

**Project:** Knights Stream Park Stages  
7 and 8

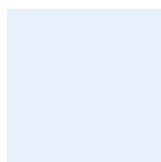
Geotechnical Subdivision Report

**Reference:** 200376

**Prepared for:** Fulton  
Hogan Land Development  
Limited

**Revision:** 3

**18 November 2014**



# Document Control Record


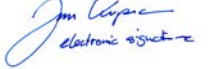
Document prepared by:

Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook Christchurch 8051  
PO Box 1061  
Christchurch 8140  
New Zealand

**T** +64 3 366 0821  
**F** +64 3 379 6955  
**E** christchurch@aurecongroup.com  
**W** aurecongroup.com

A person using Aurecon documents or data accepts the risk of:

- Using the documents or data in electronic form without requesting and checking them for accuracy against the original hard copy version.
- Using the documents or data for any purpose not agreed to in writing by Aurecon.

Document control						aurecon	
<b>Report Title</b>		Geotechnical Subdivision Report					
<b>Document ID</b>				<b>Project Number</b>	200376		
<b>File Path</b>		Z:\200376 - FH HJ Rd PC\Geotech\Phase 6\KSP 7 and 8\Docs\200376 Rpt KSP7&8 Geotech Rev3.docx					
<b>Client</b>		Fulton Hogan Land Development Limited		<b>Client Contact</b>		Greg Dewe	
<b>Rev</b>	<b>Date</b>	<b>Revision Details/Status</b>	<b>Prepared by</b>	<b>Author</b>	<b>Verifier</b>	<b>Approver</b>	
0	9 December 2013	Draft for internal review	D. Mahoney	D. Mahoney	-	-	
1	19 December 2013	Client Issue Copy	D. Mahoney	D. Mahoney	I. McPherson	M. Muirson	
2	16 January 2014	Incorporating Comments on Knights Stream	D. Mahoney	D. Mahoney	I. McPherson	M. Muirson	
3	5 November 2014	Revised subdivision layout retaining Knights Stream Channel	D. Mahoney	D. Mahoney	I. McPherson	J. Kupec	
<b>Current Revision</b>		3					
<b>Approval</b>							
<b>Author Signature</b>				<b>Approver Signature</b>			
<b>Name</b>		Dominic Mahoney		<b>Name</b>		Dr Jan Kupec	
<b>Title</b>		Senior Geotechnical Engineer		<b>Title</b>		Technical Director – Ground Engineering	



# Contents

<b>Executive Summary</b>	<b>4</b>
<b>1. Introduction</b>	<b>6</b>
<b>2. Site Conditions</b>	<b>7</b>
2.1 Site Features	7
2.2 Regional Geology and Seismicity	7
2.3 Recorded Earthquake Damage	7
<b>3. Geotechnical Investigation</b>	<b>9</b>
3.1 General	9
3.2 Environment Canterbury GIS Data	9
3.3 Cone Penetrometer Testing	10
3.4 Test Pit Excavations	10
3.5 Boreholes	10
3.6 MASW Soundings	11
3.7 Ground Water	11
<b>4. Engineering Considerations</b>	<b>13</b>
4.1 General	13
4.2 Ground Model	13
4.3 Liquefaction Assessment	14
4.4 Technical Category Classification	21
4.5 Liquefaction Mitigation	21
4.6 Council Vested Infrastructure	24
<b>5. Assessment Against RMA Section 106</b>	<b>27</b>
<b>6. References</b>	<b>28</b>
<b>7. Limitations</b>	<b>29</b>



# Appendices

## Appendix A

Figures

## Appendix B

ECan Borehole Logs

## Appendix C

CPT Logs

## Appendix D

Test Pit Logs

## Appendix E

Borehole Logs

## Appendix F

MASW Cross-Sections

## Appendix G

Liquefaction Assessment Outputs

## Appendix H

Slope/W Outputs





## Executive Summary

### Introduction

Fulton Hogan Land Development Limited (FHLD) is proposing to subdivide a 28.1ha area of rural land in Western Halswell, in Christchurch. It will be known as Knights Stream Park Stages 7 and 8. The site is located at the western end of the wider 117ha residential development being undertaken by FHLD, which when completed will comprise of approximately 1,375 residential lots. Stages 7 and 8 will comprise 213 residential lots, a pre-school and primary school, recreation reserve / playing fields, and associated roading.

FHLD has engaged Aurecon to undertake a geotechnical investigation and assessment for the entire 117ha subdivision, including these two stages. The purpose of the investigation was to assess the suitability of the land for residential development, and in particular to characterise the risk of liquefaction and lateral spreading to the development.

### Geotechnical Investigation

Based on the results of our geotechnical investigations the site is underlain by variable geology.

The northeast of the site is typically underlain by:

- 0.4 to 1m of silty-sandy topsoil.
- 2 to 3m of loose to medium dense gravel (in the eastern corner of the site this gravel layer is not present).
- 4.5 to 6.3m of interdedded layers of loose to medium dense silty-sand and sand, and soft to firm sandy-silt, silt and clayey silt material.
- Over 10m of dense to very dense sandy-gravel and gravel.

The southwest side of the site is typically underlain by:

- 1 to 5.5m of silty-sandy topsoil and in places interdedded layers soft plastic silt and clay and loose to medium dense silty-sand and sand.
- Over 10m of dense to very dense sandy-gravel and gravel.

Accounting for seasonal variation we infer groundwater level to be approximately 2m at the southeastern end deepening to 4m depth at the northwestern end.

### Liquefaction Assessment

A liquefaction assessment has been carried out at the site. The assessment indicated the following:

- As per MBIE Guidelines the site has been 'sufficiently tested' to excess of a SLS level of shaking during the 4 September 2010 Darfield Earthquake which resulted in no surface expression of liquefaction or observed ground damage.
- Under the SLS design earthquake expected reconsolidation settlements range from 0mm to over 50mm, the LSN ranges from 0 to over 20, and no surface expressions are expected.
- Under the ULS design earthquake expected reconsolidation settlements range from 0mm to over 100mm, the LSN ranges from 0 to over 30, with surface expressions expected in the eastern end of the site.
- Lateral spreading along the edge of the stormwater basin located at the southern corner of the site is expected to be less than 100mm under a ULS earthquake event.

- Liquefaction induced lateral spreading is not expected along the banks of Knight Stream. However, some localised and limited seismic induced slope instability is possible under a significant and large earthquake event.

### Technical Category Classification

Based upon the results of our liquefaction assessment the site in its current form is considered consistent with a mixture of zones of **Technical Category 1, 2 and 3 Classification**. Across the Knight Stream Park Stages 7 and 8 future land damage from liquefaction is unlikely in the Technical Category 1 area and possible in the Technical Category 2 and 3 areas in future large earthquakes.

The locations of the various Technical Category zones are shown on Figure 7 in Appendix A.

Residential properties will be located in the Technical Category 1 and 2 areas only. The area identified as having potentially Technical Category 3 characteristics is to be used for playing fields.

Due to the potential liquefaction risk at the site, recommendations for the protection of Council vested infrastructure from the effects of seismically induced liquefaction are made in this report.

### RMA Section 106 Assessment

The site is potentially susceptible to “subsidence” and “inundation” from seismically induced liquefaction. However, using appropriate liquefaction mitigation and remediation measures, as detailed in this report, we believe that the risk imposed by liquefaction will be reduced to an acceptable level. As such, the site will essentially be geotechnically stable land. **Thus in our opinion, the proposed development will generally be free of “erosion,” “falling debris,” “subsidence,” “slippage,” and “inundation” and the proposed development satisfies the intent of RMA Section 106 1(a).**

Provided that appropriate investigation and design inputs are made, as recommended in this report, subsequent use of the land following development is unlikely to accelerate, worsen, or result in material damage to the land, other land, or structures. **In our opinion therefore, the development will comply with the requirements of Clause 106 1(b) RMA.**

The geotechnical investigation was aimed at assessing the site for geotechnical suitability for subdivision into residential lots with associated access roads and rights-of-way. Detailed design of house foundations has not been addressed in the report.

Our Limitations are attached as Section 7 of this report. This report shall be read as a whole.



## 1. Introduction

FHLD is proposing to subdivide a 28.1ha area of rural land in western Halswell, in Christchurch. It will be known as Knights Stream Park Stages 7 and 8. The final layout has now been confirmed and will comprise 213 residential lots, a proposed pre-school and primary school, recreation reserve / playing fields and associated roading. The incised channel of the ephemeral Knights Stream runs through the centre of Stage 8 and along the southwestern edge of Stage 7. These two areas are in the western end of the wider 117ha residential development being undertaken by FHLD, which when completed will comprise of approximately 1,375 residential lots. See Figures 1 and 2 in Appendix A for further details.

FHLD has engaged Aurecon to undertake a geotechnical investigation and assessment for the entire 117ha subdivision, including Stages 7 and 8. The purpose of the investigation was to assess the suitability of the land for residential development, and in particular to better characterise the risk of liquefaction and lateral spreading to the development. The scope of the work undertaken was as follows:

- A detailed desk study of readily available geological and geotechnical information available for this site.
- A preliminary site walkover and reconnaissance.
- Review the existing geotechnical work carried out in the area by Aurecon.
- Undertake a liquefaction hazard assessment based upon the results of the geotechnical data.
- Provide recommendations on potential liquefaction remediation options for the site.
- Provide recommendations for further testing (if required).
- Assess the site against Sections 106 1a) and 1b) of the RMA.
- Prepare this factual and interpretive geotechnical for Stages 7 and 8 of the Knights Stream development.

The geotechnical testing has been carried out in stages collecting more information that was needed for this particular stage of the wider 117ha development.

This Revision 3 report incorporates the results of additional test pit excavations, a revised lateral spreading analysis along the banks of Knights Stream and associated Technical Category assessment. This revision supersedes all previous revisions.

Our Limitations are attached as Section 7 of this report. This report shall be read as a whole.

## 2. Site Conditions

### 2.1 Site Features

The site is located at the western end of the wider 117ha Halswell West residential development southwest Christchurch (See Figures 1 and 2 in Appendix A). The main site features are:

- The site has an approximate area of 28.1ha.
- The site is shaped as an irregular rectangle orientated northwest by southeast.
- There will be a stormwater basin located adjacent to the southern corner of the site.
- The site is bound to the northeast by Halswell Junction Road, to the southeast by previous stages of the wider Knights Stream Park development, and to the southwest and northwest by rural and rural residential properties.
- The channel of the ephemeral Knights Stream is located in the centre of the site flowing northeast to southwest and then flows along part of the southwest site boundary. The channel is one to two metres deep at the southwest end grading to nothing in the northeast side of the site.
- The site has previously been used for pastoral and cropping farming activities and was vegetated with grass. There are mature trees along part of the southwest boundary and scrub in the bed of Knights Stream.
- Parts of the site are being used for bulk earthworks associated with the neighbouring development stages.
- Drainage is inferred to be via direct soakage to the ground or via runoff to Knights Stream.

### 2.2 Regional Geology and Seismicity

The regional geology of the site is described by Brown and Weeber (1992) as '*Dominantly alluvial sand and silt overbank deposits (spy).*'

The site is located approximately 15km west of the eastern end of the Greendale Fault. Movement of the Greendale Fault generated the moment magnitude ( $M_w$ ) 7.1 Canterbury Earthquake of 4 September 2010. The site is also located approximately 11km west of the epicentre of the  $M_w$  6.2 Christchurch Earthquake on 22 February 2011 and approximately 17km west-southwest of the epicentre of the  $M_w$  6.0 major aftershock on 13 June 2011.


### 2.3 Recorded Earthquake Damage

In the days immediately after both the Darfield and Christchurch earthquakes Aurecon geotechnical engineers undertook detailed site walkovers and mapped land damage of the entire 117ha development. This included mapping of the position of ejecta, craters and sand boils. Sand boils were observed in parts of the wider 117ha development. The ejected material in the sand boils is inferred to be representative of the liquefied soils and was typically logged as a uniformly graded fine to medium sand or silty fine sand.

No surface expression of liquefaction was observed in Knights Stream Park Stages 7 and 8 following either the 4 September 2010 Darfield or the 22 February 2011 Christchurch Earthquakes.

No lateral spreading or associated ground damage was observed along the banks of Knights Stream where it runs along the southwestern site boundary

A map of the identified sand boil distribution across the site following the Darfield Earthquake is shown in Figure 3 in Appendix A. This map is compiled from high altitude images from Google Earth taken



several hours after the Darfield Earthquake, low level aerial photographs taken two days after the earthquake, and mapping from our site walkovers.

## 3. Geotechnical Investigation

### 3.1 General

During the major seismic activity in the Canterbury Region over the last three years parts of the wider 117ha site have experienced seismically induced liquefaction, in particular following the 4 September 2010 Darfield Earthquake. In order to proceed with residential development of the site geotechnical information, including an assessment of the seismically induced liquefaction susceptibility at the site is required.

An initial geotechnical investigation, including a liquefaction susceptibility assessment, was carried out across the wider site in October 2010 as part of a plan change application to have the land rezoned from rural to residential. Additional testing was undertaken between October 2011 and August 2013 to provide information for a detailed liquefaction risk assessment as part of the subdivision consenting and design process.

The geotechnical investigation comprised the following:

- A review of publically available geotechnical information from Environment Canterbury and the Canterbury Geotechnical Database.
- Cone Penetrometer Testing supervised by Geotechnical Engineers from Aurecon.
- Excavation and logging of test pits by Geotechnical Engineers from Aurecon.
- Borehole drilling and logging by Geotechnical Engineers from Aurecon.
- Undertaking of Multi-channel Analysis of Surface Waves (MASW) profiling to generate shear wave velocity profiles.


This section of the report describes the geotechnical testing undertaken on the site.

### 3.2 Environment Canterbury GIS Data

A review of the Environment Canterbury GIS Database (ECan, 2013) indicates five Environment Canterbury boreholes with logs on or directly adjacent near to the site. The borehole locations, distances from site, and depths are summarised in Table 1 below.

**Table 1: Environment Canterbury Borehole Records**

Borehole	Location	Depth	Summary of Stratigraphy
M36/7502	Adjacent to the northwest site boundary	18m	<ul style="list-style-type: none"><li>• 0 to 7.5m – Silty-Sand, Silty-Clay and Clay</li><li>• 7.5 to 18m - Gravel</li></ul>
M36/20150	100m northeast of the site on northeastern side of Halswell Junction Road	13.2m	<ul style="list-style-type: none"><li>• 0 to 13.2m - Gravel</li></ul>
M36/0888	Adjacent to the southeast site boundary	19.8m	<ul style="list-style-type: none"><li>• 0 to 4.9m – Silt and Sand</li><li>• 4.9 to 19.8m – Sand, Sandy-Gravel and Gravel</li></ul>
M36/7923	Adjacent to southern corner of site	24m	<ul style="list-style-type: none"><li>• 0 to 24m - Gravel</li></ul>
M36/4190	Adjacent to the southwest boundary of the site	24m	<ul style="list-style-type: none"><li>• 0 to 2.5m – Sand</li><li>• 2.5 to 24m - Gravel</li></ul>



The locations of the ECan borehole logs are presented in Figure 4 in Appendix A and the borehole logs are presented in Appendix B.

### **3.3 Cone Penetrometer Testing**

Aurecon has undertaken 118 Cone Penetrometer Tests (CPT) across the wider 117ha development between October 2010 and August 2013. In the vicinity of Knights Stream Park Stages 7 and 8, ten CPT soundings have been undertaken (CPT022 to 025, 143, 154, 158, 501, 504 and 507). All CPT tests were undertaken to effective refusal (a sustained tip bearing of over 30MPa) at depths between 1m and 7.8mbgl (below ground level). The locations of the CPT tests are shown in Figure 5 in Appendix A and the logs are presented as Appendix C.

The CPT logs indicate:

#### **South eastern edge of site**

- Surface to 4 - 7.8m - Interdedded layers of loose to medium dense silty-sand and sand, and soft to firm silt and clayey silt.
- 4-7.8m onwards - Sandy-Gravel

#### **Western three-quarters of the site**

- Surface to 1 - 1.8m – Loose to medium dense silty-sand and sand
- 1 - 1.8m onwards – Sandy Gravel

### **3.4 Test Pit Excavations**

Between November 2011 and October 2014 Aurecon excavated 91 exploratory test pits across the wider 117ha development. 41 test pits (TP102, 104 to 123, 131, 132, 135, 140 to 142, 149 to 153, 222, and 301 to 309) were excavated in the vicinity of KSP Stages 7 and 8. All test pits were excavated to the target depth of 3.2m and 5.8m depth and were logged in accordance with the New Zealand Geotechnical Society's field description of soil and rock (NZGS, 2005). The locations of the test pits are shown in Figure 5 in Appendix A and the logs are presented as Appendix D together with an explanatory sheet outlining the terms and symbols on the logs.

The test pit logs indicate:

#### **Northeast Side of the site**

- Surface to 0.4 - 1.7m - Silty-sand and sand.
- 0.4 – 1.7m to 2.5 - 3.5m – Gravel.
- 2.5 - 3.5m onwards – silts and sands.

#### **Southwest side of site**

- Surface to 1.5 - 2m – Silty-sand and sand.
- 1.5 - 2m onwards – Gravel.

### **3.5 Boreholes**

In November 2012 ten machined boreholes were drilled with Standard Penetrometer Testing (SPT) carried out at 1.5m centres. The boreholes were drilled to the target depth of 10.5m to 15m and were logged in accordance with the New Zealand Geotechnical Society's field description of soil and rock (NZGS, 2005). The locations of the boreholes are shown in Figure 5 in Appendix A and the logs are presented as Appendix D.

The borehole logs indicate:

#### **Northeast Side of the site**

- Surface to 0.7 - 1.1m - Topsoil
- 0.7 – 1.1m to 2.5 - 3.5m – Medium dense gravel with some sand lenses.
- 2.5 – 3.5m to 5.8 – 10.9m – Interbedded layers and lenses of soft plastic silt and clay and loose to medium dense silty-sand and sand.
- 5.8 - 10.9m onwards - Dense to very dense gravel and sandy-gravel.

#### **Southwest side of site**

- Surface to 1 - 5.5m – Interbedded layers soft plastic silt and clay and loose to medium dense silty-sand and sand.
- 1 - 5.5m onwards - Dense to very dense gravel and sandy-gravel.

### **3.6 MASW Soundings**

A series of 12 Multi-channel Analysis of Surface Waves (MASW) profile lines were undertaken by Southern Geophysical Limited. These profile lines total 2,285m in length and comprise individual MASW sounding at approximately 5m centres. From the shear wave velocity profile sections have been produced for the upper 20m of the soil profile. The MASW soundings were undertaken to obtain information between the physical control points (CPT, borehole and test pits) and particular it provided information on the thickness and extent of the upper gravel layer identified on the northeast side of the site. The locations of the profile lines are shown in Figure 6 and the velocity profiles are presented as Appendix F.

When calibrated to the test pit and borehole logs the shear wave velocity ( $V_s$ ) profiles indicate:

- Upper gravel –  $180\text{m/s} < V_s$
- Lower silts and sands –  $100\text{m/s} < V_s < 280\text{m/s}$
- Lower Gravels –  $280\text{m/s} < V_s$

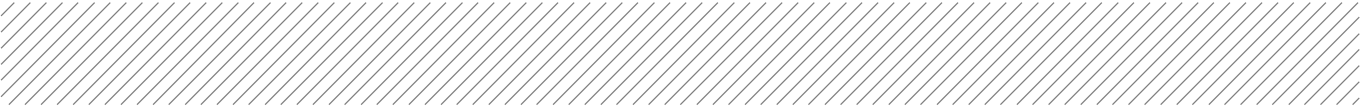
### **3.7 Ground Water**

Groundwater levels have been recorded from five sources as follows:

- The Canterbury Geotechnical Database indicates a long-term estimate of groundwater levels across the site at typically depth of 2m at the southeastern end of the site to 4m at the northwestern end. There is low confidence on this estimate.
- From the test pit logs groundwater was encountered at depths of around 2.5m at the southeastern end of the site to over 4m at the northwestern end.
- Groundwater levels were measured in a series of standpipe piezometers installed across the site by Davie Lovell-Smith. This information was provided to Aurecon in 2012 and indicated groundwater between 3m and 3.9mbgl.
- Groundwater level was recorded in the boreholes at 2.8m depth at the southeastern end to 3.5m depth towards the northwest part of the site.
- Groundwater levels have been recorded in ECan borehole M36/0888 in the southeast side of the site at 0.8m to 3.2m depth.

The groundwater levels were typically recorded in the test pits during summer (100 and 200 series test pits) and the test pits were left open for only a short period of time so that ground water levels may not have stabilised. Ground water was not encountered in the 300 series test pits. We therefore consider that the water levels from the standpipe piezometers and borehole logs are likely to more accurately





indicate groundwater levels. However, groundwater levels are known to fluctuate significantly on other parts of the wider 117ha development and groundwater levels will vary seasonally.

Once the subdivision is completed 1.75m deep stormwater basins will be constructed in the southern corner of the site. The basin will have a dry base under normal operating conditions. Therefore, once the subdivision is completed, along the southern corner of the site groundwater can be assumed to be at a depth of 2m under normal operating conditions.

Once site development is completed and accounting for seasonal variability, groundwater levels at the site are likely to be between 2m in the southeast end deepening to 4m depth in the northwest end of the site.

## 4. Engineering Considerations

### 4.1 General

FHLD is proposing to subdivide a 28.1ha area of rural land in in western Halswell, in Christchurch. It will to be known as Knights Stream Park Stages 7 and 8 and comprise 213 residential lots, a pre-school and school, associated roading, playing fields and reserve areas. There is a stormwater basin located on the southern corner of the site.

To fulfil the Ministry of Business, Innovation and Employment (MBIE, 2012) guidelines on residential development, the liquefaction risk at the site needs to be quantified. Once this liquefaction risk is quantified then appropriate mitigation measures (if required) can be developed as part of the physical site development.

This section of the report outlines details of our liquefaction assessment, and presents our recommendations for liquefaction mitigation options as part of the site development.

### 4.2 Ground Model

Based on the results of our geotechnical site investigation we infer a ground profile as presented in Table 2a and 2b.

**Table 2a: Inferred Ground Profile – Northeast Side of Site**

Layer	Depth	Thickness	Material
1	Surface to 0.4 - 1m	0.4m to 1m	Silty-sandy topsoil
2*	0.4 -1m to 2.3 – 3.5m	2m to 3m	Loose to medium dense gravel
3	2.3 – 3.5m to 5.8 – 10.9m	4.5m to 6.3m	Interbedded layers of loose to medium dense silty-sand and sand, and soft to firm sandy-silt, silt and clayey silt material.
4	5.8m – 10.9m onwards	Greater than 10m	Dense to very dense Sandy-Gavel and Gravel.

\*Note: in the eastern edge of the site this upper gravel layer is absence

**Table 2b: Inferred Ground Profile – Southwest Side of Site**

Layer	Depth	Thickness	Material
1	Surface to 1m – 5.5m	1m to 5.5m	Interbedded layers soft plastic silt and clay and loose to medium dense silty-sand and sand.
2	1m – 5.5m onwards	Greater than 10m	Dense to very dense Sandy-Gavel and Gravel.

Accounting for seasonal variation we infer groundwater level to be approximately 2m at the southeastern end deepening to 4m depth at the northwestern end.

## 4.3 Liquefaction Assessment

### 4.3.1 Introduction

Under cyclic loading loose, non-plastic materials such as gravel, sand and silt tend to decrease in volume. If these soils are saturated and rapid loading occurs under un-drained conditions, the soil densification causes pore water pressure to increase. The increase in pore water pressure results in a loss of soil strength due to a decrease in effective stress, and eventually leads to liquefaction once effective stress drops to near zero. Liquefaction can lead to large displacements of foundations, flow failures of slopes, ground surface settlement, sand boils, and post-earthquake stability failures.

Based on aerial photographs and our site walkovers no surface expression of liquefaction was observed at the site following both the 4 September 2010 Darfield Earthquake and 22 February 2011 Christchurch Earthquake. This assessment quantifies the risk of future liquefaction in terms of the technical category classification system outlined in the MBIE (2012) guidelines. This classification system is divided into three technical categories that reflect both the liquefaction experience to date and future performance expectations. The categories and corresponding criteria are summarised as follows:

- **Technical Category 1 (TC1)** – Future land damage from liquefaction is unlikely, and ground settlements are expected to be within normally accepted tolerances.
- **Technical Category 2 (TC2)** – Minor to moderate land damage from liquefaction is possible in future large earthquakes.
- **Technical Category 3 (TC3)** – Moderate to significant land damage from liquefaction is possible in future large earthquakes.

MBIE (2012) has indicated the following liquefaction and lateral spreading deformation limits for house foundations as summarised in Table 3 below:

**Table 3: Liquefaction Deformation Limits and House Foundation Implications**

Technical Category	Index Liquefaction Deformation Limits				Likely Implication for House Foundations (subject to individual assessment)
	Vertical		Lateral Spread		
	SLS	ULS	SLS	ULS	
TC1	15mm	25mm	Nil	Nil	Standard NZS3604 type foundations with tied slabs
TC2	50mm	100mm	50mm	100mm	MBIE enhanced foundation solutions
TC3	>50mm	>100mm	>50mm	>100mm	Site specific foundation solution

### 4.3.2 Liquefaction Assessment

The three primary factors that contribute to liquefaction potential are:

- Loose, non-plastic soils.
- High groundwater table.

- Sufficiently high, earthquake induced ground acceleration and sustained shaking (i.e. sufficient load cycles).

Each of these is considered below together with conclusions on the site liquefaction potential.

### Soil Character and Density

The geotechnical investigation across the site indicated lenses and layers of loose to medium dense sand, silty-sand within the upper soil profile. These layers are considered to be potentially liquefiable from a soil character and density perspective.

Some layers of the upper soils were logged as clayey silt these have been assumed to be non-liquefiable. For the CPT profiles this non-liquefiable cut-off is assumed to be where the Soil Character Index,  $I_c$ , is greater than 2.6. The underlying gravel is also considered to be non-liquefiable.

### Groundwater

Based on our site investigations and accounting for seasonal variation in ground water level, we will assume a groundwater depth of 2m in the southeastern end of the site increasing to 4mbgl in the northwestern end. Soils are potentially liquefiable below these depths.

### Earthquake Intensity

The level of ground shaking is one of the key factors in determining whether liquefaction will or will not occur. The MBIE Guidelines (2012) require analysis for Serviceability Limit State (SLS) and Ultimate Limit State (ULS) cases, using specified peak ground accelerations (PGA) of 0.13g and 0.35g respectively and a magnitude  $M_w$  7.5 event. We have also analysed an intermediate 1 in 150 year earthquake case with a PGA of 0.20g and magnitude  $M_w$  7.5 to assess the sensitivity of liquefaction to earthquake acceleration.

