Christchurch City Council

Maurice Hayes Place Housing Complex
PRO 0855

Detailed Engineering Evaluation

Quantitative Assessment Report

Christchurch City Council

Maurice Hayes Housing Complex

Quantitative Assessment Report

Maurice Hayes Place, Woolston, Christchurch 8023

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Summary

Maurice Hayes Housing Complex
PRO 0855

Detailed Engineering Evaluation
Quantitative Report - Summary
Final

Background

This is a summary of the quantitative report for the Maurice Hayes 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 19 residential units on the site.

Key Damage Observed

The residential units suffered moderate damage to non-structural elements. This included cracking of the wall linings and stepped cracking to external block veneer cladding, especially at the connection of adjacent units.

Level Survey

The floor slopes of 6 of the 19 units assessed were greater than the 5mm/m limitation set out in the MBIE guidelines [6].

Critical Structural Weaknesses

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

Indicative Building Strength

Table A: Summary of Seismic Performance by Blocks

Block	NBS%
PRO 0855 B001 (Block A)	49%
PRO 0855 B002 (Block B)	49%
PRO 0855 B003 (Block C)	49%
PRO 0855 B004 (Block D)	49%

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

The residential units have a capacity of 49% NBS, as limited by the in-plane shear capacity of the bracing walls.

Recommendations

It is recommended that;

- A strengthening works scheme be developed to increase the seismic capacity of all blocks to at least 67% NBS. This will need to consider compliance with accessibility and fire requirements.
- Veneer at height (gable ends) have the veneer ties checked.
- Cosmetic repairs be undertaken with additional fixings placed around the perimeter of bracing elements.

- A geotechnical site investigation be carried out to determine the liquefaction and lateral spread potential of the site and the shallow bearing capacities of the soils if this information is required for future construction on the site.

Contents

1 Introduction

Opus International Consultants Limited has been engaged by Christchurch City Council to undertake a detailed seismic assessment of the Maurice Hayes Housing Complex, located at Maurice Hayes Place, Woolston, Christchurch, following the Canterbury Earthquake Sequence since September 2010. The site was inspected by Opus International Consultants on 20 June 2013.

The purpose of the assessment is to determine if the buildings in the village 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.

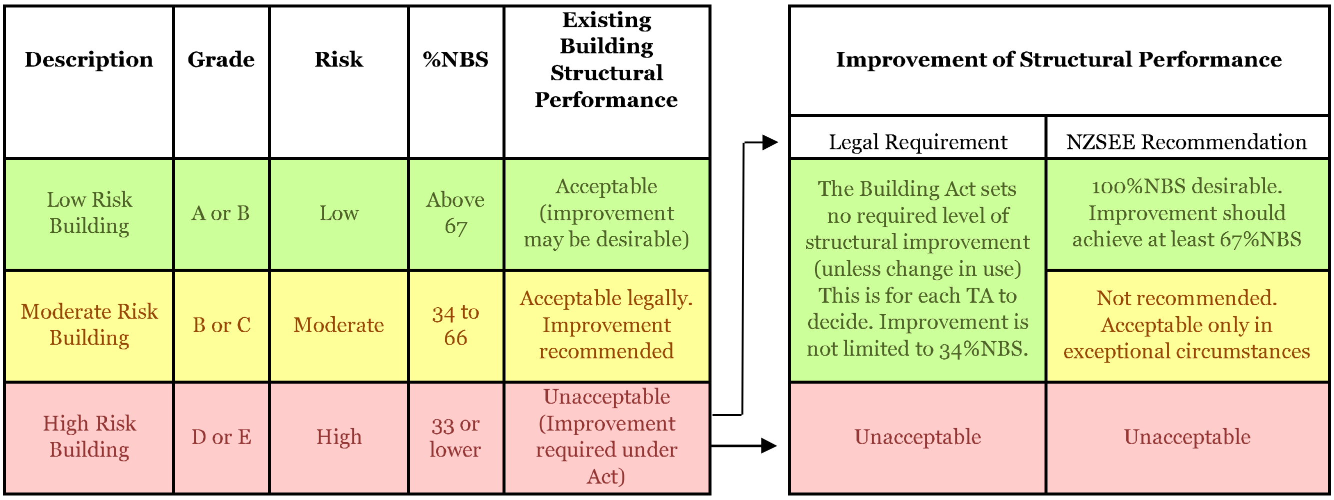
1.2 Ensuring that responsible steps are taken to minimise the risk of loss of life, injury or suffering which may result from your engineering activities, either directly or indirectly.

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
Low Risk Building	A or B	Low	Above 67	Acceptable (improvement may be desirable)
Moderate Risk Building	B or C	Moderate	34 to 66	Acceptable legally. Improvement recommended
High Risk Building	D or E	High	33 or lower	Unacceptable (Improvement required under Act)

Improvement of Structural Performance	
Legal Requirement	NZSEE Recommendation
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
	Not recommended. Acceptable only in exceptional circumstances
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 DBH 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.

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[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 19 residential units which were constructed in 1975. The units are numbered 1 to 19 and are grouped together to form blocks of four or five 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.

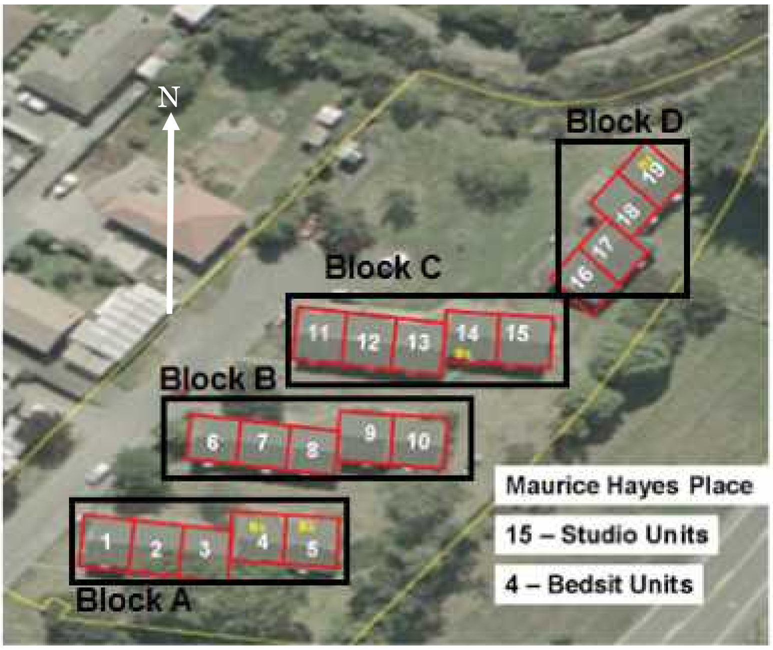


Figure 2: Site plan of Maurice Hayes Housing Complex.

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

The units are separated by 190mm block masonry fire walls with vertical reinforcement at 800mm centres and trimming bars.

The residential units are timber-framed buildings with diagonal timber braces. The roof structure comprises of timber roof trusses supporting light-weight metal roofs. Internal walls and ceilings are lined with plasterboard and external walls are clad with a block veneer. Foundations are strip footings under fire walls and around the perimeter of unreinforced floating concrete slabs. All strip footings are piled at approximately 900mm centres.

Figure 4 shows a typical floor plan of a residential unit produced from site measurements by Opus. Figure 5 shows a typical cross section from the original construction drawings.

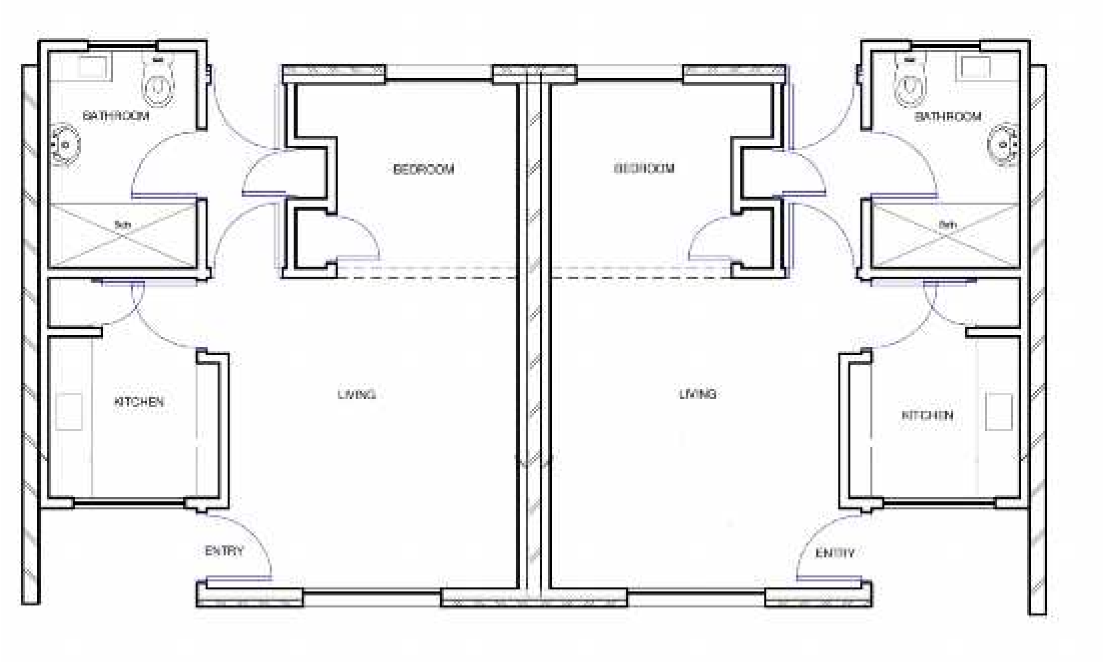


Figure 4: Typical floor plan of adjacent residential units within each block.

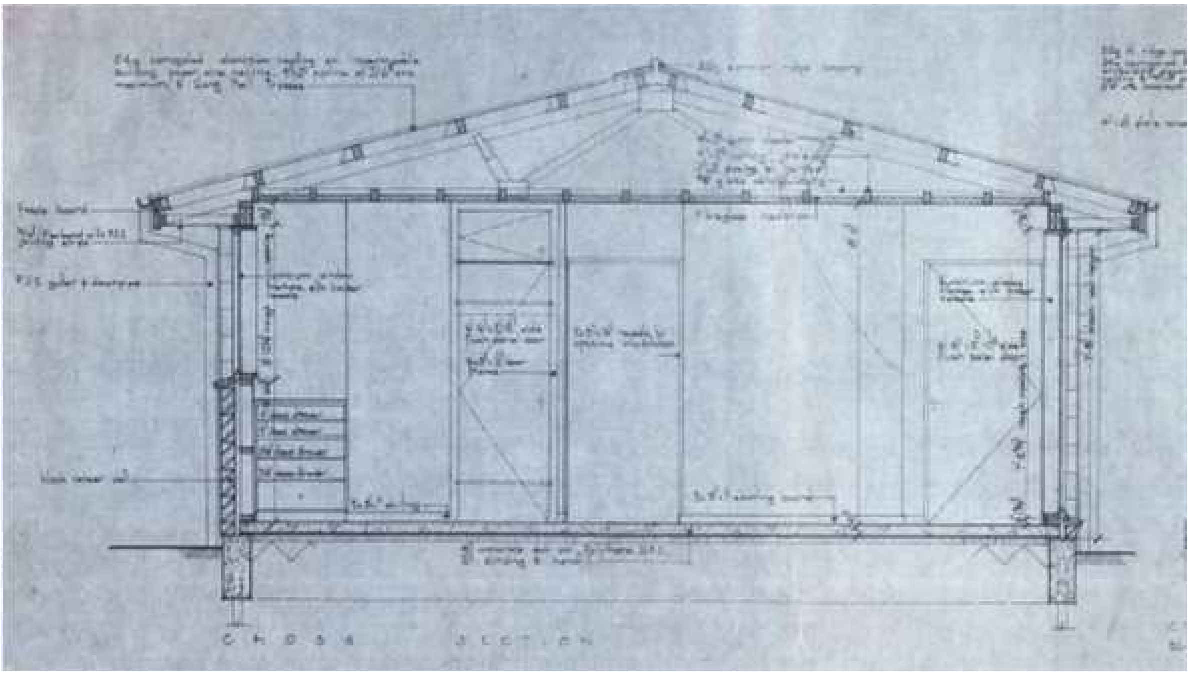


Figure 5: Typical section through residential unit.

4.2 Survey

4.2.1 Post 22 February 2011 Rapid Assessment

A structural (Level 1) assessment of the buildings/property was undertaken on 11 March, 2011 by Opus International Consultants.

4.2.2 Level Survey

A full level survey was deemed to be necessary at Maurice Hayes Housing Complex as it is located in a TC3 zone (Figure 8). Properties in TC3 zones suffered moderate to significant amounts of damage due to liquefaction and/or settlement. A full level survey was completed on all units. The values from this 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: Summary of level survey data. For this site, the floor slopes in six units were greater than the 5mm/m limitation set out in the MBIE guidelines.

4.2.3 Verticality

Several firewalls were checked for verticality. The most out of plumb wall was between units 4 and 5 with a 9mm difference from top to bottom. This is within acceptable tolerance.

4.2.4 Nail spacing

A check of nail spacing showed varied results. Indications are that some nails are at 800mm centres rather than the 300mm maximum. In walls of this era diagonal braces were placed within the element of a braced wall.

Table 2: Summary of level survey data

Block	Flat No.	Comment	Maximum Fall
A	1	pass	-
	2	pass	-
	3	pass	-
	4	pass	-
	5	pass	-
B	6	fail	6mm/m
	7	pass	-
	8	pass	-
	9	pass	-
	10	fail	6mm/m
C	11	pass	-
	12	fail	5.5mm/m
	13	pass	-
	14	fail	5.2mm/m
	15	pass	-
D	16	fail	5.5mm/m
	17	fail	7mm/m
	18	pass	-
	19	pass	-

4.3 Original Documentation

Copies of the following construction drawings were provided by CCC:

- Plans, elevations, sections and details for the construction of the residential units.

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.

Overall, Unit 14 appeared to have suffered the highest level of damage with noticeable displacement of the floor slab. No significant structural damage was observed in any of the other residential units.

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

5.1 Residual Displacements

The results of the level survey indicate that no significant ground settlement has occurred due to the earthquakes. Six units are just out of specification.

5.2 Foundations

No foundation damage was observed.

5.3 Primary Gravity Structure

No damage was evident in the timber framing or roof structure.

5.4 Primary Lateral-Resistance Structure

Some cracking of plasterboard ceiling diaphragms and wall linings was observed in many of the units, particularly surrounding window and door openings. This was consistent throughout many of the units visited.

5.5 Non Structural Elements

The pavement has displaced from the unit floor slab by around 20mm outside of multiple units (Photo 8).

Instances of stepped cracking to external block veneers along mortar joints and through the block itself was observed on only some of the unit facades. This appears to have occurred primarily around where wall openings are located.

Cracking has occurred down the block veneer wall junction line between Units 17-18 (Photo 9, 10).

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 minor damage which is typical of the construction type 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 all the residential units have the same floor plan, the analysis was simplified by conducting the analysis of each multi-unit block once and applying that result to all 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 6 and Figure 7, were used for bracing in their respective directions.

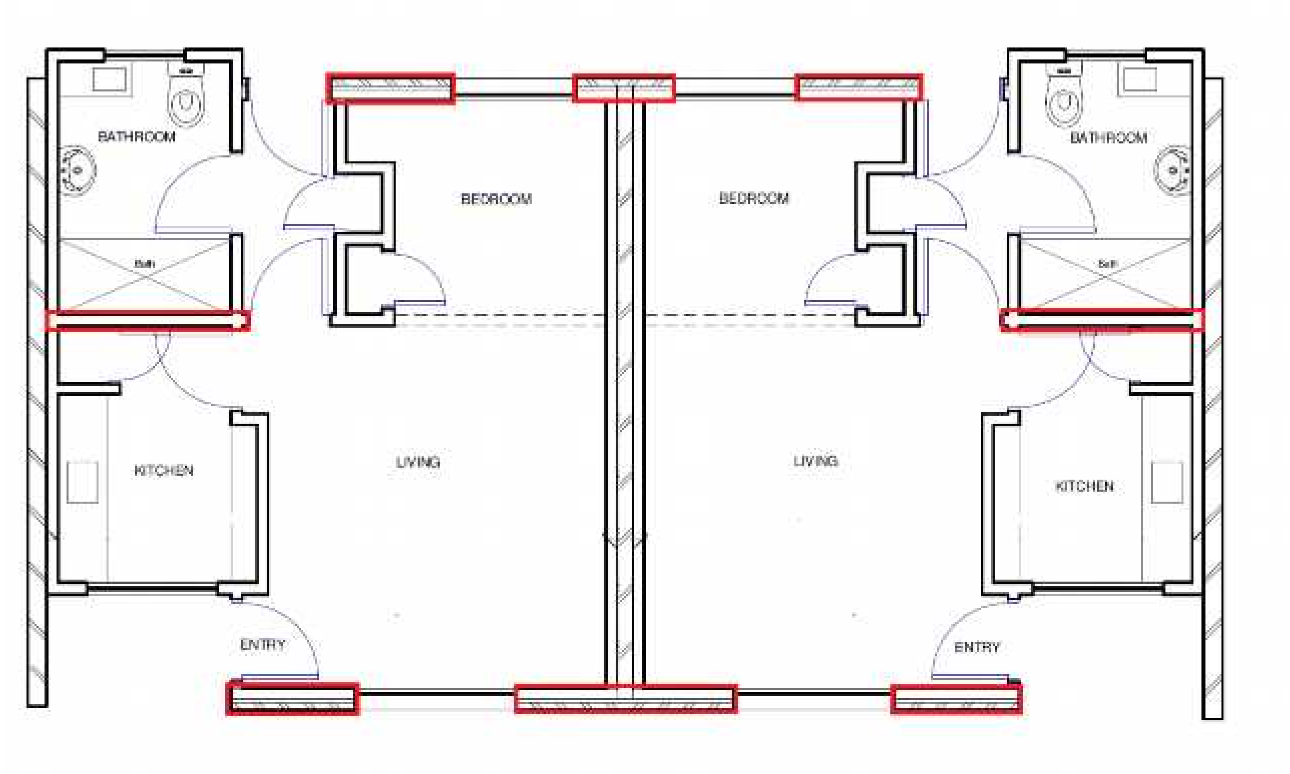


Figure 6: Walls used for bracing in the longitudinal direction.

