Christchurch City Council

Charles Street Housing Complex PRO 1039

Detailed Engineering Evaluation

Quantitative Assessment Report

Christchurch City Council

Charles Street Housing Complex

Quantitative Assessment Report

29 Charles Street, Waltham, Christchurch 8011

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Date: August 2013
Reference: 6-QC130.00
Status: Final

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Summary

Charles Street Housing Complex
PRO 1039

Detailed Engineering Evaluation
Quantitative Report - Summary
Final

Background

This is a summary of the quantitative report for the Charles Street 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 4 residential units.

Key Damage Observed

- Cracking to block veneers and GIB linings.
- Doors jammed.
- Evidence of liquefaction on site and in bedroom of unit 1 due to probable foundation failure.
- Up to 14mm/m slope on floors.

Critical Structural Weaknesses

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

Indicative Building Strength

Based on available information and following a quantitative assessment, the building's original capacity has been assessed to be 61% NBS across the building, as limited by the bracing walls in the longitudinal direction.

Table A: Summary of Seismic Performance by Blocks

Block	NBS%
PRO 1039 B001	61%

Recommendations

We recommend that further work is undertaken in order to develop the scope of the strengthening and repair options. This work should involve:

- Permanent strengthening options be developed for increasing the seismic capacity of the building to at least 67% NBS.
- All units should be re-levelled and an investigation of the concrete slab and foundations carried out for Units 1 and 2.
- A full geotechnical assessment should be carried out.
- Undertake cosmetic repairs to veneers and linings where appropriate.

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1 Introduction

Opus International Consultants Limited has been engaged by Christchurch City Council to undertake a detailed seismic assessment of the Charles Street Housing Complex, located at 29 Charles Street, Waltham, Christchurch, following the Canterbury earthquake sequence since September 2010.

The purpose of the assessment is to determine if the buildings in the complex 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 1 below.

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 12 June 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 Charles Street Housing Complex contains 4 residential units which were built in 1987. The units are numbered 1 to 4. The location of the site in Christchurch City is shown in Figure 2. A site plan showing the location of the units is shown Figure 3.

Figure 2: Location of site relative to Christchurch City CBD (Source: Google maps).

Figure 3: Site plan of Charles Street Housing Complex.

The residential units are timber-framed buildings with diagonal timber braces. The roof consists of timber roof framing supporting light-weight metal roofs. The units are separated by 190mm block masonry fire walls which consist of partially filled blockwork to the height of the roof line. Walls and ceilings are lined with GIB and GIB/pinex respectively. The cladding above and below the windows is light-weight Harditex-type cladding with the remaining wall areas clad with block veneer. The building is founded on a reinforced concrete slab foundation which is tied to ground beams and the foundation of the fire wall.

Figure 4 shows a typical cross section of a unit and Figure 5 shows a typical floor plan of the block of residential units. The values on this plan have been confirmed using site measurements by Opus.

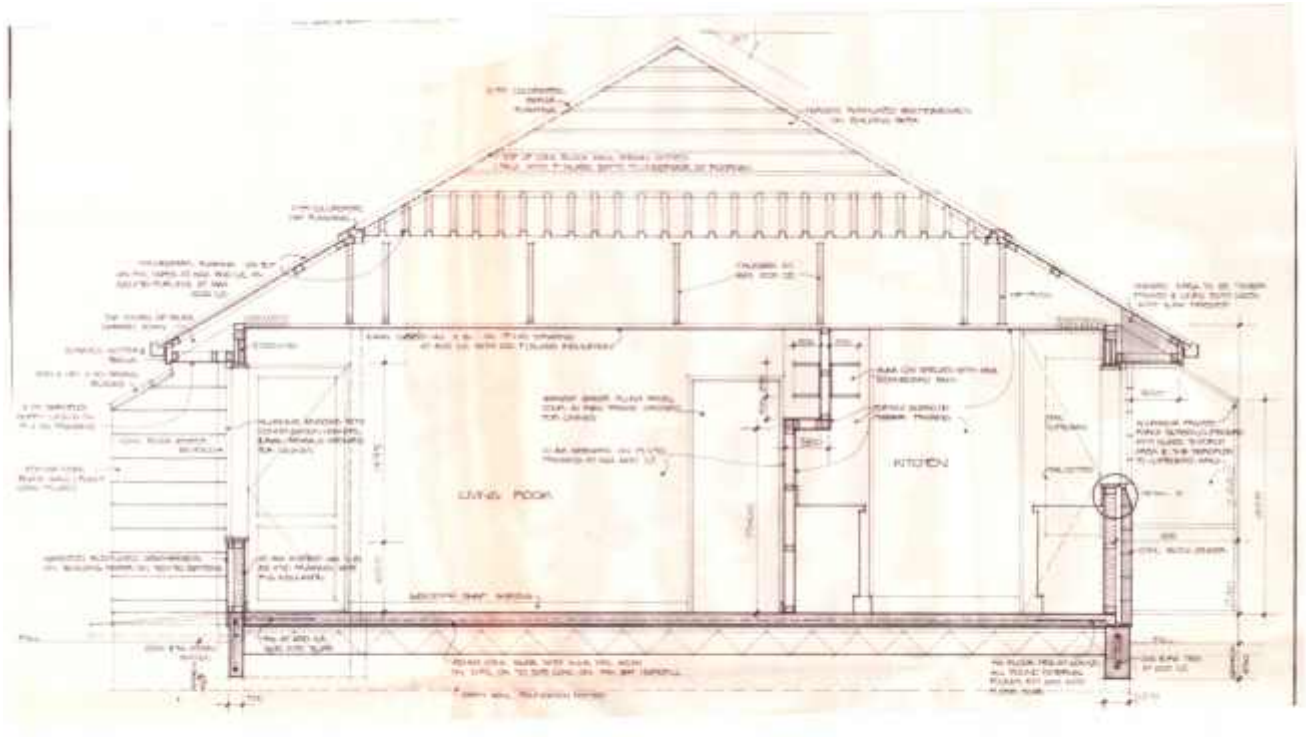


Figure 4: Typical cross section of the residential units

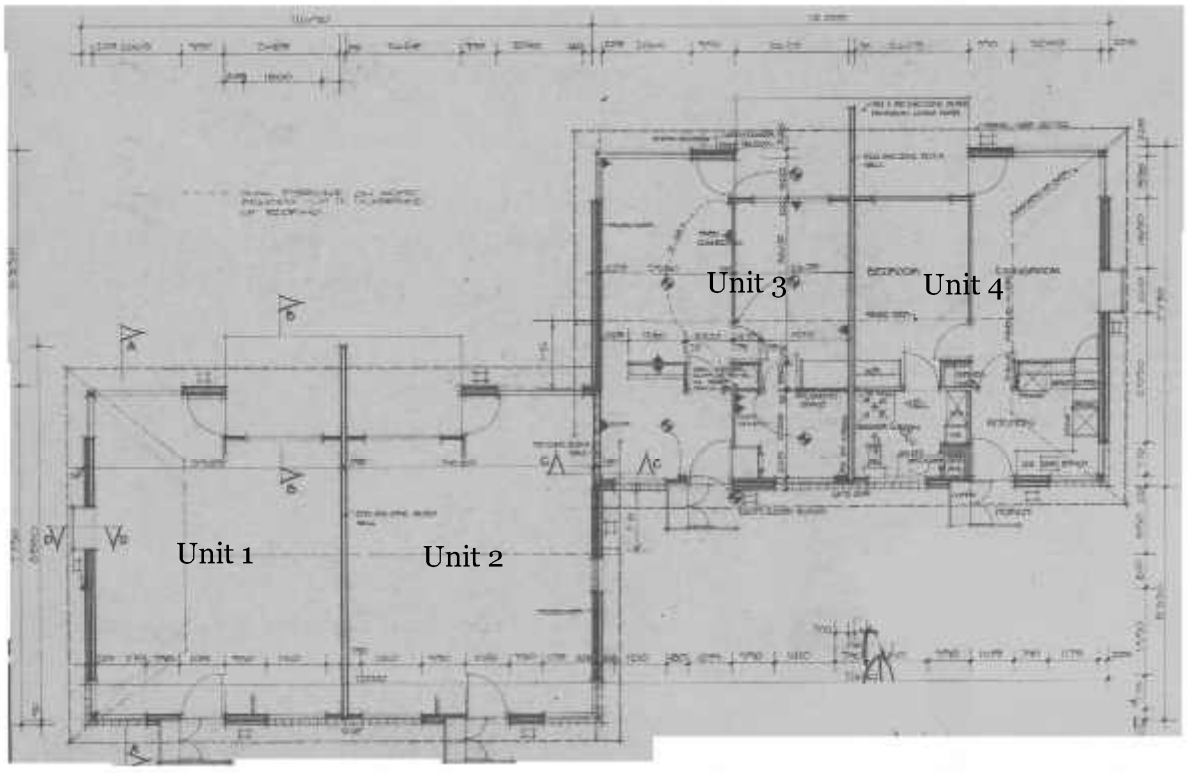


Figure 5: Floor plan of typical residential unit blocks.

4.2 Survey

4.2.1 Post 22 February 2011 Rapid Assessment

A structural (Level 2) assessment of the buildings/property was undertaken on March 7th, 2011 by Opus International Consultants. The assessment noted extensive evidence of liquefaction (both inside and outside the units), jammed doors and cracking to the block veneers.

4.2.2 Further Inspections

The site was revisited and inspected by Opus Engineers on April 3rd 2013. A laser level was used to determine floor slopes in the units. A full level survey was subsequently carried out on 20th May 2013.

4.3 Original Documentation

Copies of the following construction drawings were provided by CCC:

- Architectural plan and wall elevations of the building, titled: 'E.P.H Charles Street for CCC' by Alton Builders ltd. Reference number: 8614, dated 1986.

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 1.

5.1 Residual Displacements

A full level survey was deemed to be necessary at Charles Street Housing Complex as it is located in a TC3 zone (Figure 6). Properties in TC3 zones suffered moderate to significant amounts of damage due to liquefaction and/or settlement. A full level survey was completed for all units.

The values from the level survey could then be used to determine the floor slope of the entire unit. Results for this level survey are summarised in Table 2 and shown in Appendix 4. For this site, the floor slopes in all four units on site were greater than the 5mm/m limitation imposed by the MBIE guidelines [6]. The direction of settlement at Units 1 and 2 is towards the concrete block fire wall which is consistent with the cracking observed at the east block wall.

Table 2: Summary of Level Survey

Unit No.	Comment	Maximum Fall
1	Fail	14mm/m
2	Fail	10mm/m
3	Fail	7mm/m
4	Fail	6mm/m

Doors on the East side of the complex were unable to be opened due to racking action of the door frames. This was likely to have been caused by settlement of the floor slabs.

5.2 Foundations

No damage to the foundations was observed. However, the liquefaction still present on the bedroom floor of unit 1 (photo 8) suggests that the connection between the floor slab and firewall has been compromised. The linings on the block walls would need to be removed to confirm this.

5.3 Primary Gravity Structure

No damage to the primary gravity structure was observed.

5.4 Primary Lateral-Resistance Structure

Minor cracking to the GIB wall linings was observed in all units, especially above window and door openings.

5.5 Non Structural Elements

- Minor stepped and vertical cracking in the block veneers was observed throughout all the units (photo 6).
- Damage to the roof cladding where the fire wall has moved due to earthquake actions.

5.6 General Observations

The buildings appeared to have performed reasonably well, as would be expected for buildings of this type, during the earthquakes. They have suffered distributed amounts of damage which is typical of the construction type and age of the buildings.

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.

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 critical structural weaknesses were identified in the buildings.

6.2 Quantitative Assessment Methodology

The assessment assumptions and methodology have been included in Appendix 2. 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.

6.3 Assessment

A summary of the structural performance of the buildings is shown in the following table. 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

Structural Element/System	Critical Element	% NBS based on calculated capacity in longitudinal direction	% NBS based on calculated capacity in transverse direction.
Block A	Bracing capacity of structural walls	61%	100%

6.4 Limitations and Assumptions in Results

The observed level of damage suffered by the building was deemed low enough to not affect the capacity. Therefore the analysis and assessment of the building was based on it being in an undamaged state. There may have been damage to the building that was unable to be observed that could cause the capacity of the building to be reduced; therefore the current capacity of the building 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.
- Construction is consistent with normal practise of the era in which constructed.

7 Summary of Geotechnical Appraisal

7.1 General

CERA indicates that the Charles Street Housing Complex is located in a TC3 zone (as shown in Figure 6). This classification suggests future significant earthquakes will cause moderate to significant land damage due to liquefaction and settlement.

Figure 6: CERA Technical Categories map (location starred)

Due to the risk of damage due to the site being located in a TC3 zone, a separate geotechnical desktop study was undertaken by Opus. The following is a summary of the report attached in Appendix 5.

Tonkin and Taylor Ltd (T&T Ltd), the Earthquake Commission's (EQC) geotechnical consultants, have 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. In summary, the liquefaction evidence on site from the above mentioned events are as follows:

- 4th September earthquake: no observed liquefaction
- 22nd February 2011: Moderate to severe observed liquefaction
- 13th June 2011: Moderate to severe observed liquefaction
- 23rd December 2011: Minor observed liquefaction

There are no open watercourses or free surfaces within close proximity to the site. This suggests that the lateral spreading potential of the site is considered minor.

7.2 Summary of Conclusions

All units are timber framed dwellings with concrete masonry exterior cladding (concrete block veneer), constructed on concrete slab on grade type foundations. This is equivalent to Type C2 foundations in accordance with the Ministry of Business, Innovation, and Employment (MBIE, December 2012) guidance.

Significant liquefaction damage has occurred at 29 Charles Street as a result of the 2011 earthquake sequence. At the time of the 3 May 2013 inspection, evidence of ejected material and ground settlement was observed inside some of the units. Moderate cracking to pavements appears to be a result of differential settlement due to liquefaction.

Moderate to severe damage due to cracking was observed on the east block wall between Units 1 and 2. The stepped cracking pattern at this location is evidence of vertical downward foundation movement that caused distortion of the panel walls. The cracks developed are formed perpendicular to the stretched diagonal due to settlement of the middle footing located on the east side that separates Unit 1 from Unit 2. We believe that the heavy cladding has influenced the settlements on this location.

Boreholes and CPTs undertaken for EQC indicate the buildings are likely to be founded on layers of loose to medium dense Sand approximately 1.2 m thick overlying medium stiff Clay approximately 1.6 m thick. Liquefiable medium dense fine Sand is extending below the clay to approximately 16.7 m depth. 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 identified liquefiable layers from about 2 to 7 m and 8.5 to 15 m below ground level, mainly within the deeper medium dense sand layer. The subsurface ground profile together with the ground damage observed at the site during the recent earthquakes of 2010 and 2011, confirms that the site has a high risk of liquefaction.

7.3 Further Work and Recommendations

It is recommended that in order to determine foundation repair options at 29 Charles Street, a site specific investigation is undertaken including one further CPT, Hand Augers and Scalas. The site investigation will enable a site specific liquefaction assessment to be undertaken to identify the liquefiable layers to help determine conceptual repair and re-levelling options.

The scope of the proposed site specific geotechnical investigations will be:

- One CPT to a depth of 20 m.
- Two Hand Auger and Scala tests carried out to 3 m depth or refusal, with one located at the east side close to the block wall between Units 1 and 2.
- Geotechnical Assessment and Reporting.

- Intrusive inspection of concrete floor slab for evidence of cracking.

8 Conclusions

- None of the buildings on site are considered to be Earthquake Prone.
- The residential units have a capacity of 61% NBS, as limited by the in-plane capacity of the bracing walls. They are deemed to be a 'moderate risk' in a design seismic event according to NZSEE guidelines. Their level of risk is 5-10 times that of a 100% NBS building.
- All units on the site exceed the 5mm/m guideline set out by MBIE for floor slope.
- There is a probable foundation failure between Unit 1 and Unit 2.
- 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.

9 Recommendations

- Permanent strengthening options should be developed to increase the seismic capacity of the building to at least 67% NBS, this will need to consider compliance with accessibility and fire requirements.
- All units should be re-levelled and an investigation of the concrete slab and foundations carried out for Units 1 and 2.
- A geotechnical site investigation should be carried out heeding the recommendations of the geotechnical desktop study in Appendix 5. This information is required for future construction on the site (including new foundations).
- Cosmetic repairs should be undertaken to veneers and linings where appropriate.

10 Limitations

- This report is based on an inspection of the buildings and focuses on 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 Charles Street 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.

Appendix 1 - Photographs

Charles Street Housing Complex		
No.	Item description	Photo
1	South face elevation of Unit 1.	
2	West face elevation of Units 1 and 2, this is the same as Units 3 and 4.	

3	South and West face elevation of Unit 3.	
4	Typical cracking of plaster lined timber frame wall above door frame.	
5	Typical roof truss layout.	

6	Typical cracking of external concrete brick veneer.	
7	Minor surface expression of liquefaction.	
8	Liquefaction apparent in bedroom of Unit 1.	