The details of the design earthquakes are summarised in Table 4 below.

**Table 4: Design Ground Motions**

Design Event	Peak Ground Acceleration	Moment Magnitude
ULS EQ	0.35g	$M_w$ 7.5
SLS EQ	0.13g	$M_w$ 7.5
Intermediate EQ	0.20g	$M_w$ 7.5

Based on the New Zealand Building Code, buildings designed for the ULS event are expected to retain their structural integrity and form during an earthquake and not endanger life. Some plastic deformation of structural elements within the structure is expected to occur but ideally the damage can be repaired and the structure can be returned to service after the event, although repair may be uneconomical. Buildings are expected to perform well for the SLS event and be returned to service after only nominal repair.

The site has experienced a number of large earthquakes recently, with ground motions during the largest three events summarised in Table 5 below.

**Table 5: Recent Earthquake Ground Motions**

Event	M <sub>w</sub>	PGA <sup>(1)</sup>	Standard Deviation <sup>(1)</sup>	PGA <sub>M=7.5</sub> <sup>(2)</sup>	10 <sup>th</sup> Percentile PGA <sub>MW=7.5</sub> <sup>(2)</sup>
Sept 2010	7.1	0.32g	0.375	0.28g	0.19g
Feb 2011	6.2	0.29g	0.425	0.21g	0.12g
June 2011	6.0	0.13g	0.45	0.09g	0.05g

1) Obtained from the Bradley Seismic Model (Bradley and Hughes, 2012), accessed through the CGD.

2) Scaled to M<sub>w</sub> 7.5 by the method of Idriss and Boulanger (2008).

As indicated in Table 4, the site is estimated to have experienced PGAs up to 0.28g scaled to a Magnitude of 7.5, which is less than the ULS acceleration specified in the MBIE guidelines but greater than 170% of the design SLS PGA (0.22g). The 10th percentile PGA also exceeded the design SLS PGA and hence the site has been 'sufficiently tested' to above SLS level during the Darfield Earthquake. This 'significant' testing is consistent with no surface expression or observed ground damage at the site.

### Liquefaction Potential

The ability of the subsoils to resist the ground shaking associated with the two earthquakes has been assessed from the subsoil information obtained from the investigation. The method prescribed by the MBIE for assessing residential developments in Canterbury (MBIE, 2012) has been used as below:

- The method of Idris and Boulanger (2008) for assessing the liquefaction potential.
- The method of Robertson and Wride (1998) for fines correction with CPT data.
- The method of Zhang et. al. (2002) for calculating post liquefaction reconsolidation settlements.

Liquefaction assessments have also been undertaken using the methods outlined in Idris and Boulanger (2008) for the borehole logs and MASW derived V<sub>s</sub> profiles. The borehole and V<sub>s</sub> based methods are known to have less certainty around the calculated reconsolidation settlements and significantly less certainty with the V<sub>s</sub> derived method in general. The V<sub>s</sub> based method therefore has only been used to interpolate between physical control points of CPT and boreholes logs.

The borehole derived results typically gives larger settlements than the CPT derived method which is attributed to limited sampling interval of 1.5m for SPT (as opposed to 1cm for CPT). Therefore, where there is ambiguity between different methods in the calculated reconsolidation settlements in the same general area, preference is given to the CPT derived results, for example with the difference between BH5 and CPT158. We note that borehole BH9 has uncharacteristically high calculated reconsolidation settlement values. This is inferred to be an artefact of the borehole drilling process and not a true reflection of observed or expected ground performance.

The MBIE Guidelines use the CPT method above to estimate the reconsolidation settlement due to liquefaction, which is used to assess the potential for land and building damage, and to assign a technical category. Under the MBIE Guidelines the method of Ishihara (1985) can also be used to estimate the likelihood of surface expression of liquefaction such as sand boils and ejected groundwater. This method estimates the likelihood of surface expression based on the PGA, thickness of liquefied soil and the thickness of the non-liquefied crust.

In addition, we have also calculated the Liquefaction Severity Number (LSN), as defined by Tonkin and Taylor (2013). The LSN number is an index number which qualitatively assesses the effects of liquefaction on a site and on a shallow founded building. The LSN number is calculated by the equation below.

$$LSN = 1000 \int \frac{\varepsilon_v}{z} \cdot dz$$

Where:  $\varepsilon_v$  = volumetric reconsolidation strain

z = depth of liquefaction below ground level

The LSN number is likely to be a better index of surface damage than reconsolidation settlement because the LSN number is affected more by shallow liquefaction and less by liquefaction at depth, which is less likely to affect the ground surface or shallow founded buildings. Reconsolidation settlement places the same weighting on deep liquefaction as shallow liquefaction, even though settlement will have less impact at the ground surface with increasing depth. LSN numbers have been correlated to observed liquefaction effects during recent earthquakes in Christchurch as shown in Table 6 below.

**Table 6: LSN Ranges and Observed Effects (Tonkin and Taylor, 2013)**

LSN Range	Predominant Performance
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate expression of liquefaction, with sand boils and some structural damage
30-40	Moderate to severe expression of liquefaction, settlement can cause structural damage
40-50	Major expression of liquefaction, undulations and damage to ground surface, severe total and differential settlement of structures
>50	Severe damage, extensive evidence of liquefaction at surface, severe total and differential settlements affecting structures, damage to services

When compared to the broad descriptions of expected land performance in TC1, TC2 and TC3, as outlined in Section 5.3.1, the LSN number can be approximately correlated to technical categories as follows:

- TC1 =  $LSN_{(ULS)} < 10$
- TC2 =  $LSN_{(SLS)} < 20$  and  $LSN_{(ULS)} < 30$
- TC3 =  $LSN_{(SLS)} > 20$  or  $LSN_{(ULS)} > 30$

The calculated settlements using the MBIE methodology, likelihood of surface expression (based upon Ishihara, 1985) and LSN numbers are presented in Table 7 below. The liquefaction assessment outputs are presented in Appendix G.

Table 7: Calculated Total Settlements, LSN and Surface Expression for Design Earthquakes

Test <sup>(1)</sup>	Depth of Test [m]	GWL [m]	SLS EQ			Intermediate EQ			ULS EQ		
			Settlement <sup>(2)</sup> [mm]	LSN	Surface Expression [Yes/No]	Settlement <sup>(2)</sup> [mm]	LSN	Surface Expression [Yes/No]	Settlement <sup>(2)</sup> [mm]	LSN	Surface Expression [Yes/No]
CPT143	3.9	2.0	15	4	No	20	7	No	25	9	No
CPT154	4.4	2.0	20	7	No	45	15	No	45	15	No
CPT158	4.9	2.0	45	15	No	60	20	No	65	20	No
CPT501	8.0	2.0	80	16	No	110	26	No	110	27	Yes
CPT504	7.7	2.0	65	14	No	105	26	No	110	27	Yes
CPT507	4.5	2.0	30	8	No	55	16	No	60	19	Yes
BH1	15.0	2.0	30	5	No	115	19	No	115	19	Yes
BH2	10.5	2.0	35	8	No	100	25	No	100	25	Yes
BH3	12.0	2.0	0	0	No	0	0	No	0	0	No
BH4	12.0	2.0	85	23	No	100	28	No	130	39	Yes
BH5	15.0	2.5	40	15	No	100	29	No	105	32	Yes
BH6	10.5	2.5	0	0	No	10	3	No	10	3	No
BH7	12.0	2.5	0	0	No	50	0	No	20	4	No
BH8	15.0	2.5	30	7	No	85	18	No	105	21	No
BH9	15.0	3.0	200	25	No	240	32	No	260	37	Yes
BH10	10.5	3.0	0	0	No	0	0	No	0	0	No

1) CPT22 to 25 have not been assessed due to refusal on gravel material at depths above the groundwater table.  
2) The settlements presented in Table 7 above are to the nearest 5mm. Due to the inherent uncertainty in calculating liquefaction induced settlement, the calculated settlements are an index only. Actual settlements will vary from those above.

#### 4.3.3 Lateral Spreading

Lateral spreading occurs when subsoil liquefaction results in the surface soils moving downslope or toward a free edge, such as a river or basin. Lateral spreading can occur during an earthquake under seismic loading and following the earthquake until the excess pore water pressure are relieved and the soil regains strength.

##### Stormwater Basin

A dry stormwater basin will be located on the southern corner of the site and there is a potential risk of lateral spreading damage along the basin edge. Lateral spreading limits are defined in the MBIE (2012) guidelines in terms of lateral stretch across a house platform, which must be less than 50mm under SLS level shaking, and less than 100mm under ULS shaking for a TC2 classification.

There are no procedures mandated or suggested by MBIE for assessing lateral spreading. Due to the base of the 'free face' being located above the liquefiable layers we infer that the more traditional lateral spreading assessment methodologies are not applicable for this assessment and we have therefore calculated slope displacements using the procedure below:

- 1) Determine residual soil strength parameters for the liquefied case using the CPT results and procedures outlined in Idriss and Boulanger (2008).
- 2) Calculate the yield acceleration ( $k_y$ ) for the residual strength case using the software package Slope/W and method of Morgenstern-Price.
- 3) Calculate the slope displacement based on the PGA values specified in MBIE (2012), using the methods of Ambraseys and Menu (1988) and Bray and Travarasrou (2007).

Based upon the subsoil profiles logged in Boreholes BH4 and BH5, CPT158 and other tests around this basin carried out as part of the assessment of Stage 3 and 6 of the wider Knights Stream Park development, and the results of the liquefaction hazard assessment, the ground conditions around the stormwater basin have been modelled using the values in Table 8 below.

**Table 8: Stormwater basin lateral spreading ground model**

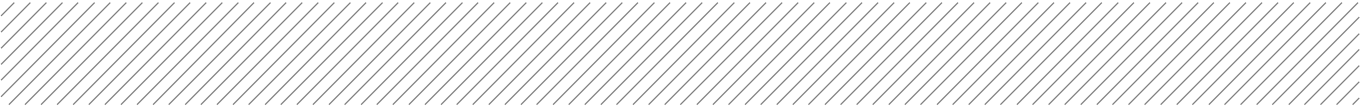
Layer	Depth	Thickness	Material	Soil Properties
1	Surface to 1.75m	0m (base of basin) 1.75m (top of bank)	Non-liquefiable Sandy-Silt Crust	$\gamma^{(1)} = 18\text{kN/m}^3$ $S_u^{(2)} = 50\text{kPa}$ Tension Cracks - Yes
2	1.75m to 5m	3.25m	Interbedded lenses of liquefiable silty-sands and non-liquefied clayey-silts and silt	$\gamma = 17\text{kN/m}^3$ Average $S_r^{(3)} = 15\text{kPa}$
3	5m onwards	Greater than 10m	Non-liquefiable dense Sandy-Gavel and Gravel	$\gamma = 20\text{kN/m}^3$ $\phi^{(4)} = 35^\circ$

Notes:

- 1)  $\gamma$  = Bulk density
- 2)  $S_u$  = Undrained shear strength
- 3)  $S_r$  = residual shear strength of liquefied soil
- 4)  $\phi$  = Friction angle

Ground water has been modelled at a depth of 1.75m being the depth corresponding to the bottom of the pond, i.e. the top of Layer 2.





Slope stability modelling has been undertaken using the software package Slope/W with the Factor of Safety (FoS) taken as the lowest values from the Bishop, and Morgenstern-Price stability algorithms. The Slope/W outputs are presented in Appendix F.

Based upon the results of the Slope/W modelling we anticipate no lateral spreading under the SLS EQ as the yield acceleration is greater than 0.13g. The methods Ambrasey and Menu (1988) and Bray and Travarasou (2007) indicate expected lateral displacements in the order of 30mm under the ULS earthquake loading conditions using both a circular and block sliding mechanisms. It is noted that these displacement values were calculated using conservative soil strength parameters.

### **Knights Stream**

The incised channel of Knights Stream runs through centre of Stage 8 and along the southwest boundary of the site. As outlined in Section 5.3.2 above the site has been sufficiently tested to beyond a SLS level earthquake event during Darfield Earthquake. This resulted in no known movement along the banks of Knights Stream.

The ground investigations carried out in this part of the site indicate that the channel is incised down through overlying silty-sandy soils with the bed of the stream at the level of the underlying gravels. Groundwater is within the underlying gravels. Therefore the upper silty-sandy soils are not saturated and hence not susceptible to liquefaction. As such there is no liquefaction induced lateral spreading risk to the lots that back onto the channel of Knights Stream.

#### **4.3.4 Summary**

Based upon our assessment:

- As per MBIE Guidelines site has been 'sufficiently tested' to excess of a SLS level of shaking during the 4 September 2010 Darfield Earthquake which caused no surface expression of liquefaction or observed ground damage.
- Under the SLS design earthquake expected reconsolidation settlements range from 0mm to over 50mm, LSN range from 0 to over 20, and no surface expressions are expected.
- Under the ULS design earthquake expected reconsolidation settlements range from 0mm to over 100mm, LSN range from 0 to over 30, with surface expressions expected in the eastern end of the site.
- Lateral spreading along the edge of the stormwater basin located at the southern corner of the site.
- Liquefaction induced lateral spreading along the incised channel of Knights Stream is not expected.
- Settlements calculated using the logs of Boreholes BH4 and 5 are significantly more than those calculated using the surrounding CPT logs (CPT 154, 158 and 507). The site has been 'sufficiently tested' with no ground damage during the Darfield Earthquake and preference has been given to the calculated settlements from these three CPT logs in the southern corner of the site.
- Settlements calculated using the log of Borehole 9 are unrealistically high (over 200mm) considering the site stratigraphy and the fact the site has been 'sufficiently tested' with no ground damage during the Darfield Earthquake. The reason for this variance is unclear but likely relates to a potentially spurious SPT 'N' blow count values.

## 4.4 Technical Category Classification

The technical category classification of the site has been assessed based upon the actual site performance during the 4 September 2010 Darfield Earthquake (where the site was 'sufficiently tested' to above SLS level without any observed ground damage), and liquefaction assessments undertaken using the CPT and borehole logs, and the interpolated subsoil profile using the  $V_s$  profiles.

Based upon the results of our liquefaction assessment the site in its current form is considered consistent with a mixture of zones of **Technical Category 1, 2 and 3 Classifications**. In Stages 7 and 8 future of Knights Stream Park land damage from liquefaction is unlikely in the Technical Category 1 area and possible in the Technical Category 2 and 3 areas in future large earthquakes.

The locations of the various Technical Category zones are shown on Figure 7 in Appendix A.

The area identified as Technical Category 1 is located in the west-northwest corner of the site. This area is underlain by shallow non-liquefiable gravels to depth.

The area identified as Technical Category 2 is located along the northeast and southeast sides of the site and in the northwest corner and currently along the incised channel of Knights Stream along the southwest site boundary. Along the northeast side of the site there is a shallow gravel layer underlain by potentially liquefiable silty-sandy soils, overlying gravels at depth. The presence of the upper gravel layer acts to create a strong crust/capping layer that suppresses the effects of liquefaction to within TC2 limits. The southeastern side of the site is effectively underlain by 4 to 5m of silty-sandy soil of varying liquefaction potential, overlying gravel to depth. The accumulated thickness of this liquefiable silty-sandy soil is sufficiently thin that the expected liquefaction risk is within TC2 limits. In the northwestern corner the water table is sufficiently deep creating a thick non-liquefiable crust that the expected liquefaction risk is within TC2 limits.

Along the banks of Knights Stream despite there being no assessed liquefaction induced lateral spreading risk, there is the potential of shaking induced bank edge movement during a major earthquake event. This movement could potentially occur to several metres back into the lots under a USL design earthquake event. The magnitude of this movement is expected to be limited and localised to the bank edge only and well within TC2 limits. We therefore consider it prudent that these lots are classified as TC2 for a lateral movement perspective despite there being very little if any liquefaction risk.

The upper silty-sandy soils in the area identified as TC3 in the eastern corner of the site by Halswell Junction Road is materially no different than along the southeastern (TC2) edge of the site. However the accumulated thickness of the liquefiable soils is sufficiently thick that the risk of liquefaction within this part of the site is potentially within TC3 limits.

## 4.5 Liquefaction Mitigation

### 4.5.1 General

It is considered that the site in its current assessed state is susceptible to varying degrees of seismically induced liquefaction in a future major seismic event.

In terms of liquefaction hazard mitigation there are four basic approaches as follows:

#### 1. Accept Liquefaction Risk

Design a structure with no regards to the liquefaction risk. This approach would only be used where there is effectively no to very little risk from seismically induced liquefaction (i.e. in Technical Category 1 areas).

## 2. Building Strengthening

Structurally design the building to accommodate the effects of liquefaction. Examples of this include using raft or piled foundations. These methods do not remove the liquefaction hazard but reinforce the structure in such a way that it maintains stability during a liquefaction event.

## 3. Ground Improvement

Improve the soil at the site so that it is less susceptible to seismically induced liquefaction. This general approach can be divided into three categories:

1. Densify the soil so that soil grain skeleton will not collapse under earthquake loading. Examples of this include compaction and replacement (refilling with material which will not liquefy).
2. Soil reinforcement. Examples include stone columns, driven piles to densify and stiffen the soil, deep soil mixing, soil cement columns etc.
3. Allow dissipation of excess pore water pressure so that liquefaction is reduced. Examples of this include installation of drains, drainage blankets, and or stone columns.

## 4. Alternative Land Use

Use the site for non-residential housing activities, such as reserve areas, playing fields etc.

The recommended approach for liquefaction mitigation in each Technical Category classification zone is discussed below.

### 4.5.2 Technical Category 1


As per the MBIE (2012) Guidelines with TC1 sites *“Future land damage from liquefaction is unlikely, and ground settlements from liquefaction effects are expected to be within normal accepted tolerances.”* Therefore, only shallow geotechnical testing is required at the building consent stage of residential development. If ‘Good Ground’ test is met, NZS3604 ‘Timber Framed Buildings’ type foundations can be used.

For the TC1 area we are effectively using an ‘Acceptance of Liquefaction’ solution as the risk sufficiently low to warrant this approach.

### 4.5.3 Technical Category 2

The sites are consistent with the deformation characteristics of TC2 and do not meet the intent of the definition of ‘Good Ground’ as per the New Zealand Standards (NZS3604 ‘Timber Framed Buildings’ and NZS4229 ‘Concrete Masonry Buildings not requiring Specific Engineering Design’). These standards are typically used to design the structural components of residential dwellings. Due to a TC2 equivalent classification the generic foundation options presented in these standards cannot generally be used.

The principal objectives of the foundation design at the site should be to provide sufficient stiffness for the house to remain in a near flat plane in a future earthquake, and to be capable of being re-levelled if differential settlement does occur. To achieve these objectives the foundation system will need to go beyond the lightly reinforced slab-on-grade floor system permitted by NZS3604 which is too flexible and lacks the strength to resist ground movement without significant damage. The chosen foundation



system should be designed to be able to accommodate settlement of ground beneath the house and to be capable of resisting imposed loads and stresses from differential settlement.

The above comments are in line with the guidance advice made by the MBIE (2012). The foundation options in the MBIE guidelines are house specific and will need to be selected and designed during the building consent stage of the site development. The suitable foundation options fall generally into two categories: shallow foundations, and deep foundations. Each of these is discussed below. For the TC2 area we are effectively using a 'Building Strengthening' type approach to liquefaction mitigation where the foundations are strengthened to withstand the effects of liquefaction.

**It should be noted that this report provides guidance only on residential foundation design and should not be taken as detailed design.** Other foundation solutions are available (i.e. ground improvement to achieve TC1 site characteristics etc.) However these options are unlikely to be economic relative to the options below and are not recommended at this stage.

### Shallow Foundations

A shallow foundation, such as a raft, is intended to tie the superstructure together and to minimise structural damage if there is any ground movement during or following a future major seismic event. A properly detailed raft foundation is unlikely to prevent settlement of the dwelling but will reduce differential settlement and will also allow the house to be re-levelled if required. Raft foundations are generally suitable for dwellings with concrete floor slabs only.

Raft foundations can take several forms, including:

- A gravel raft (either with or without geogrid reinforcement) with a reinforced concrete slab formed on top of the gravel raft.
- A double reinforced concrete raft cast onto the in situ ground.
- A reinforced ground beam grid with slab foundation cast onto the in situ ground (rib raft).

An alternative shallow foundation option is to use a suspended wooden floor with short piles and ring foundations as given in NZS3604. However, with this option, the site foundation soils must have 300kPa rupture bearing capacity and the building must have lightweight cladding and roofing systems.

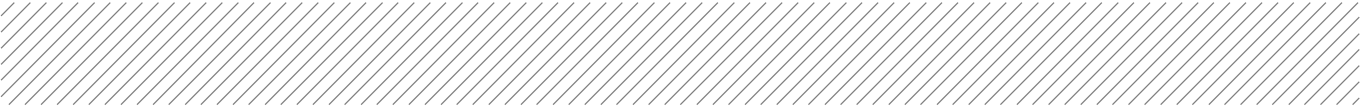
### Deep Foundations

Deep foundations such as piles will transfer structural loads from the structure to deeper and stronger non-liquefiable soil layers which will minimise any structural damage associated with ground liquefaction and settlement during and after a major seismic event. Piled foundations will minimise both total and differential settlements.

Piled foundations for a residential house typically comprise driven piles and can be either concrete (typically used if a concrete floor system is to be used), or timber (typically used if a timber floor and sub-floor system is to be used). A piled foundation system does not require any special soil preparation, but will require site specific investigation and design. Based upon the results of the ground testing, pile foundations would likely be founded well into the sandy gravel material at typically 4m to 5.5m below the finished ground level.

### Discussion and Recommendations

The recommendations above are based on Section 5 of the MBIE(2012) guidelines. Schematics and typical cross sections of these foundation systems are presented in the guideline.



The raft foundation options are likely to be cheaper than the piled foundation options but piled foundations are often recommended for residential housing as piled foundations minimise settlement and damage during a large seismic event.

If piled foundations are adopted, then the floor slab should be well reinforced to provide continuity across the building floor and foundation elements. The objective is to provide additional capacity in the floor slab and enhance its ability to redistribute loads, if necessary, during large seismic events. All pile heads need to be adequately tied into the floor slab. An alternative approach could be to utilise the NZS3604 suspended wooden floor system founded directly onto the deep driven timber piles.

During detailed foundation design particular attention should be given to detailing the connections of buried services (water and sewer pipes, power conduits, etc.) between the house foundation and the in situ ground. The design should allow sufficient movement and ductility to account for seismic shaking and liquefaction induced movement, and to allow for easy reinstatement in the event of future damage.

Due to the presence of shallow gravel layer along the northeast side of the site underlain by liquefiable silty-sandy deposits, we do not currently recommend using deep piles in this area. Deep piles could be a viable foundation system along the eastern edge of the site where the upper soils are silty-sandy material and are underlain by the gravel founding layer.

To provide site specific geotechnical information for use in foundation design in TC2 areas it is recommended that a site specific geotechnical assessment be carried out by suitability qualified chartered engineer with experienced in residential house development in accordance with the MBIE guidelines.

#### **4.5.4 Technical Category 3**

The area identified as being potentially Technical Category 3 is going to be used for playing field and recreation reserves. As such, it poses no significant risk to residential development. As such this is effectively the 'Alternative Land Use' approach to liquefaction mitigation and this area identified as having potential TC3 characteristics poses no undue risk to the residential development of Knights Stream Park Stages 7 & 8.

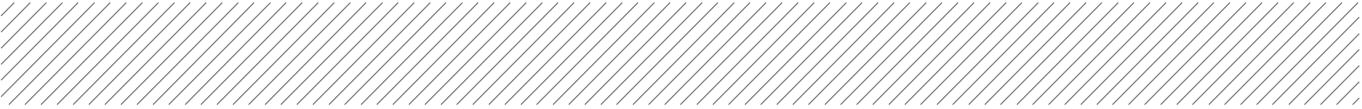
### **4.6 Council Vested Infrastructure**

For the area identified as TC1 no specific liquefaction mitigations measures are required for Council vested infrastructure. The area identified as TC3 is to be used as playing fields. Therefore, there is no buried infrastructure of any significance and hence no liquefaction mitigation is required. The potential effects of liquefaction will need to be considered when designing the Council vested infrastructure in TC2 areas. At this stage, in line with earlier stages of wider Knights Stream Park and Longhurst Development it is recommended that any liquefaction mitigation measures are designed for the 1 in 150 year intermediate level earthquake and to accept increasing levels of damage for larger events.

This section describes the proposed liquefaction mitigation measures for the infrastructure at Knights Stream Park Stages 7 and 8. The proposed liquefaction mitigation measures are in line with the Christchurch City Council Capital Programme Group Technical Memorandum *'Earthquake Learnings – Amendments to the IDS and the CSS for Pipes Infrastructure in Christchurch City, to Mitigate Against Future Earthquake Damage.'*

#### **4.6.1 Buried Structures**

In order to minimise lifting / floatation all buried services founded below design groundwater level such as manhole risers, pump station chambers, etc. should be designed to have neutral buoyancy and to



resist the uplift forces associated with liquefied soil, not just groundwater buoyancy forces. Spaces around buried structures should be backfilled with free draining, granular, non-liquefying fill in order to alleviate pore water pressure build up during a large seismic event thereby reducing the potential for liquefaction in the soils immediately surrounding the buried structure.

Manhole inverts and pipe entry and exit levels should be designed to accommodate liquefaction induced differential settlements. The hydraulic design of the pipes entering and exiting the manhole risers should be designed to accommodate up to 75mm vertical movement both up and down. Manhole risers should have strap rings to hold the manhole riser sections together in order to reduce lateral displacement of the manhole risers. Additionally, manhole connectors with greater than 90mm sealing lengths should be used to minimise the potential for joint pull-out.

It is recommended that the finalised design of each buried service (manhole riser, pump station, etc.) is confirmed on a case by case basis during construction once the site specific ground conditions are identified, in particular if the infrastructure element is being founded directly into gravel.

Buried structures within 10m of the top edge of the Knights Stream Park stormwater basin at the should be designed to accommodate up to 100mm of lateral movement.

#### **4.6.2 Pipes and Service Conduits**

In line with the Christchurch City Council Capital Programme Group Technical Memorandum, all pipes and service conduits should be made from flexible material (e.g. plastic) where practicable. For gravity reticulated sewer lines, all pipe joints and intersections with manhole risers should be installed with short slip collars to allow greater capacity of joint movement and increase joint resilience. Pressurised sewer lines should be constructed from PE pipe and should have end restraints at pump stations. Well-designed end restraints combined with the PE pipe material itself will improve the resilience of the pressure line and help prevent damage.

