED BY: Pro-Drill
DATUM	NZMG	DRILL FLUID: Mud	LOGGED BY: RKH CHECKED: RAP

GEOLOGICAL									ENGINEERING DESCRIPTION								
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
YALDHURST MEMBER OF THE SPRINGSTON FORMATION (ALLUVIAL)			0	SPT		1/5/6/ 7/6/9 N=28		0.0	0		SW	M	MD				Fine to medium SAND, grey. Medium dense, moist.
			0	HQTT				-0.5	5.5								5.45m to 6.5m no recovery
								-1.0	6.0								
									6.5		GW	M	D				Fine to coarse GRAVEL with minor sand, grey. Dense, moist. Gravel is subrounded. Sand is fine to coarse.
				SPT		8/7/8/ 7/9/10 N=34		-1.5									
			19	HQTT				-2.0	7.0								6.95m to 7.8m no recovery
								-2.5	7.5								
											GW	M	D				Fine to coarse GRAVEL with some cobbles and minor sand, grey. Dense, moist, Gravel is subrounded. Sand is fine to coarse.
									8.0		GW	M	D				Sandy, fine to coarse GRAVEL, grey. Dense, moist. Gravel is subrounded. Sand is fine to coarse.
				SPT		2/5/8/ 11/13/10 N=42		-3.0									8.2m to 9.95m no recovery
			0	HQTT				-3.5	8.5								
								-4.0	9.0								- Drillers' notes indicate gravels end at 9.0m
								-4.5	9.5								
				SPT		1/1/2/ 1/2/1 N=6			10								

T+T DATATEMPLATE.GDT dlm

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: STM 08
Hole Location: 17 Wades Ave

SHEET 3 OF 5

PROJECT: CHRISTCHURCH 2011 EARTHQUAKE | LOCATION: ST MARTINS | JOB No: 52000.3200

CO-ORDINATES 5738869.98 mN, 2482120.82 mE
R.L. 5.15 m
DATUM NZMG

DRILL TYPE: Rotary
DRILL METHOD: Triple Tube/Wash Drilling
DRILL FLUID: Mud

HOLE STARTED: 15/6/11
HOLE FINISHED: 16/6/11
DRILLED BY: Pro-Drill
LOGGED BY: RKH CHECKED: RAP

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	ENGINEERING DESCRIPTION
YALDHURST MEMBER OF THE SPRINGSTON FORMATION (ALLUVIAL)			10	HQTT				-5.0	10.5		GW	M	L				Sandy, fine to coarse GRAVEL, grey. Dense, moist. Gravel is subrounded. Sand is fine to coarse. 10.5
								-5.5	11.0		SW	M	MD				Fine to medium SAND with some silt, grey. Medium dense, moist. 11.0
				SPT		1/2/3/ 3/4/6 N=16		-6.0					MD				- becoming medium dense
			100	HQTT		✱FC	B	-6.5	11.5								11.5
CHRISTCHURCH FORMATION (MARINE & ESTUARINE)						✱FC	B	-7.0	12.0		SW	M	MD				Fine to medium SAND with trace silt, grey. Medium dense, moist. 12.0
				SPT		2/2/5/ 5/6/9 N=25		-7.5	12.5								12.5
						✱FC	B	-8.0	13.0								13.0
			100	HQTT		✱FC	B	-8.5	13.5								13.5
						✱FC		-9.0	14.0		ML	W	VSt				Sandy SILT, grey. Very stiff, wet, non plastic. Sand is fine to medium. 14.0
				SPT		3/3/4/ 7/9/13 N=33		-9.5	14.5								14.5
			60	HQTT					15								14.9m to 15.5m no recovery

SOIL DESCRIPTION
Soil type, minor components, plasticity or particle size, colour.

ROCK DESCRIPTION
Substance: Rock type, particle size, colour, minor components.
Defects: Type, inclination, thickness, roughness, filling.

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: STM 08
Hole Location: 17 Wades Ave

SHEET 4 OF 5

PROJECT: CHRISTCHURCH 2011 EARTHQUAKE		LOCATION: ST MARTINS	JOB No: 52000.3200
CO-ORDINATES	5738869.98 mN 2482120.82 mE	DRILL TYPE: Rotary	HOLE STARTED: 15/6/11 HOLE FINISHED: 16/6/11
R.L.	5.15 m	DRILL METHOD: Triple Tube/Wash Drilling	DRILLED BY: Pro-Drill
DATUM	NZMG	DRILL FLUID: Mud	LOGGED BY: RKH CHECKED: RAP

GEOLOGICAL															ENGINEERING DESCRIPTION
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m) / DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	WEATHERING / MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
CHRISTCHURCH FORMATION (MARINE & ESTUARINE)			13	SPT		4/5/10/ 10/11/12 N=43		-10.0 / 15.5 / -10.5 / 16.0 / -11.0 / 16.5 / -11.5								14.9m to 15.5m no recovery 15.6m to 16.9m no recovery
RICCARTON GRAVELS			0	SPT		5/7/10/ 15/25 for 75mm N>50		17.0 / -12.0 / 17.5 / -12.5 / 18.0 / -13.0 / 18.5		GW	M	VD				Fine to coarse GRAVEL with some cobbles, grey. Very dense, moist. Gravel is subrounded. 17.0m to 18.5m no recovery
				SPT		10/15/18/ 12/15/4 for 10mm N>50		-13.5 / 19.0		GW	M	VD				Fine to coarse GRAVEL with some silt and sand, brownish grey. Very dense, moist. Gravel is subrounded. Sand is fine to coarse.
			37	HQTT				-14.0 / 19.5 / -14.5 / 20		GW	M	VD				Fine to coarse GRAVEL with some cobbles, grey. Very dense, moist. Gravel is subrounded to subangular. 19.3m to 20.45 no recovery

T+T DATATEMPLATE.GDT dlm

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: STM 08
Hole Location: 17 Wades Ave

SHEET 5 OF 5

PROJECT: CHRISTCHURCH 2011 EARTHQUAKE | LOCATION: ST MARTINS | JOB No: 52000.3200

CO-ORDINATES 5738869.98 mN
2482120.82 mE

R.L. 5.15 m

DATUM NZMG

DRILL TYPE: Rotary

DRILL METHOD: Triple Tube/Wash Drilling

DRILL FLUID: Mud

HOLE STARTED: 15/6/11
HOLE FINISHED: 16/6/11
DRILLED BY: Pro-Drill
LOGGED BY: RKH CHECKED: RAP

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	COMPRESSIVE STRENGTH (MPa) 1 5 20 60 100 250	DEFECT SPACING (mm) 60 250 600 2000	SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
RICCARTON GRAVELS				SPT		5/10/18/ 20/12 for 20mm N>50		-15.0				M	VD				19.3m to 20.45 no recovery
									20.5								**End of borehole at 20.45mbgl.** No Piezometer installed.
								-15.5									
									21.0								
								-16.0									
									21.5								
								-16.5									
									22.0								
								-17.0									
									22.5								
								-17.5									
									23.0								
								-18.0									
									23.5								
								-18.5									
									24.0								
								-19.0									
									24.5								
								-19.5									
									25								

T+T DATATEMPLATE.GDT dlm

Calibration Certificate

C10CFIIP.C10267 / 002

4-Jan-12

Geomil equipment

Cone number :	C10CFIIP.C10267	**Client :**	Perry Drilling LTD.
			37 Glenlyon Avenue
Kind of cone :	Compression		Greerton Tauranga
			New Zealand

Calibration date : 4-Jan-12

Channel 1: Cone resistance		**Channel 2:** Local sleeve friction		**Channel 3:** Pore pressure		**Channel 4:** Inclination X		**Channel 5:** Inclination Y	
Load limit :	100 kN	**Load limit :**	22.5 kN	**Load limit :**	50 bar	**Angle limit :**	± 20 °	**Angle limit :**	± 20 °
Area :	10 cm²	**Area :**	150 cm²						
Zeroshift :	191 mV	**Zeroshift :**	207 mV	**Zeroshift :**	208 mV				
Load (kN)	**Output (mV)**	**Load (kN)**	**Output (mV)**	**Load (bar)**	**Output (mV)**	**Angle (°)**	**Output (mV)**	**Angle (°)**	**Output (mV)**
0	0	0.000	0	0	0	-20	2156	-20	2155
2	167	0.450	186	5	772	-15	2236	-15	2232
5	418	1.125	468	10	1546	-10	2324	-10	2315
10	836	2.250	952	15	2321	-5	2422	-5	2411
25	2091	5.625	2391	20	3096	0	2496	0	2498
50	4183	11.250	4789	25	3870	5	2588	5	2577
75	6252	16.875	7195	30	4642	10	2676	10	2666
100	8332	22.000	9398	35	5414	15	2762	15	2752
75	6250	22.500	9616	40	6185	20	2841	20	2842
50	4176	22.000	9408	45	6955				
25	2084	16.875	7221	50	7724				
10	831	11.250	4833						
5	415	5.625	2426						
2	167	2.250	979						
0	-1	1.125	496						
		0.450	209						
		0.000	-2						
100 kN equals 100 MPa		**22.5 kN equals 1.5 MPa**		**50 bar equals 5 MPa**					
Zeroshift error :	0.01 %	Zeroshift error :	0.02 %						
Max. linearity :	0.20 %	Max. linearity :	0.26 %						
Max. hysteresis :	0.08 %	Max. hysteresis :	0.46 %						

Calibration instrument(s) :	**Certificate number(s) :**	**Date :**
C2 E26990 + CW-921007.01 Mark III	3230930	11-Mar-08

Remarks :

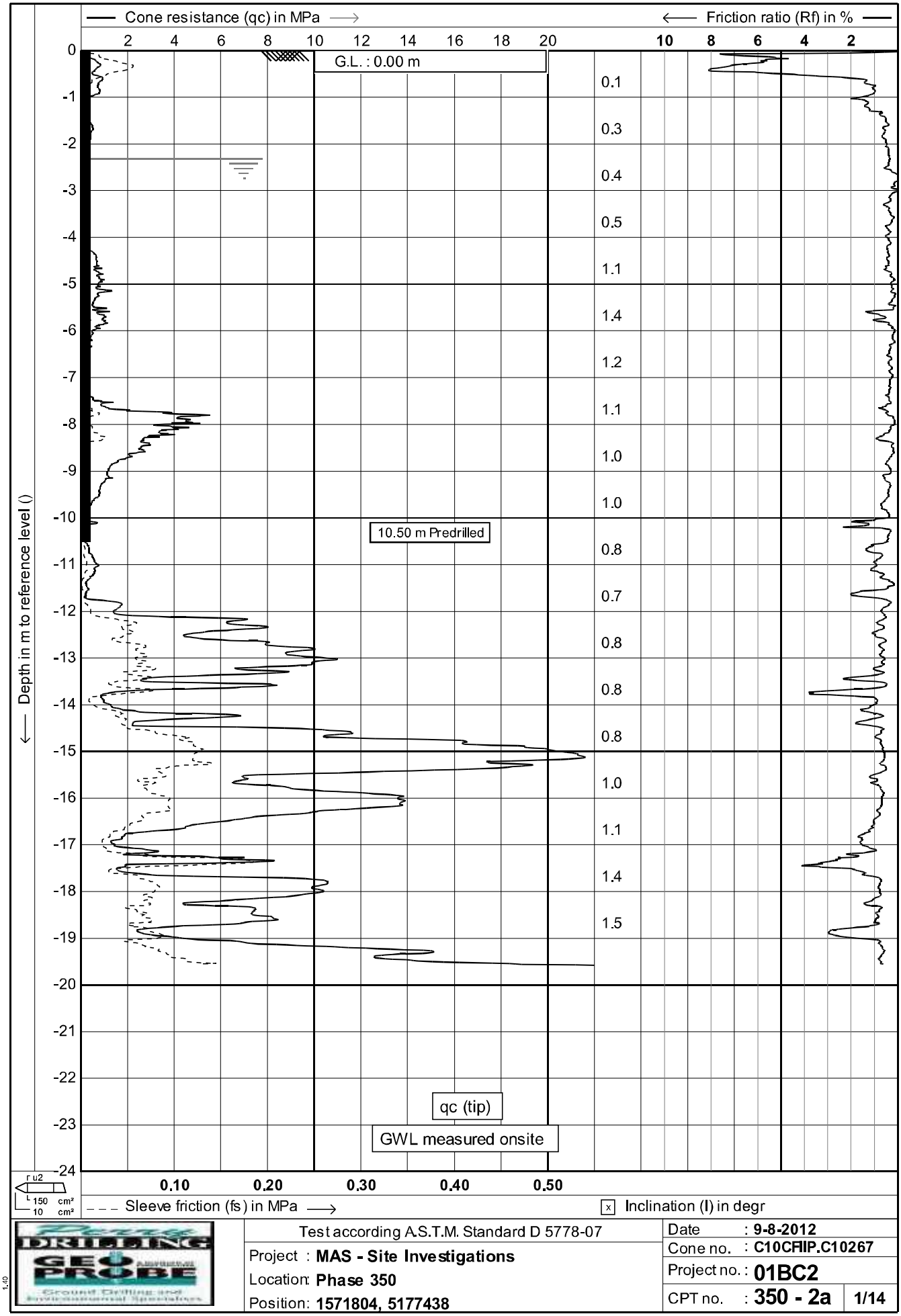
Hereby we declare that the electrical cone with serial number C10CFIIP.C10267 has been calibrated and that the specifications are according to the prEN ISO 22476-1.11, Application Class 1 and NEN 5140, Class 1.

Date :	4-Jan-12	**Date :**	4-Jan-12
Approved by technician :		**Approved by supervisor :**	
P. Treffers		**J.E. Jansen**	

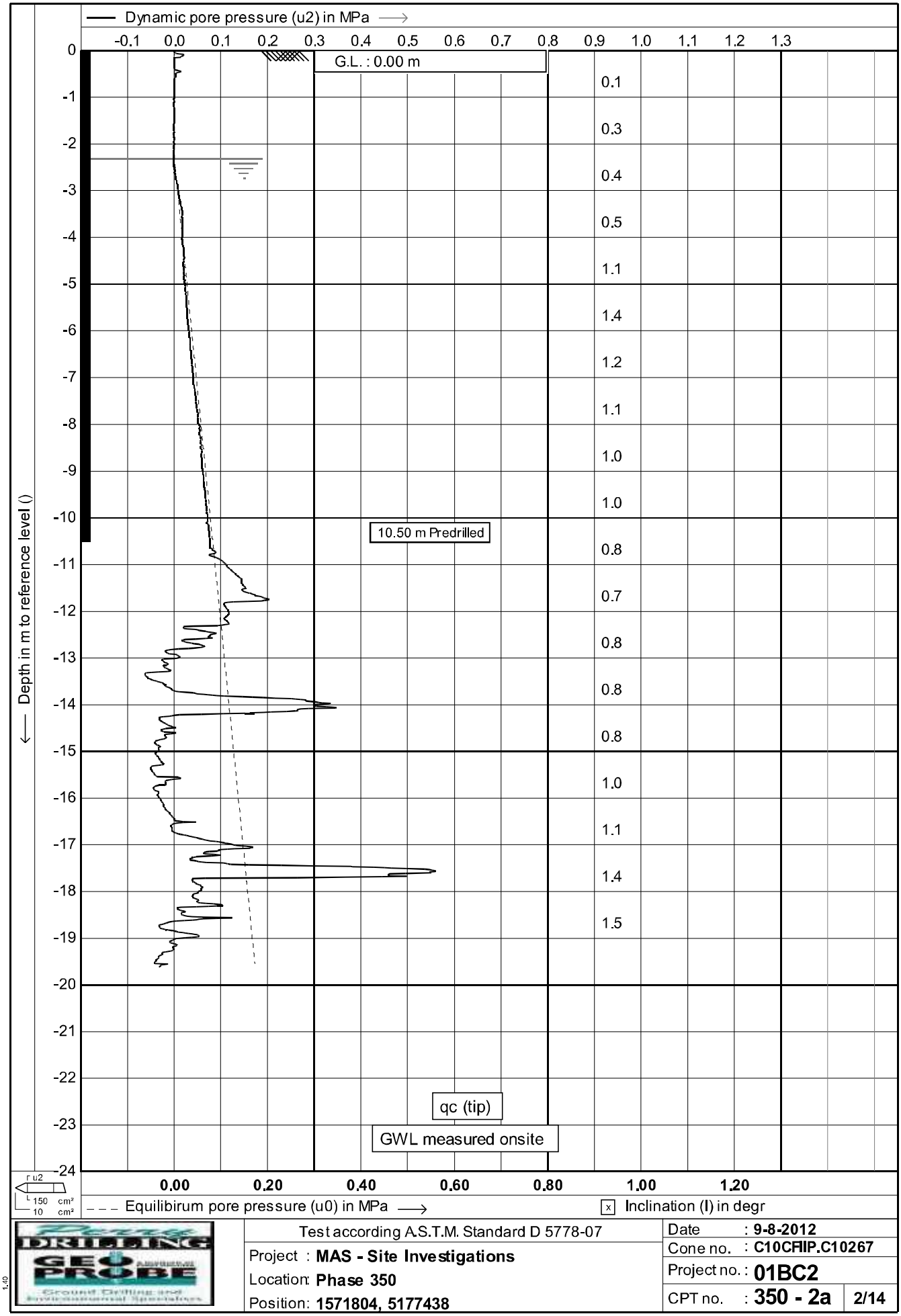
Westbaan 240 - 2841 MC Moordrecht - The Netherlands
P.O. Box 450 - 2800 AL Gouda - The Netherlands
T. +31 (0) 172 427 800 - F. +31 (0) 172 427 801
info@geomil.com - www.geomil.com

Bank Rabobank - Account no. 1350.49.229
IBAN NL78 RABO 0135 0492 29 - BIC RABONL2U
VAT no. NL812396212B01 - Chamber of Commerce no. 24353053
All business transacted is subject to METAALUNIE conditions*

**Dutch Organisation of Entrepreneurs in Small and Medium Sized Businesses in the Metalworking and Mechanical Engineering Industry*



Test according A.S.T.M. Standard D 5778-07	Date	: 9-8-2012
Project : **MAS - Site Investigations**	Cone no.	: C10CFIIP.C10267
Location: **Phase 350**	Project no.	: 01BC2
Position: **1571804, 5177438**	CPT no.	: 350 - 2a 1/14



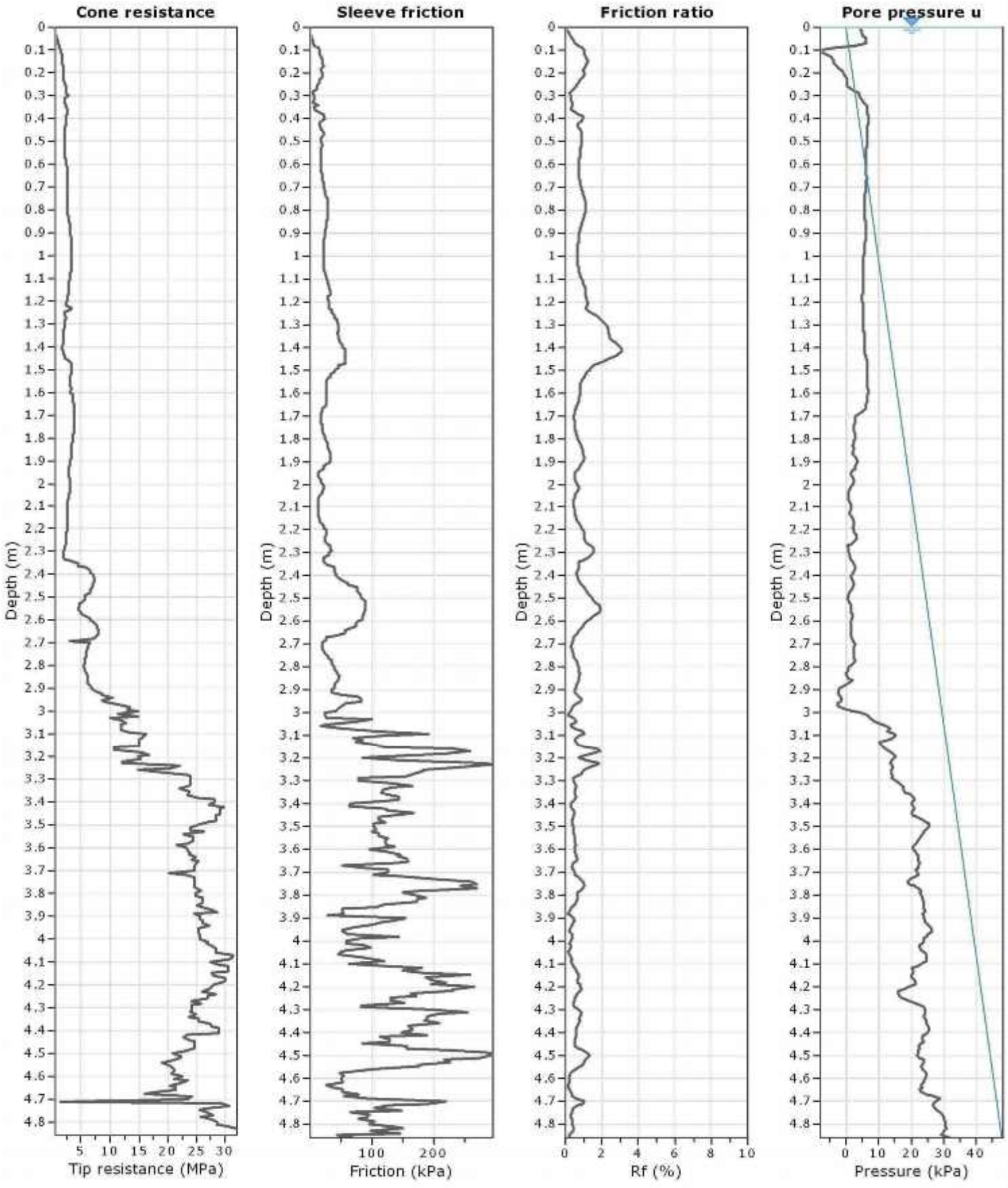
Test according A.S.T.M. Standard D 5778-07	Date	: 9-8-2012
Project : **MAS - Site Investigations**	Cone no.	: C10CFIIP.C10267
Location: **Phase 350**	Project no.	: 01BC2
Position: **1571804, 5177438**	CPT no.	: 350 - 2a 2/14

Brown Bros (NZ) Ltd.
Hamilton (07) 849 2919
Auckland (09) 298 0449
www.brownbro.co.nz

CPT: STM-POD05-CPTB005

Project: **Christchurch TC3 Geotechnical Investigations** **Water level (a) applied.** Total depth: 4.86 m, Date: 27/09/2012

Location: **73 St Martins Rd, St Martins** **Coord: 43 33.355 S 172 39.023 E** Cone Type: 10cm² Standard Piezocone, Cone ID: 4447



Disclaimers

version 1.0

1. For the raw data

The data presented on this page is factual and based on the results of CPT testing undertaken with reasonable diligence. Any interpretation of this data is the sole responsibility of the user.

2. Water levels

(a) Assumed
For those test sites where we cannot get reliable measurements, the water levels will be reported as zero value.

(b) Measured onsite
Where water level measurements are reported, the depth was determined immediately after the test with a dip device. These values should be used with caution because little time has been allowed for recharge or equalising.

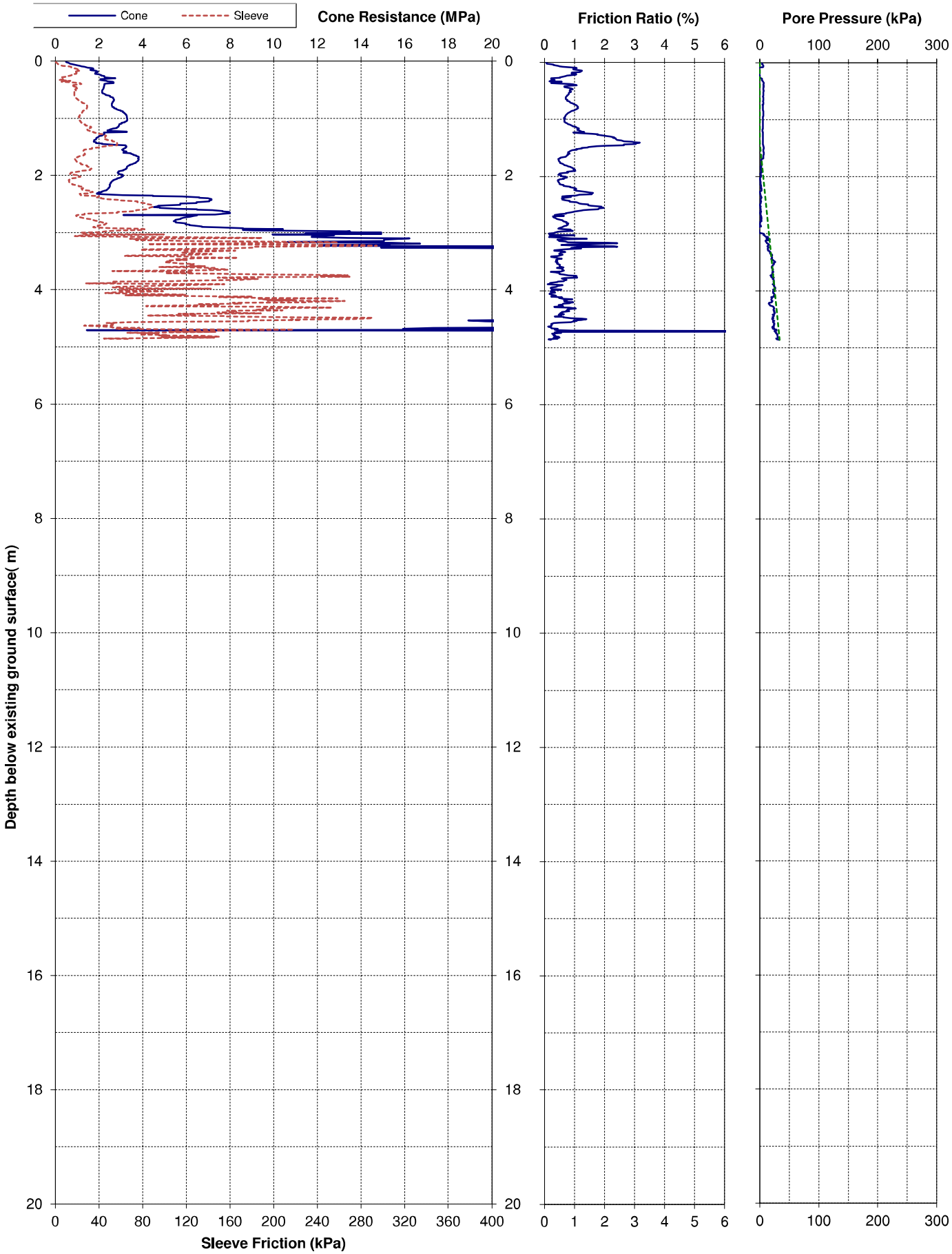
(c) Estimated based on CPT data
Where the hydrostatic line is moved to align with the CPT data.

The static pore water pressure line shown is assumed to be hydrostatic from the phreatic surface. The validity of this assumption must be checked by the user.

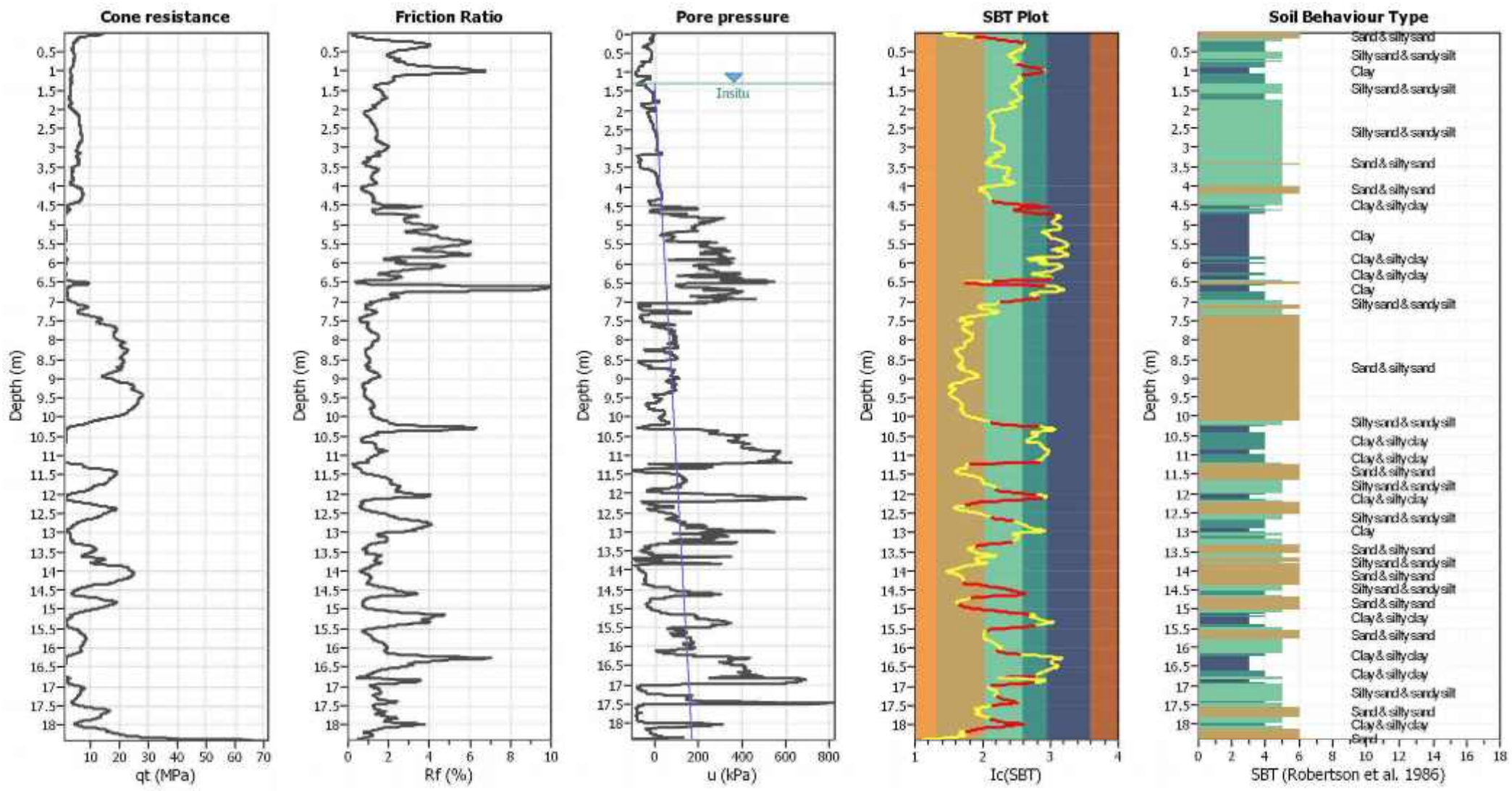
3. For the inferred CPT parameters

The data presented here is informative for the engineer and interpreted based on published methods with reasonable care using an automated process of calculation. The user of this data has the sole responsibility for drawing any interpretation or conclusions from this data, including ensuring the calculation methods adopted are applicable for these materials through which this CPT has been pushed.

Project:	Christchurch TC3 Geotechnical Investigations			Page: 1 of 1	STM-POD05-CPTB05
Test Date:	27-Sep-2012	Suburb:	St Martins Opawa	Operator:	Brown Bros
Pre-Drill:	0m	Assumed GWL:	1.4mBGL	Located By:	Survey GPS
Position:	2481764.2mE	5739000.42mN	6.21mRL	Coord. System:	NZMG
Address:	Road verge, 73 Saint Martins Rd			Datum Reference:	MSL (CCC 20/01/12 Datum -9.043)



CPT basic interpretation plots



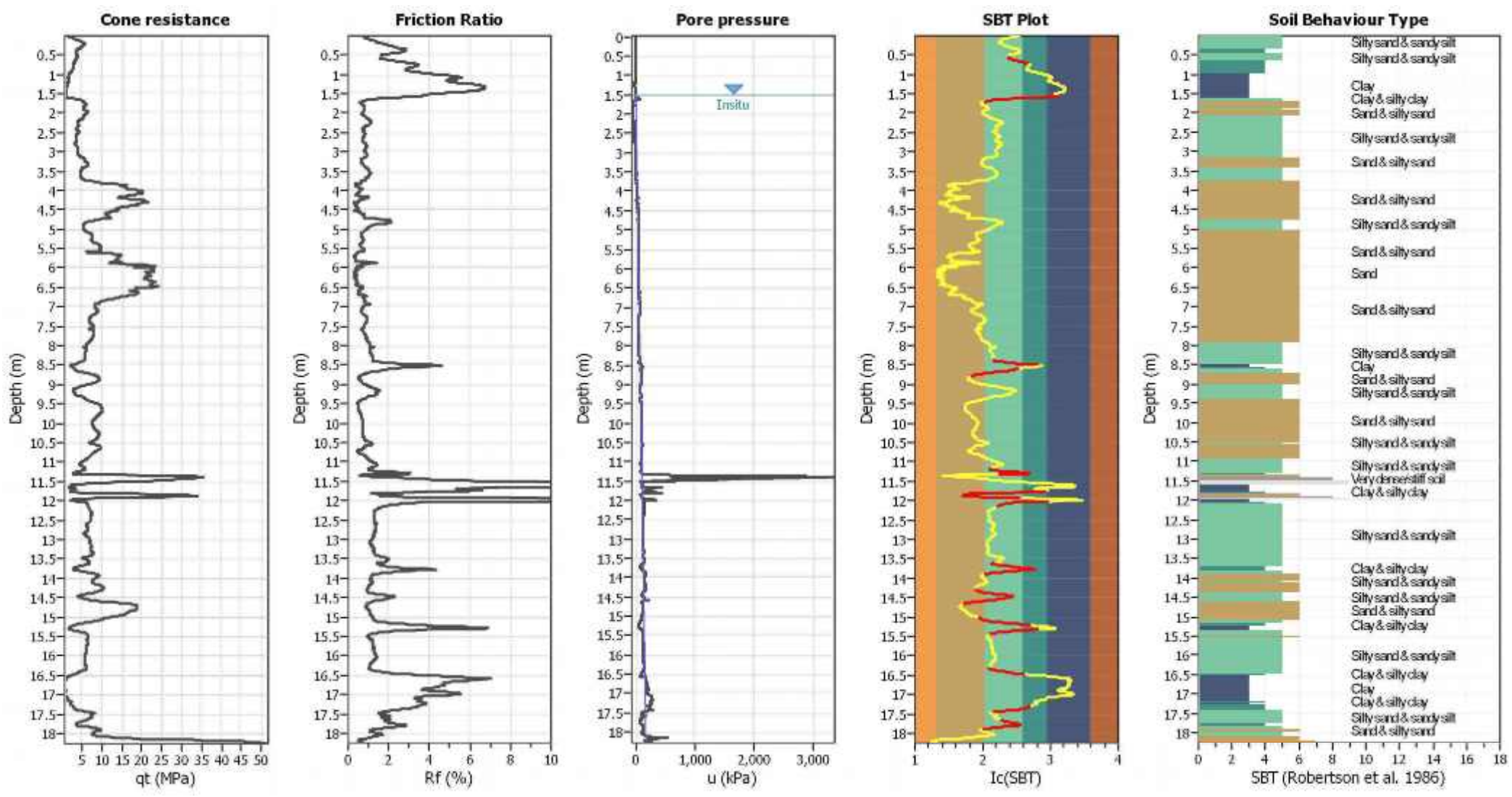
Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	2.50 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.30 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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

CPT basic interpretation plots



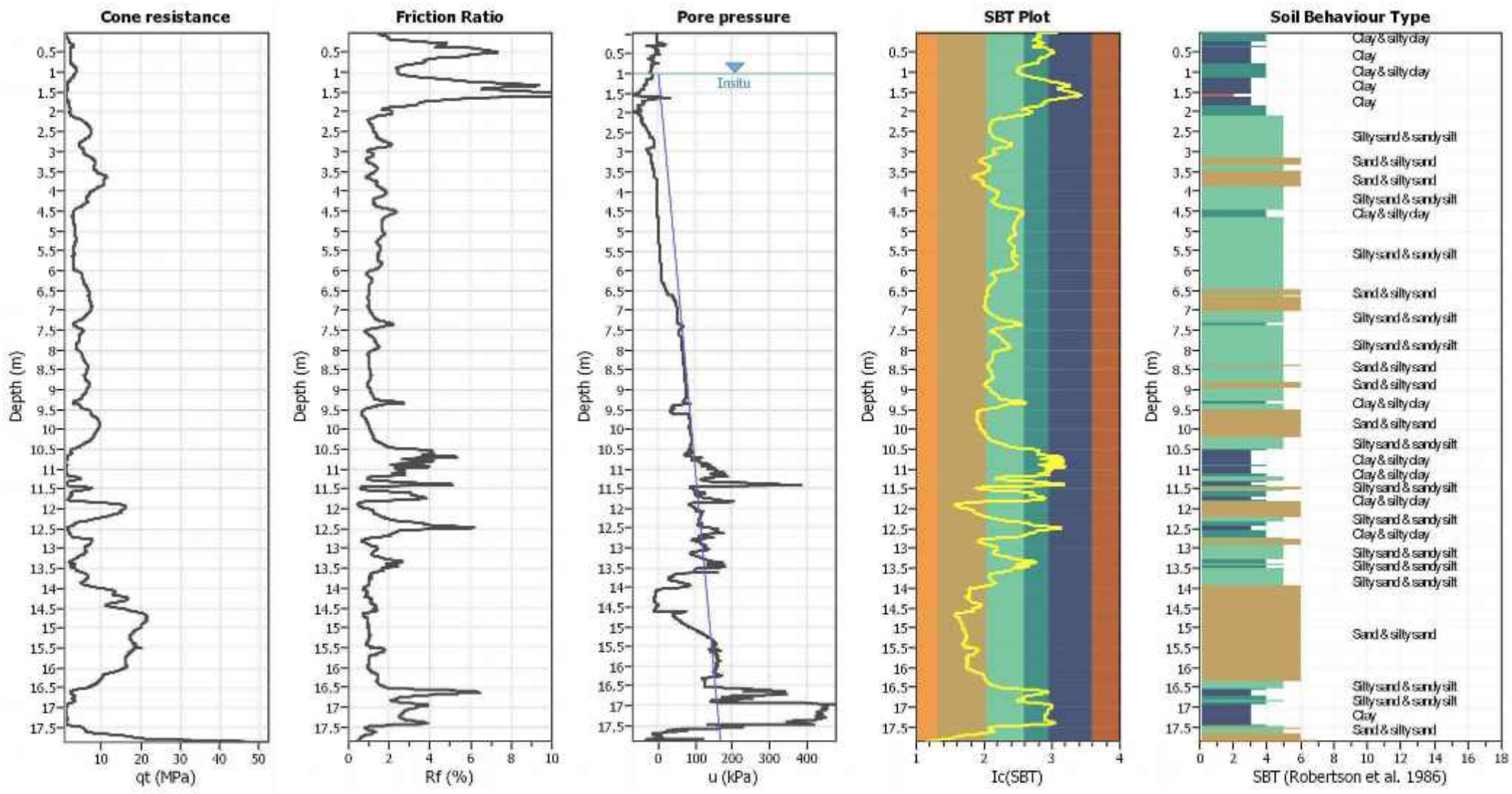
Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	2.50 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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