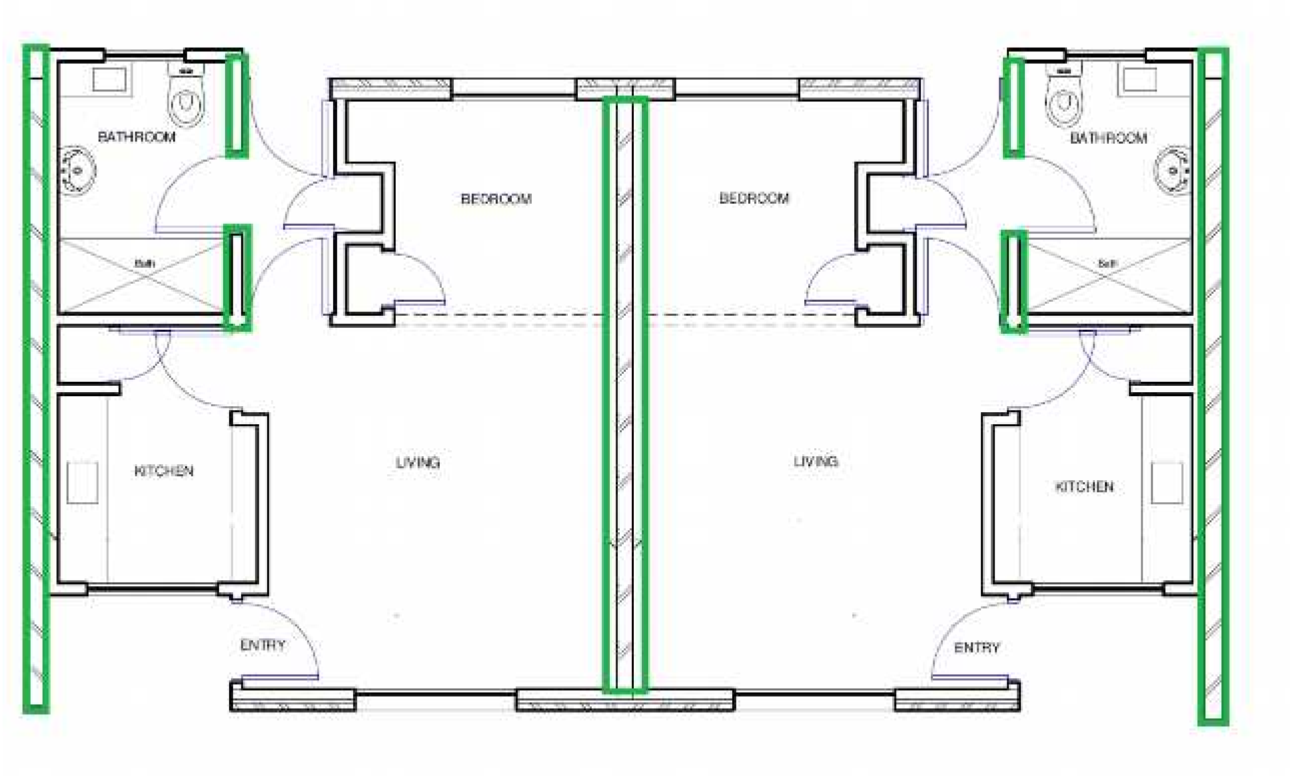


Figure 7: Walls used for bracing in the transverse direction.

6.3 Limitations and Assumptions in Results

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.
- Construction is consistent with normal practise of the era in which constructed.

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.
All Multi-Unit Blocks	Bracing capacity of structural walls.	49%	100%

7 Geotechnical Appraisal

7.1 General

CERA indicates that Maurice Hayes Place Housing Complex is located on the boundary of a TC2/TC3 zone (Figure 8). 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 8: CERA Technical Categories map (loc. starred).

7.2 Liquefaction Potential

Differential settlement is expected to occur due to variable thicknesses of liquefiable layers with expected differential settlements of up to 150mm, for a ULS earthquake event. This indicates that the land is comparable to MBIE Technical Category Three (TC3). Lateral spread is also likely to occur due to the proximity of the stream to the north.

8 Conclusions

- None of the buildings on site are considered to be Earthquake Prone.
- The residential units have a capacity of 49% NBS, as limited by the in-plane capacity of the bracing walls presuming braces within the wall element. 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 (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. However, based on the nature of construction, this is unlikely to result in the collapse of concrete ground beams beneath the block work and masonry walls.
- The floor slabs are not tied to the foundations. The predicted differential settlement is expected to result in the slab moving down relative to the firewalls and cracking or creating voids under the slab in other areas.

9 Recommendations

It is recommended that;

- A strengthening works scheme be developed to increase the seismic capacity of all blocks to at least 67% NBS. This will need to consider compliance with accessibility and fire requirements.
- Veneer at height (gable ends) have the veneer ties checked.
- Cosmetic repairs be undertaken with additional fixings placed around the perimeter of bracing elements.
- A geotechnical site investigation be carried out to determine the liquefaction potential of the site and the shallow bearing capacities of the soils if this information is required for future construction on the site.

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 Maurice Hayes 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 A - Photographs

Maurice Hayes Housing Complex		
Residential Units		
1	Typical exterior (front)	
2	Typical exterior (side)	

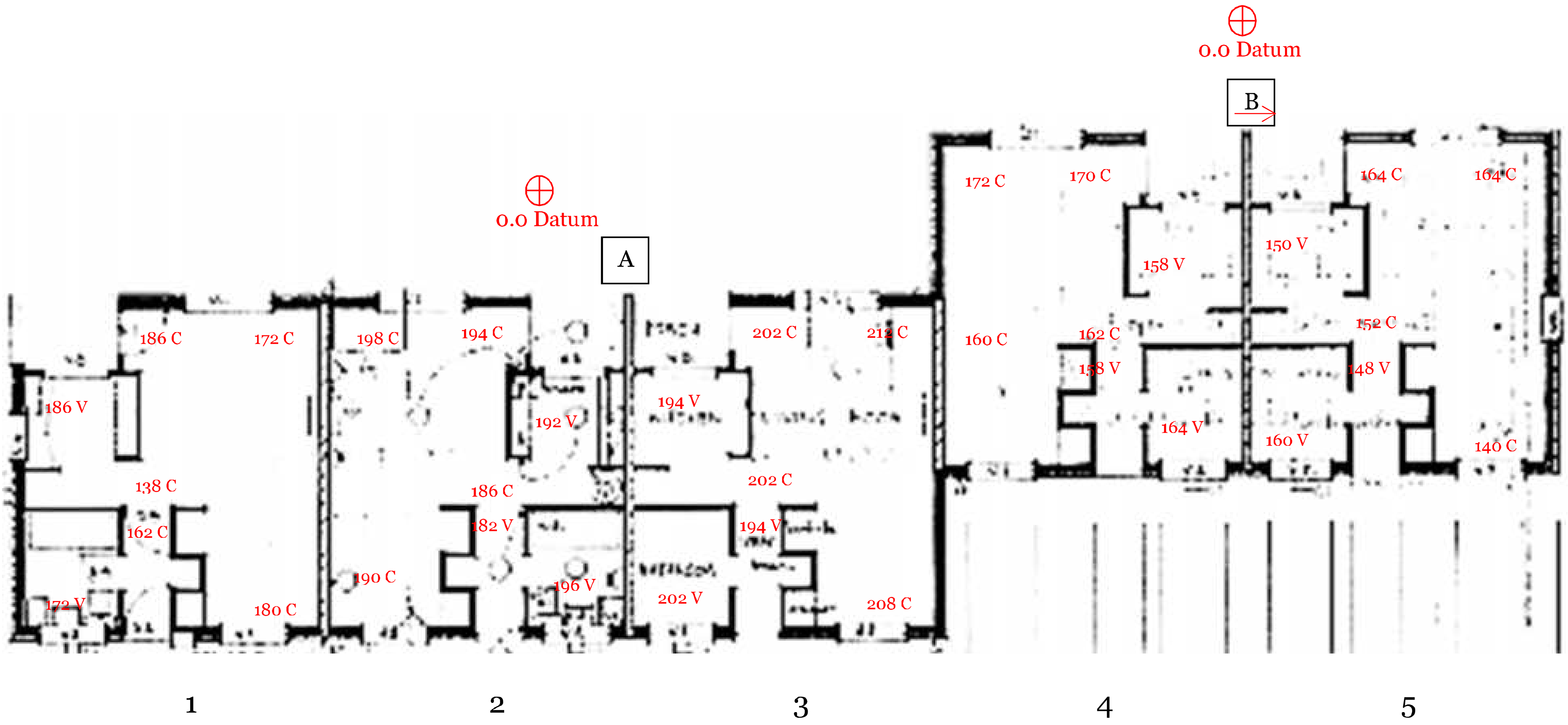
3	Typical exterior (rear)	
4	Typical roof cavity	
5	Stepped cracking of exterior block veneer	

6	Stepped cracking of exterior block veneer	
7	Stepped cracking of exterior block veneer	
8	Pavement displaced from the unit floor slab by approx. 30mm	

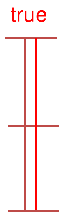
9	Cracking of exterior block veneer at wall junction between units 17-18	
10	Cracking of exterior block veneer at wall junction between units 17-18	

11	Cracking to plasterboard wall lining	
12	Cracking to plasterboard ceiling lining	

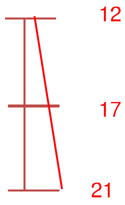
Appendix B - Level Survey

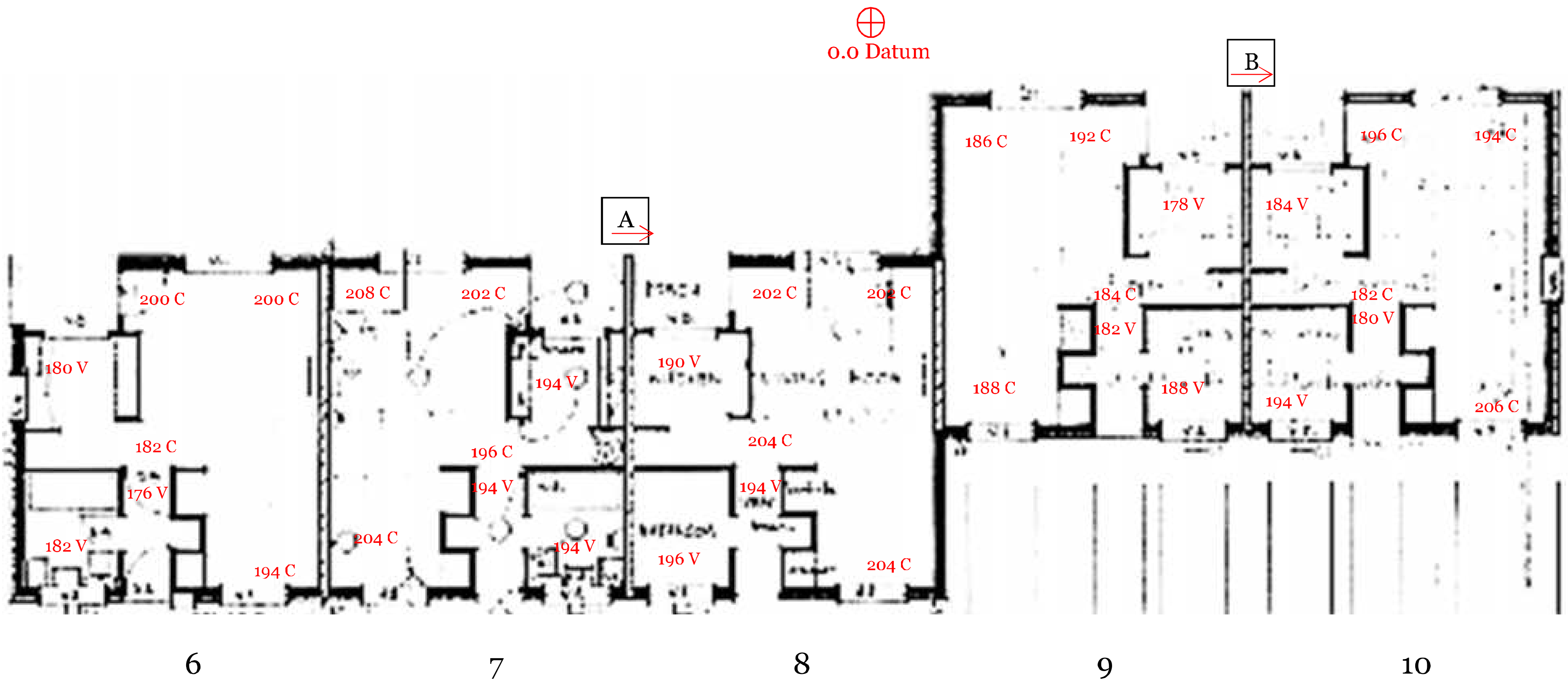


Fire wall A

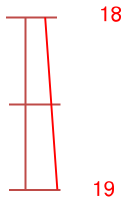


Fire wall B

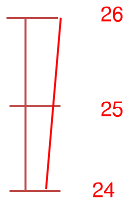


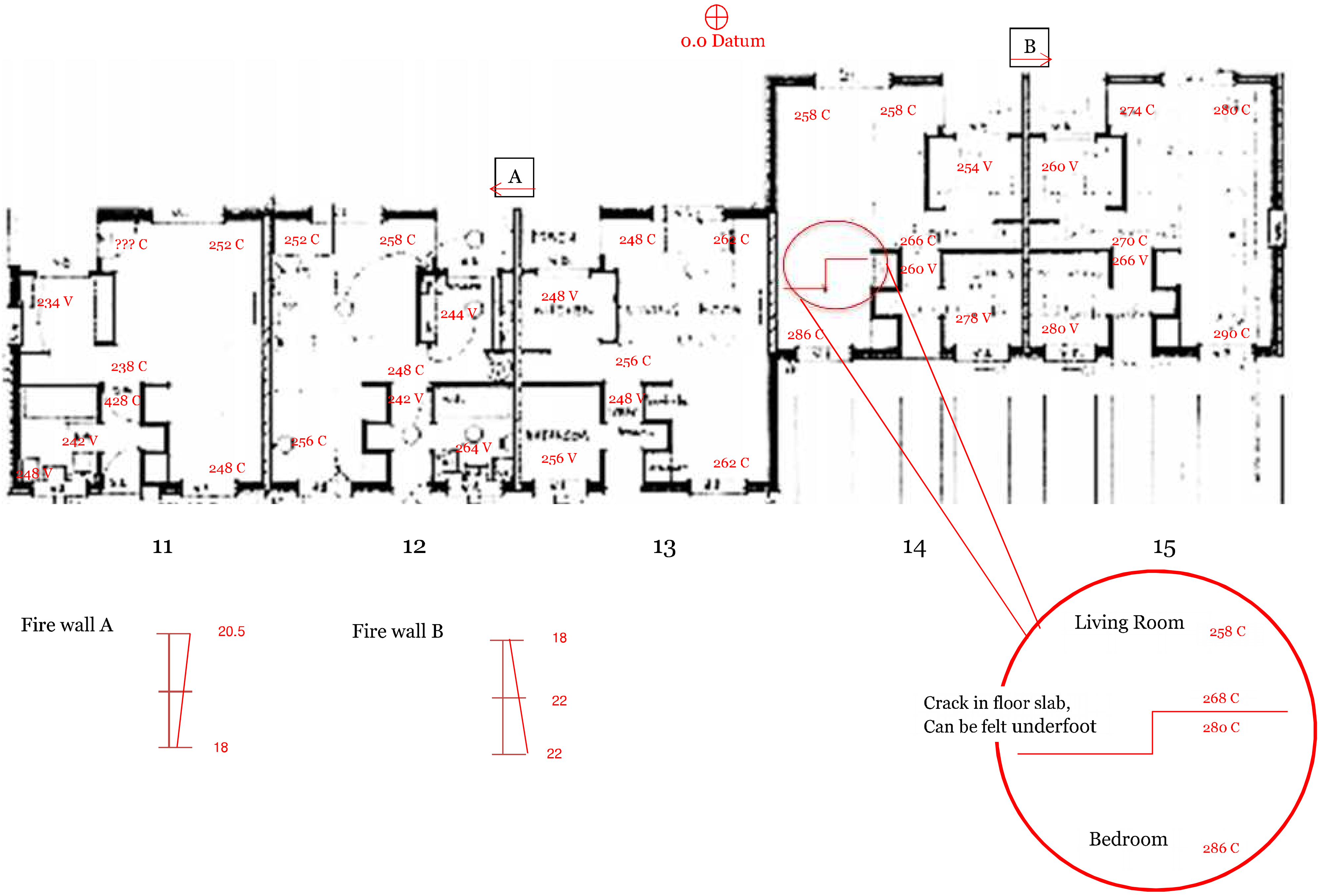


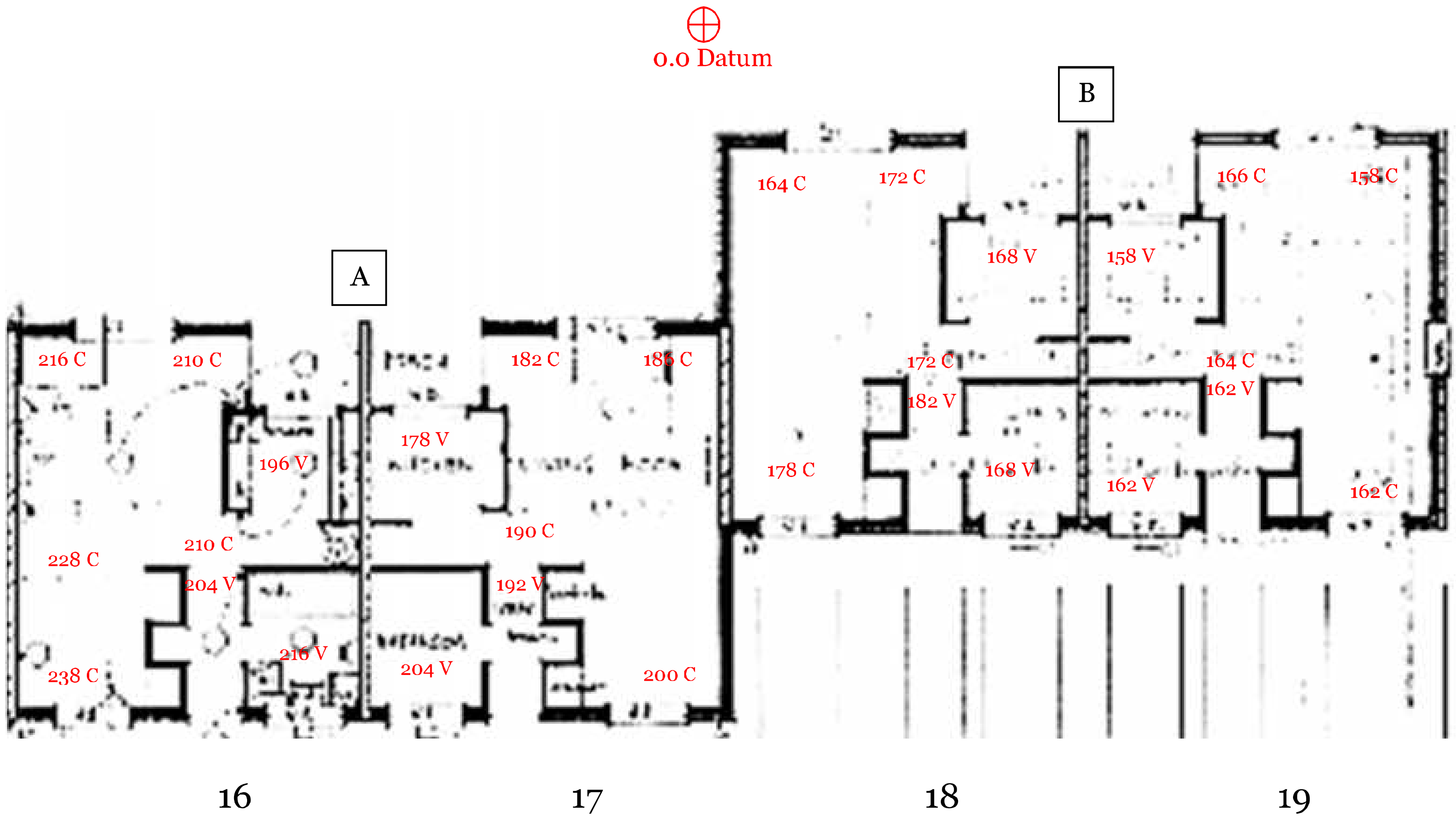
Fire wall A



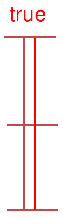
Fire wall B



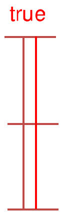
0.0 Datum
A
B
??? C
252 C
234 V
238 C
428 C
242 V
248 V
248 C
252 C
258 C
244 V
248 C
242 V
256 C
264 V
248 C
262 C
248 V
256 C
248 V
256 V
262 C
258 C
258 C
254 V
260 V
274 C
280 C
266 C
260 V
270 C
266 V
286 C
278 V
280 V
290 C
11
12
13
14
15
Fire wall A
20.5
18
Fire wall B
18
22
22
Living Room
258 C
Crack in floor slab,
Can be felt underfoot
268 C
280 C
Bedroom
286 C



Fire wall A



Fire wall B



Appendix C - Geotechnical Appraisal

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30 October 2013

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

QC381.00

Geotechnical Desk Study – Maurice Hayes Place

1. Introduction

Christchurch City Council (CCC) has commissioned Opus International Consultants (Opus) to undertake a Geotechnical Desk Study and site walkover of the Maurice Hayes Place Pensioner Cottages in Woolston. The purpose of this study is to: collate existing subsoil information, undertake an appraisal of the potential geotechnical hazards at this site, and determine whether further subsoil investigations are required. The site walkover was completed by Opus International Consultants on 19 June 2013.