As noted above, for hydraulic pipes (sewer, stormwater, and possibly reticulated water), the pipe sizes and gradients should be designed in such a way that they can accommodate post liquefaction differential settlement, both positive and negative. Differential settlements of 75mm should be used for design.

All pipes and conduits should be founded into the non-liquefiable crust material where possible. If the founding depth of the pipes and conduits extends down to liquefiable silty sandy material the service trenches should be backfilled with non-liquefiable geotechnically competent fill.

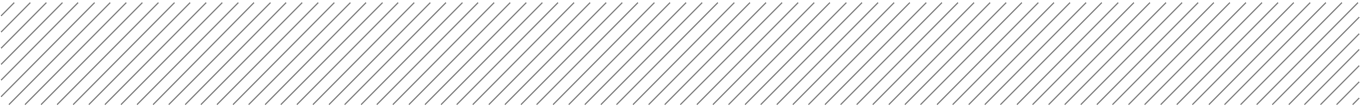
All service trenches located below the water table should be lined with a geosynthetic filter fabric material (i.e. Bidim A19 or similar) to separate potentially liquefiable soils from non-liquefiable granular bedding and backfill material. For shallow service trenches founded above the water table, a filter fabric is not required but is generally recommended.

By providing a filter fabric and filling the service trenches with non-liquefiable geotechnically competent fill the trench backfill is non-liquefiable and will therefore limit liquefaction induced settlement or flotation. Additionally, if a pipe was to rupture, by having a filter fabric encasing the bedding material there is less likelihood of sand material infiltrating into and blocking the pipeline.

#### **4.6.3 Pavements**

At this stage it is inferred that the pavement is unlikely to be significantly affected by seismically induced liquefaction. However, to ensure robustness of the pavement following a liquefaction inducing major earthquake it is recommended that the pavement be designed to accommodate the potentially adverse effect of seismically induced liquefaction. The pavement should be designed in such a way





that it can bridge any localised voids / settlements that may be caused by seismically induced liquefaction, and prevent liquefiable soil from penetrating into the pavement structure.

If subsoil drains are to be installed as part of the subdivision development for stormwater control, then it is recommended extending the subsoil drainage under the foot print of the roading network.

Drainage will increase the thickness of non-liquefied crust below the pavement areas as well as the residential sections, thereby minimising the likelihood of liquefaction induced damage.

A geosynthetic filter fabric (i.e. Bidim A29 or similar) should be placed directly onto the in situ sub-grade material prior to the placement of the granular sub-base fill to limit fines migration from the sub-grade to the sub-base during a liquefaction inducing seismic event and the potential loss of pavement strength.

## 5. Assessment Against RMA Section 106

Section 106 of the Resource Management Act (RMA) states *inter alia*

*... “a consent authority may refuse to grant a subdivision consent, or may grant a subdivision consent subject to conditions, if it considers that:*

- a) the land in respect of which a consent is sought, or any structure on the land, is or is likely to be subject to material damage by erosion, falling debris, subsidence, slippage, or inundation from any source; or*
- b) any subsequent use that is likely to be made of the land is likely to accelerate, worsen, or result in material damage to the land, other land, or structure by erosion, falling debris, subsidence, slippage, or inundation from any source; or*
- c) sufficient provision has not been made for legal and physical access to each allotment to be created by the subdivision.”*

No erosion was observed on the site. However the silty soils that directly underlie the site are inferred to be potentially susceptible to erosion when left unvegetated. We infer that the site is not susceptible to falling debris or slippage due to the topographical location.

It is noted that issues surround stormwater discharge are being dealt with in the detailed civil engineering design by Davie Lovell-Smith and any potential “inundation” susceptibility due to stormwater is being addressed as part of the detailed subdivision civil engineering design.

Due to the potential for seismically induced liquefaction, we infer that parts of the site are potentially susceptible to varying degrees to subsidence and inundation from liquefaction. However, if the appropriate liquefaction mitigation measures, as outlined in this report, are undertaken, then the risk of subsidence and inundation from liquefaction is significantly reduced to an acceptable level as defined by the MBIE. Therefore, if appropriate liquefaction mitigation measures are implemented in or opinion the site will be free of “subsidence”, or “inundation”. The proposed subdivision development therefore generally complies with the intent of Section 106 (a).

The site is underlain by fine grained soils and there is potential for erosion and rilling from run-off or wind if vegetation cover is removed for prolonged periods of time from both stormwater runoff if it is not discharged in a controlled manner, and from the wind. The susceptibility to erosion of the silty soils can be minimised by using appropriate industry standard design measures during construction.

The site has been identified as being susceptible to seismically induced liquefaction and hence has the potential for “subsidence”, “and “inundation.” Provided that appropriate liquefaction mitigation measures are implemented, as recommended in this report, subsequent use of the land following development is unlikely to accelerate, worsen, or result in material damage to the land, other land, or structures. In our opinion therefore, the development will comply with the intent of section 106 (b).

Section 106 (c) is not directly relevant to a geotechnical appraisal and therefore has not been considered in detail in this report.



## 6. References

Ambrasey and Menu, 1988. *Earthquake induced ground displacements*. Earthquake Engineering and Structural Dynamics. Vol 16, No. 7, pp. 985 – 1006.

Bradley and Hughes, 2012. *Conditional Peak Ground Accelerations in the Canterbury Earthquakes for Conventional Liquefaction Assessment*. Technical Report for the Ministry of Business, Innovation and Employment, April 2012. 22p.

Bray and Travasarou, 2007. *Simplified procedure for estimating earthquake-induced deviatoric slope displacements*. Journal of Geotechnical and Geoenvironmental Engineering, Vol 133, No. 4, pp. 381 – 392.

Brown and Weeber, (compilers), 1992. *Geology of the Christchurch urban area*. Institute of Geological and Nuclear Sciences, 1:25,000 geological map 1. 1 sheet + 104p. Lower Hutt, New Zealand.

ECan, 2013. <http://canterburymaps.govt.nz/Viewer/#webmap=0c3ca2ccfe1145c5849dc39864590d0b> Accessed 21 November 2013.

Idris and Boulanger, 2008. *Soil Liquefaction During Earthquakes*. EERI monograph MNO12. Earthquake Engineering Institute, Oakland, California, USA.

Ishihara, 1985. *Stability of natural deposits during earthquakes*. Proceedings, 11<sup>th</sup> International Conference on Soil Mechanics and Foundation engineering, Vol 1, pp. 321-376.

Ministry of Business, Innovation and Employment, 2012. Revised issue of *Repairing and rebuilding houses affected by the Canterbury earthquakes*. December 2012. Ministry of Business, Innovation and Employment, Wellington, New Zealand.

NZGS, 2005. *Field Description of Soil and Rock. Guideline for the Field Classification and Description of Soil and Rock for Engineering Purposes*. NZ Geotechnical Society Inc, Wellington, New Zealand.

Robertson and Wride, 1998. *Evaluating cyclic liquefaction potential using the cone penetration test*. Canadian Geotechnical Journal, Vol. 35, pp. 442 – 459.

Tonkin and Taylor Ltd, 2013. *Liquefaction Vulnerability Study*. Prepared for the Earthquake Commission, T&T Ref. 52020.0200/v1.0.

Zhang, Robertson, and Brachman, 2002. *Estimating liquefaction-induced ground settlements from CPT for level ground*. Canadian Geotechnical Journal, Vol. 39, pp.1168 – 1180.



## 7. Limitations

We have prepared this report in accordance with the brief as provided. The contents of the report are for the sole use of the Client and no responsibility or liability will be accepted to any third party. Data or opinions contained within the report may not be used in other contexts or for any other purposes without our prior review and agreement.

The recommendations in this report are based on data collected at specific locations and by using appropriate investigation methods with limited site coverage. Only a finite amount of information has been collected to meet the specific financial and technical requirements of the Client's brief and this report does not purport to completely describe all the site characteristics and properties. The nature and continuity of the ground between test locations has been inferred using experience and judgment and it must be appreciated that actual conditions could vary from the assumed model.

Subsurface conditions relevant to construction works should be assessed by contractors who can make their own interpretation of the factual data provided. They should perform any additional tests as necessary for their own purposes.

Subsurface conditions, such as groundwater levels, can change over time. This should be borne in mind, particularly if the report is used after a protracted delay.

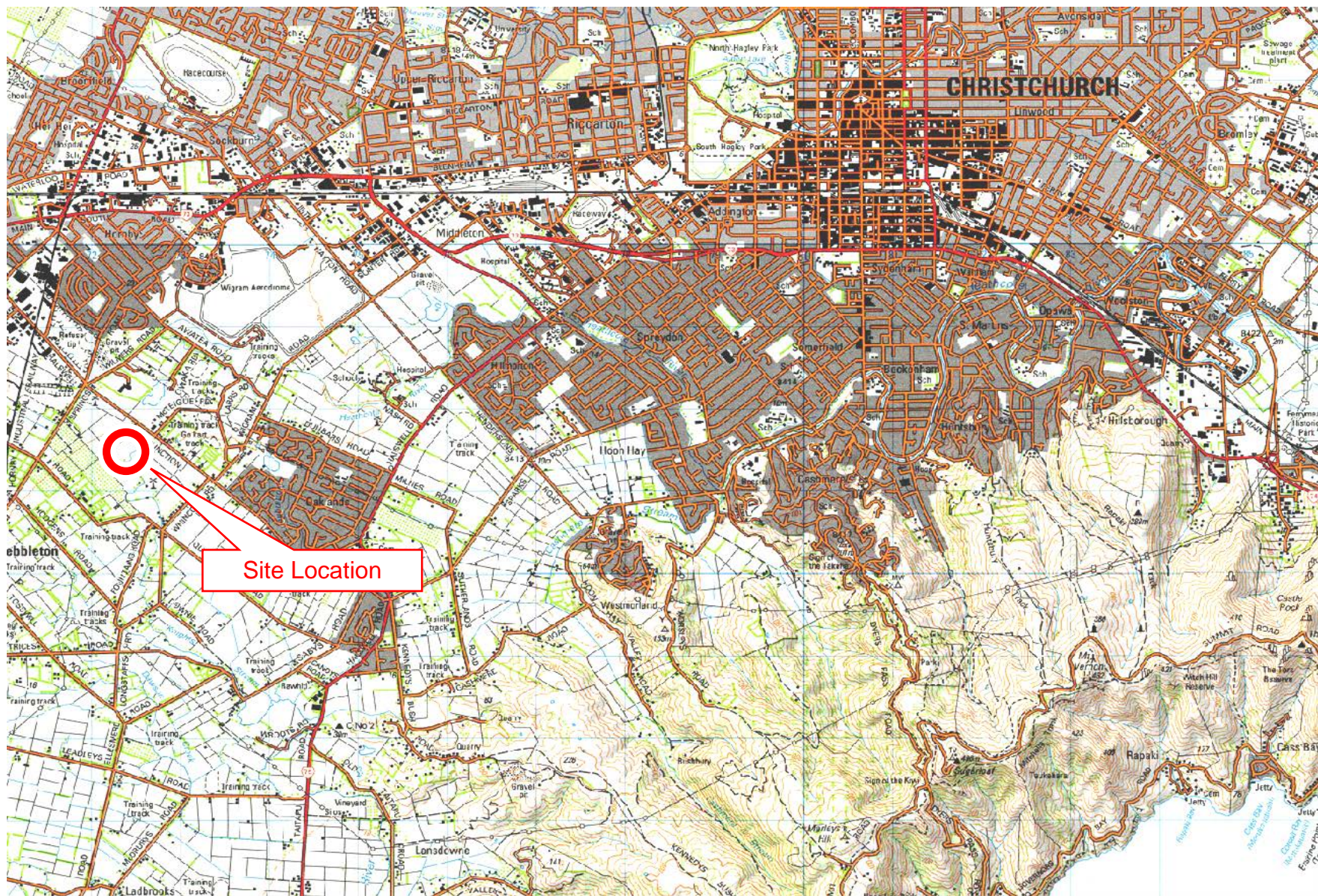
This report is not to be reproduced either wholly or in part without our prior written permission.



# Appendix A

## Figures





CLIENT

PRELIMINARY NOT FOR CONSTRUCTION

ALL DIMENSIONS APPROXIMATE ONLY

SCALE

SIZE

TITLE

SITE LOCATION

FIGURE

FIGURE 1

NTS

A4

BY

D. MAHONEY

APPROVED

I. MCPHERSON

REFERENCE

BACKGROUND IMAGE: SOURCED FROM LINZ. CROWN  
COPYRIGHT RESERVED

PROJECT

KNIGHTS STREAM PARK  
STAGES 7 & 8

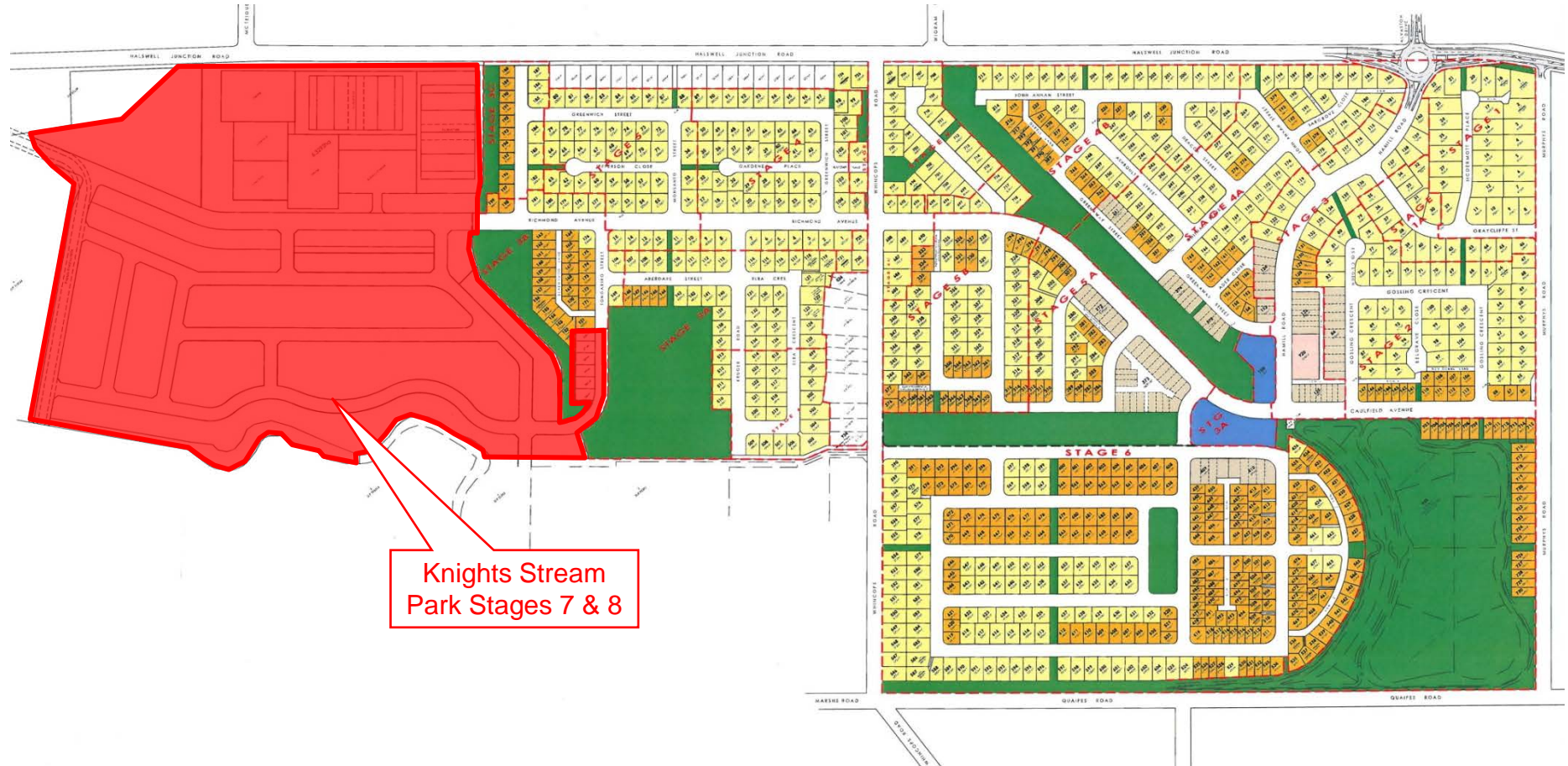
DATE

18 NOVEMBER 2014

FIGURE No.

PROJECT  
200376WBS  
002TYPE  
FIGDISC  
TRANUMBER  
01REV  
3





Knights Stream  
Park Stages 7 & 8

CLIENT

PRELIMINARY NOT FOR CONSTRUCTION

ALL DIMENSIONS APPROXIMATE ONLY

SCALE

SIZE

NTS

A4

TITLE

SITE LOCATION – WIDER DEVELOPMENT

BY

D. MAHONEY

APPROVED

I. MCPHERSON

REFERENCE

BACKGROUND IMAGE: DAVIE LOVELL-SMITH LIMITED

DATE

18 NOVEMBER 2014

FIGURE No.

PROJECT

200376

WBS

002

TYPE

FIG

DISC

TRA

NUMBER

02

REV

3

FIGURE

FIGURE 2

PROJECT

KNIGHTS STREAM PARK  
STAGES 7 & 8

## Legend



Approximate Site Boundary



Approximate KSP Stage 7 & 8



Approximate zones of surface expression of liquefaction identified from aerial photographs and site observations



Extensive of liquefaction in the northeastern paddock. Due to long grass at the time of the aerial photographs and site walkovers the exact extent of liquefaction is difficult to fully map



CLIENT

PRELIMINARY NOT FOR CONSTRUCTION

ALL DIMENSIONS APPROXIMATE ONLY

SCALE

SIZE

TITLE

IDENTIFIED AREAS OF SURFACE EXPRESSION OF LIQUEFACTION FOLLOWING THE DARFIELD EQ

NTS

A4

BY

D. MAHONEY

APPROVED

I. MCPHERSON

REFERENCE

BACKGROUND IMAGE: © 2010 GOOGLE © 2012 GEO EYE, © 2012 WHEREIS © SENSIS PLY LTD

DATE

18 NOVEMBER 2014

FIGURE No.

PROJECT

200376

WBS

002

TYPE

FIG

DISC

TRA

NUMBER

02

REV

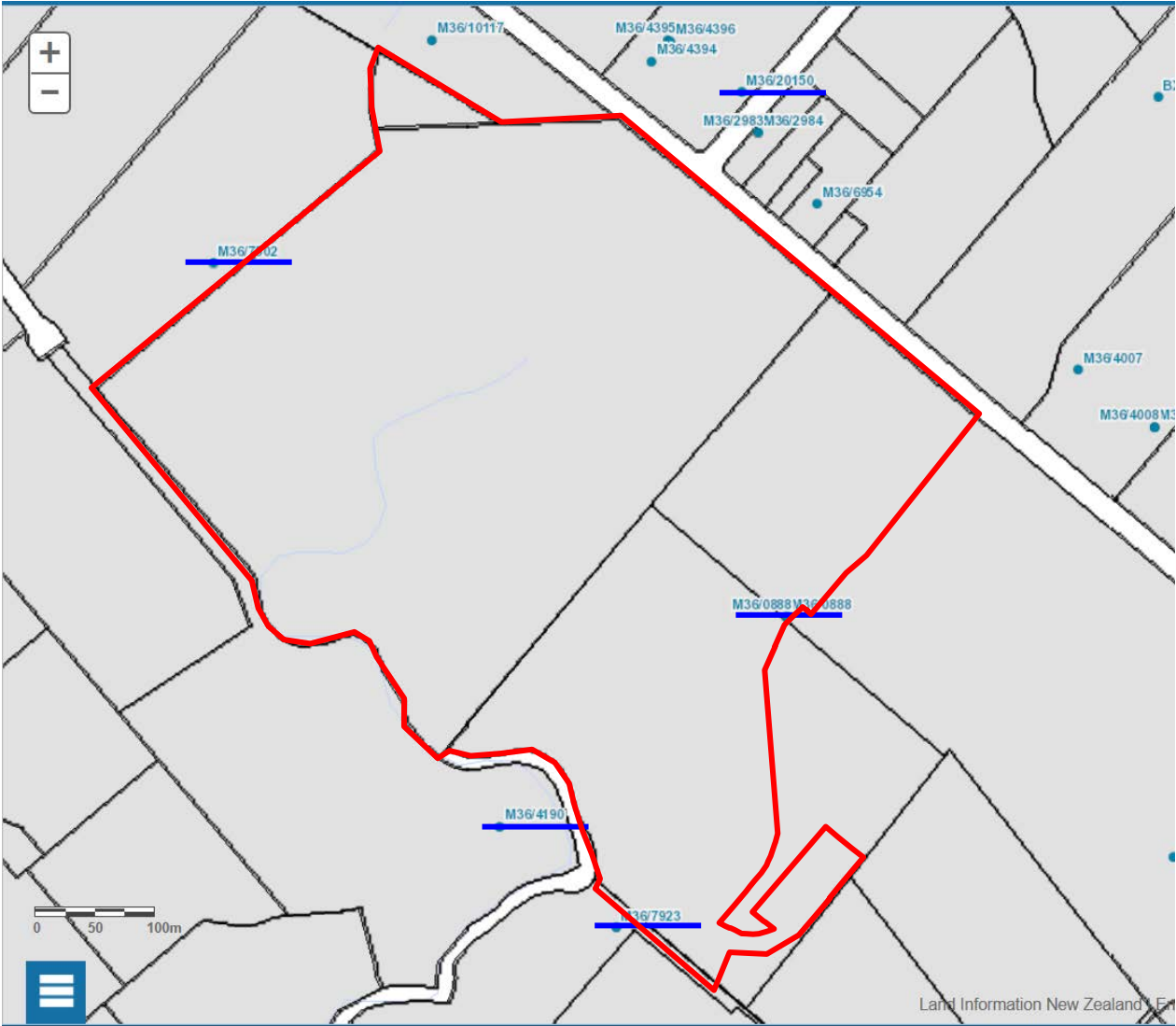
3

FIGURE


FIGURE 3



PROJECT

KNIGHTS STREAM PARK  
STAGES 7 & 8



Legend

 Site Boundary



 ECan borehole with usable log





FUTURE CONNECTION TO  
HALSWELL JUNCTION ROAD

D.P.318764

D.P.30676

MCH

HALSWELL JUNCTION ROAD

CHANGING ROOMS

Pre School  
Location  
2000m<sup>2</sup>

PROPOSED PRIMARY SCHOOL

D.P.318764

Knight's Stream

D.P.30292

## Legend



Site Boundary



CPT157

Cone Penetration Test



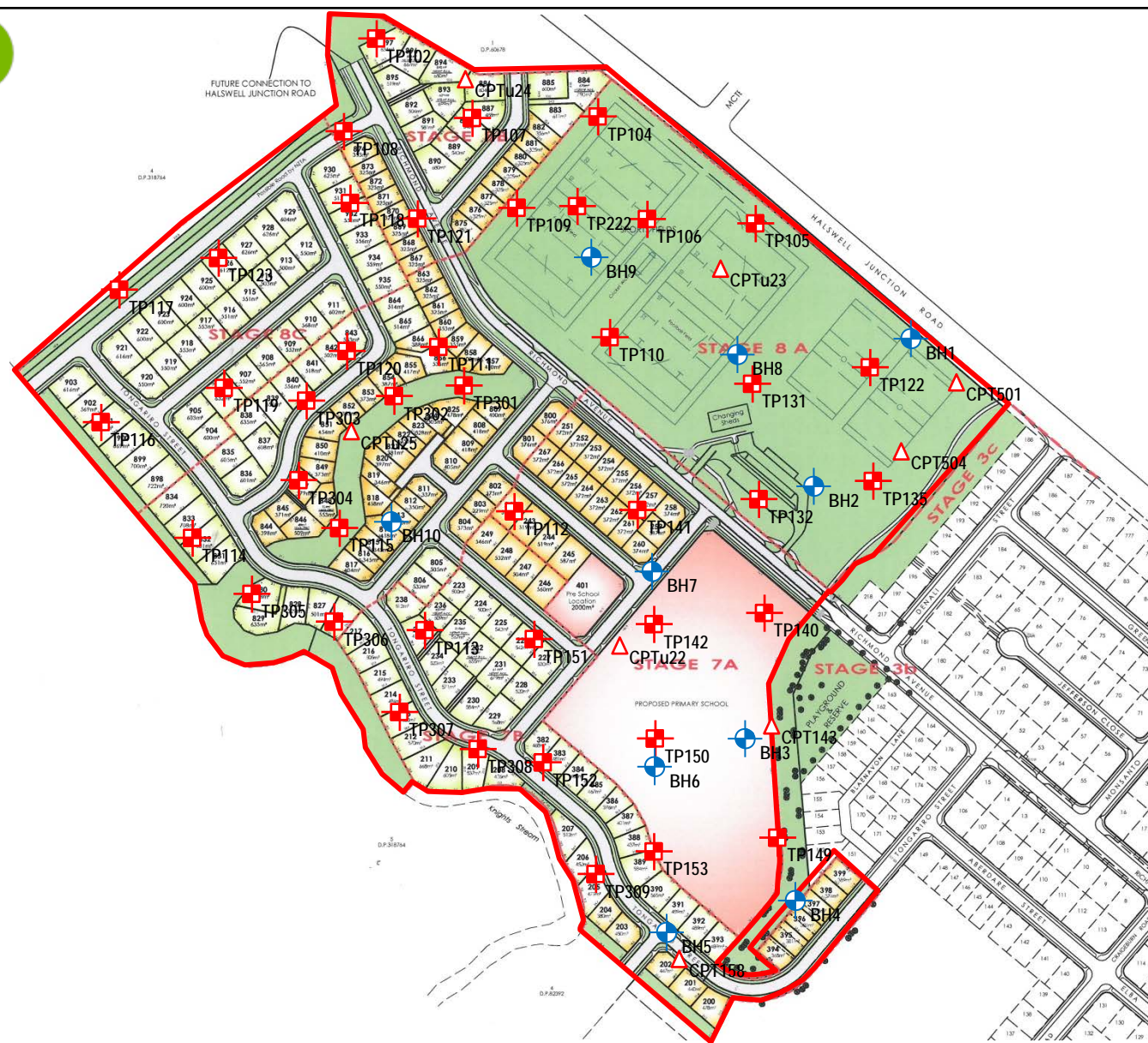
TP147

Test Pit



BH8

Borehole



CLIENT

PRELIMINARY NOT FOR CONSTRUCTION

ALL DIMENSIONS APPROXIMATE ONLY

SCALE

SIZE

TITLE

GEOTECHNICAL SITE INVESTIGATION  
- TEST LOCATIONS

**aurecon** **Fulton Hogan**

FIGURE

FIGURE 5

BY

D. MAHONEY

APPROVED

I. MCPHERSON

REFERENCE

BACKGROUND IMAGE: DAVIE LOVELL-SMITH DRAWING  
E.18447 R1

PROJECT

KNIGHTS STREAM PARK  
STAGES 7 & 8

DATE

18 NOVEMBER 2014

FIGURE No.