9	Typical kitchen layout.	
10	Typical bedroom layout.	
11	Typical living room area.	

Appendix 2 - 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 analyses, 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 resistance 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 3 – CERA Spreadsheet

Detailed Engineering Evaluation Summary Data V1.11

Location

Building Name:	Charles Street Housing Complex				Reviewer:	Mary Ann Halliday	
		Unit	No:	Street	CPEng No:	67073	
Building Address:			29	Charles Street	Company:	OPUS International Consultants Ltd	
Legal Description:	Residential Units				Company project number:	6-QC130.00	
					Company phone number:	6433635400	
		Degrees	Min	Sec			
GPS south:		-43	32	35.06	Date of submission:	Aug-13	
GPS east:		172	39	27.63	Inspection Date:	27-Jun-13	
					Revision:	Final	
Building Unique Identifier (CCC):	PRO 1039				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):			
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):	5.00

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:	mat slab		if Foundation type is other, describe:	
Building height (m):	3.50		height from ground to level of uppermost seismic mass (for IEP only) (m):	
Floor footprint area (approx):	150			
Age of Building (years):	26		Date of design:	1976-1992
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:	load bearing walls		
Roof:	timber framed	rafter type, purlin type and cladding	
Floors:	concrete flat slab	slab thickness (mm)	100
Beams:	timber	type	
Columns:			
Walls:			

Lateral load resisting structure

Lateral system along:	lightweight timber framed walls	**Note: Define along and across in detailed report!**		
Ductility assumed, μ:	2.00		note typical wall length (m)	
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			
Ductility assumed, μ:	2.00		note typical wall length (m)	
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)	
Roof Cladding:	Metal	describe	lightweight
Glazing:	aluminium frames		
Ceilings:	strapped or direct fixed		
Services(list):			

Available documentation

Architectural	partial	original designer name/date	1987
Structural	partial	original designer name/date	1987
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:			Describe damage:	
Settlement:	0-25mm		notes (if applicable):	
Differential settlement:	1:150 or more		notes (if applicable):	
Liquefaction:	0-2 $m^3/100m^2$		notes (if applicable):	
Lateral Spread:	none apparent		notes (if applicable):	
Differential lateral spread:	none apparent		notes (if applicable):	
Ground cracks:	none apparent		notes (if applicable):	
Damage to area:	moderate to substantial (1 in 5)		notes (if applicable):	

Building:

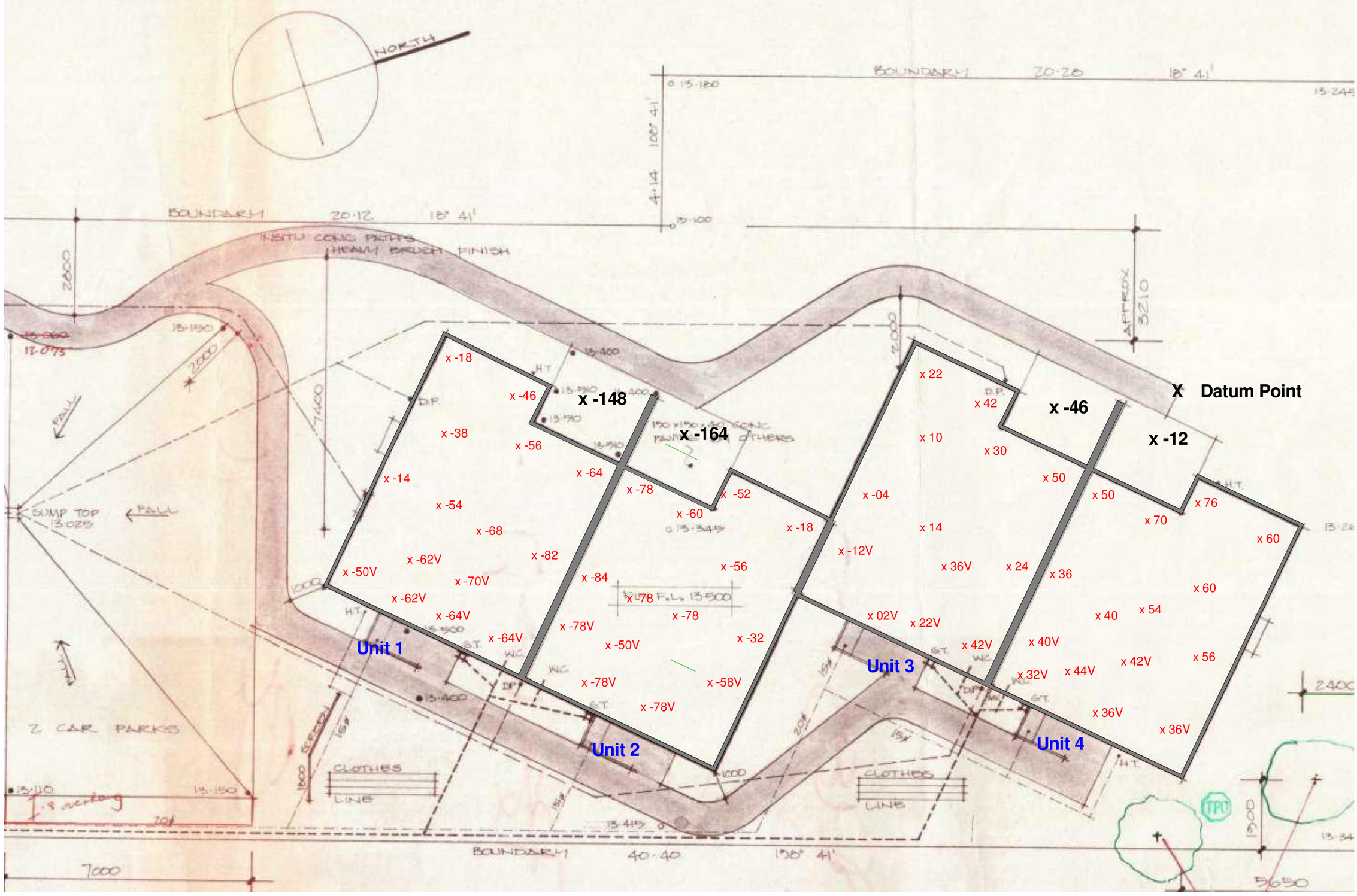
Current Placard Status: green

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?:	no	Describe:	
CSWs:	Damage?:	no	Describe:	
Pounding:	Damage?:	no	Describe:	
Non-structural:	Damage?:	yes	Describe:	GIB cracking, veneer cracking

Recommendations

Level of repair/strengthening required:	minor non-structural			Describe:	
Building Consent required:				Describe:	
Interim occupancy recommendations:				Describe:	
Along	Assessed %NBS before e'quakes:	61%	##### %NBS from IEP below	If IEP not used, please detail assessment methodology:	Quantitative
	Assessed %NBS after e'quakes:	61%			
Across	Assessed %NBS before e'quakes:	100%	##### %NBS from IEP below		
	Assessed %NBS after e'quakes:	100%			

Appendix 4 – Level Survey



Revision	Amendment	Approved	Revision Date

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Project
Christchurch City Council

Title
Level Survey Charles Street

Drawn	Designed	Approved	Revision Date
Author	Designer	Approver	

Project No.	Scale	Drawing No.	Sheet No.	Revision
	1 : 100		A101	RA

Original sheet size A3 (420x297) Plot date: 21/05/2013 12:47:54 p.m. P:\Projects\6-QUAKE.01\CCC_Residential units\Charles Street\Charles Street - PRO 1039 Drawings\Charles Street,.rvt

Appendix 5 – Geotechnical Desktop Study

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9 July 2013

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

QC 130.00/045SC

Geotechnical Desk Study – 29 Charles Street, Waltham

1. Introduction

Christchurch City Council has commissioned Opus International Consultants (Opus) to undertake a Geotechnical Desk Study and site walkover of the 29 Charles Street housing units in Waltham. The purpose of this study is to: collate existing subsoil information, undertake an appraisal of the potential geotechnical hazards at this site, interpretation of level survey results and determine whether further investigations are required. The site walkover was completed by Opus International Consultants on 3 May 2013.

This geotechnical desk study has been undertaken without the benefit of any site specific investigations and is therefore preliminary in nature.

2. Desktop Study

2.1 Site Description

Charles Street housing units are located at 29 Charles Street, Waltham, 2 km southeast of the centre of Christchurch; refer to Site Location Plan in Appendix B. The site is bounded by residential areas to the north, south, east and west.

Charles Street complex was built in 1987 and consists of two single storey buildings approximately 90 m^2 and three car parking areas. The combined footprint area of the two buildings is approximately 180 m^2 with each building having approximate dimensions of 7.8 m x 11.7 m. Each building consists of two units with each unit having 45 m^2 areas; refer to Walkover Inspection Plan in Appendix C and Available Structural Drawings in Appendix D. Each building has a simple rectangular floor plan and all are single storey timber framed structures with concrete block veneer walls and a prefinished Trimdeck Colorsteel roof. The units are separated by 200 mm block masonry party walls and are founded on concrete perimeter footings (150-250 mm wide), founded at 450 mm depth below ground level and a reinforced concrete slab (100 mm thickness) on grade reinforced with mesh. The floor slab reinforcement does not appear to be tied to the footing reinforcement.

The ground profile is relatively flat and low lying with an average elevation of 5 m. The ground surrounding the two buildings is predominantly grassed surfaces with a concrete driveway leading into a car park, immediately south of the buildings.

2.2 Regional Geology

The published geological map of the area (Geology of the Christchurch Urban Area 1:25,000, Brown and Weeber, 1992) indicates the site is underlain by alluvial sand and silt of overbank deposits.

2.3 Expected Ground Conditions

The locations of Boreholes and Cone Penetrometer Tests (CPT) undertaken by the Earthquake Commission (EQC) have been reviewed (refer Site Location Plan in Appendix B and borehole logs in Appendix E).

Material logs available from the above sources have been used to infer the ground conditions at the site, as shown in Table 1 below.

Table 1: Inferred Ground Conditions

Stratigraphy	Average N_{60} and q_c (MPa)	Thickness (m)	Depth Encountered (m)	Groundwater table (m) below ground level
Loose fine to medium Sand with Silt	N_{60}=8 q_c=2.4	1.2	0.0	1.5
Medium stiff Clay and silty Clay	N_{60}=5 q_c=1.5	1.6	1.2	
Medium dense fine to medium Sand and silty Sand	N_{60}=28 q_c=13	13.9	2.8	
Medium dense Sand and sandy Silt	N_{60}=26 q_c=10	1.8	16.7	
Soft to medium stiff Clay to silty Clay	N_{60}=6 q_c=1	-	18.5	

The Boreholes and CPT's extended to 20 m below ground level. Based on ECan boreholes the Riccarton Gravel formation is expected to be encountered at approximately 26 to 27 m depth ground level.

Groundwater depths of approximately 1.5 and 2 m below ground level have been interpreted from the EQC Borehole Logs and ECan Borehole Logs (refer Appendix E).

2.4 Information from Canterbury Geotechnical Database

The Canterbury Geotechnical Database (Project Orbit) has been developed for the use of Professional Geotechnical and Structural Engineers to access geotechnical data shared by other engineers and their clients, and to share their own data in return.

The database is available to professional engineering companies, the Government, scientific and academic institutions, the Earthquake Commission, councils and insurers and other data providers.

The information retrieved from Project Orbit for 29 Charles Street is summarised in Table 2.

Table 2: Summary of retrieved information from Canterbury Geotechnical Database

Site Location: 29 Charles Street, Waltham, Christchurch CERA residential zone: Green DBH Residential Foundation Technical Category: TC 3	
Layer	**Retrieved Information**
EQC Aerial Photography	16/6/2011: sand ejecta at paved areas on the south entrance of 29 Charles Street. Possible sand ejecta on same side at 24/12/2011 but poor aerial photography prohibits exact interpretation.
EQC Liquefaction Interpreted from Aerial Photography	• 4th September 2010: No observed liquefaction on site. • 22nd February 2011: Moderate to severe observed liquefaction. • 13th June 2011: Moderate to severe observed liquefaction. • 23rd December 2011: Minor observed liquefaction on site but moderate to severe observed liquefaction 20 m southwest of the building footprint.
EQC Liquefaction and Lateral Spreading Observations	• 4th September 2010: No observations. • 22nd February 2011: No lateral spreading but minor to moderate quantities of ejected material to the north of the site. From road observations, the site was surrounded by severe quantities of ejected material. • 13th June 2011 road observations: Moderate to major liquefaction; ejected material often observed.
EQC Observed Ground Crack Locations	No ground cracks were recorded by EQC on this site; however cracking up to 200 mm was recorded to the east, west and north of the site.
EQC Vertical Ground Movements	From all earthquake events: vertical elevation change is between 0.1 m to 0.4 m due to settlement.
EQC Horizontal Ground Movements	Observed from LiDAR: main ground movements to the east or southeast.
EQC Event Specific Groundwater Surface Elevations	Event specific water surface depth: • September 2010: 2 to 3 m • February 2011: 1 to 2 m • June 2011: 0 to 2m • December 2011: 1 to 2m
Conditional Peak Ground Acceleration (PGA) for Liquefaction Assessment	• 4th September 2010: 0.23 g • 22nd February 2011: 0.52 g • 16th April 2011: 0.18 g • 13th June 2011 (M 6.0):0.30 g • 23rd December 2011 (M 5.9): 0.21 g
Hazard Maps	• ECan Liquefaction Assessment Area Map 2012: MBIE TC Zoned. • GNS Science Post 4th September 2010: No observations. • GNS Science Post 22nd February 2011: Observed liquefaction on site is probable. • ECan Liquefaction Hazard Maps-2004: High liquefaction potential on site when groundwater table is high.

2.4 Liquefaction Hazard

For the development of liquefaction phenomena (ejecta), three main conditions must be met (Day, 2000):

- Soil types susceptible to liquefaction (e.g. sands in a loose state);
- Groundwater table near the ground surface or at the surface level;
- Earthquake intensity and duration;

In the case of 29 Charles Street, all three of these conditions have been satisfied and thus there is potential for future liquefaction from an earthquake event.

A liquefaction hazard study was conducted by the Canterbury Regional Council (ECan) in 2004 to identify areas of Christchurch susceptible to liquefaction during an earthquake. The buildings on 29 Charles Street are located on an area identified as having 'high liquefaction potential', for a high groundwater table scenario. The liquefaction potential is moderate for a low groundwater table based on the same study.
Tonkin and Taylor Ltd (T&T Ltd), the Earthquake Commission's (EQC) geotechnical consultants, have 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. In summary, the liquefaction evidence on site from the above mentioned events are as follows:

- 4th September earthquake: no observed liquefaction
- 22nd February 2011: Moderate to severe observed liquefaction
- 13th June 2011: Moderate to severe observed liquefaction
- 23rd December 2011: Minor observed liquefaction

There are no open watercourses or free surfaces within close proximity to the site. This suggests that the lateral spreading potential of the site is considered minor.

Following the recent strong earthquakes in Canterbury, the Canterbury Earthquake Recovery Authority (CERA, 2012) has zoned land in the Greater Christchurch area according to its expected ground performance in future large earthquakes.

The Ministry of Business, Innovation and Employment (MBIE) has sub-divided the CERA "Green" residential recovery zone land on the flat in Christchurch into technical categories. The three technical categories are summarised in Table 3 which has been adapted from the MBIE guidance document (MBIE, 2012).

The land at 29 Charles Street has been zoned as Green TC 3 land, which indicates liquefaction damage is possible in a future large earthquake. Individual engineering assessment is required to select the appropriate foundation repair or rebuild option.

Table 3: Index Criteria for Foundation Technical Categories

Foundation Technical Category	Future land performance expected from liquefaction	Nominal SLS land settlement	Nominal ULS land settlement	Nominal Lateral Stretch
TC1 (where confirmed)	Liquefaction damage is unlikely in a future large earthquake	0-15 mm	0-25 mm	Generally not expected
TC2 (where confirmed)	Liquefaction damage is possible in a future large earthquake	0-50 mm	0-100 mm	<50 mm
TC3 (where confirmed)	Liquefaction damage is possible in a future large earthquake	>50 mm	>100 mm	>50 mm

A preliminary liquefaction assessment has been completed using CLiq Software (Version 1.7.1.6, 2006) adopting the Idriss & Boulanger Method (2008) with settlements calculated using Zhang et al. (2002). Cone Penetrometer Tests (CPTs) form the basis for the prediction of liquefaction potential, with a Magnitude 7.5 earthquake considered, and earthquake groundwater depth of 1.0 m below ground level. The CLiq analysis was undertaken using two CPTs located within approximately 15 m of the site boundary, as specified in Table 4 (refer to Site Location Plan in Appendix B).

Both the Serviceability and Ultimate Limit States have been assessed for an Importance Level 2 Structure (with Peak Ground Accelerations (PGAs) as specified in Table 4). The free field liquefaction induced subsidence estimates have been calculated over the complete test depth (typically 20 m) and are presented in Table 4 (refer Appendix F for CLiq output). For comparison with MBIE (2012) guidelines the estimated settlement in the top 10 m of the soil profile has also been presented.

Table 4: Estimated Liquefaction Induced Settlements

CPT	Event	Mag / PGA	Depth to Groundwater (m)	Estimated Settlement (mm)	Estimated Settlement in top 10 m of soil profile (mm)
CPT 15869 (20.06 m) (WTM-POD02-CPT002)	ULS	M7.5 / 0.35g	1.0	205	125
	SLS	M7.5 / 0.13g	1.0	80	50
CPT 8580 (19.64 m) (WTM-POD02-CPT008)	ULS	M7.5 / 0.35g	1.0	230	170
	SLS	M7.5 / 0.13g	1.0	100	90

Total liquefaction induced free field subsidence of up to 230 mm has been predicted in a future Ultimate Limit State (ULS) earthquake event, for a ground water depth of 1.0 m. The total subsidence predicted to occur in the top 10 m at Serviceability Limit State (SLS) is between 50 and 90 mm; this vertical settlement from liquefaction at SLS is categorised as 'minor to moderate' according to MBIE guidance (Table 12.5, MBIE, December 2012). Differential settlement is expected to occur due to variable thicknesses of liquefiable layers with expected differential settlements of up to 170 mm, for a ULS earthquake event.

The Liquefaction Potential Index (LPI) is another tool used to identify the soil's susceptibility to liquefaction. This index weights the potential impact of the predicted liquefaction with the depth. Results obtained from the liquefaction analysis with CLiq indicate an LPI of up to 32 in a ULS seismic event; this categorises the site as a very high liquefaction risk.

3. Observations

A walkover site inspection of 29 Charles Street was carried out by an Opus Geotechnical Engineer on 3 May 2013. The following observations were made (refer to Walkover Inspection Plan in Appendix C and Site Inspection Photographs at Appendix A):

- Vertical separation crack in Unit 1 (photograph 1). The vertical crack develops across the height of the building for a length of 2.4 m and progressively widens from 1 mm at the bottom to 4 mm at the top of 2.4 m height.
- Liquefaction ejecta material outside the entrance of Unit 2 and cracks smaller than 5 mm developed on the paved footpath outside Unit 2 (photograph 2).
- Liquefaction ejecta material outside Unit 3 entrance. Three cracks less than 5 mm wide are present on the paved footpath (photograph 3).
- Diagonal cracking 15 mm to 20 mm wide on the footpath outside Unit 4 entrance (photograph 4).
- Liquefaction ejecta material (grey sand) on the north-eastern corner of Unit 4 (photograph 5).
- Cracking developed on block wall under the northeast window of Unit 4. The crack is stepped. The width of the crack is 3 mm (photograph 6).
- Cracking developed on block wall below the east window of Unit 4. The crack is stepped. The width of the crack is less than 3 mm (photograph 7).
- Horizontal crack on east block wall of Unit 2. The crack widens towards the rear entrance of this Unit. The length of the crack is 760 mm and is 10 mm wide on the entrance (photograph 8).
- Stepped crack pattern on the east block wall between Unit 1 and Unit 2. The cracks are between 5 and 10 mm wide and the length of crack is 4.2 meters. The cracking is widening from Unit 1 towards Unit 2 from 1 mm to 10 mm (photographs 9, 10 and 11).

4. Level Survey

A summary of the level survey (refer Appendix G) undertaken by Opus Surveyors at 29 Charles Street is given in Table 5.

Table 5: Level Survey Summary

Unit no.	Critical variation in floor level (mm)	Approximate distance between survey points (m)	Maximum slope (angular distortion) (%)	Direction of fall
1	68	4.8	1.4	North
2	66	6.5	1.01	North
3	54	8.1	0.66	North
4	44	7.7	0.57	Northwest

5. Discussion

All Units are timber framed dwellings with concrete masonry exterior cladding (concrete block veneer), constructed on concrete slab on grade type foundations. This is equivalent to Type C2 foundations in accordance with the MBIE (MBIE, December 2012) guidance.

Significant liquefaction damage has occurred at 29 Charles Street as a result of the 2011 earthquake sequence. At the time of the 3 May 2013 inspection, evidence of ejected material and ground settlement was observed inside some of the units. Moderate cracking to pavements appears to be a result of differential settlement due to liquefaction.

Moderate to severe damage due to cracking was observed on the east block wall between Units 1 and 2. The stepped cracking pattern at this location is evidence of vertical downward foundation movement that caused distortion of the panel walls. The cracks developed are formed perpendicular to the stretched diagonal due to settlement of the middle footing located on the east side that separates Unit 1 from Unit 2 (refer Appendix C and photographs 9, 10 and 11 in Appendix A). We believe that the heavy cladding has influenced the settlements on this location.