This Geotechnical Desk Study has been prepared in accordance with the Engineering Advisory Group's Guidance on Detailed Engineering Evaluation of Earthquake Affected Non-residential Buildings in Canterbury, Revision 5, 19 July 2011.

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

The Maurice Hayes Place Pensioner Cottages are located approximately 5km south east of Christchurch city centre, at 841 Ferry Road near the intersection of Dyers Road/Ferry Road/Tunnel Road in Woolston. The site is bounded by Ferry Road and Dyers Road to the south and east respectively, residential properties to the west, and a tributary to the Heathcote River to the north. The Heathcote river is approximately 150m south of the site. See Site Location Plan in Appendix B.

The Maurice Hayes Place Pensioner Cottages were designed in 1973 and comprise 4 blocks with 19 single storey residential units. The units are constructed of concrete masonry block veneer with Gib board wall partitions on timber framing and reinforced masonry firewall between units.

The site is relatively flat with a slight gradient towards the tributary at the north end of the site from approximately unit 16.

2.2 Available Drawings

Drawings prepared by City Architects Division of the Christchurch City Council for Maurice Hayes Pensioner Cottages were sourced from the CCC property file. See Appendix D for extracts of the Structural Drawings.

The drawings indicate that the buildings are founded on prestressed concrete piles, typically 100mm by 75mm, spaced at 900mm centres to an unknown depth. No as built records of pile length have been obtained. Prestressed piles are located beneath the exterior perimeter walls and also the internal fire walls. The prestressed concrete piles are connected typically by a 550mm deep continuous strip footing. Reinforced concrete floor slabs were used and laid on hardfill and a 50mm thick binding layer. The floor slabs were laid on the continuous strip footings at the building edges. The floor slab and continuous strip footings do not appear to be connected.

2.3 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 predominately by alluvial sand and silt overbank deposits belonging to the Yaldhurst member of the Springston Formation (spy).

A groundwater depth of approximately 1m has been shown on a borehole log shown on the City Architects drawings.

2.4 Expected Ground Conditions

Ground investigation data is available from investigations by Environment Canterbury (ECan) and the Earthquake Commission (EQC). Four cone penetration tests (CPT) within 150m of the site were identified, with one of the CPTs (CPT973) located onsite. CPT973 extended to a depth of 30m. The nearest borehole was located 130m north east from the site. The borehole and CPTs were used to determine the expected soil profile of the site. Refer to Site Location Plan in Appendix B and Surrounding Site Investigations logs in Appendix E.

Two shallow boreholes conducted adjacent to Blocks B & D confirmed the presence of Silt to a depth of 2.0m.

Soil horizons identified in the borehole log were able to be identified in the outer CPTs and the closest CPT to the site. It is estimated that the soils have reasonable horizontal continuity across the site. This information obtained from ECan and EQC databases has been used to infer the ground conditions at the site, as shown in Table 1 below

Table 1: Inferred Ground Conditions

Stratigraphy	Thickness (m)	Depth Encountered (m)
TOPSOIL and Clayey SILT	2.5-3.5	Surface
Fine to medium SAND loose to medium dense	16.5-18	2.5-3.5
Silty SAND and sandy SILT	-	20-20.5

The Riccarton Gravel formation is expected to be encountered at least 30m below ground level.

The tributary of the Heathcote River at the north end of the site has a water level approximately 1-2m below surrounding ground level. Groundwater level was recorded as 1.45m bgl at well CPT-WSW-48.

2.5 Liquefaction Hazard

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 Maurice Hayes site is located on the boundary of having ‘high liquefaction potential’ and ‘liquefaction not predicted’, for a low groundwater scenario.

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. The maps indicate no evidence of liquefaction after the September earthquake, moderate to severe observed liquefaction of the site after both the February 2011 and June 2011 seismic events, and minor observed liquefaction after the December 2011 seismic event.

EQC maps showing observed crack locations (refer to Observed Crack Map in Appendix F) after the February 2011 seismic event, indicate some ground cracking (typically 10-50mm and <10mm wide) approximately 120m to the south east of the site towards the Heathcote river. No ground cracking was observed at the site or to the north east and west of the site. The crack mapping is incomplete and only observations made by the EQC mapping teams are presented. Cracks in roads were often not able to be mapped because roads were repaired before mapping teams arrived. It is also unlikely that EQC inspectors visited Maurice Hayes Place. Due to the presence of a high ground water level, liquefiable soils, and nearby cracks, indicates that there is a moderate risk of ground movement in a future seismic event.

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 2 which has been adapted from the MBIE guidance document (MBIE, 2012).

Maurice Hayes Place has been zoned as N/A-Urban Non-residential. However, the neighbouring residential properties have been zoned as Green-TC2 to the west and Green-TC3 to the east, which indicates either (TC2) minor and moderate land deformations are expected in future small to medium sized earthquakes or (TC3) 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

A preliminary liquefaction assessment has been completed using CLiq Software (Version 1.7, 2012) adopting the NCEER Method. CPTs form the basis for the prediction of liquefaction potential, with a Magnitude 7.5 earthquake considered, and earthquake groundwater depth of 1.45 m below ground level. The CLiq analysis was undertaken using the CPTs located within 150m of the site. Table 3 summarises the liquefaction results. Refer to Site Location Plan in Appendix B for the location of the CPTs.

Both the Serviceability and Ultimate Limit States have been assessed for an Importance Level 2 Structure with Peak Ground Accelerations (PGAs) as shown in Table 3. The free field liquefaction induced subsidence estimates have been calculated over the complete test depth and are presented in Table 3 (refer Appendix G for CLiq output). For comparison with MBIE (2012) guidelines, the estimated settlement in the top 10m of the soil profile has also been presented.

Table 3: Estimated Liquefaction Induced Settlements

CPT	Test Depth (m)	Event	Mag / PGA	Depth to Groundwater (m)	Estimated Settlement (mm)	Estimated Settlement in top 10m of soil profile (mm)
CPT 973 (CPT-WSW-42)	29.9	ULS	M7.5 / 0.35g	1.45	270	110
		SLS	M7.5 / 0.13g		35	15
CPT 6698 (WST-POD03-CPT001)	20.1	ULS	M7.5 / 0.35g	1.45	300	120
		SLS	M7.5 / 0.13g		70	35
CPT 978 (CPT-WSW-47)	13.54	ULS	M7.5 / 0.35g	1.45	160	80
		SLS	M7.5 / 0.13g		25	18
CPT 979 (CPT-WSW-48)	10.7	ULS	M7.5 / 0.35g	1.45	80	65
		SLS	M7.5 / 0.13g		5	4

Total liquefaction induced free field subsidence of up to 300mm has been predicted in a future ULS earthquake event, for a ground water depth of 1.45m. The total subsidence predicted to occur in the top 10m is greater than 100mm for CPT 973 and CPT 6698, which indicates that the future land performance is comparable to MBIE Technical Category Three (TC3). The CLiq output are presented in Appendix G.

Differential settlement is expected to occur due to variable thicknesses of liquefiable layers with expected differential settlements of up to 150mm, for a ULS earthquake event.

The Liquefaction Severity Number (LSN) is another tool to identify the expected land damage from liquefaction. LSN considers depth weighted volumetric densification strain within soil layers to predict the liquefaction land damage. Tonkin & Taylor (T&T) correlated LSN to the predominant observed land performance and damage attributes. Table 13.1 within the referenced T&T Liquefaction Vulnerability Study presents the results of this correlation, and this table is reproduced in Table 5 herein.

Estimates indicate that CPT973 has a LSN of 40-50 in a ULS seismic event, and a LSN of 10-20 in a SLS seismic event. This categorises the site as having major expression of liquefaction, severe total and differential settlement of structures for an ULS seismic event and having minor expression of liquefaction with sand boils in an SLS seismic event.

The Liquefaction Potential Index (LPI) is also 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 of CPT973 indicate an LPI of up to 20 in a ULS seismic event and an LPI of less than 5 in a SLS seismic event. This categorises the site as a significant liquefaction risk for the ULS and low liquefaction risk for the SLS seismic event.

Table 4 below summarises the relationship between LPI and the risk of liquefaction occurring at a site.

Table 4: 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

Table 5: 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. Observations

A walkover site inspection of Maurice Hayes Place was carried out by an Opus Geotechnical Engineer on 19 June 2013. The following observations were made (refer to Walkover Inspection Plan in Appendix C and Site Photographs in Appendix A):

- Uplift, sand and silt evidence of liquefaction at properties entrance, refer to photo 2.
- 8mm crack between concrete path sections at unit 4/5 entrance, refer to photo 5.
- Differential settlement of the concrete porch at Unit 1. Up to 30mm and evident throughout site, refer to photo 7.
- Differential settlement of concrete path sections. Up to 40mm and evident throughout site, refer to photo 6 and 9.
- 4mm crack around concrete lamp post, refer to photo 8.
- Step crack in brick wall and foundation on south side of unit 6, refer to photo 11.
- Depression in pavement, refer to photo 17 and 18.
- 4mm vertical crack of the brick wall between unit 17 and 18 on the west side, refer to photo 19.
- 1-2mm cracking along bottom of brick wall and concrete floor slab of the north corner of unit 19, refer to photo 21
- 1-4mm crack at corner of window near entrance side of unit 19, refer to photo 23.
- 4mm crack in pavement, refer to photo 25.

No significant liquefaction or lateral spreading damage was observed during the site visit. All units seemed level with minimal foundation damage indicating that the site settled relatively uniformly during the seismic events. Due to the amount of time since the 2010 and 2011 earthquakes, it is likely that signs of land damage that may have existed, have either been cleaned or become less apparent by the time of the Opus site inspection.

The step cracking of unit 6 suggests discontinuous settlement. The vertical crack between units 17 and 18 suggests that Block D has experienced lateral displacement. The lateral displacement is likely to be towards the tributary stream. No other evidence of lateral displacement was identified on the site visit.

The following is a summary of the liquefaction identified from aerial photography taken after the largest earthquake events from the initial September 2010 earthquake.

September 2010: No image of the site

February 2011: Sand, silt, and water from liquefaction seen throughout site especially at the north end of the site. Sand/silt boils of approximately 2-10m wide.

June 2011: Sand, silt, and water from liquefaction seen throughout site especially at the north end of the site. Sand/silt boils of approximately 1-3m wide. The volume of ejected material was significantly less than that of the February event.

December 2011: No liquefaction evident.

4. Level Survey

A summary of the level survey undertaken by Opus Structural Engineer on 20 June 2013 at Maurice Hayes Place is given in Table 6.

The Pass and Fail criteria illustrated in Table 6 is based on Table 2.3 of MBIE guidance for shallow foundations. The MBIE Guidance however is not directly applicable for shallow piled foundations. The survey results indicate the units at the northern end of the site have suffered more significant differential settlement than the southern end.

Table 6: Summary of level survey data

Block	Flat No.	Comment	Maximum Fall
A	1	pass	-
	2	pass	-
	3	pass	-
	4	pass	-
	5	pass	-
B	6	fail	6mm/m
	7	pass	-
	8	pass	-
	9	pass	-
	10	fail	6mm/m
C	11	pass	-
	12	fail	5.5mm/m
	13	pass	-
	14	fail	5.2mm/m
	15	pass	-
D	16	fail	5.5mm/m
	17	fail	7mm/m
	18	pass	-
	19	pass	-

The highlighted rows indicate foundations that have a floor slope greater than 5mm/m (0.5%).

5. Discussion

At the time of the 18 June 2013 inspection, little evidence of ejected material and differential ground settlement was observed. Minor localised damage to pavements such as depressions and to buildings such as brick veneer and foundation cracking 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, or in the vicinity, after the February 2011 and June 2011 seismic event with minor observed liquefaction after the December 2011 seismic events.

The level survey results have been assessed and indicated moderate variations (up to 30mm with slopes greater than 0.5%) in floor level in Units 6, 10, 12, 14, and 16-17 in the Maurice Hayes Place complex. Foundation relevel of these units is likely required. The survey results indicate the buildings are likely to be founded on shallow piles. No differential settlement between the ground and the foundations has been observed.

Boreholes and CPTs undertaken for EQC indicate the residential complex is likely to be founded on 2.5 to 3.5m of Clayey SILT overlying 16.5 to 18m of loose to medium Sand/ silty Sand, with groundwater depths of approximately 1.0-2.0 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 identified liquefiable layers from 2 to 20m at CPT 973 and CPT 6698 for a ULS seismic event. For a ULS seismic event the site is expected to have a very high risk of liquefaction and moderate risk of lateral spreading. For a SLS seismic event the site is expected to have minor to moderate risk of liquefaction and lateral spreading.

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. 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 Maurice Hayes Place.

Based on our liquefaction assessment of adjacent CPT's, the site is considered to be equivalent to TC3. The site is considered to have a moderate risk of lateral spread.

6. Recommendations

It is recommended that in order to determine foundation repair options at Maurice Hayes Place, a site specific investigation is undertaken including CPTs, Hand Augers and Scalas. We also propose the depth of the existing piled foundations is verified. The site investigation will enable a liquefaction and lateral spreading assessment to determine conceptual repair and relevelling options.

The scope of the proposed site specific investigations will include:

- 3 additional CPT's to a depth of 20m
- Hand Auger and Scala tests should then be carried out to 3m depth or refusal at units 6, 10, 12, 14, 16, and 17.
- Confirmation of the depth of the existing pile foundations.
- 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 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

Brown, LJ; Webber, JH 1992: Geology of the Christchurch Urban Area. Scale 1:25,000. Institute of Geological and Nuclear Sciences geological map, 1 sheet + 104p.

Environment Canterbury, Canterbury Regional Council (ECan) website:

ECan 2004: The Solid Facts on Christchurch Liquefaction. Canterbury Regional Council, Christchurch, 1 sheet.

Project Orbit, 2011: Interagency/organisation collaboration portal for Christchurch recovery effort. https://canterburygeotechnicaldatabase.projectorbit.com/

GNS Science reporting on Geonet Website: http://www.geonet.org.nz/canterbury-quakes/aftershocks/ updated on 28 February 2013.

'Repairing and rebuilding houses affected by the Canterbury earthquakes': Ministry of Business, Innovation and Employment (December 2012).

Appendices:

Appendix A: Site Inspection Photographs
Appendix B: Site Location Plan
Appendix C: Walkover Inspection Plan
Appendix D: Structural Details
Appendix E: Surrounding Site Investigations
Appendix F: EQC Map Output
Appendix G: CLiq Liquefaction Analysis

Prepared By:

Thomas de Malmanche
Graduate Geotechnical Engineer

Reviewed By:

Graham Brown
Senior Geotechnical Engineer

Appendix A:
Site Inspection Photographs

Photo 1: Rear elevation of Block A (unit 1 -5) and unit 6

Photo 2: Damaged access road

Photo 3: Rear elevation of Block A

Photo 4: South east side elevation, unit 10 and unit 15 visible

Photo 5: Spreading of concrete porch, up to 8mm

Photo 6: Front elevation of Block A, differential settlement of concrete path and liquefaction sand evident

Photo 7: Front porch unit 1, differential settlement

Photo 8: Crack at lamp post adjacent unit 1

Photo 9: West elevation of Block B (unit 6 – 7)

Photo 10: Back elevation of unit 15 and undulating ground profile

Photo 11: Back elevation of unit 6, step cracking of brick wall and foundation crack

Photo 12: Front elevation of Block B

Photo 13: Back elevation of unit 14 & 15

Photo 14: Separation of concrete path and curb damage


Photo 15: West elevation of Block C (unit 11 - 15)


Photo 16: Front elevation of Block C (and block D)

Photo 17: Pavement depression north of Block C

Photo 18: Pavement depression

Photo 19: Brick veneer crack between unit 17 & 18

Photo 20: Rear elevation of unit 18 & 19

Photo 21: Cracking between brick veneer and foundation, north east corner of unit 19

Photo 22: Front elevation of Block D (unit 16 - 19)

Photo 23: Cracking of brick veneer and foundation, north west corner beneath window of unit 19

Photo 24: Stream on the north boundary of site

Photo 25: Pavement cracking on access road

Appendix B:

Site Location Plan

⬭ CPTs assessed for liquefaction potential.