PROJECT  
200376

WBS  
002

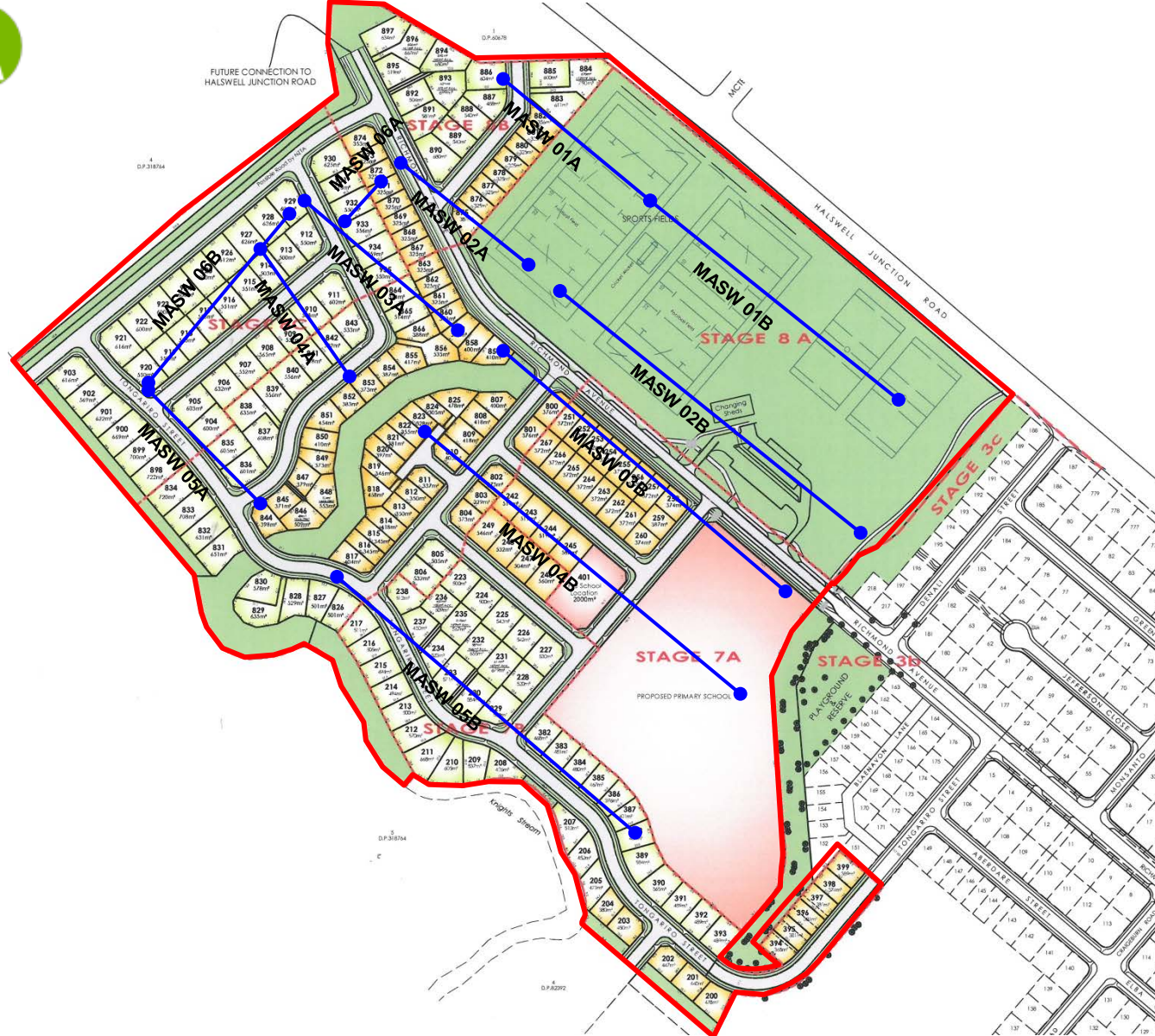
TYPE  
FIG

DISC  
TRA

NUMBER  
02

REV  
3





## Legend



Site Boundary



MASW 01B MASW Line

CLIENT

PRELIMINARY NOT FOR CONSTRUCTION

ALL DIMENSIONS APPROXIMATE ONLY

SCALE

SIZE

TITLE

GEOTECHNICAL SITE INVESTIGATION  
- MASW SECTIONS

NTS

A4

BY

D. MAHONEY

APPROVED

I. MCPHERSON

DATE

18 NOVEMBER 2014

REFERENCE

BACKGROUND IMAGE: DAVIE LOVELL-SMITH DRAWING  
E.18447 R1

FIGURE No.

PROJECT  
200376

WBS  
002

TYPE  
FIG

DISC  
TRA

NUMBER  
03

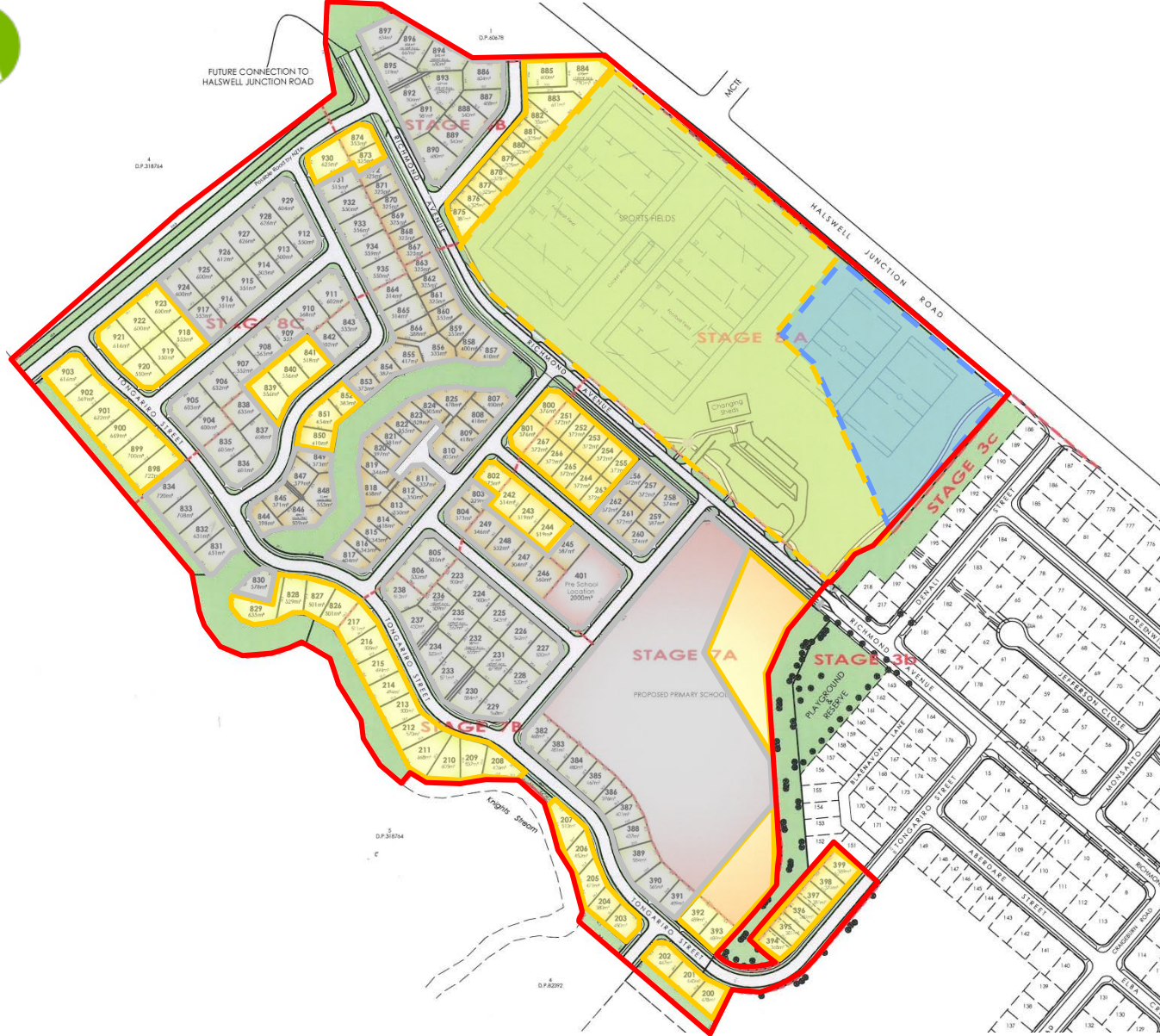
REV  
3

FIGURE





FIGURE 6

PROJECT

KNIGHTS STREAM PARK  
STAGES 7 & 8



### Legend

-  Site Boundary
-  TC1 Equivalent
-  TC2 Equivalent
-  TC3 Equivalent





# Appendix B

## ECan Borehole Logs

# Borelog for well M36/0888

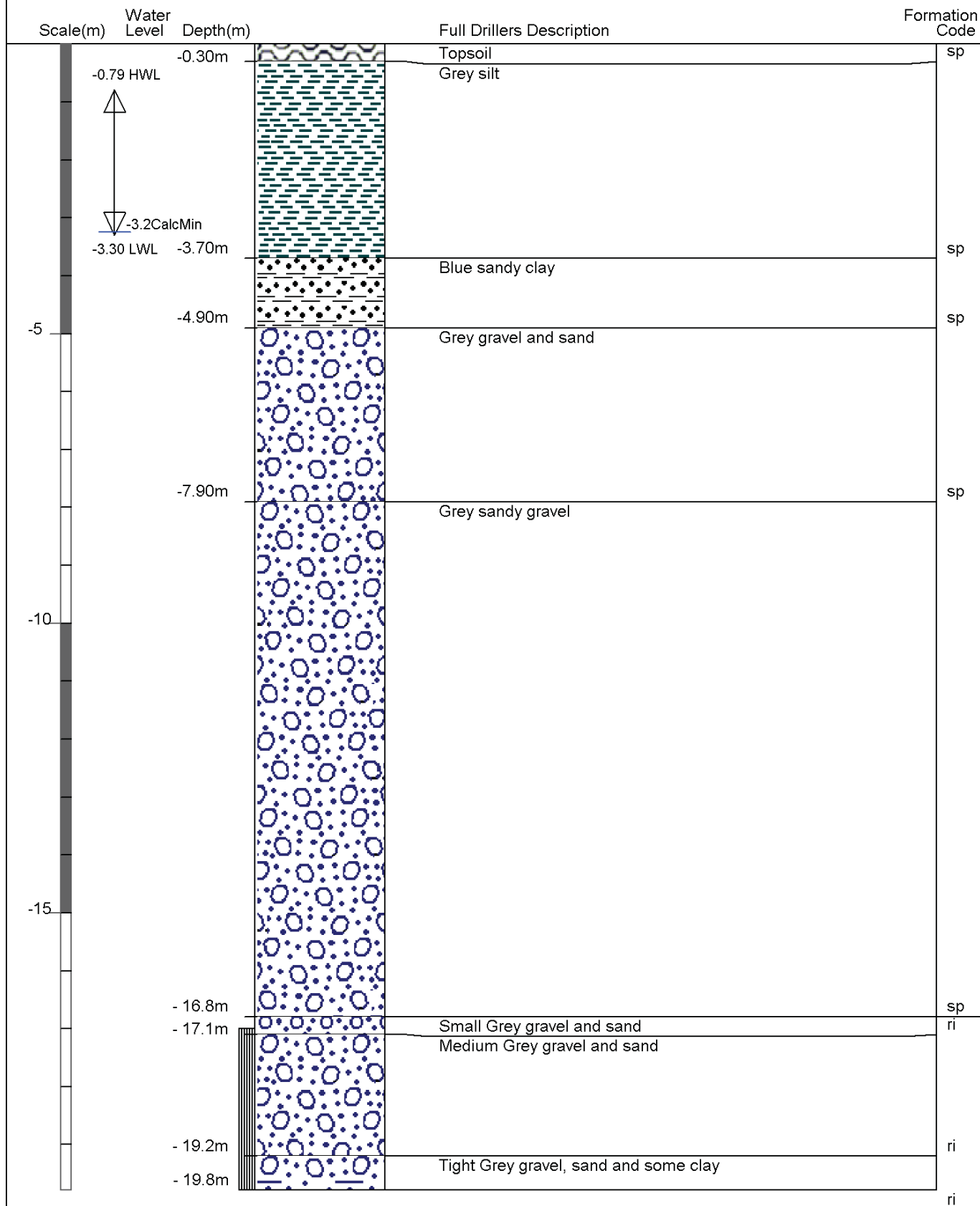
Gridref: M36:731-372 Accuracy : 4 (1=best, 4=worst)

Ground Level Altitude : 17.69 +MSD

Driller : A M Bisley & Co

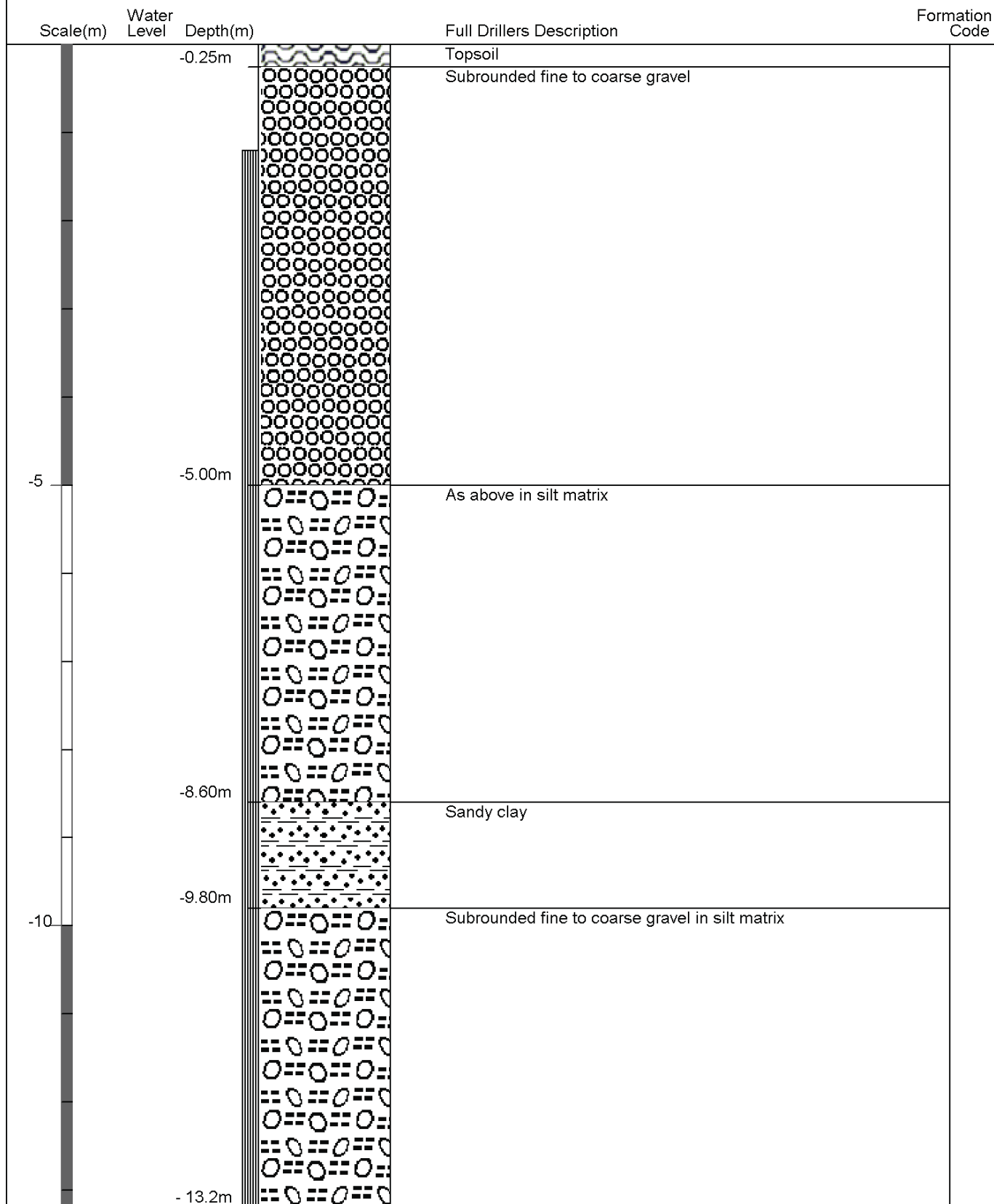
Drill Method : Cable Tool

Drill Depth : -19.79m Drill Date : 2/12/1972



# Borelog for well M36/20150

Gridref: M36:72736-37744 Accuracy : 2 (1=high, 5=low)  
 Ground Level Altitude : 19 +MSD  
 Driller : McMillan Water Wells Ltd  
 Drill Method : Rotary/Percussion  
 Drill Depth : -13.2m Drill Date : 20/10/2008



# Borelog for well M36/10117

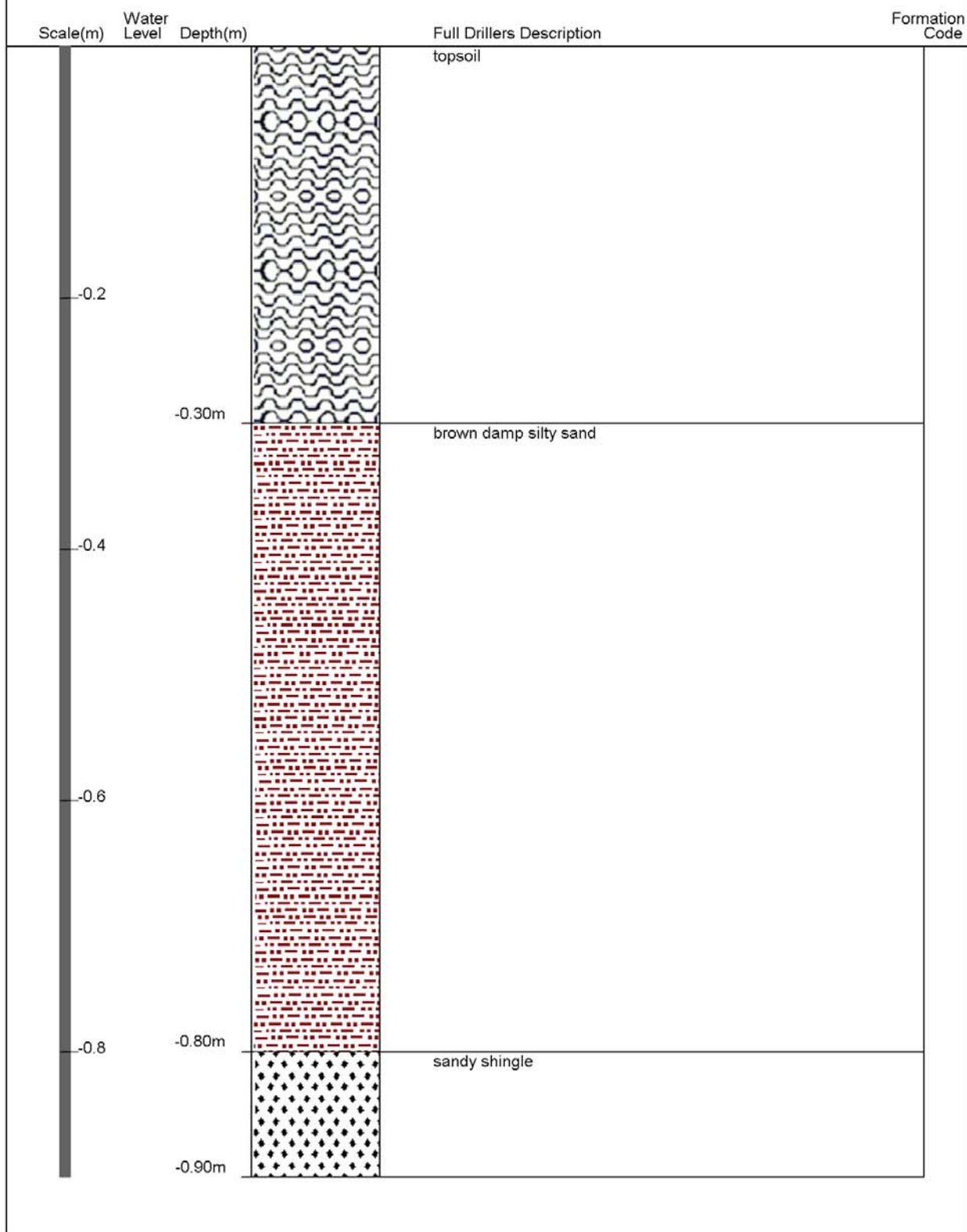
Gridref: M36:72475-37788 Accuracy : 3 (1=high, 5=low)

Ground Level Altitude : 19.2 +MSD

Well name : CCC BorelogID 6350

Drill Method : Not Recorded

Drill Depth : -0.9m Drill Date : 11/10/2006



# Borelog for well M36/7923

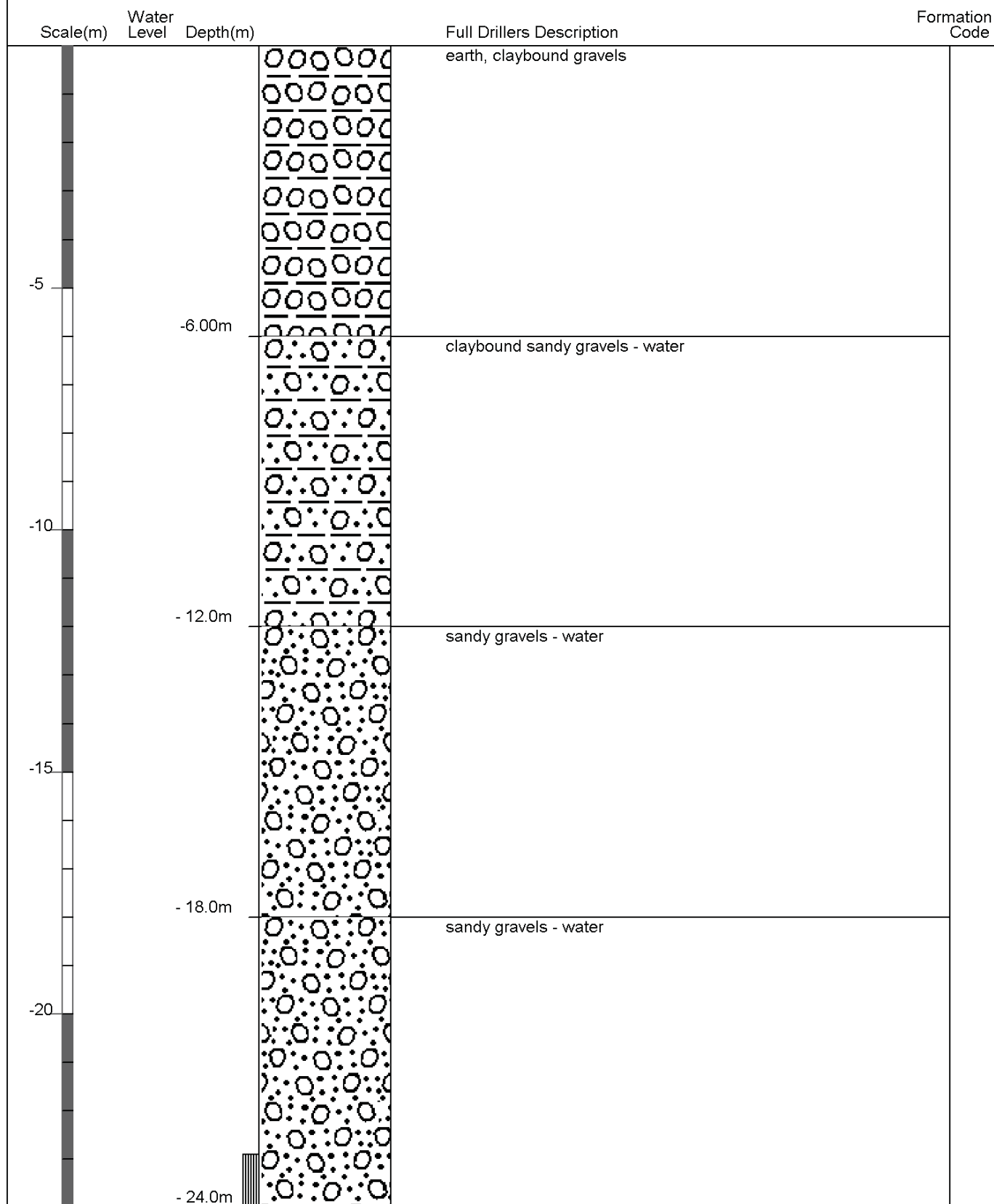
Gridref: M36:7263-3704 Accuracy : 2 (1=high, 5=low)