CPT basic interpretation plots



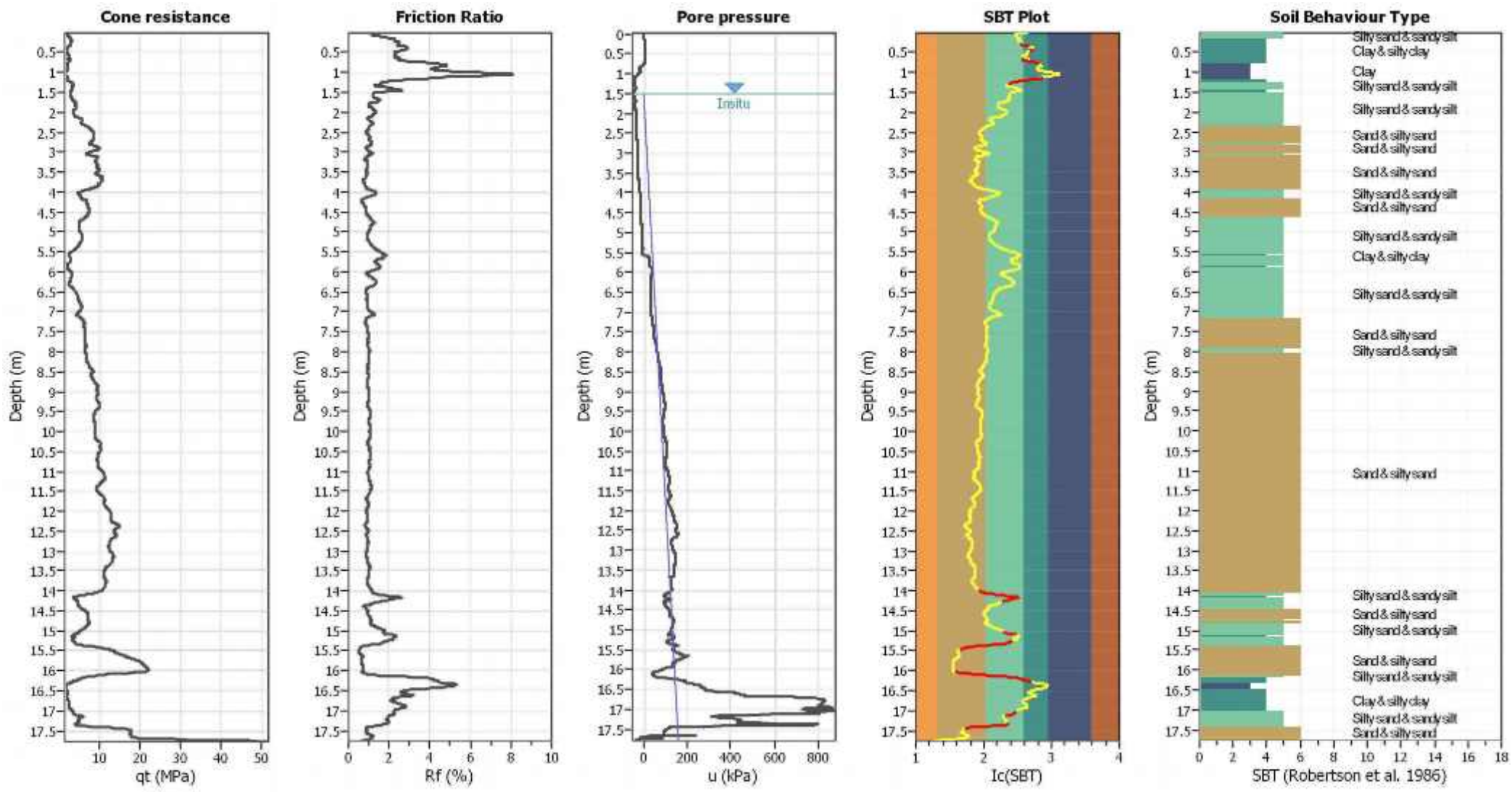
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.13	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
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

CPT basic interpretation plots



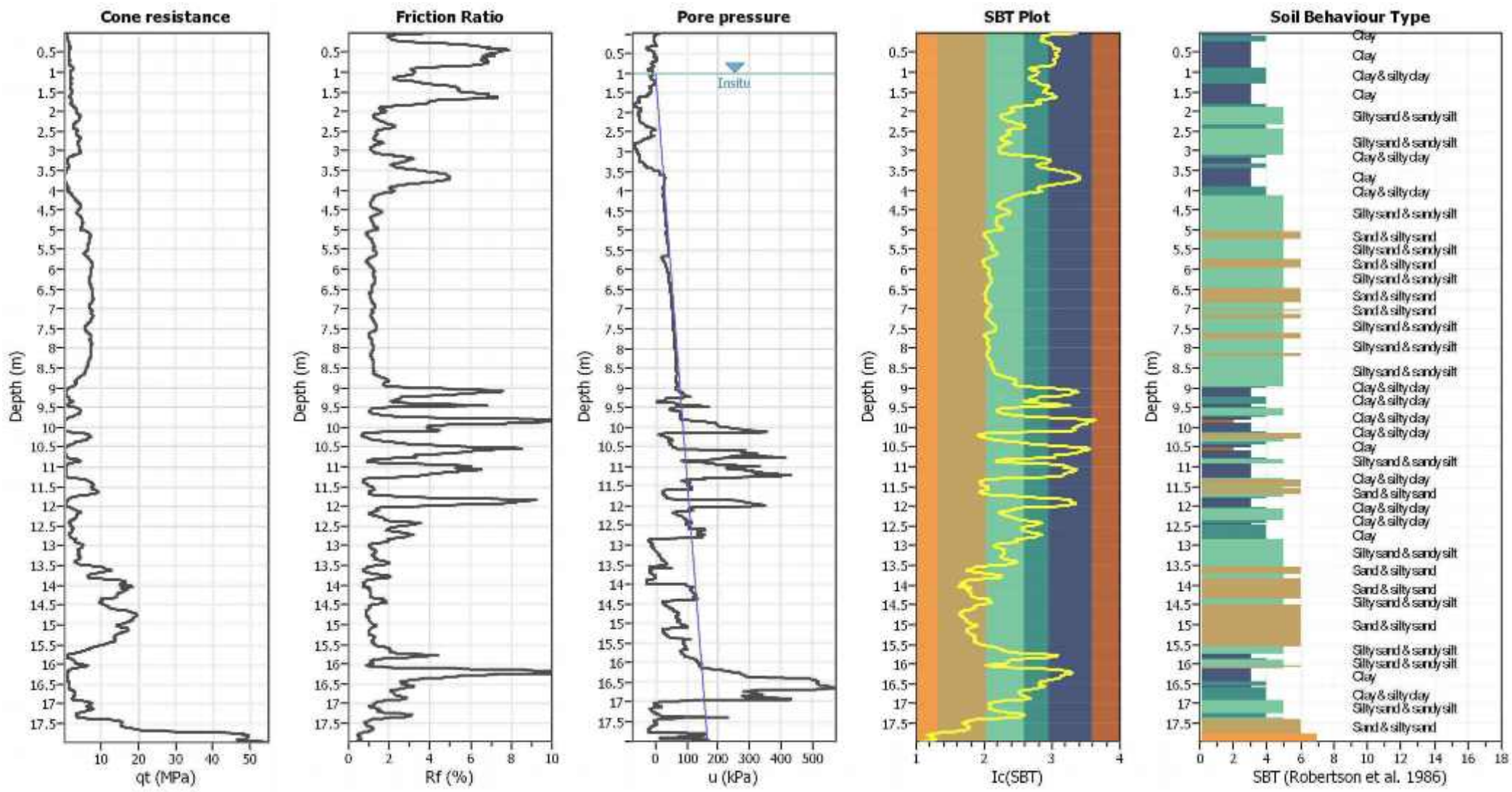
Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	2.50 m	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.35	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.50 m	Fill height:	N/A	Limit depth:	N/A

SBT legend

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

CPT basic interpretation plots



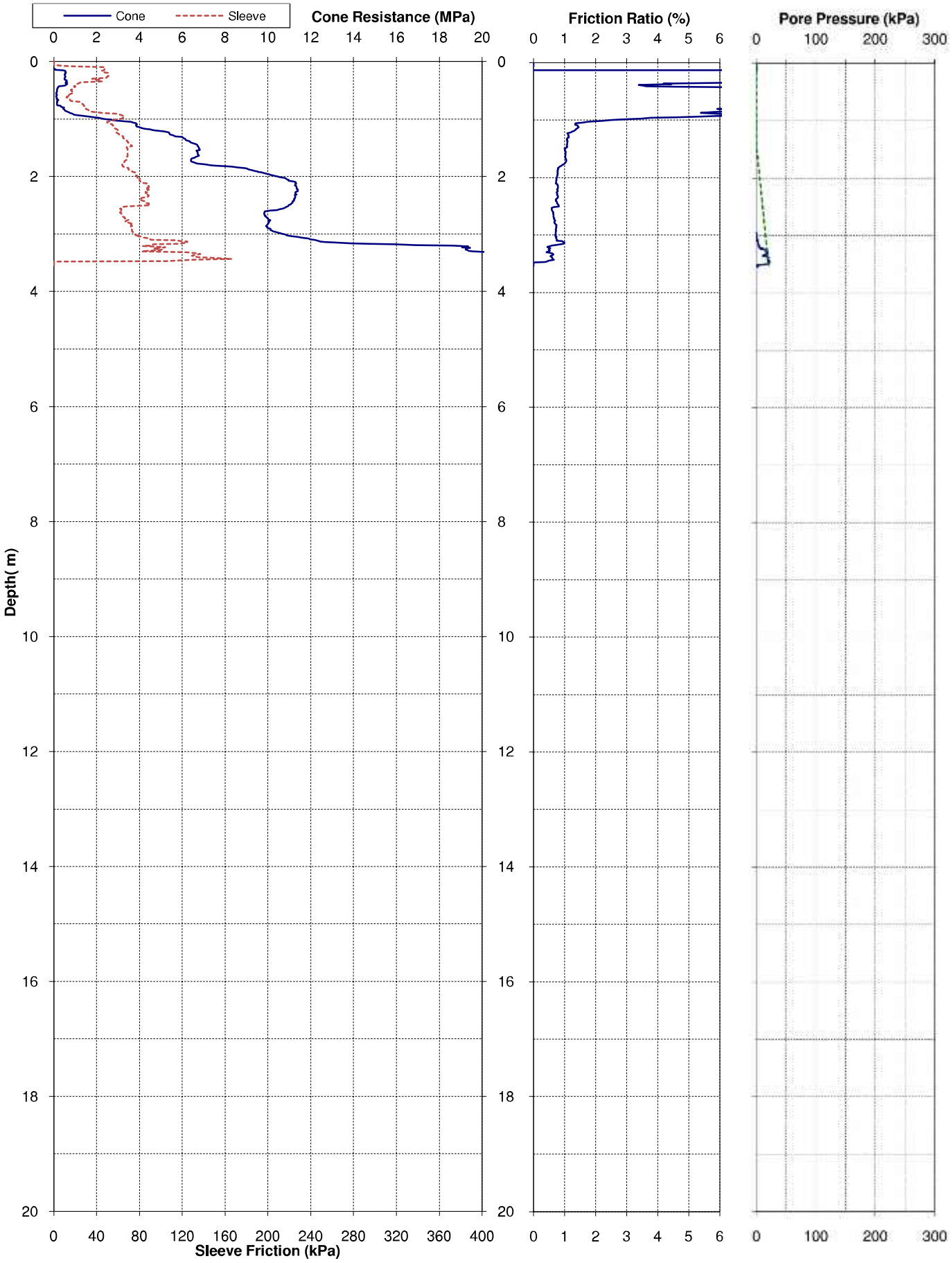
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.13	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 m	Fill height:	N/A	Limit depth:	N/A

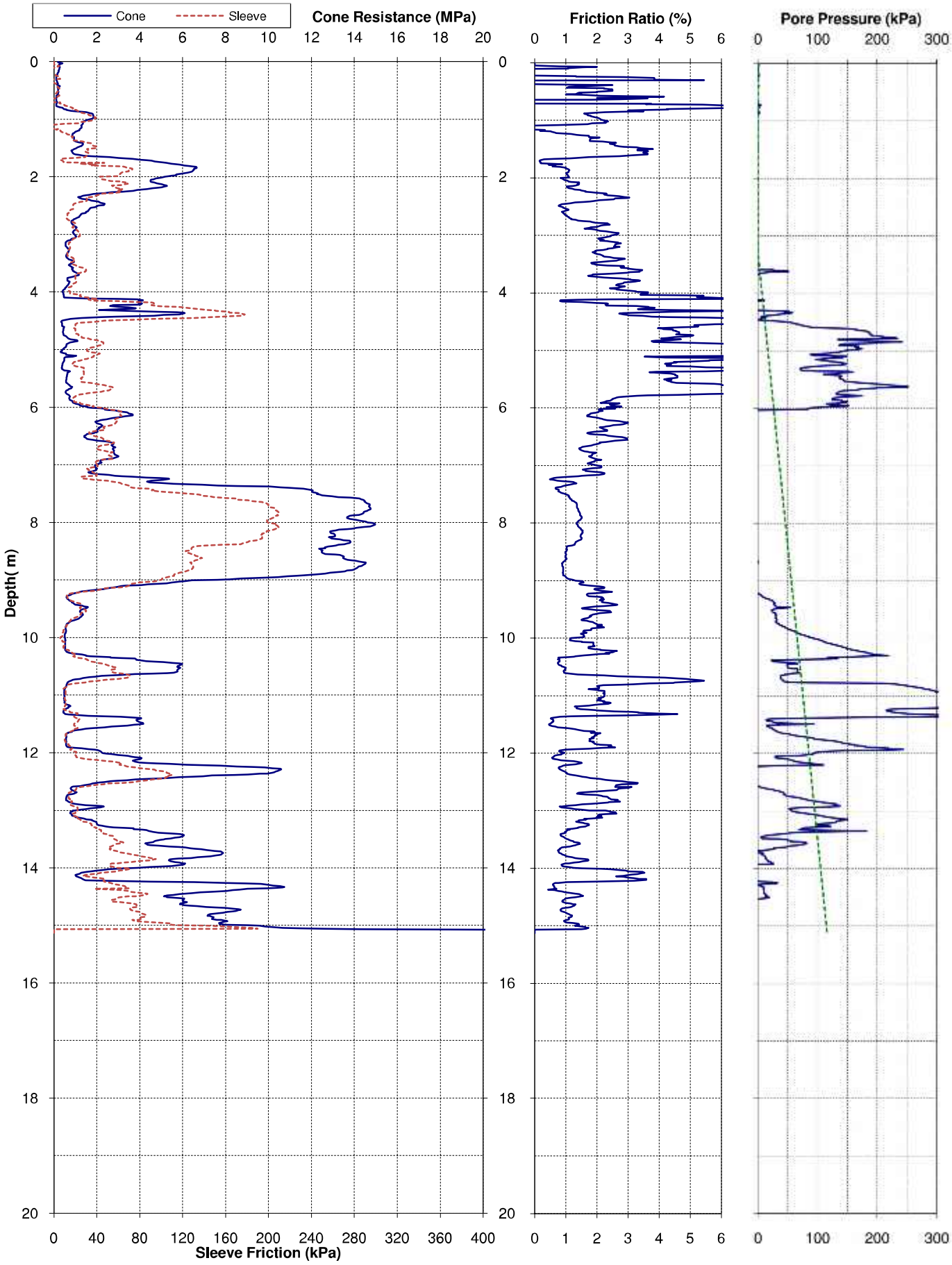
SBT legend

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

Project:	Christchurch 2011 Earthquake - EQC Ground Investigations			Page: 1 of 1		CPT-STM-13
Test Date:	9-May-2011	Location:	St Martins	Operator:	Opus	
Pre-Drill:	1.2m	Assumed GWL:	1.4mBGL	Located By:	Survey GPS	
Position:	2481942.1mE	5738976.3mN	5.419mRL	Coord. System:	NZMG & MSL	
Other Tests:				Comments:		



Project:	Christchurch 2011 Earthquake - EQC Ground Investigations			Page: 1 of 1		CPT-STM-27
Test Date:	9-May-2011	Location:	St Martins	Operator:	Perry	
Pre-Drill:	1.2m	Assumed GWL:	3.3mBGL	Located By:	Survey GPS	
Position:	2481825.3mE	5738810.9mN	5.973mRL	Coord. System:	NZMG & MSL	
Other Tests:				Comments:		



Geoscience Consulting (NZ) Ltd
5 Norwich Quay, Lyttelton
PO Box 110, Lyttelton

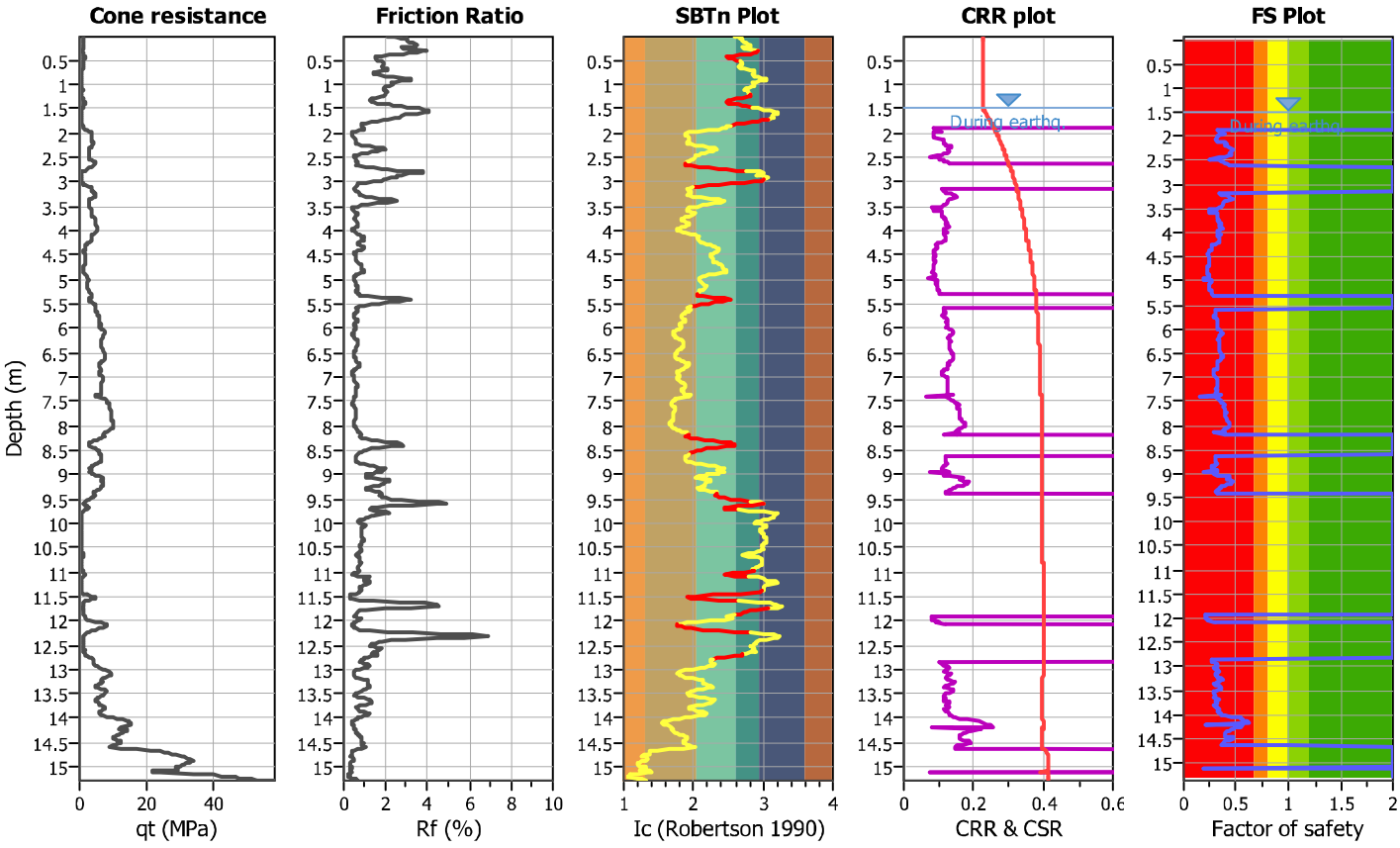
LIQUEFACTION ANALYSIS REPORT

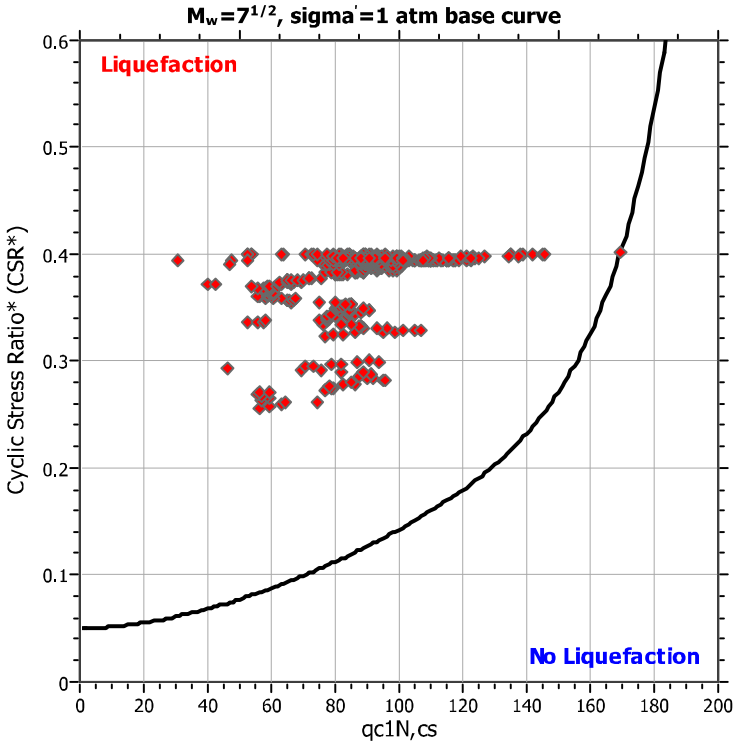
Project title : 123 Wilsons Road **Location : St Martins**

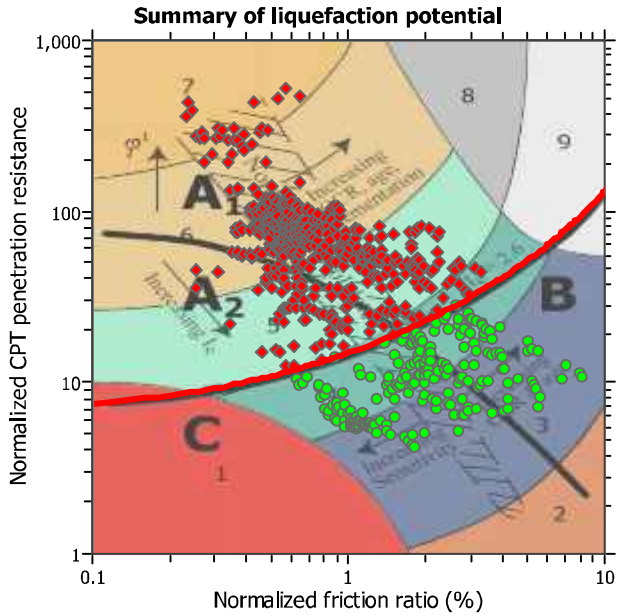
CPT file : 123WilsonsRdCPT01

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:	Sands only
Fines correction method:	R&W (1998)	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:	Yes		
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

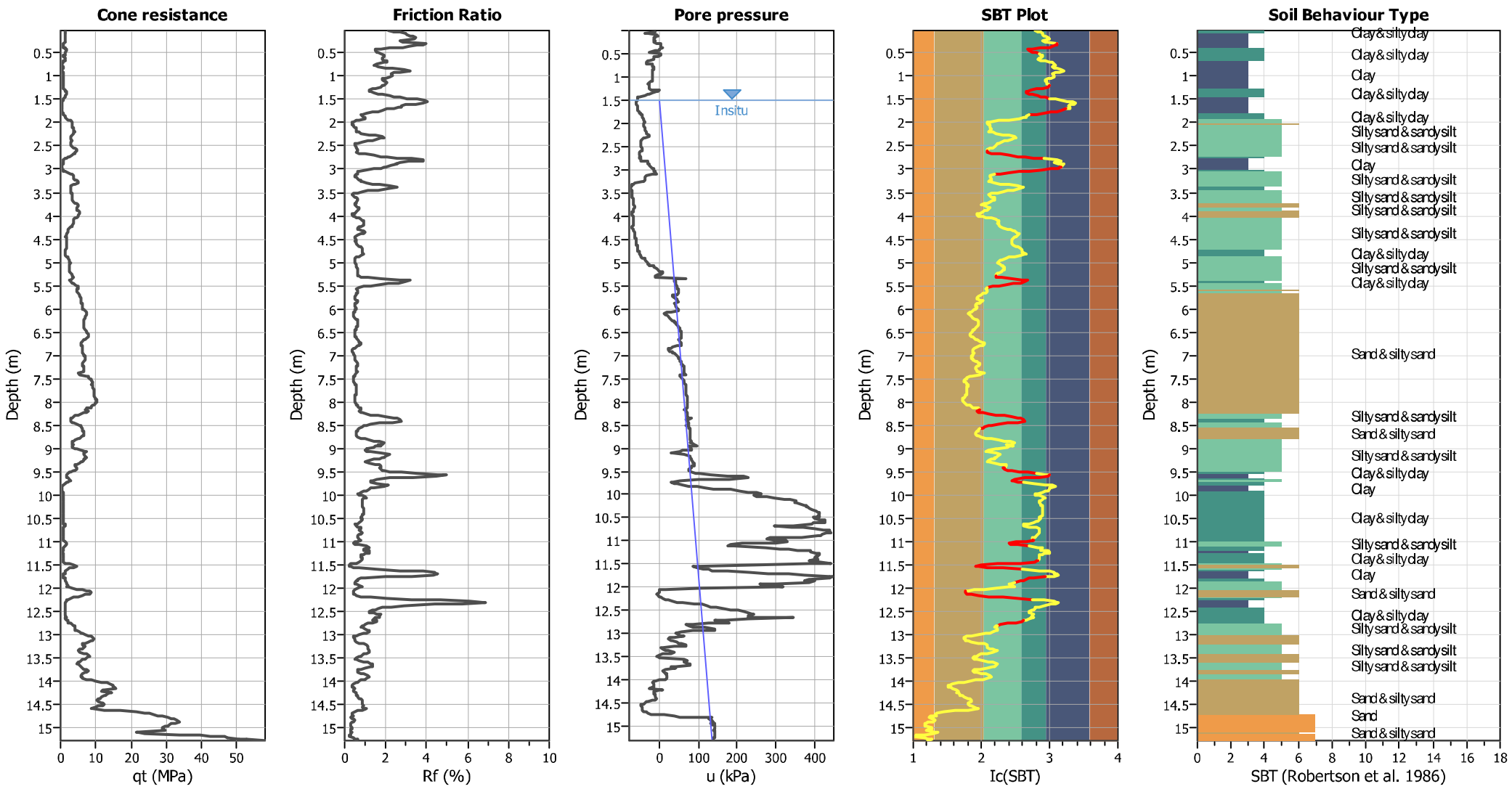






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and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

CPT basic interpretation plots



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.35	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
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

CPT ANALYSIS NOTES

Soil Type

Interpretation using chart of Robertson & Campanella (1983). This is a simple but well proven interpretation using cone tip resistance (q_C) and friction ratio (f_R) only. No normalisation for overburden stress is applied. Cone tip resistance measured with the piezocone is corrected with measured pore pressure (u_C).

- sand (and gravel)
- silt-sand
- silt
- clay-silt
- clay
- peat

Liquefaction Screening

The purpose of the screening is to highlight susceptible soils, that is sand and silt-sand in a relatively loose condition. This is not a full liquefaction risk assessment which requires knowledge of the particular earthquake risk at a site and additional analysis. The screening is based on the chart of Shibata and Teparaksa (1988).

- high susceptibility
- medium susceptibility
- low susceptibility

High susceptibility is here defined as requiring a shear stress ratio of 0.2 to cause liquefaction with D_{50} for sands assumed to be 0.25 mm and for silty sands to be 0.05 mm.

Medium susceptibility is here defined as requiring a shear stress ratio of 0.4 to cause liquefaction with D_{50} for sands assumed to be 0.25 mm and for silty sands to be 0.05 mm.

Low susceptibility is all other cases.

Relative Density (D_R)

Based on the method of Baldi et. al. (1986) from data on normally consolidated sand.

Undrained Shear Strength (S_U)

Derived from the bearing capacity equation using $S_U = (q_C - \sigma_{VO})/15$.

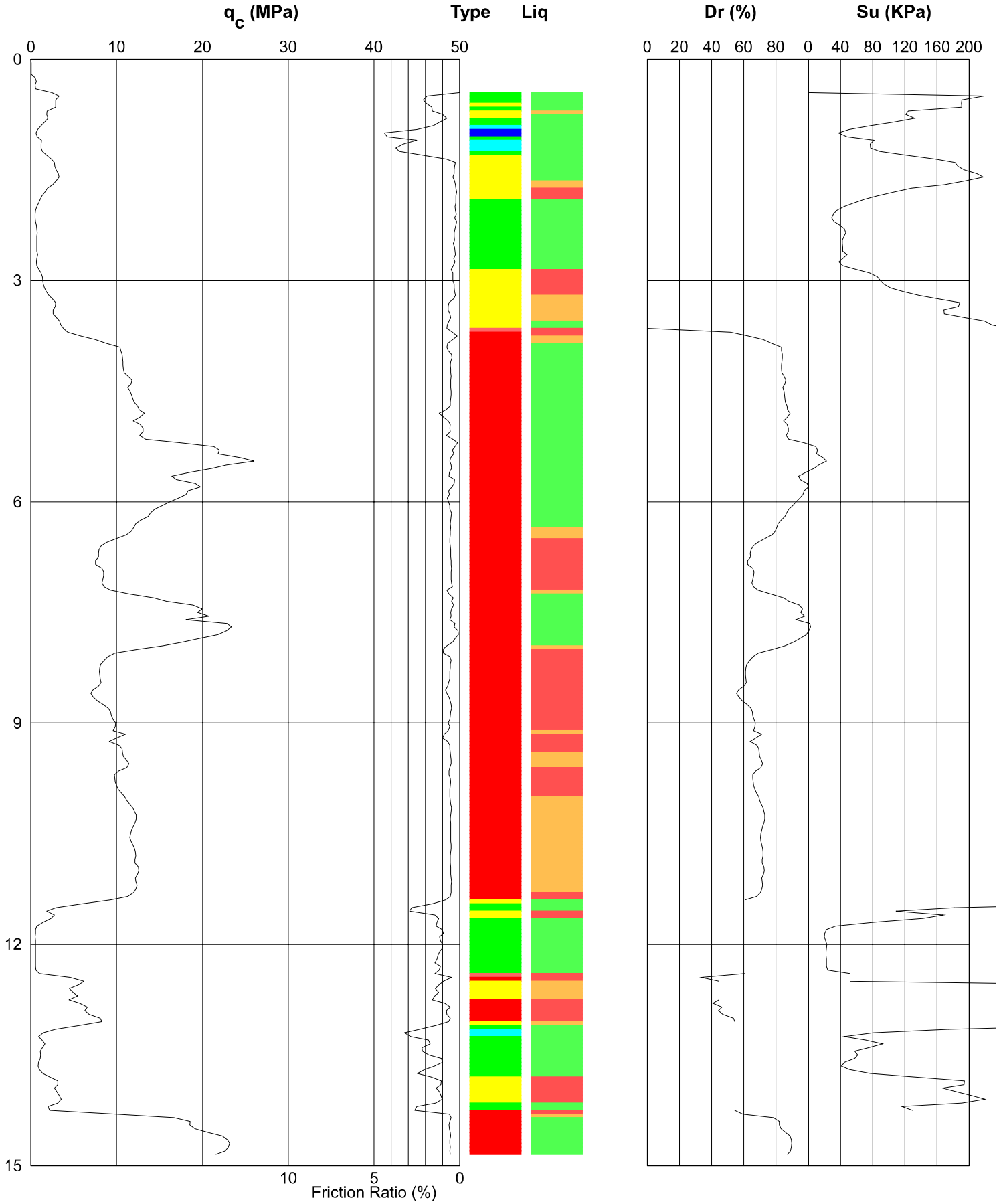
McMILLAN
DRILLING SERVICES

CLIENT : MWH / Mainzeal JV
LOCATION : 2-121 Wilsons Road, Christchurch
DATE : 18-2-2013
OPERATOR : S.Cardona
REMARK 1 : CPTu001
REMARK 2 : Effective Refusal

JOB # : 11524
TEST #: 1
CONE TYPE/SERIAL #: I-CFXYP20-10/ 081034T

McMILLAN DRILLING SERVICES
120 High St Southbridge CANTERBURY NZ
Ph +64 3 324 2571 Fax +64 3 324 2431
www.drilling.co.nz

PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT



Job No:	11524	Date:	18-2-2013
CPT No:	CPTu001	Operator:	S.Cardona
Project:	MWH / Mainzeal JV	Remark:	Effective Refusal
Location:	2-121 Wilsons Road, Christchurch		

McMILLAN DRILLING SERVICES

CPT CALIBRATION AND TECHNICAL NOTES

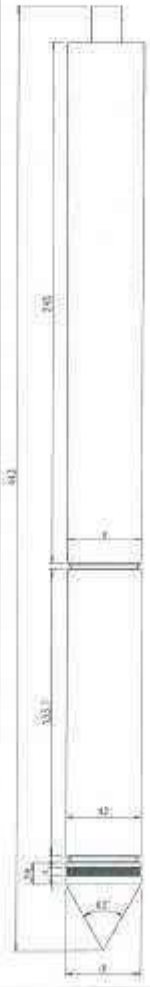
These notes describe the technical specifications and associated calibration references pertaining to the following cone types:

- ELCI-10CFXY measuring cone resistance, sleeve friction and inclination (standard cone);
- ELCI-CFXYP20-10 measuring cone resistance, sleeve friction, inclination and pore pressure (piezo cone).

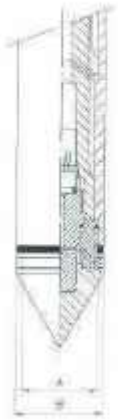
Dimensions

Dimensional specifications for both cone types are detailed below. All tolerances are routinely checked prior to testing and measurements taken are manually recorded on CPT field sheets. All field sheets are kept on file and available on request.

A.P. van den Berg Machinefabriek b.v. tel. :0513-631355 fax. :0513-631212	DEVIATION of Straightness + MINIMAL Dimensions tip, (friction)jacket, thread adapter	Standards: EN ISO 22476-1 NEN 5140 APB standard
Type of cone:	10 cm^2	
Diameter of tip: (acc. to EN ISO 22476-1)	$35,3 \leq d1 \leq 36,0$	
Diameter friction jacket:	$d_1 \leq d_2 < d_1 + 0,35$	
Tip: (production dimension)	$d = 35,7\ ^{+0,2}_{0}$	
Jacket (C-cone):	$d_2 = 35,7\ ^{+0,2}_{0}$	
Friction jacket (CF-cone):	$d_2 = 35,9\ ^{+0,1}_{0}$	
Tip for used cone:	$d_1 = 35,5\ ^{+0,1}_{0}$	
Minimal diameter jacket: (C-cone)	$d_2 = 35,2$ (APB std.)	
Minimal diameter of friction jacket: (CF-cone)	$d_2 = 35,3$	
Use "used cone"-tip when friction jacket diameter:	$d_2 \leq 35,65$	
Minimal diameter of thread adaptor:	$d = 35,3$	
Height dimension tip edge:	$7 \leq h_c \leq 10$	
Maximal deviation of straightness:	1 mm on a length of 1000 mm (max. oscillation 1,0 mm.)	



Cone surface ratio



McMILLAN DRILLING SERVICES

03-07-2012

CPT CALIBRATION AND TECHNICAL NOTES (cont.)

Calibration

Each cone has a unique identification number that is electronically recorded and reported for each CPT test. The identification number enables the operator to compare 'zero-load offsets' to manufacturer calibrated zero-load offsets.

The recommended maximum zero-load offset for each sensor is determined as ± 10% of the maximum measuring range although the more conservative trigger point adopted by McMillan Drilling Services is ± 10% of the nominal range.

In addition to maximum zero-load offsets, McMillan Drilling Services also limits the difference in zero load offset before and after the test as ± 1% of the maximum measuring range. See table below:

	Tip (MPa)	Friction (MPa)	Pore Pressure (MPa)
Maximum Measuring Range:	150	1.50	3.00
Nominal Measuring Range:	100	1.00	2.00
Max. 'zero-load offset':	10	0.10	0.20
Max 'before and after test':	1.5	0.015	0.03

Note: The zero offsets are electronically recorded and reported for each test in the same units as that of each sensor.