Approximate Scale:1 to 1250 at A3

SOURCE:canterburyrecovery.projectorbit.com (Accessed on 21/06/2013)

OPUS

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Project: Maurice Hayes Place, 841 Ferry Road, Woolston
Project No.: 6-QC381.00
Client: Christchurch City Council

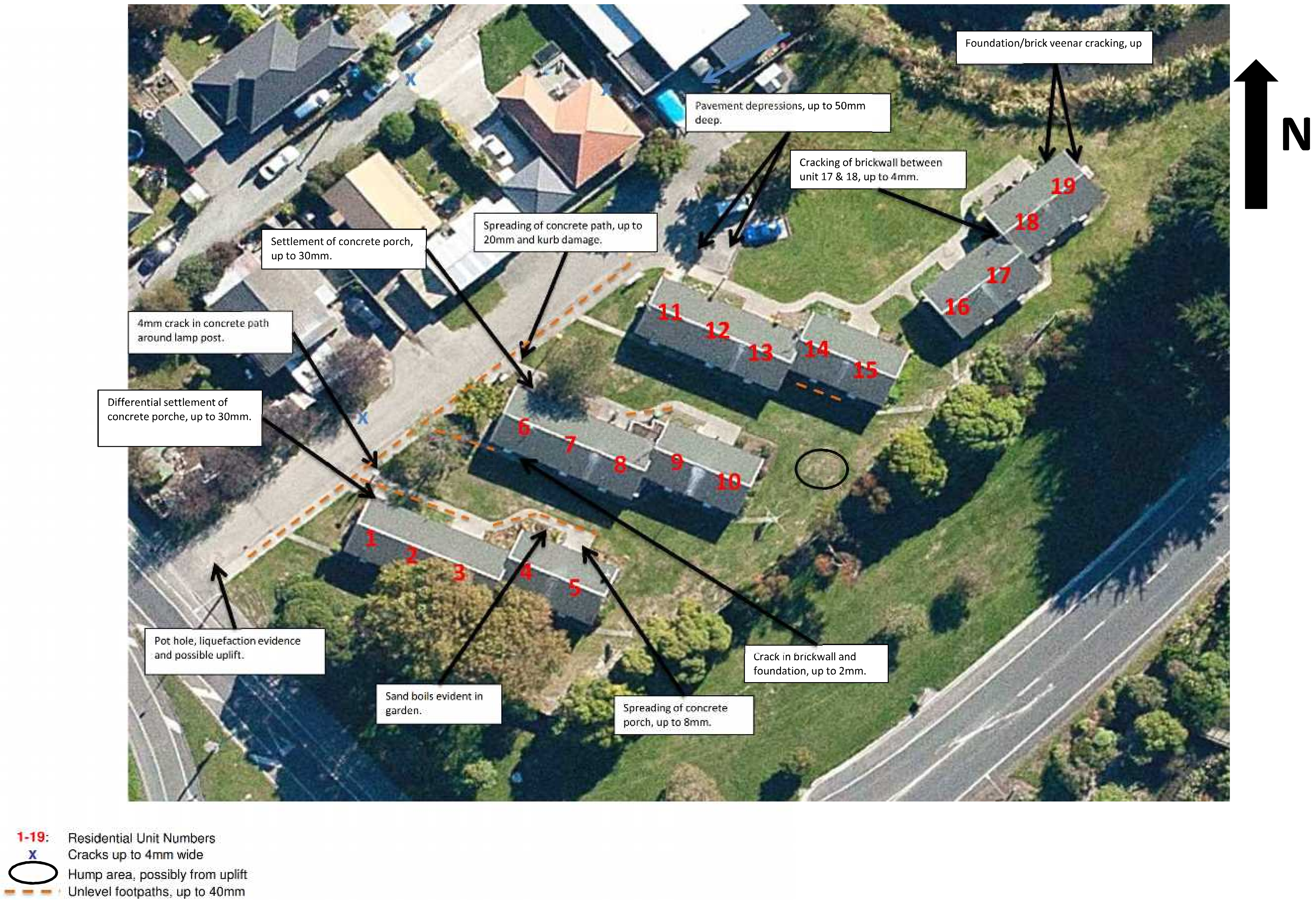
Site Location Plan

Drawn: Opus Geotechnical Engineer

Date: 10-Oct-13

Appendix C:

Walkover Inspection Plan



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Project: Maurice Hayes Place, Woolston
Project No.: 6-QC381.00/005HC
Client: Christchurch City Council

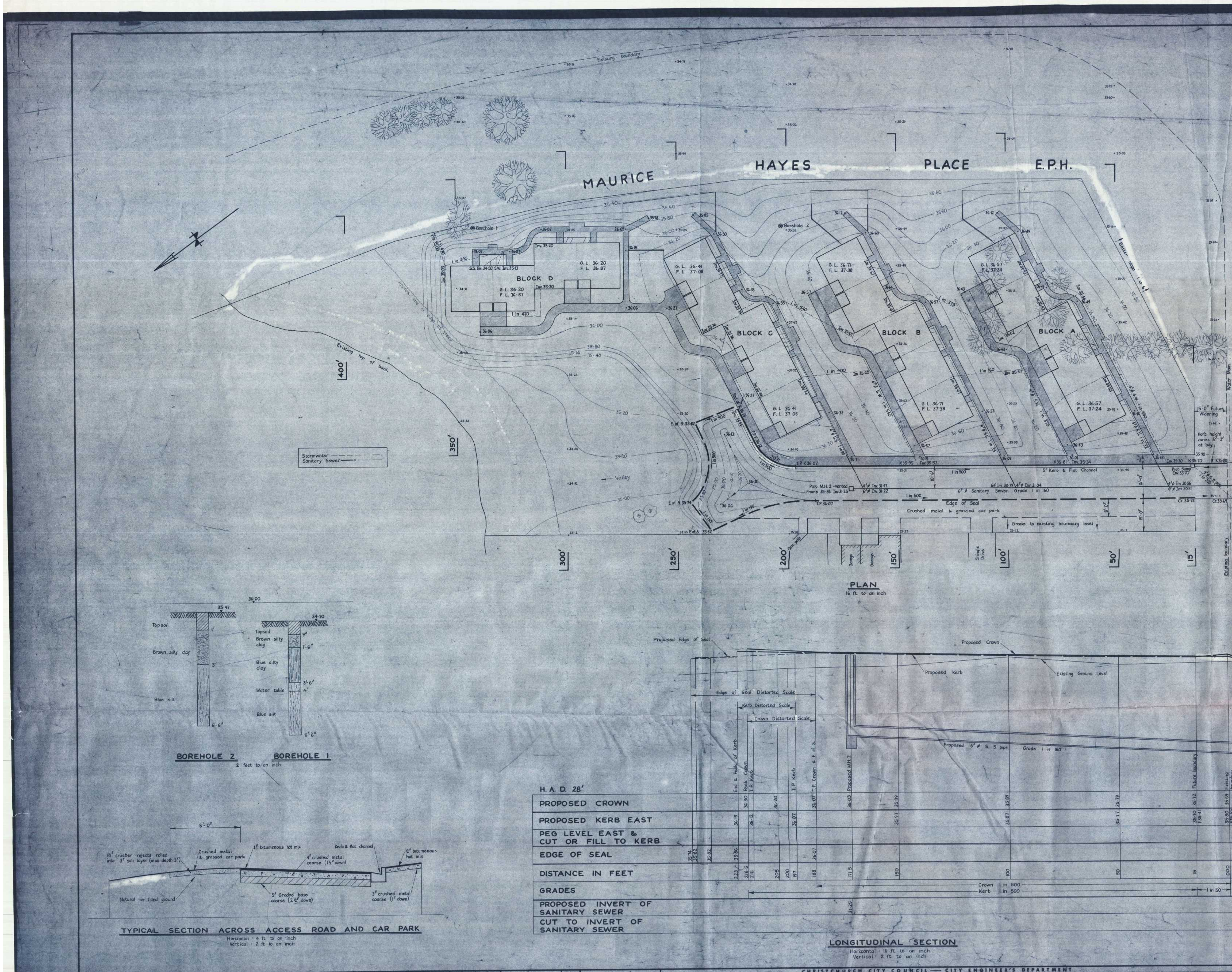
Walkover Inspection Plan

Drawn: Opus Geotechnical Engineer

Date: 18-Jun-13

Appendix D:

Structural Details



Service	Initial	Service	Initial
H.P. Water		Land and Survey	
Sewer		Planning	
S.W. Drainage			
Gas			
Cables (M.E.D.)			
" (P.O.)			

	Book	Page	Initial	Date
Surveyed				
Levelled				
B.M.				
Compiled from				

		Date
Designed	J. Welch	Oct. 73
Drawn	D. R. Storey	Oct. 73
Traced	D. R. Storey	Oct. 73
Dwg. Chk.		
Des. Chk.		
Indexed	[illegible]	10/8/73

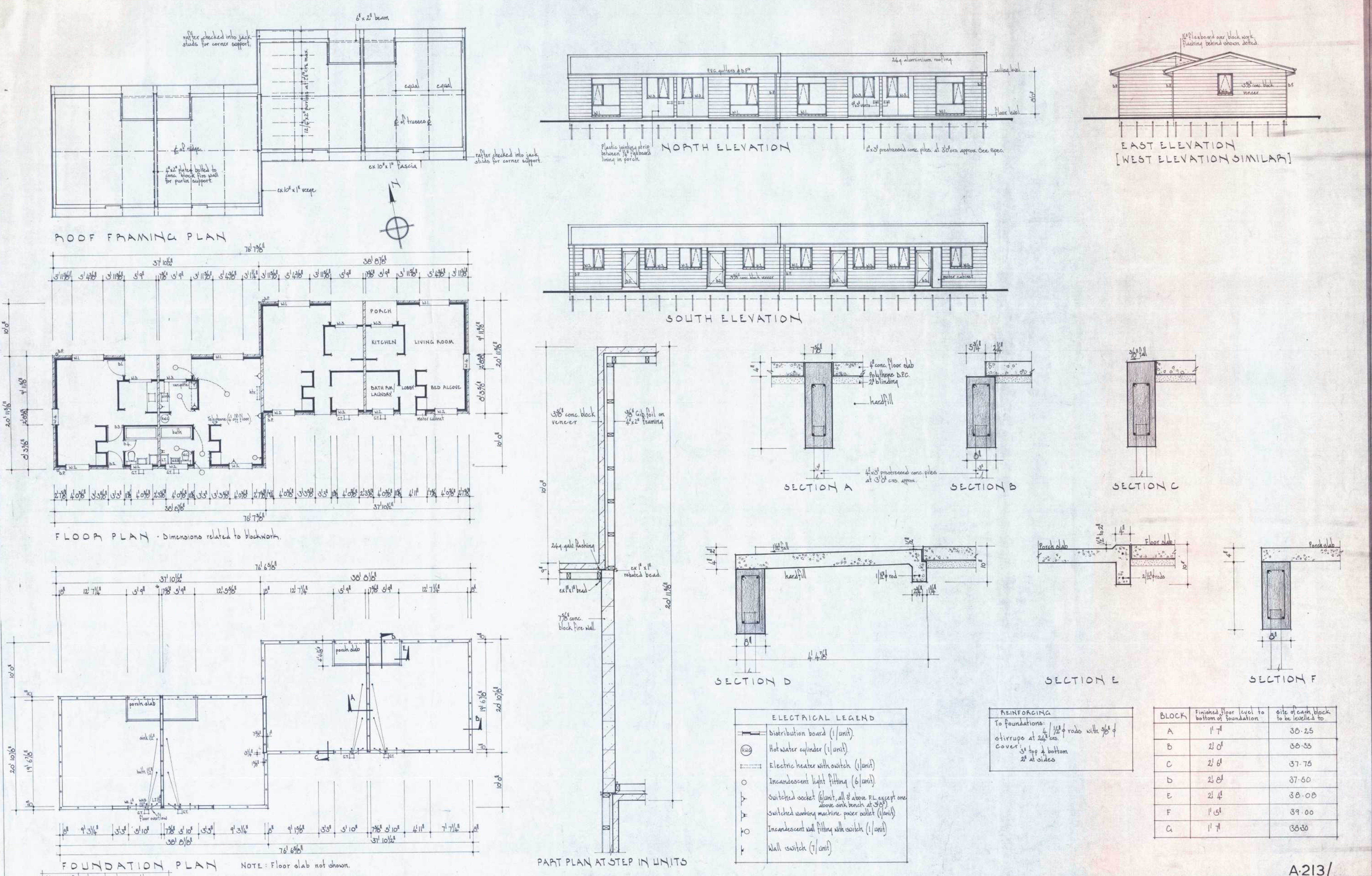
Approved

Design Engineer Date

City Engineer

CHRISTCHURCH CITY COUNCIL — CITY ENGINEER'S DEPARTMENT

FERRY ROAD, TUNNEL ROAD, PENSIONER COTTAGES
ACCESS ROAD, SANITARY SEWER, STORMWATER PIPING,
LAYOUT PLAN (EXISTING AND DESIGN LEVELS)



ELECTRICAL LEGEND	
▬	Distribution board (1/unit).
(HWC)	Hot water cylinder (1/unit).
┅	Electric heater with switch (1/unit)
○	Incandescent light fitting (6/unit).
▷	Switched socket (6/unit, all 3' above F.L. except one above sink bench at 3'8")
▷	Switched washing machine power outlet (1/unit)
⊢○	Incandescent wall fitting with switch (1/unit)
⊢	Wall switch (7/unit)

REINFORCING

To foundations: 4/½" ϕ rods with ⅜" ϕ stirrups at 24" crs.
Cover: 3" top & bottom
2" at sides

BLOCK	Finished floor level to bottom of foundation	site of each block to be levelled to
A	1' 7"	38·25
B	2' 0"	38·33
C	2' 6"	37·75
D	2' 8"	37·50
E	2' 4"	38·08
F	1' 5"	39·00
G	1' 7"	38·30

A·213/

CITY ARCHITECT'S DIVISION

CHRISTCHURCH CITY COUNCIL

CITY ENGINEER'S DEPARTMENT

CONSULTANT

~~JURA PLACE~~ - ELDERLY PERSONS HOUSING [SERIES 2]

FERRY RD/TUNNEL RD

SCALES	DESIGN	AMENDMENTS	SHEET TITLE	REFERENCE	SHEET
⅛" to 1'0" 1" to 1'0" ½" to 1'0"	DSN DRN G.M.L TCD G.M.L CKD	21-3-74. Site levelled to 38·30 for Block G.	BLOCK A & B & C GENERAL ARRANGEMENT PLANS FOUNDATION DETAILS	JOB FILE BU 18/1/30 CONT 14-73/74	A3

DATE

CONTRACTOR SHALL VERIFY ALL DIMENSIONS BEFORE STARTING WORK

OF 8

Appendix E:
Surrounding Site Investigations

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: BH-01
Hole Location:
WST-POD03-BH01
(105 Kotuku Crescent)
SHEET 1 OF 3

PROJECT: CHCH TC3 GEOTECHNICAL INVESTIGATIONS
LOCATION: WOOLSTON
JOB No: 52003.000

CO-ORDINATES	5739442.52 mN 2485208.55 mE	DRILL TYPE: Roto-Sonic	HOLE STARTED: 10/9/12
		DRILL METHOD: PQDT/Auto SPT	HOLE FINISHED: 11/9/12
R.L.	2.11 m		DRILLED BY: Boart Longyear
DATUM	NZMG, MSL (CCC 20/01/12 Datum -9.043m)	DRILL FLUID: LP2000	LOGGED BY: T&T-SB CHECKED: BMcD

GEOLOGICAL | ENGINEERING DESCRIPTION

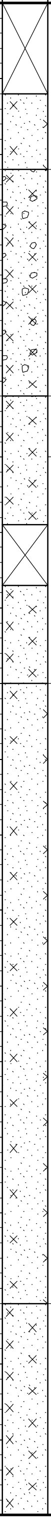
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.

CHRISTCHURCH FORMATION (MARINE/ ESTUARINE)

DEPTH (m)	WATER	CORE RECOVERY (%)	METHOD	TESTS	SAMPLES
0.0–1.95	▼	70	PQDT	*FC1.5	B
1.95–3.0		100	PQDT		
3.0–3.45		100	SPT	*FC3.0 0/0//0/1/2/4 N=7	B
3.45–4.5		0	PQDT		
4.5–4.95		100	SPT	3/2//3/4/5/5 N=17	
4.95–6.0		100	PQDT		
6.0–6.45		100	SPT	*FC6.0 2/3//5/7/6/3 N=21	B
6.45–7.5		100	PQDT		
7.5–7.95		100	SPT	2/3//3/2/0/2 N=7	
7.95–9.0		100	PQDT		
9.0–9.45		100	SPT	*FC9.0 2/1//2/1/3/4 N=10	B
9.45–10.0		100	PQDT		

R.L. (m): 2, 1, 0, -1, -2, -3, -4, -5, -, -7

DEPTH (m): 1, 2, 3, 4, 5, 7, 8, 9, 10



CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION
SP	M		Fine to medium SAND with minor silt, light brown, moist, poorly graded. 0.0 to 0.6m- no recovery. 1.0m- wet.
SM	W		Silty fine to medium SAND with trace gravel and trace rootlets, light brown, wet, poorly graded. Gravel is fine to medium. 1.5m- no SPT test, SPT rod fell under own weight. 1.5m- greyish brown.
SP			Fine to medium SAND with some silt, grey, wet, poorly graded.
SM		L	Silty fine to medium SAND, grey, loose, wet, poorly graded. 3.45 to 3.85m- no recovery.
SP		MD	Fine to medium SAND with trace silt, grey, medium dense, wet, poorly graded.
		L	7.5m- loose.
SM			Silty fine to medium SAND, grey, loose, wet, poorly graded.

FLUID LOSS | CASING | SHEAR STRENGTH (kPa) 10 25 50 100 200 | COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250 | DEFECT SPACING (mm) 50 250 1000 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.

T+T DATATEMPLATE.GDT RCB

Log Scale 1:50

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: BH-01
Hole Location:
WST-POD03-BH01
(105 Kotuku Crescent)
SHEET 2 OF 3

PROJECT: CHCH TC3 GEOTECHNICAL INVESTIGATIONS
LOCATION: WOOLSTON
JOB No: 52003.000

CO-ORDINATES 5739442.52 mN
2485208.55 mE
R.L. 2.11 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: Boart Longyear
LOGGED BY: T&T-SB
CHECKED: BMcD

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.

CHRISTCHURCH FORMATION (MARINE/ ESTUARINE)

CORE RECOVERY (%)	METHOD	TESTS	SAMPLES
100	PQDT		
100	SPT	1/1//3/2/1/1 N=7	
100	PQDT		
100	SPT	*FC12.0 2/1//0/0/0/0 N=0	B
70	PQDT		
100	PQDT		
100	SPT	*FC15.0 6/8//8/7/4/2 N=21	B
81	PQDT		
100	SPT	4/10// 13/7/5/9 N=34	
100	PQDT		
100	SPT	2/2// 2/6/10/13 N=31	
100	PQDT		

FLUID LOSS | WATER | CASING

R.L. (m): -8, -9, -10, -11, -12, -13, -14, -15, -1, -17

DEPTH (m): 11, 12, 13, 14, 15, 1, 17, 18, 19, 20

GRAPHIC LOG

CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION
SM	W	L	Silty fine to medium SAND, grey, loose, wet, poorly graded.
SP		VL	Fine to medium SAND with trace silt, very loose, wet, poorly graded. 13.5 to 14.0m- no recovery, no SPT, "too soft".
		MD	15.0m- medium dense.
		D	16.3 to 16.5m- no recovery. 16.5m- brownish grey, dense.
ML		H	SILT with minor sand, grey, hard, wet, low plasticity. Sand is fine to medium.
SP		D	Fine to medium SAND with trace silt, grey, dense, wet, poorly graded.
ML		H	SILT with minor sand, grey, hard, wet, low plasticity. Sand is fine to medium. 19.5m- no SPT.