Ground Level Altitude : 17.7 +MSD

Driller : East Coast Drilling

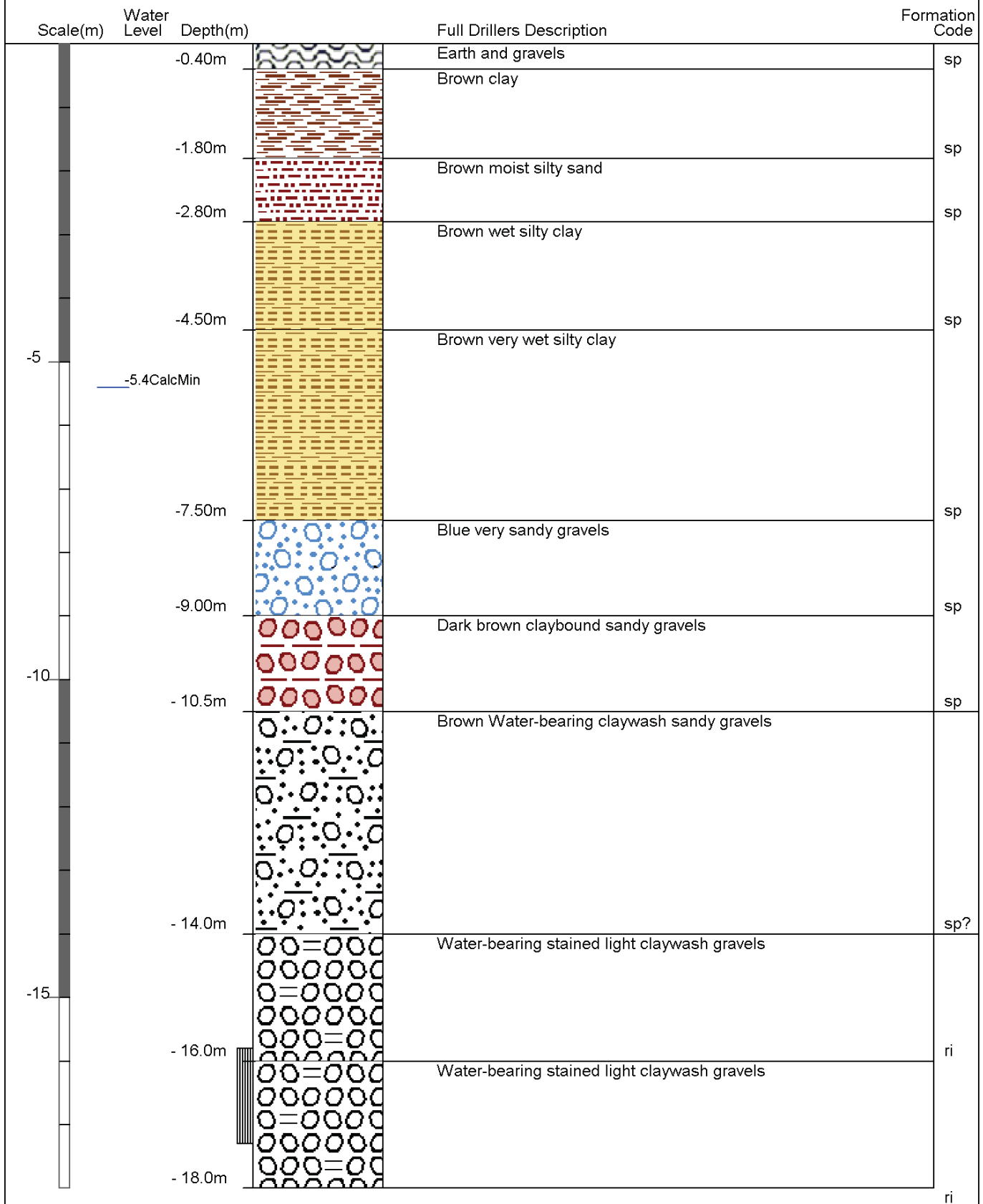
Drill Method : Rotary Rig

Drill Depth : -24m Drill Date : 25/05/2005



# Borelog for well M36/7502

Gridref: M36:7229-3760 Accuracy : 2 (1=high, 5=low)  
 Ground Level Altitude : 19.7 +MSD  
 Driller : McMillan Water Wells Ltd  
 Drill Method : Rotary/Percussion  
 Drill Depth : -18m Drill Date : 17/11/2003





# Borelog for well M36/4190

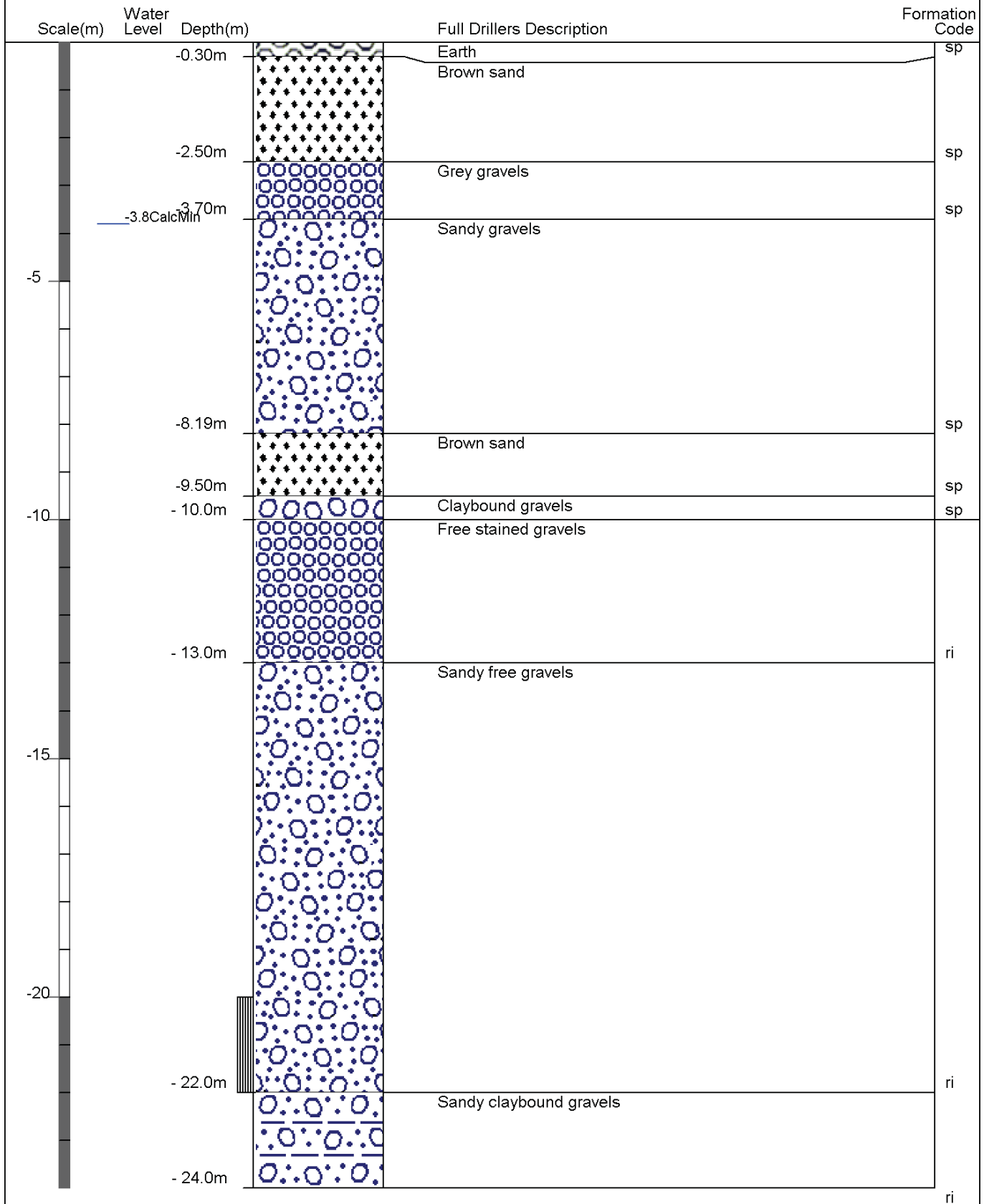
Gridref: M36:72532-37125 Accuracy : 2 (1=best, 4=worst)

Ground Level Altitude : 18.3 +MSD

Driller : McMillan Water Wells Ltd

Drill Method : Rotary/Percussion

Drill Depth : -24m Drill Date : 29/05/1990

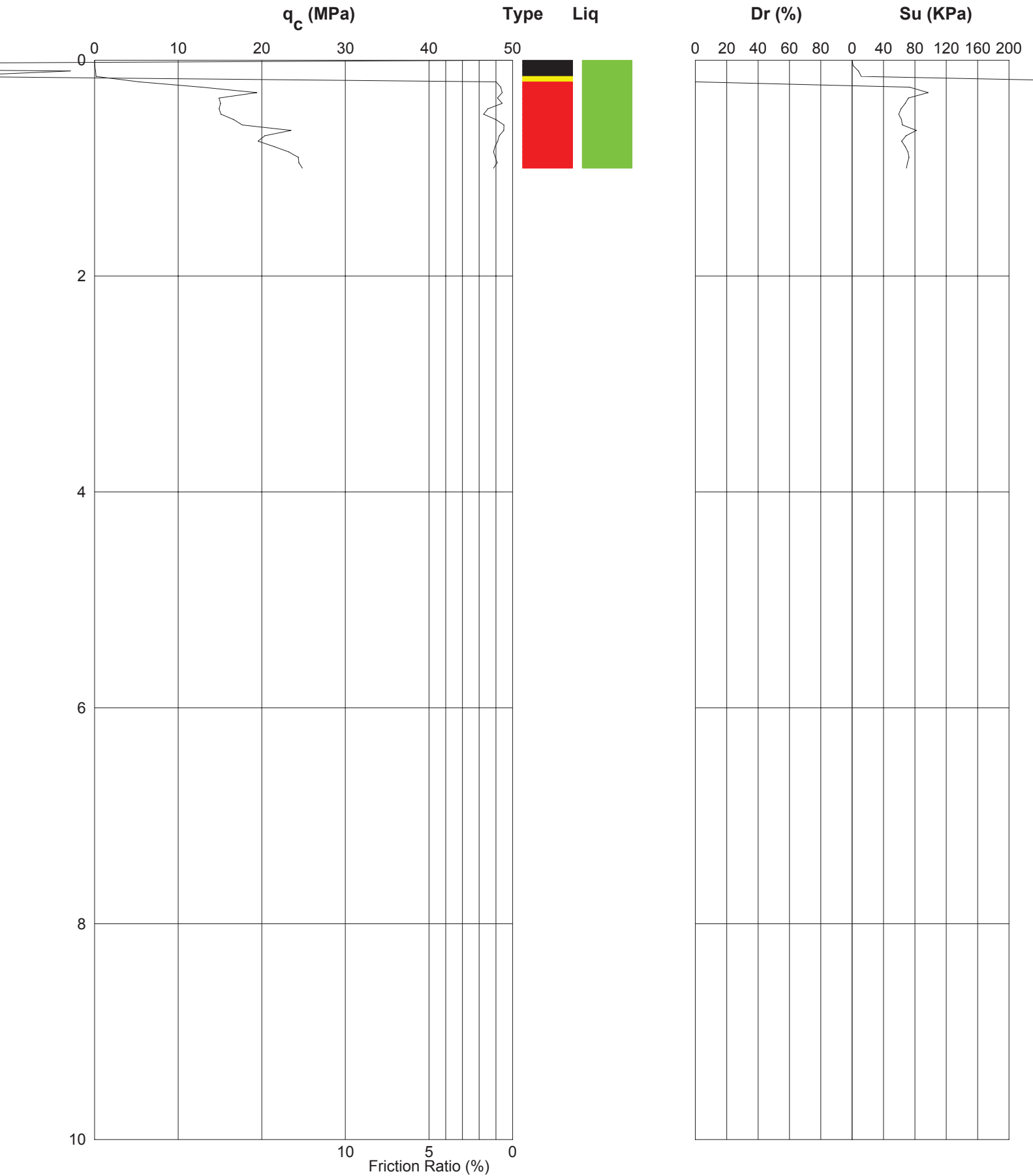




# Appendix C

## CPT Logs

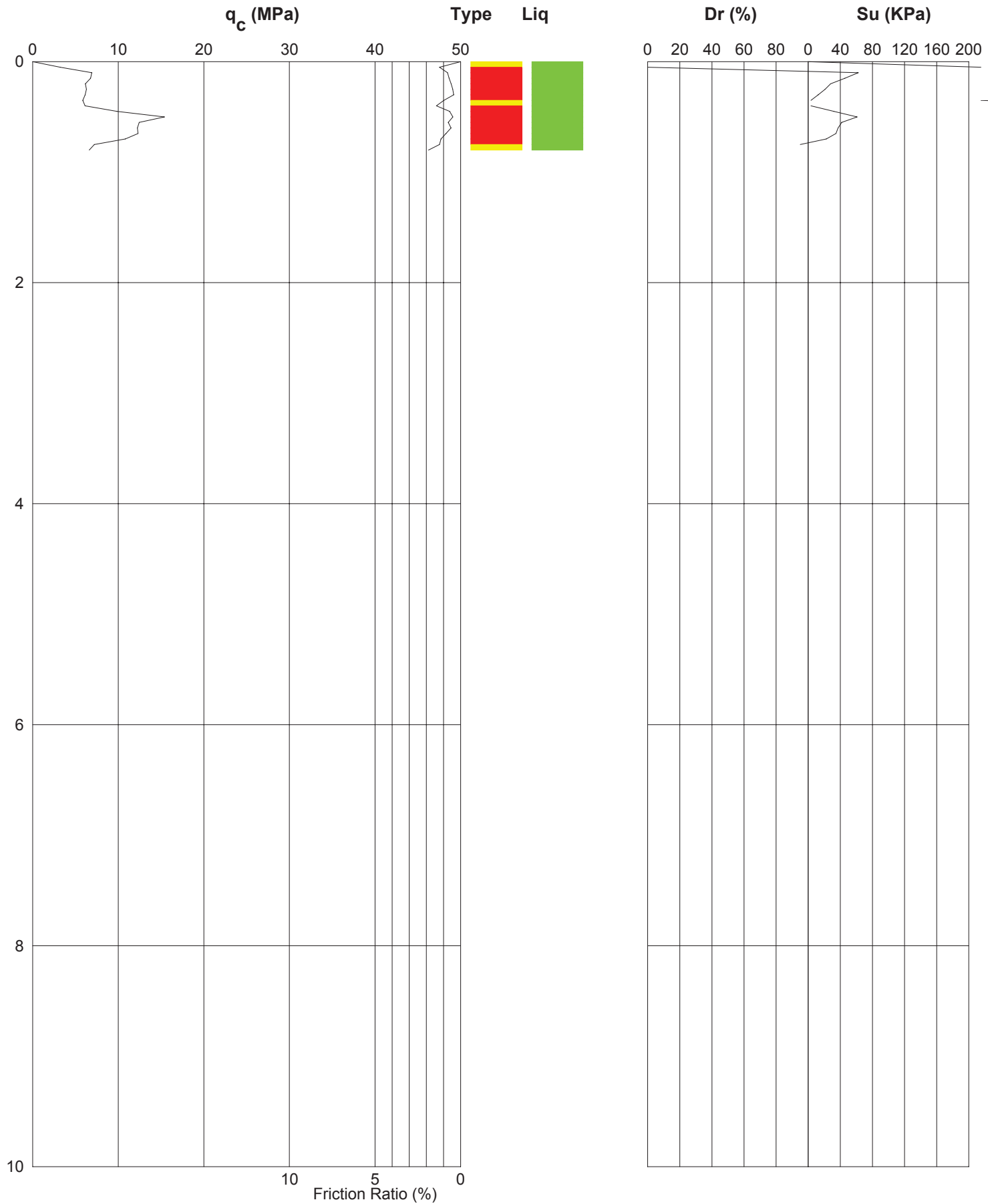
# PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT



Job No: 8200  
 CPT No: CPT022  
 Project: Fulton Hogan Ltd  
 Location: Halswell Junction Rd

Date: 27-10-2010  
 Operator: N Barnes  
 Remark: Effective Refusal

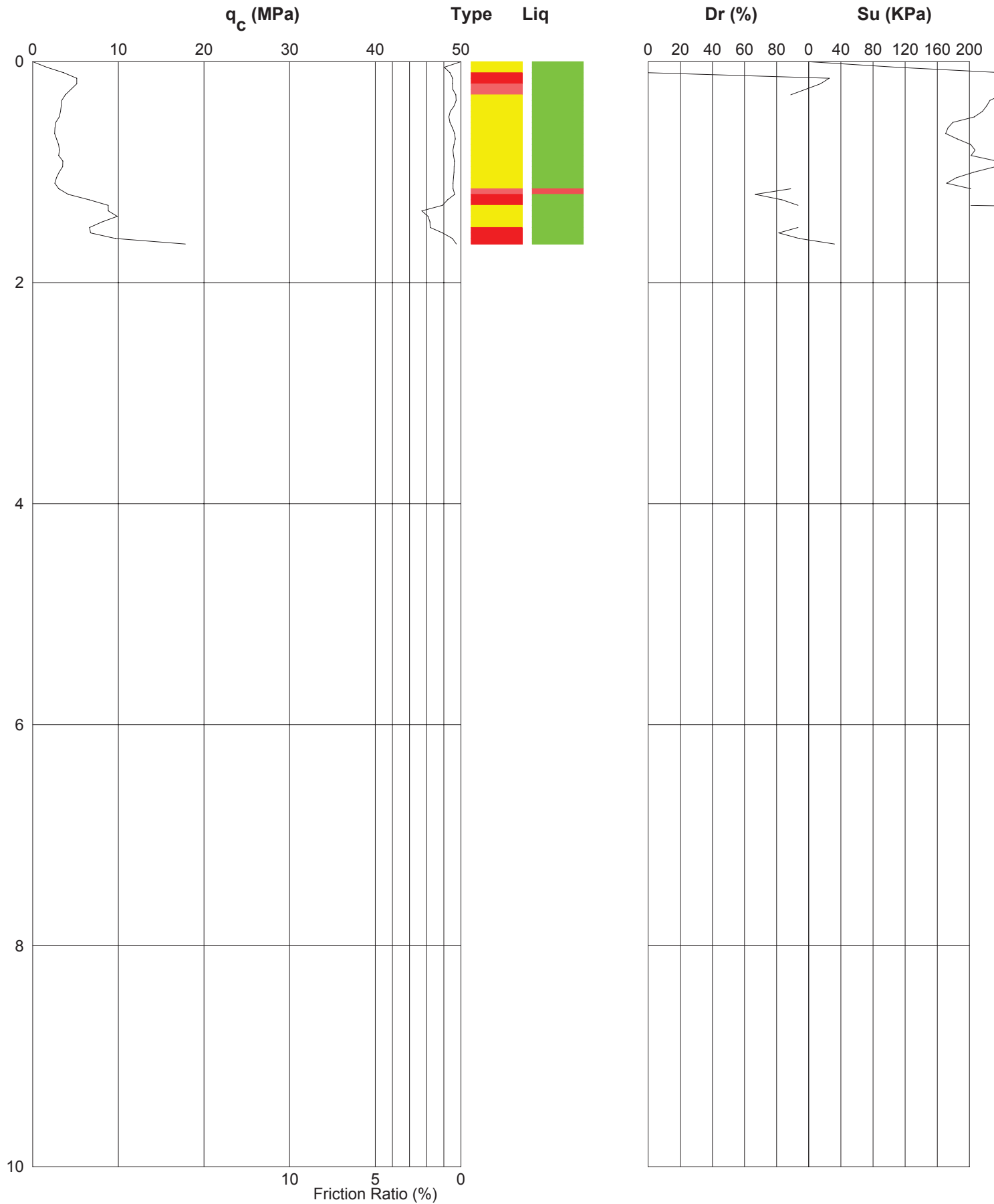
# PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT



Job No: 8200  
 CPT No: CPT023  
 Project: Fulton Hogan Ltd  
 Location: Halswell Junction Rd

Date: 27-10-2010  
 Operator: N Barnes  
 Remark: Effective Refusal

# PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT



Job No: 8200  
 CPT No: CPT024  
 Project: Fulton Hogan Ltd  
 Location: Halswell Junction Rd

Date: 27-10-2010  
 Operator: N Barnes  
 Remark: Effective Refusal

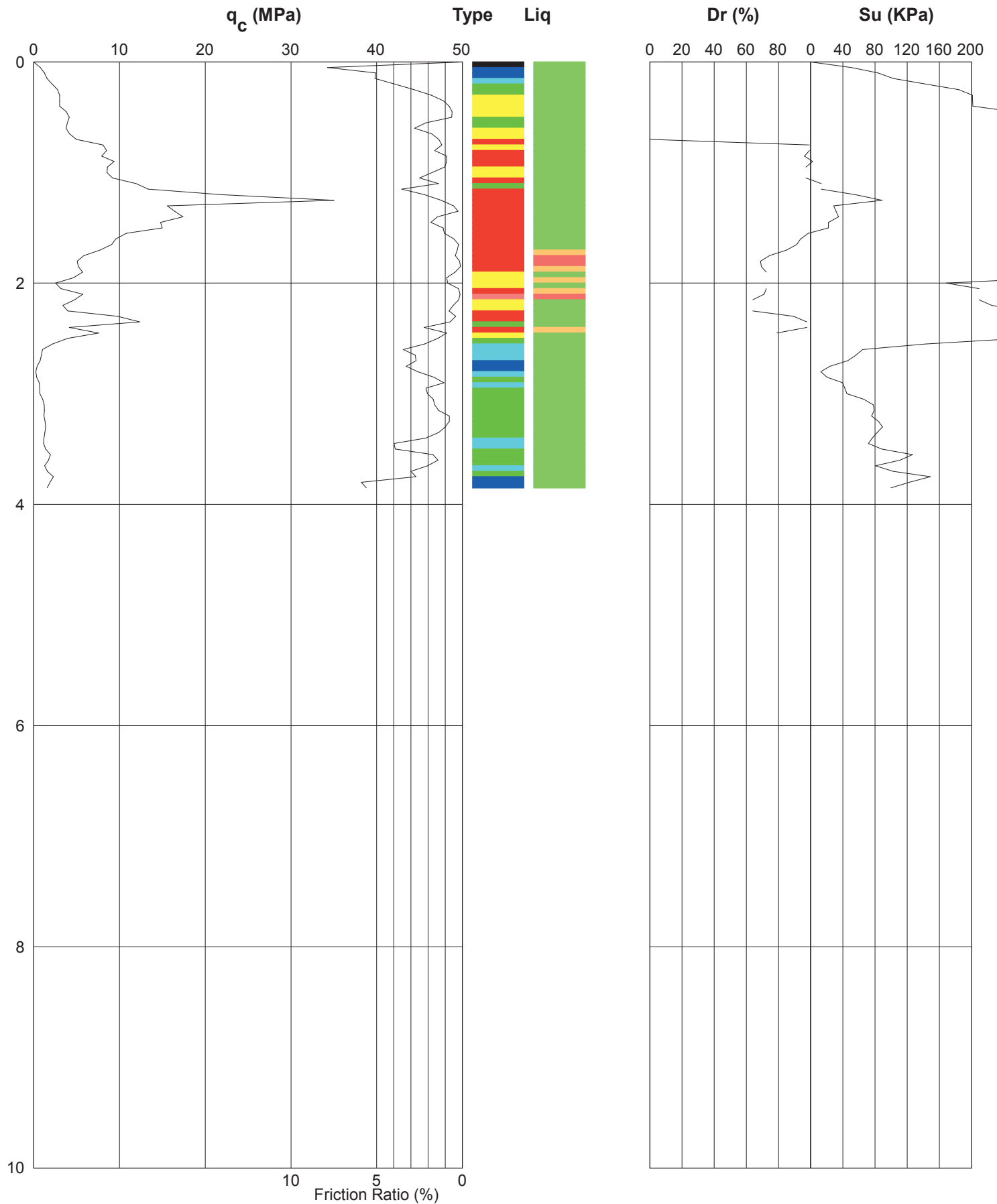
# PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT



Job No: 8200  
 CPT No: CPT025  
 Project: Fulton Hogan Ltd  
 Location: Halswell Junction Rd

Date: 27-10-2010  
 Operator: N Barnes  
 Remark: Effective Refusal

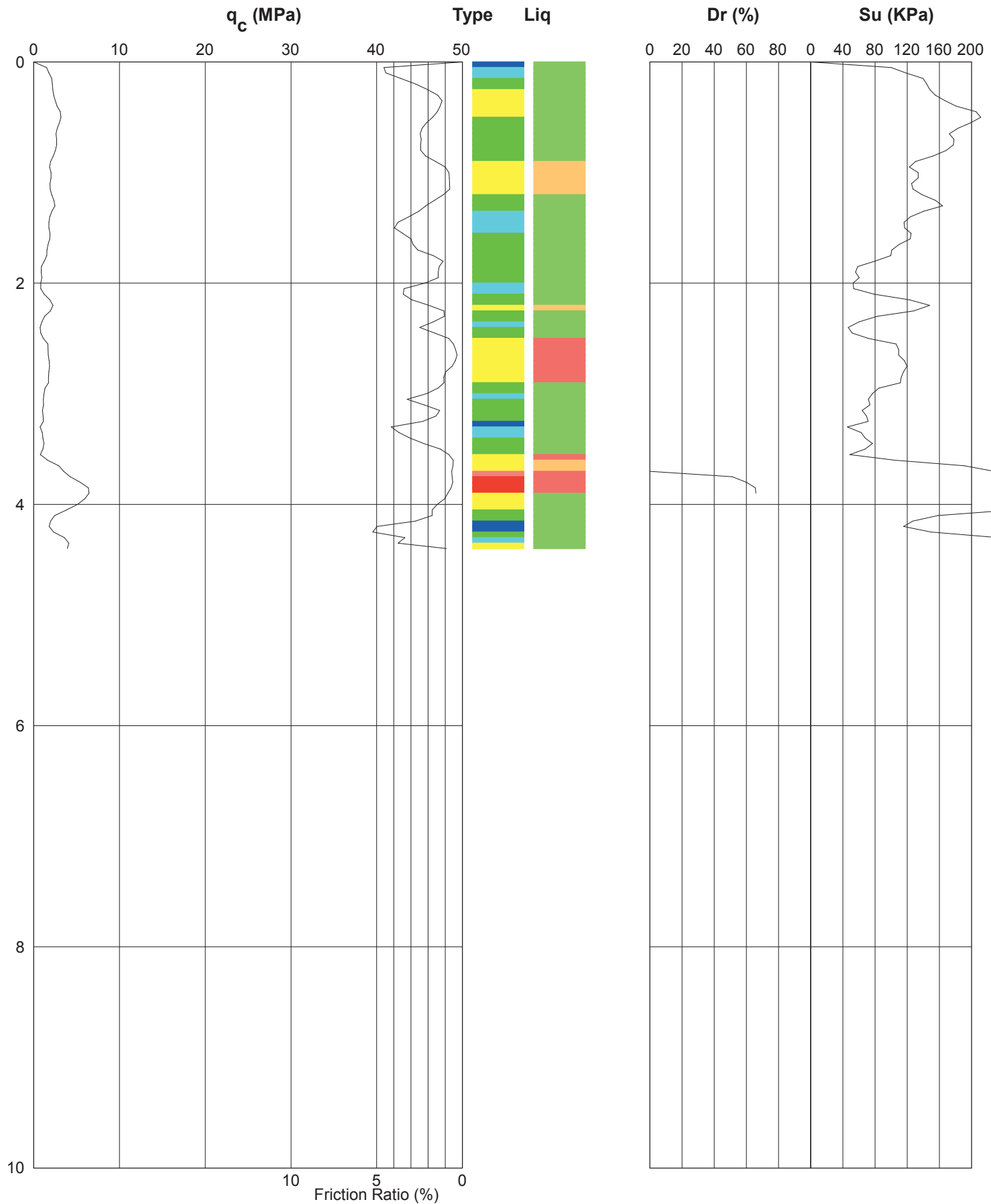
# PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT



Job No: 9308  
 CPT No: CPTu143  
 Project: Aurecon (NZ) Ltd  
 Location: Halswell Junction Rd