Cracking was also observed under the east and northeast windows of Unit 4. These cracks developed as a result of shearing stresses that concentrated around the window openings due to earthquake induced loadings.

The level survey results have been assessed and indicated variations between 44 mm and 68 mm within each unit. The direction of settlement at Units 1 and 2 is towards the separation masonry block fire wall which is consistent with the cracking observed at the east block wall. More important, the slope (angular distortion) varied between 0.57 % and 1.4 % which is in excess of the maximum acceptable slope of 0.5 % recommended by MBIE. According EQC, the maximum acceptable angular distortion is 25 mm every 6 m or a slope of 0.41 %. In accordance with the MBIE guidance (December 2012), both units will require a foundation re-level. Although the level survey in Units 3 and 4 indicates that the floors are out of level, there is insufficient evidence that this is all due to movement in the earthquakes.

Boreholes and CPTs undertaken for EQC indicate the buildings are likely to be founded on layers of loose to medium dense Sand approximately 1.2 m thick overlying medium stiff Clay approximately 1.6 m thick. Liquefiable medium dense fine Sand is extending below the clay to approximately 16.7 m depth. 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 identified liquefiable layers from about 2 to 7 m and 8.5 to 15 m below ground level, mainly within the deeper medium dense sand layer. The subsurface ground profile together with the ground damage observed at the site during the recent earthquakes of 2010 and 2011, confirms that the site has a high risk of liquefaction.

GNS Science indicates an elevated risk of seismic activity is expected in the Canterbury region as a result of the earthquake sequence following the September 2010 earthquake. Recent advice (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 (1 July 2013 – 30 June 2014). Such an event may cause liquefaction induced land damage similar to that experienced, dependent on the location of the earthquake's epicentre. This confirms that there is currently a risk of liquefaction and further differential settlement at 29 Charles Street.

6. Recommendations

It is recommended that in order to determine foundation repair options at 29 Charles Street, a site specific investigation is undertaken including one further CPT, Hand Augers and Scalas. The site investigation will enable a site specific liquefaction assessment to be undertaken to identify the liquefiable layers to help determine conceptual repair and re-levelling options.

The scope of the proposed site specific geotechnical investigations will be:

- One CPT to a depth of 20 m.
- Two Hand Auger and Scala tests should be carried out to 3 m depth or refusal, with one located at the east side close to the block wall between Units 1 and 2.
- Geotechnical Assessment and Reporting.
- Inspection of concrete floor slab for evidence of cracking.

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 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 assessment provided in this Document. Opus's 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, or its surroundings or any laws or regulations.

8. References

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Appendices:

Appendix A: Site Inspection Photographs
Appendix B: Site Location Plan
Appendix C: Walkover Inspection Plan
Appendix D: Available Structural Drawings
Appendix E: EQC Site Investigations and ECan Wells
Appendix F: CLiq Liquefaction Analysis
Appendix G: Opus Level Survey

Appendix A:
Site Inspection Photographs

Photograph 1: Vertical crack on the north window of Unit 1.

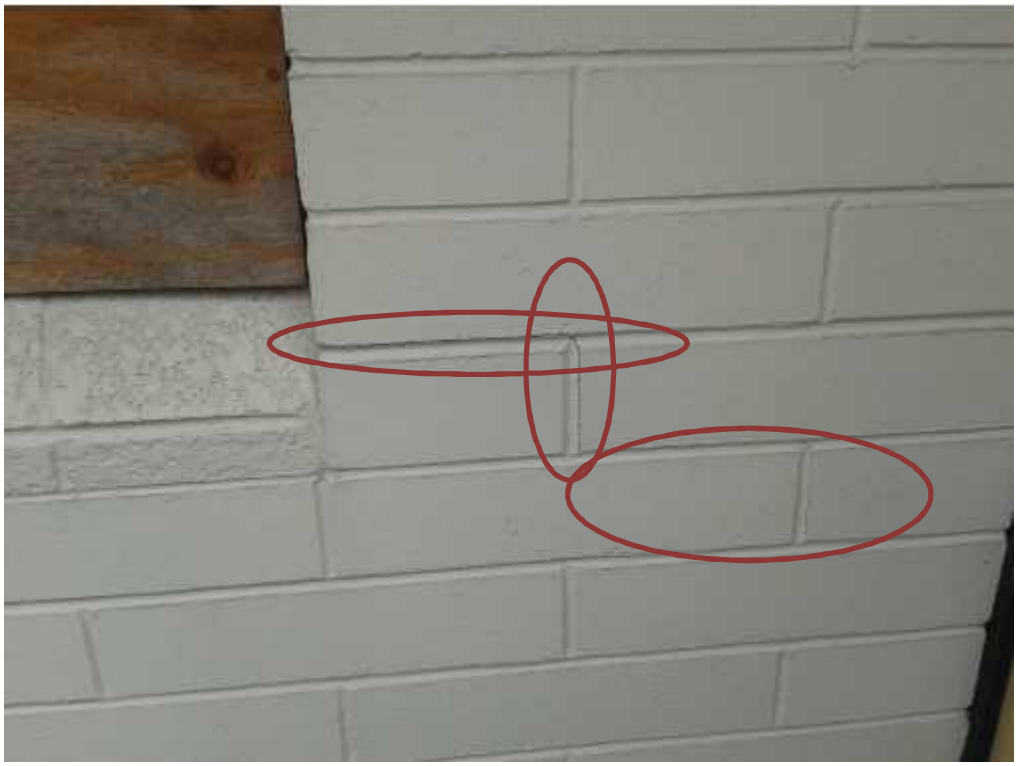
Photograph 2: Liquefaction ejecta (grey silty sand) in front of Unit 2 entrance. Cracks less than 5 mm are present.

Photograph 3: Liquefaction material (grey sand) in the Unit 3 entrance. Three cracks less than 5 mm wide are present on the paved footpath.

Photograph 4: Diagonal cracking 15 mm to 20 mm wide on the footpath outside Unit 4 entrance.

Photograph 5: Liquefaction ejecta material (grey sand) on the north-eastern corner of Unit 4.

Photograph 6: Cracking 3 mm wide developed on block wall below the east window of Unit 4.



Photograph 7: Step cracking less than 3 mm wide developed on block wall below the east window of Unit 4.

Photograph 8: Horizontal crack 10 mm wide on east block wall of Unit 2.

Photograph 9: Stepped crack pattern on the east block wall between Unit 1 and Unit 2.

Photograph 10: Stepped crack pattern on the east block wall between Unit 1 and Unit 2 towards Charles Street.

Photograph 11: Stepped crack pattern on the east block wall of Unit 2.

Appendix B:
Site Location Plan

CPT 8580
CPT 15869

BOREHOLE 10087

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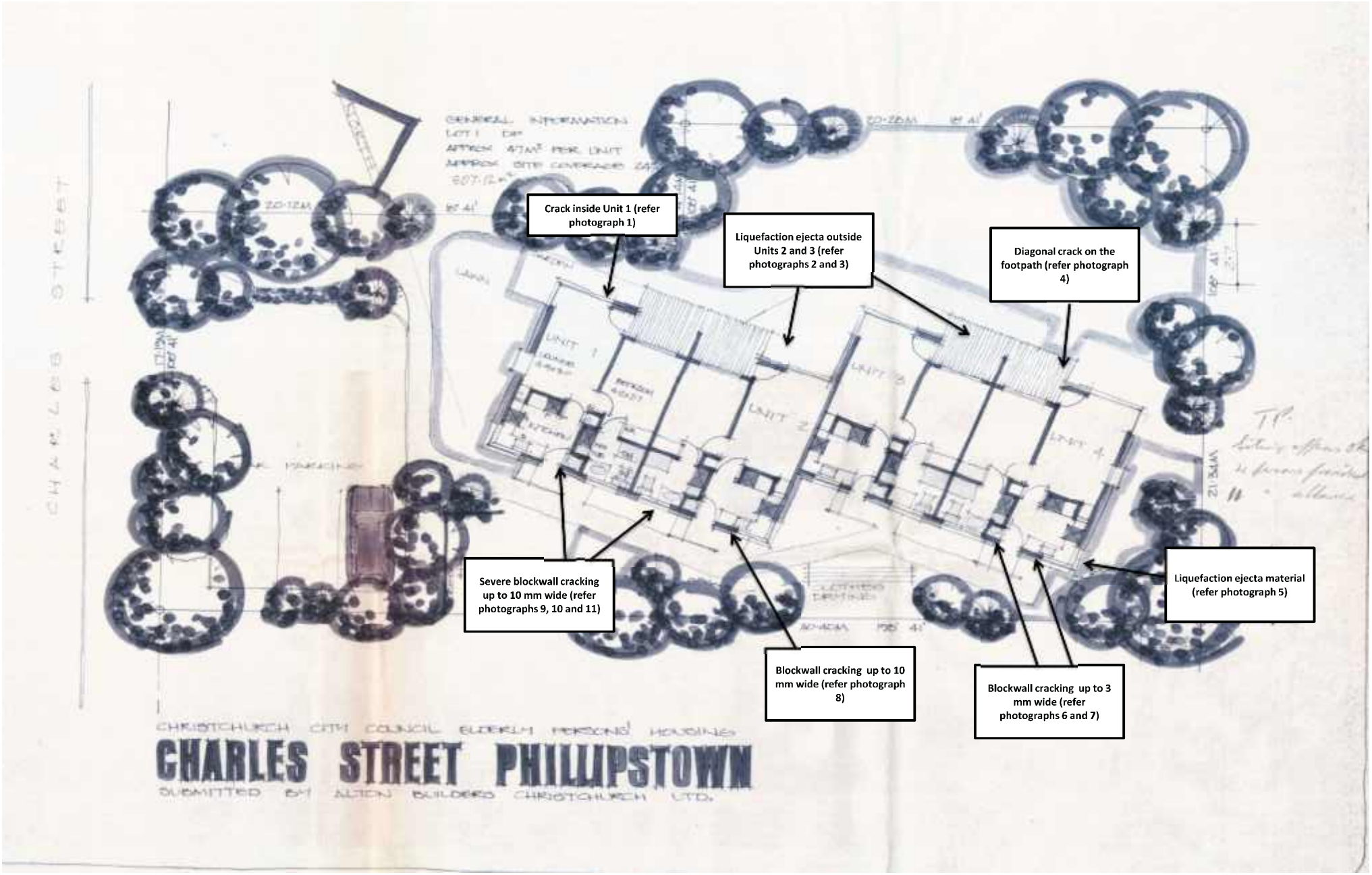
Project No.: QC130.00-045SC
Client: Christchurch City Council

APPENDIX B: Site Location Plan

Drawn: Opus Geotechnical Engineer

Date: 7-May-13

Appendix C:
Walkover Inspection Plan



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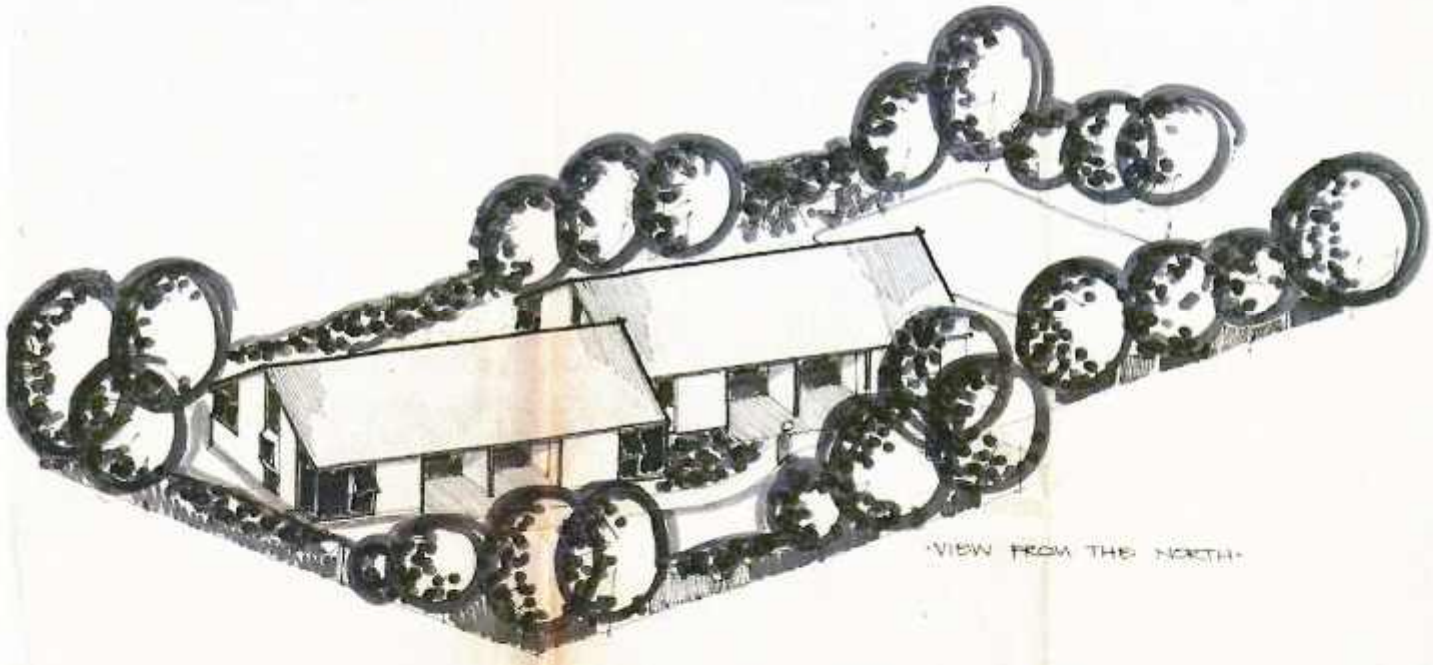
Project: 29 Charles Street, Christchurch
Project No.: QC130.00-045SC
Client: Christchurch City Council