SHEAR STRENGTH (kPa): 10 25 50 100 200
COMPRESSIVE STRENGTH (MPa): 1 5 20 50 100 250
DEFECT SPACING (mm): 50 250 1000 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.

11, 12, 13, 14, 15, 1, 17, 18, 19

T+T DATATEMPLATE.GDT RCB

Log Scale 1:50

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: BH-01
Hole Location:
WST-POD03-BH01
(105 Kotuku Crescent)
SHEET 3 OF 3

PROJECT: CHCH TC3 GEOTECHNICAL INVESTIGATIONS
LOCATION: WOOLSTON
JOB No: 52003.000

CO-ORDINATES 5739442.52 mN
2485208.55 mE
R.L. 2.11 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: Boart Longyear
LOGGED BY: T&T-SB
CHECKED: BMcD

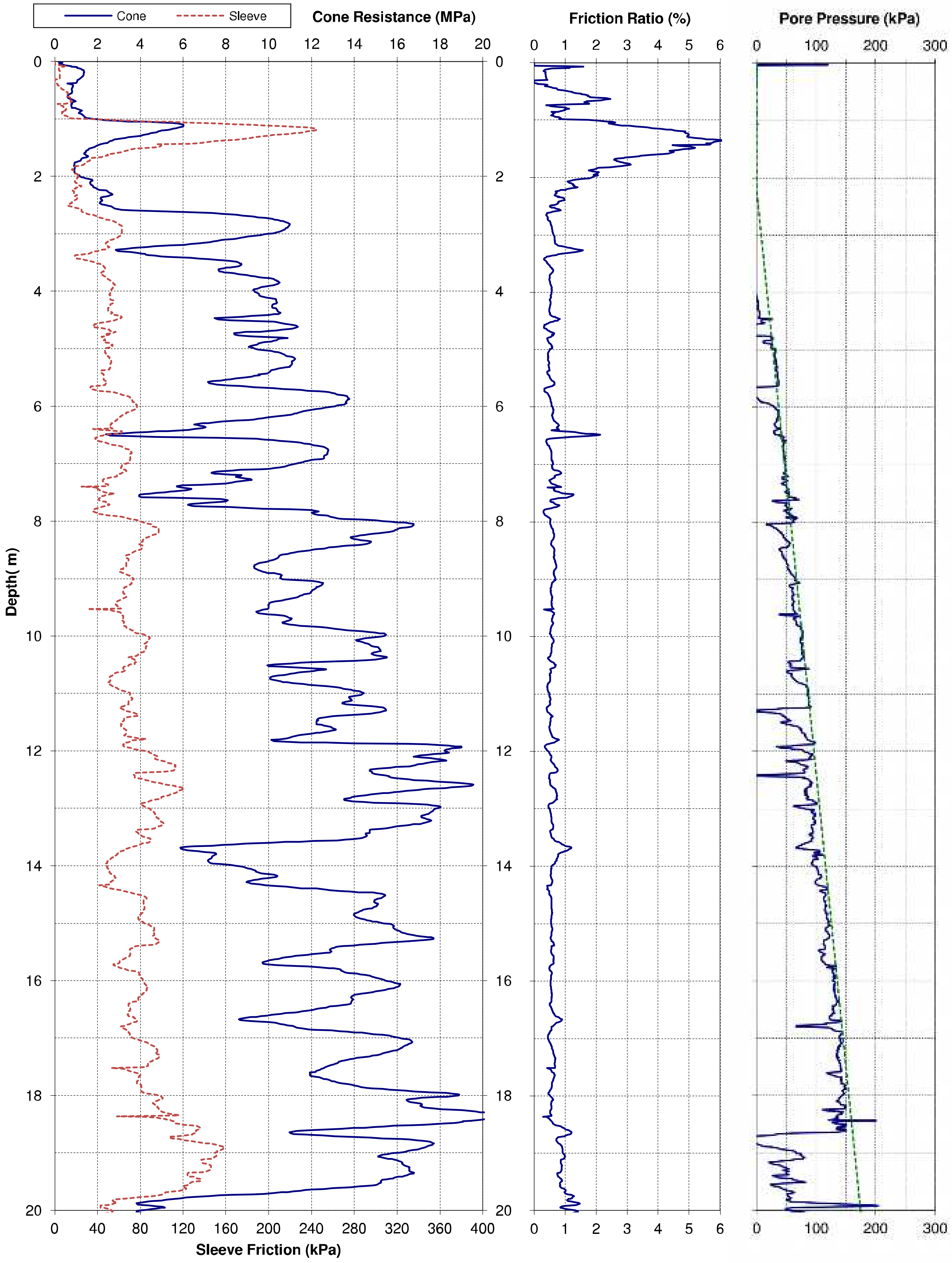
GEOLOGICAL										ENGINEERING DESCRIPTION							
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa) 10 25 50 100 200	COMPRESSIVE STRENGTH (MPa) 1 5 20 50 100 250	DEFECT SPACING (mm) 50 250 1000 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.
								-18									End of borehole at 19.95mbgl (target depth)
								-19	21								21
								-20	22								22
								-21	23								23
								-22	24								24
								-23	25								25
								-24	2								2
								-25	27								27
								-2	28								28
								-27	29								29
									30								

T+T DATATEMPLATE.GDT RCB

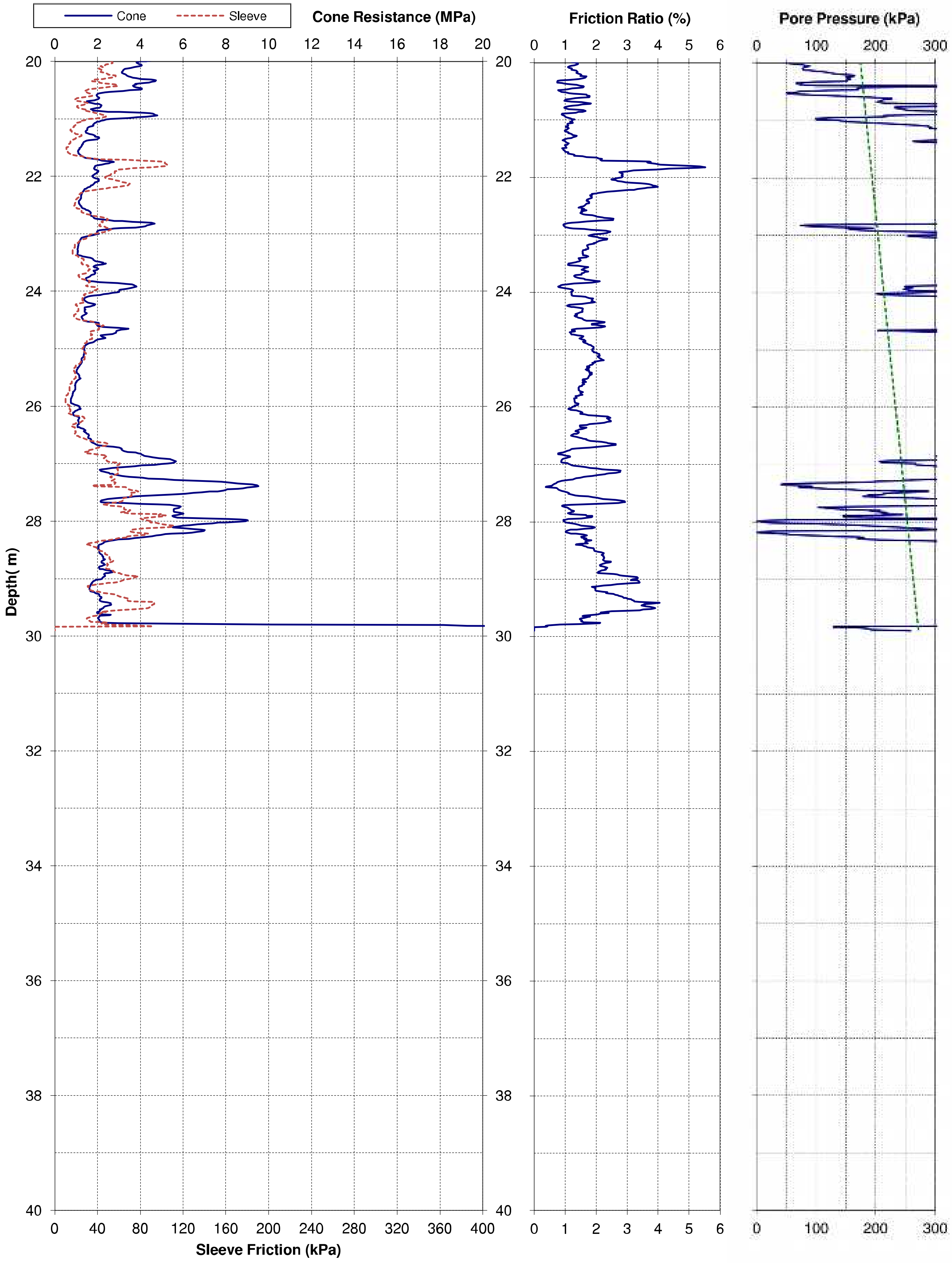
Log Scale 1:50

CPT-WSW-42

Project:	Christchurch 2011 Earthquake - EQC Ground Investigations			**Page:**	1 of 2
Test Date:	1-Jun-2011	**Location:**	Woolston	**Operator:**	Perry
Pre-Drill:	1.2m	**Assumed GWL:**	2.2mBGL	**Located By:**	Survey GPS
Position:	2485015.8mE	5739325.6mN	1.65mRL	**Coord. System:**	NZMG & MSL
Other Tests:				**Comments:**	



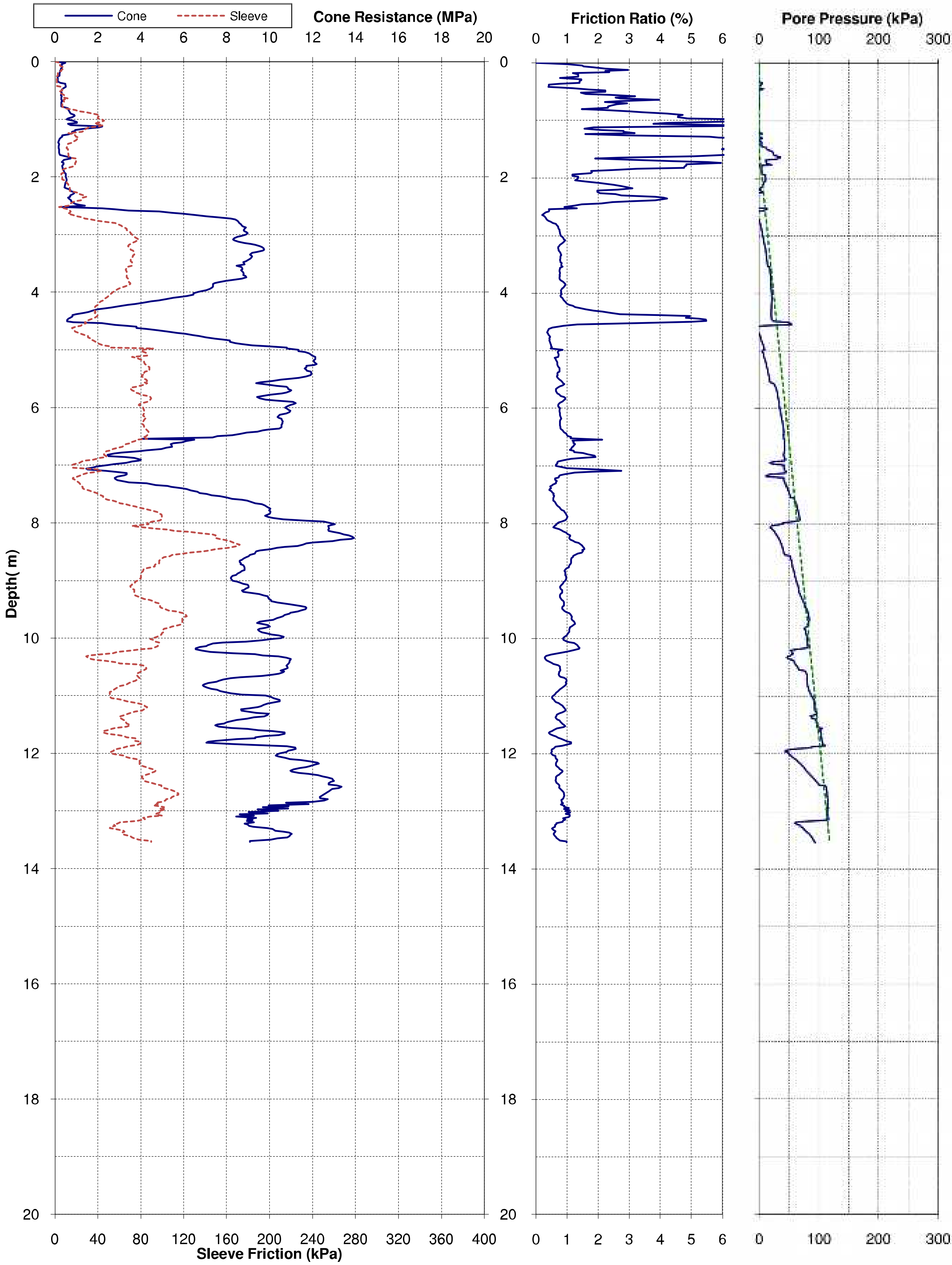
Project:	Christchurch 2011 Earthquake - EQC Ground Investigations		**Page:** 2 of 2		**CPT-WSW-42**
Test Date:	1-Jun-2011	**Location:** Woolston	**Operator:**	Perry	
Pre-Drill:	1.2m	**Assumed GWL:** 2.2mBGL	**Located By:**	Survey GPS	
Position:	2485015.8mE	5739325.6mN 1.65mRL	**Coord. System:**	NZMG & MSL	
Other Tests:			**Comments:**		



T+T Ref: 52000.3000 Printed: 26/09/2011 6:34 p.m. Template: CPT Graph Template v0.41.xls

Project:	Christchurch 2011 Earthquake - EQC Ground Investigations			**Page:**	1 of 1
Test Date:	13-Jun-2011	**Location:**	Woolston	**Operator:**	Geotech
Pre-Drill:	1.2m	**Assumed GWL:**	1.5mBGL	**Located By:**	Survey GPS
Position:	2484989.5mE	5739457.1mN	1.54mRL	**Coord. System:**	NZMG & MSL
Other Tests:				**Comments:**	