Date: 19/09/11  
 Operator: B. Powell  
 Remark: Effective Refusal

# PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT

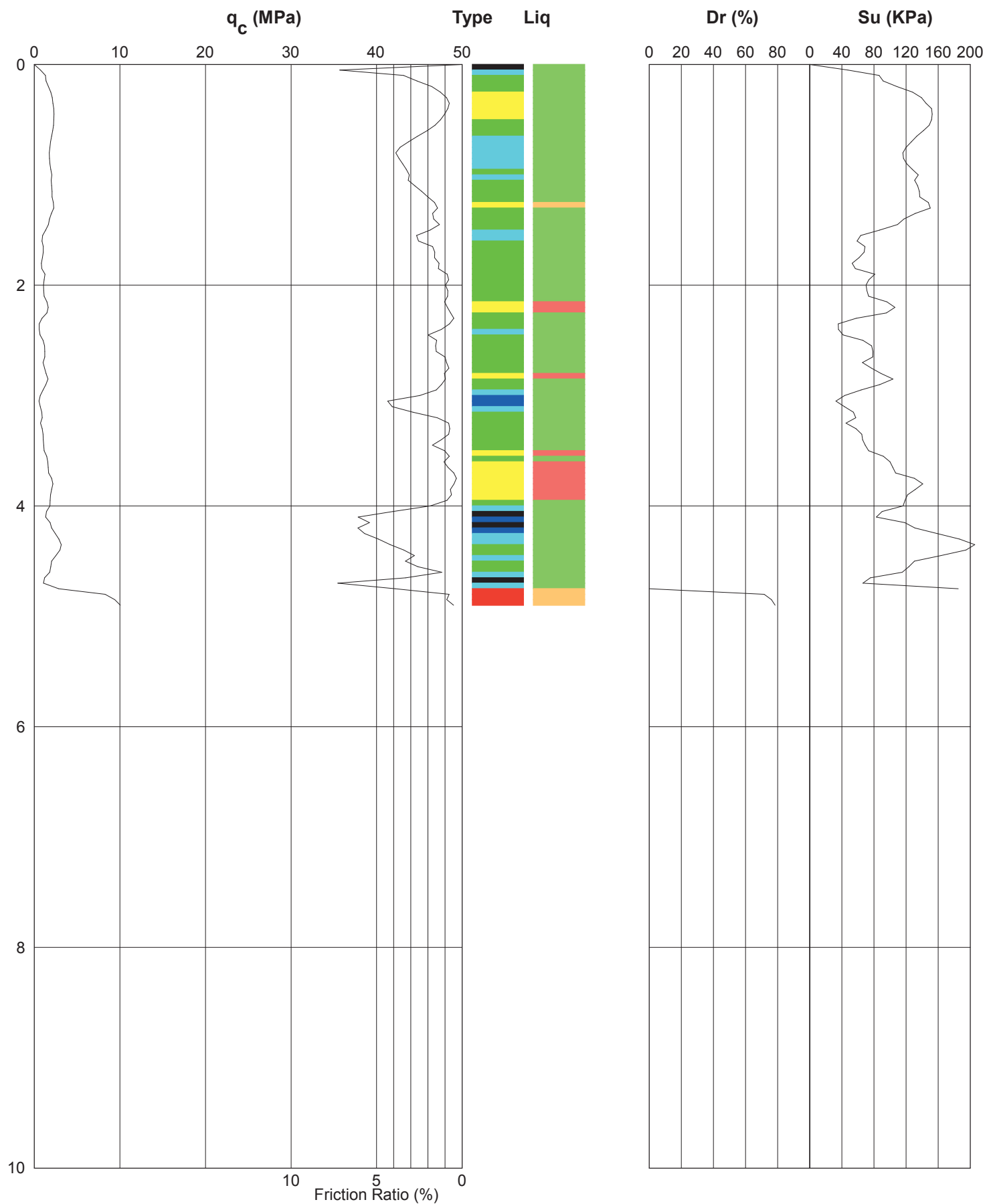


Job No: 9308  
CPT No: CPTu154  
Project: Aurecon (NZ) Ltd  
Location: Halswell Junction Rd

Date: 19/09/11  
Operator: B. Powell  
Remark: Effective Refusal



# PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT



Job No: 9308

CPT No: CPTu158

Project: Aurecon (NZ) Ltd

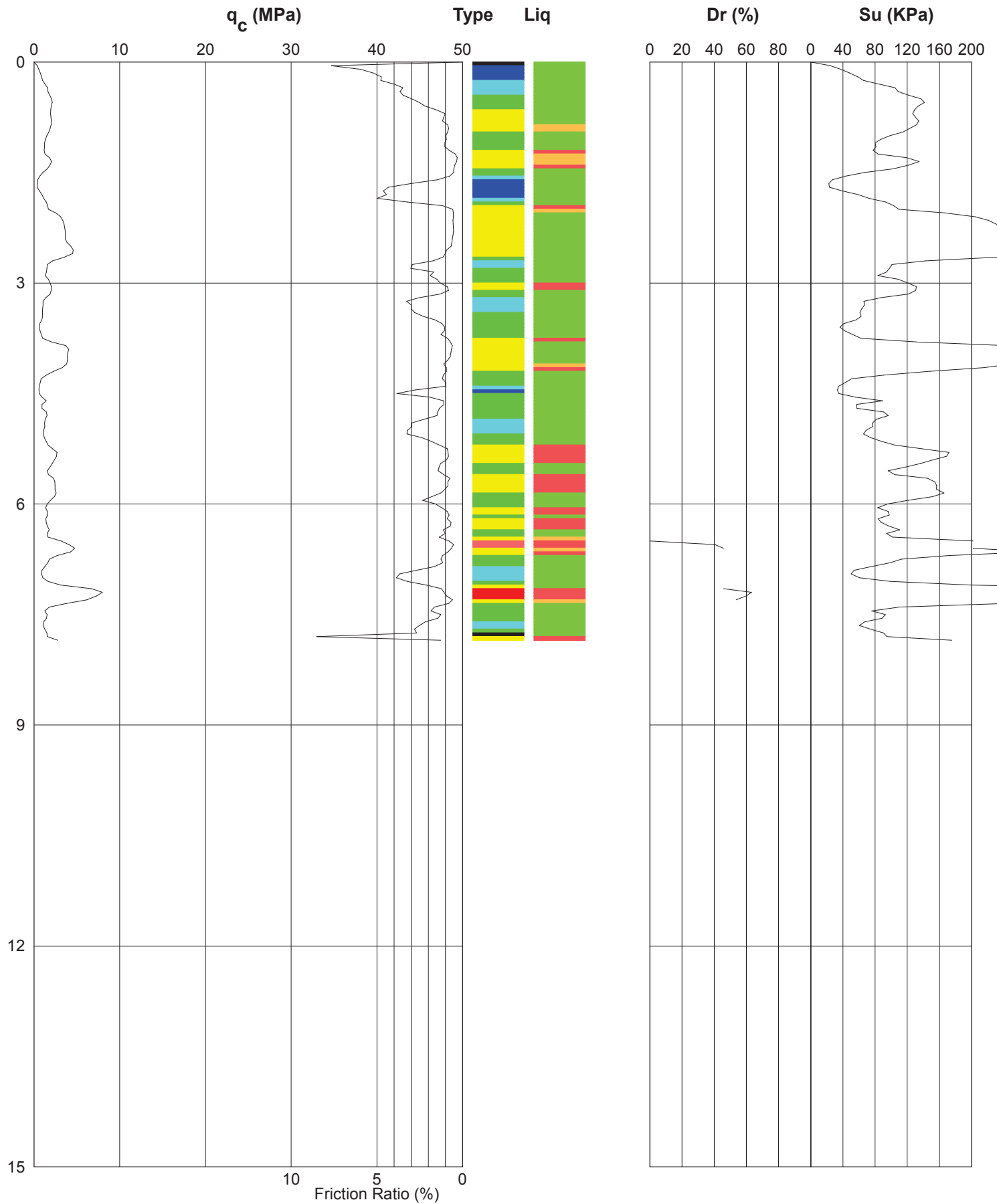
Location: Halswell Junction Rd

Date: 19/09/11

Operator: B. Powell

Remark: Effective Refusal

# PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT



Job No: 10866

CPT No: CPT501

Project: Aurecon NZ Ltd

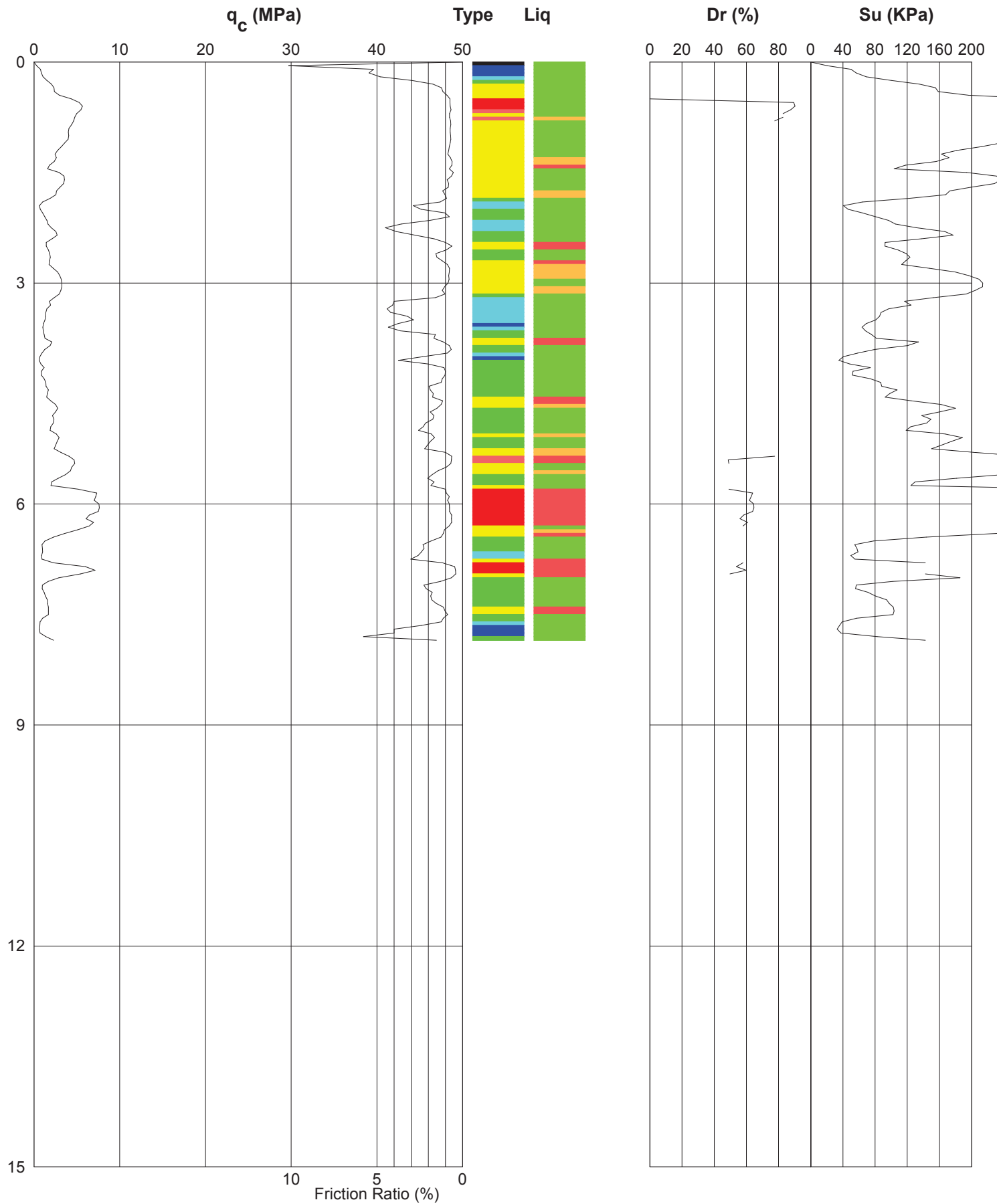
Location: Halswell Junction Road (Fulton Hogan Land Development)

Date: 07/09/2012

Operator: B. Powell

Remark: Effective Refusal

# PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT



Job No: 10866

CPT No: CPT504

Project: Aurecon NZ Ltd

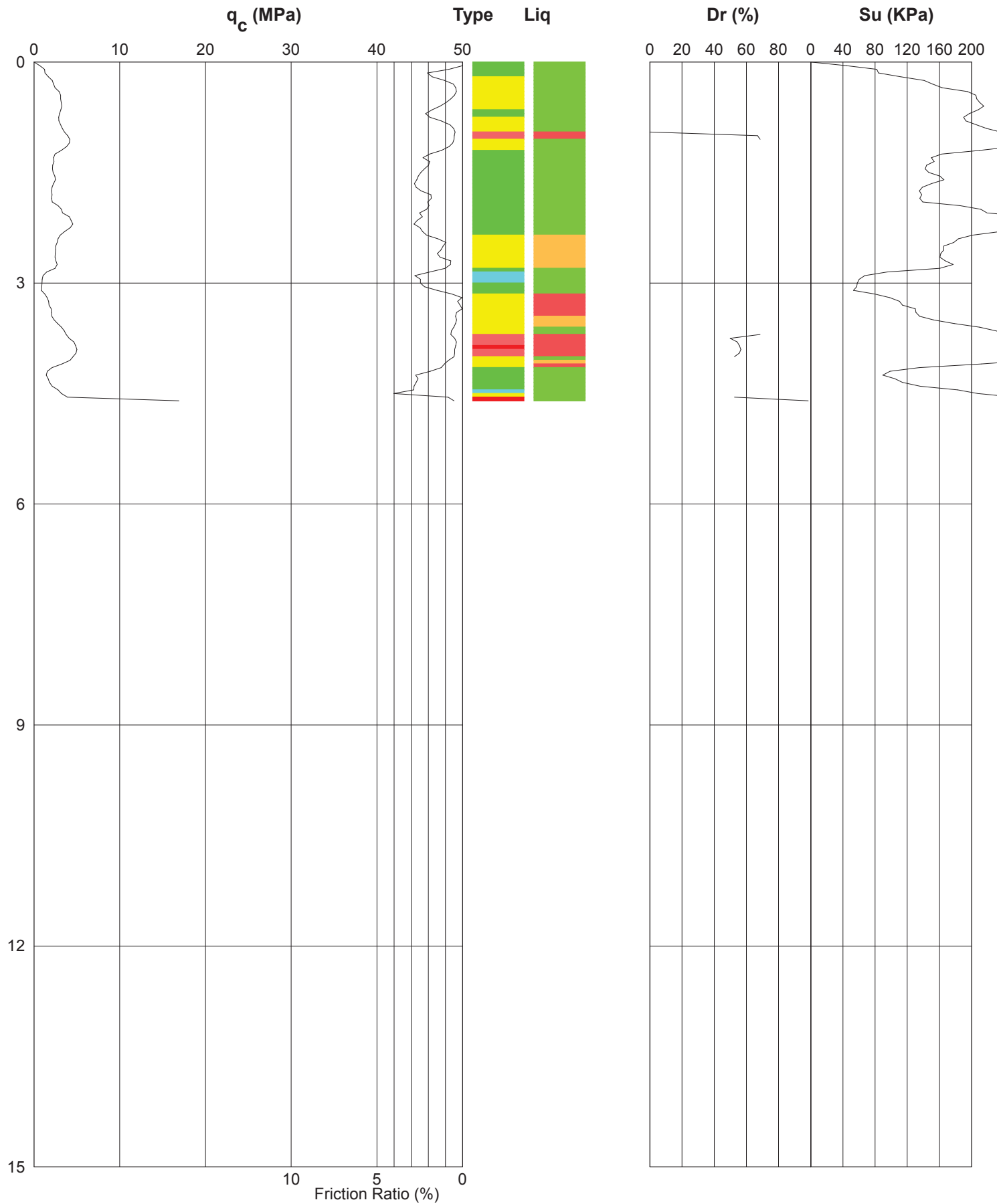
Location: Halswell Junction Road (Fulton Hogan Land Development)

Date: 07/09/2012

Operator: B. Powell

Remark: Effective Refusal

# PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT



Job No: 10866

CPT No: CPT507

Project: Aurecon NZ Ltd

Location: Halswell Junction Rd (Fulton Hogan LD)

Date: 20-7-2012

Operator: S.Cardona





Remark: Effective Refusal



# Appendix D


## Test Pit Logs

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562467 m Northing: 5176130 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5				Shear vane at 0.25m: 116/25kPa Shear vane at 0.35m: 60/16kPa		SILT with trace of rootlets; dark brown; very stiff; dry; low plasticity. (TOPSOIL).	
1.0							
1.5							
2.0						SAND with some Silt; greyish brown; loosely packed; dry to moist. Sand is fine grained and poorly graded.	
2.5							
3.0							
3.5							
4.0							
4.5						GRAVEL with some Sand; tightly packed. Gravel is fine to coarse grained, well graded and rounded to subrounded.  at 2.0m with Cobble inclusions.	
						End of Test Pit at 4.5m (Target Depth Reached)	

Remarks:

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562637 m Northing: 5176076 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5				Shear vane at 0.2m: 140kPa		<p>SILT with trace of rootlets; dark brown; very stiff; dry; low plasticity. (TOPSOIL).</p> <p>Sandy SILT; greyish brown; very stiff; dry to moist; low plasticity. Sand is fine to medium grained and poorly graded.</p> <p>GRAVEL with some Sand; brownish grey; dry. Gravels are fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse and well graded.</p> <p>at 0.9m becomes moist.</p> <p>at 1.8m with Cobble inclusions.</p> <p>at 2.3m becomes some Silt; redish brown mottled.</p> <p>SILT with some Sand; blueish grey with redish brown mottling; moist; moderate plasticity. (Dialant).</p>	
1.0							
1.5							
2.0							
2.5							
3.0							
3.5				Shear vane at 3.5m: 36/16kPa			
4.0							
4.5							

Remarks:



Aurecon (New Zealand) Limited  
Unit 1, 150 Cavendish Rd  
PO BOX 1061  
Christchurch 8140  
New Zealand  
www.aurecongroup.com  
Email: christchurch@ap.aurecongroup.com  
Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955

Client: **Fulton Hogan Land Development Limited**  
Project Name: **Halswell West**  
Location: **Halswell Junction Road**  
Project Reference: **200376**

# TP104

Sheet 2 of 2

#### TEST PIT INFORMATION

Excavator Type: 20 Ton excavator  
Test Pit Dimensions:  
Contractor: Taylors Contracting Co Ltd

#### CO-ORDINATES NZTM

Easting: 1562637 m  
Northing: 5176076 m  
Ground Level: N/A

Date Started: 3/12/2012  
Date Completed: 3/12/2012


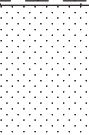


Logged by: TJP  
Input by: TJP  
Checked by: DPM  
Verified by:

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
5.5					x x x x x x x x x x x x	SILT with some Sand; blueish grey with redish brown mottling; moist; moderate plasticity. (Dialant). (Layer Continued from previous page)	
6.0						End of Test Pit at 5.3m (Target Depth Reached)	
6.5							
7.0							
7.5							
8.0							
8.5							
9.0							
9.5							

Remarks:



<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562729 m Northing: 5176002 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5				Shear vane at 0.2m: 50/15kPa		SILT with trace of rootlets; dark brown; very stiff; dry; low plasticity. (TOPSOIL).	
0.70						SAND; greyish brown; loosely packed; moist. Sand is fine to medium grained and poorly graded.	
1.0						GRAVEL with some Sand; browish grey; moist. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
3.40						SILT some Sand; grey with redish brown mottling; saturated; moderate plasitcity. Sand is fine grained and poorly graded. (Dialent)	


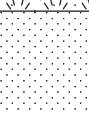



Remarks:

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562729 m Northing: 5176002 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
5.5					x x x x x x x x x x x x x x x x x x	SILT some Sand; grey with redish brown mottling; saturated; moderate plasiticy. Sand is fine grained and poorly graded. (Dialent)( <i>Layer Continued from previous page</i> ) 5.50 End of Test Pit at 5.5m (Target Depth Reached)	
6.0							
6.5							
7.0							
7.5							
8.0							
8.5							
9.0							
9.5							

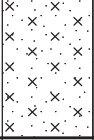
Remarks:

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562669 m Northing: 5175997 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5						SILT with trace of rootlets; dark brown; very stiff; dry; low plasticity. (TOPSOIL).	
						SAND with some Silt; greyish brown; loosely packed; moist. Sand is fine grained and poorly graded.	
1.0						GRAVEL some Sand; greyish brown; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.  at 1.0m to 1.2m redish brown.	
2.5						at 2.5m with Cobble inclusions.	
4.5						Sandy SILT; grey with redish brown mottling; saturated; moderate plasiticy. (Dialent).	


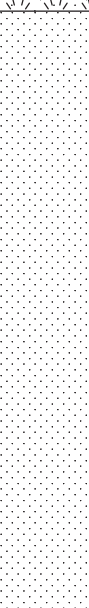

Remarks:  
Piezo Installed

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562669 m Northing: 5175997 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
5.5						Sandy SILT; grey with redish brown mottling; saturated; moderate plasiticy. (Dialent).(Layer Continued from previous page)  End of Test Pit at 5.5m (Target Depth Reached)	
6.0							
6.5							
7.0							
7.5							
8.0							
8.5							
9.0							
9.5							




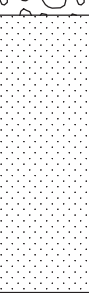

Remarks:  
Piezo Installed

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562539 m Northing: 5176071 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5				Shear vane at 0.35m: 28/18kPa		SILT with trace of rootlets; dark brown; very stiff; dry; low plasticity. (TOPSOIL).	
1.0						SAND with some Silt; greyish brown; loosely packed; dry to moist. Sand is fine grained and poorly graded.	
1.5							
2.0							
2.5						GRAVEL with some Sand; greyish brown; tightly packed; dry to moist. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse and well graded.	
3.0						at 3.0m with Cobble inclusions; moist.	
3.5							
4.0							
4.5							
5.0							







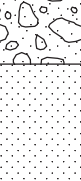


Remarks: End of Test Pit at 5m (Target Depth Reached)

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562443 m Northing: 5176062 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5				Shear vane at 0.3m: 50/16kPa		SILT with some Sand; dark brown; stiff; dry; low plasticity. Sand is fine grained and poorly graded. (TOPSOIL).	
						SAND with some Silt; greyish brown; loosely packed; dry to moist. Sand is fine grained and poorly graded.	
1.0						GRAVEL with some Sand; brownish grey; loosely packed; dry to moist. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
3.0						SAND; brownish grey; loosely packed; moist. Sand is fine to medium grained and poorly graded.	
3.5						at 3.5m with minor organic Peat inclusions and occasional Silt pockets. Peat is amorphous and fibrous. at 3.7m with some Silt.	
4.0						End of Test Pit at 4.1m (Test Pit Wall Collaspe)	
4.5							

Remarks:


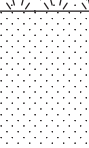

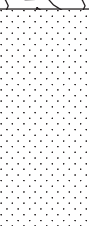

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562576 m Northing: 5176003 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5				Shear vane at 0.2m: 54/23kPa		SILT with trace of rootlets; dark brown; very stiff; dry; low plasticity. (TOPSOIL).	
1.0						SAND with some Silt; greyish brown; loosely packed; dry. Sand is fine grained and poorly graded.	
1.5						GRAVEL with some Sand; greyish brown; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
2.0						Sandy GRAVEL; greyish brown; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
2.5						at 2.3m with occasional Cobbles; moist.	
3.0							
3.5							
4.0						SAND; grey with redish brown staining; loosely packed; moist to wet. Sand is fine to medium grained and poorly graded.	
4.5							

Remarks: End of Test Pit at 5m (Target Depth Reached)



<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562648 m Northing: 5175904 m Ground Level: N/A	Date Started: 3/13/2012 Date Completed: 3/13/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5				Shear vane at 0.2m: 66/18kPa		SILT with some Sand; dark brown; stiff; dry; low plasticity. Sand is fine grained and poorly graded. (TOPSOIL).	
						SAND with some Silt; light brown; loosely packed; dry. Sand is fine to medium grained and poorly graded.	
1.0						GRAVEL some Sand; brownish grey; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse and well graded.	
2.0						at 2.2m brownish red. (Iron staining).	
3.0						SAND some Silt; greyish brown; loosely packed; dry to moist. Sand is fine to medium grained and poorly graded.	
3.5						at 3.5m tree branch 100mm diameter.	
4.0						SILT some Sand; grey with orange brown mottling; firm to stiff; moist; moderate plasticity.	
4.5						End of Test Pit at 4.7m (Maximum achievable depth)	


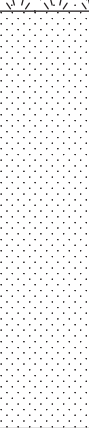

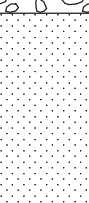

Remarks:

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562516 m Northing: 5175899 m Ground Level: N/A	Date Started: 3/13/2012 Date Completed: 3/13/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5						SILT with some Sand; dark brown; stiff; dry; low plasticity. Sand is fine grained and poorly graded. (TOPSOIL).	
0.80						SAND with some Silt; light brown; loosely packed; dry. Sand is fine to medium grained and poorly graded.	
1.0						GRAVEL with some Sand; brownish grey; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
2.0						at 2.6m to 2.7m lense containing minor Sand; redish brown; moist.	
2.5						at 2.9m to 3.0m lense containing minor sand; redish brown; moist.	
3.0							
3.5							
4.0							
4.5						SILT some Sand; light brown with grey mottling; firm; dry to moist; moderate plasticity.	
5.00							

Remarks: End of Test Pit at 5m (Maximum achievable depth)

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562573 m Northing: 5175772 m Ground Level: N/A	Date Started: 3/13/2012 Date Completed: 3/13/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5						SILT with some Sand; dark brown; stiff; dry; low plasticity. Sand is fine grained and poorly graded. (TOPSOIL).	
1.0						SAND with some Silt; light brown with some orange staining; loosely packed; dry. Sand is fine grained and poorly graded.	
1.5							
2.0						GRAVEL with some Sand greyish brown with pockets of brown; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
2.5						at 2.5m becoming redish brown; moist. Gravel is fine to medium grained and poorly graded.	
3.0						at 2.9m becoming greyish brown. Gravel is fine to coarse grained and well graded.	
3.5							
4.0						SAND with some Silt; light grey; loosely packed; moist. Sand is fine to medium grained and poorly graded.	
4.5						Silty SAND; grey with orange mottling; loosely packed; moist to saturated; low to medium plasticity. Sand is fine grained and poorly graded.	
5.0							

Remarks: End of Test Pit at 5m (Maximum achievable depth)





<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562492 m Northing: 5175904 m Ground Level: N/A	Date Started: 3/13/2012 Date Completed: 3/13/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5						SILT with some Sand; dark brown; stiff; dry; low plasticity. Sand is fine grained and poorly graded. (TOPSOIL).	
1.0						SAND with some Silt; light brown; loosely packed; dry. Sand is fine to medium grained and poorly graded.	
1.5							
2.0						GRAVEL with some sand and occasional Cobble; greyish brown; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse and well graded.	
2.5							
3.0							
3.5							
4.0							
4.5						End of Test Pit at 4.5m (Target Depth Reached)	

Remarks:


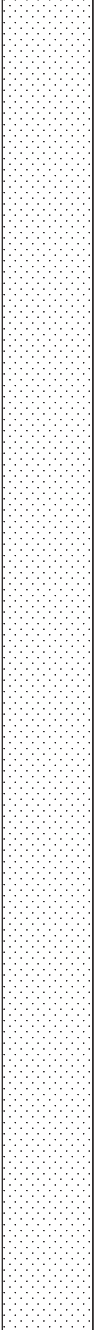
<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562446 m Northing: 5175761 m Ground Level: N/A	Date Started: 3/13/2012 Date Completed: 3/13/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5						SILT with some Sand with pockets of organic Peat; dark brown with pockets of white; stiff; dry; low plasticity. Peat is spongy and amorphous.	
1.0						at 0.8m occasional bone. GRAVEL with some Sand; greyish brown; loosely packed; dry to moist. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
1.5							
2.0						at 1.9m becomes grey; moist.	
2.5							
3.0		▼					
3.5						End of Test Pit at 3.5m (Test Pit Wall Collaspe)	
4.0							
4.5							

Remarks:

On the edge of clear dumping area.