APPENDIX C: Walkover Inspection Plan

Drawn: Opus Geotechnical Engineer

Date: 7-May-13

Appendix D:
Available Structural Drawings

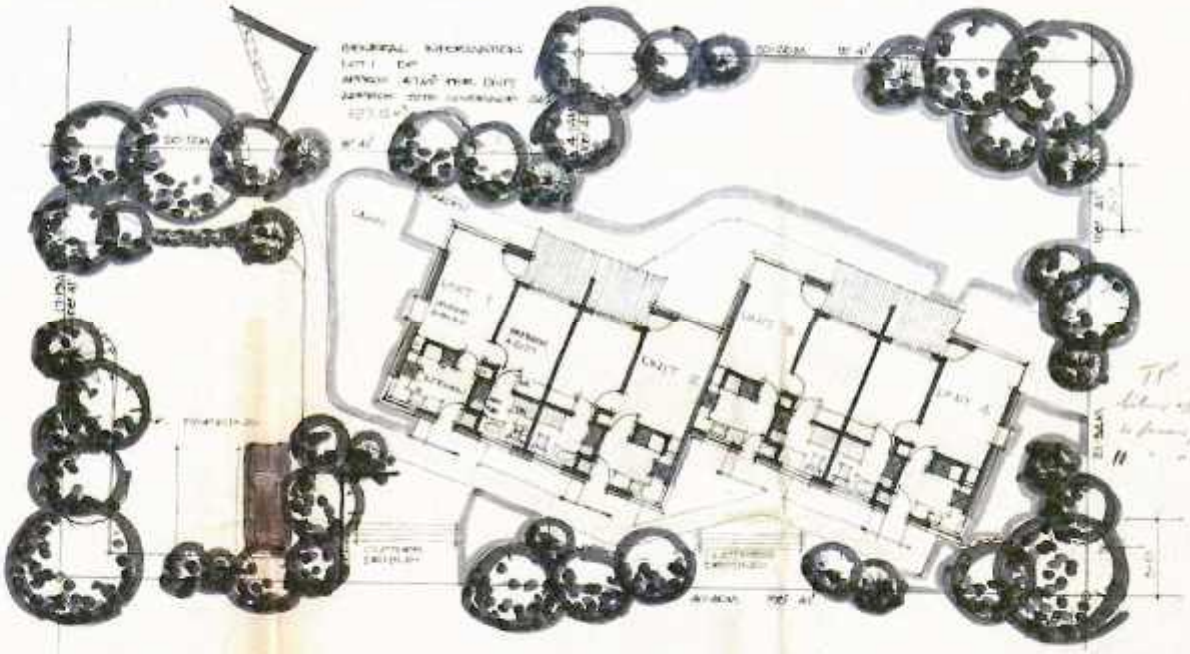


VIEW FROM THE NORTH

CHRISTCHURCH CITY COUNCIL BLOOMFIELD PROJECT HOUSING

CHARLES STREET PHILLIPSTOWN

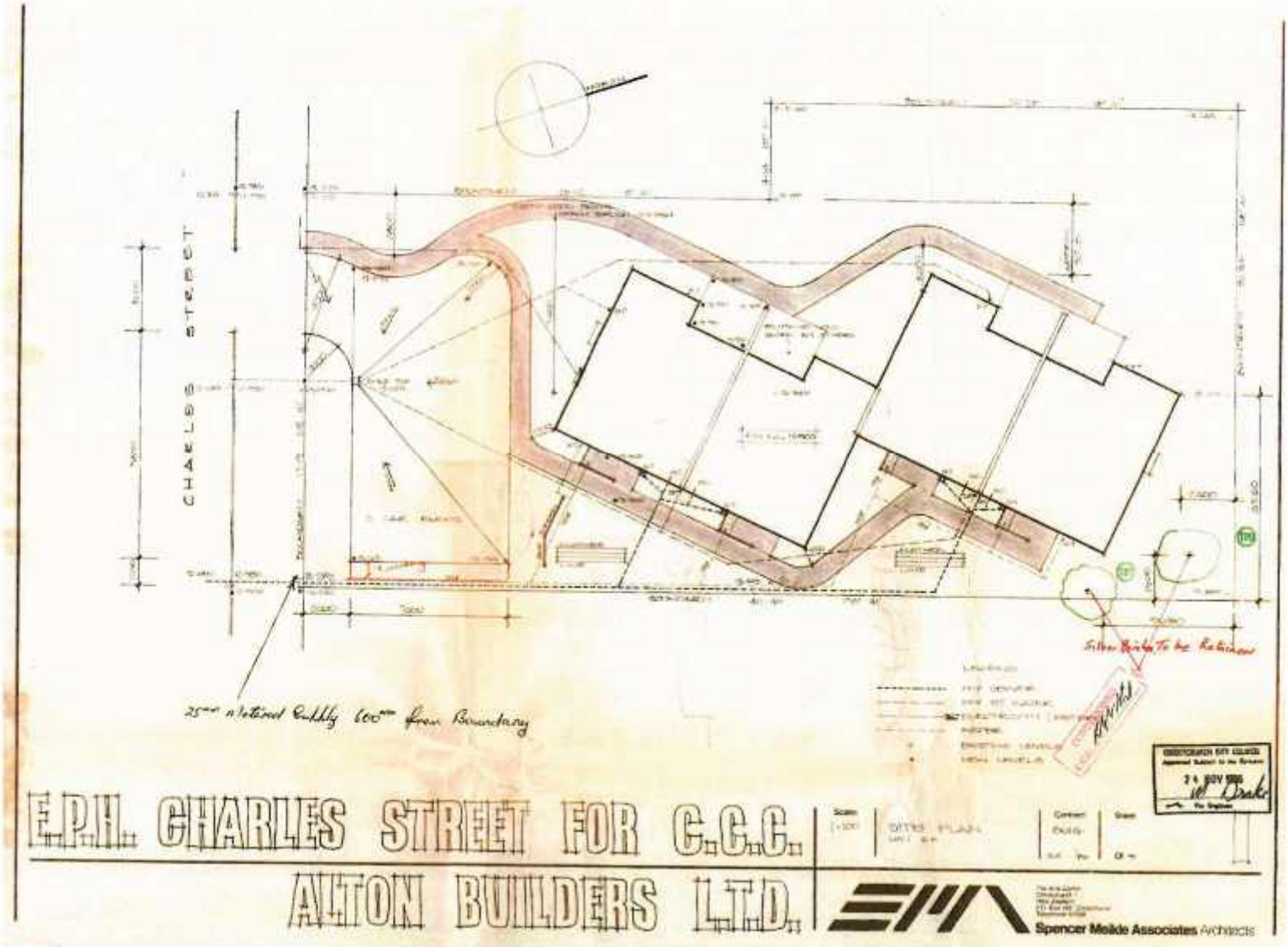
SUBMITTED BY ALSTON BUILDERS CHRISTCHURCH CITY



CHRISTCHURCH CITY COUNCIL BUILDING HOUSING

CHARLES STREET PHILLIPSTOWN

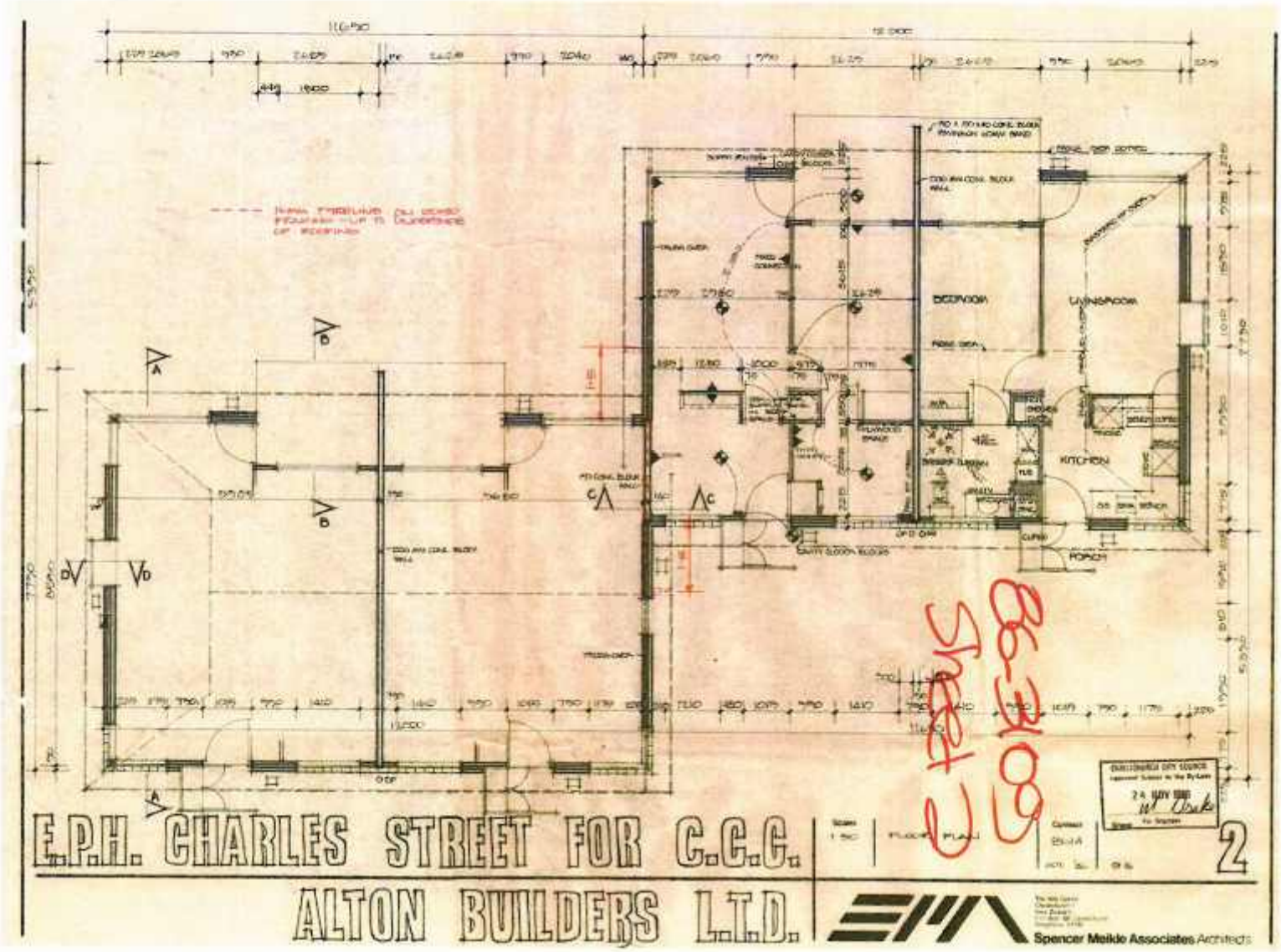
SUBMITTED BY ALTEN BUILDERS CHRISTCHURCH LTD.

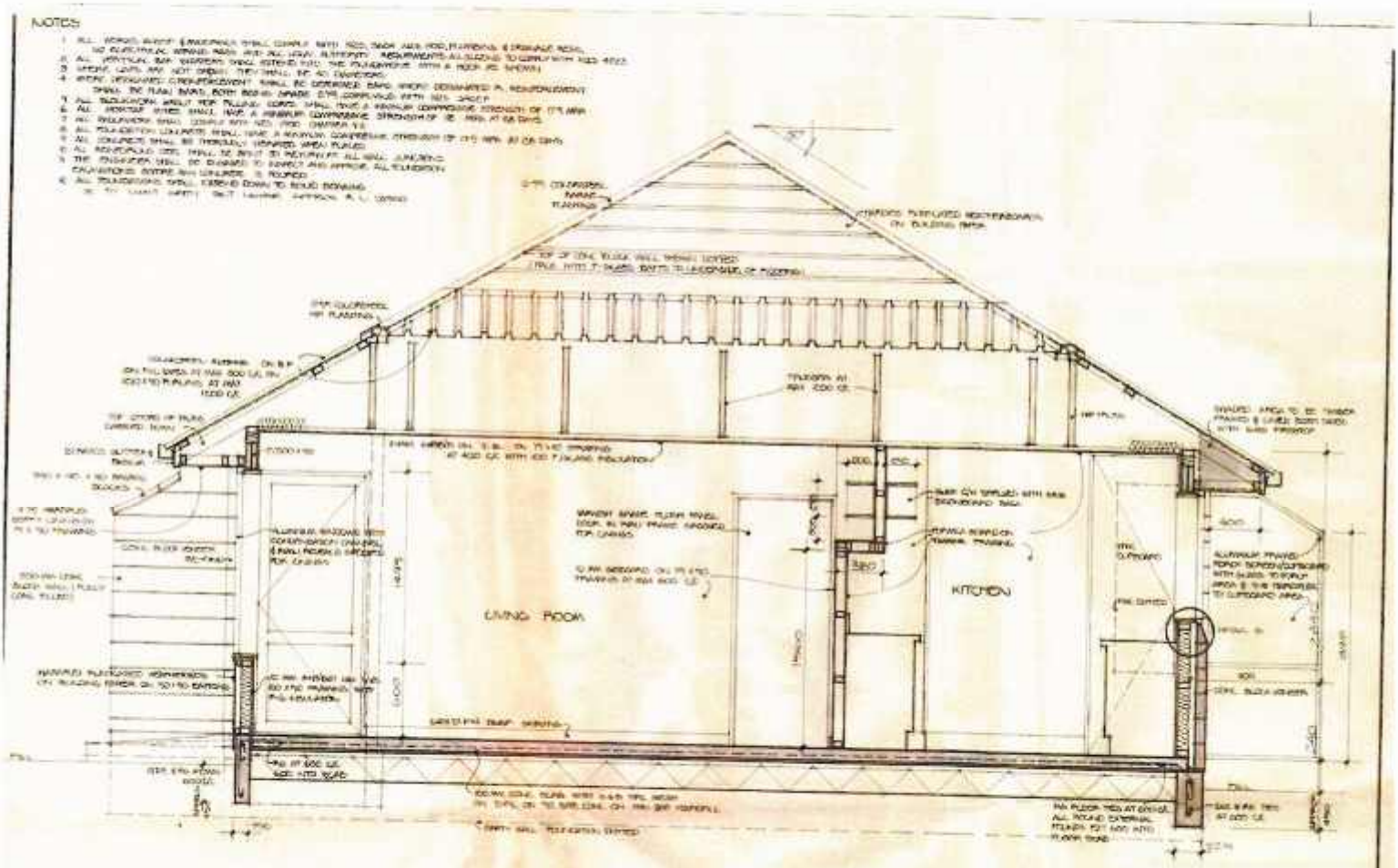


E.P.H. CHARLES STREET FOR C.C.C.

ALTON BUILDERS LTD.

Spencer Meikle Associates Architects


BEDROOM
LIVINGROOM
KITCHEN
PORCH
E.P.H. CHARLES STREET FOR C.C.C.
ALTON BUILDERS L.T.D.
2
Spencer Meikle Associates Architects



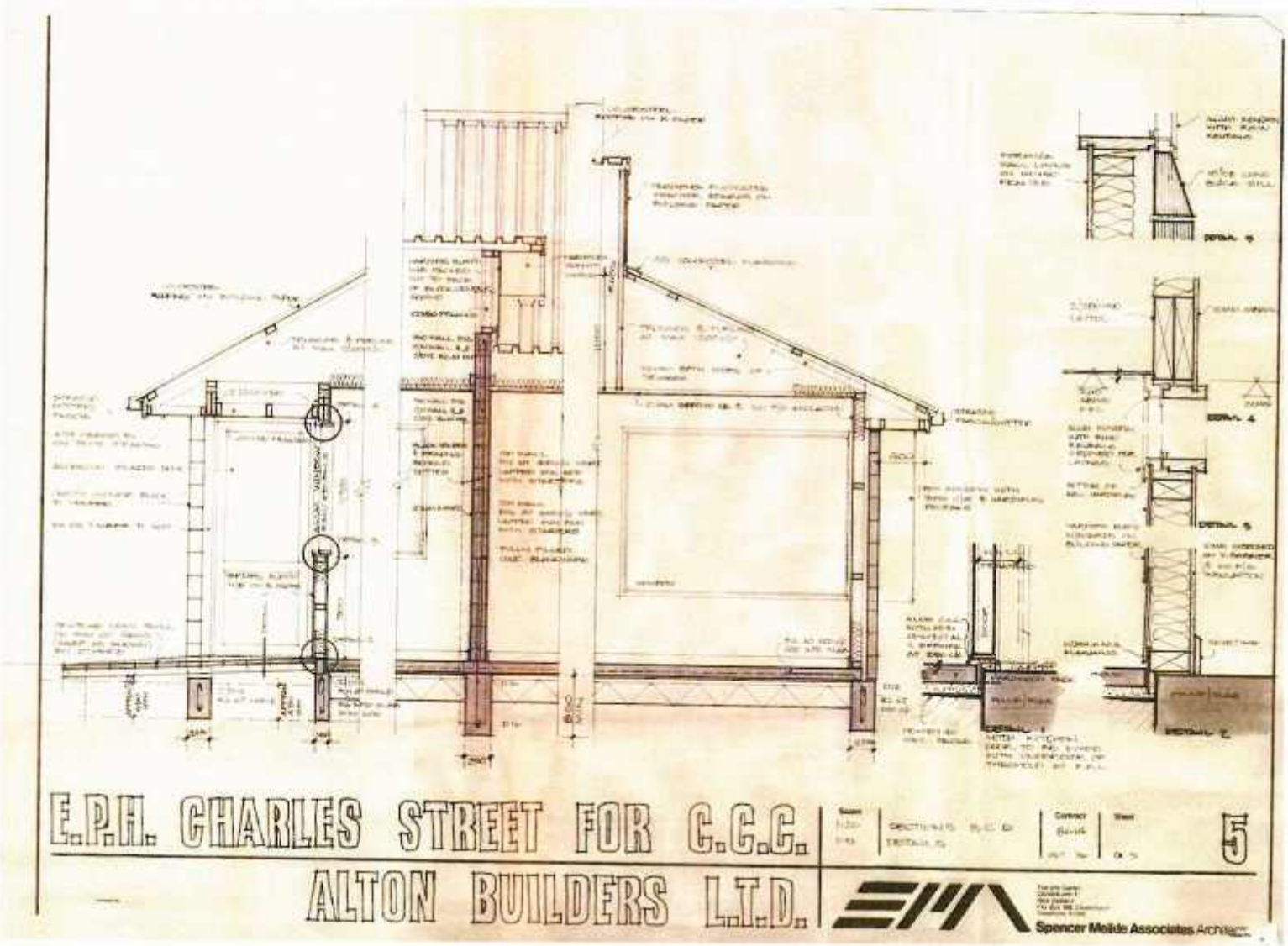
E.P.H. CHARLES STREET FOR C.C.C.

ALTON BUILDERS L.T.D.

SECTION A

4

Spencer Meikle Associates Architects



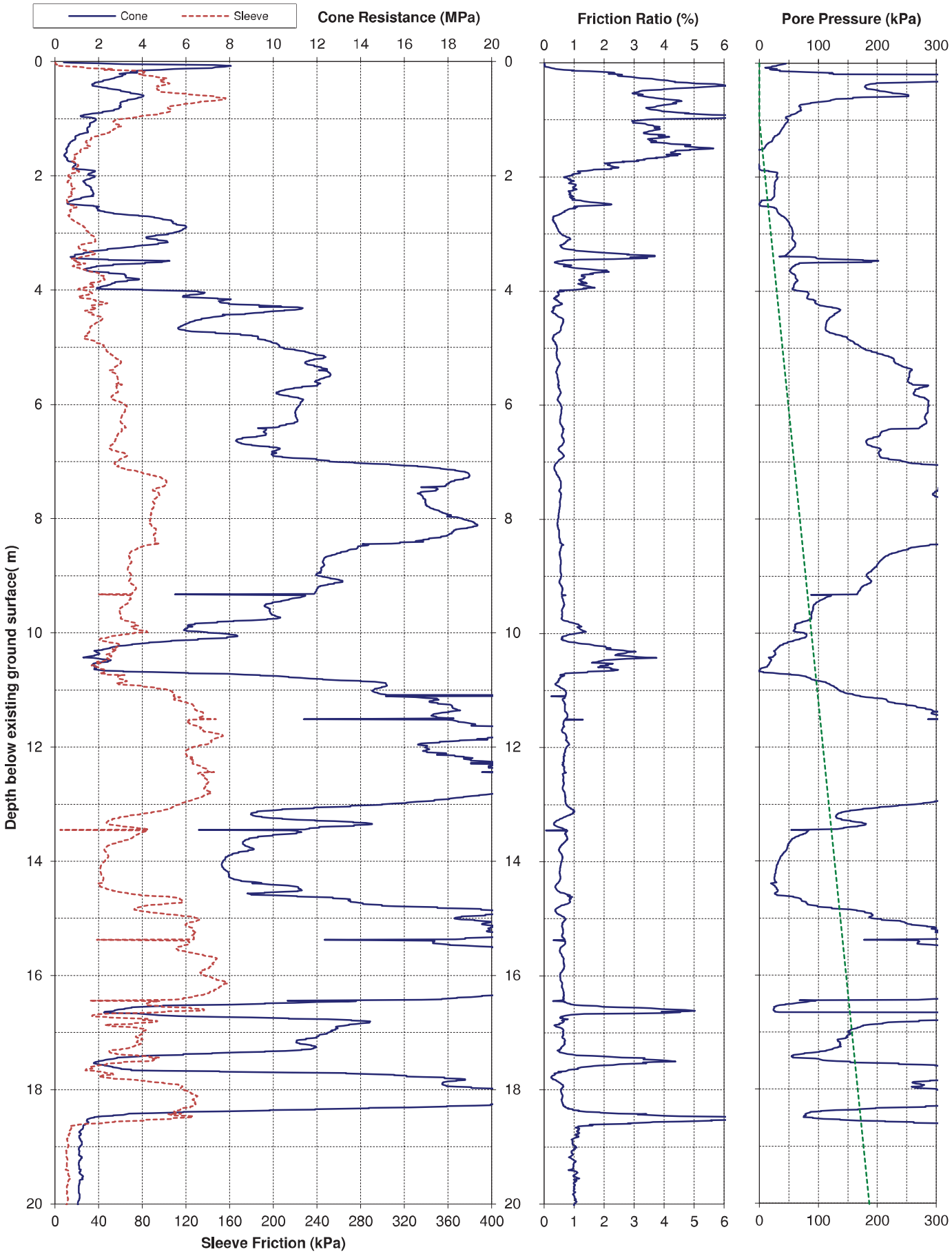
E.P.H. CHARLES STREET FOR C.C.C.

ALTON BUILDERS L.T.D.