TEST CERTIFICATE
Icone (all versions)

Supplier:	A.P. v.d. Berg Machinefabriek, Heerenveen The Netherlands
Production-order:	59507
Client:	Mc Milla.
Cone-type:	ELCI- CFXYP20-10
Cone-number:	08.034

To test / To check item	**Required value**	**Checked value**
Isolation-resistance	>0.5 G-Ohm	1 Gohm
Straightness total Icone (10 cm2). (Base part Icone: S <= 0,2 mm) **For dimensions 15cm Icones: see standard/table.**	S<= 2,2 mm	1.46 mm
Zero-Value Tip	Good	-3,631 MPa
Zero-Value Local Friction	Good	-0,1340 MPa
Zero-Value Pore Pressure	Good	-123 kPa
Zero-Value Inclination X Zero-Value Inclination Y	-2° < X <+2° -2° < Y <+2°	-0,0 ° -0,1 °
Measurements Tip resistance OK?	(Yes)	0-50MPa
Influence of Tip on Local Friction and Pore Pressure? Tip: **Max Load**; Mantle free? 10cm2:**150 kN.** // 15 cm2:**225 kN.**	(No influence)	
Measurements Local Friction OK?	(Yes)	0-0,75MPa
Local Friction: **Max Load**	(O.K)	
Measurements Pore Pressure OK?	(Yes)	0-2000kPa
Measurements Inclination OK?	(Yes)	±10°
Cone recognition on disconnecting and connecting Icone again?	(Yes)	
Software version **1.8** installed? Check at opening screen. **Exception: GEO LYNBY uses v. 1.7 ! NOTE DOWN versionnbr.:**	Version:	1.8
Check alarm-settings Icone. Alarm values are set. (Kill Shutdown)	(O.K)	

Remarks:

Calibrated by:	C.J. Ouwejan	Date: 15-01-13	Sign.:
Final check:	J.E. Ten Lage	Date: 16-01-13	Sign.:

Geoscience Consulting (NZ) Ltd
5 Norwich Quay, Lyttelton
PO Box 110, Lyttelton

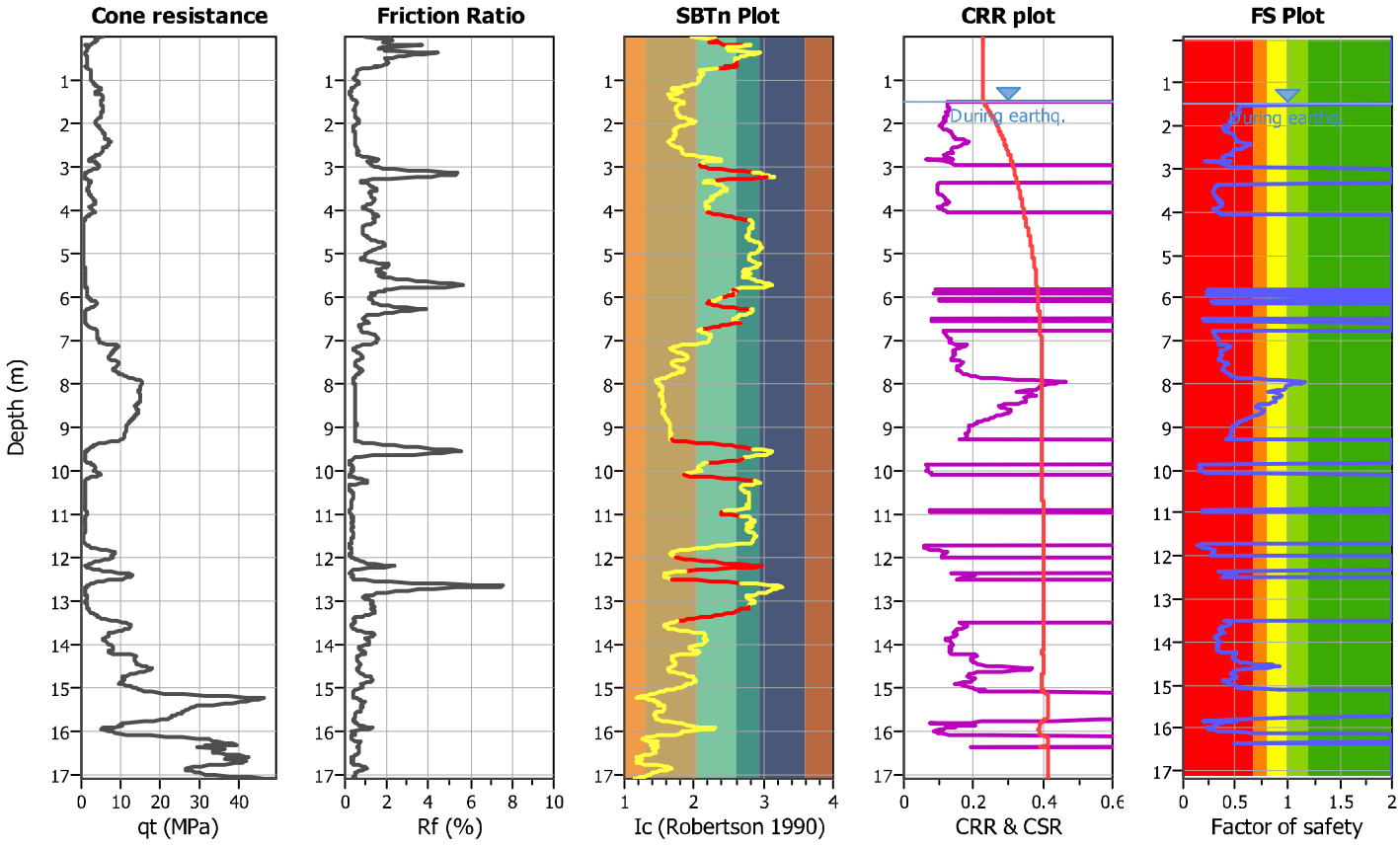
LIQUEFACTION ANALYSIS REPORT

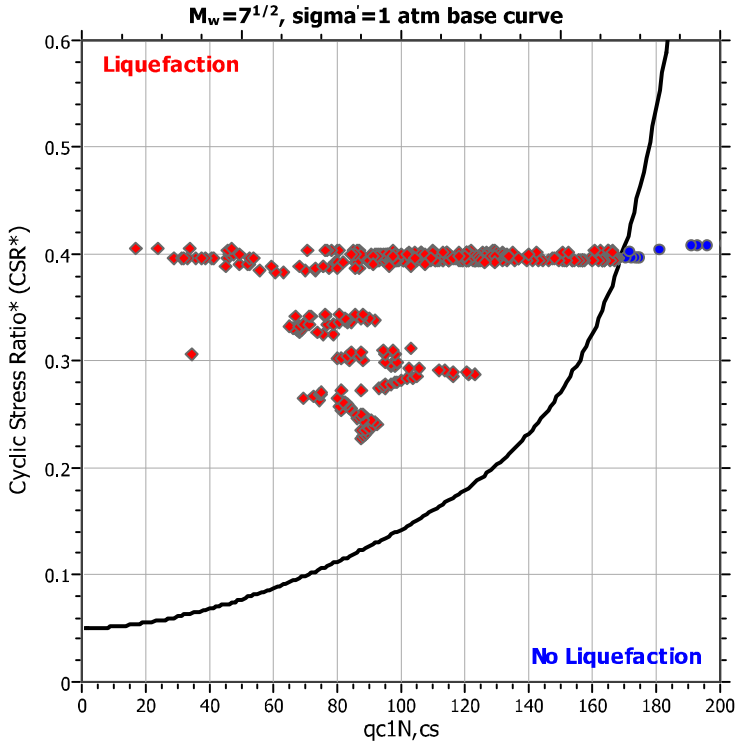
Project title : 123 Wilsons Road **Location : St Martins**

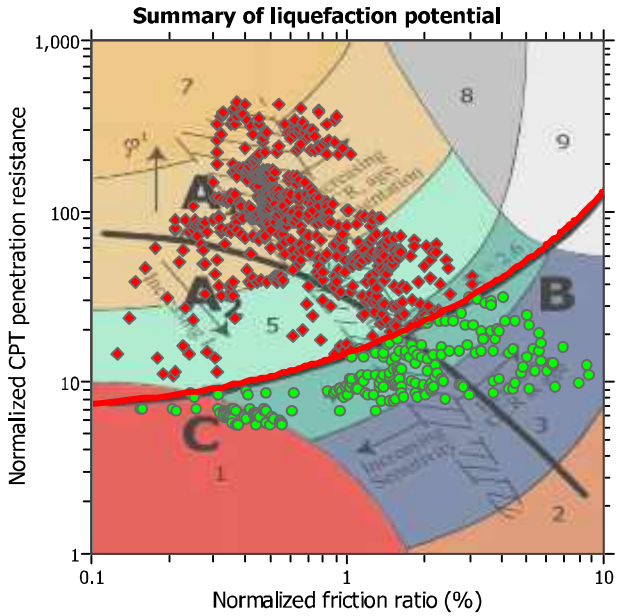
CPT file : 123WilsonsRdCPT02

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:	Sands only
Fines correction method:	R&W (1998)	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:	Yes		
Peak ground acceleration:	0.35	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

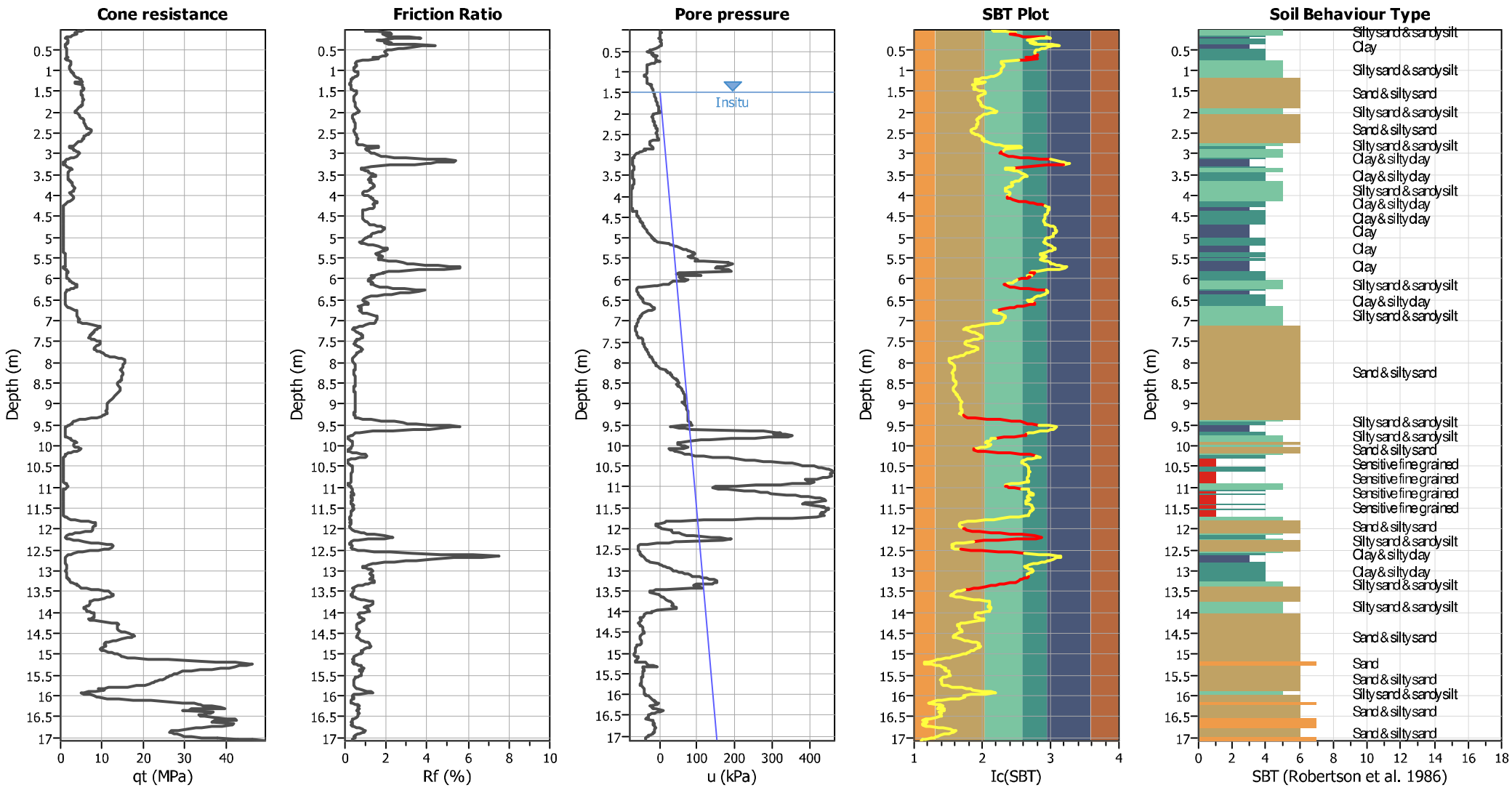






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and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

CPT basic interpretation plots



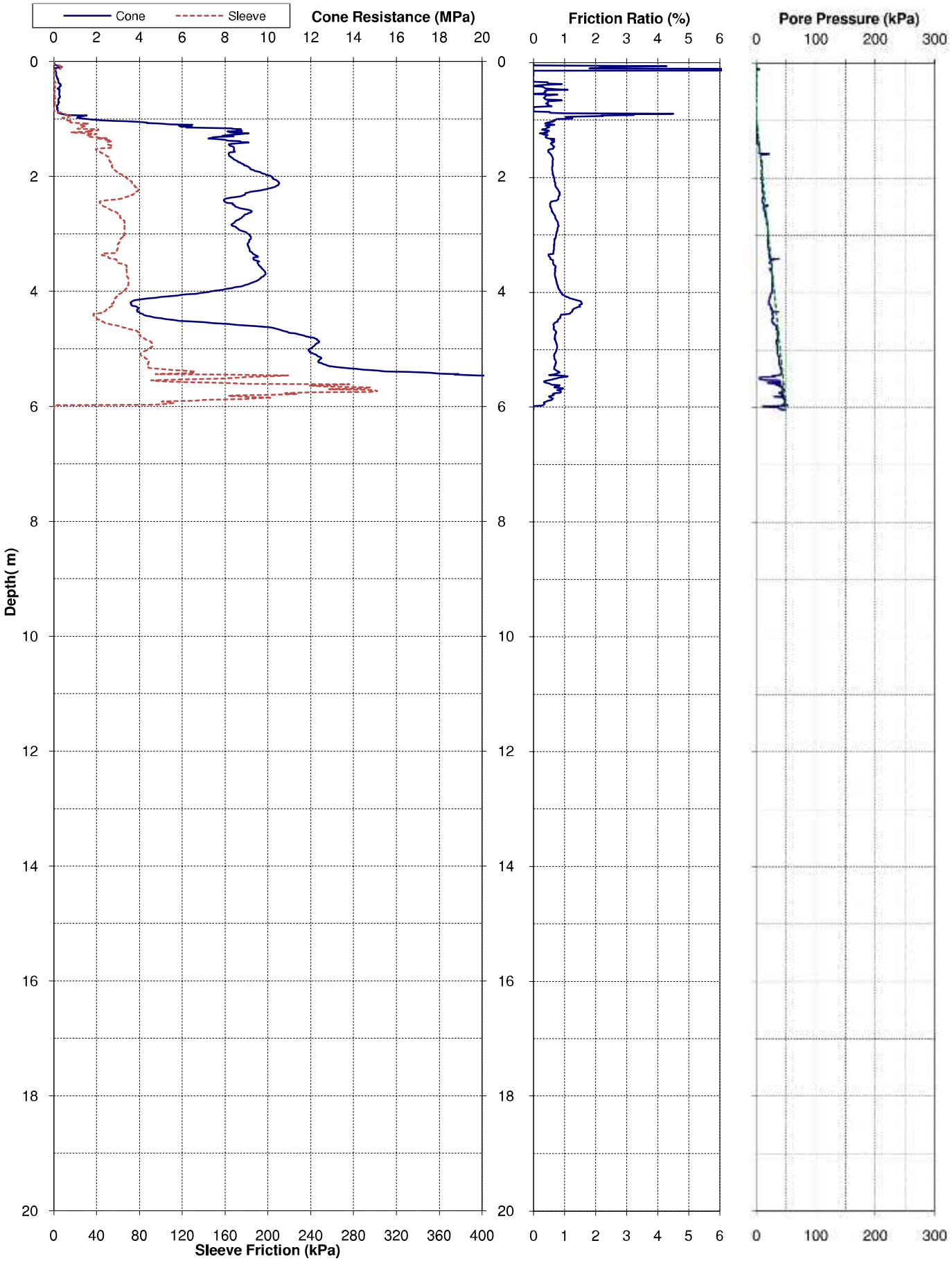
Input parameters and analysis data

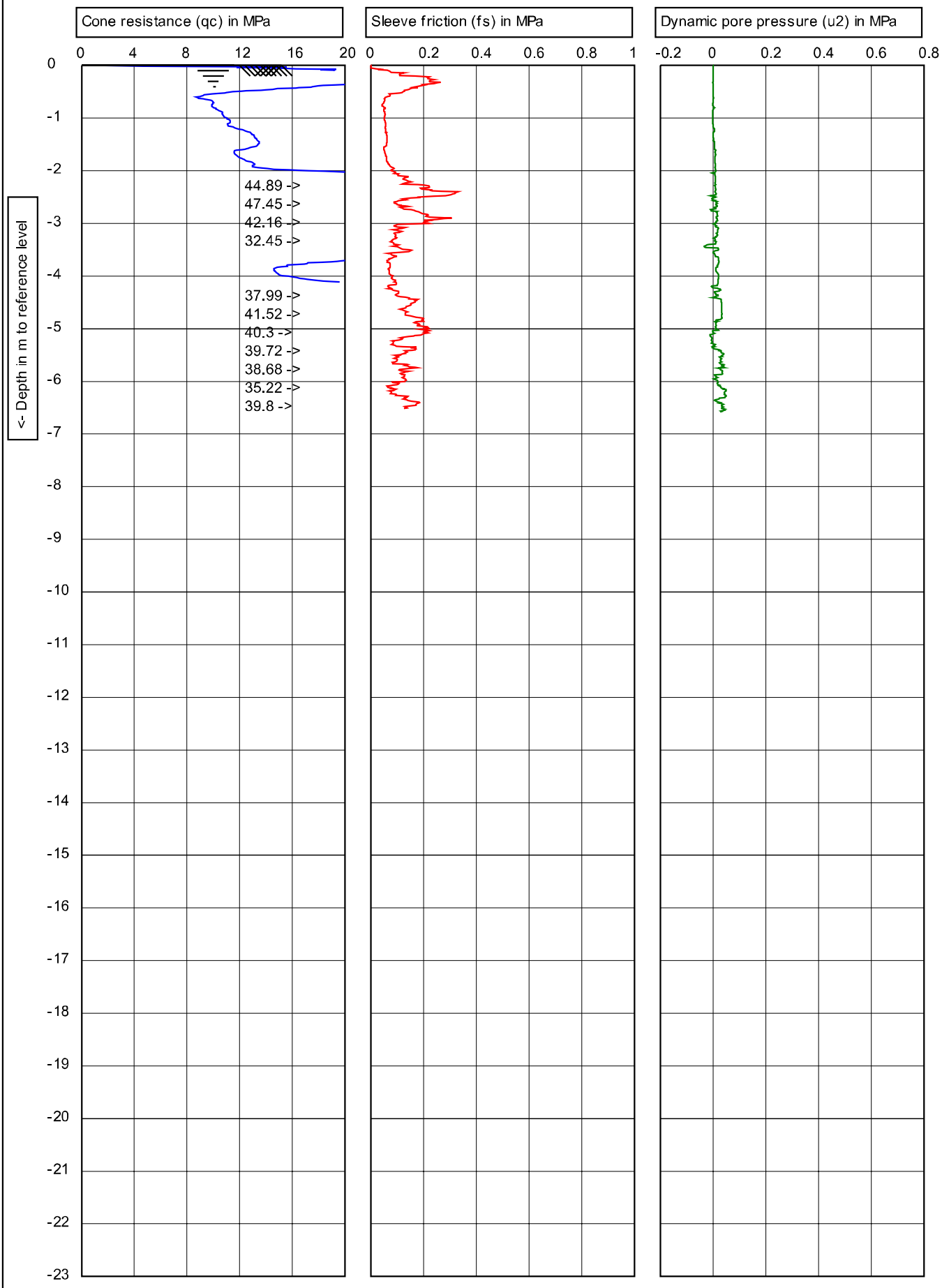
Analysis method:	I&B (2008)	Depth to GWT (erthq.):	1.50 m	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	Sands only
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	.
Peak ground acceleration:	0.35	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
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

Project:	Christchurch 2011 Earthquake - EQC Ground Investigations			Page: 1 of 1		CPT-STM-28
Test Date:	9-May-2011	Location:	St Martins	Operator:	Perry	
Pre-Drill:	1.2m	Assumed GWL:	0.9mBGL	Located By:	Survey GPS	
Position:	2482116.6mE	5738876.3mN	5.302mRL	Coord. System:	NZMG & MSL	
Other Tests:				Comments:		





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HAMILTON LABORATORY

Test according to A.S.T.M standard D-5778-12

G.L. **0** W.L.: **0**

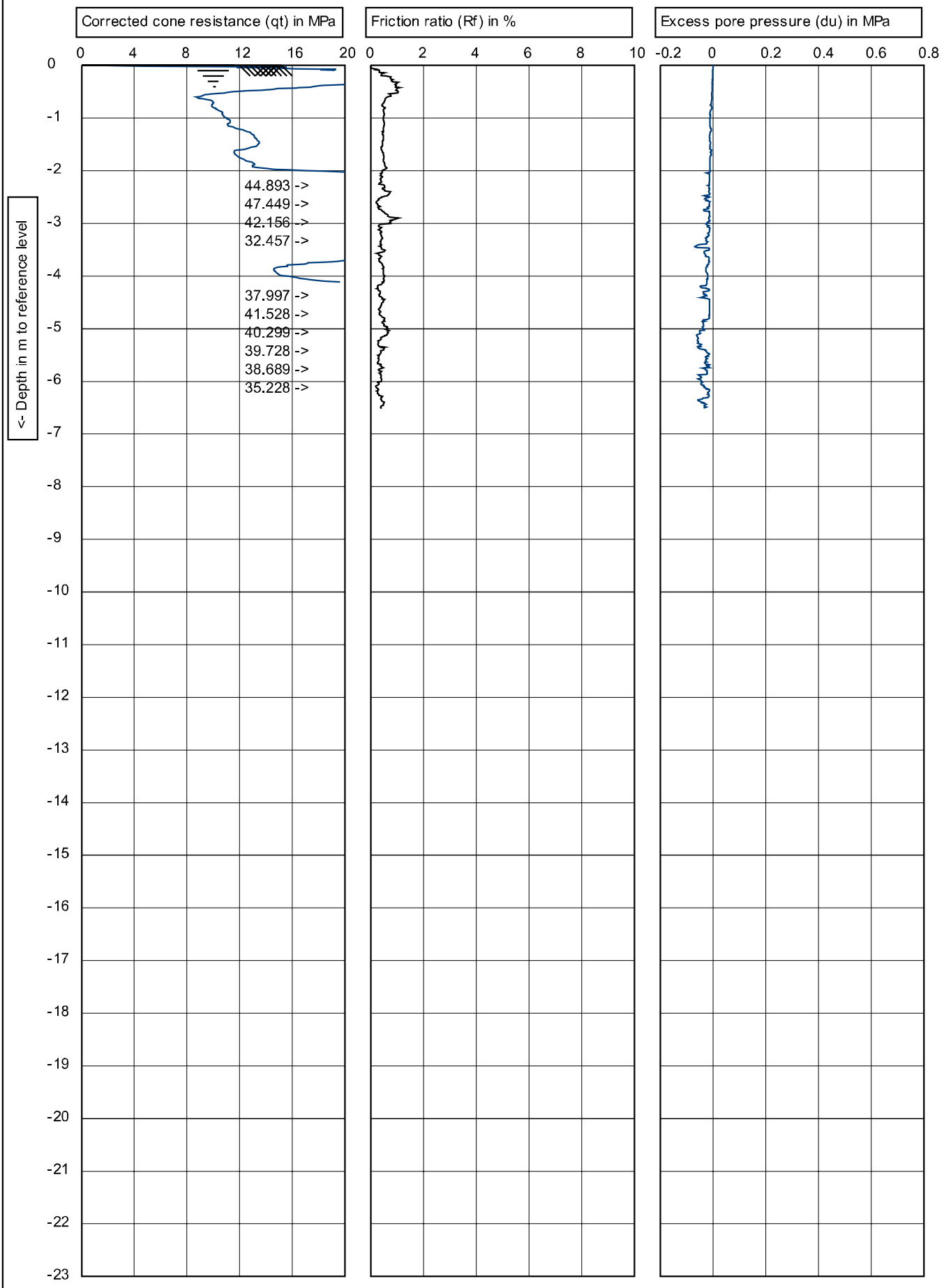
Project: **TC3- 1/26 Wades Ave**

Location: **GPS:E1572155 N5177281**

Position:

Predrill :	**0**
Date:	**5/12/2012**
Cone no.:	**C10CFIIP.C11284**
Project no.:	**2-68292.12_031**
CPT no.:	STM-POD04-CPT13 **1/6**

CPTask V1.20



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HAMILTON LABORATORY

r u2
L 150 cm²
10 cm²

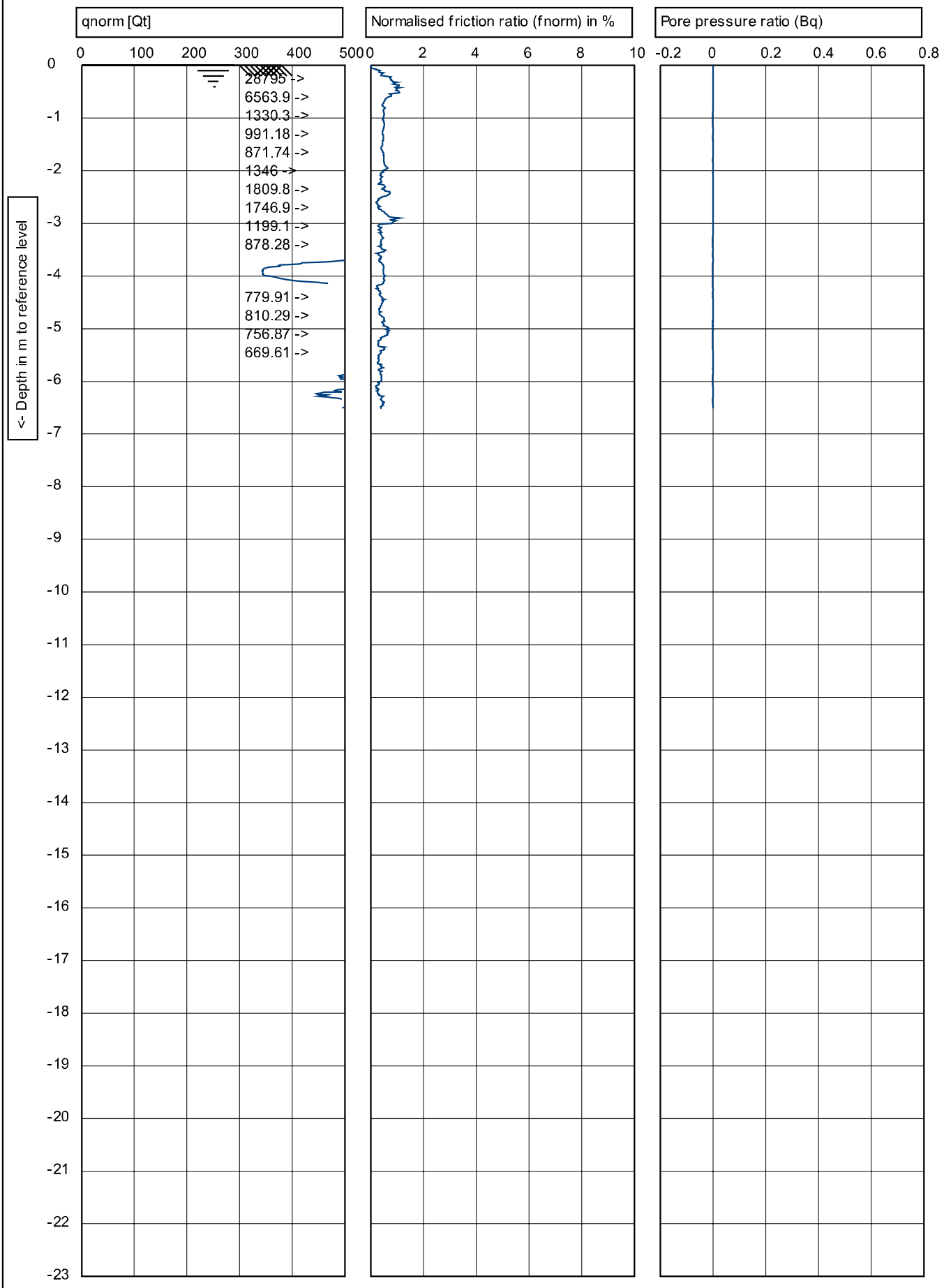
Test according to A.S.T.M standard D-5778-12

G.L. **0** W.L.: **0**

Project: **TC3- 1/26 Wades Ave**
Location: **GPS:E1572155 N5177281**
Position:

Predrill :	**0**
Date:	**5/12/2012**
Cone no.:	**C10CFIIP.C11284**
Project no.:	**2-68292.12_031**
CPT no.:	STM-POD04-CPT13 **2/6**

CPTask V1.20



OPUS
HAMILTON LABORATORY

r u2
L 150 cm²
10 cm²

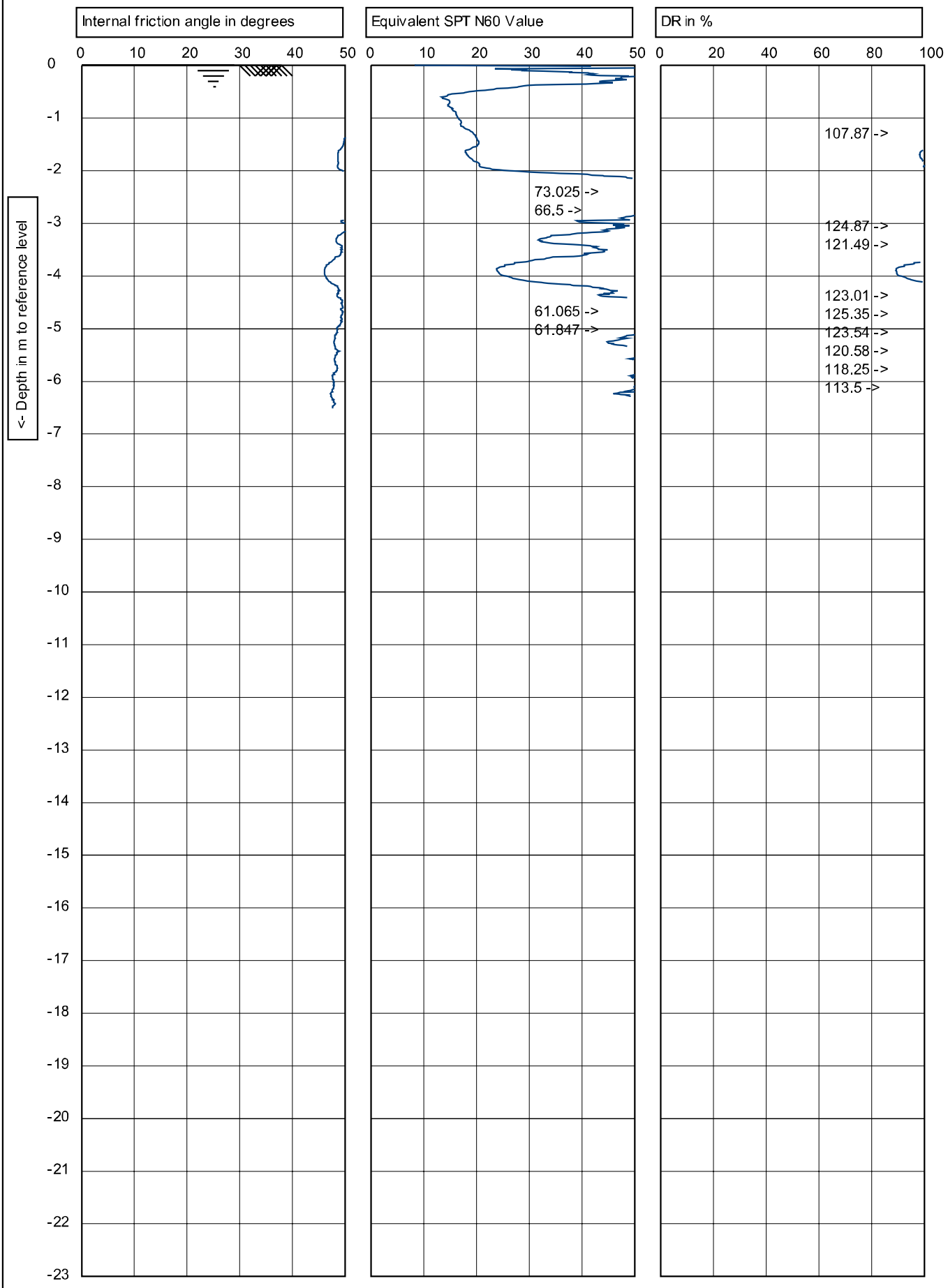
Test according to A.S.T.M standard D-5778-12

G.L. **0** | W.L.: **0**

Project: **TC3- 1/26 Wades Ave**
Location: **GPS:E1572155 N5177281**
Position:

Predrill :	**0**
Date:	**5/12/2012**
Cone no.:	**C10CFIIP.C11284**
Project no.:	**2-68292.12_031**
CPT no.:	STM-POD04-CPT13 **3/6**

CPTask V1.20



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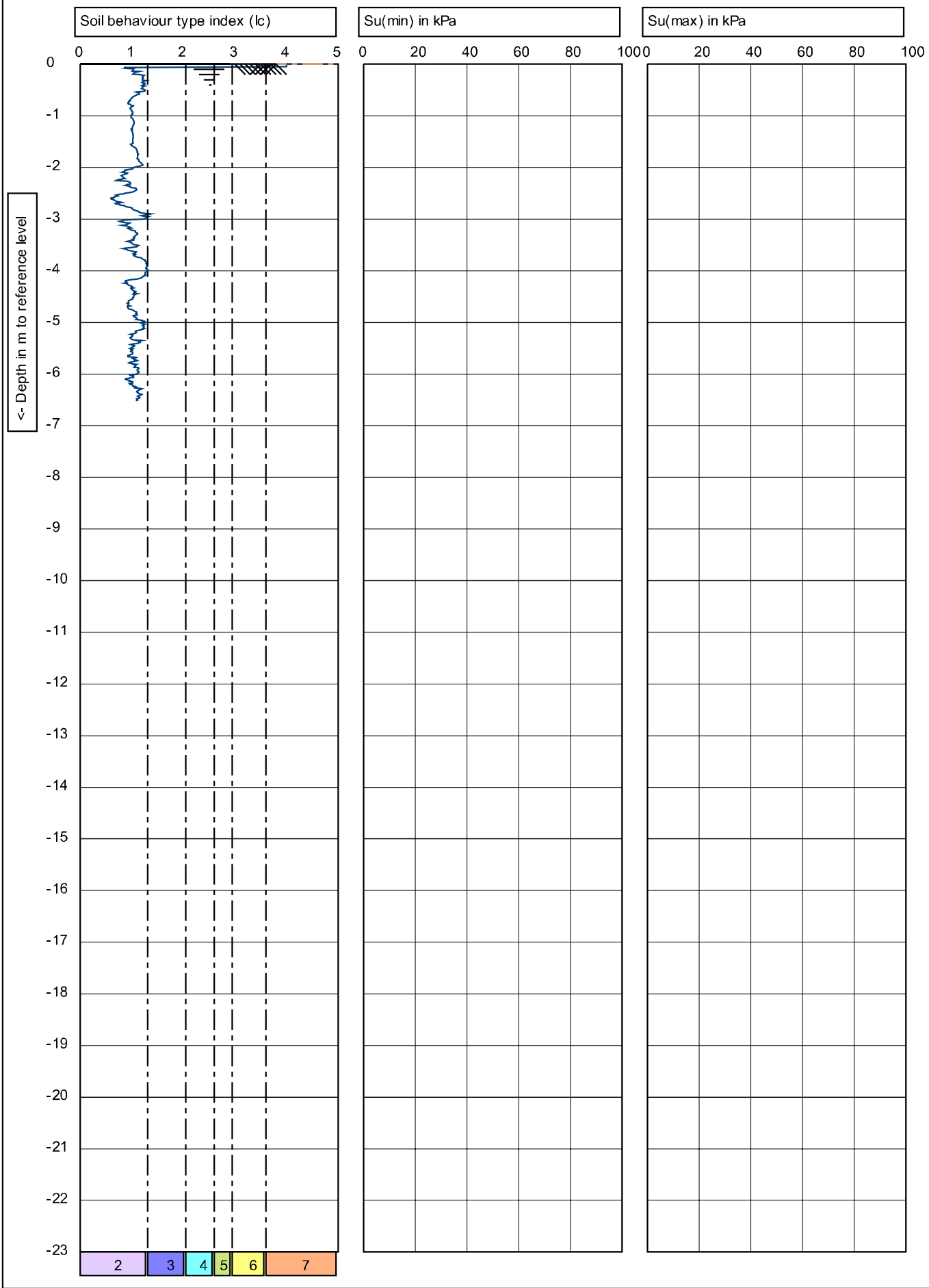
Test according to A.S.T.M standard D-5778-12

G.L. **0** W.L.: **0**

Project: **TC3- 1/26 Wades Ave**
Location: **GPS:E1572155 N5177281**
Position:

Predrill :	**0**
Date:	**5/12/2012**
Cone no.:	**C10CFIIP.C11284**
Project no.:	**2-68292.12_031**
CPT no.:	STM-POD04-CPT13 **4/6**

CPTask V1.20



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CPTask V1.20

r u2
L 150 cm²
10 cm²

Test according to A.S.T.M standard D-5778-12

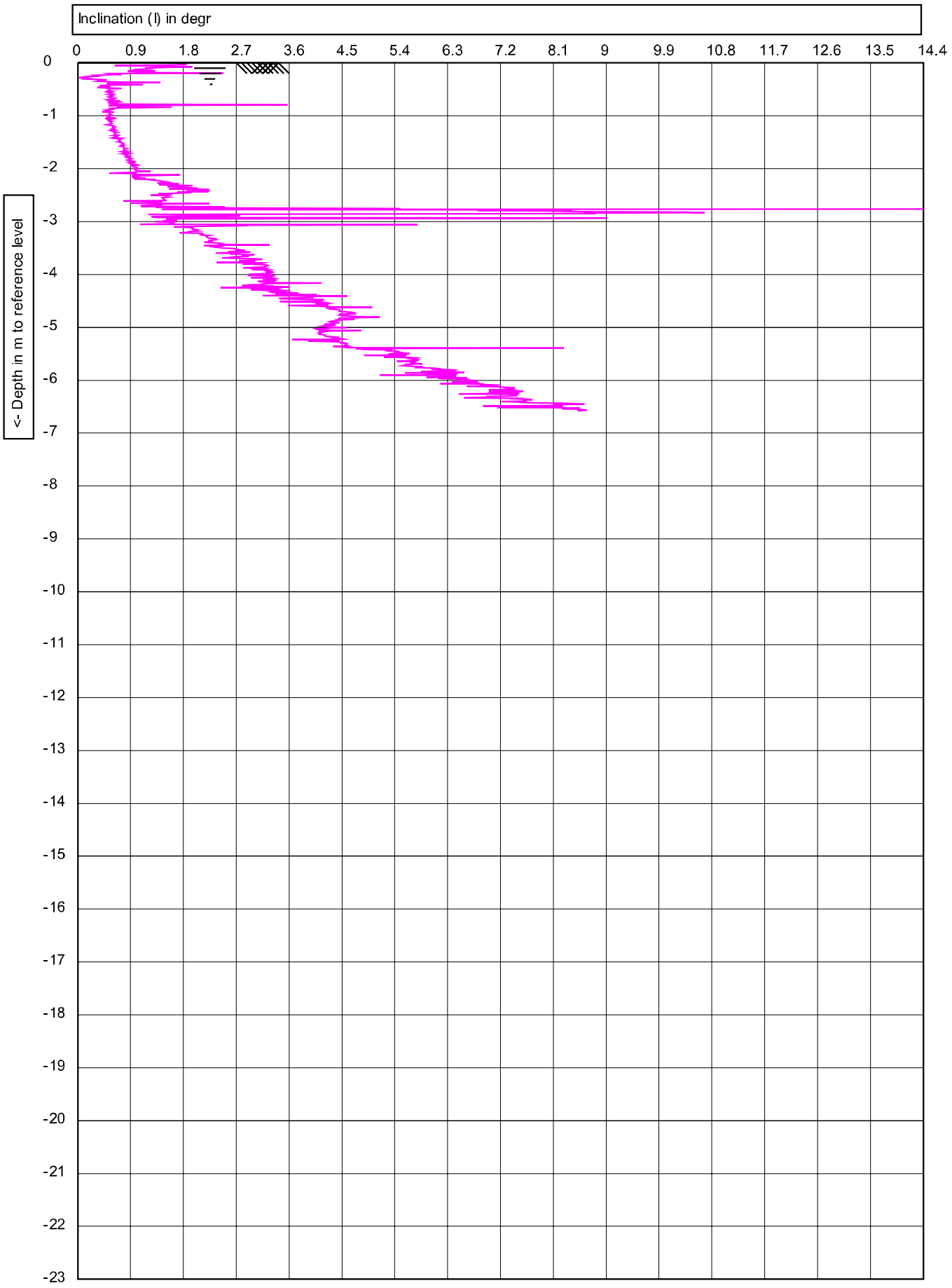
G.L. **0** W.L.: **0**

Project: **TC3- 1/26 Wades Ave**

Location: **GPS:E1572155 N5177281**

Position:

Predrill :	**0**
Date:	**5/12/2012**
Cone no.:	**C10CFIIP.C11284**
Project no.:	**2-68292.12_031**
CPT no.:	STM-POD04-CPT13 **5/6**



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r u2
150 cm²
10 cm²

Test according to A.S.T.M standard D-5778-12

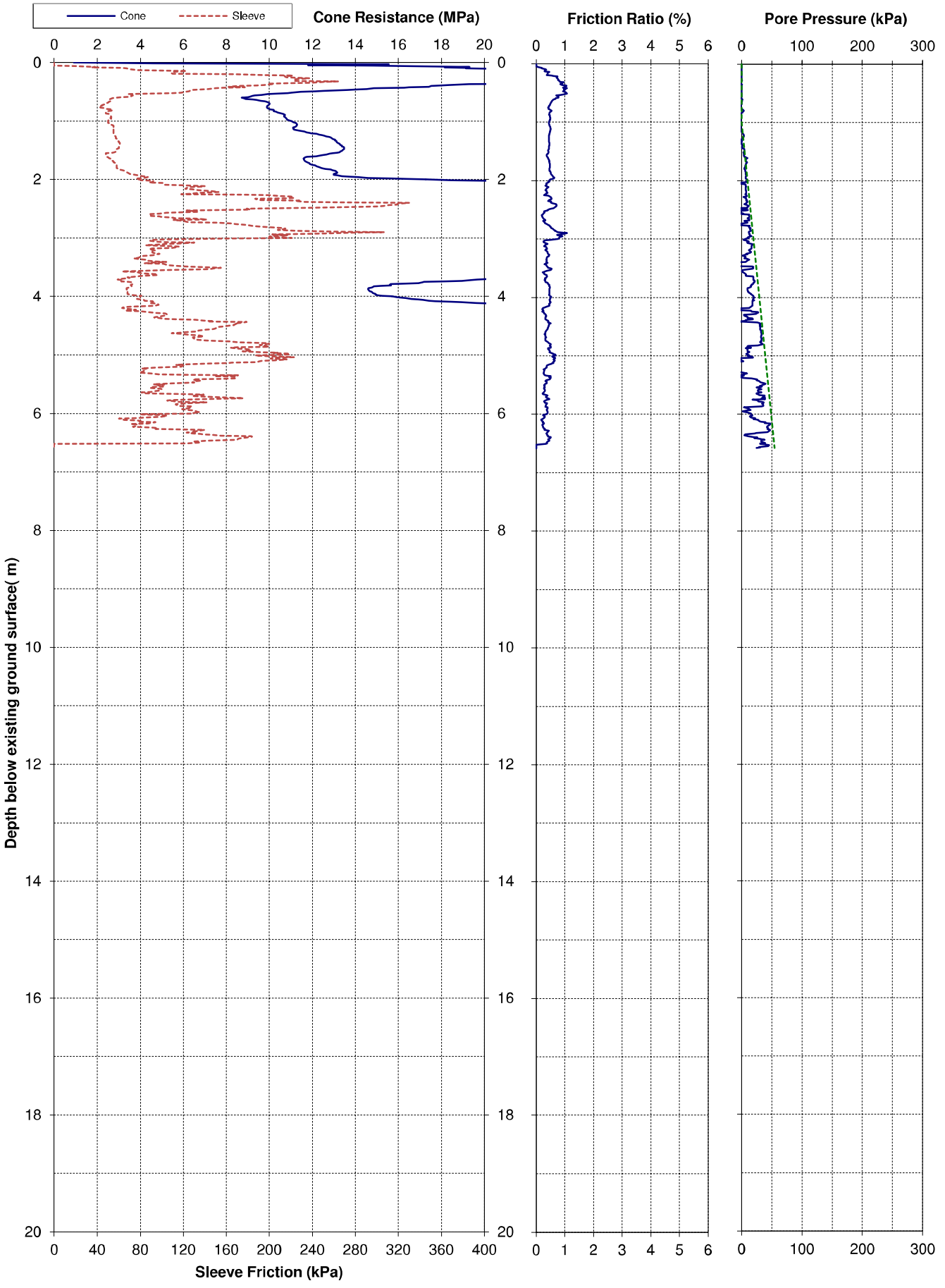
G.L. **0** W.L.: **0**

Project: **TC3- 1/26 Wades Ave**
Location: **GPS:E1572155 N5177281**
Position:

Predrill :	**0**
Date:	**5/12/2012**
Cone no.:	**C10CFIIP.C11284**
Project no.:	**2-68292.12_031**
CPT no.:	STM-POD04-CPT13 **6/6**

CPTask V1.20

Project:	Christchurch TC3 Geotechnical Investigations			Page: 1 of 1	STM-POD04-CPT013
Test Date:	5-Dec-2012	Suburb:	St Martins Opawa	Operator:	Opus
Pre-Drill:	0m	Assumed GWL:	1mBGL	Located By:	Survey GPS
Position:	2482152.41mE	5738889.32mN	5.16mRL	Coord. System:	NZMG
Address:	In road, 1/26 Wades Ave			Datum Reference:	MSL (CCC 20/01/12 Datum -9.043)



T+T Ref: 52003.2000

Printed: 15/01/2013 12:34 p.m.