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562262 m Northing: 5175838 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5						SILT with some Sand; dark brown; stiff; dry; low plasticity. Sand is fine grained and poorly graded. (TOPSOIL).	
1.0						SAND with some Silt; light brown; loosely packed; dry; low plasticity. Sand is fine to medium grained and poorly graded.	
1.5							
2.0							
2.5							
3.0						at 3.0m with occasional pockets of Silt; grey with pockets of light grey; soft; moderate plasticity.	
3.5							
4.0							
4.5							

Remarks:





Aurecon (New Zealand) Limited  
Unit 1, 150 Cavendish Rd  
PO BOX 1061  
Christchurch 8140  
New Zealand  
www.aurecongroup.com  
Email: christchurch@ap.aurecongroup.com  
Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955

Client: **Fulton Hogan Land Development Limited**  
Project Name: **Halswell West**  
Location: **Halswell Junction Road**  
Project Reference: **200376**

# TP116

Sheet 2 of 2

#### TEST PIT INFORMATION

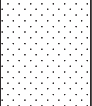
Excavator Type: 20 Ton excavator  
Test Pit Dimensions:  
Contractor: Taylors Contracting Co Ltd

#### CO-ORDINATES NZTM

Easting: 1562262 m  
Northing: 5175838 m  
Ground Level: N/A

Date Started: 3/12/2012  
Date Completed: 3/12/2012

Logged by: TJP  
Input by: TJP  
Checked by: DPM  
Verified by:

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
5.5						SAND with some Silt; light brown; loosely packed; dry; low plasticity. Sand is fine to medium grained and poorly graded. (Layer Continued from previous page)	
6.0						End of Test Pit at 5.4m (Maximum achievable depth)	
6.5							
7.0							
7.5							
8.0							
8.5							
9.0							
9.5							

Remarks:




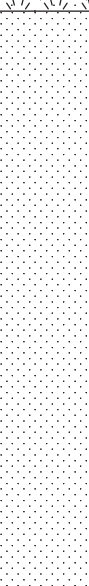

Aurecon (New Zealand) Limited  
Unit 1, 150 Cavendish Rd  
PO BOX 1061  
Christchurch 8140  
New Zealand  
www.aurecongroup.com  
Email: christchurch@ap.aurecongroup.com  
Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955

Client: **Fulton Hogan Land Development Limited**  
Project Name: **Halswell West**  
Location: **Halswell Junction Road**  
Project Reference: **200376**

# TP117



Sheet 1 of 2

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562272 m Northing: 5175942 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5				Shear vane at 0.2m: 55/15kPa		SILT with some Sand; dark brown; very stiff; dry; low plasticity. (TOPSOIL).	
1.0						SAND with some Silt; light brown; loosely packed; dry to moist. Sand is fine grained and poorly graded.	
2.0							
2.5						SILT with some Sand; light brown; firm to stiff; moist; moderate plasticity. Sand is fine grained.	
3.0							
3.5							
4.0							
4.5							


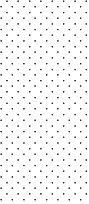


Remarks:

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562272 m Northing: 5175942 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
5.5						SILT with some Sand; light brown; firm to stiff; moist; moderate plasticity. Sand is fine grained. <i>(Layer Continued from previous page)</i>	
5.5						5.50 GRAVEL with some Sand; brownish grey; moist. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and poorly graded.	
6.0						5.80 End of Test Pit at 5.8m (Maximum achievable depth)	
6.5							
7.0							
7.5							
8.0							
8.5							
9.0							
9.5							


Remarks:

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562445 m Northing: 5176006 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5				Shear vane at 0.3m: 55/4kPa		SILT with trace of rootlets; dark brown; very stiff; dry; low plasticity. (TOPSOIL).	
1.0						SAND with some Silt; greyish brown; loosely packed; dry to moist. Sand is fine grained and poorly graded.	
1.5						Sandy GRAVEL; greyish brown; loosely packed; dry to moist. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to medium and poorly graded.	
2.0							
2.5							
3.0							
3.5							
4.0		▼				GRAVEL with some sand; greyish brown; loosely packed; dry to moist. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to medium and poorly graded.	
4.5							


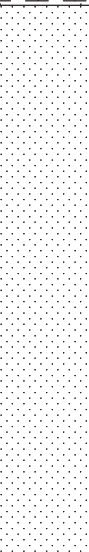

Remarks:

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562445 m Northing: 5176006 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
5.5						End of Test Pit at 5.2m (Target Depth Reached)	
6.0							
6.5							
7.0							
7.5							
8.0							
8.5							
9.0							
9.5							


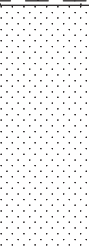




Remarks:

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562355 m Northing: 5175863 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5						SILT with trace of rootlets; dark brown; very stiff; dry; low plasticity. (TOPSOIL).	
1.0						SAND with some Silt; light brown; loosely packed; dry. Sand is fine to medium grained and poorly graded.	
1.5							
2.0							
2.5						Sandy GRAVEL; light greyish brown; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
3.0						GRAVEL some Sand; greyish brown; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
3.5						End of Test Pit at 2.9m (Target Depth Reached)	
4.0							
4.5							

Remarks:

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562448 m Northing: 5175895 m Ground Level: N/A	Date Started: 3/13/2012 Date Completed: 3/13/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5						SILT with some Sand; dark brown; stiff; dry; low plasticity. Sand is fine grained and poorly graded. (TOPSOIL).	
1.0						SAND with some Silt; light brown; loosely packed; dry. Sand is fine to medium grained and poorly graded.	
1.5						SILT with some Sand; brownish grey with redish brown mottling; firm to stiff; dry; low to moderate plasticity.	
2.0						GRAVEL with some Sand; brownish grey; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
3.0						SILT with some Sand; grey with orange mottling; soft to firm; moist; moderate plasticity.	
3.5						End of Test Pit at 4.2m (Target Depth Reached)	
4.0							
4.5							

Remarks:










<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562503 m Northing: 5175997 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5				Shear vane at 0.2m: 51/18kPa		SILT with some Sand; dark brown; stiff; dry; low plasticity. Sand is fine grained and poorly graded. (TOPSOIL).	
						SAND with some Silt; greyish brown; loosely packed. Sand is fine grained and poorly graded.	
1.0						GRAVEL with some Sand minor Cobbles; brownish grey; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
2.0							
2.5							
3.0						at 3.0m becoming moist.	
3.5							
4.0						at 3.7m no Sand or Cobbles. Gravel is fine to medium grained and poorly graded.	
4.5						End of Test Pit at 4.3m (Target Depth Reached)	











Remarks:

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562845 m Northing: 5175883 m Ground Level: N/A	Date Started: 3/13/2012 Date Completed: 3/13/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5						SILT with some Sand; dark brown; stiff; dry; low plasticity. Sand is fine grained and poorly graded. (TOPSOIL).	
						SAND with some Silt; light brown; loosely packed; dry. Sand is fine to medium grained and poorly graded.	
1.0						GRAVEL with some Sand; orangish brown; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
1.5						at 1.1m becomes greyish brown.	
2.0						SILT with some Sand; grey; soft to firm; moist; moderate plasticity.	
2.5						GRAVEL with some Sand; greyish brown; loosely packed; dry to moist. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
						at 2.4m becomes minor Sand and minor organics; dark redish brown. Moist. SILT some Sand; grey with orange mottling. Firm; moist; moderate plasticity.	
3.0							
3.5						End of Test Pit at 3.2m (Test Pit Wall Collaspe)	
4.0							
4.5							






Remarks:

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562758 m Northing: 5175870 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5						SILT with some Sand; dark brown; stiff; dry; low plasticity; sand is fine grained and poorly graded. (TOPSOIL).	
						SAND with some Silt; light brown; loosely packed; dry; sand is fine to medium grained and poorly graded.	
						GRAVEL with some Sand; brownish grey; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
1.0						at 0.8m to 0.9m lense containing minor Sand and minor organics; dark redish brown.	
1.5						at 1.2m with minor Sand and minor organics; dark redish brown. at 1.3m becoming brown.	
2.0							
2.5							
3.0							
3.5						SAND with minor Silt; grey; soft; moist. Sand is fine grained and poorly graded.	
						End of Test Pit at 3.5m (Test Pit Wall Collaspe)	
4.0							
4.5							









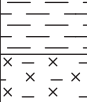

Remarks:

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562762 m Northing: 5175783 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5				Shear vane at 0.2m: 38/10kPa		SILT with some Sand; dark brown; stiff; dry; low plasticity. Sand is fine grained and poorly graded. (TOPSOIL).	
						SAND with some Silt; light brown; loosely packed; dry. Sand is fine to medium grained and poorly graded.	
1.0						GRAVEL with some Sand; grey; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse and well graded.	
1.5						at 1.8m becoming greyish brown.	
2.0							
2.5							
3.0							
3.5						SILT with some sand; grey with orange mottling; firm; dry to moist; moderate plasticity.	
4.0						at 4.2m becoming grey; soft; moist.	
4.5						SAND with some Silt; grey; loosely packed; moist. Sand is fine to medium grained and poorly graded.	
						End of Test Pit at 4.9m (Maximum achievable depth)	

Remarks:

<b>TEST PIT INFORMATION</b> Excavator Type: 20T Excavator Test Pit Dimensions: 3.1 x 3.2m Contractor: Taylors Contracting Co. Ltd.	<b>CO-ORDINATES NZTM</b> Easting: 1563052 m Northing: 5175539 m Ground Level: N/A	Date Started: 3/11/2011 Date Completed: 3/11/2011	Logged by: JC Input by: JC Checked by: DPM Verified by: JK
---	--	--	---

Depth (m)	Sample	Water Level (m)	Graphic Log	Shear Vane Tests	Pocket Penetrometer Tests	Soil Description	Elevation (m)
0.5						Silty CLAY with grass rootlets; dark brown. Firm; dry; low plasticity (TOPSOIL)	
						0.30 Silty fine SAND; dark brownish grey. Loosely packed; moist; poorly graded; silt, firm (SPRINGSTON FORMATION)	
						0.70 Silty CLAY with occasional remains of rootlets; orangish brown mottled light grey. Soft becoming firm; moist; high plasticity (SPRINGSTON FORMATION)	
1.0						1.00 CLAY with occasional organic remains including carbonaceous patches and preserved rootlets; orangish brown mottled pale grey with specks of black and orange iron staining on rootlets. Stiff; moist; low plasticity; friable (SPRINGSTON FORMATION)	
1.5							
2.0							
2.5							
3.0						3.00 Clayey SILT; bluish grey. Soft to firm; wet to saturated; low plasticity (SPRINGSTON FORMATION)	
3.5							
4.0						4.00 End of Test Pit at 4m (at required depth)	
4.5							


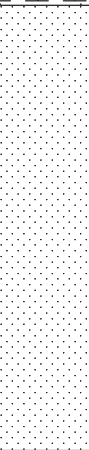

Remarks:

Seepage at 3.0mbgl.  
Some wall collapse below 3.0mbgl.  
No standing water after 10 minutes.

Logged by: JC  
Input by: JC  
Checked by: DPM  
Verified by: JK


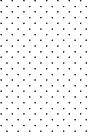



Sheet 1 of 1

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562766 m Northing: 5175696 m Ground Level: N/A	Date Started: 3/13/2012 Date Completed: 3/13/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5						SILT with some Sand; dark brown; stiff; dry; low plasticity. Sand is fine grained and poorly graded. (TOPSOIL).	
1.0						SAND with some Silt; brownish grey; loosely packed; dry. Sand is fine grained and poorly graded.	
1.5							
2.0						GRAVEL with some Sand; brownish grey; loosely packed; dry. Gravel is fine to coarse, well graded and rounded to subrounded. Sand is fine to coarse; well graded. at 2.0m with minor Sand. Gravel is fine to medium grained and poorly graded. Sand is coarse and poorly graded.	
2.5							
3.0						End of Test Pit at 2.6m (Test Pit Wall Collaspe)	
3.5							
4.0							
4.5							

Remarks:


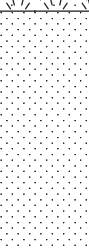


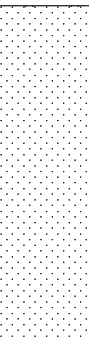
<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562669 m Northing: 5175775 m Ground Level: N/A	Date Started: 3/13/2012 Date Completed: 3/13/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5				Shear vane at 0.2m: 50/10kPa		SILT with some Sand; dark brown; stiff; dry; low plasticity. Sand is fine grained and poorly graded. (TOPSOIL).	
						SAND with some Silt; light brown; loosely packed; dry. Sand is fine to medium grained and poorly graded.	
1.0						GRAVEL with some Sand and occasional Cobbles; greyish brown; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
1.5						SAND with some Silt; light brown; loosely packed; dry. Sand is fine to medium grained and poorly graded.	
2.0						GRAVEL with some Sand occasional Cobbles; greyish brown; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded. at 2.0m to 2.1m lense containing some organics and minor Sand; black; moist.	
2.5							
3.0							
3.5							
4.0						at 3.8m becoming moist.	
4.5						End of Test Pit at 4m (Target Depth Reached)	

Remarks:


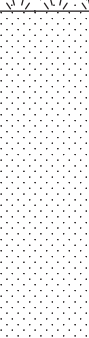




<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562682 m Northing: 5175686 m Ground Level: N/A	Date Started: 3/13/2012 Date Completed: 3/13/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5						SILT with some Sand; dark brown; stiff; dry; low plasticity. Sand is fine grained and poorly graded. (TOPSOIL).	
1.0						SAND with some Silt; light brown; loosely packed; dry. Sand is fine to medium grained and poorly graded.	
1.5						GRAVEL with some Sand; brownish grey; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
2.0						SILT with some Sand; brown; firm to stiff; dry; low to moderate plasticity.	
2.5						SAND with some Silt; brown; loosely packed; dry to moist. Sand is fine to medium grained and poorly graded.	
3.0							
3.5						End of Test Pit at 3.5m (Target Depth Reached)	
4.0							
4.5							









Remarks:  
Piezo installed.

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562776 m Northing: 5175521 m Ground Level: N/A	Date Started: 3/13/2012 Date Completed: 3/13/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5						SILT with some Sand; dark brown; stiff; dry; low plasticity. Sand is fine grained and poorly graded. (TOPSOIL).	
1.0						SAND with some Silt; light brown; loosely packed; dry. Sand is fine to medium grained and poorly graded.	
1.5						GRAVEL with some Sand and occasional Cobbles; brownish grey; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
2.0							
2.5							
3.0						at 2.8m to 2.9m lense containing orange; moist. at 3.0m becoming moist to saturated.	
3.5						End of Test Pit at 3.2m (Target Depth Reached)	
4.0							
4.5							







Remarks:

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562684 m Northing: 5175600 m Ground Level: N/A	Date Started: 3/13/2012 Date Completed: 3/13/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5						SILT with some Sand; dark brown; stiff; dry; low plasticity. Sand is fine grained and poorly graded. (TOPSOIL).	
1.0						GRAVEL with some Sand; brownish grey; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
1.5							
2.0							
2.5							
3.0							
3.5						SILT with some Sand; grey; soft to firm; moist; moderate plasticity.	
4.0						End of Test Pit at 3.7m (Target Depth Reached)	
4.5							




Remarks:

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562590 m Northing: 5175675 m Ground Level: N/A	Date Started: 3/13/2012 Date Completed: 3/13/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5						SILT with some Sand; dark brown; stiff; dry; low plasticity. Sand is fine grained and poorly graded. (TOPSOIL).	
0.5						SAND with some Silt; light brown; loosely packed; dry. Sand is fine to medium grained and poorly graded.	
1.0						GRAVEL with some Sand; grey; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is medium to coarse grained and poorly graded. at 1.0m becoming brownish grey. at 1.2m with occasional Cobbles.	
1.5						SILT with some Sand; orangish brown; firm; dry to moist; moderate plasticity.	
2.0						GRAVEL with some Sand occasional Cobbles; brownish grey; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is medium to coarse grained and poorly graded. at 3.4m becoming moist.	
2.5							
3.0							
3.5							
4.0							
4.5						End of Test Pit at 4.3m (Target Depth Reached)	

Remarks:


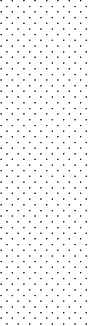

<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562596 m Northing: 5175584 m Ground Level: N/A	Date Started: 3/13/2012 Date Completed: 3/13/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5						0.10 SILT with some Sand; dark brown; stiff; dry; low plasticity. Sand is fine grained and poorly graded. (TOPSOIL). SAND with some Silt; light brown; loosely packed; dry. Sand is fine to medium grained and poorly graded.	
1.0							
1.5						1.50 GRAVEL with some Sand; greyish brown; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
2.0							
2.5							
3.0						2.80 Sandy GRAVEL; greyish brown; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse grained and well graded.	
3.5						at 3.5m becoming moist.	
4.0							
4.5							

Remarks:




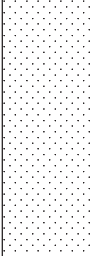


<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562681 m Northing: 5175512 m Ground Level: N/A	Date Started: 3/13/2012 Date Completed: 3/13/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5				Shear vane at 0.2m: 64/12kPa		SILT with some Sand; dark brown; stiff; dry; low plasticity. Sand is fine grained and poorly graded. (TOPSOIL).	
1.0						SAND with some Silt; light brown; loosely packed; dry. Sand is fine grained and poorly graded.	
1.5						GRAVEL with some Sand; greyish brown; loosely packed; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is medium to coarse grained and poorly graded.	
2.0						at 2.5m becoming occasional Cobbles.	
2.5							
3.0							
3.5							
4.0						End of Test Pit at 4m (Test Pit Wall Collaspe)	
4.5							

Remarks:

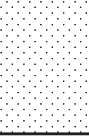
<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562624 m Northing: 5176006 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
0.5						<p>0.10 SILT with some Sand; dark brown; stiff; dry; low plasticity. Sand is fine grained and poorly graded. (TOPSOIL).</p> <p>0.40 GRAVEL with some Sand and occasional shell fragment; brownish grey; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to medium and poorly graded. (Possible Fill).</p> <p>0.90 Silty SAND; greyish brown; loosely packed; dry; low plasticity. Sand is fine grained and poorly graded. (Possible Fill).</p>	
1.0						<p>1.00 GRAVEL with some sand; browish grey; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse and poorly graded. (Possilbe Fill).</p> <p>Sandy GRAVEL with minor Cobble inclusions; browish grey; dry. Gravel is fine to coarse grained, well graded and rounded to subrounded. Sand is fine to coarse and poorly graded. (Possible Fill).</p>	
2.0						at 2.3m metal plow shoe.	
2.5						<p>2.40 SILT with some Sand; grey with redish brown mottling; moist; low plasticity.</p>	
4.0						<p>4.00 SAND with minor Silt; dark grey with orange brown staining; loosely packed. Sand is fine to medium grained and poorly graded.</p>	
4.5							

Remarks:



<b>TEST PIT INFORMATION</b> Excavator Type: 20 Ton excavator Test Pit Dimensions: Contractor: Taylors Contracting Co Ltd	<b>CO-ORDINATES NZTM</b> Easting: 1562624 m Northing: 5176006 m Ground Level: N/A	Date Started: 3/12/2012 Date Completed: 3/12/2012	Logged by: TJP Input by: TJP Checked by: DPM Verified by:
---	--	--	--

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
5.5		▼				SAND with minor Silt; dark grey with orange brown staining; loosely packed. Sand is fine to medium grained and poorly graded. (Layer Continued from previous page)	
6.0						End of Test Pit at 5.5m (Target Depth Reached)	
6.5							
7.0							
7.5							
8.0							
8.5							
9.0							
9.5							

Remarks:

# TEST PIT RECORD

TEST PIT NO. **TP301**

PROJECT NO. **200376**

PROJECT **Knight Stream Park**

METHOD **TP**

CO-ORDINATES (NZTM)

**E 1562495**

**N 5175872**

LOGGED

**K. MA**

CHECKED

**R. SMITH**

MACHINE & NO.

CONTRACTOR

GROUND LEVEL **+18.80** m RL

DATE




**10/16/2014**

DATE

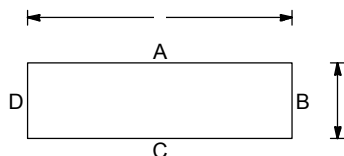
**10/22/2014**

## STRATA

## SAMPLES & TESTS

Depth	Legend	Description	Depth	No	Remarks/Tests
0.00-0.30		<b>Sandy GRAVEL</b> with rootlets; brown to dark brown. "Stiff", clay and slightly moist; gravel is fine to coarse, rounded to subrounded (TOPSOIL/FILL).			
0.30-0.80		<b>SAND</b> ; dark brown. Loose to medium dense; moist; sand is fine (FILL).			
0.80-1.90		<b>GRAVEL</b> with trace to minor sand, trace of corrugated iron sheets and timber pieces; dark brown. Moist; gravel is fine to coarse; rounded (FILL).			
End of Trial pit/trench at 1.90m, on 16/10/2014 Termination Reason: Terminated Due to Inferred Gravel.					

SHORING/SUPPORT: **None**  
STABILITY:



## GENERAL REMARKS

Coordinates approximated from CERA public viewer using post-earthquake aerial imagery (24/12/2011) accurate to +/- 1.0m. Ground level approximated from vertical LiDAR data accurate to +/- 1.0m; based on Lyttelton Vertical Datum. Groundwater was not

All dimensions in metres

CLIENT **Fulton Hogan**

✓ Pocket Penetrometer Test  
✓ Insitu Vane Shear Test

Water Level: **Not** encountered.

# TEST PIT RECORD

TEST PIT NO. **TP302**

PROJECT NO. **200376**

PROJECT **Knight Stream Park**

METHOD **TP**

CO-ORDINATES (NZTM)

**E 1562462**

**N 5175851**

LOGGED

**K. MA**

CHECKED

**R. SMITH**

MACHINE & NO.

CONTRACTOR

GROUND LEVEL **+18.40** m RL

DATE





**10/16/2014**

DATE

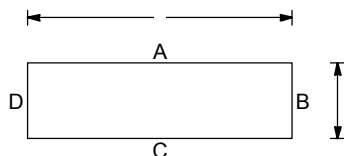
**10/22/2014**

## STRATA

## SAMPLES & TESTS

Depth	Legend	Description	Depth	No	Remarks/Tests
0.00-0.30		<b>Gravelly SAND</b> with trace silt and rootlets; dark brown (TOPSOIL).			
0.30-0.60		<b>Sandy GRAVEL</b> , fine medium, rounded, brown.			
0.60-1.30		<b>SAND</b> ; brown. Loose; moist; sand is fine to medium.			
1.30-1.60		<b>GRAVEL</b> with some fine sand; brow; gravel is fine to coarse; rounded.			
		End of Trial pit/trench at 1.60m, on 16/10/2014 <i>Termination Reason:</i> Terminated Due to Inferred Gravel.			

SHORING/SUPPORT: **None**  
STABILITY:



## GENERAL REMARKS

Coordinates approximated from CERA public viewer using post-earthquake aerial imagery (24/12/2011) accurate to +/- 1.0m. Ground level approximated from vertical LiDAR data accurate to +/- 1.0m; based on Lyttelton Vertical Datum. Groundwater was

All dimensions in metres

CLIENT **Fulton Hogan**

☞ Pocket Penetrometer Test  
☑ Insitu Vane Shear Test

☑ Water encountered at 1.6m bgl.

# TEST PIT RECORD

TEST PIT NO. **TP303**

PROJECT NO. **200376**

PROJECT **Knight Stream Park**

METHOD **TP**

CO-ORDINATES (NZTM)

**E 1562412**

**N 5175832**

LOGGED

**K. MA**

CHECKED

**R. SMITH**

MACHINE & NO.

CONTRACTOR

GROUND LEVEL **+19.00** m RL

DATE

**10/16/2014**

DATE

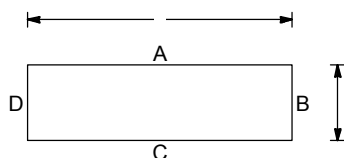
**10/22/2014**

## STRATA

## SAMPLES & TESTS

Depth	Legend	Description	Depth	No	Remarks/Tests
0.00-0.30		<b>SAND</b> with minor silt; dark brown. Dry to moist (TOPSOIL).			
0.30-2.40		<b>SAND</b> ; brown mottled orange. Moist.			
2.40-4.20		<b>Sandy SILT</b> , grey brown. Moist, low plasticity.			
End of Trial pit/trench at 4.20m, on 16/10/2014 <i>Termination Reason:</i> Terminated Due to Inferred Gravel.					

SHORING/SUPPORT: **None**  
STABILITY:



## GENERAL REMARKS

Coordinates approximated from CERA public viewer using post-earthquake aerial imagery (24/12/2011) accurate to +/- 1.0m. Ground level approximated from vertical LiDAR data accurate to +/- 1.0m; based on Lyttelton Vertical Datum. Groundwater was

All dimensions in metres

CLIENT **Fulton Hogan**

☐ Pocket Penetrometer Test  
☑ Insitu Vane Shear Test

☑ Water encountered at 4.2m bgl.