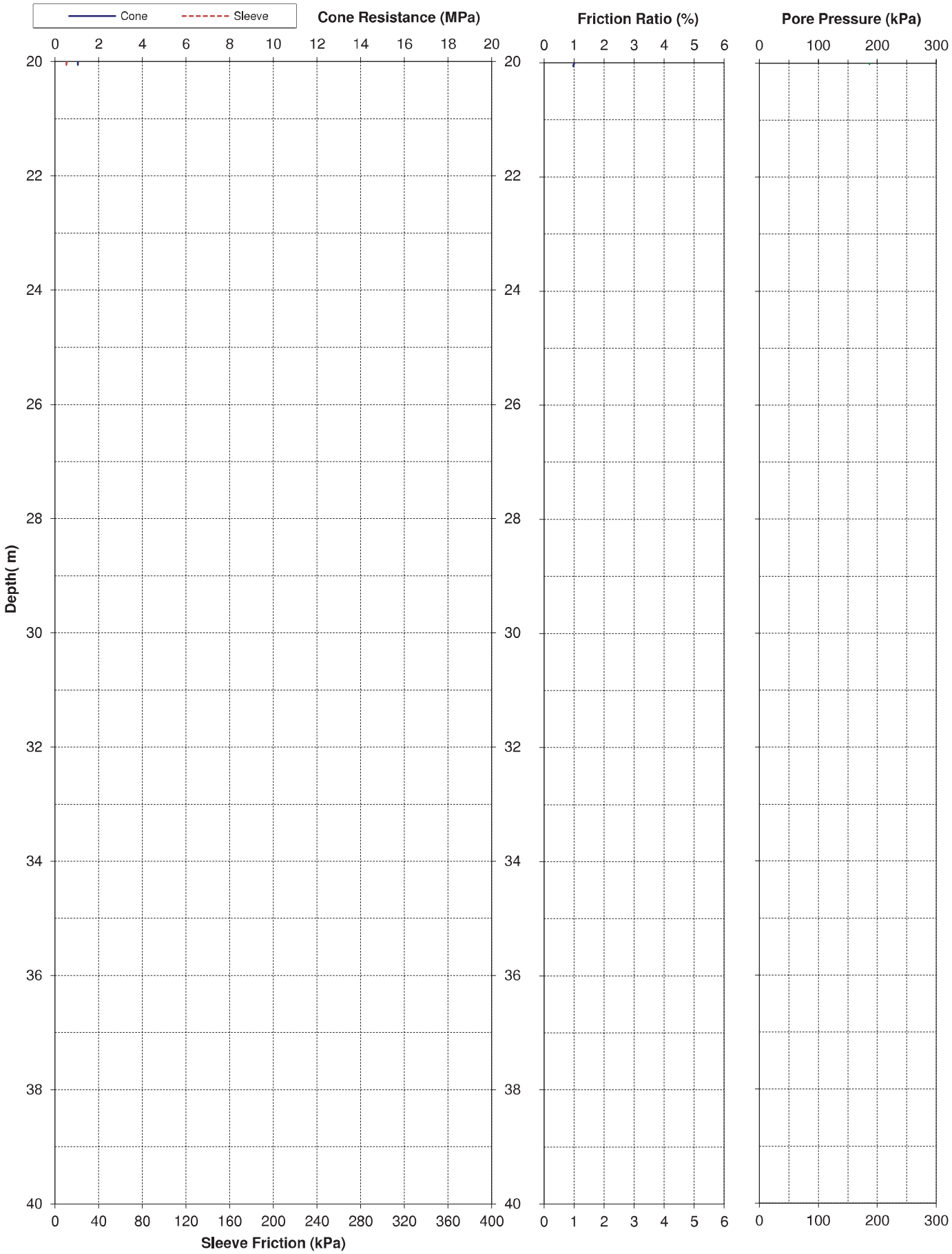
Spencer Meilde Associates Architects

Appendix E: EQC Site Investigations and ECan Wells

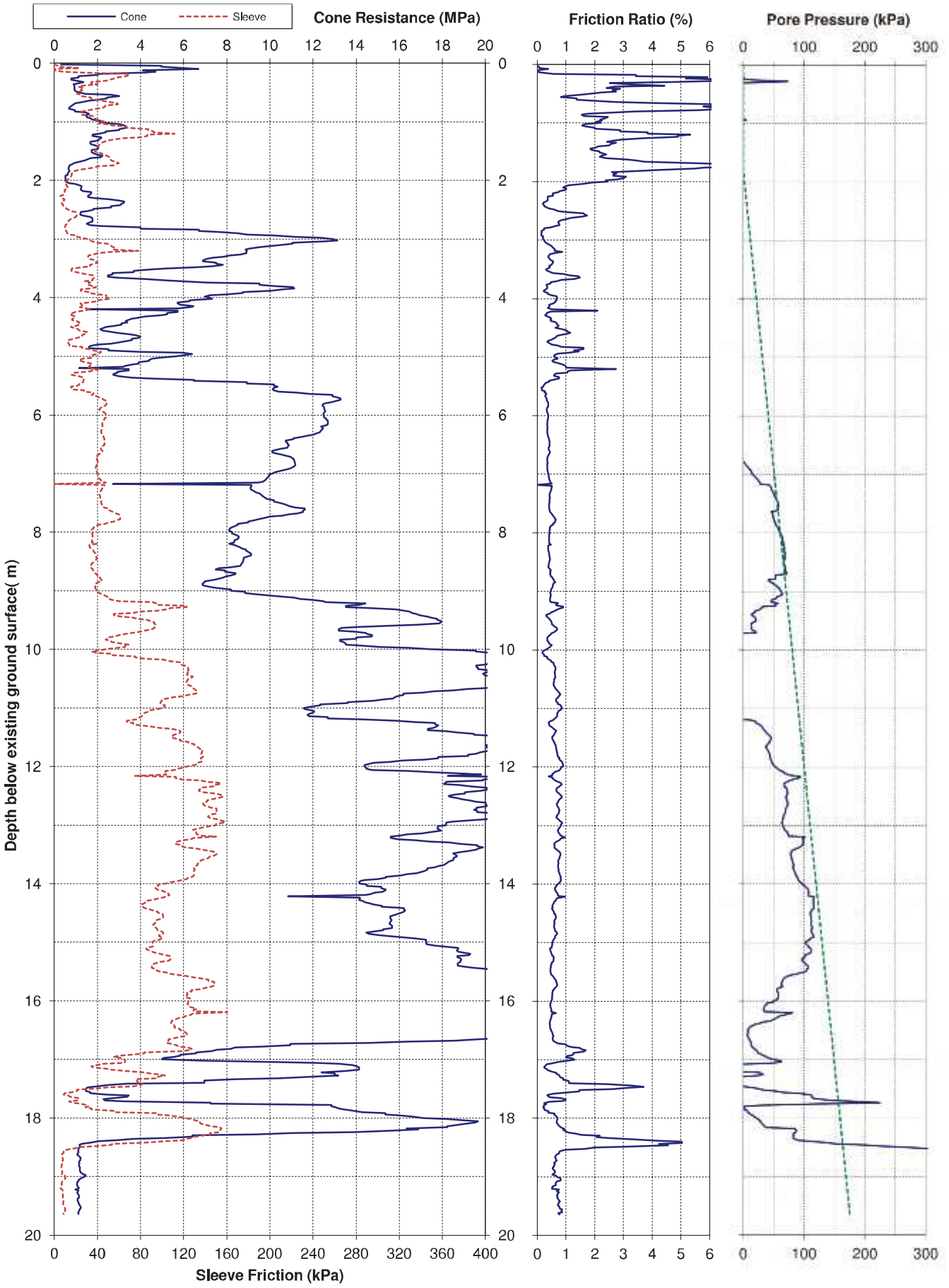
Project:	Christchurch TC3 Geotechnical Investigations				**Page:** 1 of 2	**WTM-POD02-CPT002**	
Test Date:	5-Oct-2012	**Suburb:**	Waltham	**Operator:**	Brown Bros		
Pre-Drill:	0m	**Assumed GWL:**	1mBGL	**Located By:**	Survey GPS		
Position:	2482323.65mE	5740436.77mN	4.07mRL	**Coord. System:**	NZMG		
Address:	4/62 Barbour St			**Datum Reference:**	MSL (CCC 20/01/12 Datum -9.043)		



Project:	Christchurch TC3 Geotechnical Investigations			Page: 2 of 2		WTM-POD02-CPT002
Test Date:	5-Oct-2012	Location:	Waltham	Operator:	Brown Bros	
Pre-Drill:	0m	Assumed GWL:	1mBGL	Located By:	Survey GPS	
Position:	2482323.7mE	5740436.8mN	4.07mRL	Coord. System:	NZMG	
Other Tests:				Comments:		



Project:	Christchurch TC3 Geotechnical Investigations			Page: 1 of 1	WTM-POD02-CPT008
Test Date:	19-Sep-2012	Suburb:	Waltham	Operator:	Geotechnics
Pre-Drill:	0m	Assumed GWL:	1.8mBGL	Located By:	Survey GPS
Position:	2482363.78mE	5740447.68mN	4.3mRL	Coord. System:	NZMG
Address:	65B Grafton St			Datum Reference:	MSL (CCC 20/01/12 Datum -9.043)



T+T Ref: 52003.2000

Printed: 8/11/2012 1:55 p.m.

Template: CPT Graph Template TC3.xls

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: BH-02
Hole Location:
WTM-POD02-BH02
(68 Grafton Street)
SHEET 1 OF 2

PROJECT: CHCH TC3 GEOTECHNICAL INVESTIGATION	LOCATION: WALTHAM	JOB No: 52003.000
CO-ORDINATES 5740467.43 mN 2482418.6 mE	DRILL TYPE: Roto-Sonic	HOLE STARTED: 7/7/12
	DRILL METHOD: PQDT/Auto SPT	HOLE FINISHED: 7/7/12
R.L. 4.35 m		DRILLED BY: Pro-Drill
DATUM NZMG, MSL (CCC 20/01/12 Datum -9.043m)	DRILL FLUID: LP2000	LOGGED BY: MOSS-DR CHECKED: BMcD

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.

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.

GEOLOGICAL UNIT	CORE RECOVERY (%)	METHOD	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION
ASPHALT										ASPHALT.
FILL					4		GW	W		Sandy fine to coarse GRAVEL with trace silt, grey, subangular to rounded, wet, well graded. Sand is fine to coarse.
YALDHURST MEMBER OF THE SPRINGSTON FORMATION (ALLUVIAL)	100	PQDT					ML			Fine to coarse GRAVEL with some silt and some sand, grey, subangular to subrounded, wet, well graded. Sand is fine to coarse.
			*FC1.2	B	3	1				SILT with minor sand, grey, wet, non plastic to low plasticity. Sand is fine to medium. 1.15m- trace organics. 1.5 to 1.95m- no recovery. 1.5m- saturated, no SPT test.
	70	PQDT			2	2	SM	S		Silty fine to medium SAND, brownish grey, saturated, poorly graded.
	100	SPT	*FC3.0 1/0//0/0/1/1 N=2	B	1	3			VL	3.0m- very loose.
	100	PQDT				4				4.0m- trace organics.
CHRISTCHURCH FORMATION (MARINE/ ESTUARINE)	100	SPT	1/1//1/2/2/3 N=8		0		SP		L	Fine to medium SAND with minor silt, grey, very loose, saturated, poorly graded. 4.5m- loose.
	100	PQDT			-1	5				
	100	SPT	*FC6.0 2/2//3/3/4/5 N=15	B	-2	6			MD	6.0m- medium dense.
	100	PQDT					SW			6.45 to 7.0m- fine to coarse sand. 6.8 to 7.5m- trace fine gravel, rounded.
						7	SP			
	100	SPT	1/1//1/3/4/4 N=12		-3					
	100	PQDT			-4	8				
	100	SPT	*FC9.0 1/1//2/3/4/7 N=16	B	-5	9				
	100	PQDT				10				9.65 to 10.0m- minor fine to medium gravel, subangular to subrounded.

Log Scale 1:50

T+T DATATEMPLATE.GDT rcb
BOREHOLE LOG 7/20/12 WTM-POD02.GPJ 29-Nov-2012

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: BH-02
Hole Location:
WTM-POD02-BH02
(68 Grafton Street)
SHEET 2 OF 2

PROJECT: CHCH TC3 GEOTECHNICAL INVESTIGATION	LOCATION: WALTHAM	JOB No: 52003.000
CO-ORDINATES 5740467.43 mN 2482418.6 mE	DRILL TYPE: Roto-Sonic	HOLE STARTED: 7/7/12
	DRILL METHOD: PQDT/Auto SPT	HOLE FINISHED: 7/7/12
R.L. 4.35 m		DRILLED BY: Pro-Drill
DATUM NZMG, MSL (CCC 20/01/12 Datum -9.043m)	DRILL FLUID: LP2000	LOGGED BY: MOSS-DR CHECKED: BMcD

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.

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.

Geological unit	Core recovery (%)	Method	Tests	Samples	R.L. (m)	Depth (m)	Classification symbol	Moisture condition	Strength/density classification	Description
CHRISTCHURCH FORMATION (MARINE/ ESTUARINE)	100	PQDT			-6		SP	S	MD	Fine to medium SAND with minor silt, grey, medium dense, saturated, poorly graded.
	100	SPT	2/1// 3/4/8/12 N=27							
	100	PQDT			-7	11				
	100	SPT	*FC12.0 2/2//3/5/9/9 N=26	B	-8	12				
	100	PQDT			-9	13				
	100	SPT	2/3//4/5/6/8 N=23							
	100	PQDT			-10	14				
	100	SPT	*FC15.0 4/4// 6/6/8/11 N=31	B	-11	15			D	15.0m- dense.
	100	PQDT			-12	16				
	100	SPT	1/3//4/4/4/3 N=15				SM		MD	Silty fine to medium SAND, grey, dense, saturated, poorly graded. 16.5m- medium dense.
	100	PQDT			-13	17	ML		VSt	SILT with minor sand, grey, very stiff, saturated, low plasticity. Sand is fine to medium.
							SP		MD	Fine to medium SAND with some silt, grey, medium dense, saturated, poorly graded. 18.0m- very loose.
	100	SPT	1/0//0/1/0/0 N=1		-14	18			VL	
	70	PQDT			-15	19	ML		VS	SILT with some sand, grey, very soft, saturated, low plasticity. Sand is fine to medium.
						20				19.5m- casing sunk, no SPT. 19.5 to 19.95m- no recovery. End of borehole at 19.95mbgl (target depth)

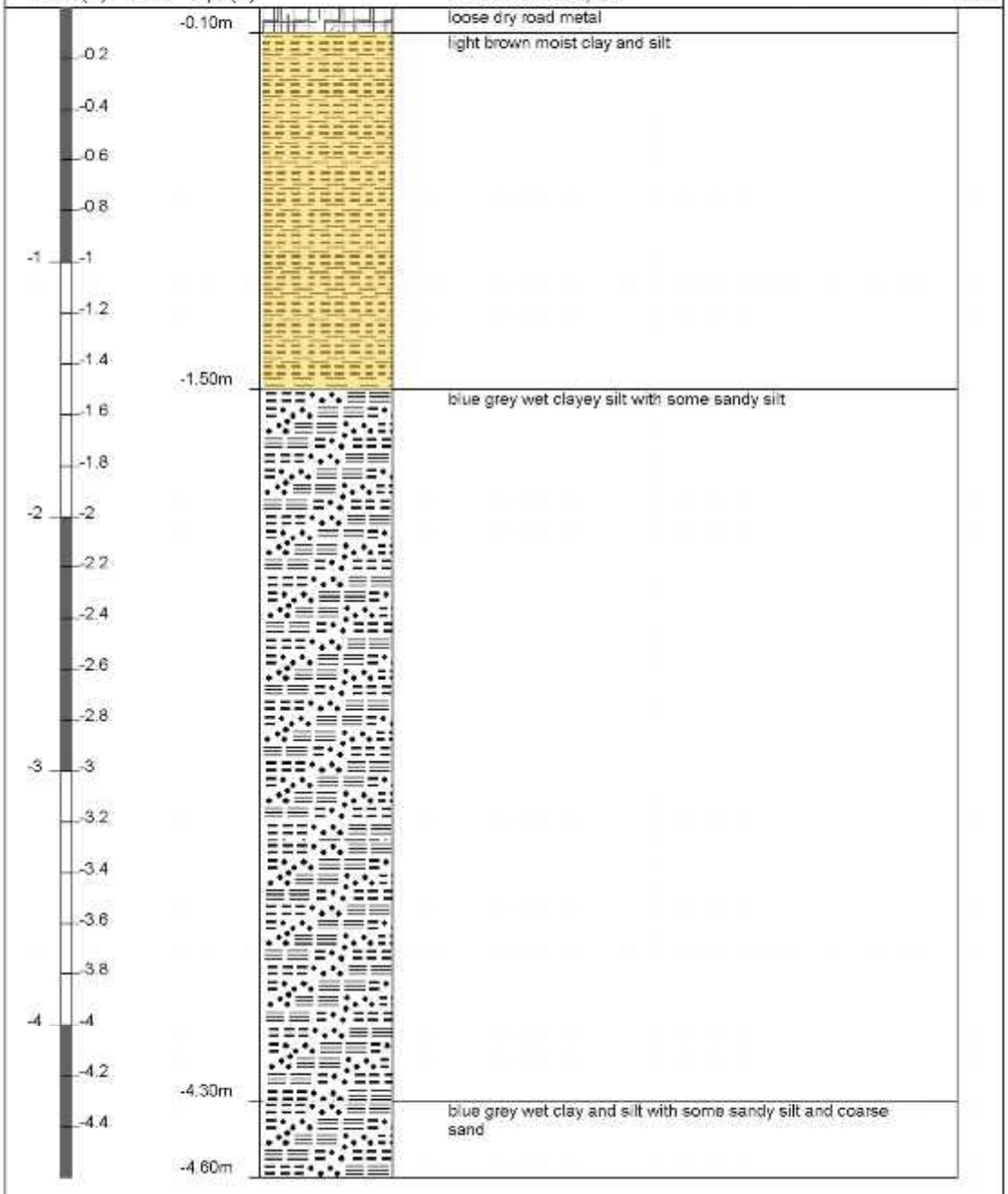
T+T DATATEMPLATE.GDT rcb

Log Scale 1:50

Borelog for well M35/12581

Gridref: M35:82126-40330 Accuracy : 3 (1=high, 5=low)
Ground Level Altitude : 4.9 +MSD
Well name : CCC BorelogID 684
Drill Method Not Recorded
Drill Depth : -4.6m Drill Date :

Environment Canterbury Regional Council

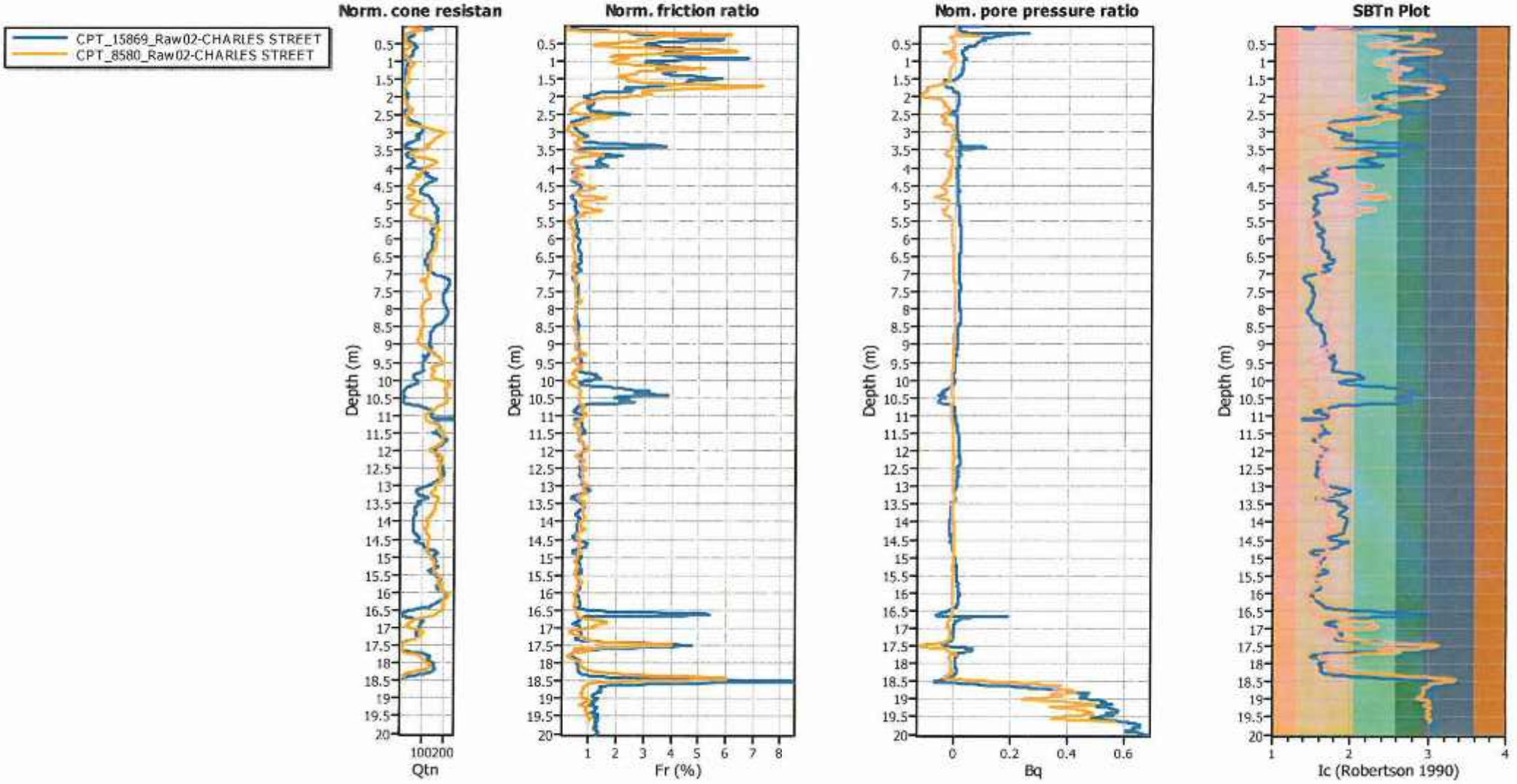


Appendix F:
CLiq Liquefaction Analysis

OPUS International Consultants
20 Moorhouse Avenue +64 3 363 5400
Christchurch 8011, New Zealand
www.opus.co.nz