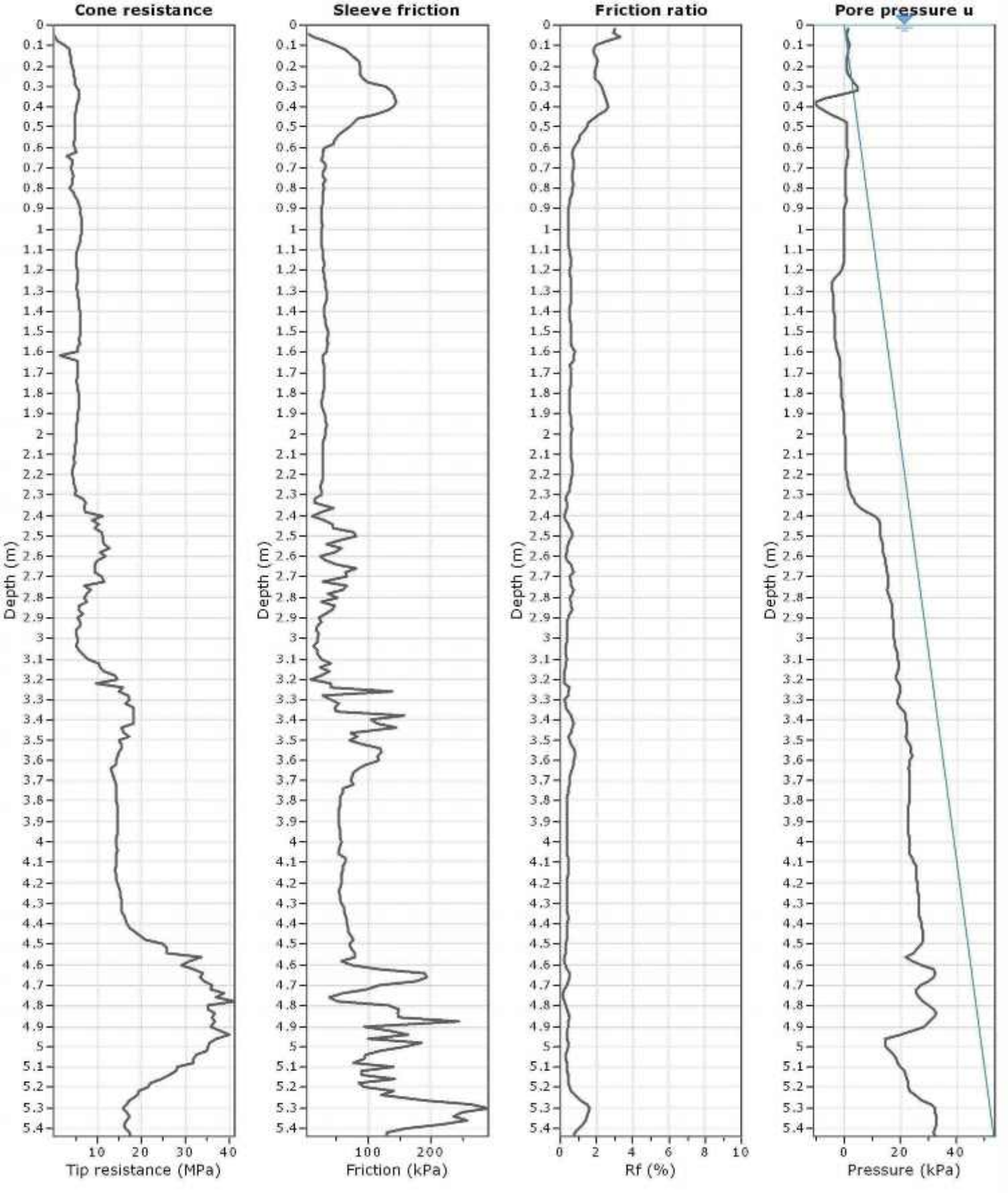
Template: CPT Graph Template TC3 (2).xls

Brown Bros (NZ) Ltd.
Hamilton (07) 849 2919
Auckland (09) 298 0449
www.brownbro.co.nz

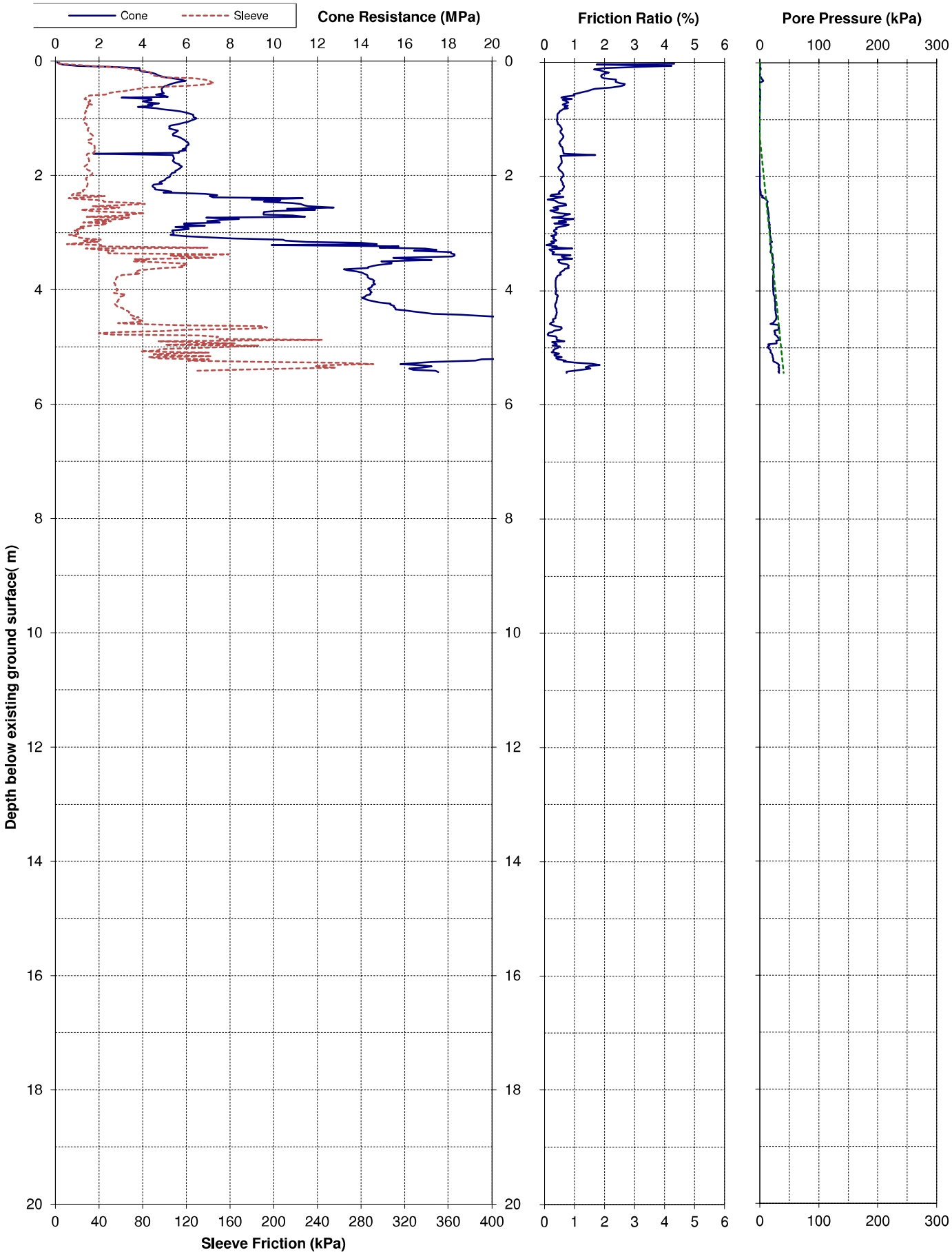
CPT: STM-POD04-CPT008

Project: **Christchurch TC3 Geotechnical Investigations** **Water level (a) applied.** Total depth: 5.44 m, Date: 28/11/2012

Location: **28 Wades Ave, St Martins** **Coord: 43 33.316 S 172 39.589 E** Cone Type: 10cm² Standard Piezocone, Cone ID: 4467



Project:	Christchurch TC3 Geotechnical Investigations			Page: 1 of 1	STM-POD04-CPT008
Test Date:	28-Nov-2012	Suburb:	St Martins Opawa	Operator:	Brown Bros
Pre-Drill:	0m	Assumed GWL:	1.3mBGL	Located By:	Survey GPS
Position:	2482167.58mE	5738884.93mN	5.52mRL	Coord. System:	NZMG
Address:	28 Wades Ave			Datum Reference:	MSL (CCC 20/01/12 Datum -9.043)



Disclaimers

1. For the raw data

The data presented on this page is factual and based on the results of CPT testing undertaken with reasonable diligence. Any interpretation of this data is the sole responsibility of the user.

2. Water levels

(a) Assumed
For those test sites where we cannot get reliable measurements, the water levels will be reported as zero value.

(b) Measured onsite
Where water level measurements are reported, the depth was determined immediately after the test with a dip device. These values should be used with caution because little time has been allowed for recharge or equalising.

(c) Estimated based on CPT data
Where the hydrostatic line is moved to align with the CPT data.

The static pore water pressure line shown is assumed to be hydrostatic from the phreatic surface. The validity of this assumption must be checked by the user.

3. For the inferred CPT parameters

The data presented here is informative for the engineer and interpreted based on published methods with reasonable care using an automated process of calculation. The user of this data has the sole responsibility for drawing any interpretation or conclusions from this data, including ensuring the calculation methods adopted are applicable for these materials through which this CPT has been pushed.

Appendix D

EQC Map Output

© Opus International Consultants Ltd

SOURCE: https://canterburygeotechnicaldatabase.projectorbit.com/ (Accessed on 8/7/2013)

OPUS
Opus International Consultants Ltd
Christchurch Office
20 Moorhouse Ave
PO Box 1482
Christchurch, New Zealand
Tel: +64 3 363 5400 Fax: +64 3 365 7857

Project:	Cresselly Place, St Martins, Christchurch
Project No.:	6-QC335.00
Client:	Christchurch City Council

EQC Observed Ground Cracking

Drawn: Opus Geotechnical Engineer

Date: 12-Jul-13

Appendix E

CLiq Liquefaction Analysis Output

© Opus International Consultants Ltd

Appendix E.1

CLiq NCEER (1998) SLS1 Liquefaction Analysis Output

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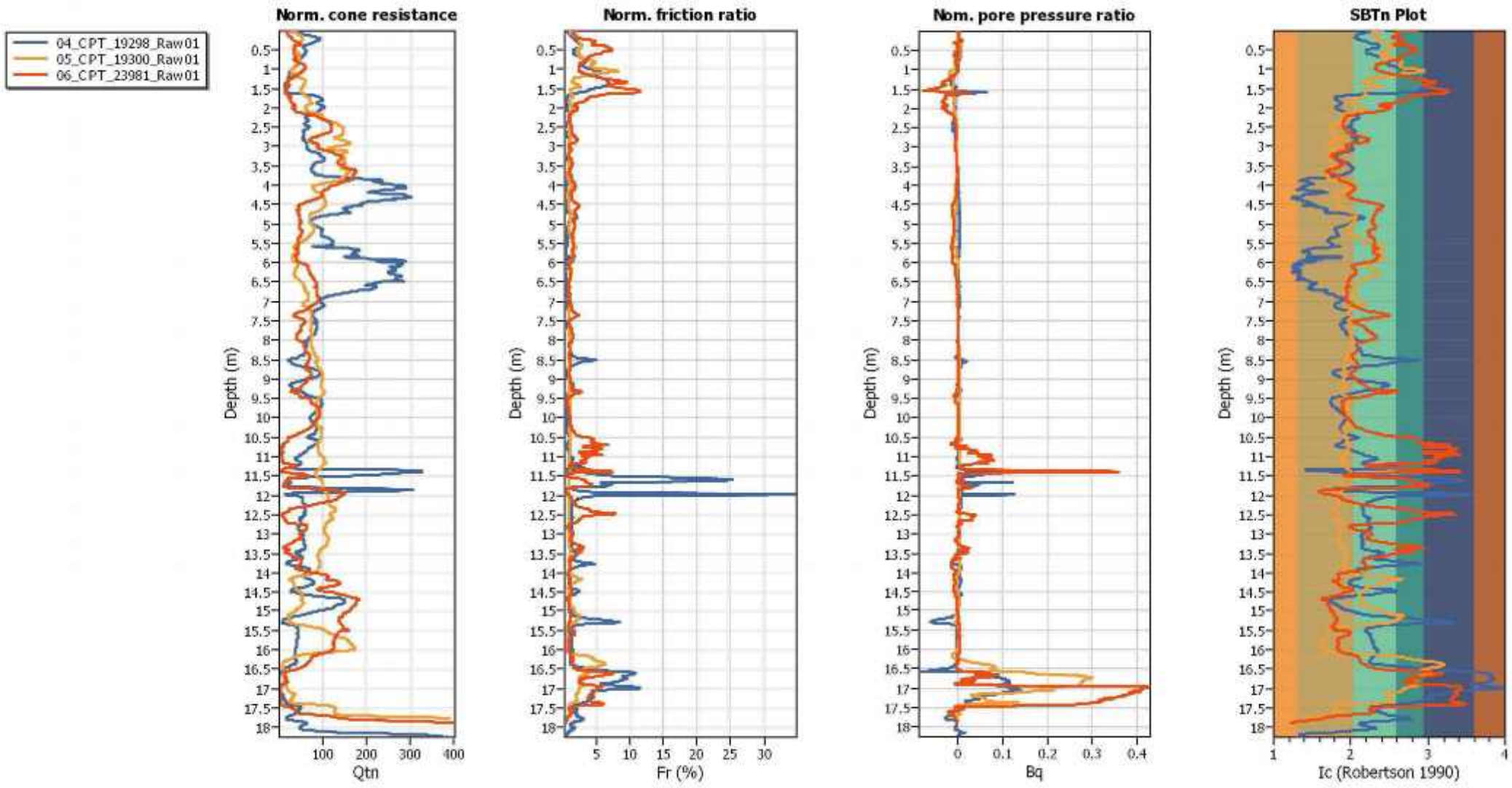
20 Moorhouse Avenue
PO Box 1482
Christchurch 8140

Project: Cresselly Place

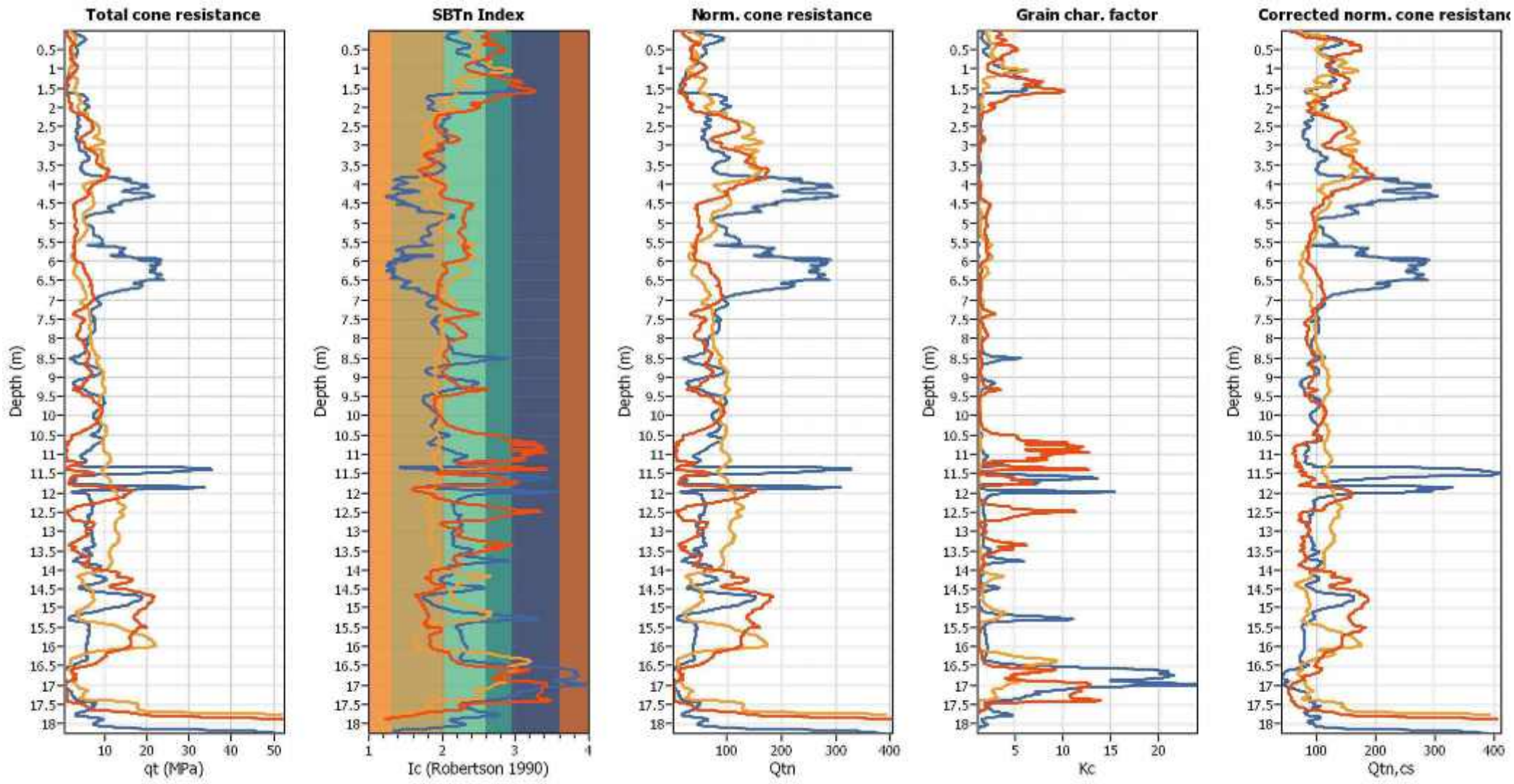
Overlay Normalized Plots



Opus International Consultants Ltd
20 Moorhouse Avenue
PO Box 1482
Christchurch 8140

Project: Cresselly Place

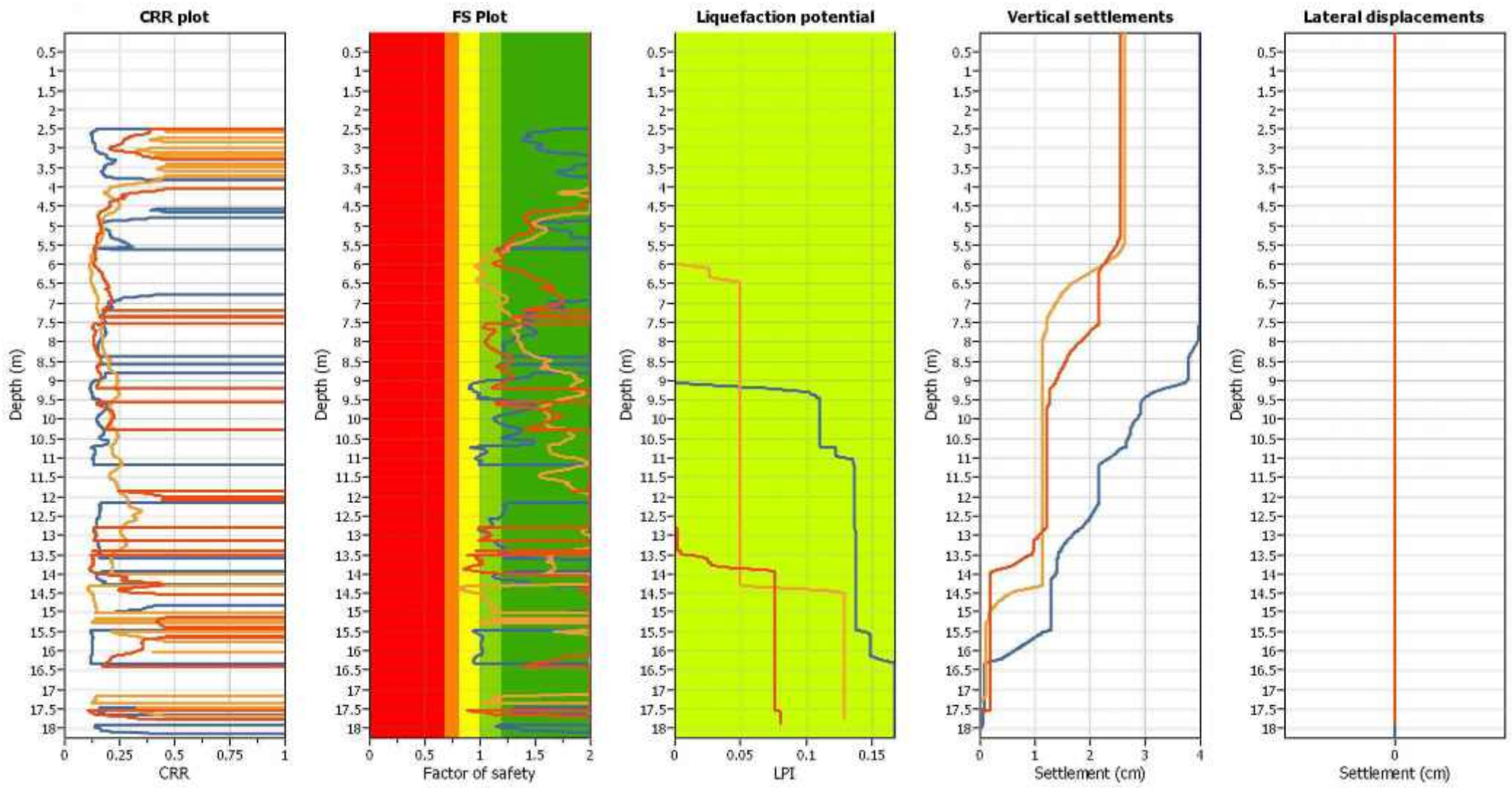
Overlay Intermediate Results



Opus International Consultants Ltd
20 Moorhouse Avenue
PO Box 1482
Christchurch 8140

Project: Cresselly Place

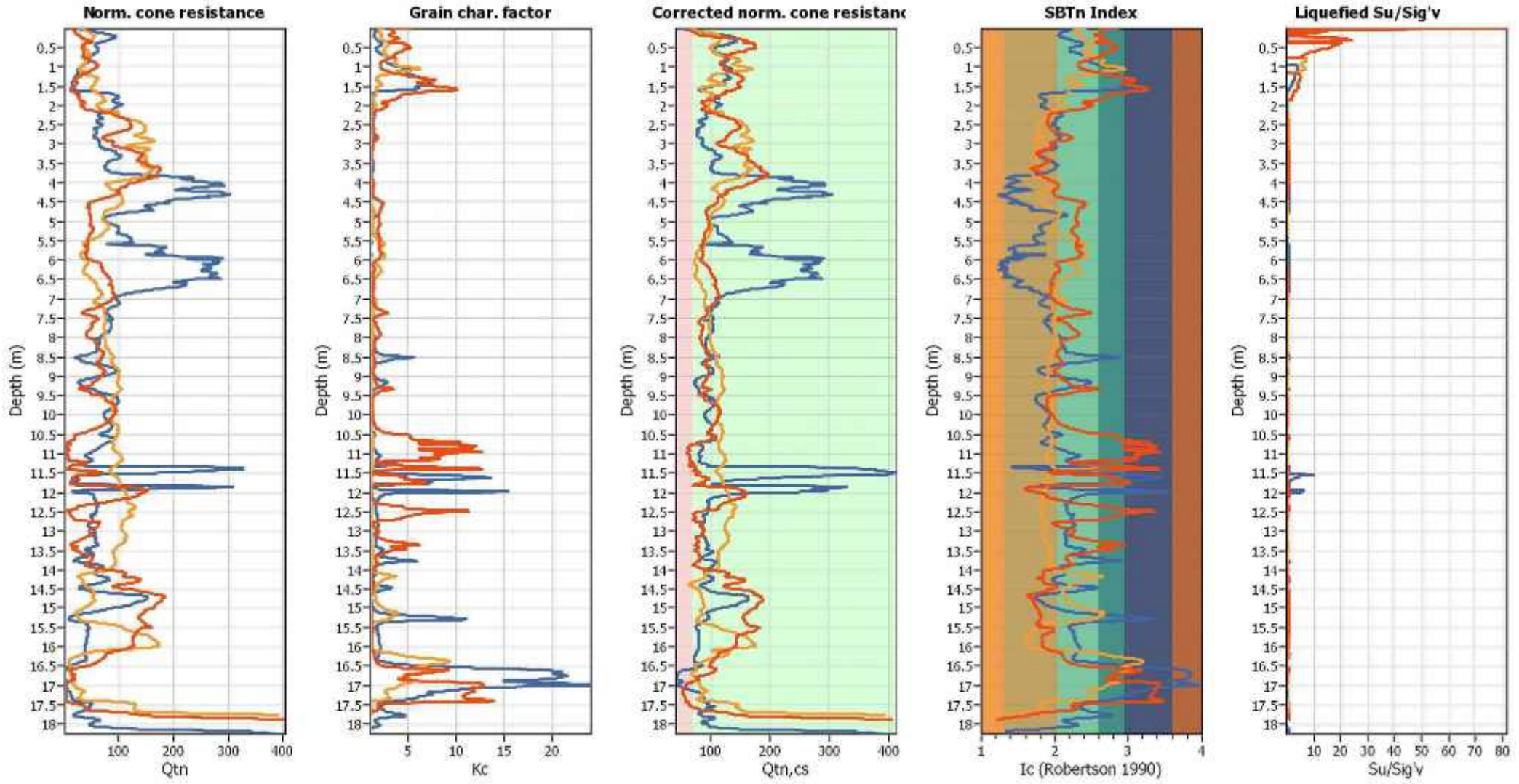
Overlay Cyclic Liquefaction Plots



Opus International Consultants Ltd
20 Moorhouse Avenue
PO Box 1482
Christchurch 8140

Project: Cresselly Place

Overlay Strength Loss Plots



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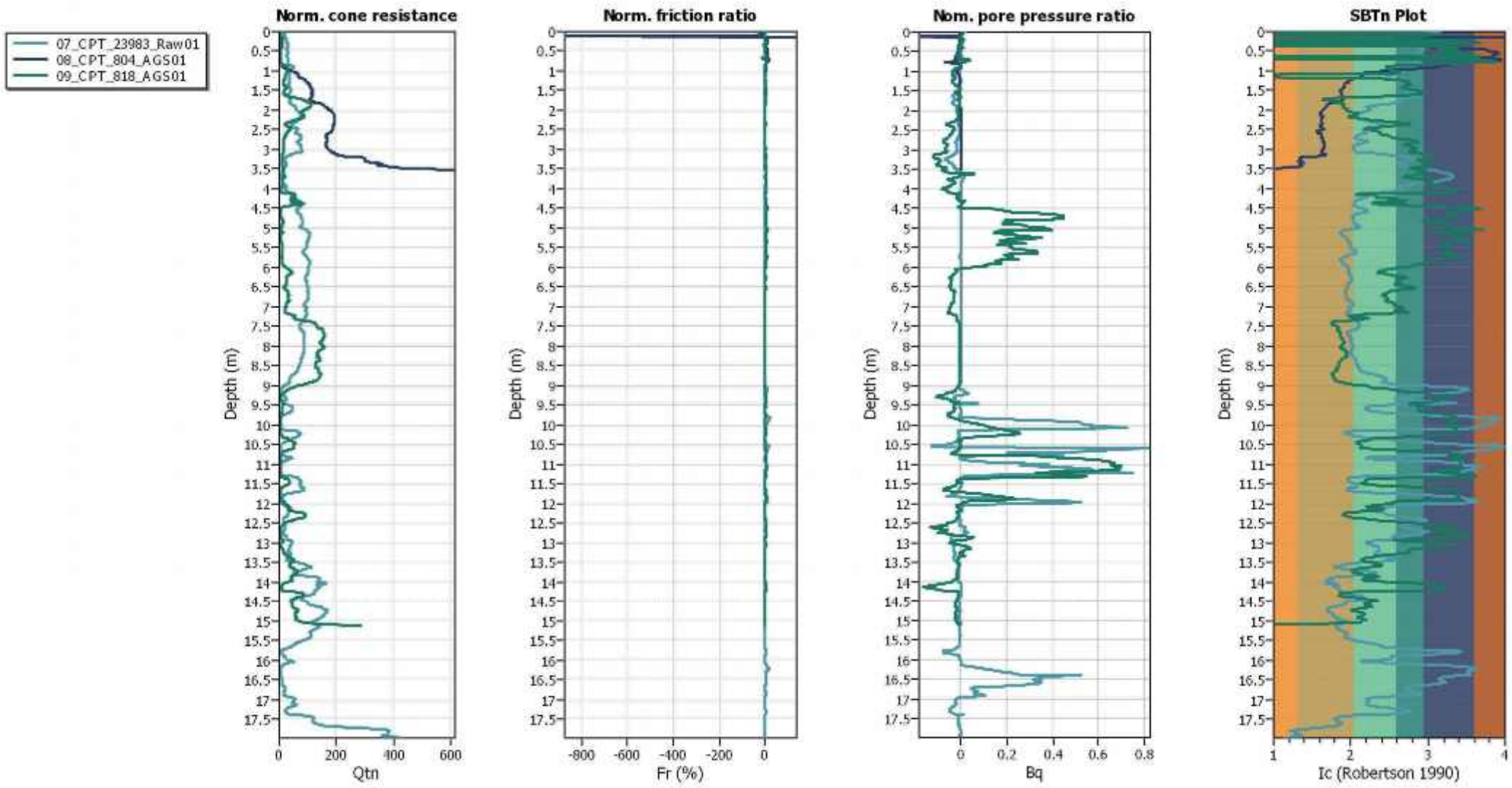
Project: Cresselly Place

Overlay Normalized Plots



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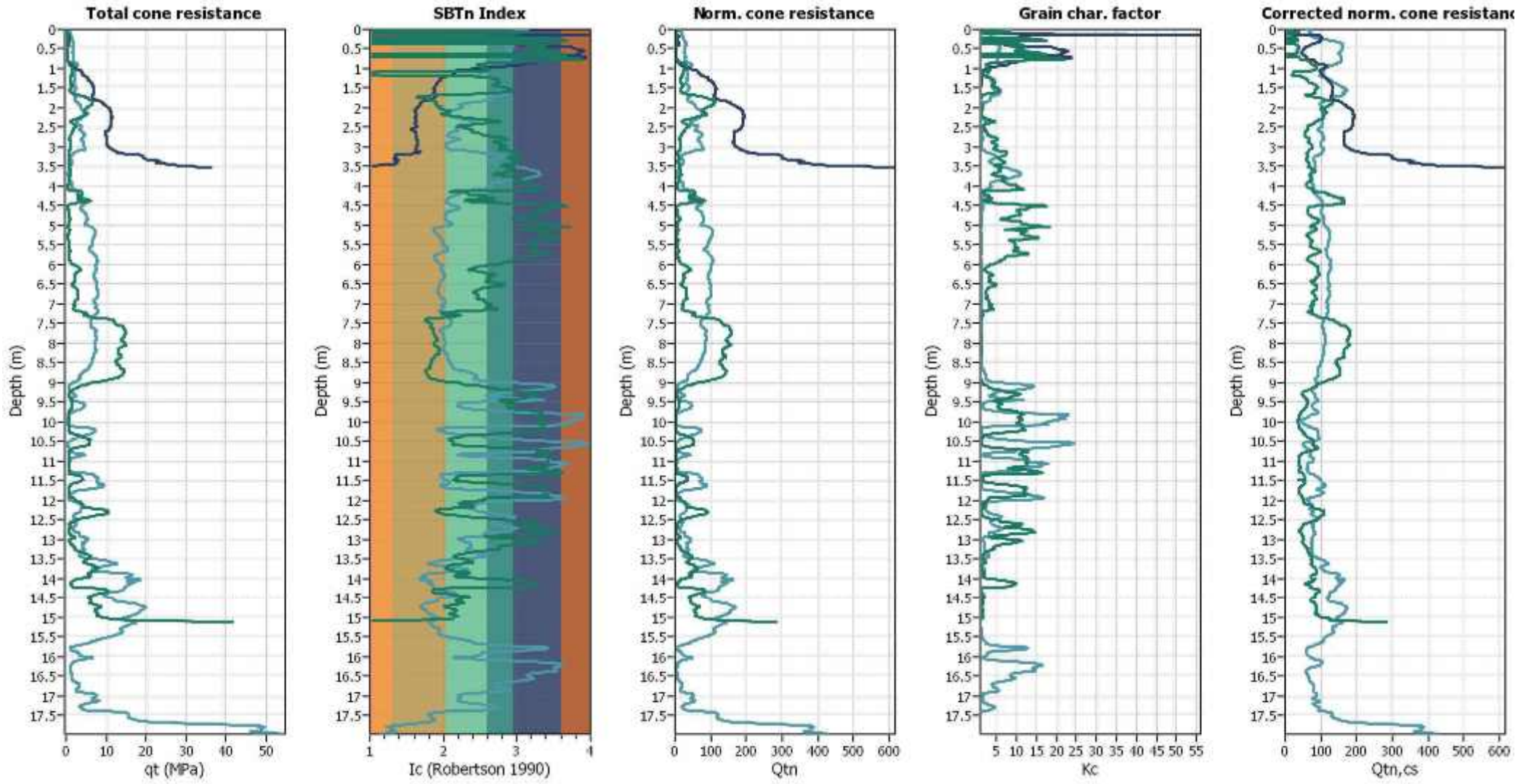
Project: Cresselly Place

Overlay Intermediate Results



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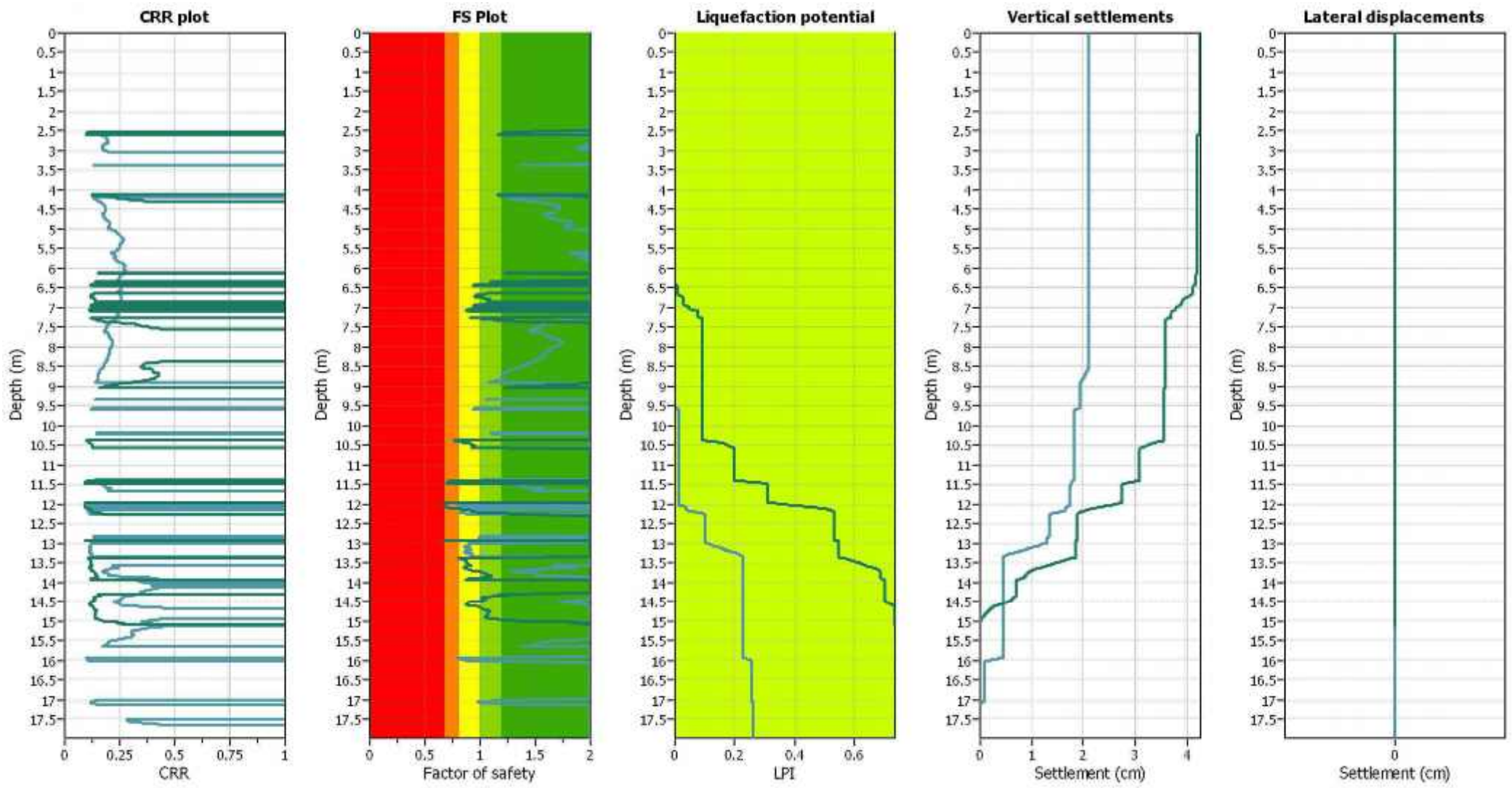
Project: Cresselly Place

Overlay Cyclic Liquefaction Plots



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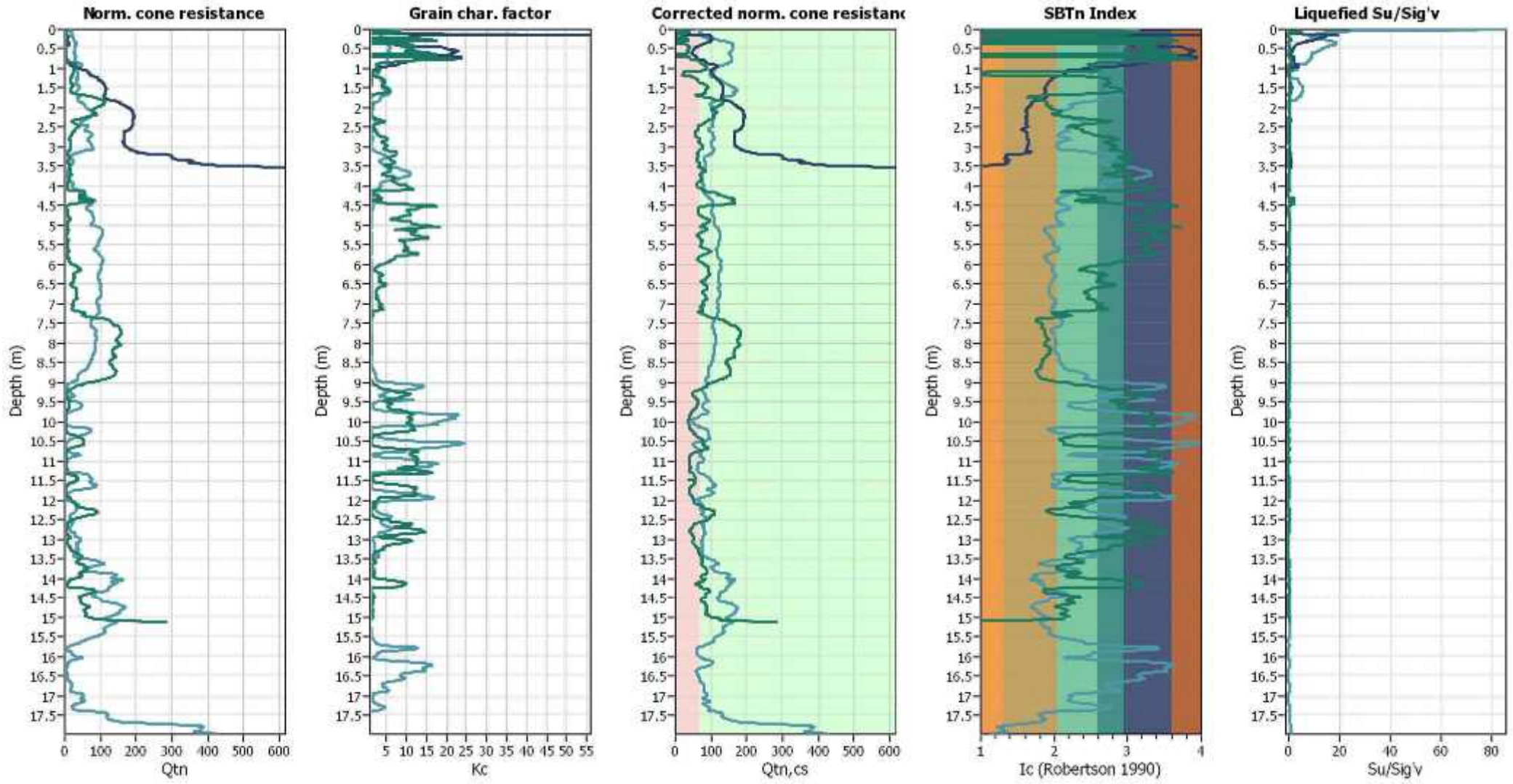
Project: Cresselly Place