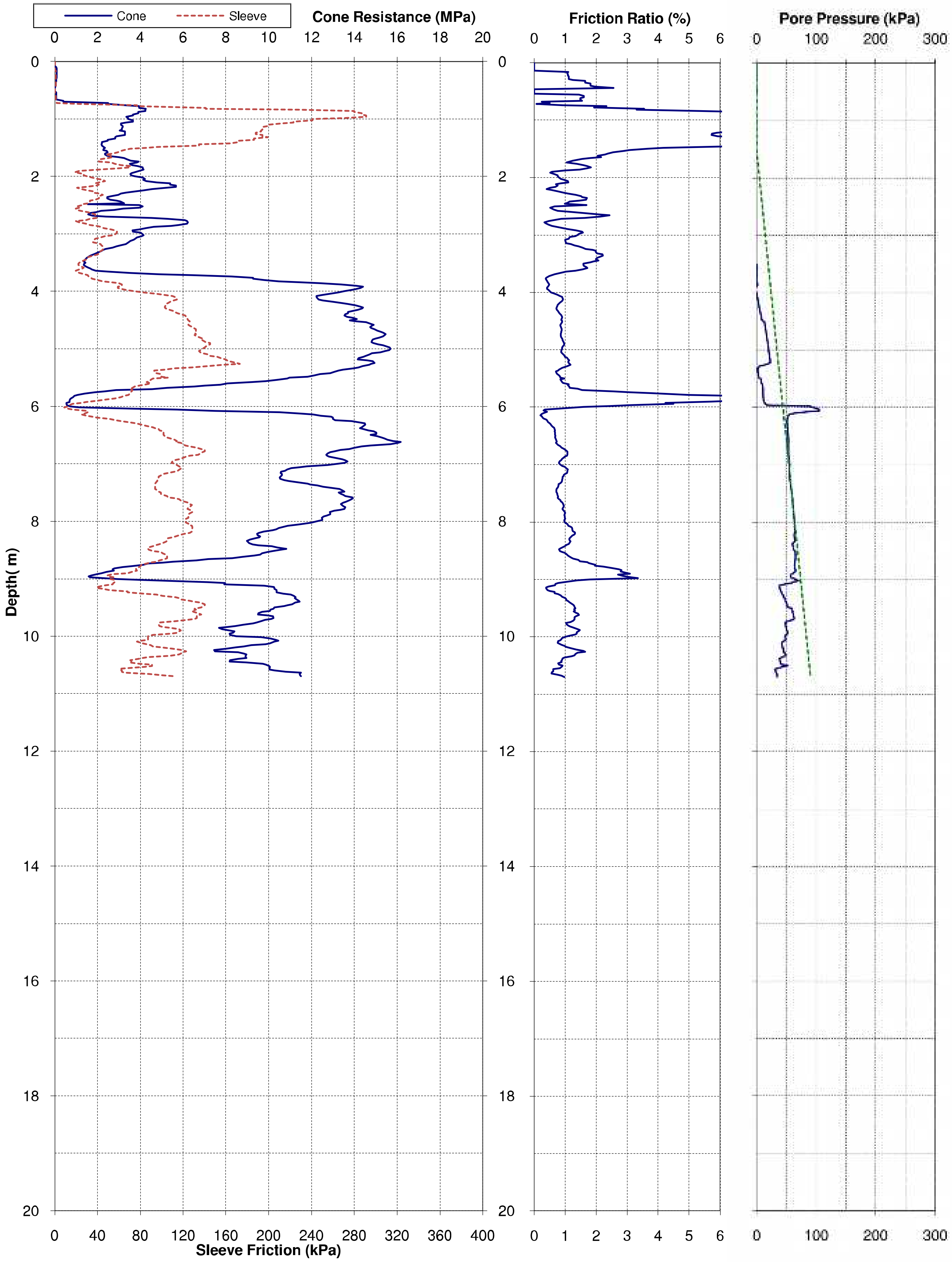
CPT-WSW-47

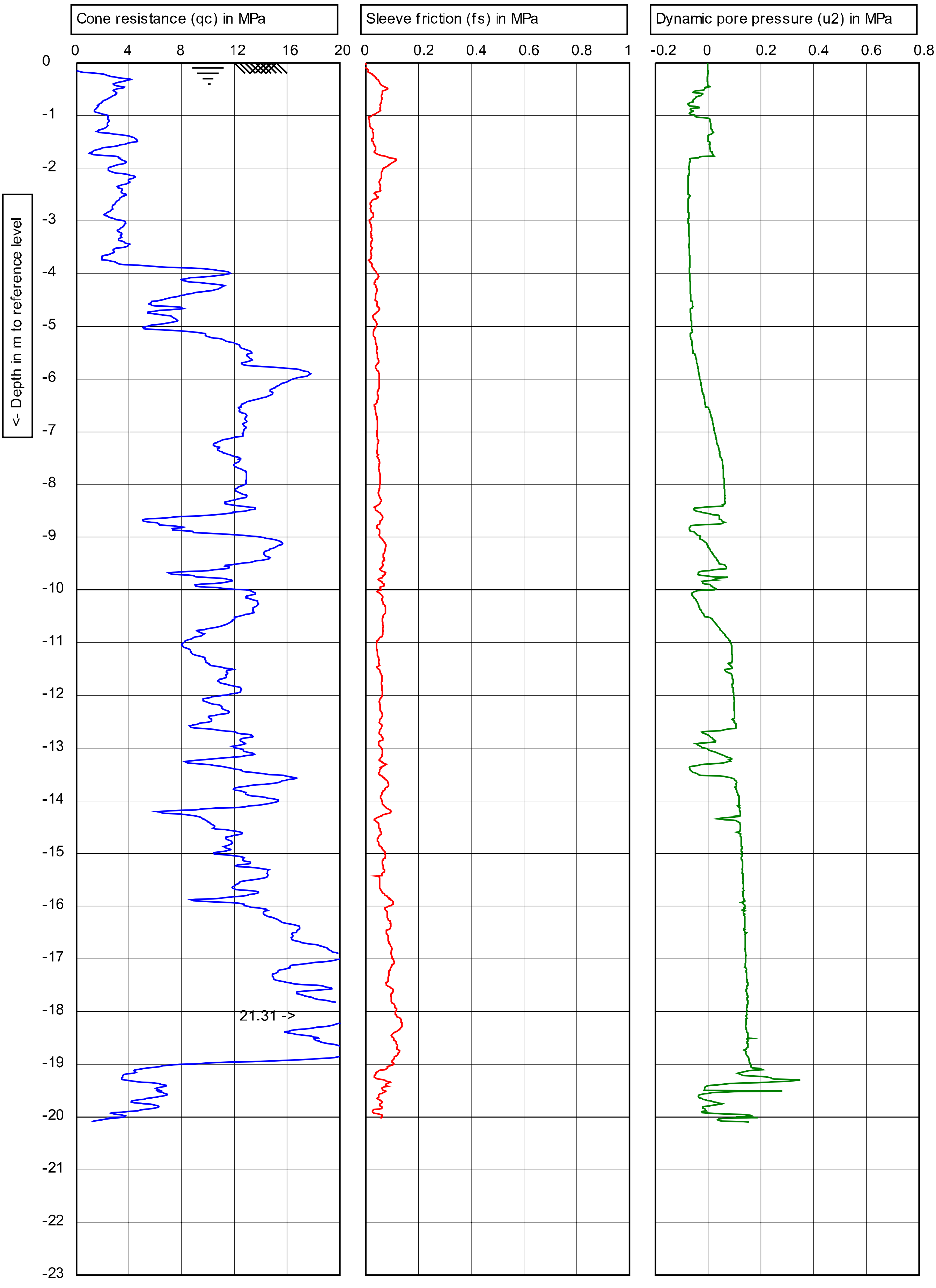


T+T Ref: 52000.3000 Printed: 8/09/2011 4:15 p.m. Template: CPT Graph Template v0.41.xls

Project:	Christchurch 2011 Earthquake - EQC Ground Investigations			**Page:**	1 of 1
Test Date:	13-Jun-2011	**Location:**	Woolston	**Operator:**	Geotech
Pre-Drill:	1.2m	**Assumed GWL:**	1.5mBGL	**Located By:**	Survey GPS
Position:	2485207.8mE	5739391.3mN	1.99mRL	**Coord. System:**	NZMG & MSL
Other Tests:				**Comments:**	

CPT-WSW-48





OPUS
HAMILTON LABORATORY

u2
150 cm²
10 cm²

Test according to A.S.T.M standard D-5778-07

G.L. **0**

W.L.: **0**

Project: **Geotechnical Investigation**

Location: **GPS: E1575166 N5177830**

Position:

Predrill : **0**

Date: **5/10/2012**

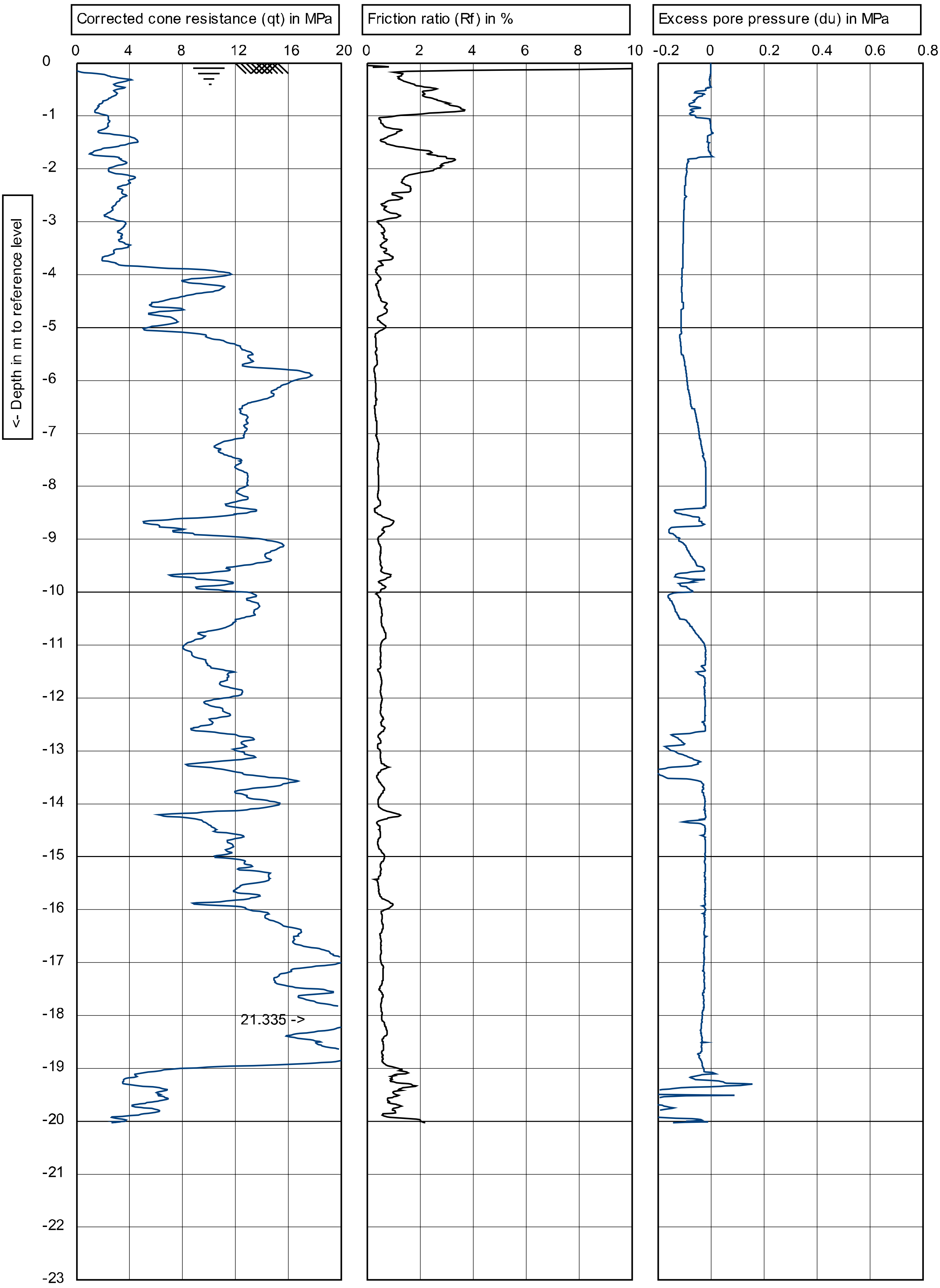
Cone no.: **C10CFIIP.C10021**

Project no.: **2-68292.12_029**

CPT no.: **WST-POD03-CPT001**

1/5

CPTask V1.20

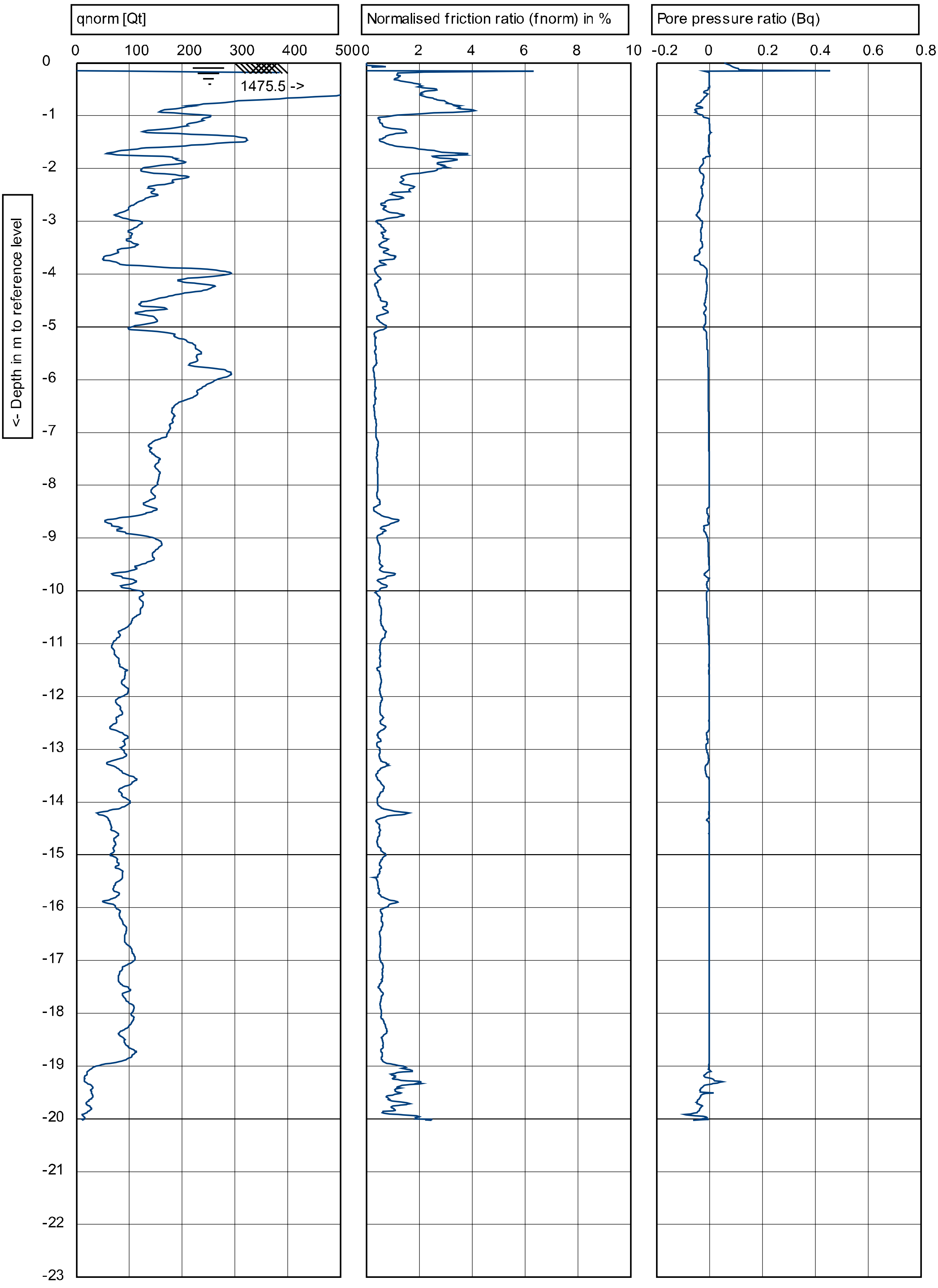


OPUS
HAMILTON LABORATORY

u2
150 cm²
10 cm²

Test according to A.S.T.M standard D-5778-07		Predrill :	0
G.L. **0**	W.L.: **0**	Date:	**5/10/2012**
Project: **Geotechnical Investigation**		Cone no.:	**C10CFIIP.C10021**
Location: **GPS: E1575166 N5177830**		Project no.:	**2-68292.12_029**
Position:		CPT no.:	**WST-POD03-CPT001** **2/5**

CPTask V1.20



HAMILTON LABORATORY

u2
150 cm²
10 cm²

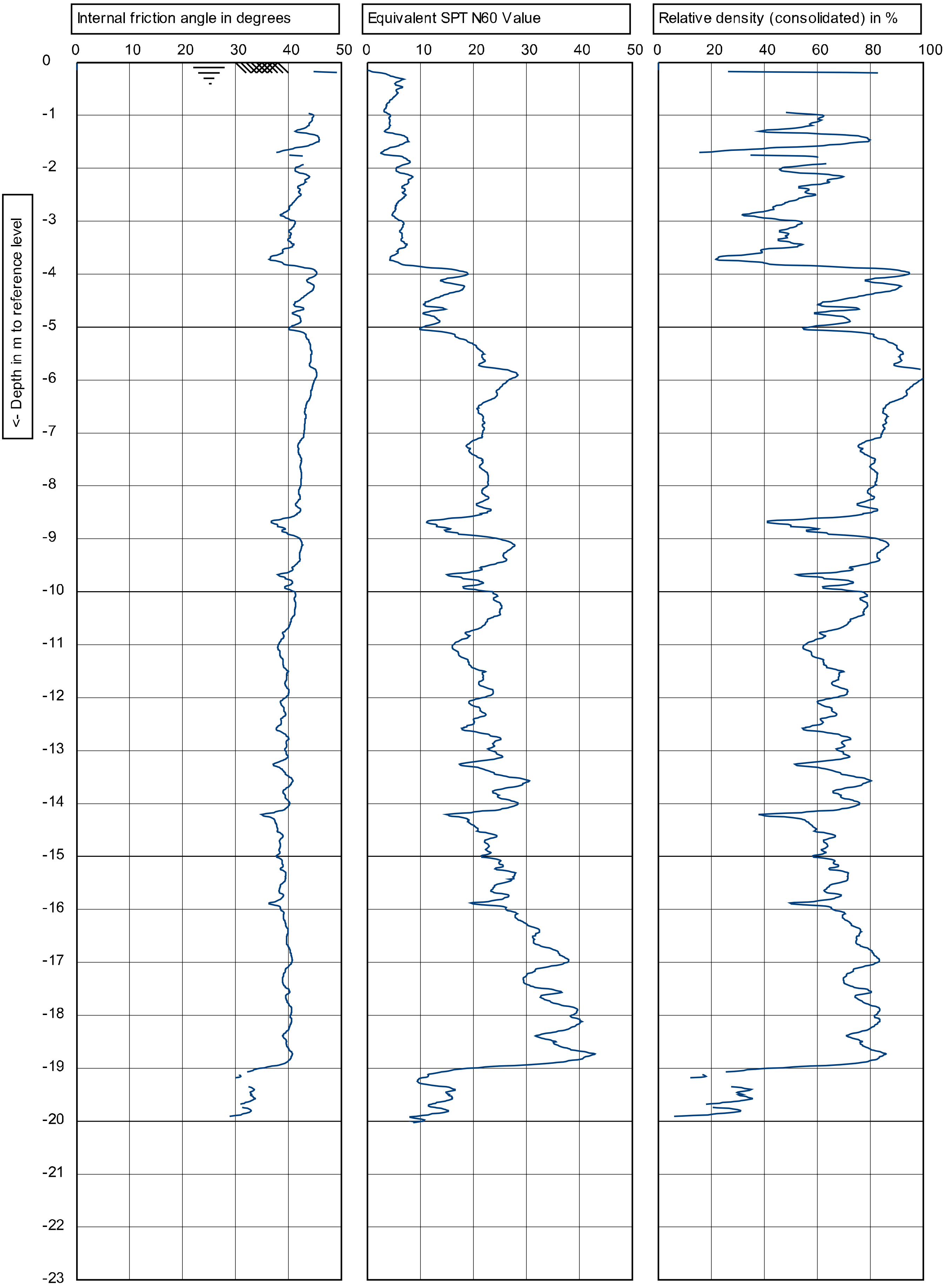
Test according to A.S.T.M standard D-5778-07

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

Project: **Geotechnical Investigation**
Location: **GPS: E1575166 N5177830**
Position:

Predrill : **0**
Date: **5/10/2012**
Cone no.: **C10CFIIP.C10021**
Project no.: **2-68292.12_029**
CPT no.: **WST-POD03-CPT001** **3/5**