Project: 29 Charles Street Waltham - SLS

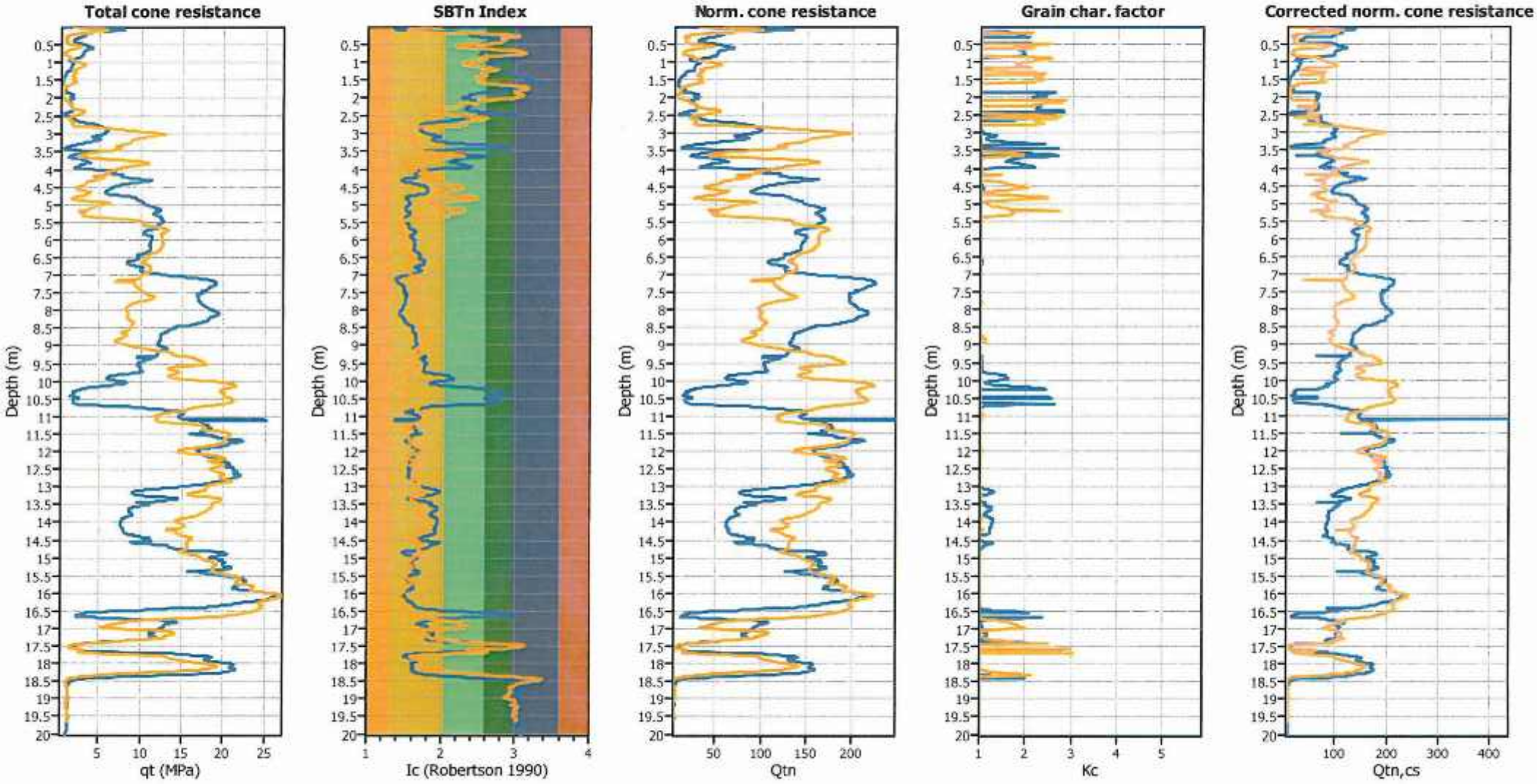
Overlay Normalized Plots



OPUS International Consultants
20 Moorhouse Avenue +64 3 363 5400
Christchurch 8011, New Zealand
www.opus.co.nz

Project: 29 Charles Street Waltham - SLS

Overlay Intermediate Results



OPUS International Consultants
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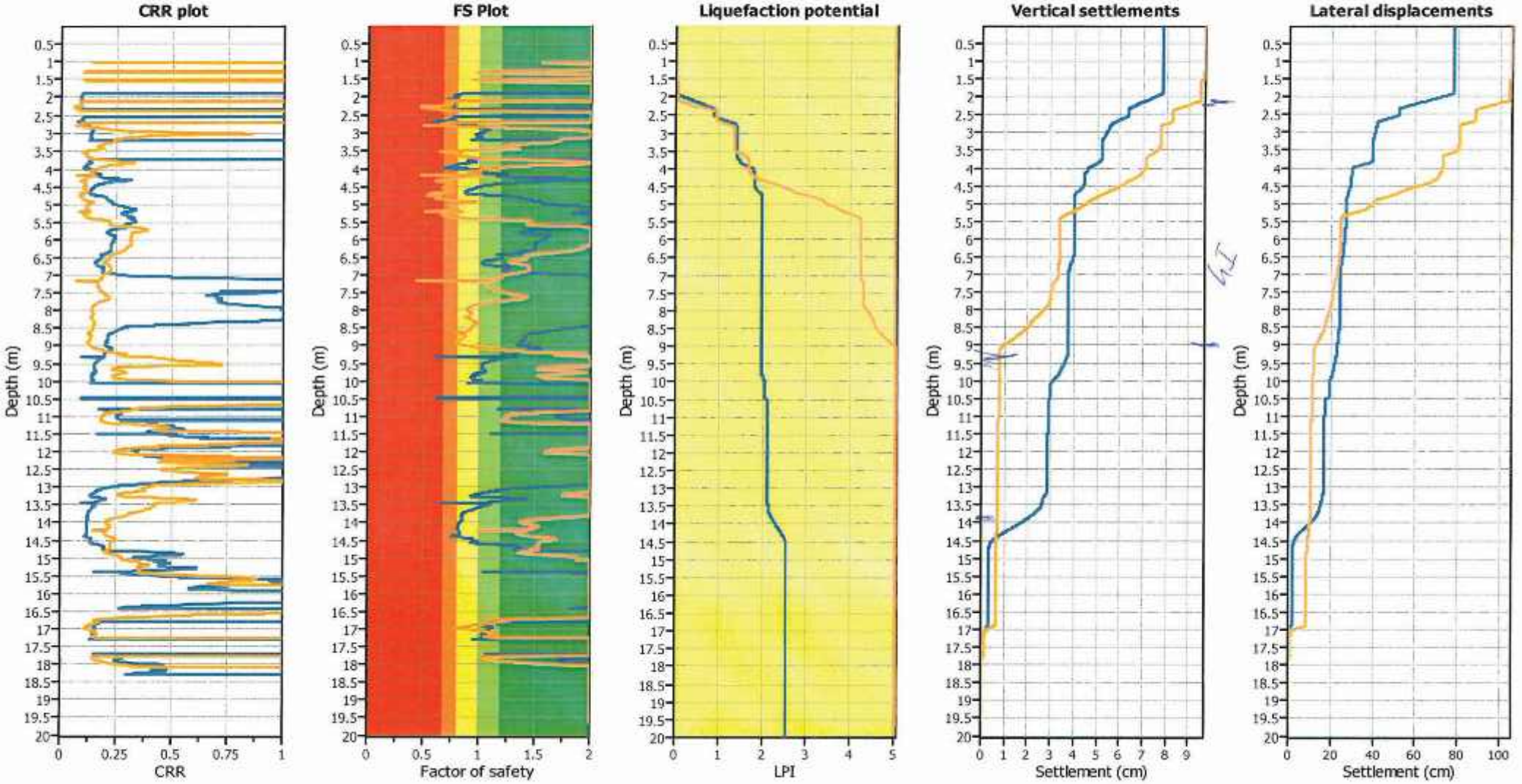
Christchurch 8011, New Zealand
www.opus.co.nz

Project: 29 Charles Street Waltham - SLS

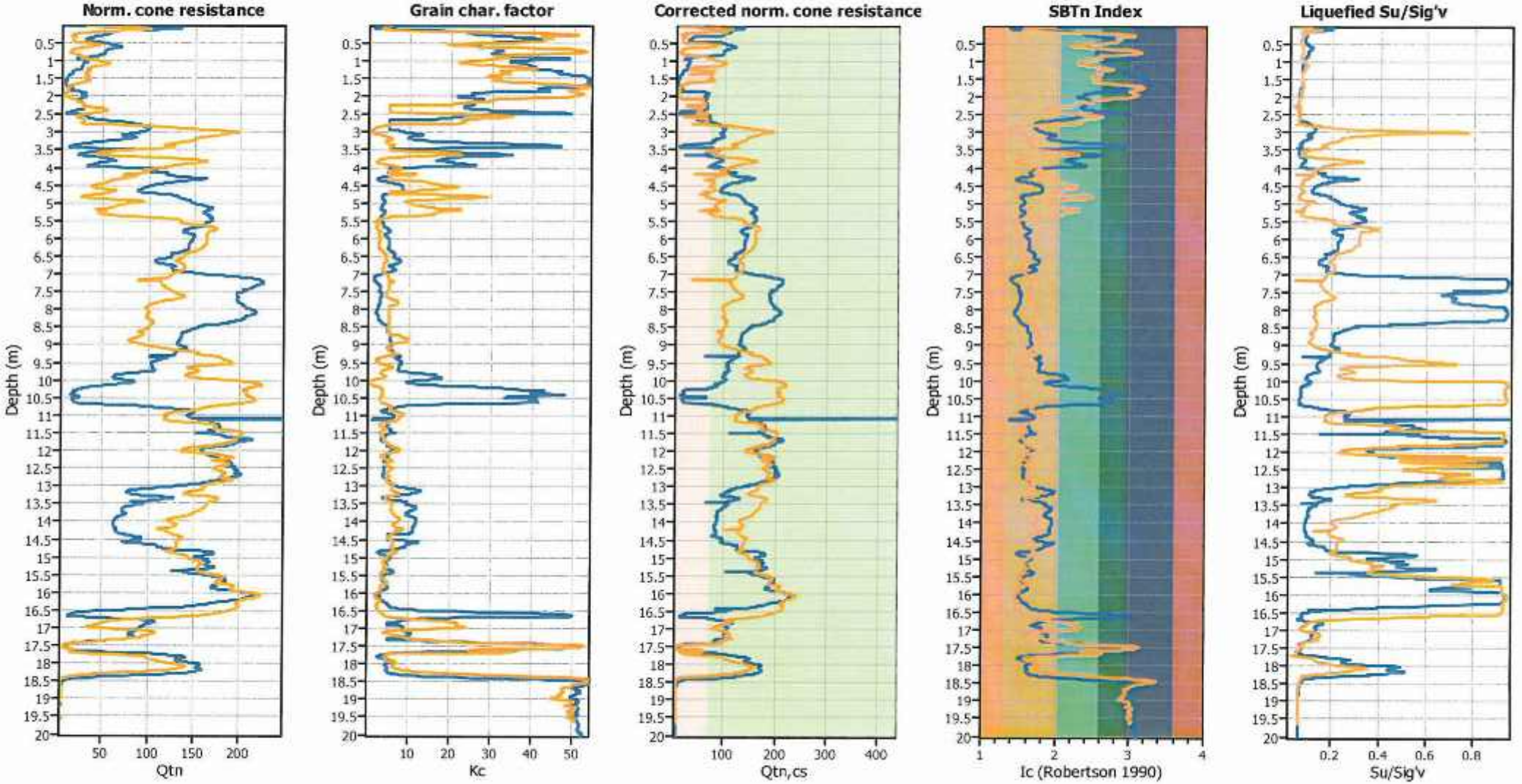
Overlay Cyclic Liquefaction Plots



OPUS International Consultants
20 Moorhouse Avenue +64 3 363 5400
Christchurch 8011, New Zealand
www.opus.co.nz

Project: 29 Charles Street Waltham - SLS

Overlay Strength Loss Plots



OPUS International Consultants
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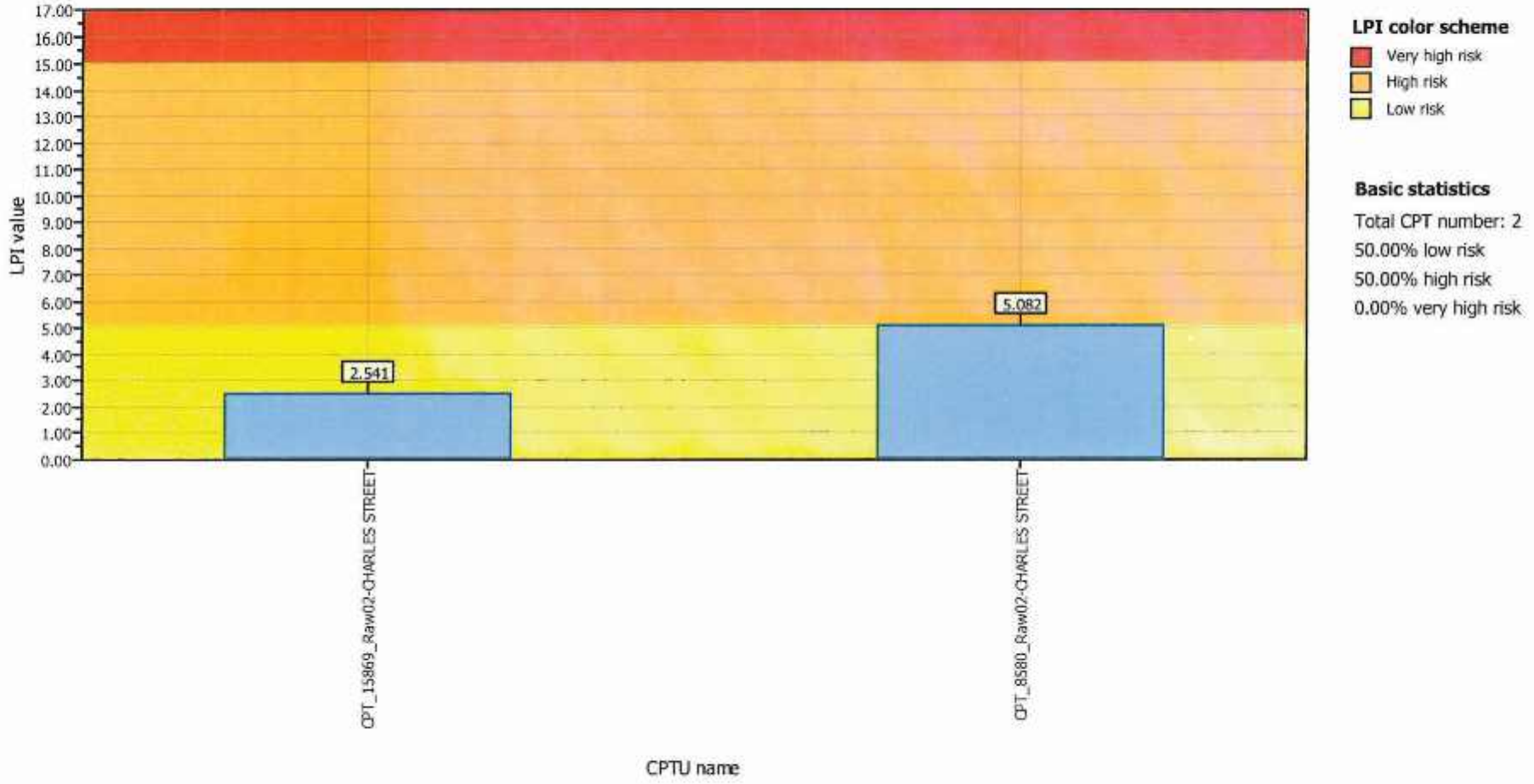
Christchurch 8011, New Zealand
www.opus.co.nz