Overlay Strength Loss Plots



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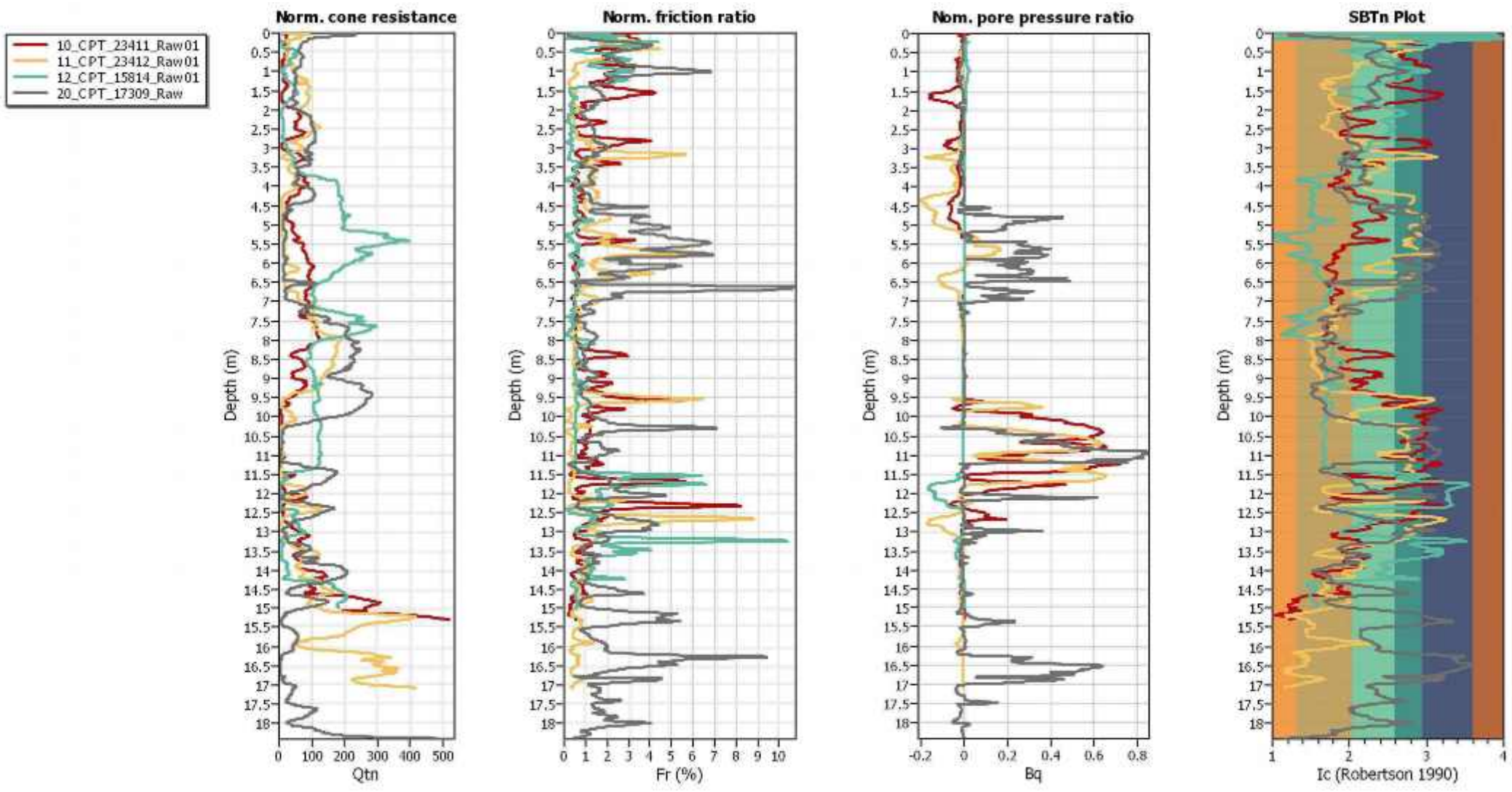
Project: Cresselly Place

Overlay Normalized Plots



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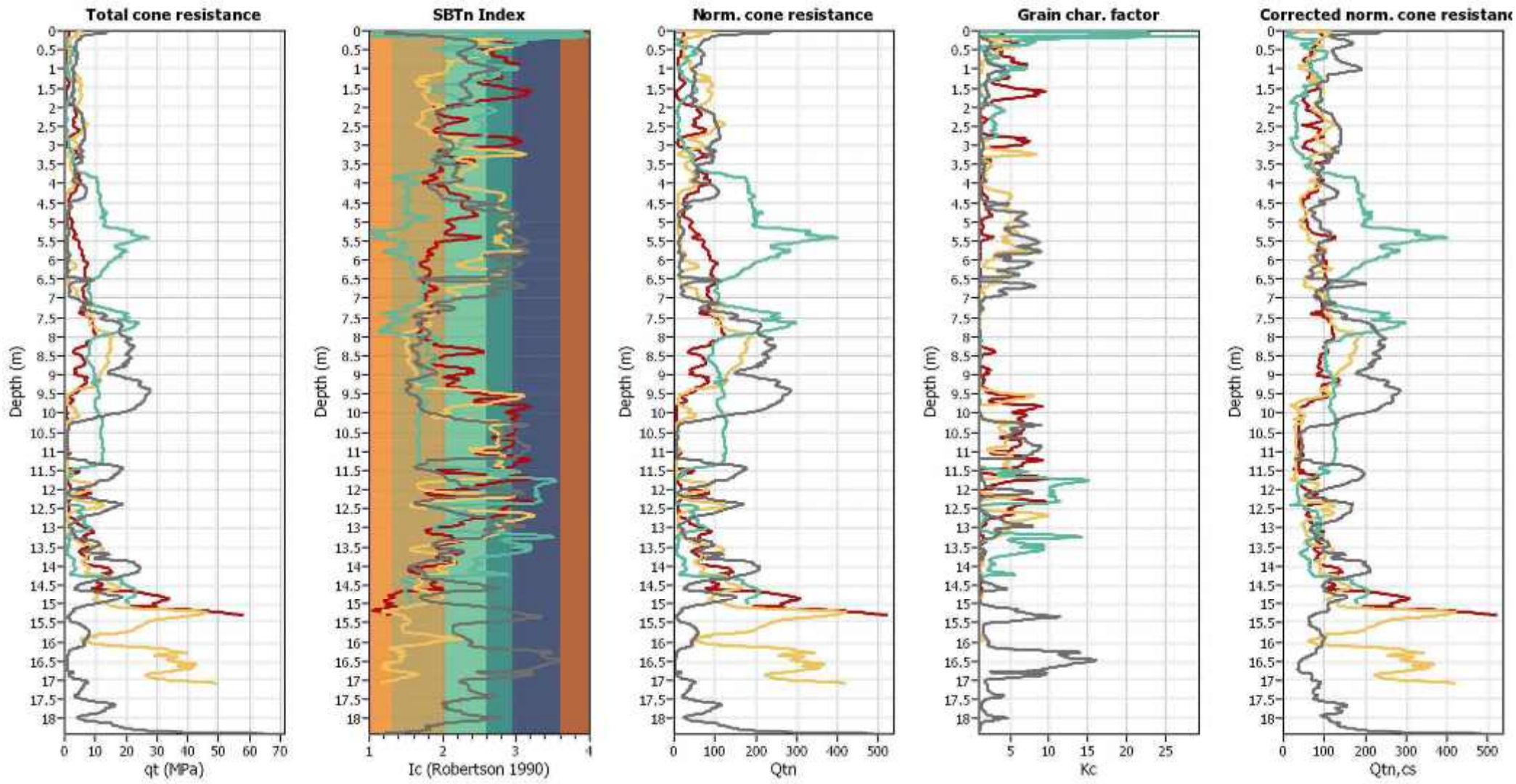
Overlay Intermediate Results



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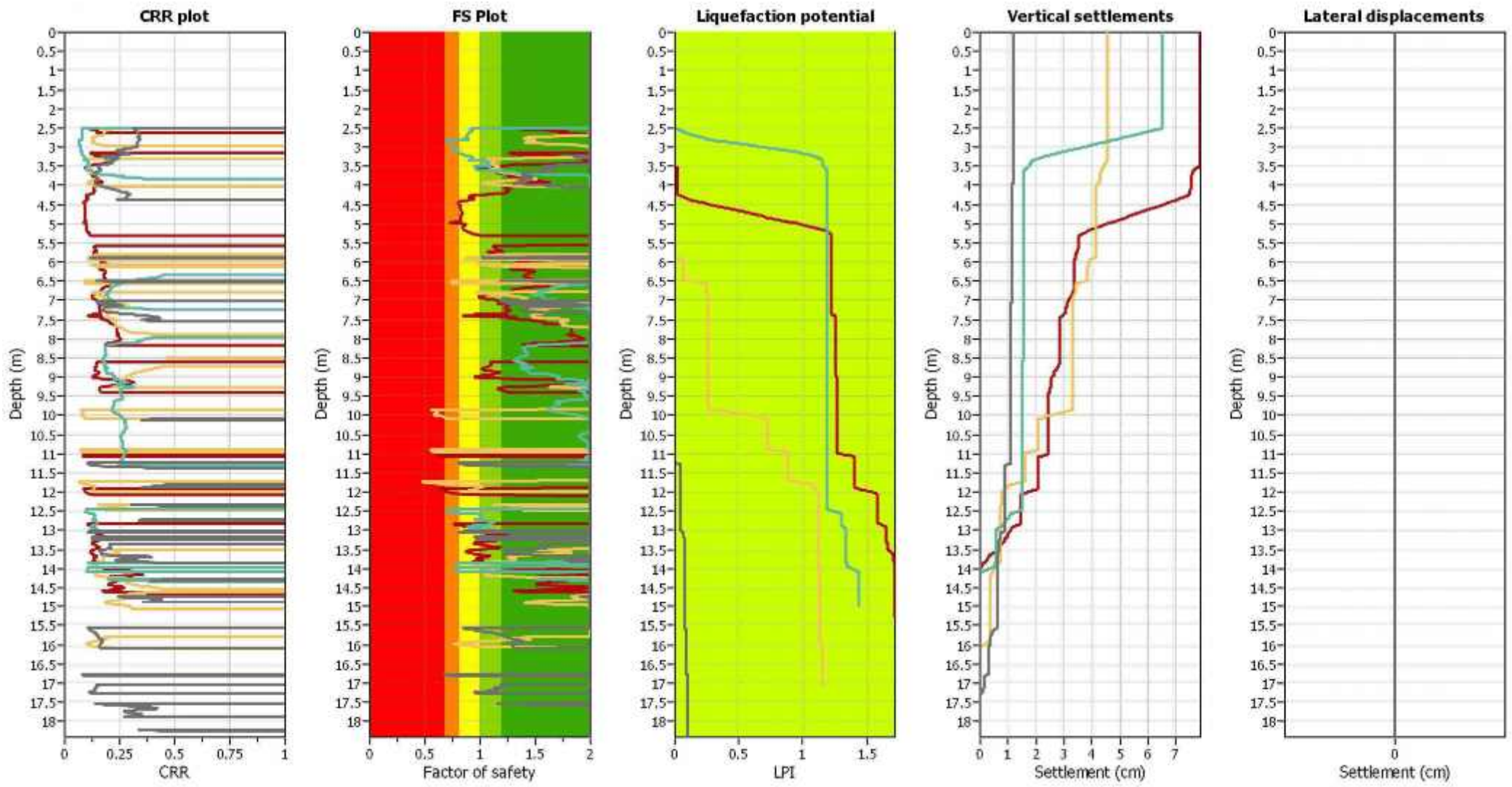
Project: Cresselly Place

Overlay Cyclic Liquefaction Plots



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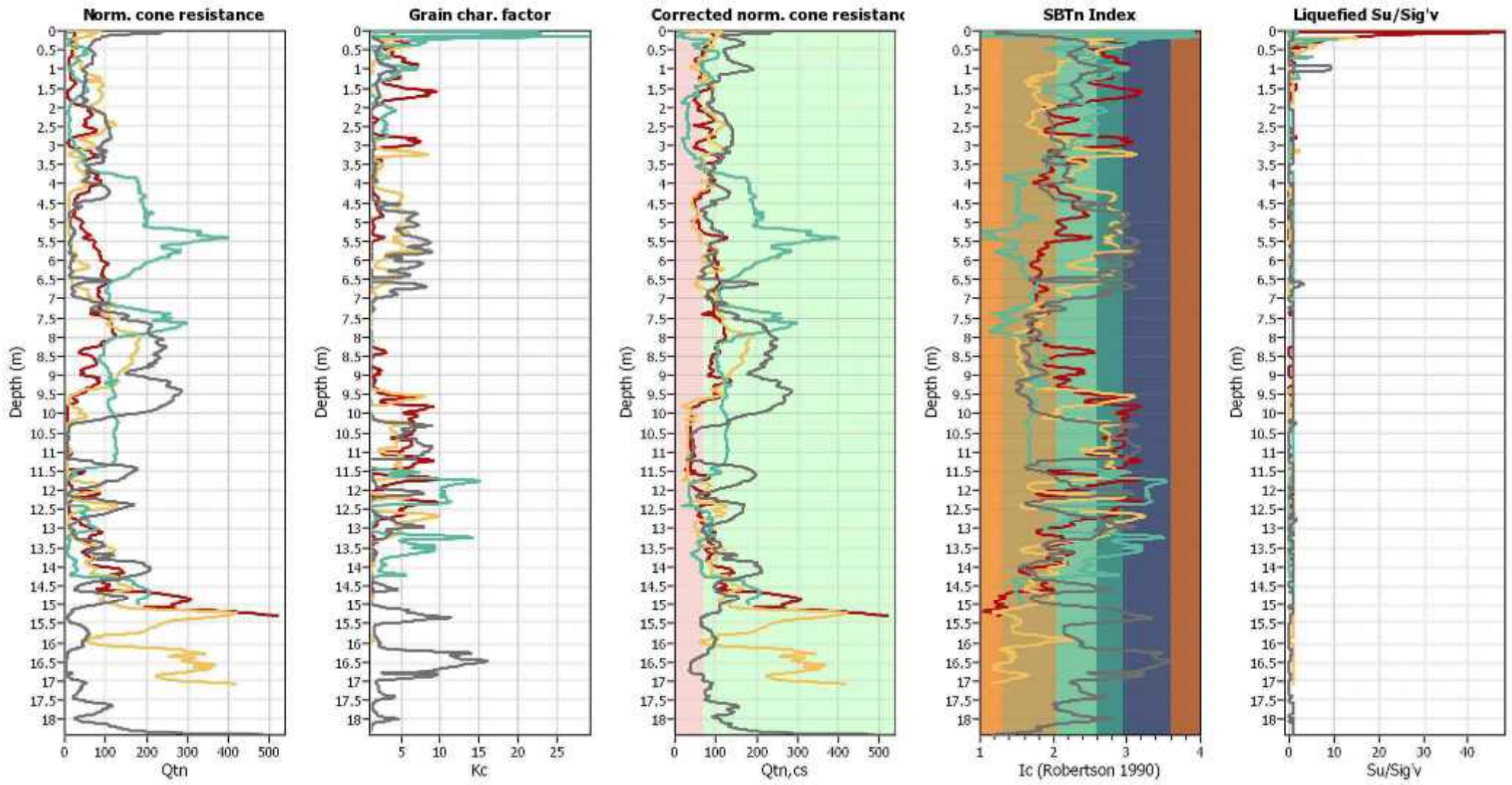
Overlay Strength Loss Plots



Appendix E.2

CLiq Idriss and Boulanger (2008) SLS1 Liquefaction Analysis Output

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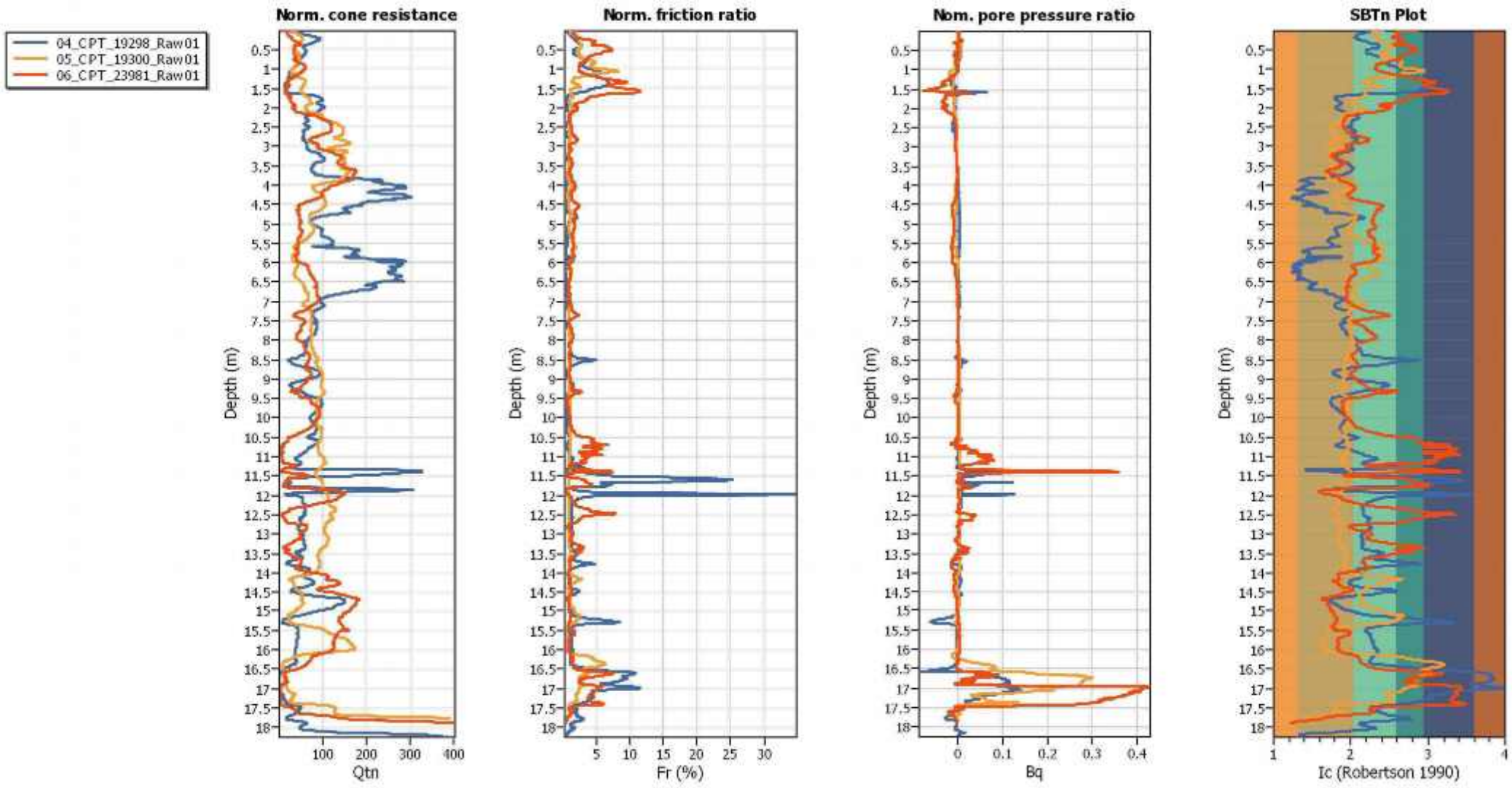
Overlay Normalized Plots



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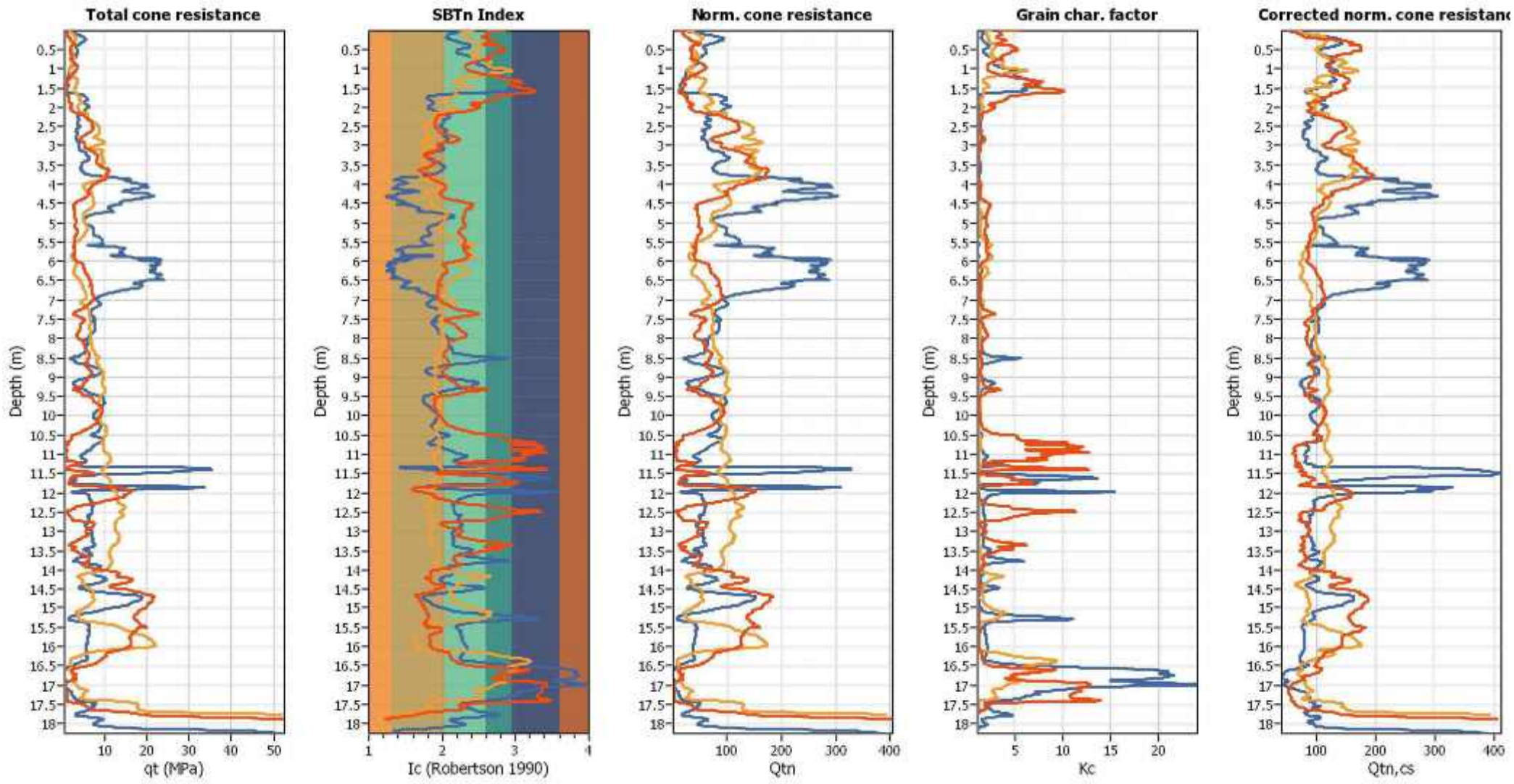
Project: Cresselly Place

Overlay Intermediate Results



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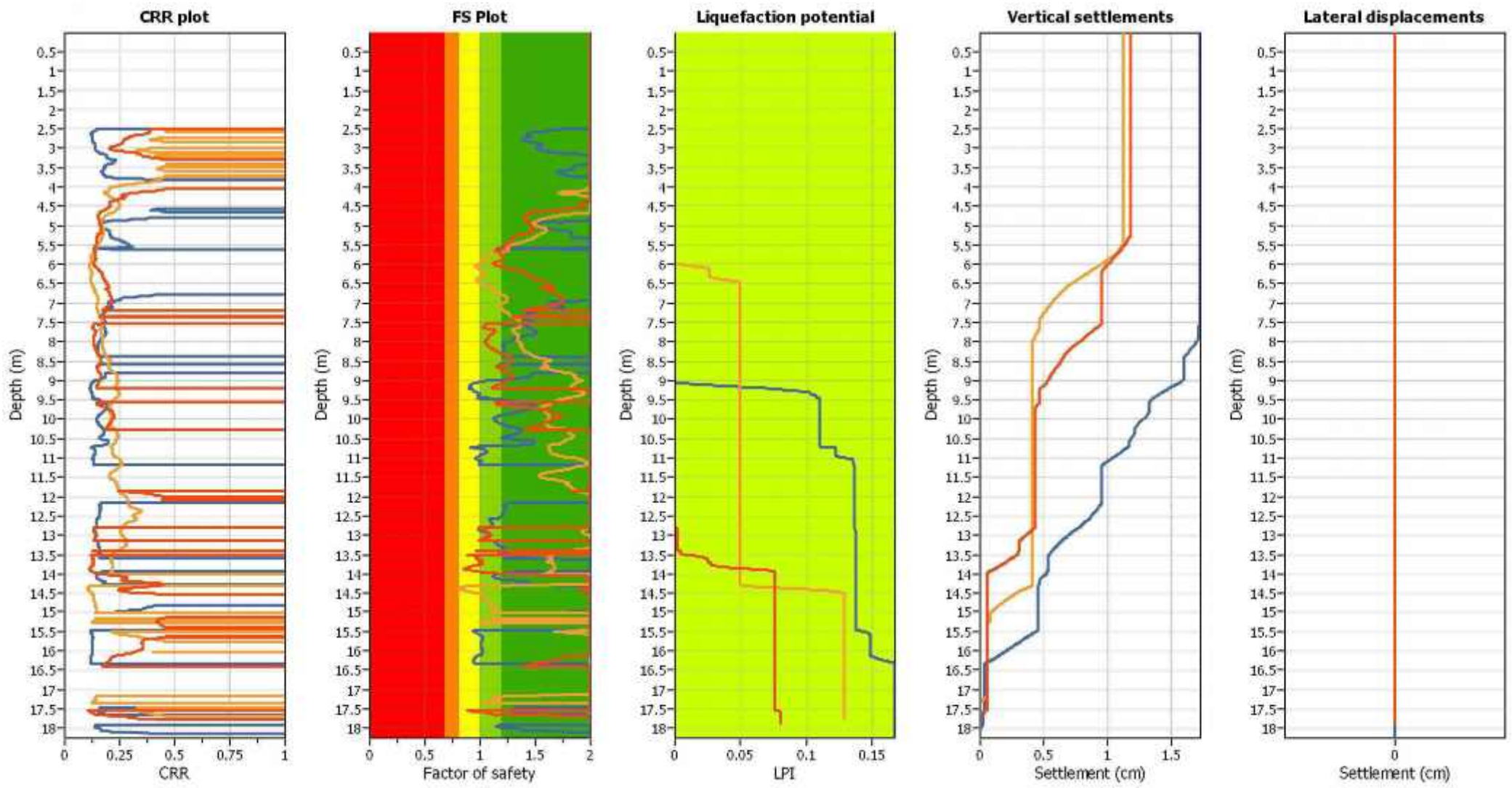
Project: Cresselly Place

Overlay Cyclic Liquefaction Plots



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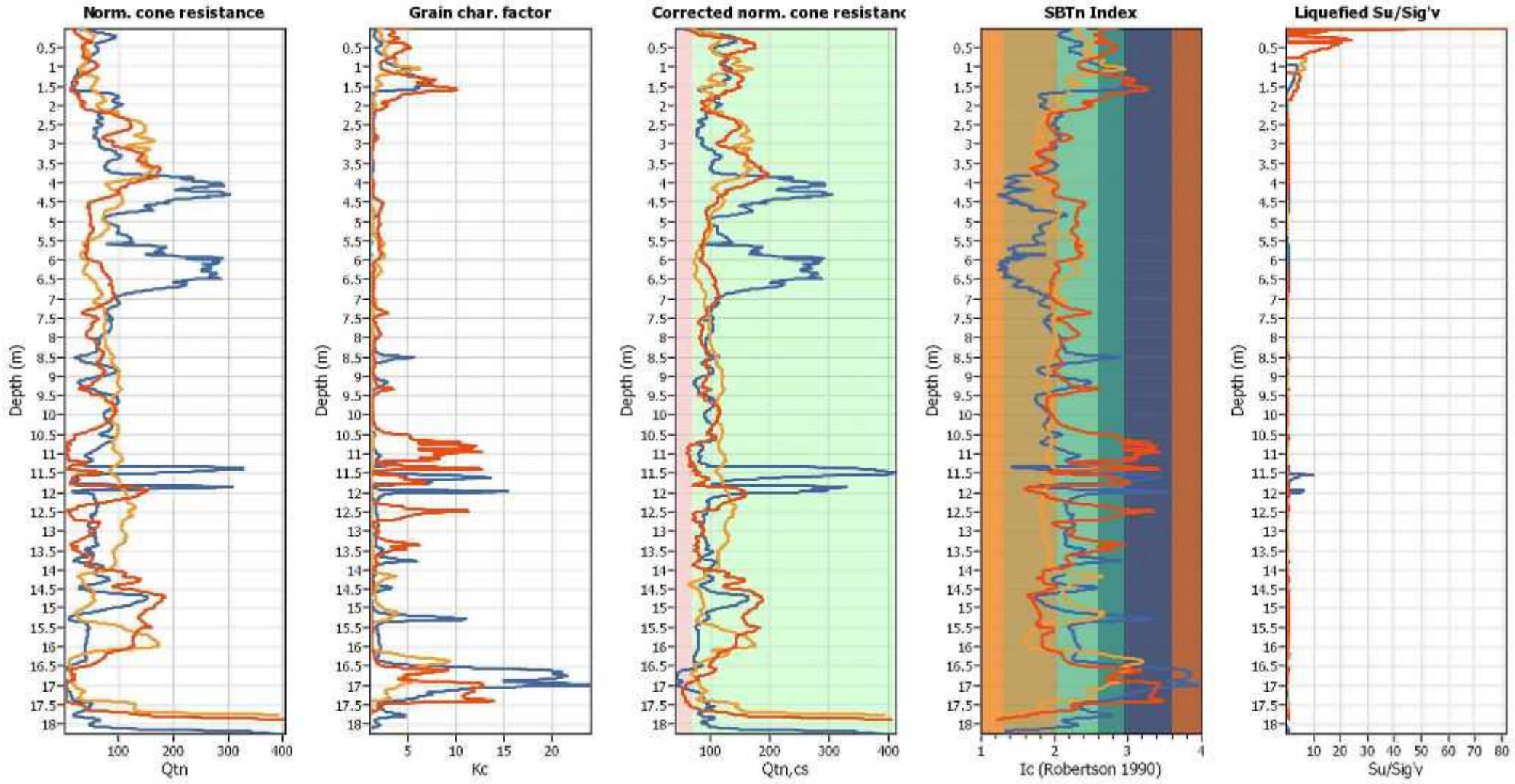
Project: Cresselly Place

Overlay Strength Loss Plots



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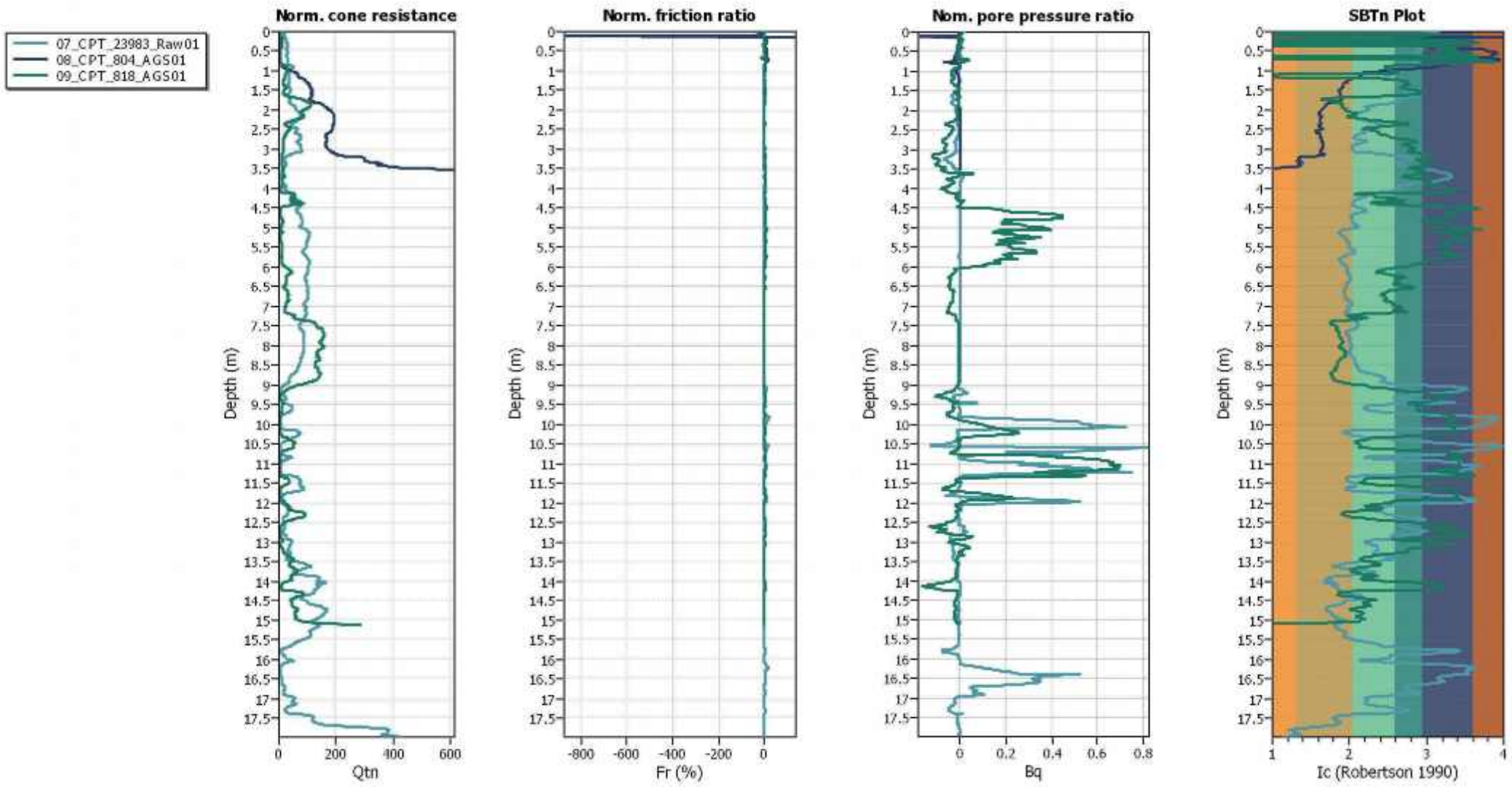
Project: Cresselly Place

Overlay Normalized Plots



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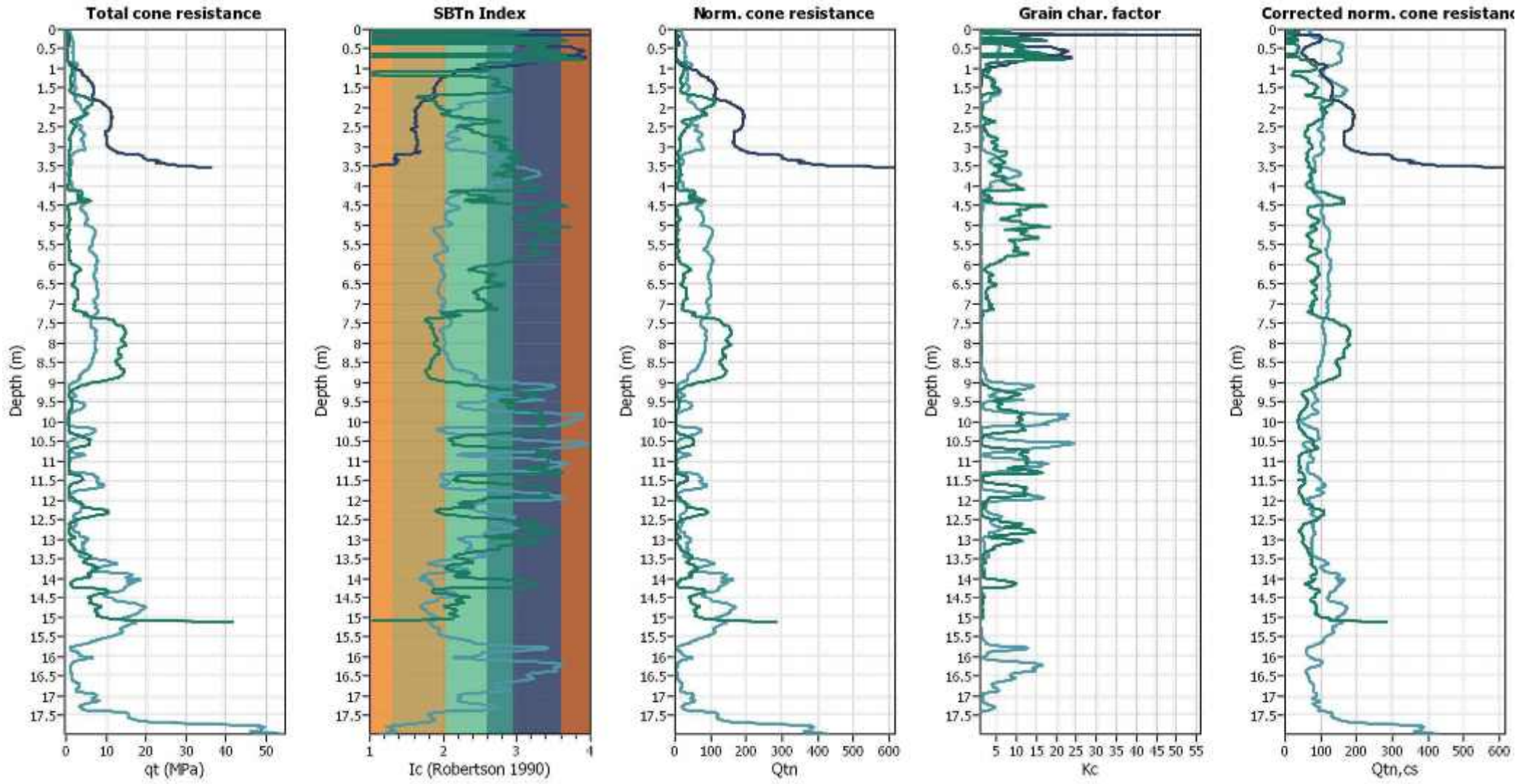
Project: Cresselly Place