CPTask V1.20



OPUS
HAMILTON LABORATORY

u2
150 cm²
10 cm²

Test according to A.S.T.M standard D-5778-07

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

Predrill : **0**

Date: **5/10/2012**

Project: **Geotechnical Investigation**

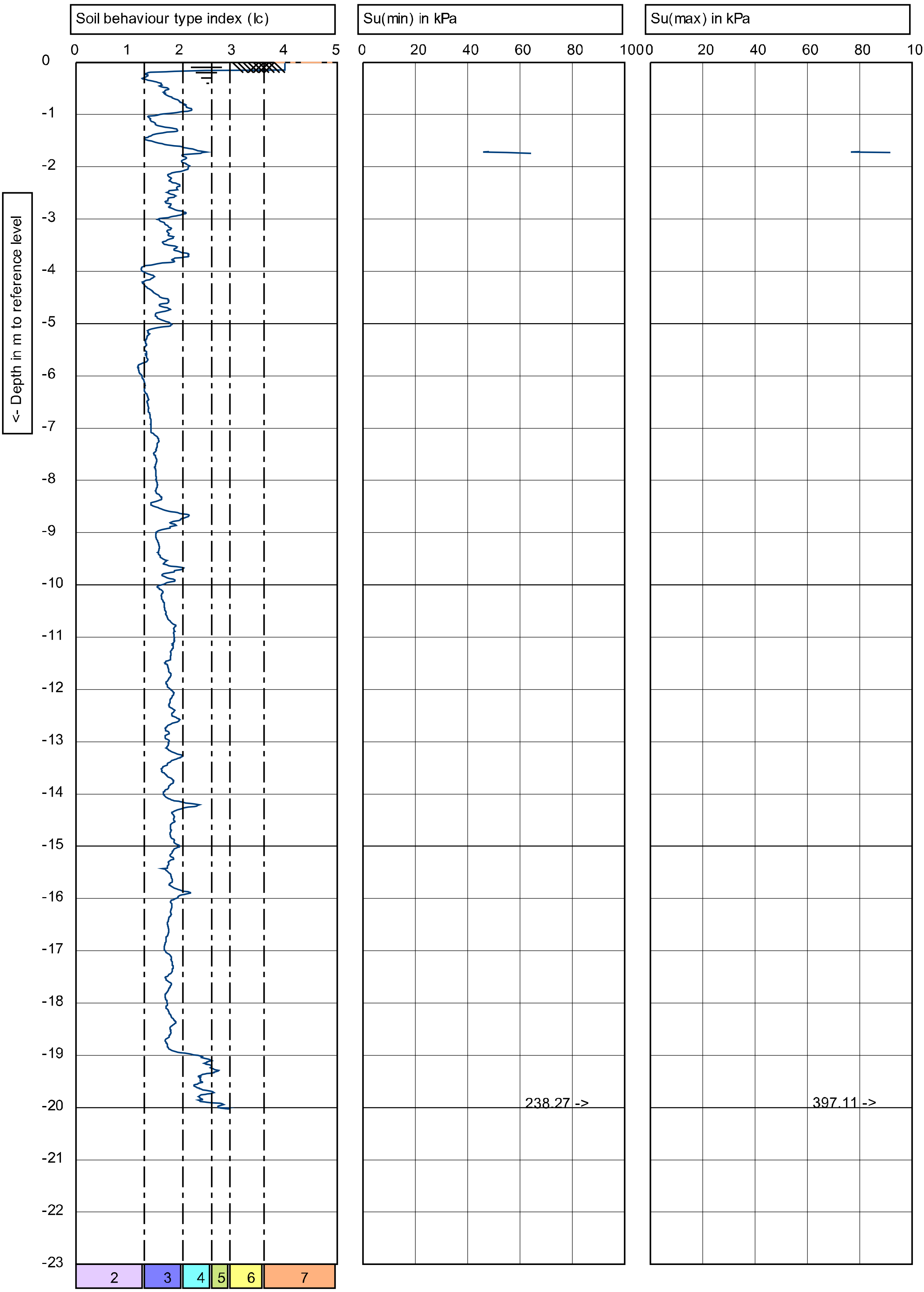
Location: **GPS: E1575166 N5177830**

Position:

Cone no.: **C10CFIIP.C10021**

Project no.: **2-68292.12_029**

CPT no.: **WST-POD03-CPT001**



OPUS
HAMILTON LABORATORY

u2
150 cm²
10 cm²

Test according to A.S.T.M standard D-5778-07

G.L. **0**

W.L.: **0**

Project: **Geotechnical Investigation**

Location: **GPS: E1575166 N5177830**

Position:

Predrill : **0**

Date: **5/10/2012**

Cone no.: **C10CFIIP.C10021**

Project no.: **2-68292.12_029**

CPT no.: **WST-POD03-CPT001**

5/5

CPTask V1.20

Appendix F:
EQC Map Output

Approximate Scale: 1 to 1000 at A3.

SOURCE:canterburyrecovery.projectorbit.com (Accessed on 21/06/2013)

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: Maurice Hayes Place, 841 Ferry Road, Woolston
Project No.: 6-QC381.00
Client: Christchurch City Council

EQC Observed Ground Cracking

Drawn: Opus Geotechnical Engineer

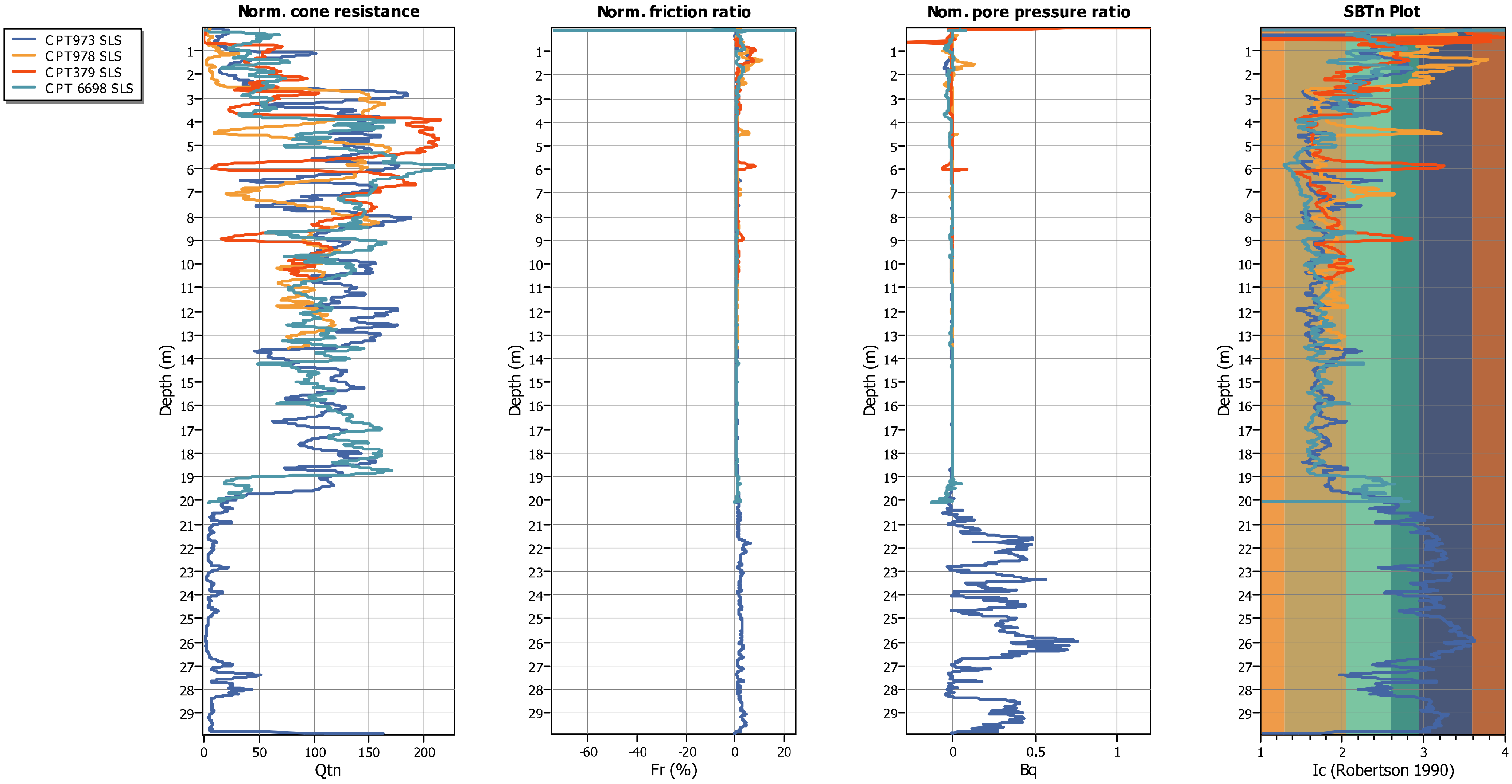
Date: 1-Jul-13

Appendix G:

CLiq Liquefaction Analysis

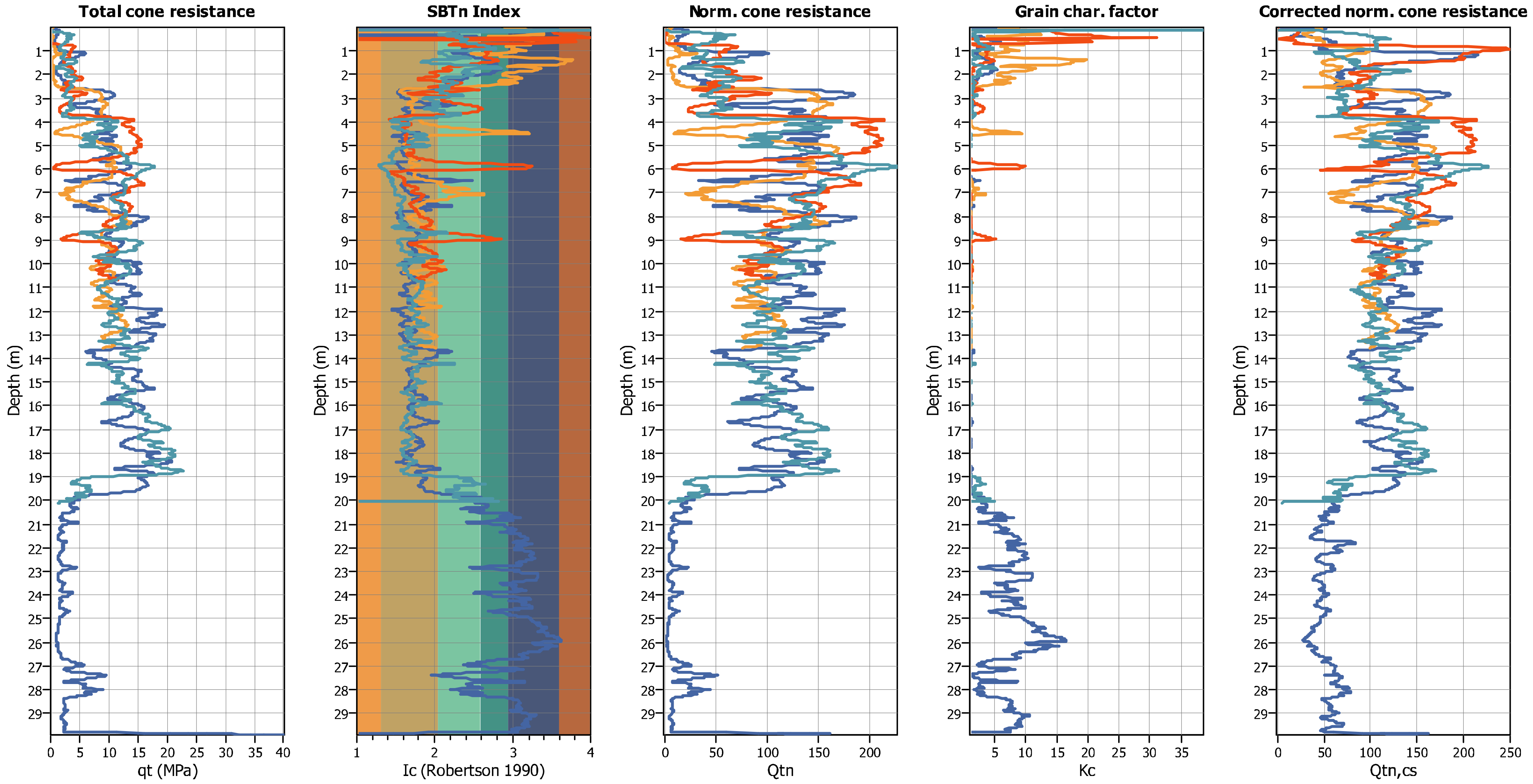
Project:

Overlay Normalized Plots



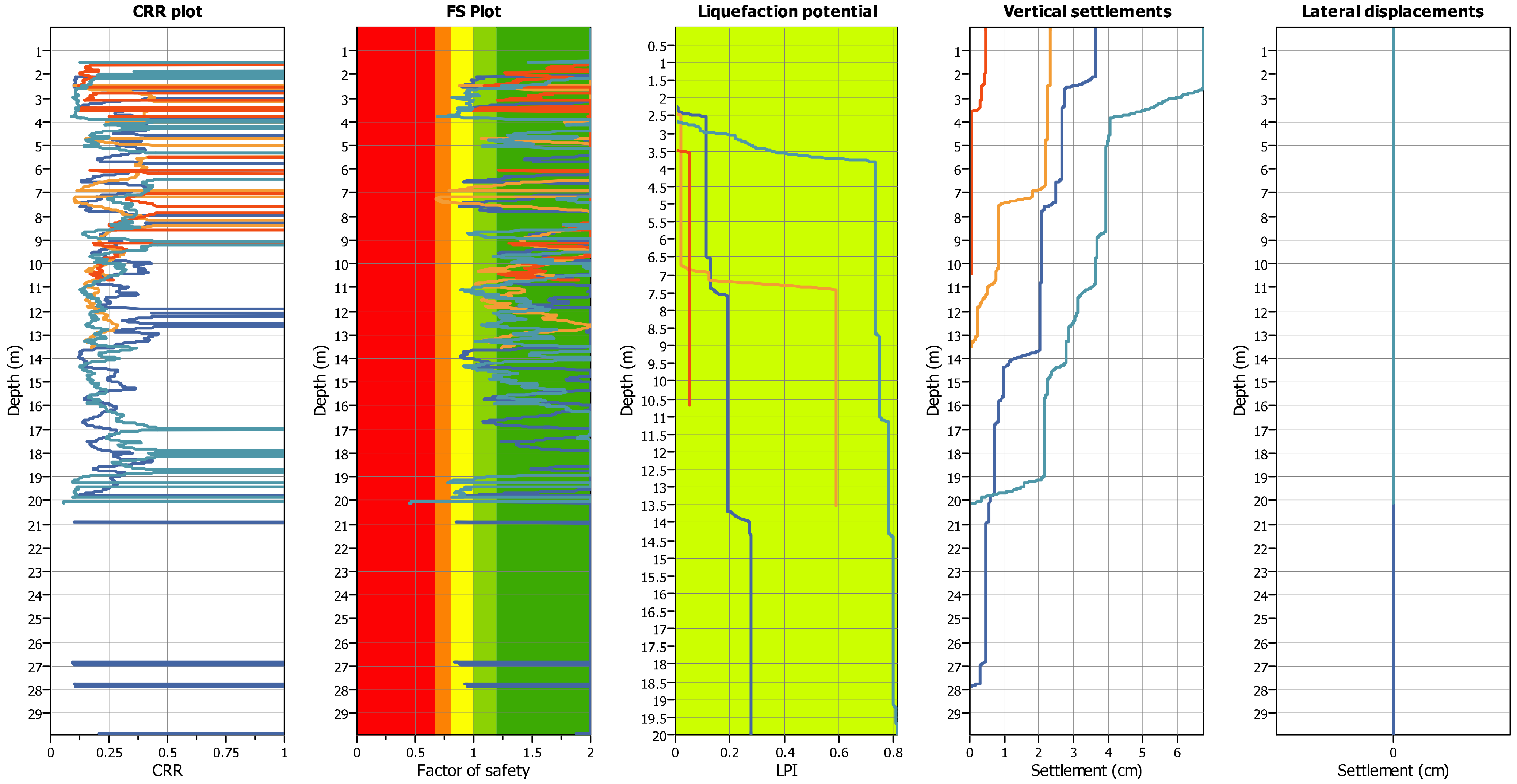
Project:

Overlay Intermediate Results



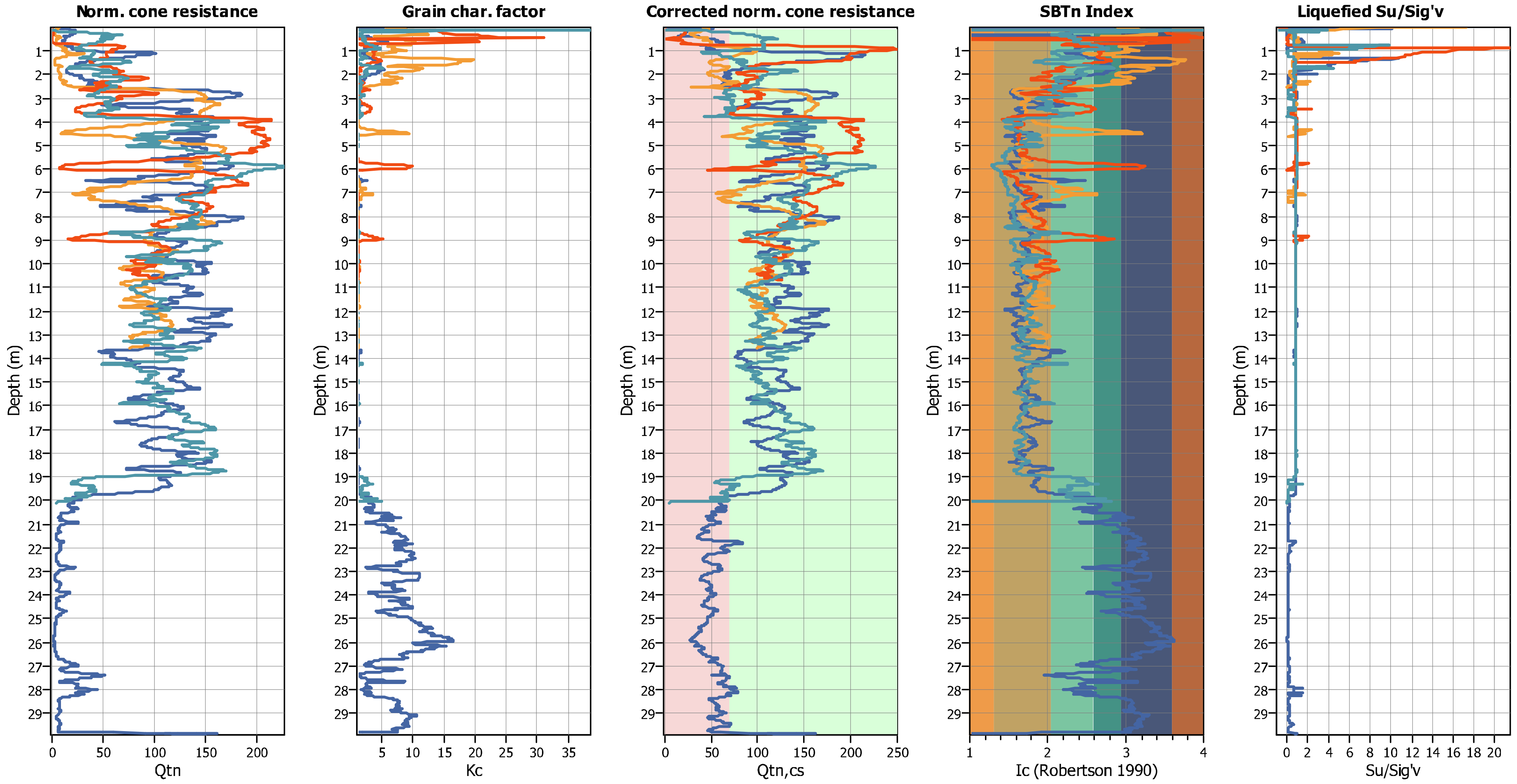
Project:

Overlay Cyclic Liquefaction Plots



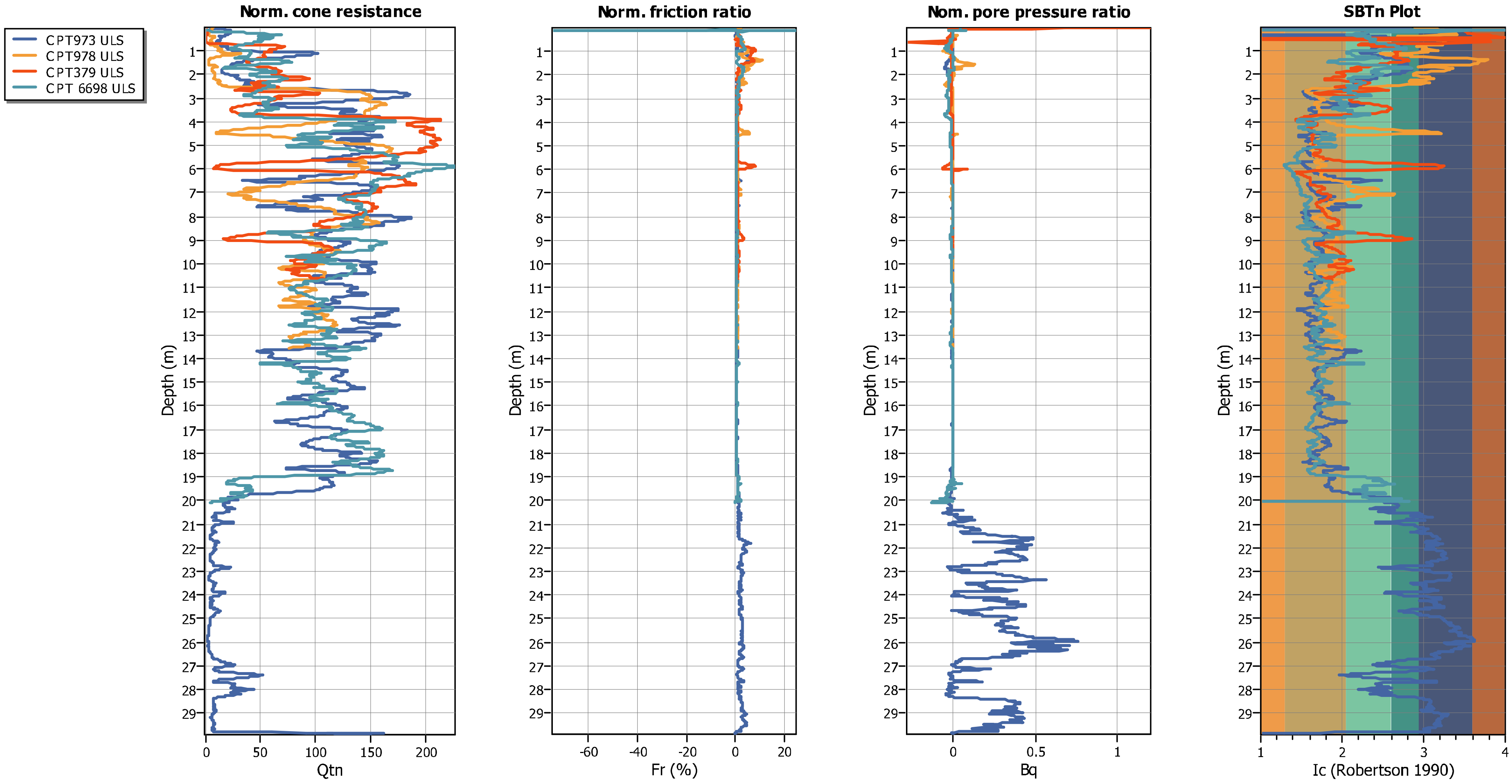
Project:

Overlay Strength Loss Plots



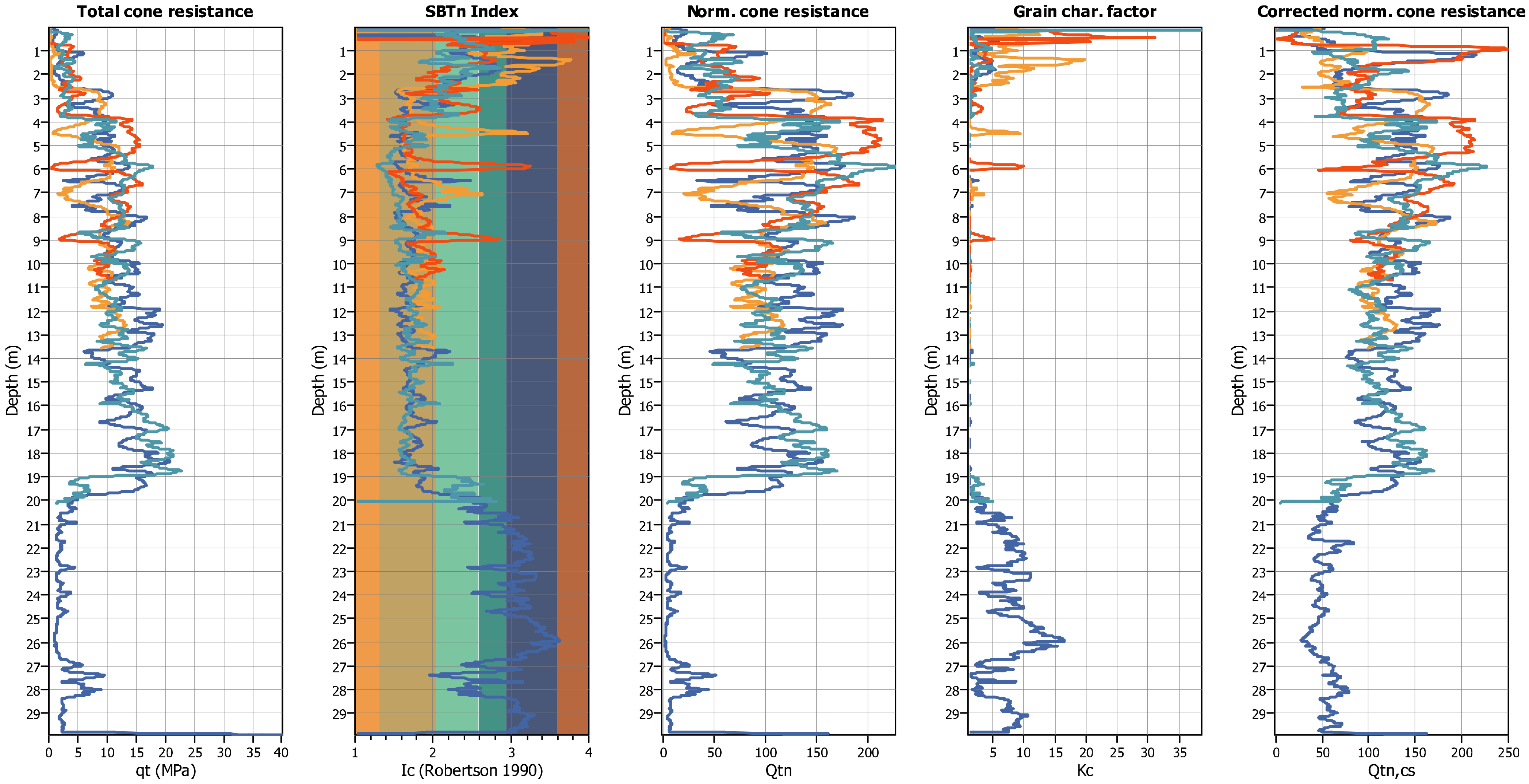
Project:

Overlay Normalized Plots



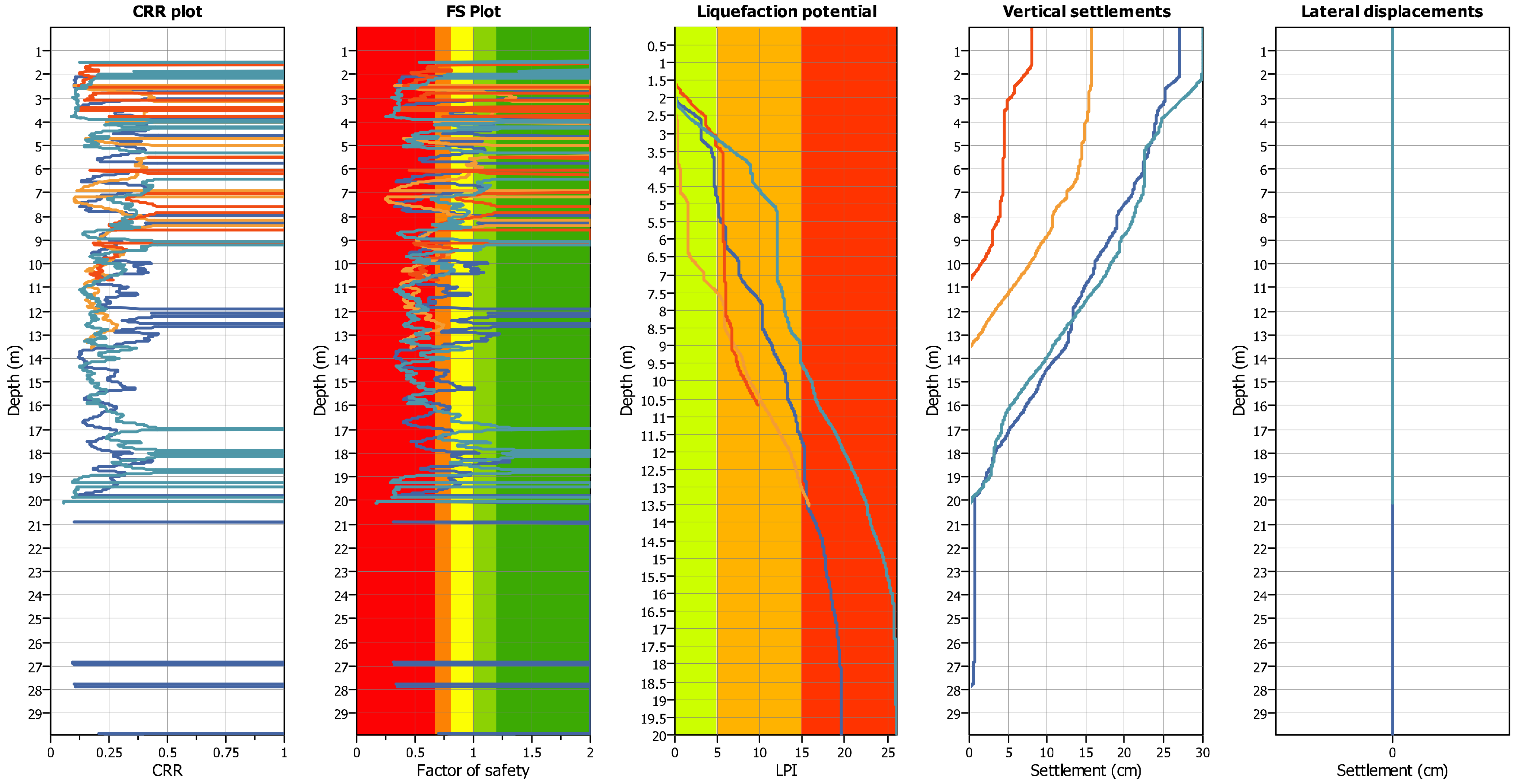
Project:

Overlay Intermediate Results


Total cone resistance
SBTn Index
Norm. cone resistance
Grain char. factor
Corrected norm. cone resistance

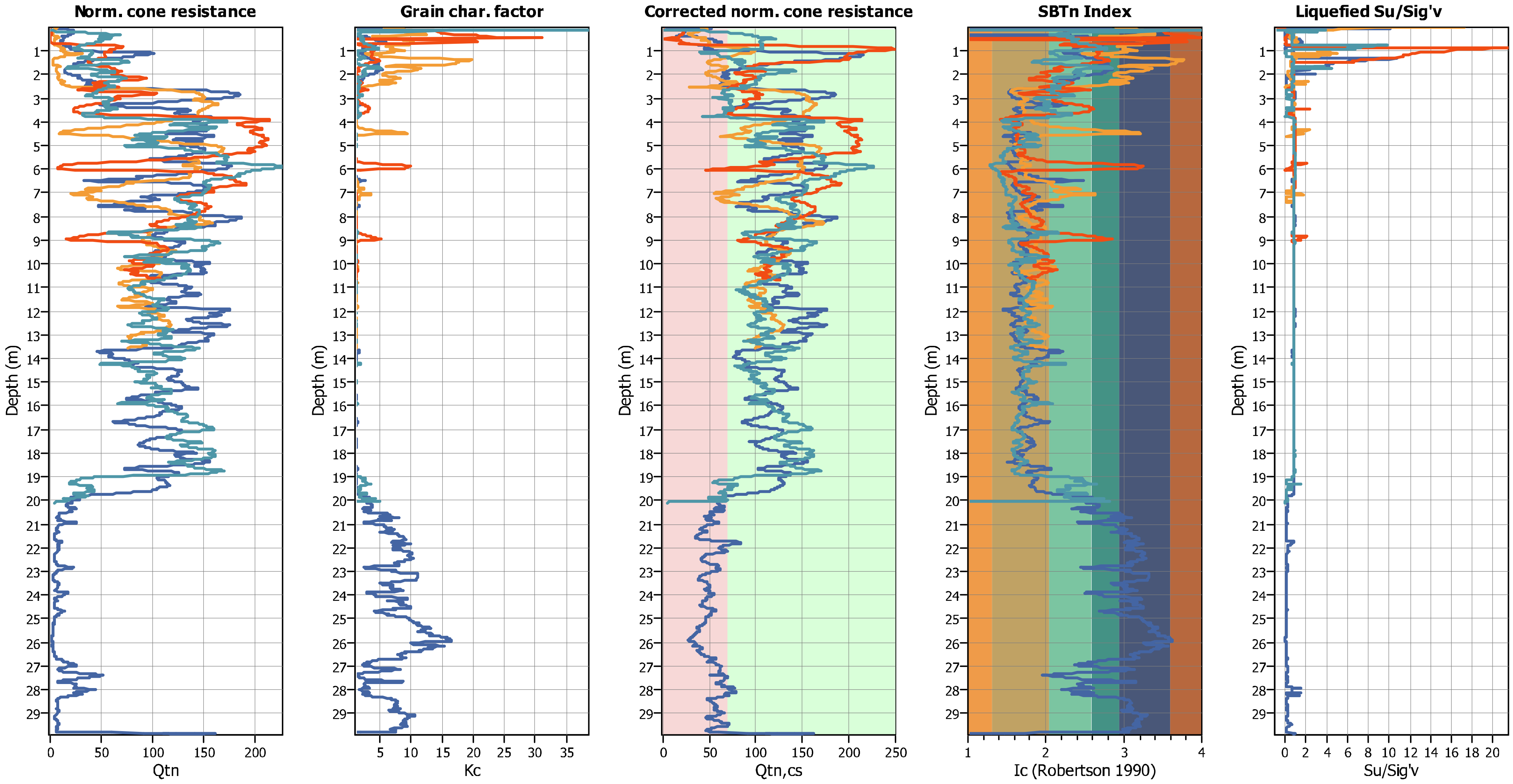
Project:

Overlay Cyclic Liquefaction Plots



Project:

Overlay Strength Loss Plots



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 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 2.5 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 V1.11

Location

Building Name: Maurice Hayes Housing Complex

Unit No: Street

Building Address: Units 1-19 | Maurice Hayes Place

Legal Description: Residential Units

Degrees Min Sec

GPS south: -43.55298279

GPS east: 172.6907356

Building Unique Identifier (CCC): PRO 0855

Reviewer: Mary Ann Halliday

CPEng No: 67073

Company: OPUS International Consultants Ltd

Company project number: 6-QC381.00

Company phone number: 6433635400

Date of submission: Nov-13

Inspection Date: 20-Jun-13

Revision: Final

Is there a full report with this summary? yes

Site

Site slope: slope < 1in 10

Soil type:

Site Class (to NZS1170.5):

Proximity to waterway (m, if <100m): 20

Proximity to clifftop (m, if < 100m):

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

Max retaining height (m):

Soil Profile (if available):

If Ground improvement on site, describe:

Approx site elevation (m): 2.80

Building

No. of storeys above ground: 1 single storey = 1

Ground floor split? no

Storeys below ground 0

Foundation type: mat slab

Building height (m):

Floor footprint area (approx):

Age of Building (years): 38

Ground floor elevation (Absolute) (m):

Ground floor elevation above ground (m):

if Foundation type is other, describe:

height from ground to level of uppermost seismic mass (for IEP only) (m):

Date of design: 1965-1976

Strengthening present?

If so, when (year)?

And what load level (%g)?

Brief strengthening description:

Use (ground floor): multi-unit residential

Use (upper floors):

Use notes (if required):

Importance level (to NZS1170.5): IL2

Gravity Structure

Gravity System: frame system

Roof: timber truss — truss depth, purlin type and cladding

Floors: concrete flat slab — slab thickness (mm)

Beams: timber — type

Columns:

Walls:

Lateral load resisting structure

Lateral system along: lightweight timber framed walls

Ductility assumed, μ: 2.00

Period along: 0.10 0.00

Total deflection (ULS) (mm):

maximum interstorey deflection (ULS) (mm):

Note: Define along and across in detailed report!

note typical wall length (m)

estimate or calculation? estimated

estimate or calculation?

estimate or calculation?

Lateral system across: lightweight timber framed walls

Ductility assumed, μ: 2.00

Period across: 0.10 0.00

Total deflection (ULS) (mm):

maximum interstorey deflection (ULS) (mm):

note typical wall length (m)

estimate or calculation? estimated

estimate or calculation?

estimate or calculation?

Separations:

north (mm):

east (mm):

south (mm):

west (mm):

leave blank if not relevant

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 1972

Structural partial — original designer name/date 1972

Mechanical none — original designer name/date

Electrical partial — original designer name/date 1972

Geotech report full — original designer name/date 2013

Damage

Site:

(refer DEE Table 4-2)

Site performance:

Describe damage:

Settlement: — notes (if applicable):

Differential settlement: — notes (if applicable):

Liquefaction: — notes (if applicable):

Lateral Spread: — notes (if applicable):

Differential lateral spread: — notes (if applicable):

Ground cracks: — notes (if applicable):

Damage to area: — notes (if applicable):

Building:

Current Placard Status: green

Along Damage ratio: 0%

Describe (summary):

Describe how damage ratio arrived at:

Across Damage ratio: 0%

Describe (summary):

$$Damage\_Ratio = \frac{(\%NBS\,(before) - \%NBS\,(after))}{\%NBS\,(before)}$$

Diaphragms Damage?: no Describe:

CSWs: Damage?: no Describe:

Pounding: Damage?: no Describe:

Non-structural: Damage?: yes Describe: minor GIB cracking

Recommendations

Level of repair/strengthening required: — Describe:

Building Consent required: — Describe:

Interim occupancy recommendations: — Describe:

Along Assessed %NBS before e'quakes: 49% ##### %NBS from IEP below

Assessed %NBS after e'quakes: 49%

If IEP not used, please detail assessment methodology: Quantitative

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