Project title : 29 Charles Street Waltham - SLS

Location : Waltham, Christchurch

Overall Liquefaction Potential Index report



LPI color scheme

- Very high risk
- High risk
- Low risk

Basic statistics

Total CPT number: 2
50.00% low risk
50.00% high risk
0.00% very high risk

OPUS International Consultants
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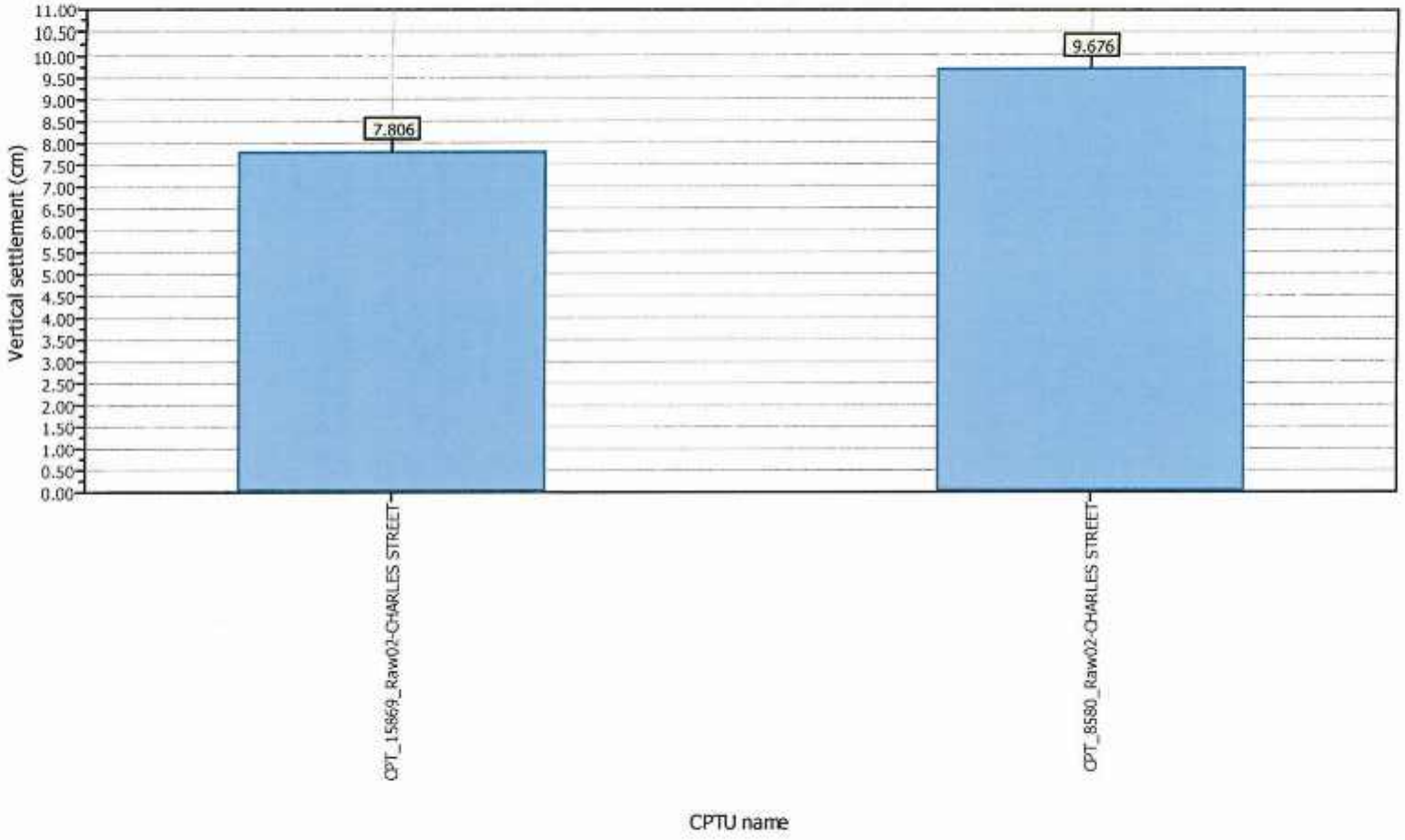
Christchurch 8011, New Zealand
www.opus.co.nz

Project title : 29 Charles Street Waltham - SLS

Location : Waltham, Christchurch

Overall vertical settlements report

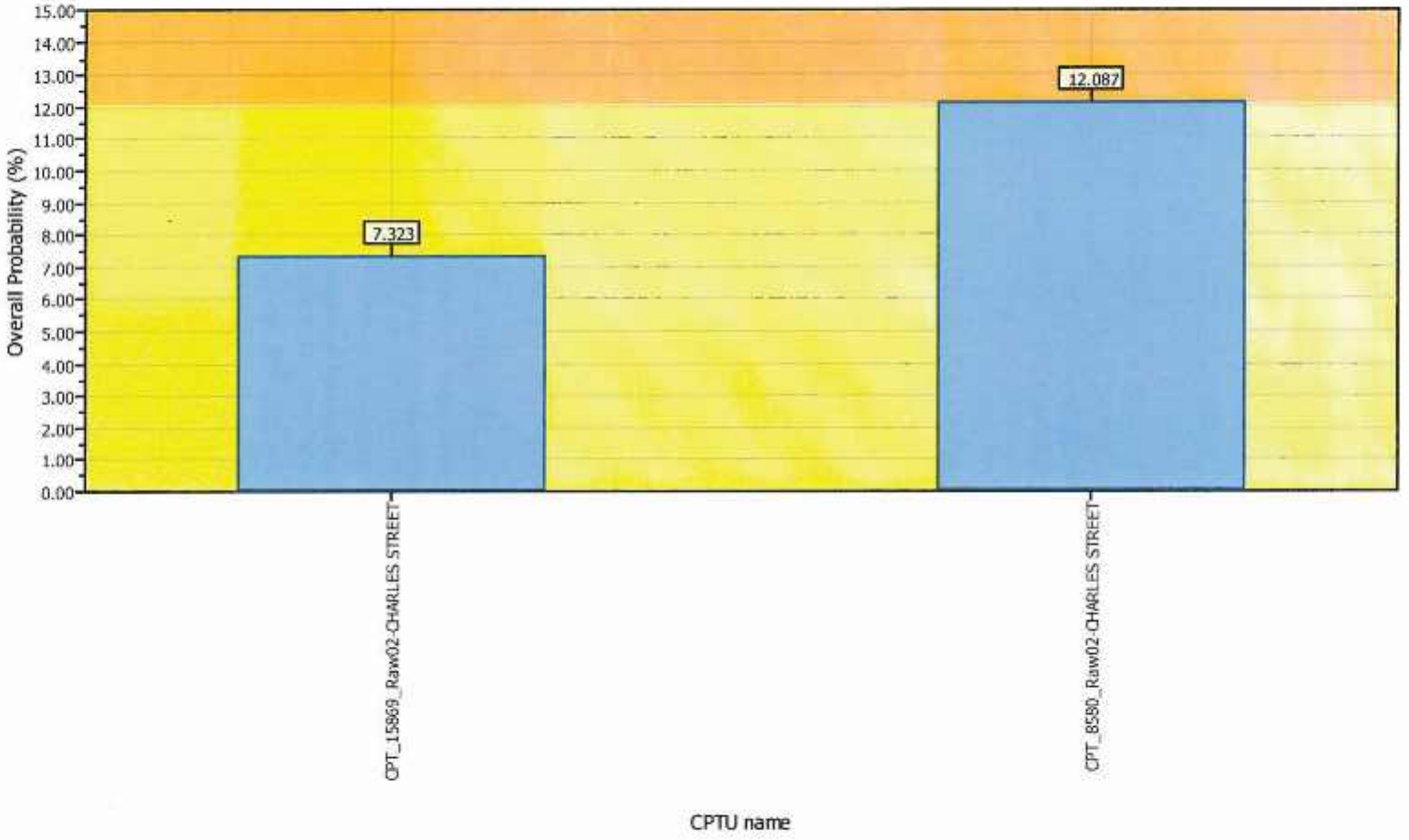


OPUS International Consultants
20 Moorhouse Avenue +64 3 363 5400
Christchurch 8011, New Zealand
www.opus.co.nz

Project title : 29 Charles Street Waltham - SLS

Location : Waltham, Christchurch

Overall Probability for Liquefaction report



Probability color scheme

- Very High Probability
- High Probability
- Low Probability

Basic statistics

Total CPT number: 2
50.00% low probability
50.00% high probability
0.00% very high probability

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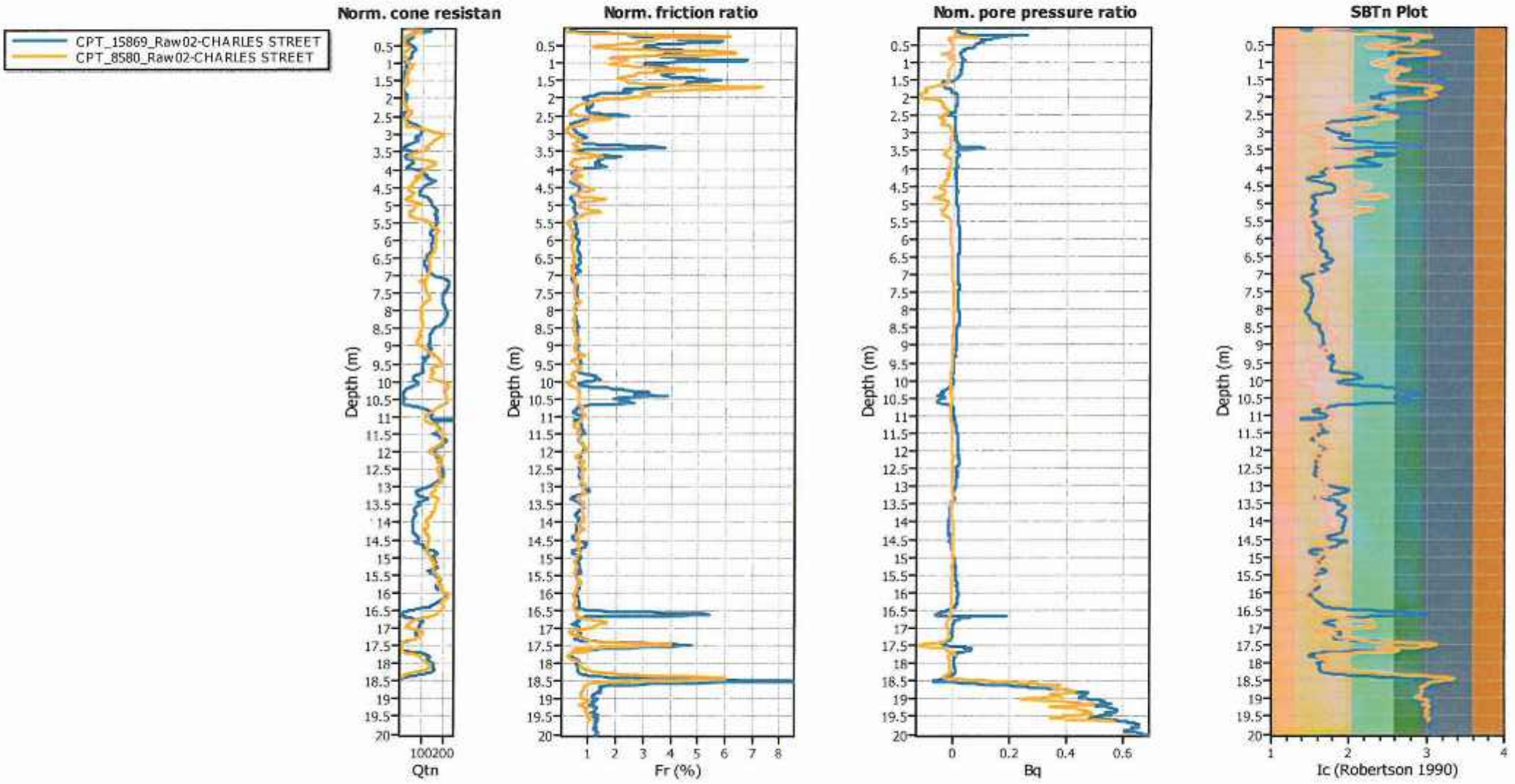
20 Moorhouse Avenue +64 3 363 5400
Christchurch 8011, New Zealand
www.opus.co.nz

Project: 29 Charles Street, Waltham - ULS

Overlay Normalized Plots



OPUS International Consultants
20 Moorhouse Avenue +64 3 363 5400
Christchurch 8011, New Zealand
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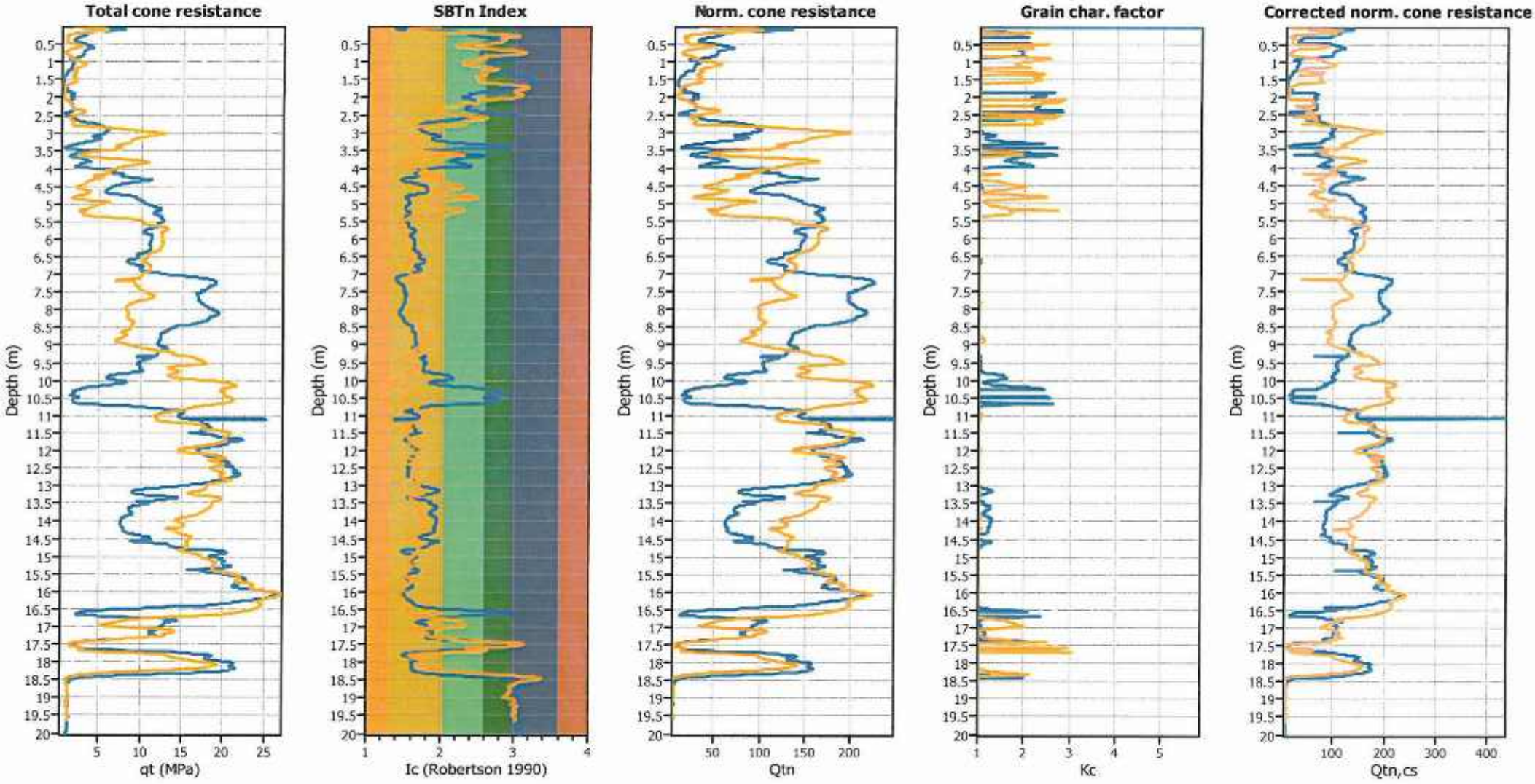
Project: 29 Charles Street, Waltham - ULS

Overlay Intermediate Results



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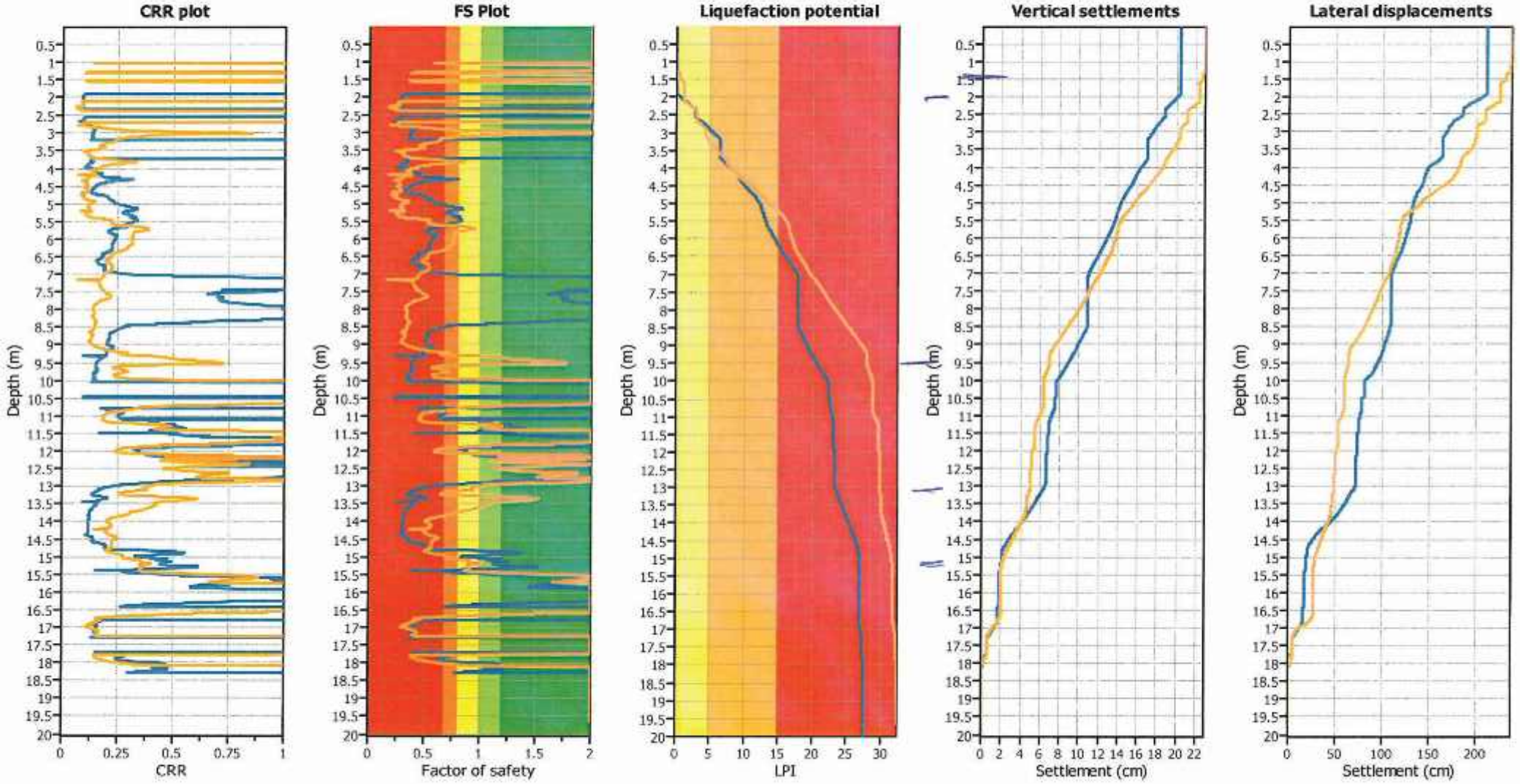
Project: 29 Charles Street, Waltham - ULS