Overlay Intermediate Results



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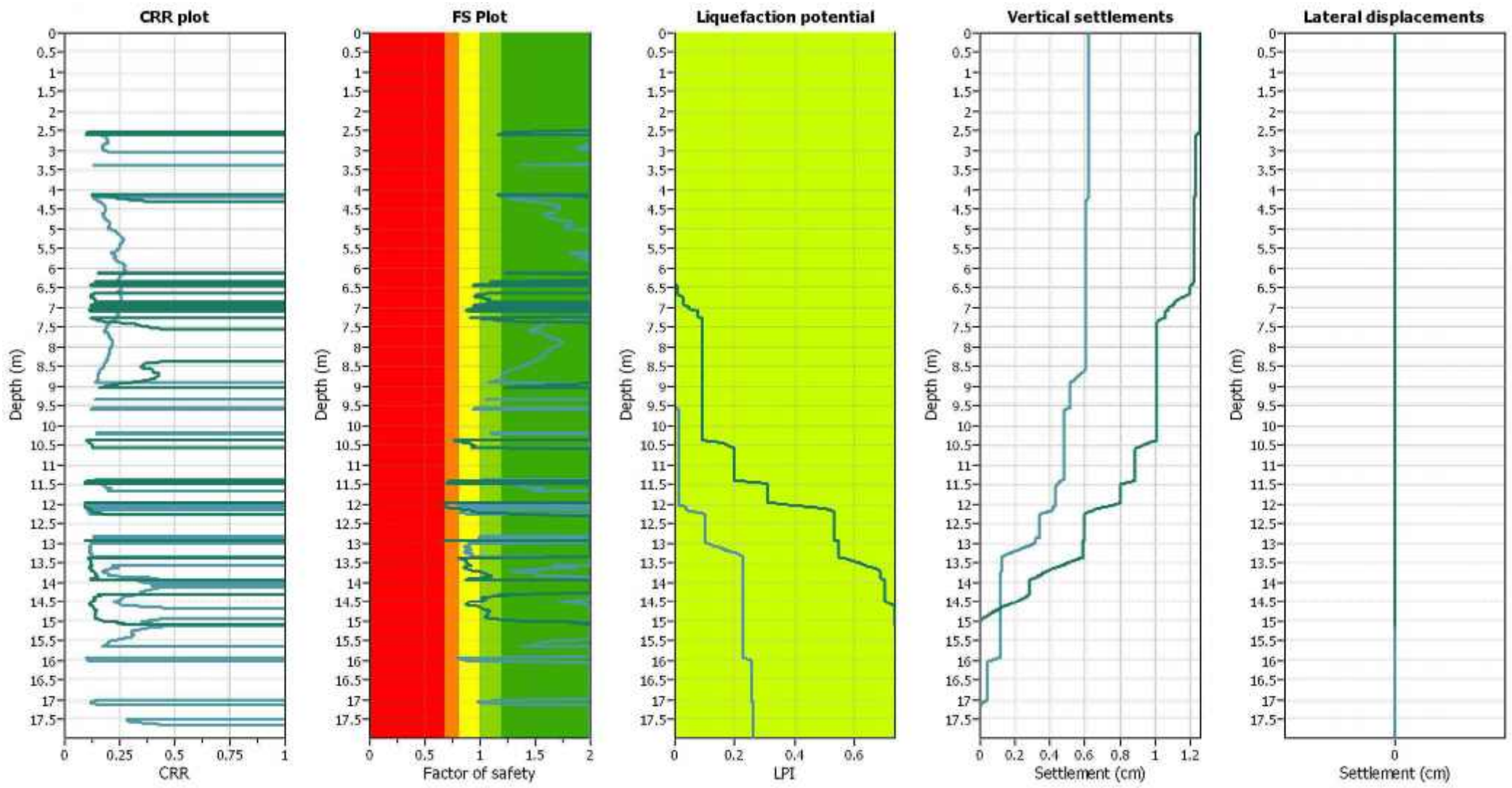
Project: Cresselly Place

Overlay Cyclic Liquefaction Plots



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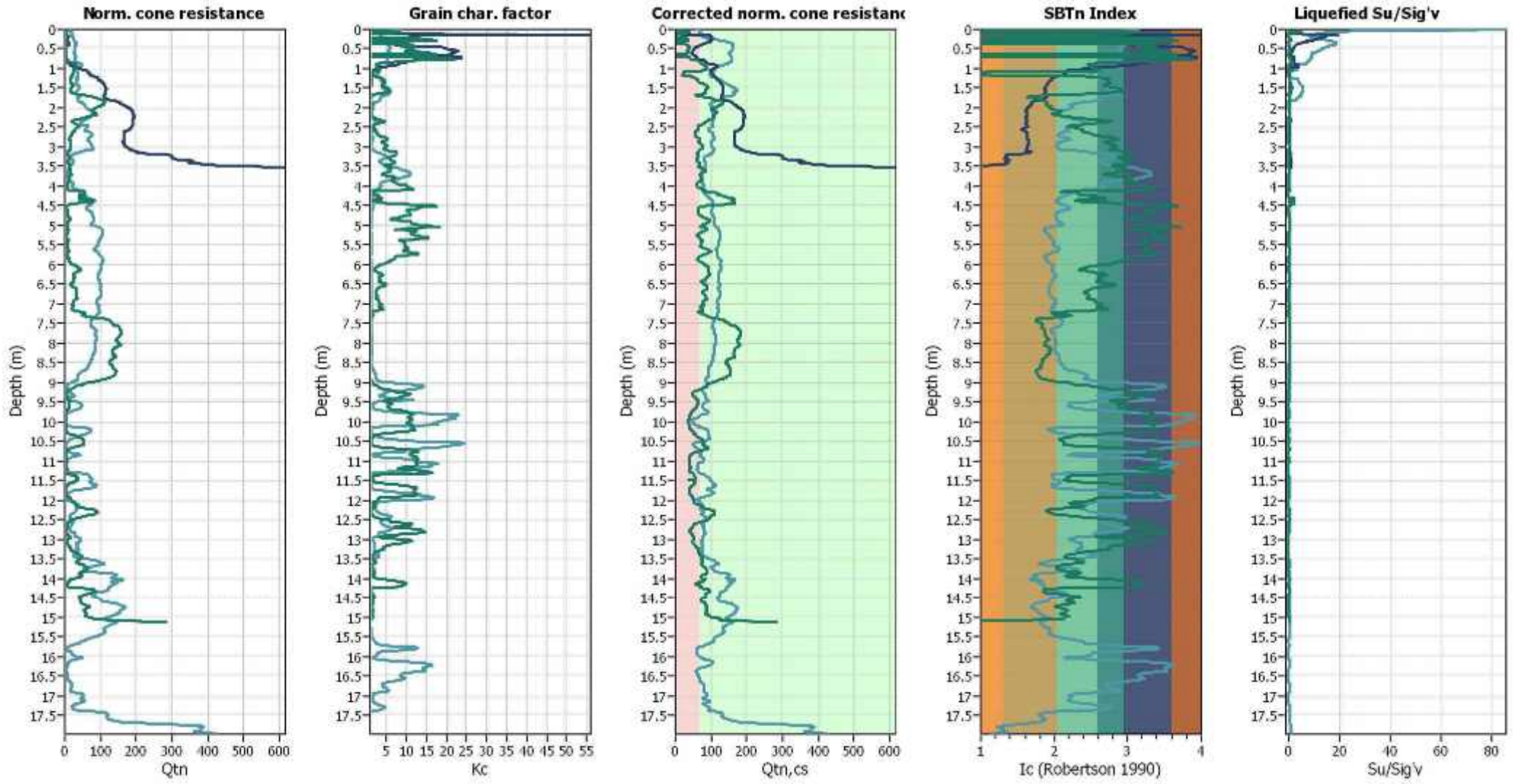
Project: Cresselly Place

Overlay Strength Loss Plots



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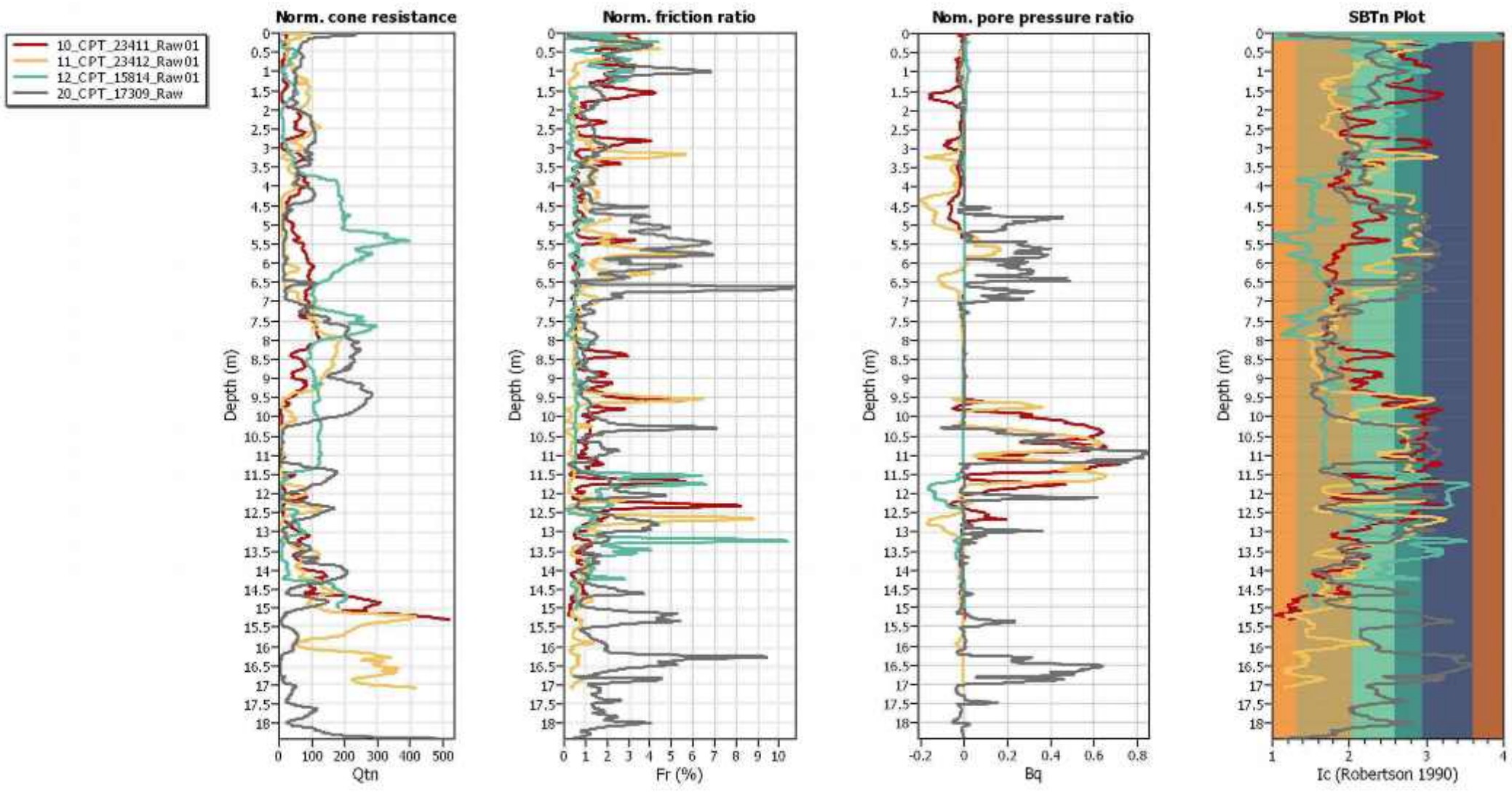
Project: Cresselly Place

Overlay Normalized Plots



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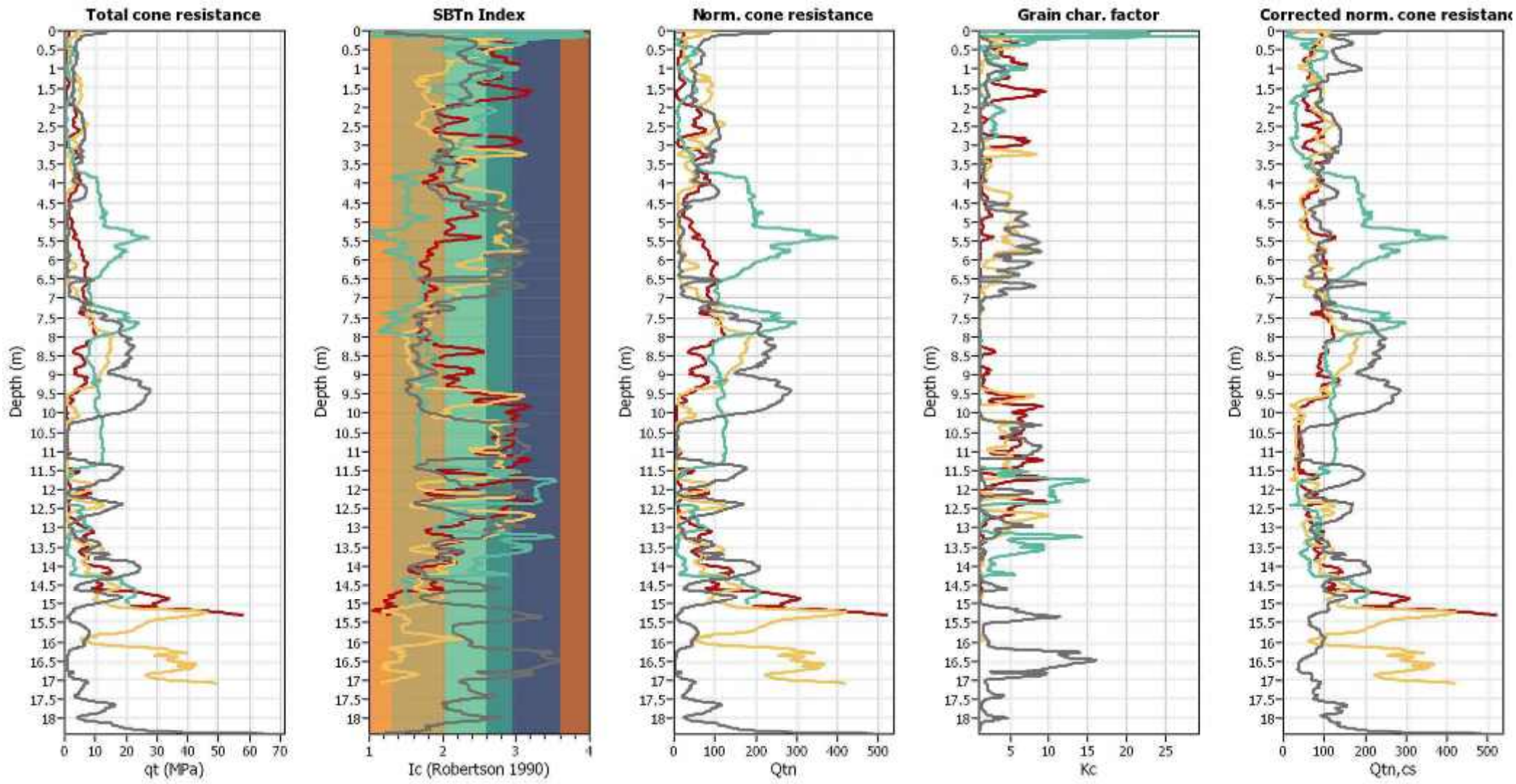
Overlay Intermediate Results



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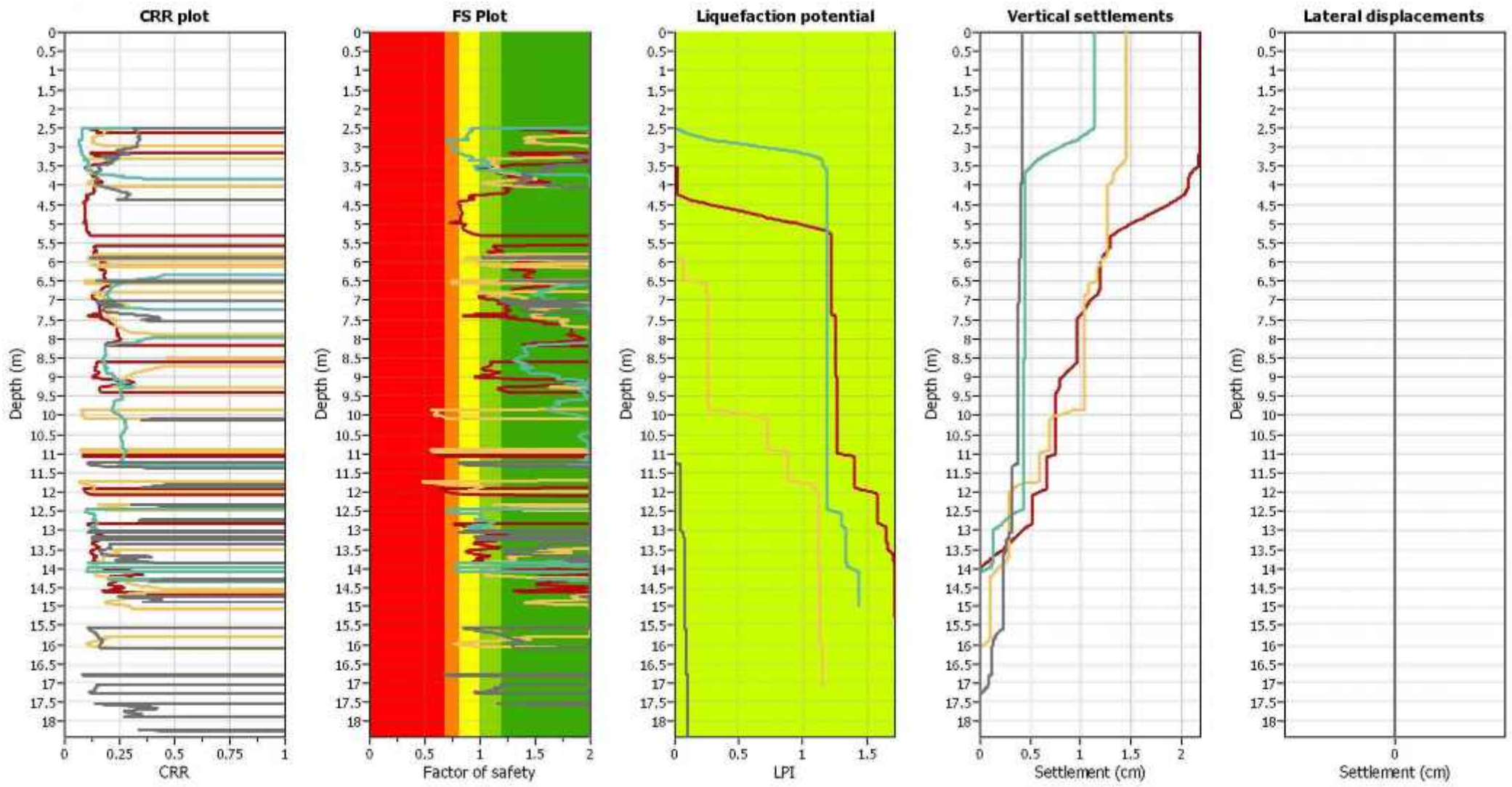
Overlay Cyclic Liquefaction Plots



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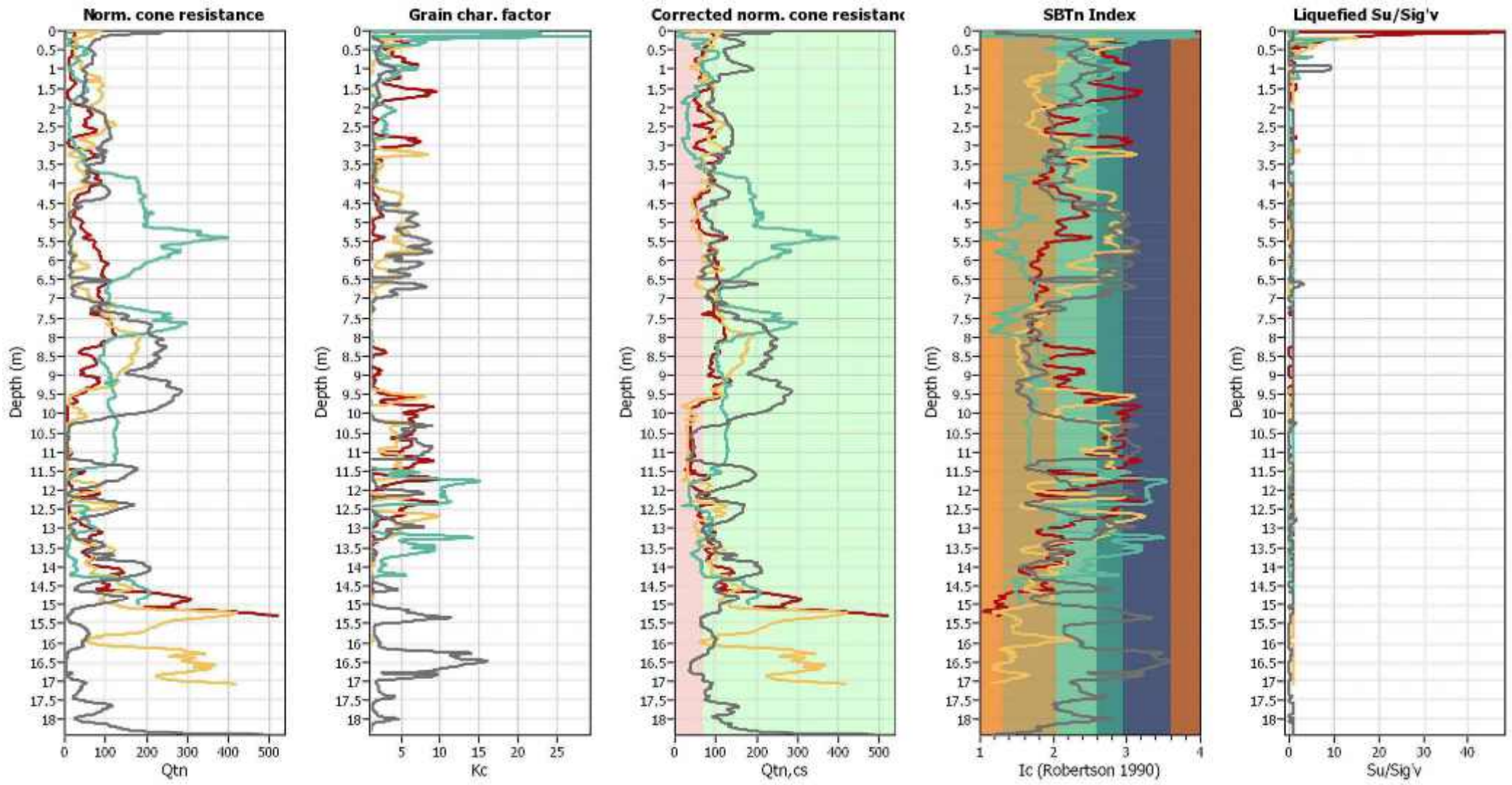
Overlay Strength Loss Plots



Appendix E.3

CLiq NCEER (1998) ULS Liquefaction Analysis Output

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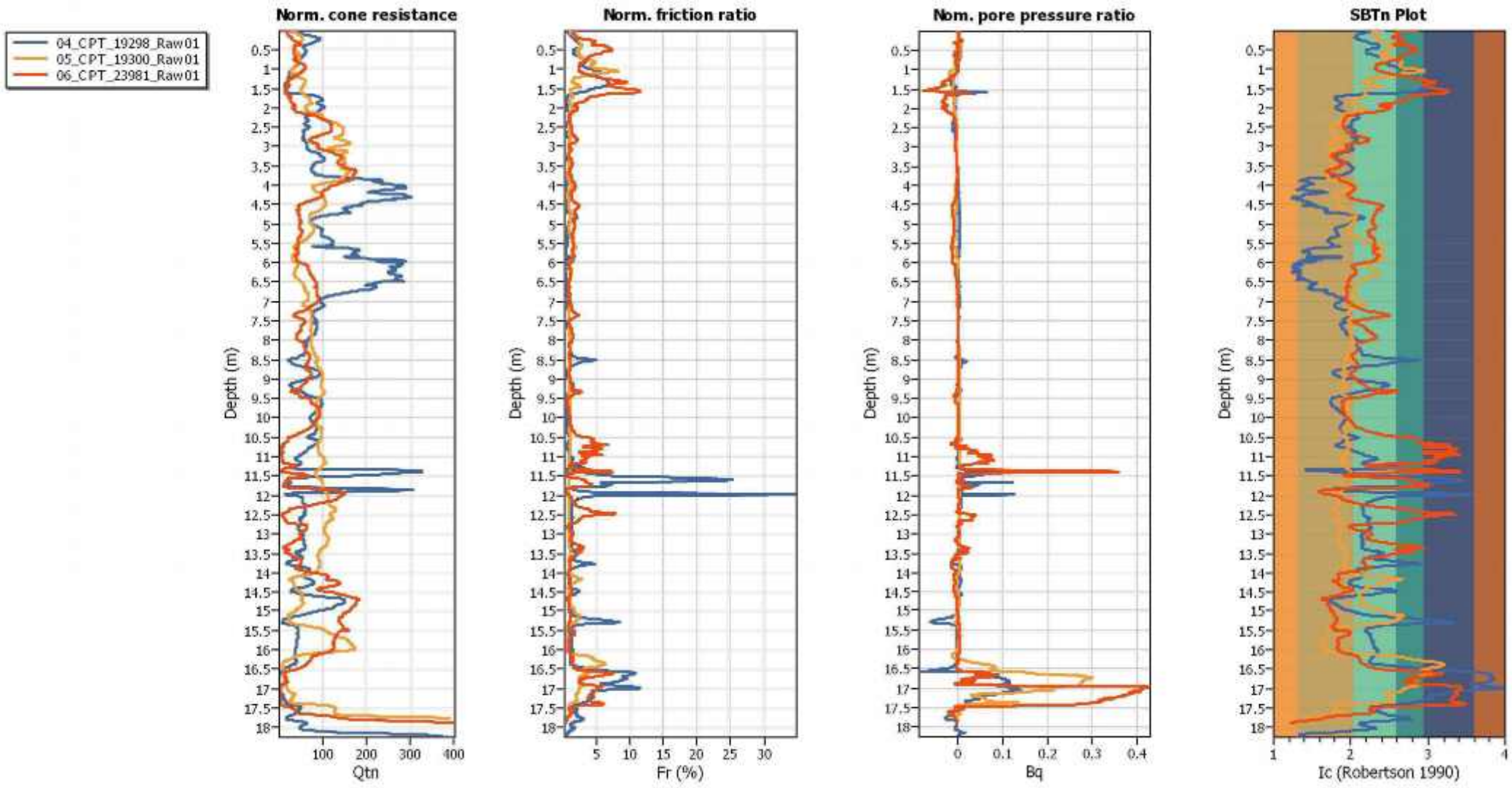
Project: Cresselly Place

Overlay Normalized Plots



Opus International Consultants Ltd
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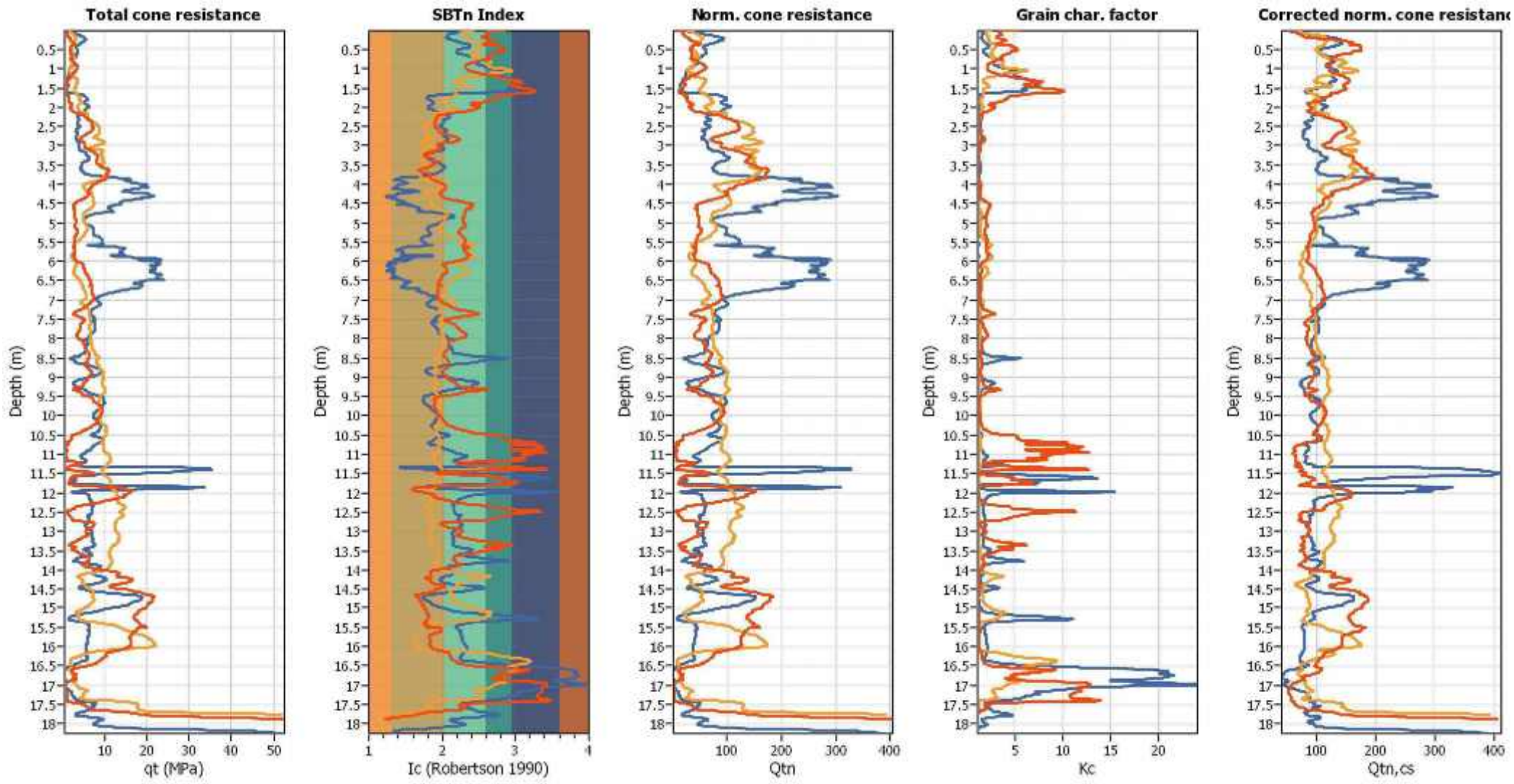
PO Box 1482
Christchurch 8140

Project: Cresselly Place

Overlay Intermediate Results



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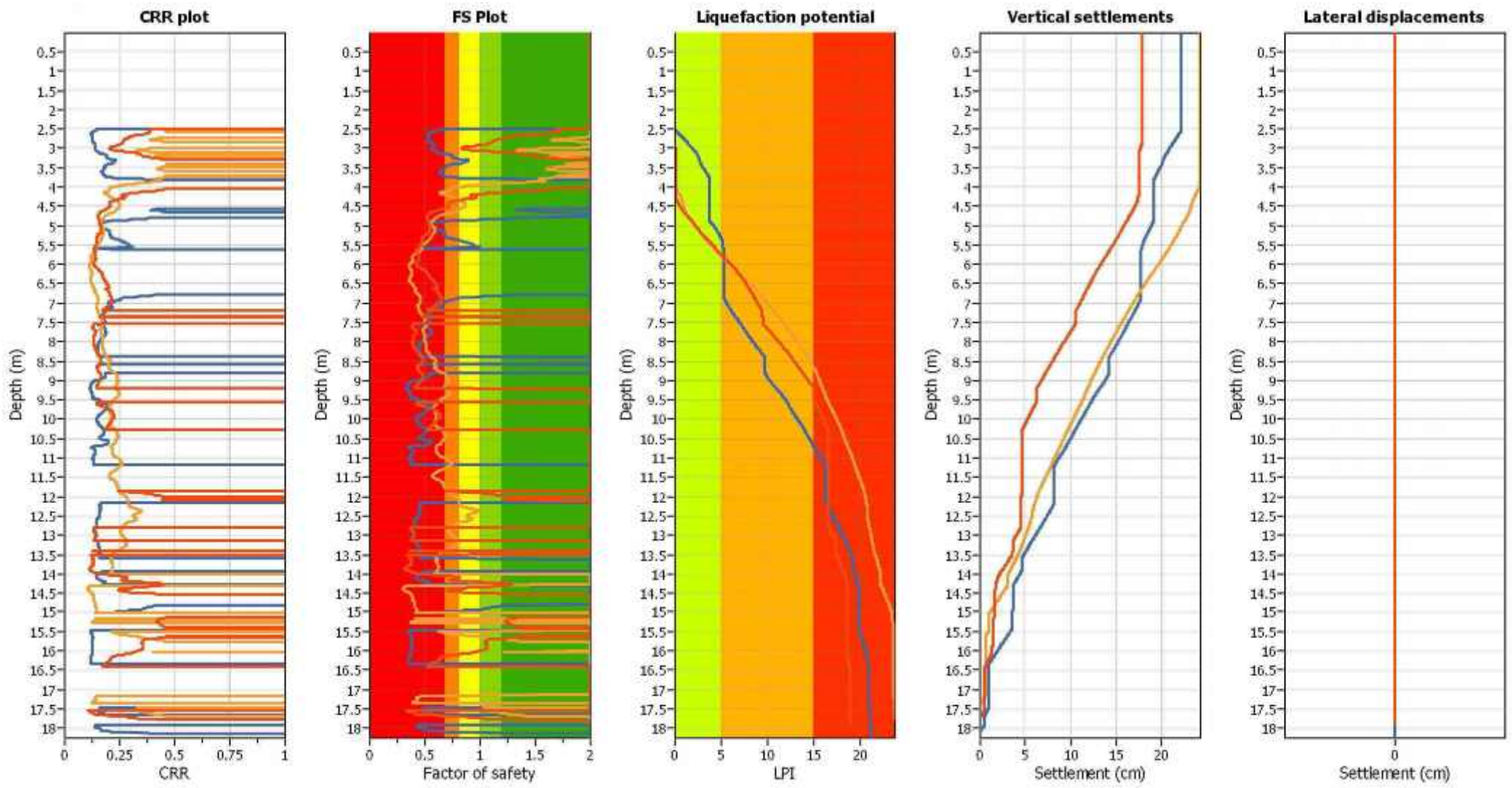
Christchurch 8140

Project: Cresselly Place

Overlay Cyclic Liquefaction Plots



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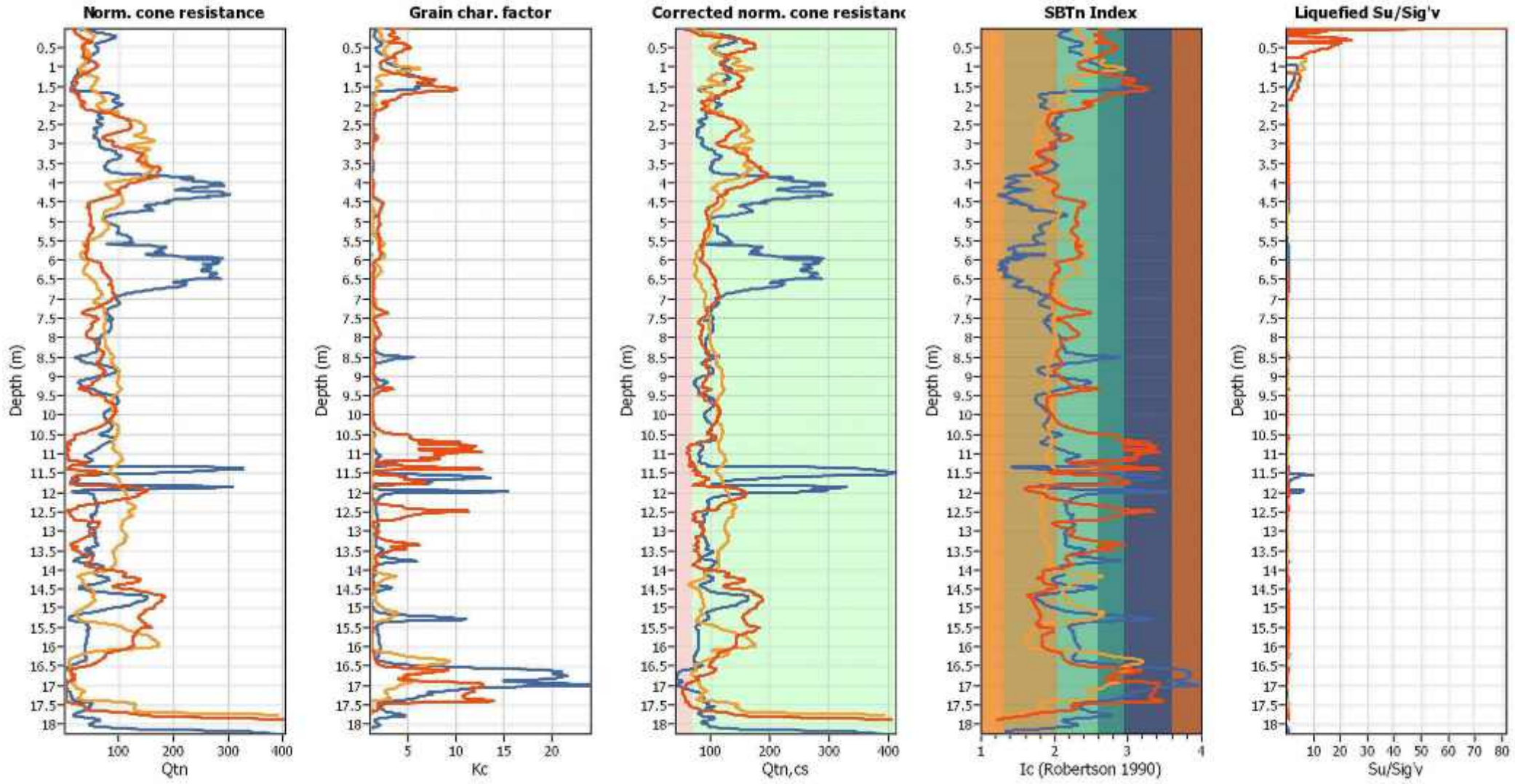
Project: Cresselly Place

Overlay Strength Loss Plots



Opus International Consultants Ltd
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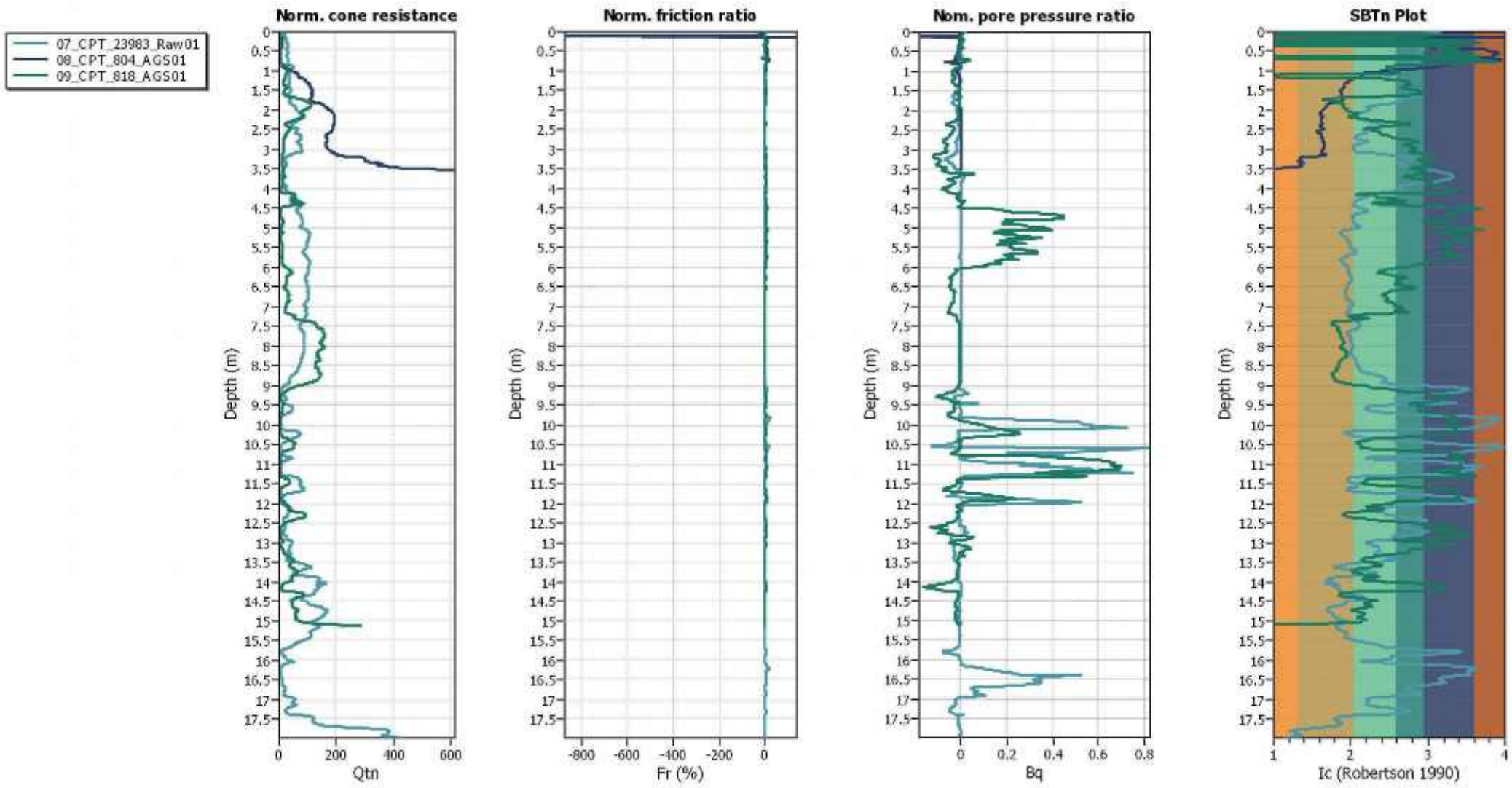
Christchurch 8140

Project: Cresselly Place

Overlay Normalized Plots



Opus International Consultants Ltd
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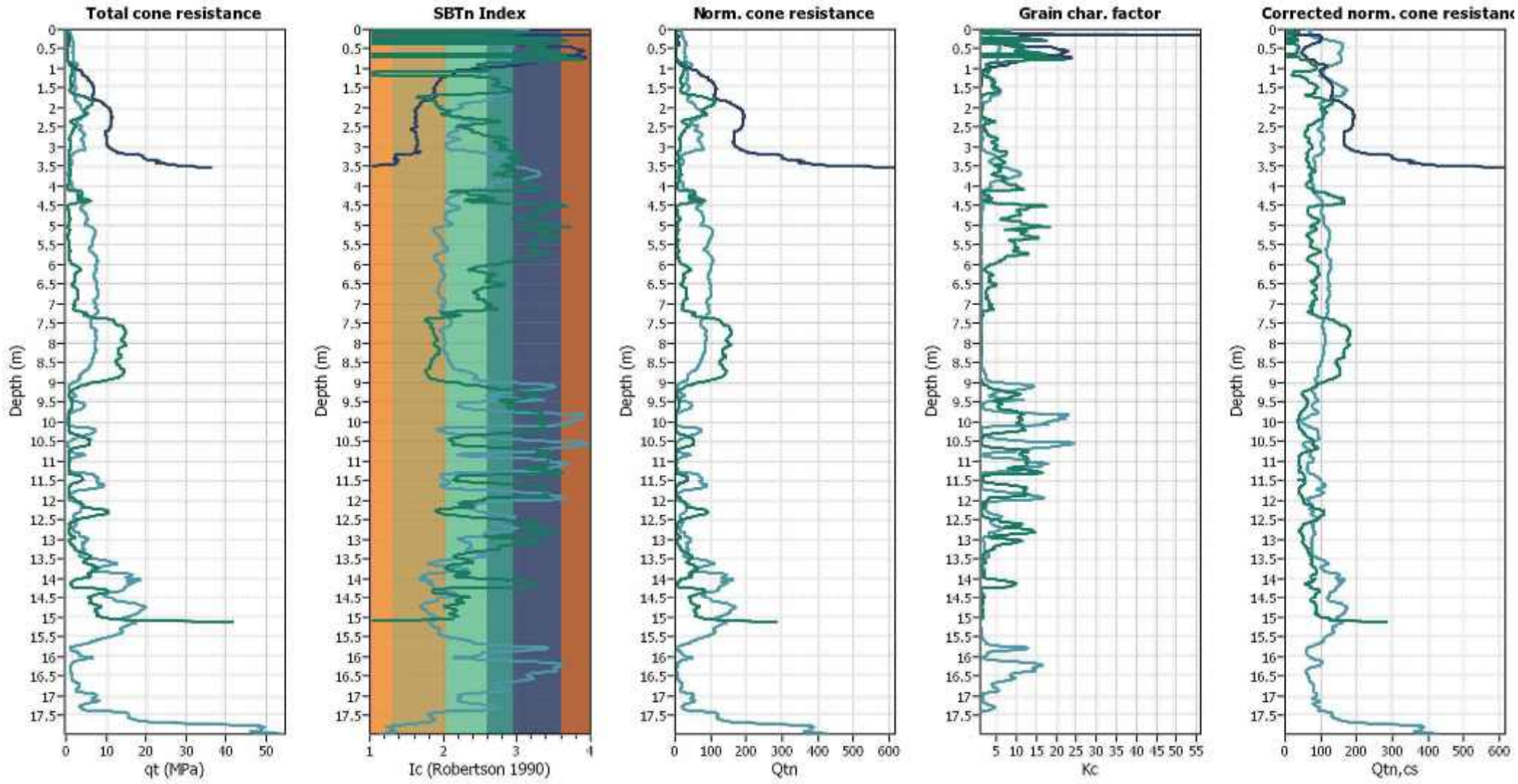
Christchurch 8140

Project: Cresselly Place

Overlay Intermediate Results



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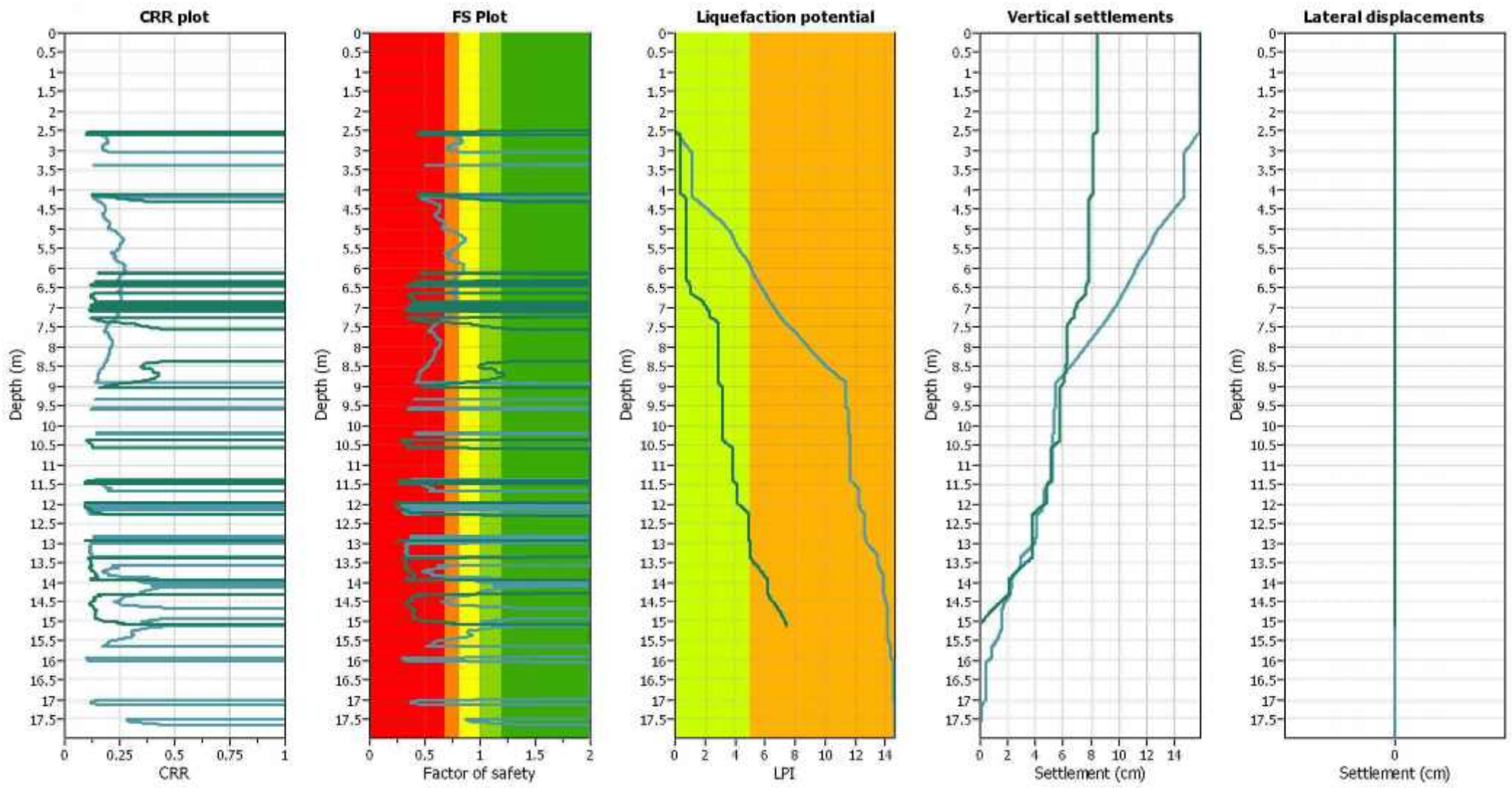
Project: Cresselly Place

Overlay Cyclic Liquefaction Plots



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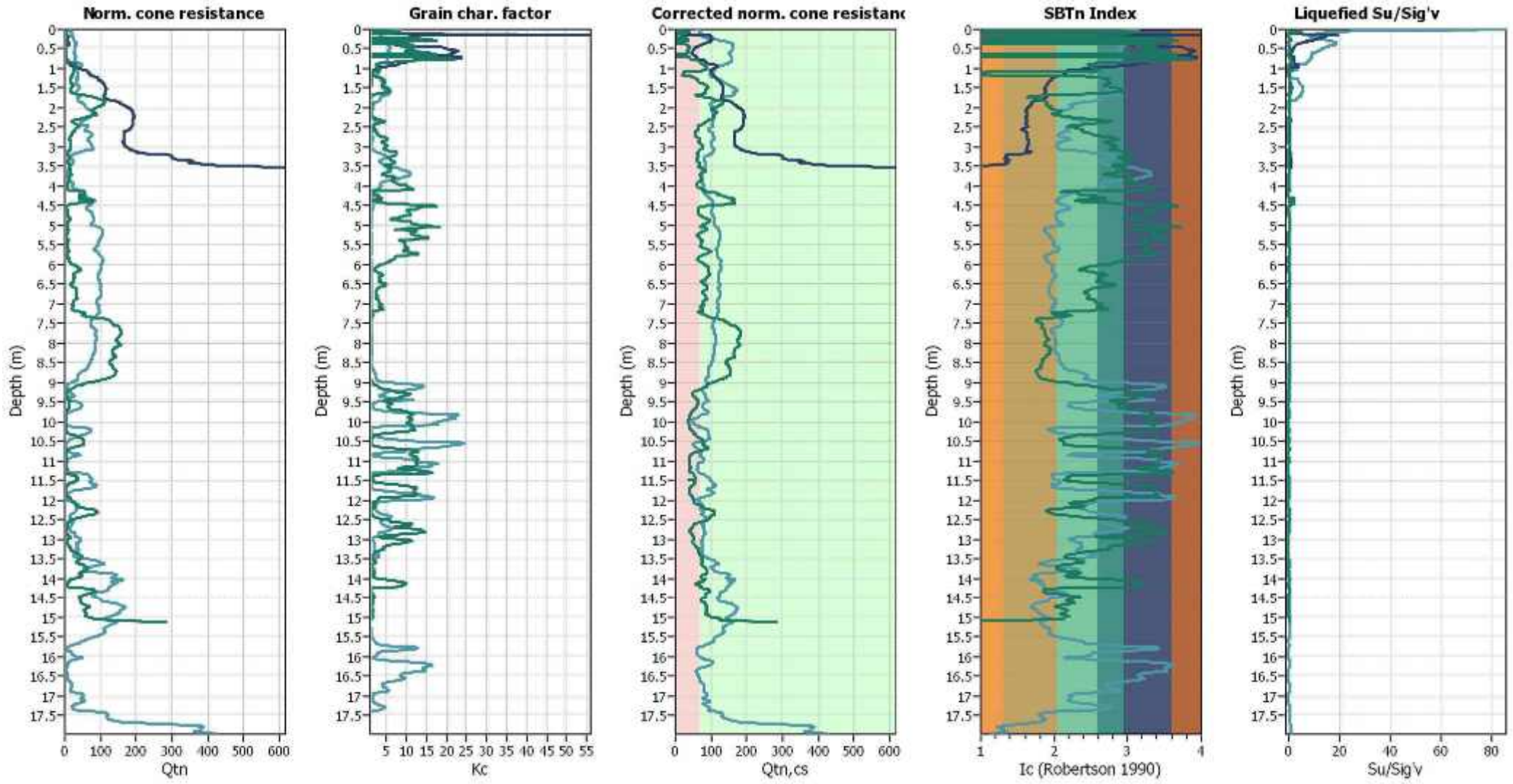
Project: Cresselly Place

Overlay Strength Loss Plots



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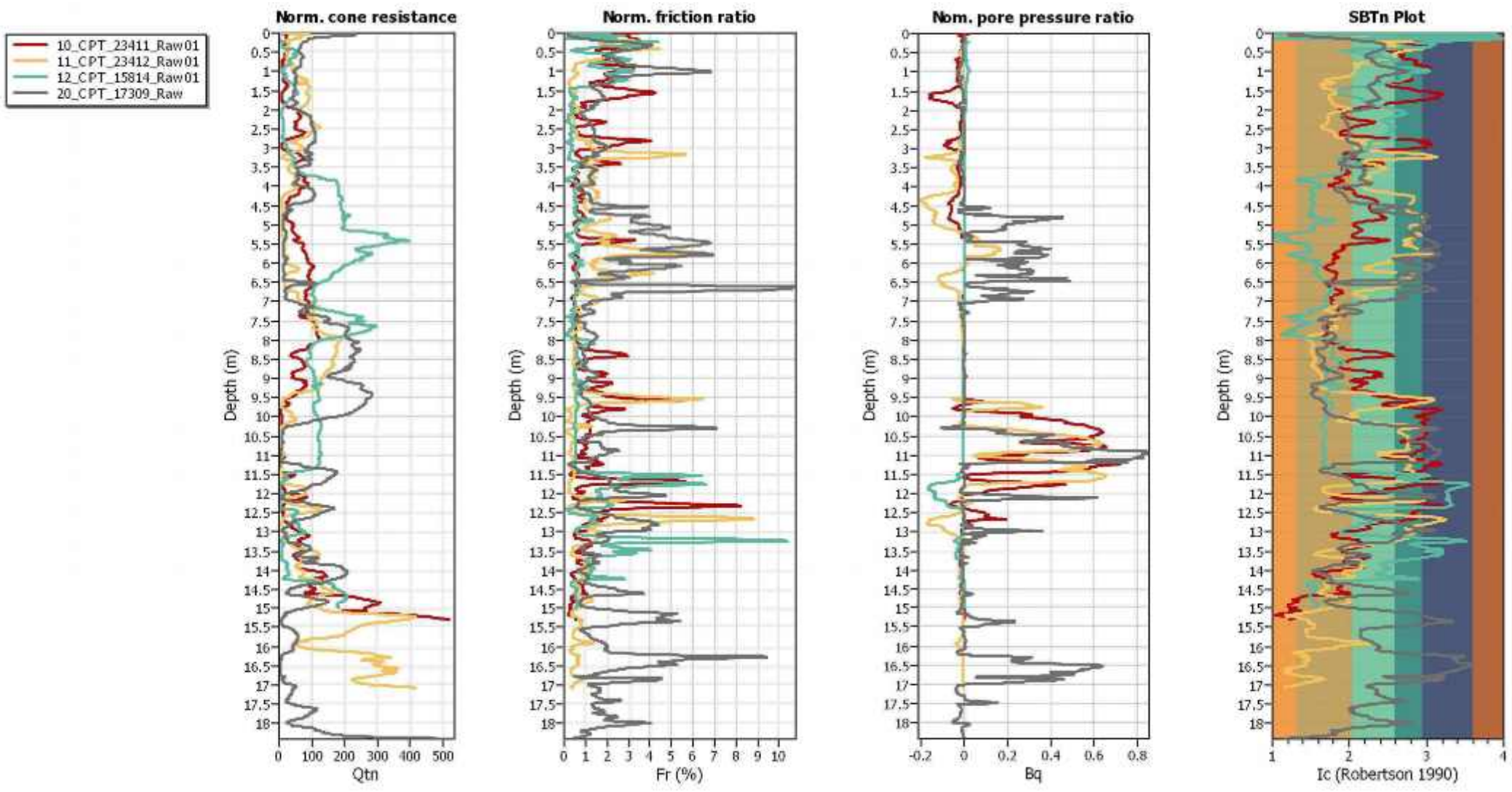
Overlay Normalized Plots



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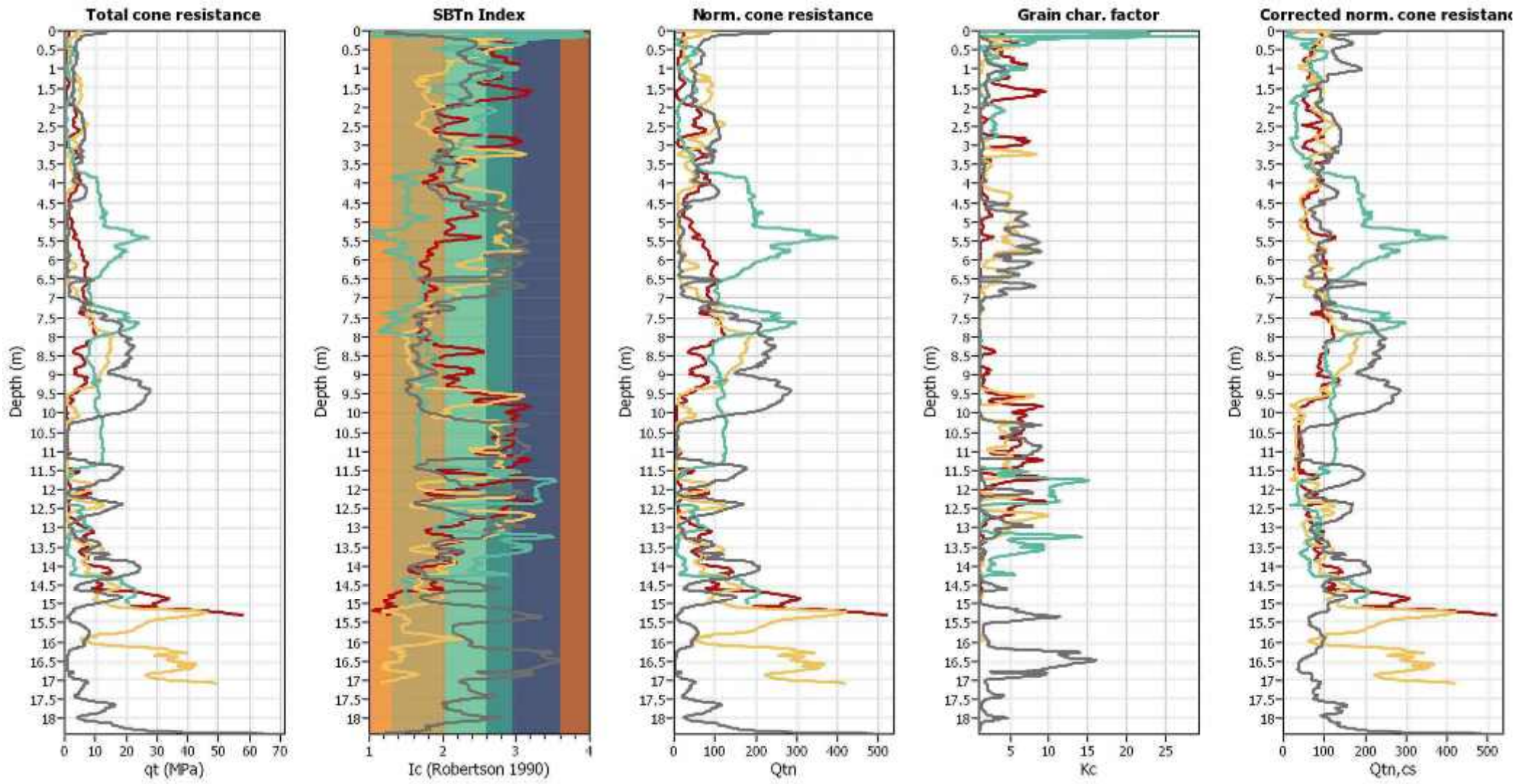

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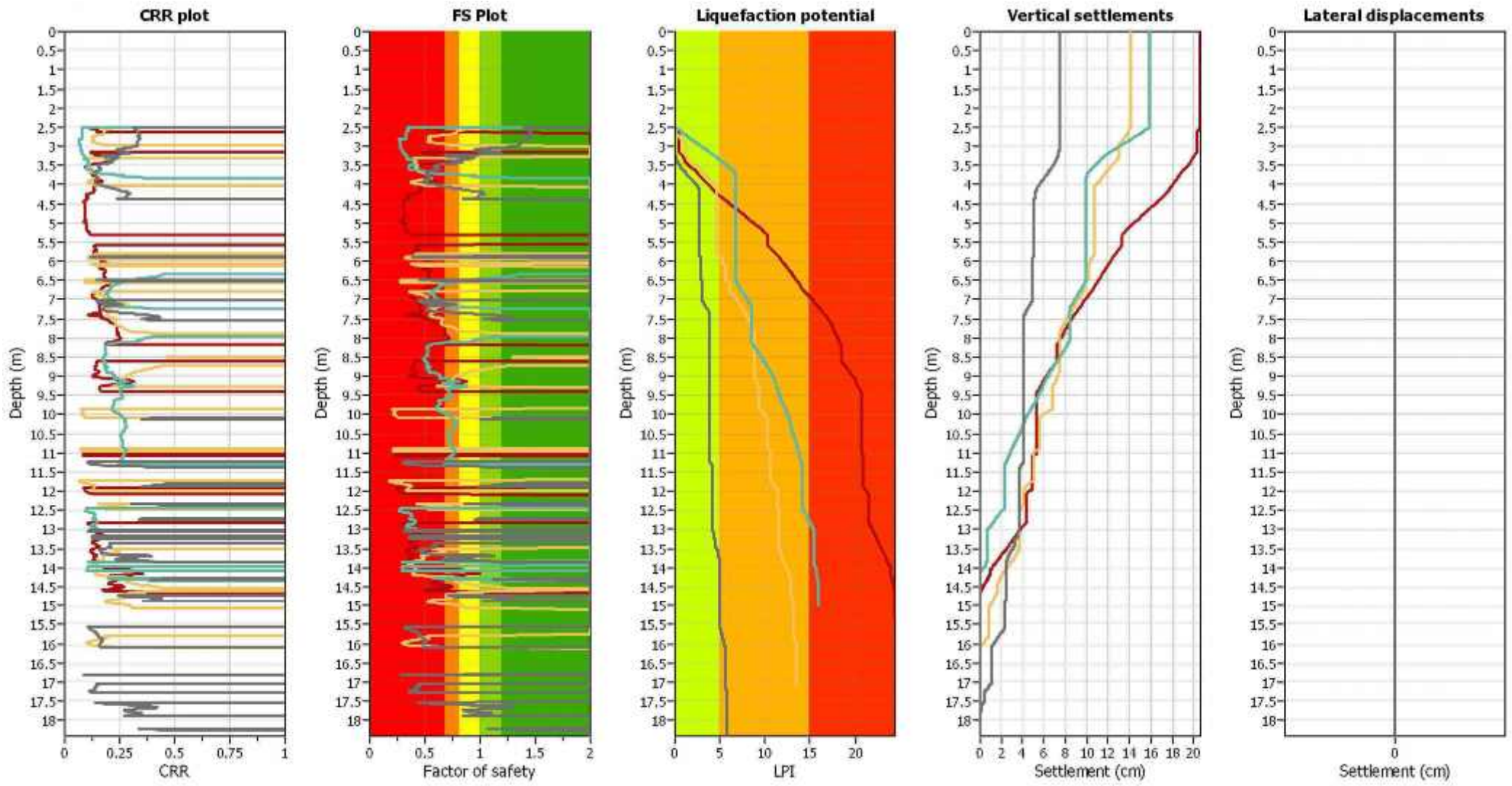
Overlay Cyclic Liquefaction Plots



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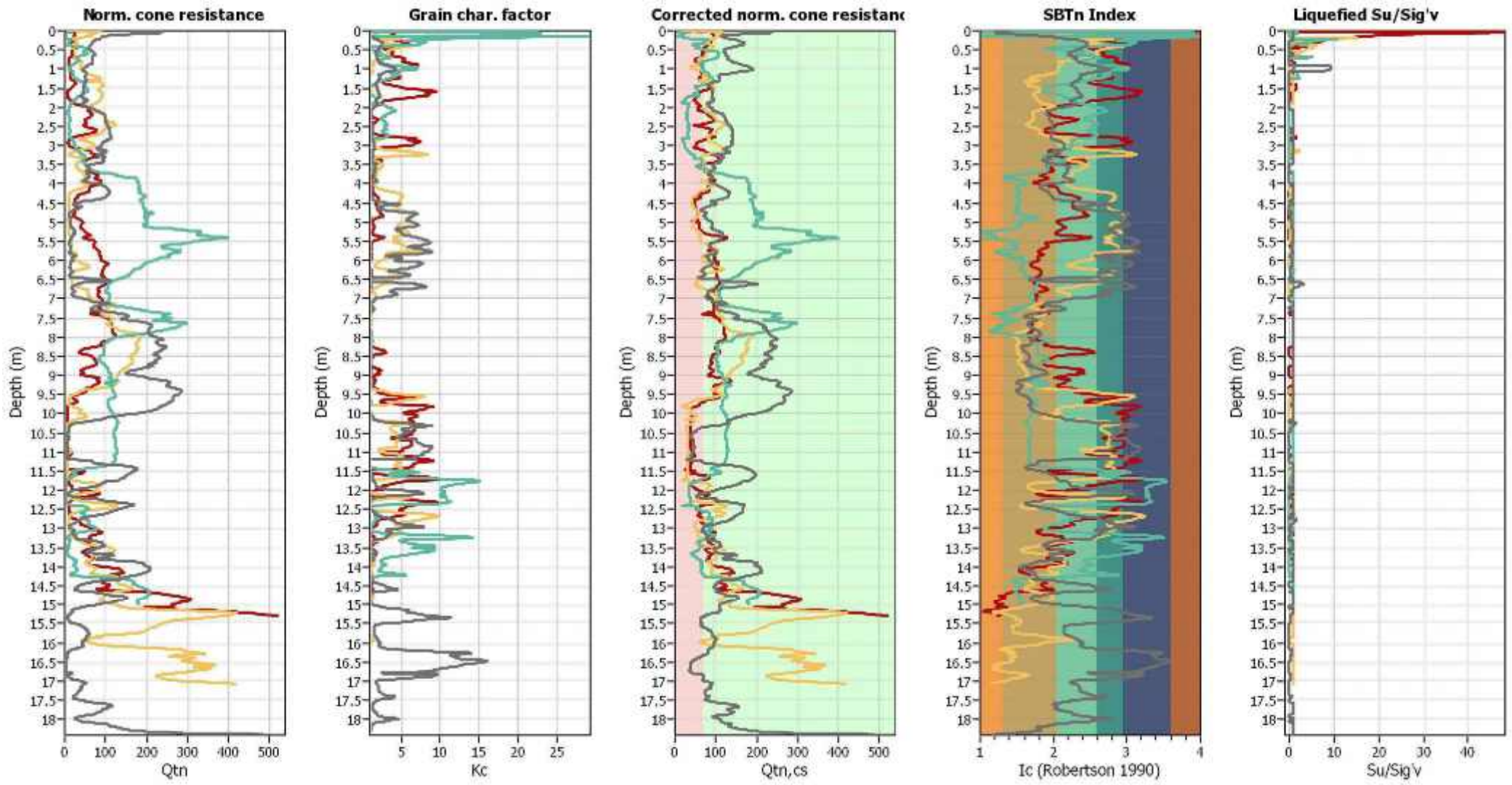
Overlay Strength Loss Plots



Appendix E.4

CLiq Idriss and Boulanger (2008) ULS Liquefaction Analysis Output

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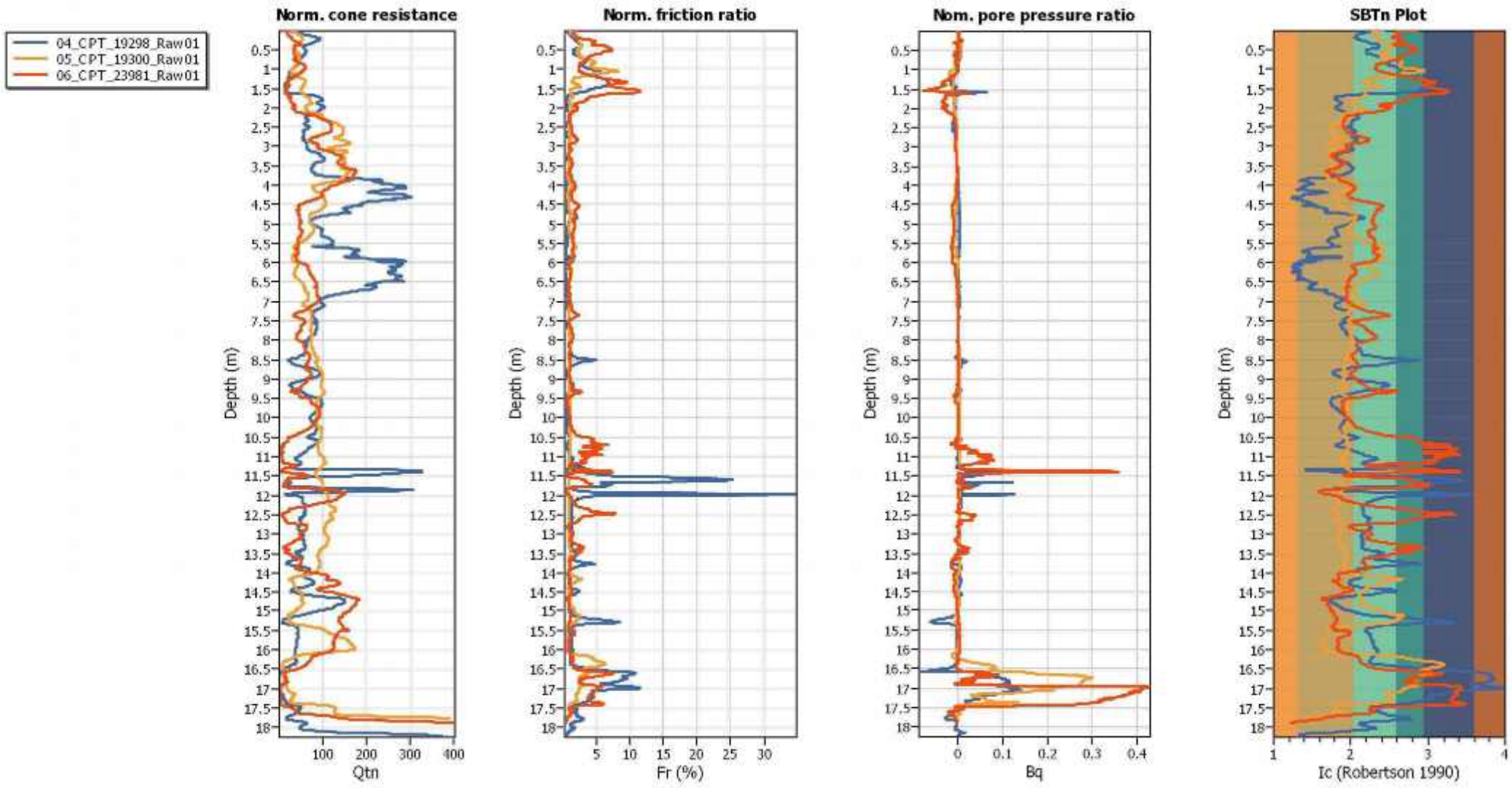
Overlay Normalized Plots



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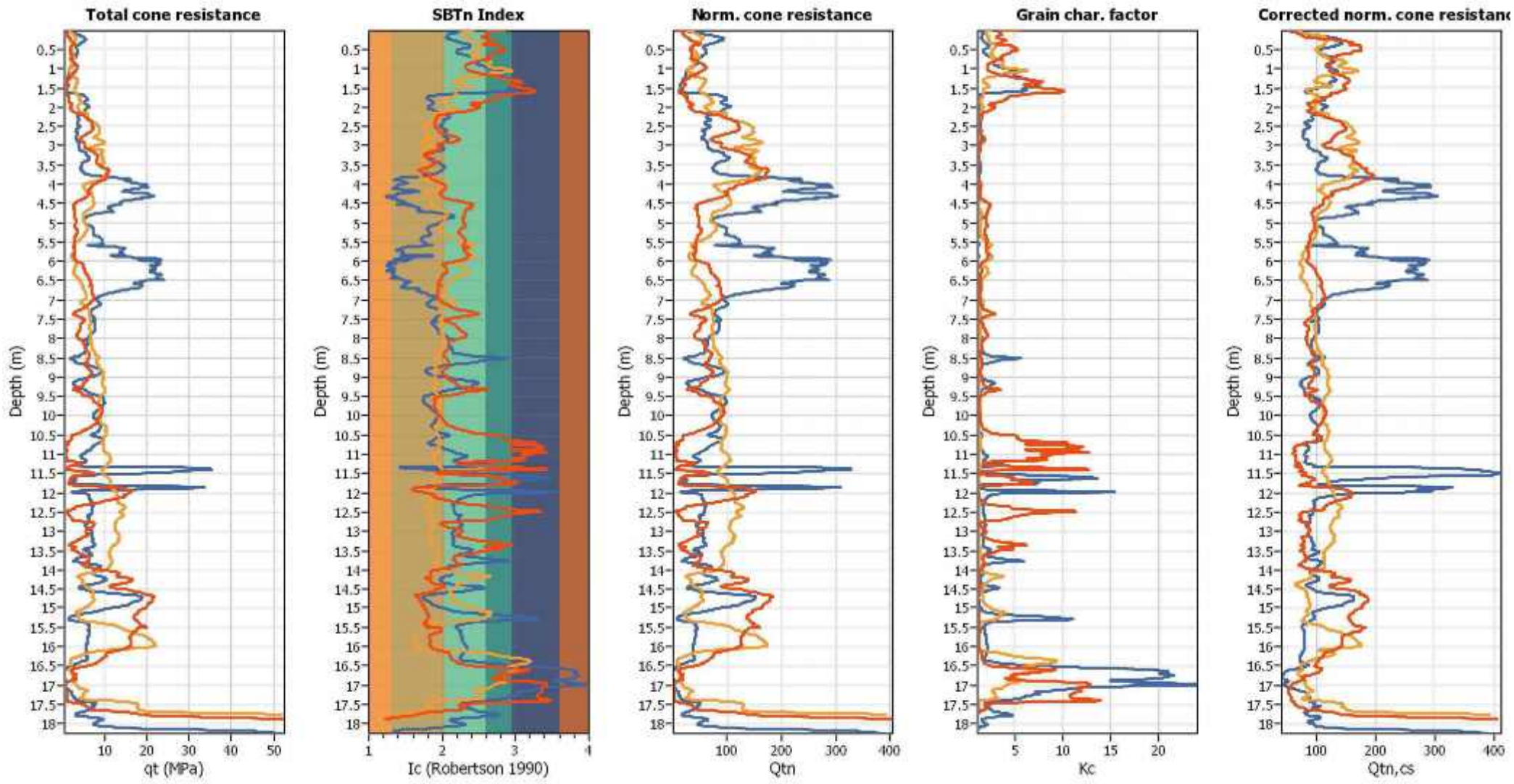
Project: Cresselly Place

Overlay Intermediate Results



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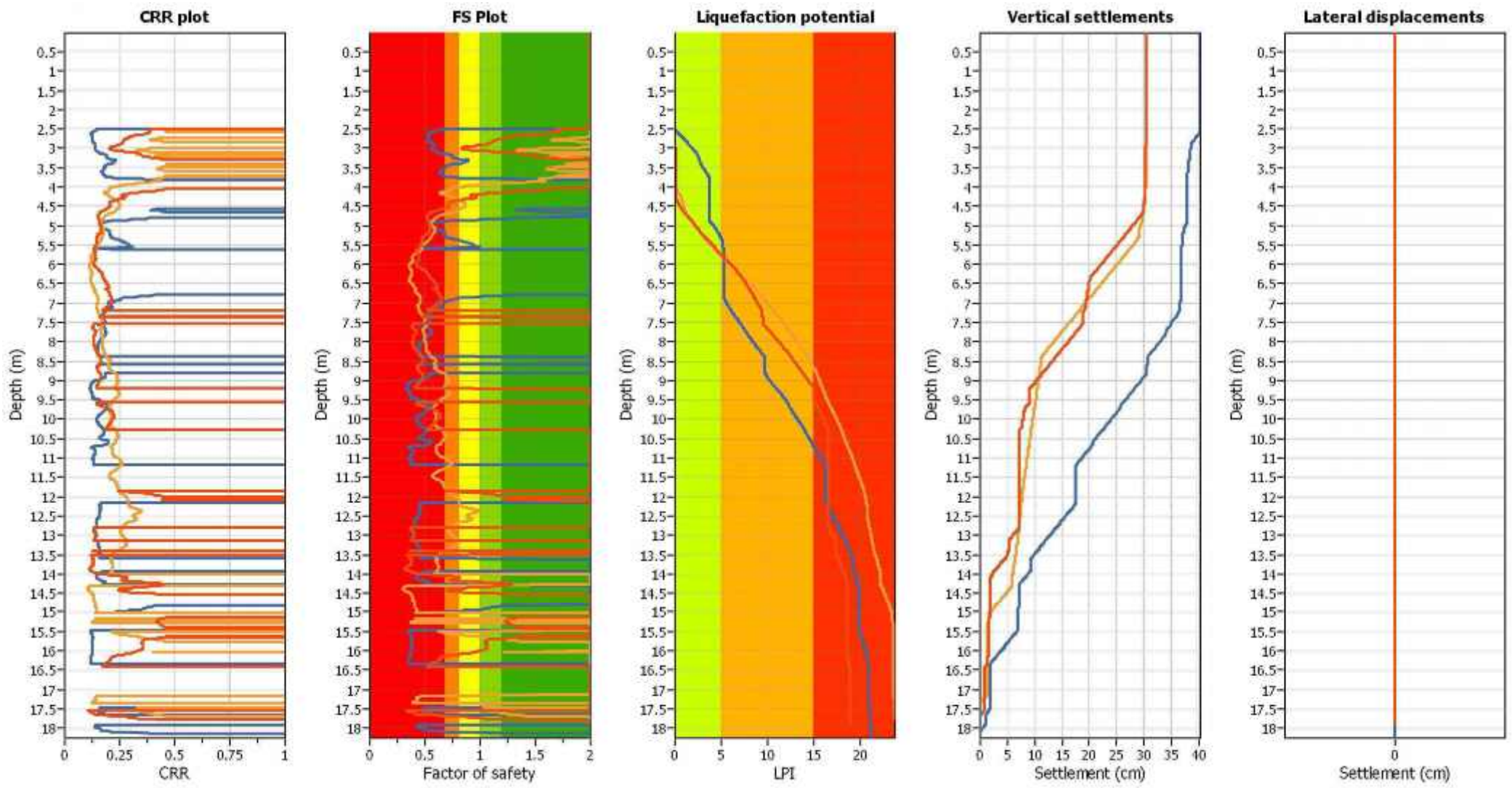
Overlay Cyclic Liquefaction Plots



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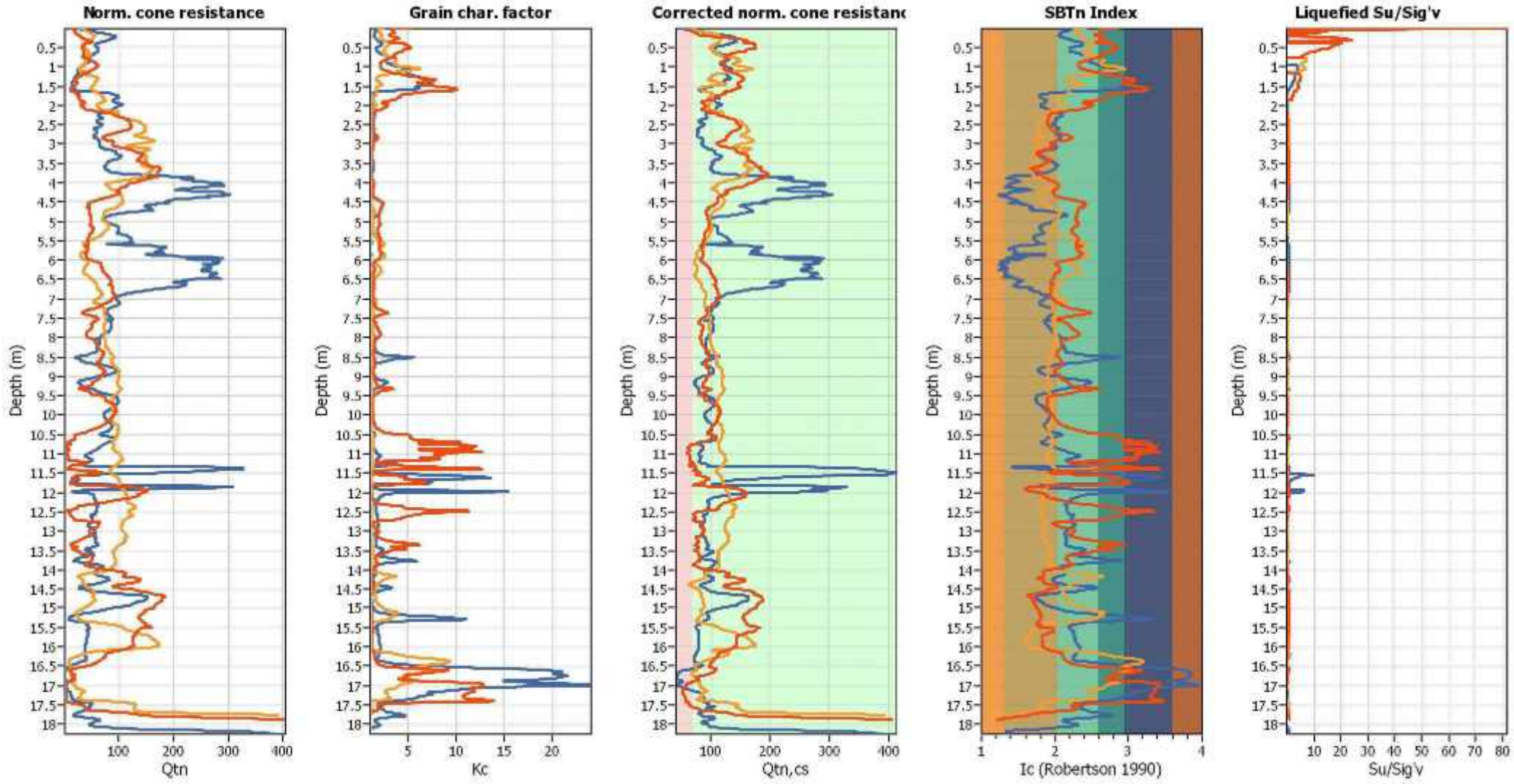
Project: Cresselly Place