Overlay Cyclic Liquefaction Plots



OPUS International Consultants
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Christchurch 8011, New Zealand
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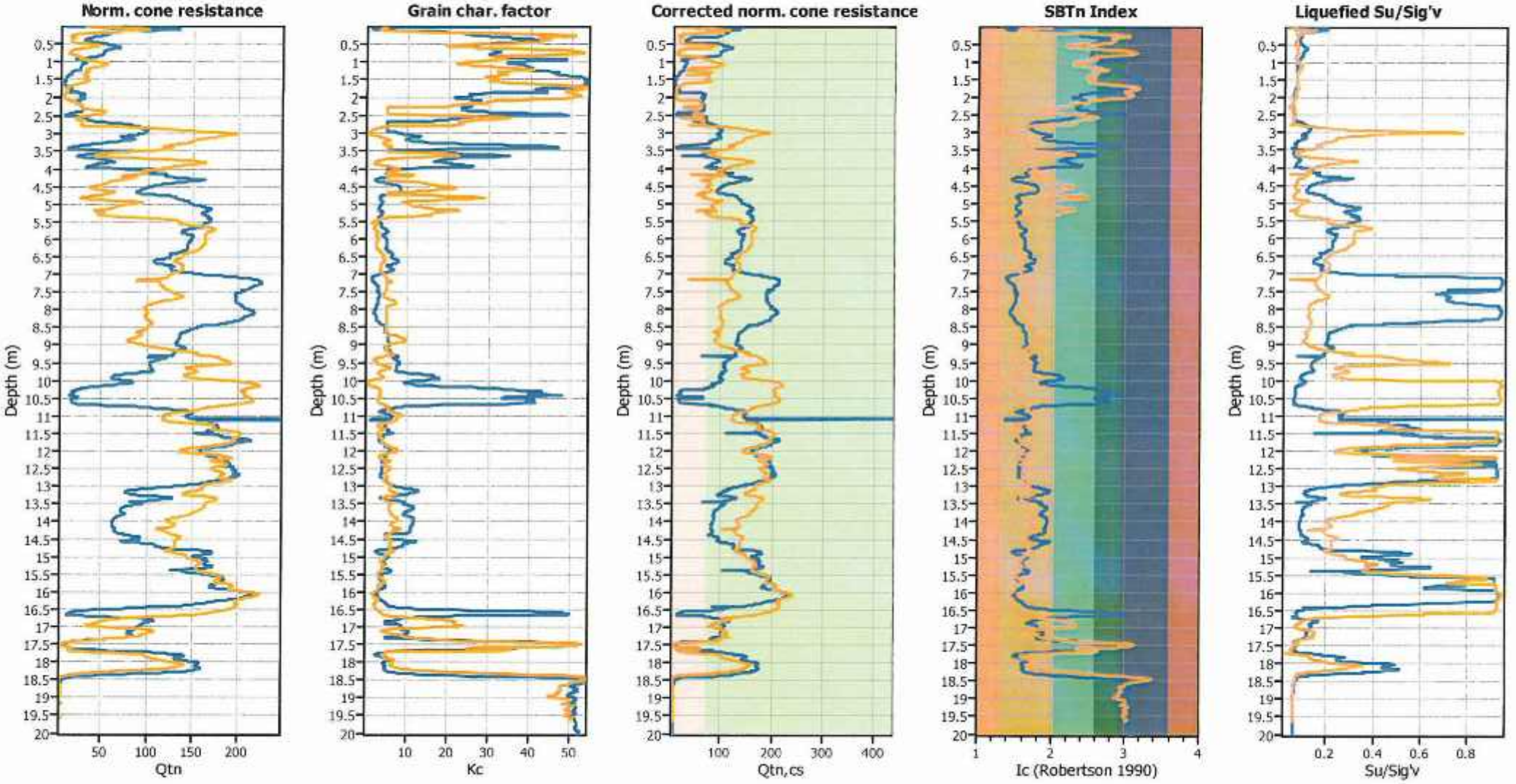
Project: 29 Charles Street, Waltham - ULS

Overlay Strength Loss Plots

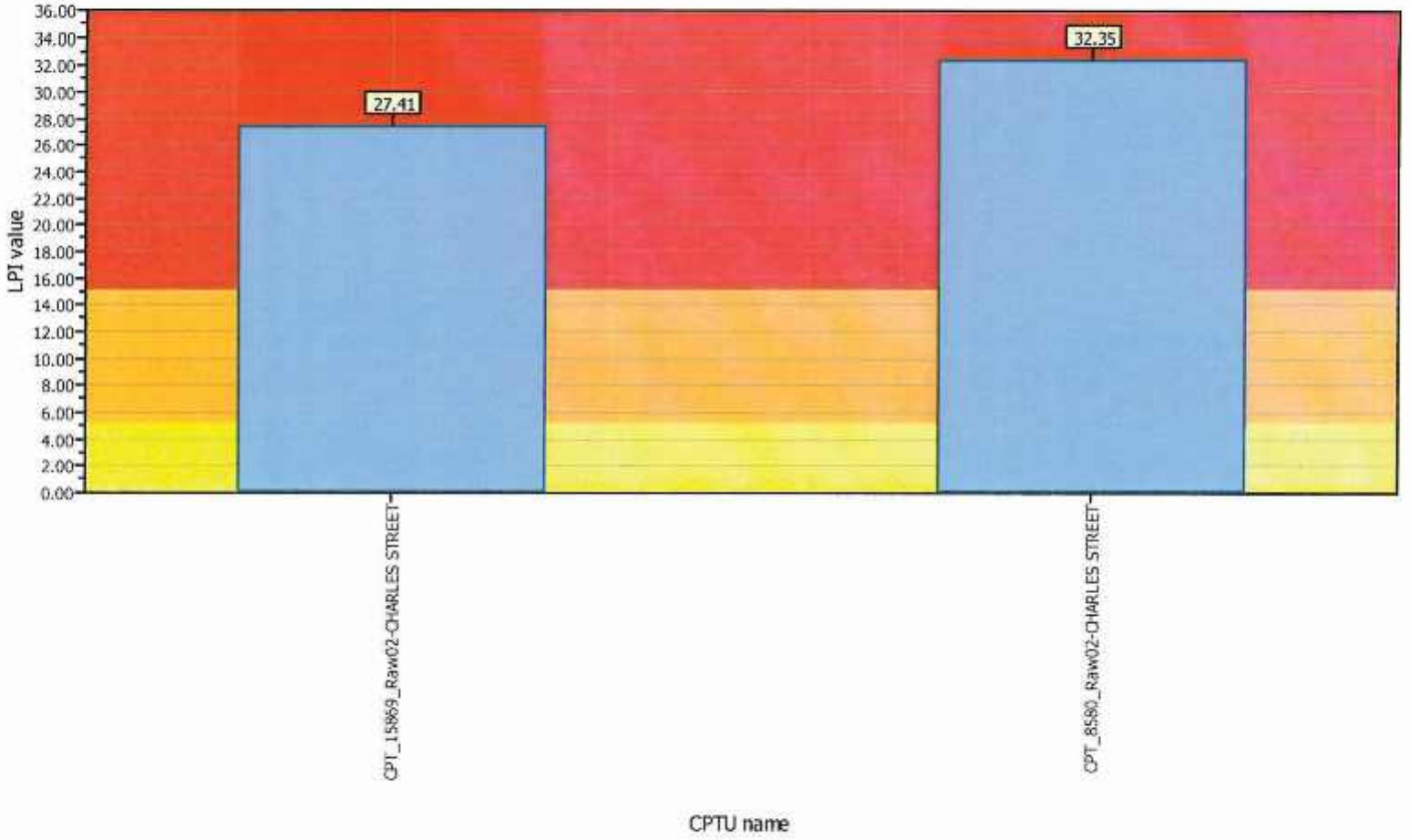


OPUS International Consultants
20 Moorhouse Avenue +64 3 363 5400
Christchurch 8011, New Zealand
www.opus.co.nz

Project title : 29 Charles Street, Waltham - ULS

Location : Waltham, Christchurch

Overall Liquefaction Potential Index report



LPI color scheme

- Very high risk
- High risk
- Low risk

Basic statistics

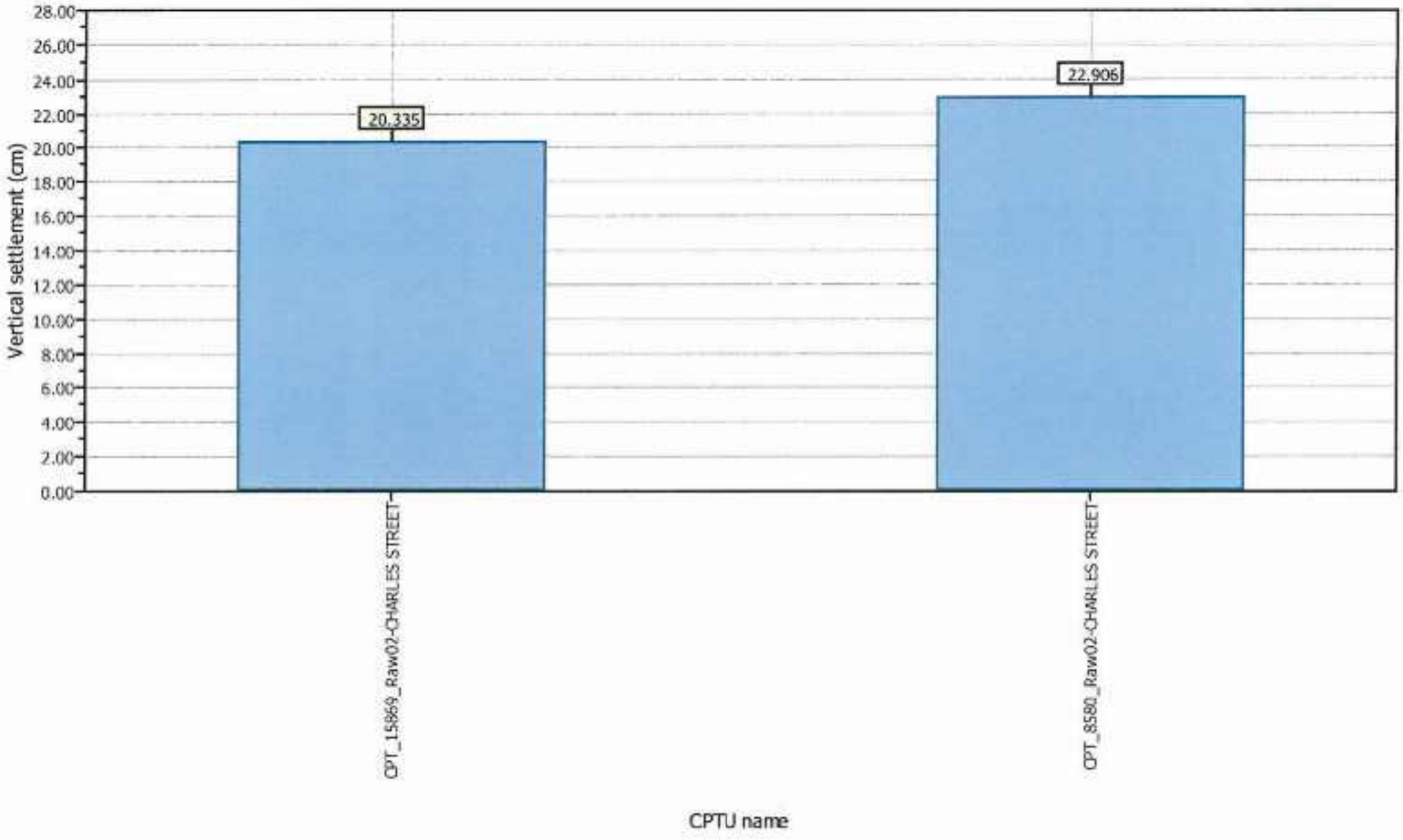
Total CPT number: 2
0.00% low risk
0.00% high risk
100.00% very high risk

OPUS International Consultants
20 Moorhouse Avenue +64 3 363 5400
Christchurch 8011, New Zealand
www.opus.co.nz

Project title : 29 Charles Street, Waltham - ULS

Location : Waltham, Christchurch

Overall vertical settlements report



OPUS International Consultants
20 Moorhouse Avenue +64 3 363 5400
Christchurch 8011, New Zealand
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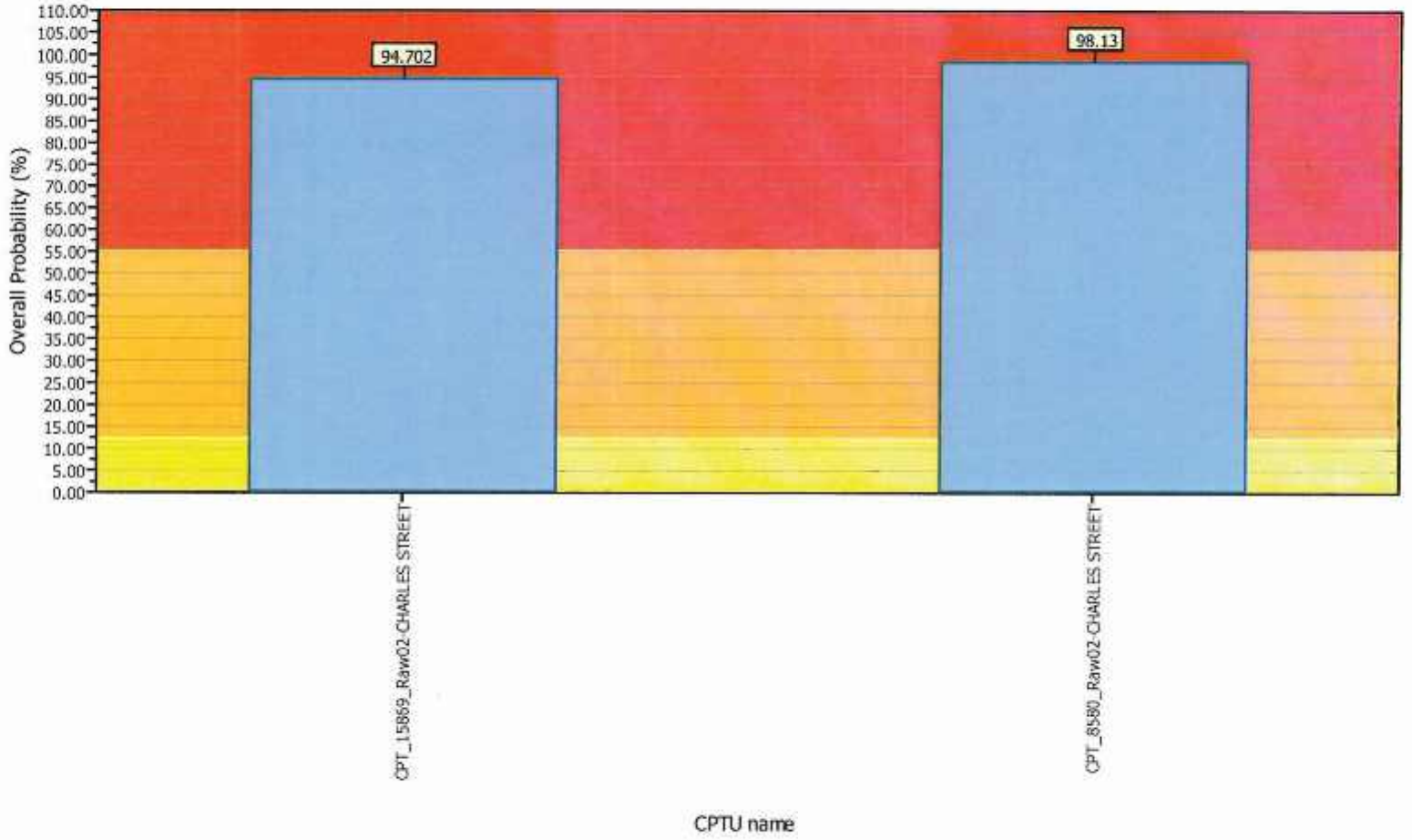
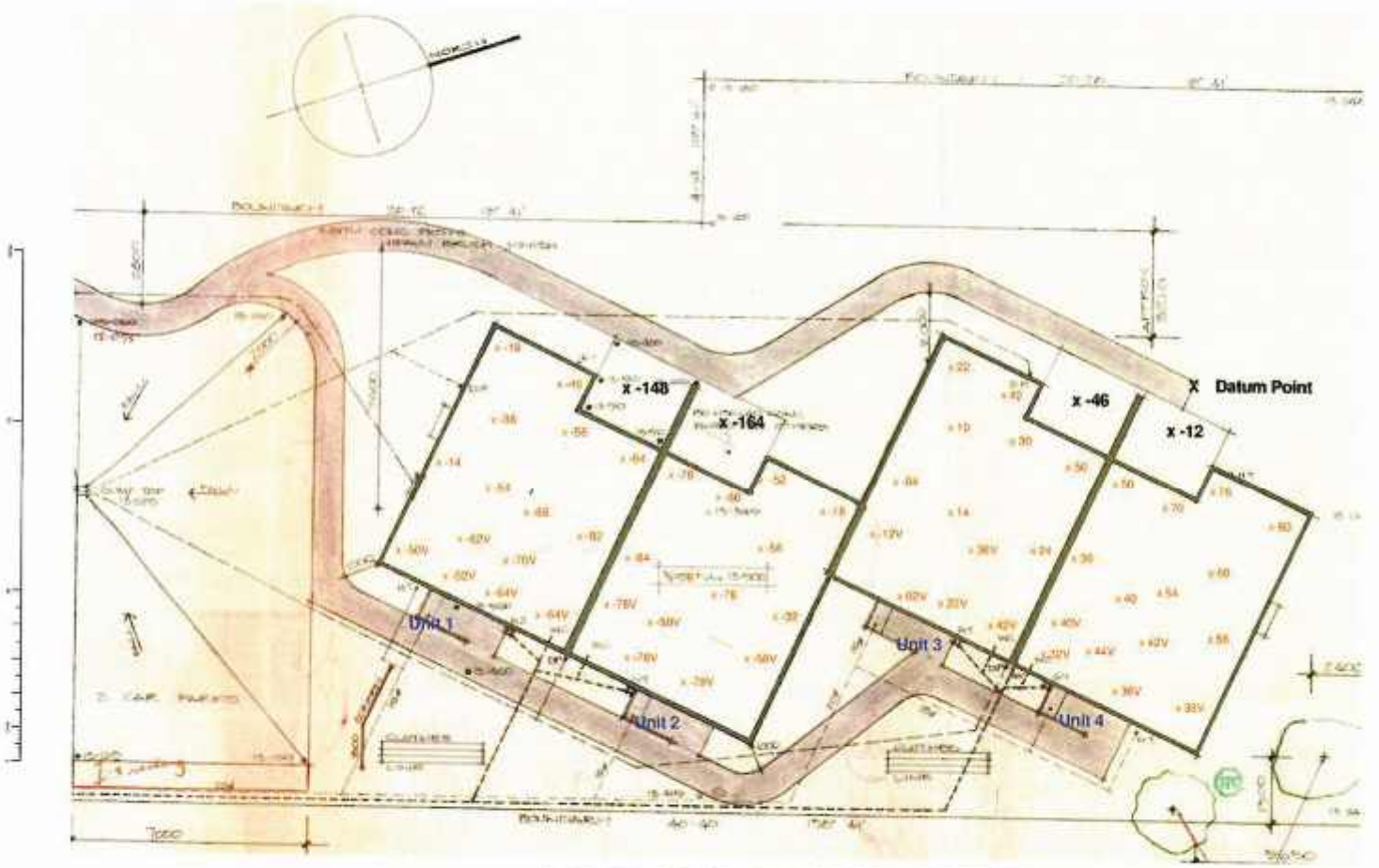
Project title : 29 Charles Street, Waltham - ULS

Location : Waltham, Christchurch

Overall Probability for Liquefaction report



Appendix G:
Opus Level Survey



OPUS
Christchurch Office

Christchurch City Council

Level Survey Charles Street

1 : 100

A101 RA

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w: www.opus.co.nz