Overlay Strength Loss Plots



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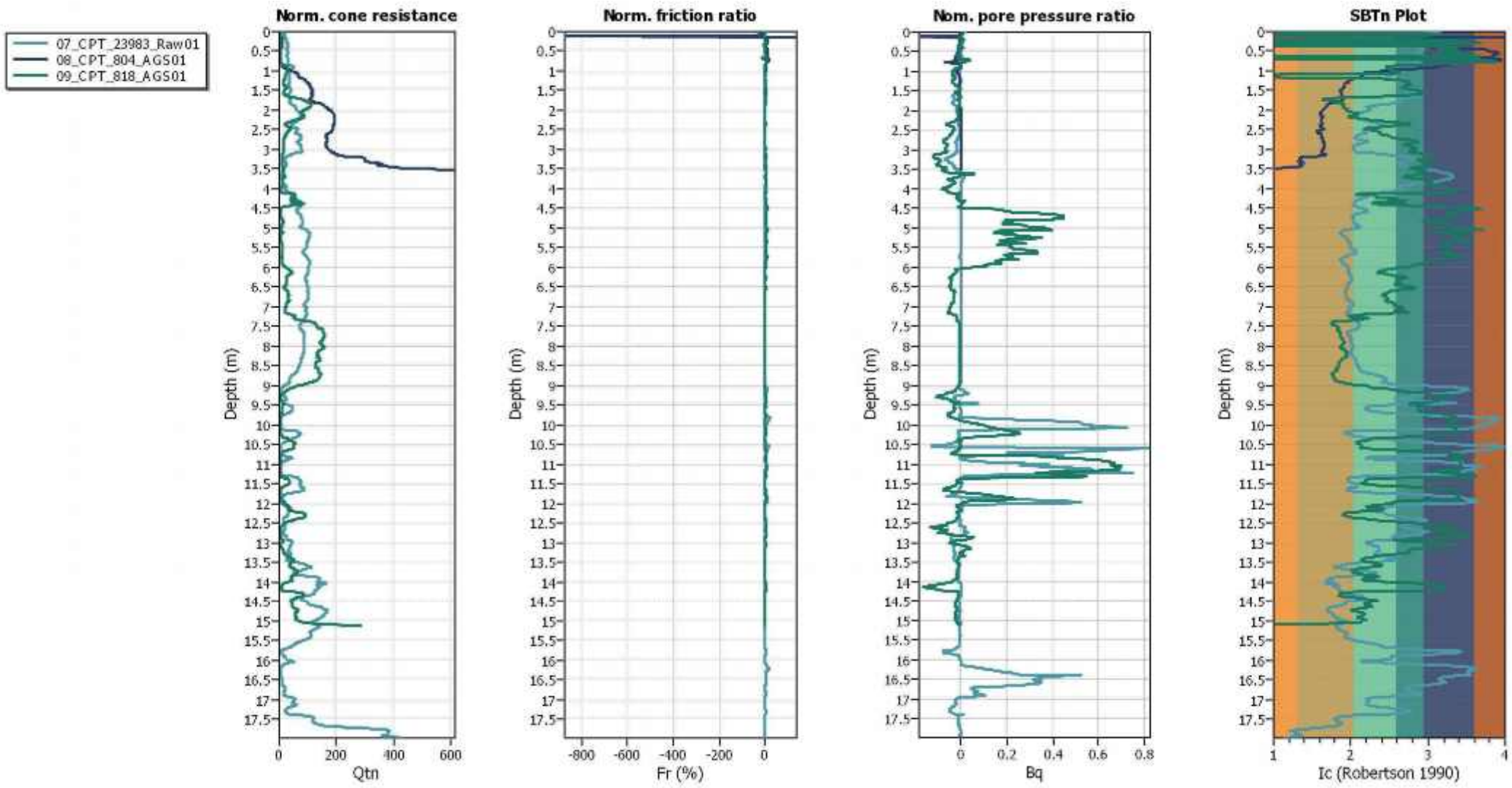
Project: Cresselly Place

Overlay Normalized Plots



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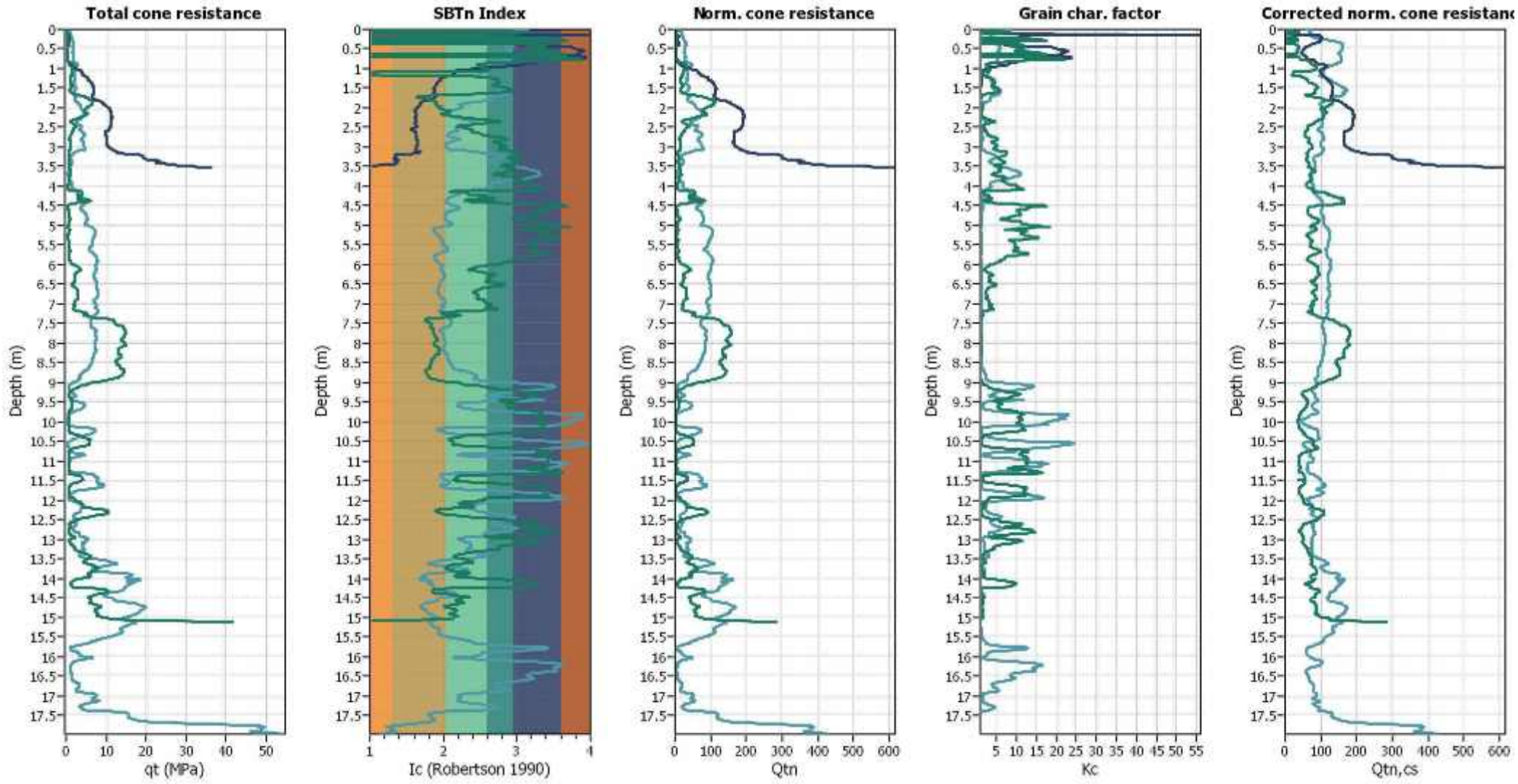
Project: Cresselly Place

Overlay Intermediate Results



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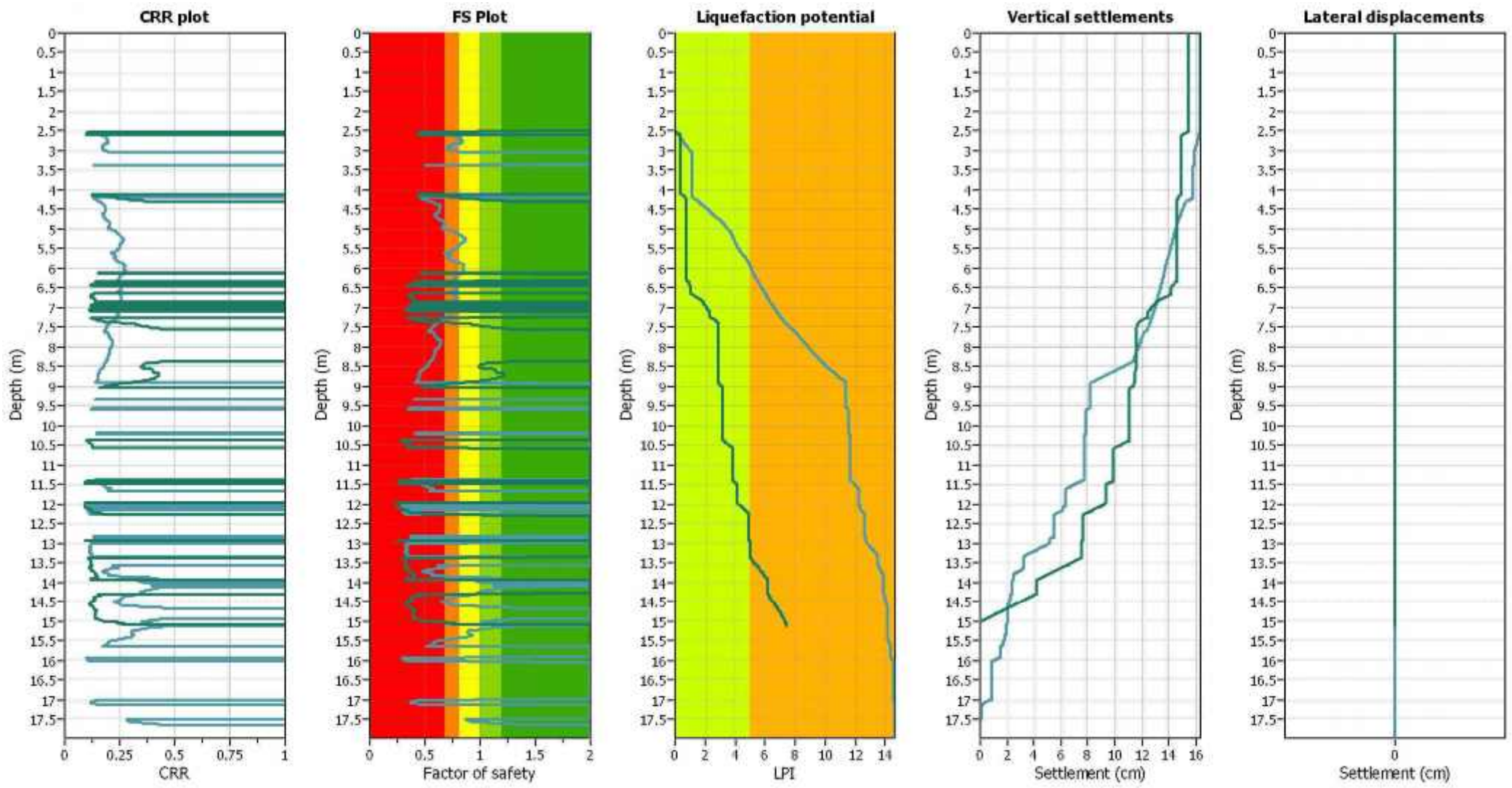
Overlay Cyclic Liquefaction Plots



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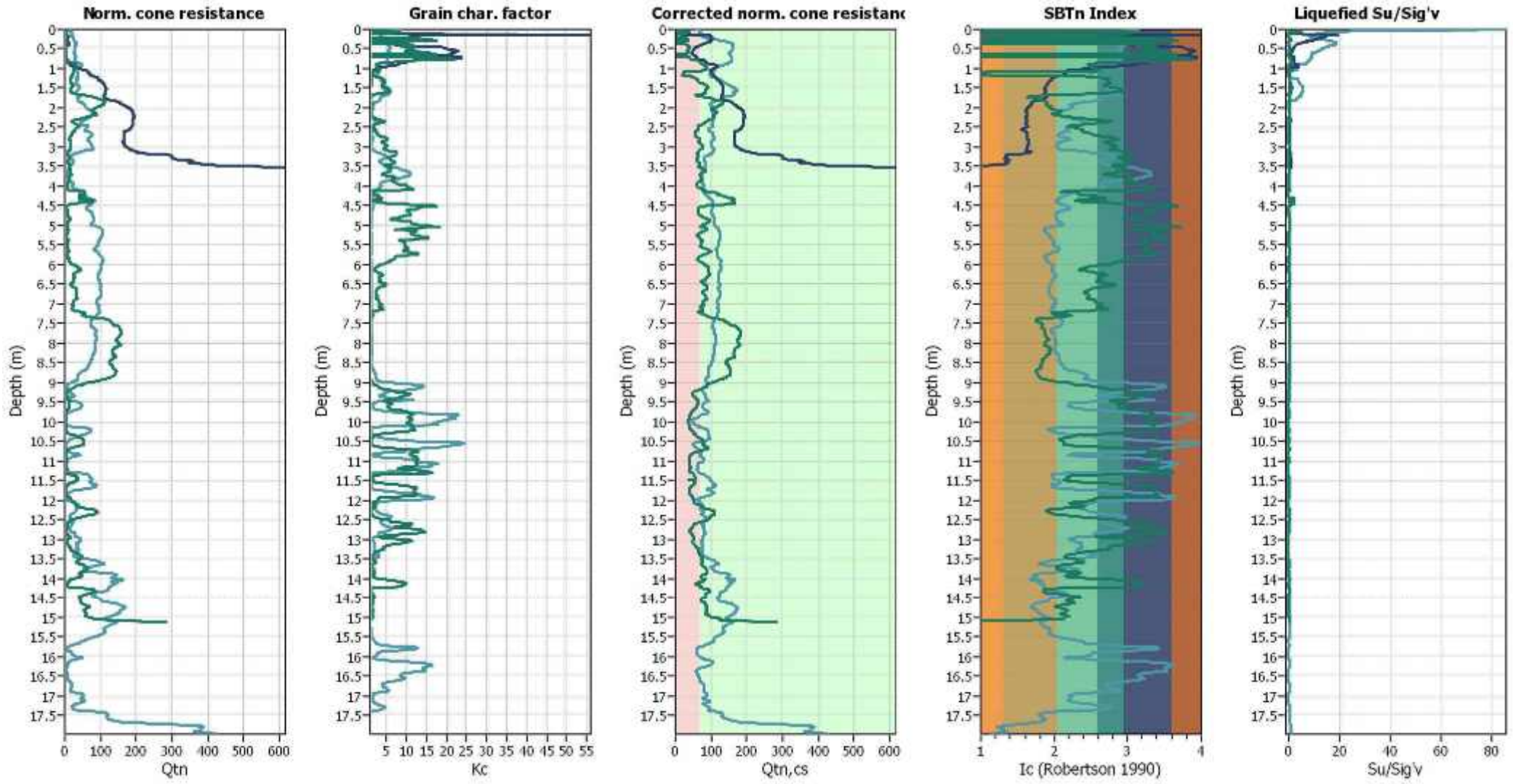
Project: Cresselly Place

Overlay Strength Loss Plots



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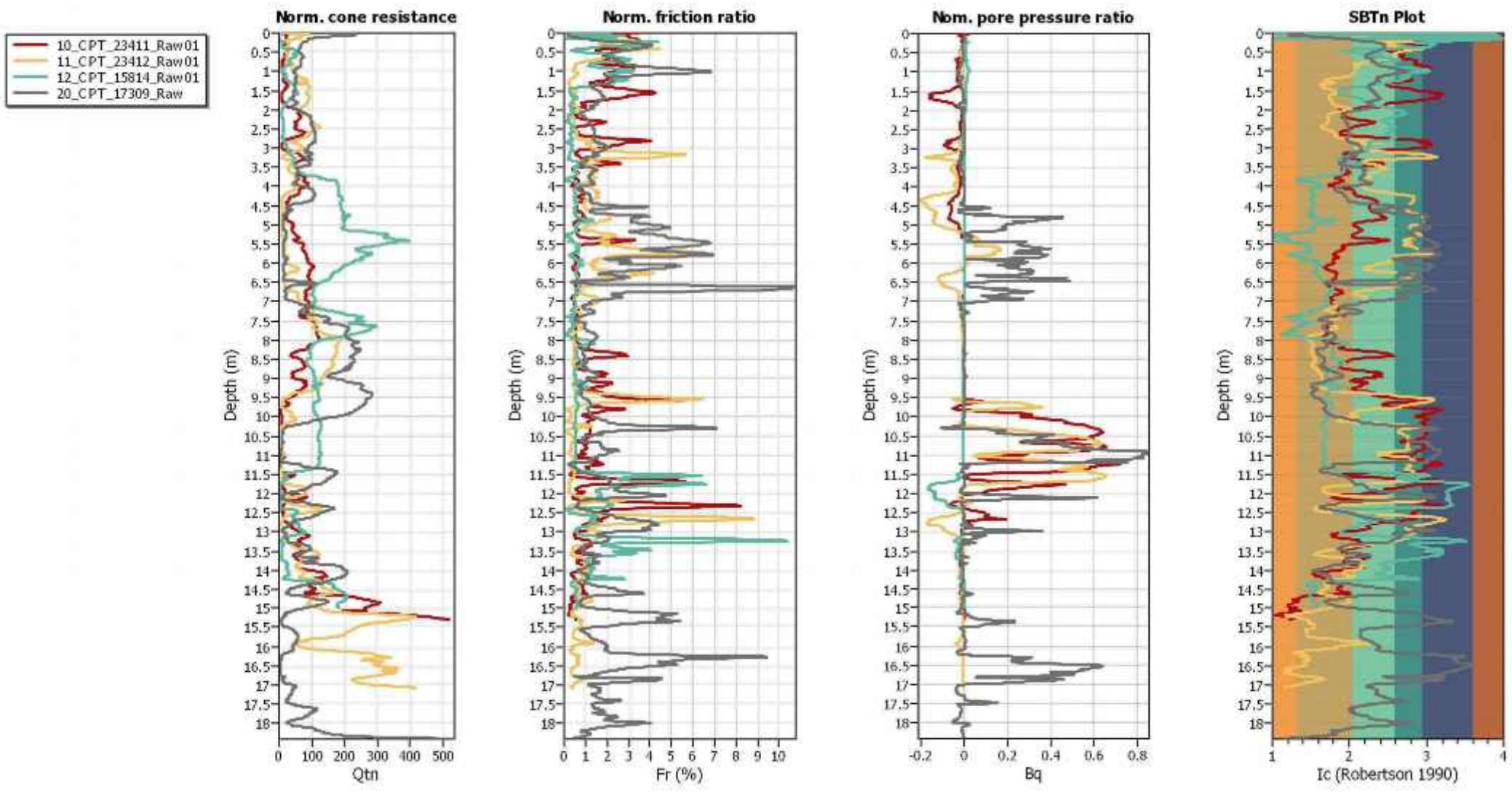

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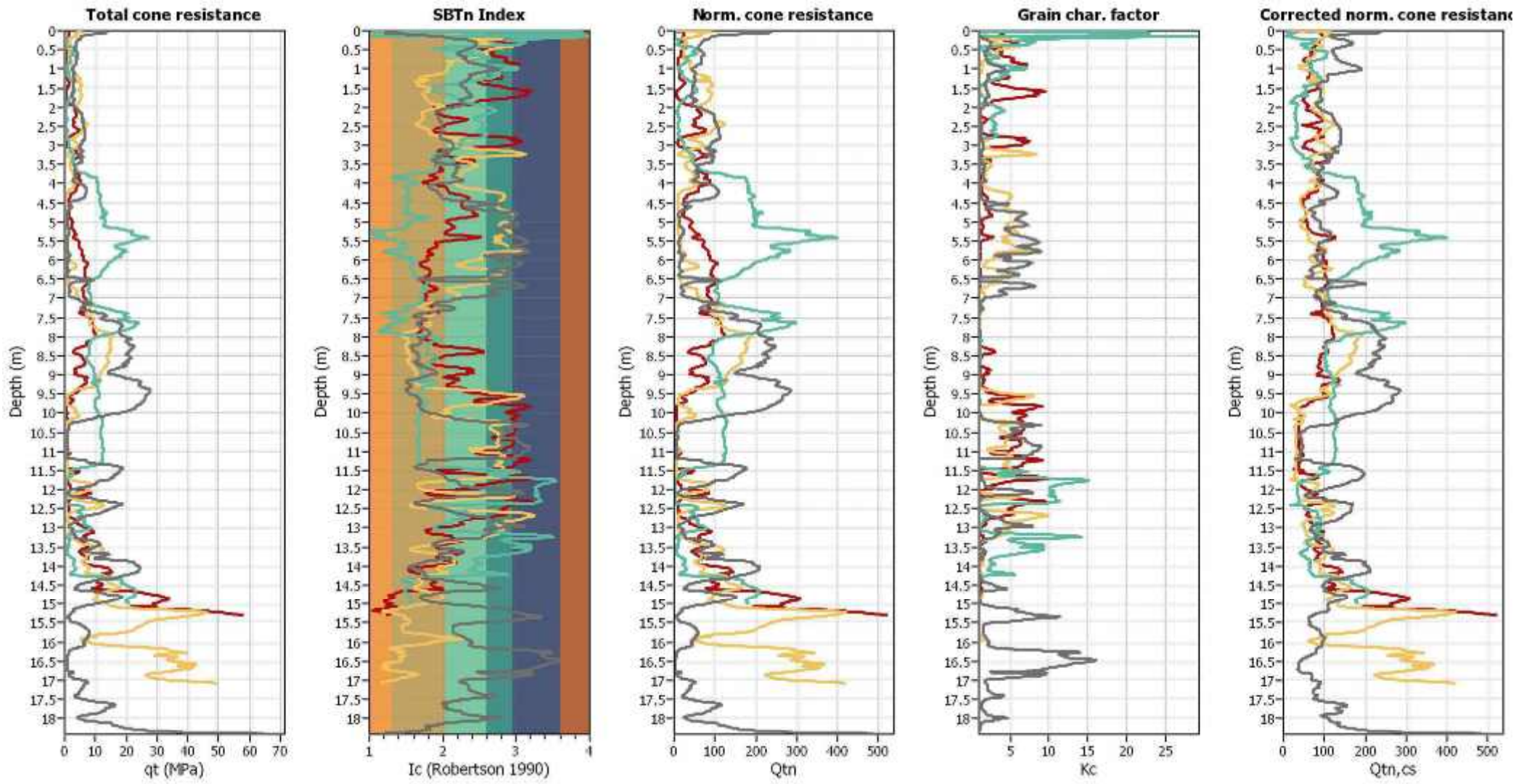

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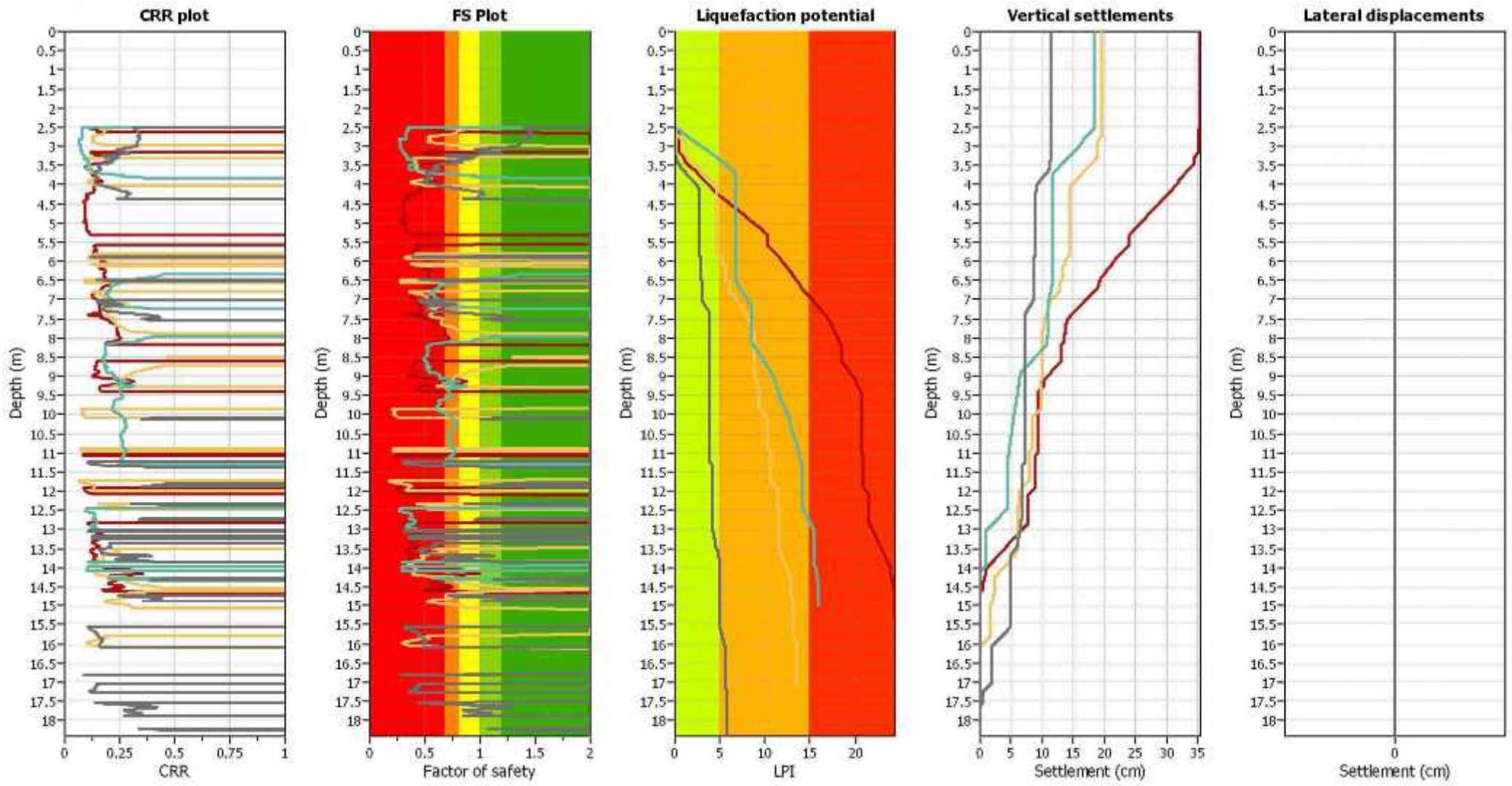
Overlay Cyclic Liquefaction Plots



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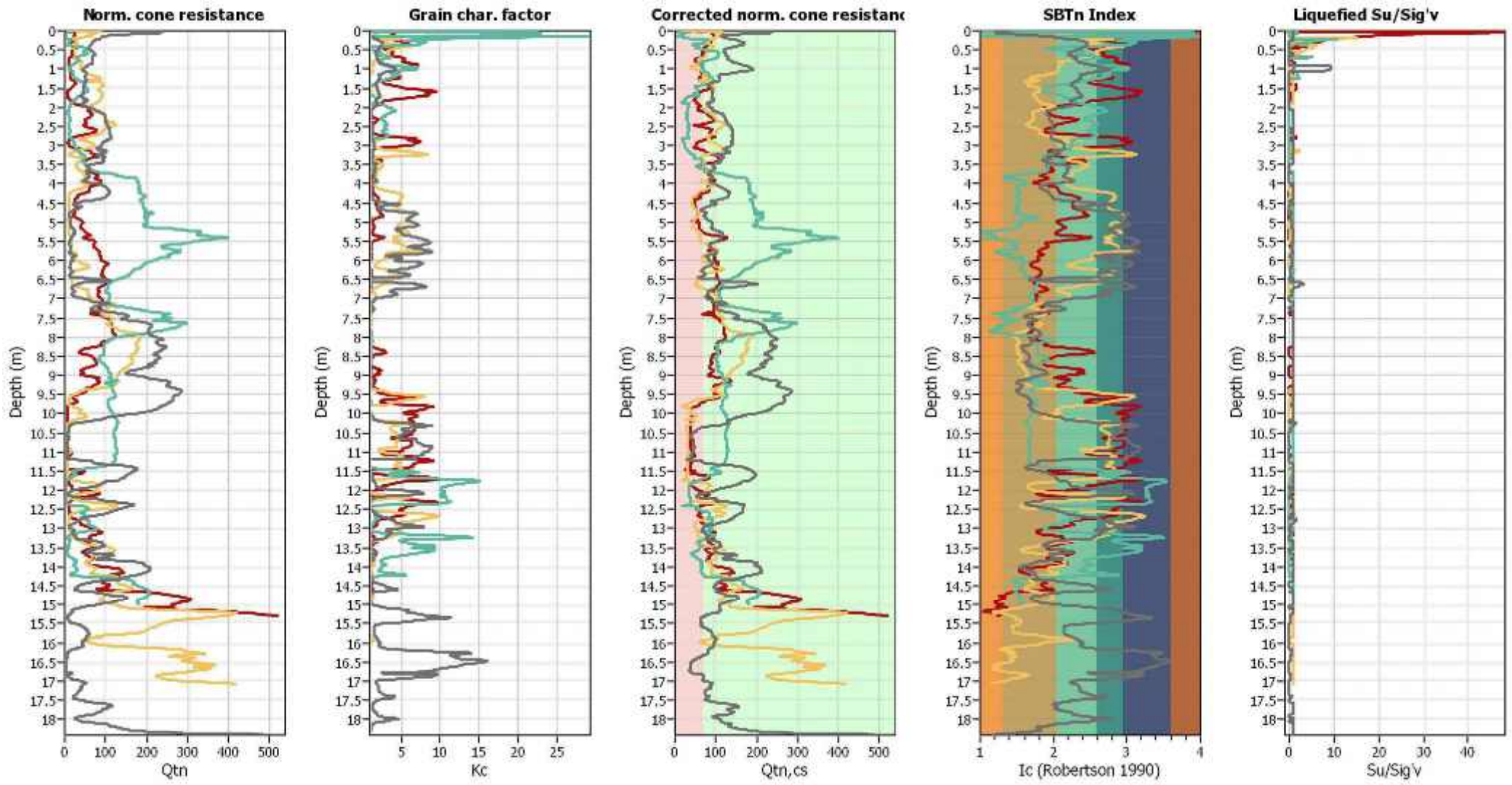

Appendix D - Methodology and Assumptions

Seismic Parameters

As per NZS 1170.5:

- T < 0.4s (assumed)
- Soil: Category D
- Z = 0.3
- R = 1.0 (IL2, 50 year)
- N(T,D) = 1.0

For the analysis a μ of 2 was assumed for the residential units.

Analysis Procedure

As the units are small and have a number of closely spaced walls in both directions, the fibrous plaster board ceilings are assumed to be capable of transferring loads to all walls. It was therefore assumed that a global method could be used to carry the forces down to ground level in each direction. Bracing capacities were found by assuming a certain kN/m rating for the walls along each line. Due to the relatively unknown nature of the walls, the kN/m rating was taken as 3 kN/m for all timber walls with an aspect ratio (height: length) of less than 2:1. This was scaled down to zero kN/m at an aspect ratio of 3.5:1 as per NZSEE guidelines. %NBS values were then found through the ratio of bracing demand to bracing capacity for all walls in each direction.

Additional Assumptions

Further assumptions about the seismic performance of the buildings were:

- Foundations and foundation connections had adequate capacity to resist and transfer earthquake loads.
- Connections between all elements of the lateral load resisting systems are detailed to adequately transfer their loads sufficiently and are strong enough so as to not fail before the lateral load resisting elements.

Appendix E - CERA DEE Spreadsheet

Detailed Engineering Evaluation Summary Data V1.14

Location

Building Name:	Cresselly Place Housing Complex				Reviewer:	Mary Ann Halliday	
		Unit	No:	Street	CPEng No:	67073	
Building Address:			133	Wilsons	Company:	Opus International Consultants	
Legal Description:					Company project number:	6-QC335.00	
					Company phone number:		
		Degrees	Min	Sec			
GPS south:		43	33	24.32	Date of submission:	13/12/2013	
GPS east:		172	39	7.33	Inspection Date:	8/07/2013	
					Revision:	1	
Building Unique Identifier (CCC):	PRO0980				Is there a full report with this summary?	yes	

Site

Site slope:	flat	Max retaining height (m):	
Soil type:		Soil Profile (if available):	
Site Class (to NZS1170.5):	D		
Proximity to waterway (m, if <100m):		If Ground improvement on site, describe:	
Proximity to clifftop (m, if < 100m):			
Proximity to cliff base (m,if <100m):		Approx site elevation (m):	

Building

No. of storeys above ground:	1	single storey = 1	Ground floor elevation (Absolute) (m):	
Ground floor split?	no		Ground floor elevation above ground (m):	
Storeys below ground	0			
Foundation type:	timber piles		if Foundation type is other, describe:	
Building height (m):	3.00		height from ground to level of uppermost seismic mass (for IEP only) (m):	
Floor footprint area (approx):	140			
Age of Building (years):	52		Date of design:	1935-1965
Strengthening present?	no		If so, when (year)?	
			And what load level (%g)?	
Use (ground floor):	multi-unit residential		Brief strengthening description:	
Use (upper floors):				
Use notes (if required):				
Importance level (to NZS1170.5):	IL2			

Gravity Structure

Gravity System:	frame system		
Roof:	timber framed	rafter type, purlin type and cladding	
Floors:	timber	joist depth and spacing (mm)	
Beams:	timber	type	
Columns:	timber	typical dimensions (mm x mm)	
Walls:	non-load bearing	0	

Lateral load resisting structure

Lateral system along:	lightweight timber framed walls	**Note: Define along and across in detailed report!**	note typical wall length (m)	
Ductility assumed, μ:	2.00			
Period along:	0.10	0.00	estimate or calculation?	estimated
Total deflection (ULS) (mm):			estimate or calculation?	
maximum interstorey deflection (ULS) (mm):			estimate or calculation?	
Lateral system across:	lightweight timber framed walls		note typical wall length (m)	
Ductility assumed, μ:	2.00			
Period across:	0.10	0.00	estimate or calculation?	estimated
Total deflection (ULS) (mm):			estimate or calculation?	
maximum interstorey deflection (ULS) (mm):			estimate or calculation?	

Separations:

north (mm):		leave blank if not relevant
east (mm):		
south (mm):		
west (mm):		

Non-structural elements

Stairs:			
Wall cladding:	brick or tile	describe (note cavity if exists)	Red Brick
Roof Cladding:	Metal	describe	
Glazing:	timber frames		
Ceilings:	strapped or direct fixed		
Services(list):			

Available documentation

Architectural	partial	original designer name/date	
Structural	partial	original designer name/date	
Mechanical	none	original designer name/date	
Electrical	none	original designer name/date	
Geotech report	none	original designer name/date	

Damage

Site: (refer DEE Table 4-2)	Site performance:	Poor	Describe damage:	
	Settlement:	100-200mm	notes (if applicable):	
	Differential settlement:	1:150 or more	notes (if applicable):	
	Liquefaction:	5-10 m³/100m²	notes (if applicable):	
	Lateral Spread:	250-500mm	notes (if applicable):	
	Differential lateral spread:	1:100-1:50	notes (if applicable):	
	Ground cracks:	100-200mm/20m	notes (if applicable):	
	Damage to area:	widespread to major (in in 3 to most)	notes (if applicable):	

Building:

	Current Placard Status:	yellow		
Along	Damage ratio:	0%	Describe how damage ratio arrived at:	
	Describe (summary):			
Across	Damage ratio:	0%	$Damage\_Ratio = \frac{(\%NBS(before) - \%NBS(after))}{\%NBS(before)}$	
	Describe (summary):			
Diaphragms	Damage?:	yes	Describe:	
CSWs:	Damage?:	no	Describe:	
Pounding:	Damage?:	no	Describe:	
Non-structural:	Damage?:	yes	Describe:	

Recommendations

	Level of repair/strengthening required:	minor non-structural		Describe:	
	Building Consent required:	no		Describe:	
	Interim occupancy recommendations:	partial occupancy		Describe:	
Along	Assessed %NBS before e'quakes:	72%	##### %NBS from IEP below	If IEP not used, please detail assessment methodology:	Equivalent Static
	Assessed %NBS after e'quakes:	72%			
Across	Assessed %NBS before e'quakes:	100%	##### %NBS from IEP below		
	Assessed %NBS after e'quakes:	100%			

Detailed Engineering Evaluation Summary Data V1.14

Location

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					Revision:	1	
Building Unique Identifier (CCC):	PRO0980				Is there a full report with this summary?	yes	

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Proximity to cliff base (m,if <100m):		Approx site elevation (m):	

Building

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Ground floor split?	no		Ground floor elevation above ground (m):	
Storeys below ground	0			
Foundation type:	timber piles		if Foundation type is other, describe:	
Building height (m):	3.00		height from ground to level of uppermost seismic mass (for IEP only) (m):	
Floor footprint area (approx):	140			
Age of Building (years):	52		Date of design:	1935-1965
Strengthening present?	no		If so, when (year)?	
			And what load level (%g)?	
Use (ground floor):	multi-unit residential		Brief strengthening description:	
Use (upper floors):				
Use notes (if required):				
Importance level (to NZS1170.5):	IL2			

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Gravity System:	frame system		
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Floors:	timber	joist depth and spacing (mm)	
Beams:	timber	type	
Columns:	timber	typical dimensions (mm x mm)	
Walls:	non-load bearing	0	

Lateral load resisting structure

Lateral system along:	lightweight timber framed walls	**Note: Define along and across in detailed report!**	note typical wall length (m)	
Ductility assumed, μ:	2.00			
Period along:	0.10	0.00	estimate or calculation?	estimated
Total deflection (ULS) (mm):			estimate or calculation?	
maximum interstorey deflection (ULS) (mm):			estimate or calculation?	
Lateral system across:	lightweight timber framed walls		note typical wall length (m)	
Ductility assumed, μ:	2.00			
Period across:	0.10	0.00	estimate or calculation?	estimated
Total deflection (ULS) (mm):			estimate or calculation?	
maximum interstorey deflection (ULS) (mm):			estimate or calculation?	

Separations:

north (mm):		leave blank if not relevant
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west (mm):		

Non-structural elements

Stairs:			
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Roof Cladding:	Metal	describe	
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Ceilings:	strapped or direct fixed		
Services(list):			

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	Lateral Spread:	250-500mm	notes (if applicable):	
	Differential lateral spread:	1:100-1:50	notes (if applicable):	
	Ground cracks:	100-200mm/20m	notes (if applicable):	
	Damage to area:	widespread to major (in in 3 to most)	notes (if applicable):	

Building:

	Current Placard Status:	red		
Along	Damage ratio:	14%	Describe how damage ratio arrived at:	
	Describe (summary):			
Across	Damage ratio:	0%	$Damage\_Ratio = \frac{(\%NBS(before) - \%NBS(after))}{\%NBS(before)}$	
	Describe (summary):			
Diaphragms	Damage?:	yes	Describe:	
CSWs:	Damage?:	no	Describe:	
Pounding:	Damage?:	no	Describe:	
Non-structural:	Damage?:	yes	Describe:	

Recommendations

	Level of repair/strengthening required:	minor non-structural		Describe:	
	Building Consent required:	no		Describe:	
	Interim occupancy recommendations:	do not occupy		Describe:	
Along	Assessed %NBS before e'quakes:	72%	##### %NBS from IEP below	If IEP not used, please detail assessment methodology:	Equivalent Static
	Assessed %NBS after e'quakes:	62%			
Across	Assessed %NBS before e'quakes:	100%	##### %NBS from IEP below		
	Assessed %NBS after e'quakes:	100%			

Opus International Consultants Ltd
20 Moorhouse Avenue
PO Box 1482, Christchurch Mail Centre,
Christchurch 8140
New Zealand

t: +64 3 363 5400
f: +64 3 365 7858
w: www.opus.co.nz