# TEST PIT RECORD

TEST PIT NO. **TP304**

PROJECT NO. **200376**

PROJECT **Knight Stream Park**

METHOD **TP**

CO-ORDINATES (NZTM)

**E 1562414**

**N 5175775**

LOGGED

**K. MA**

CHECKED

**R. SMITH**

MACHINE & NO.

CONTRACTOR

GROUND LEVEL **+18.70** m RL

DATE




**10/16/2014**

DATE

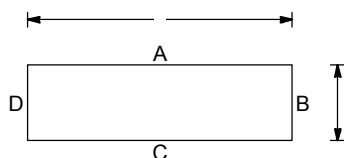
**10/22/2014**

## STRATA

## SAMPLES & TESTS

Depth	Legend	Description	Depth	No	Remarks/Tests
0.00-0.40		<b>SAND</b> with minor silt; dark brown. Dry to moist (TOPSOIL).			
0.40-1.40		<b>SAND</b> ; brown. Loose; moist; sand is fine.			
1.40-2.60		<b>Sandy GRAVEL</b> ; brown. Moist, gravel is fine to medium; rounded.			
		End of Trial pit/trench at 2.60m, on 16/10/2014 <i>Termination Reason:</i> Terminated Due to Inferred Gravel.			

SHORING/SUPPORT: **None**  
STABILITY:



## GENERAL REMARKS

Coordinates approximated from CERA public viewer using post-earthquake aerial imagery (24/12/2011) accurate to +/- 1.0m. Ground level approximated from vertical LiDAR data accurate to +/- 1.0m; based on Lyttelton Vertical Datum. Groundwater was

All dimensions in metres

CLIENT **Fulton Hogan**

Pocket Penetrometer Test  
Insitu Vane Shear Test

Water encountered at 2.6m bgl.

# TEST PIT RECORD

TEST PIT NO. **TP305**

PROJECT NO. **200376**

PROJECT **Knight Stream Park**

METHOD **TP**

CO-ORDINATES (NZTM)

**E 1562369**

**N 5175704**

LOGGED

**K. MA**

CHECKED

**R. SMITH**

MACHINE & NO.

CONTRACTOR

GROUND LEVEL **+19.00** m RL

DATE




**10/16/2014**

DATE

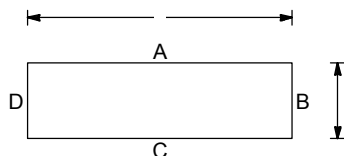
**10/22/2014**

## STRATA

## SAMPLES & TESTS

Depth	Legend	Description	Depth	No	Remarks/Tests
0.00-0.40		<b>SAND</b> with minor silt and rootlets; blackish brown. Moist; sand is fine (TOPSOIL).			
0.40-1.70		<b>SAND</b> with minor silt; brown. Loose; moist to very moist; sand is fine.			
1.70-2.70		<b>Sandy GRAVEL</b> ; greyish brown. Very moist; gravel is fine to medium, rounded.			
<p>End of Trial pit/trench at 2.70m, on 16/10/2014 Termination Reason: Terminated Due to Inferred Gravel.</p>					

SHORING/SUPPORT: **None**  
STABILITY:



## GENERAL REMARKS

Coordinates approximated from CERA public viewer using post-earthquake aerial imagery (24/12/2011) accurate to +/- 1.0m. Ground level approximated from vertical LiDAR data accurate to +/- 1.0m; based on Lyttelton Vertical Datum. Groundwater was

All dimensions in metres

CLIENT **Fulton Hogan**

☞ Pocket Penetrometer Test  
☑ Insitu Vane Shear Test

☑ Water encountered at 2.7m bgl.

# TEST PIT RECORD

TEST PIT NO. **TP306**

PROJECT NO. **200376**

PROJECT **Knight Stream Park**

METHOD **TP**

CO-ORDINATES (NZTM)

**E 1562432**

**N 5175690**

LOGGED

**K. MA**

CHECKED

**R. SMITH**

MACHINE & NO.

CONTRACTOR

GROUND LEVEL **+19.10** m RL

DATE




**10/16/2014**

DATE

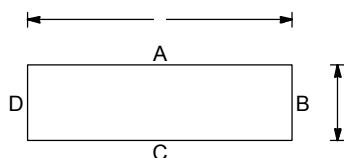
**10/22/2014**

## STRATA

## SAMPLES & TESTS

Depth	Legend	Description	Depth	No	Remarks/Tests
0.00-0.30		<b>SAND</b> with trace silt; dark brown (TOPSOIL).			
0.30-1.40		<b>SAND</b> with minor silt; brown. Loose; moist to very moist; sand is fine.			
1.40-2.80		<b>Sandy GRAVEL</b> ; brownish grey. Vrey moist; gravel is fine to medium; sand is medium to coarse.			
		End of Trial pit/trench at 2.80m, on 16/10/2014 <i>Termination Reason:</i> Terminated Due to Inferred Gravel.			

SHORING/SUPPORT: **None**  
STABILITY:



## GENERAL REMARKS

Coordinates approximated from CERA public viewer using post-earthquake aerial imagery (24/12/2011) accurate to +/- 1.0m. Ground level approximated from vertical LiDAR data accurate to +/- 1.0m; based on Lyttelton Vertical Datum. Groundwater was

All dimensions in metres

CLIENT **Fulton Hogan**

☞ Pocket Penetrometer Test  
☑ Insitu Vane Shear Test

☑ Water encountered at 2.8m bgl.

# TEST PIT RECORD

TEST PIT NO. **TP307**

PROJECT NO. **200376**

PROJECT **Knight Stream Park**

METHOD **TP**

CO-ORDINATES (NZTM)

**E 1562472**

**N 5175621**

LOGGED

**K. MA**

CHECKED

**R. SMITH**

MACHINE & NO.

CONTRACTOR

GROUND LEVEL **+18.80** m RL

DATE




**10/16/2014**

DATE

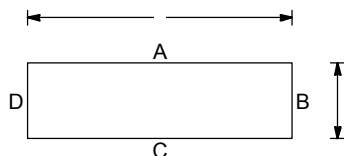
**10/22/2014**

## STRATA

## SAMPLES & TESTS

Depth	Legend	Description	Depth	No	Remarks/Tests
0.00-0.50		<b>SAND</b> with minor silt; dark brown. Dry to moist (TOPSOIL)			
0.50-1.90		<b>SAND</b> with trace of silt; brown. Loose; moist; sand is fine.			
1.90-3.20		<b>Sandy GRAVEL</b> with trace silt and trace rootlets; brownish grey. Moist to wet; gravel is fine to coarse, rounded.			
		End of Trial pit/trench at 3.20m, on 16/10/2014 <i>Termination Reason:</i> Terminated Due to Inferred Gravel.			

SHORING/SUPPORT: **None**  
STABILITY:



## GENERAL REMARKS

Coordinates approximated from CERA public viewer using post-earthquake aerial imagery (24/12/2011) accurate to +/- 1.0m. Ground level approximated from vertical LiDAR data accurate to +/- 1.0m; based on Lyttelton Vertical Datum. Groundwater was

All dimensions in metres

CLIENT **Fulton Hogan**

☞ Pocket Penetrometer Test  
☑ Insitu Vane Shear Test

▼ Water encountered at 3.2m bgl.



# TEST PIT RECORD

TEST PIT NO. **TP308**

PROJECT NO. **200376**

PROJECT **Knight Stream Park**

METHOD **TP**

CO-ORDINATES (NZTM)

**E 1562532**

**N 5175583**

LOGGED

**K. MA**

CHECKED

**R. SMITH**

MACHINE & NO.

CONTRACTOR

GROUND LEVEL **+18.20** m RL

DATE




**10/16/2014**

DATE

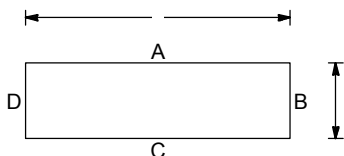
**10/22/2014**

## STRATA

## SAMPLES & TESTS

Depth	Legend	Description	Depth	No	Remarks/Tests
0.00-0.20		<b>SAND</b> with minor silt; dark brown. Dry to moist (TOPSOIL).			
0.20-1.60		<b>SAND</b> ; brown mottled orange. Loose; moist; sand is fine to medium.			
1.60-2.40		<b>Sandy GRAVEL</b> ; grey. sand is medium to coarse; gravel is fine to coarse.			
		End of Trial pit/trench at 2.40m, on 16/10/2014 <i>Termination Reason:</i> Terminated Due to Inferred Gravel.			

SHORING/SUPPORT: **None**  
STABILITY:



## GENERAL REMARKS

Coordinates approximated from CERA public viewer using post-earthquake aerial imagery (24/12/2011) accurate to +/- 1.0m. Ground level approximated from vertical LiDAR data accurate to +/- 1.0m; based on Lyttelton Vertical Datum. Groundwater was

All dimensions in metres

CLIENT **Fulton Hogan**

Pocket Penetrometer Test  
Insitu Vane Shear Test

Water encountered at 2.4m bgl.

# TEST PIT RECORD

TEST PIT NO. **TP309**

PROJECT NO. **200376**

PROJECT **Knight Stream Park**

METHOD **TP**

CO-ORDINATES (NZTM)

**E 1562625**

**N 5175483**

LOGGED

**K. MA**

CHECKED

**R. SMITH**

MACHINE & NO.

CONTRACTOR

GROUND LEVEL **+18.30** m RL

DATE




**10/16/2014**

DATE

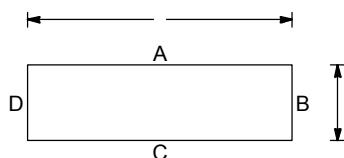
**10/22/2014**

## STRATA

## SAMPLES & TESTS

Depth	Legend	Description	Depth	No	Remarks/Tests
0.00-0.50		<b>SAND</b> with minor silt; dark brown. Dry to moist (TOPSOIL).			
0.50-2.20		<b>SAND</b> ; with trace silt; brown mottled orange. Loose; slightly moist; sand is fine.			
2.20-2.80		<b>Gravelly SAND</b> ; grey. Moist to wet; sand is medium to coarse; gravel is fine to medium, rounded.			
		End of Trial pit/trench at 2.80m, on 16/10/2014 <i>Termination Reason:</i> Terminated Due to Inferred Gravel.			

SHORING/SUPPORT: **None**  
STABILITY:



## GENERAL REMARKS


Coordinates approximated from CERA public viewer using post-earthquake aerial imagery (24/12/2011) accurate to +/- 1.0m. Ground level approximated from vertical LiDAR data accurate to +/- 1.0m; based on Lyttelton Vertical Datum. Groundwater was

All dimensions in metres

CLIENT **Fulton Hogan**

☞ Pocket Penetrometer Test  
☑ Insitu Vane Shear Test

☑ Water encountered at 2.8m bgl.



# Appendix E

## Borehole Logs

# BOREHOLE RECORD

HOLE NO.

BH1

PROJECT NO.

200376

PROJECT **Knights Stream Park. Stage 6&7  
Halswell Junction Road**

METHOD **Direct Push Drilling**

CO-ORDINATES ( )

SHEET **1** of **2**

MACHINE & NO. **9700-D Truck**
**E 1562878**

DATE from **20/11/2012** to **21/11/2012**
**N 5175904**

FLUSHING MEDIUM **Water**

ORIENTATION **VERTICAL**

GROUND-LEVEL m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples Type Ref Depth	Reduced Level	Depth (m)	Legend	STRATA DESCRIPTION SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION, GRADING, BEDDING, PLASTICITY, ETC. (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)
				73							0.00		Silty SAND, brwnish grey, moist, fine to medium (TOPSOIL).
				100				(4, 4, 4, 4, 4, 4) N = 16			0.80		Sandy GRAVEL with occasional cobbles, grey, medium dense, dry, medium to coarse, rounded to subangular; sand, fine to coarse.
				100				(4, 5, 5, 6, 6, 8) N = 25			2.30		2.00m Becomes wet SAND, grey, medium dense, wet, medium to coarse.
				100				(1, 1, 1, 1, 1, 1) N = 4			3.85		3.60m lense of gravel, medium, rounded.
				100				(0, 0, 0, 0, 1, 3) N = 4			4.30		Sandy GRAVEL, grey, wet, medium to coarse, rounded to subangular; sand, medium to coarse.
				100				(0, 0, 0, 0, 1, 9) N = 11			4.50		SAND, grey, wet, fine to medium, liquefies upon tapping.
				100				(3, 9, 11, 10, 10, 15) N = 46			6.60		Silty SAND, brown, loose, wet, fine, liquefies upon tapping.
				100							7.50		Sandy SILT, grey, wet, firm, non plastic; sand, fine, liquefies upon tapping.
				100							7.95		SAND, grey, medium dense, wet, medium, to coarse.
				100							8.25		CLAY, grey, moist, soft, high plascitivity.
				100							8.70		Sandy GRAVEL, grey, wet, medium to coarse, rounded to subangular; sand, medium to coarse.
				100							9.00		Cobbly GRAVEL, grey, wet, coarse, rounded to subangular. Sandy GRAVEL, orangish brown, dense, wet, fine to coarse, rounded to subangular; sand coarse.

- Small Disturbed Sample
- Large Disturbed Sample
- SPT Liner Sample
- Thin Wall Undisturbed Sample
- U100 Undisturbed Sample
- Pocket Penetrometer Test
- Piston Sample
- Water Level
- Impression Packer Test
- Standard Penetration Test
- Permeability Test
- Piezometer / Standpipe Tip
- Packer Test
- In-situ Vane Shear Test

LOGGED **A.PEREIRA**

DATE **21/11/2012**

CHECKED **D. MAHONEY**

DATE **29/11/2012**

## REMARKS

# BOREHOLE RECORD

HOLE NO. **BH1**  
PROJECT NO. **200376**

PROJECT **Knights Stream Park. Stage 6&7  
Halswell Junction Road**

METHOD **Direct Push Drilling**

CO-ORDINATES ( )

SHEET **2** of **2**

MACHINE & NO. **9700-D Truck**
**E 1562878**

DATE from **20/11/2012** to **21/11/2012**
**N 5175904**

FLUSHING MEDIUM **Water**

ORIENTATION **VERTICAL**

GROUND-LEVEL m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples Type Ref Depth	Reduced Level	Depth (m)	Legend	STRATA DESCRIPTION SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION, GRADING, BEDDING, PLASTICITY, ETC. (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)
				100							10.00		
				80				(11, 12, 10, 9, 9, 9) N = 37			10.30		GRAVEL with trace of sand and cobbles, grey, medium dense, wet, medium to coarse, rounded to subangular.
											11.03		Sandy GRAVEL, brownish grey, wet, medium to coarse, rounded to subangular; sand, coarse.
											11.70		
				67				(4, 5, 6, 7, 7, 7) N = 27			12.00		Cobbly GRAVEL with some sand, brownish grey, medium dense, wet, medium to coarse, rounded to subangular; sand, coarse. Sandy GRAVEL with trace of cobbles, grey, fine to coarse, rounded to subangular; sand, coarse.
											13.50		GRAVEL, grey, loose, wet, medium to coarse, rounded.
				73				(4, 3, 2, 2, 2, 2) N = 8			14.10		Sandy GRAVEL, grey, dense, wet, medium to coarse, rounded.
											15.00		
								(5, 9, 8, 8, 7, 10) N = 33					End of DPD at 15.00m, on 21/11/2012 Termination Reason: Target depth reached

- Small Disturbed Sample
- Large Disturbed Sample
- SPT Liner Sample
- Thin Wall Undisturbed Sample
- U100 Undisturbed Sample
- Pocket Penetrometer Test
- Piston Sample
- Water Level
- Impression Packer Test
- Standard Penetration Test
- Permeability Test
- Piezometer / Standpipe Tip
- Packer Test
- In-situ Vane Shear Test

LOGGED **A. PEREIRA**  
DATE **21/11/2012**  
CHECKED **D. MAHONEY**  
DATE **29/11/2012**

## REMARKS

# BOREHOLE RECORD

HOLE NO. **BH2**  
PROJECT NO. **200376**

PROJECT **Knights Stream Park. Stage 6&7  
Halswell Junction Road**

METHOD **Direct Push Drilling**

CO-ORDINATES ( )

SHEET **1** of **2**

MACHINE & NO. **9700-D Truck**

**E 1562802**

DATE from **19/11/2012** to **20/11/2012**

**N 5175793**

FLUSHING MEDIUM **Water**

ORIENTATION **VERTICAL**

GROUND-LEVEL m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	STRATA DESCRIPTION SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION GRADING, BEDDING, PLASTICITY, ETC. (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)
				80					Type Ref Depth		0.00		Silty SAND, brown, moist, fine to medium. (TOPSOIL)
								(6, 9, 7, 6, 5, 6) N = 24			0.95		Sandy GRAVEL, grey, dry, medium to coarse, rounded to subrounded; sand, fine to coarse.
								(1, 1, 1, 1, 0, 1, 0) N = 2			1.50		GRAVEL with trace of cobbles, fine to coarse, grey, medium dense, rounded to subangular.
								(2, 1, 1, 1, 1, 1) N = 4			3.00		Silty SAND with occasional gravel, grey and brown, very loose, wet, fine to medium; gravel, medium, rounded.
				100				(24, 32, 41, 19) N = 60/150 mm			4.50		Silty SAND, brownish grey, loose, wet, fine to medium, liquefies upon tapping.
								(10, 12, 13, 11, 13, 12) N = 49			5.30		CLAY grey with orange mottling, moist, firm, high plasticity.
								(10, 13, 14, 17, 21, 8) N = 60			5.53		Silty SAND, grey, wet, fine to medium.
				80							5.83		Sandy GRAVEL, grey, very dense, wet, fine to medium, rounded to subrounded; sand, medium to coarse.
													6.50m becomes coarse
											8.10		Sandy GRAVEL, brownish grey, very dense, wet, coarse, rounded to subangular; sand coarse.
													9.00m with trace of cobbles

- Small Disturbed Sample
- Large Disturbed Sample
- SPT Liner Sample
- Thin Wall Undisturbed Sample
- U100 Undisturbed Sample
- Pocket Penetrometer Test
- Piston Sample
- Water Level
- Impression Packer Test
- Standard Penetration Test
- Permeability Test
- Piezometer / Standpipe Tip
- Packer Test
- In-situ Vane Shear Test

LOGGED **A. PEREIRA**

DATE **21/11/2012**

CHECKED **D. MAHONEY**

DATE **29/11/2012**

REMARKS

# BOREHOLE RECORD

HOLE NO. **BH2**

PROJECT NO. **200376**

PROJECT **Knights Stream Park. Stage 6&7**  
**Halswell Junction Road**

METHOD **Direct Push Drilling**

CO-ORDINATES ( )

SHEET **2** of **2**

MACHINE & NO. **9700-D Truck**

**E 1562802**

DATE from **19/11/2012** to **20/11/2012**

**N 5175793**

FLUSHING MEDIUM **Water**

ORIENTATION **VERTICAL**

GROUND-LEVEL m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples <small>Type Ref Depth</small>	Reduced Level	Depth (m)	Legend	STRATA DESCRIPTION <small>SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION GRADING, BEDDING, PLASTICITY, ETC. (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)</small>
								(13, 16, 17, 17, 16, 10) N = 60			10.00		
											10.50		End of DPD at 10.50m, on 20/11/2012 Termination Reason: Target depth reached

- Small Disturbed Sample
- Large Disturbed Sample
- SPT Liner Sample
- Thin Wall Undisturbed Sample
- U100 Undisturbed Sample
- Pocket Penetrometer Test
- Piston Sample
- Water Level
- Impression Packer Test
- Standard Penetration Test
- Permeability Test
- Piezometer / Standpipe Tip
- Packer Test
- In-situ Vane Shear Test

LOGGED **A. PEREIRA**

DATE **21/11/2012**

CHECKED **D. MAHONEY**

DATE **29/11/2012**

REMARKS

# BOREHOLE RECORD

HOLE NO. **BH3**  
PROJECT NO. **200376**

PROJECT **Knights Stream Park. Stage 6&7  
Halswell Junction Road**

METHOD **Direct Push Drilling**

CO-ORDINATES ( )

SHEET **1** of **2**

MACHINE & NO. **9700-D Truck**

**E 1562753**

DATE from **09/11/2012** to **09/11/2012**

**N 5175600**

FLUSHING MEDIUM **Water**

ORIENTATION **VERTICAL**

GROUND-LEVEL m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	STRATA DESCRIPTION SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION GRADING, BEDDING, PLASTICITY, ETC. (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)
				87					Type Ref Depth		0.00		Silty SAND, Brown moist. (TOPSOIL)
											0.90		
											1.10		Sandy GRAVEL, grey, moist, medium to coarse, rounded; sand medium to coarse.
											1.45		SAND with some silt, grey, wet, medium to coarse.
				73				(4, 4, 2, 3, 3, 2) N = 10					Sandy GRAVEL with trace of cobbles, grey, loose, moist, fine to coarse, rounded; sand, fine to coarse.
											3.00		
				70				(1, 0, 1, 2, 1, 2) N = 6					Sandy CLAY, grey with orange mottling, soft, wet, high plasticity; sand, fine.
											4.50		
				100				(2, 2, 2, 9, 11, 12) N = 34					SAND brownish grey, dense, wet, medium to coarse.
											4.90		
											5.30		Silty SAND, yellowish brown, wet, fine to medium.
											6.00		Sandy GRAVEL, brownish grey, wet, fine to medium, rounded; sand, fine to medium.
				73				(4, 6, 7, 9, 10, 13) N = 39					GRAVEL, grey, dense, wet, medium to coarse, rounded
											6.75		
													Sandy GRAVEL grey and brown, dense, wet, medium to coarse, rounded; sand medium to coarse.
				93				(4, 4, 6, 7, 11, 12) N = 36					7.50m become coarse with some cobbles
											9.00		
								(9, 8, 8, 9, 10, 16) N = 43					SAND, grey, dense, wet, coarse
				93							9.80		
													Sandy GRAVEL, brownish grey, wet, fine to coarse,

- Small Disturbed Sample
- Large Disturbed Sample
- SPT Liner Sample
- Thin Wall Undisturbed Sample
- U100 Undisturbed Sample
- Pocket Penetrometer Test
- Piston Sample
- Water Level
- Impression Packer Test
- Standard Penetration Test
- Permeability Test
- Piezometer / Standpipe Tip
- Packer Test
- In-situ Vane Shear Test

LOGGED **A. PEREIRA**

DATE **13/11/2012**

CHECKED **D. MAHONEY**

DATE **29/11/2012**

## REMARKS



# BOREHOLE RECORD

HOLE NO.	<b>BH3</b>
PROJECT NO.	<b>200376</b>

PROJECT **Knights Stream Park. Stage 6&7**  
**Halswell Junction Road**

METHOD **Direct Push Drilling**

CO-ORDINATES ( )

SHEET **2** of **2**

MACHINE & NO. **9700-D Truck**

**E 1562753**

DATE from **09/11/2012** to **09/11/2012**

**N 5175600**

FLUSHING MEDIUM **Water**

ORIENTATION **VERTICAL**

GROUND-LEVEL m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples Type Ref Depth	Reduced Level	Depth (m)	Legend	STRATA DESCRIPTION SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION GRADING, BEDDING, PLASTICITY, ETC. (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)
				93				(10, 12, 11, 12, 14, 15) ↓ N = 52			10.00		rounded; sand, coarse.
				63							10.25		GRAVEL, grey, wet, coarse, rounded.
											10.50		Gravelly COBBLES with trace of sand, grey, very dense, wet; gravel, medium to coarse, subrounded; sand, coarse.
								(13, 11, 12, 14, 17) ↓ N = 60			12.00		End of DPD at 12.00m, on 09/11/2012 Termination Reason: Target depth reached

- Small Disturbed Sample
- Large Disturbed Sample
- SPT Liner Sample
- Thin Wall Undisturbed Sample
- U100 Undisturbed Sample
- Pocket Penetrometer Test
- Piston Sample
- Water Level
- Impression Packer Test
- Standard Penetration Test
- Permeability Test
- Piezometer / Standpipe Tip
- Packer Test
- In-situ Vane Shear Test

LOGGED **A. PEREIRA**

DATE **13/11/2012**

CHECKED **D. MAHONEY**

DATE **29/11/2012**

REMARKS

# BOREHOLE RECORD

HOLE NO. **BH4**  
PROJECT NO. **200376**

PROJECT **Knights Stream Park. Stage 6&7  
Halswell Junction Road**

METHOD **Direct Push Drilling**

CO-ORDINATES ( )

SHEET **1** of **2**

MACHINE & NO. **9700-D Truck**

**E 1562789**

DATE from **08/11/2012** to **09/11/2012**

**N 5175476**

FLUSHING MEDIUM **Water**

ORIENTATION **VERTICAL**

GROUND-LEVEL m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	STRATA DESCRIPTION SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION, GRADING, BEDDING, PLASTICITY, ETC. (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)
				80							0.00		Silty SAND, brown, moist. (TOPSOIL)
											0.35		SAND, grey with orange and brown mottling, dry to moist, fine to coarse.
								(2, 1, 2, 1, 0, 2) N = 5			1.25		Sandy SILT, grey, with orange mottling, moist to wet, plastic; sand is fine.
				92							2.30		Silty SAND, grey with orange mottling, moist to wet, fine to medium grained.
								(0, 0, 0, 0, 1, 0) N = 1			3.00		Sandy SILT, brown and orange, wet, low plasticity; sand, fine to medium grained.
				77							3.60		Silty SAND, grey, wet, fine to medium grained, (liquefies upon tapping).
											3.80		SAND with some silt, grey, wet, dense, medium to coarse grained.
								(2, 1, 2, 2, 2, 3) N = 9			4.35		Silty SAND, grey with orange mottling, wet, fine.
				100							4.50		Clayey SAND, brown and orange, loose, moist, fine grained; clay, firm, moist, low plasticity.
											4.75		SAND, grey, wet, fine to coarse grained, (liquefies upon tapping).
											5.15		Silty SAND, grey with orange mottling, wet, fine grained; silt, low plasticity.
											5.40		Sandy GRAVEL, grey and brown, wet, medium to coarse, rounded; Sand, medium to coarse.
				63				(8, 11, 12, 11, 9, 10) N = 42			5.80		Gravel with trace of cobbles, grey, wet, medium to coarse, rounded.
											6.00		Gravelly SAND, grey, dense, wet, coarse; gravel, medium to coarse, rounded.
											6.30		Gravel with trace of cobbles, grey, wet, medium to coarse.
								(28, 23, 33, 21) N = 54/150 mm			7.50		Gravelly SAND, grey, very dense, wet, coarse; gravel, medium to coarse grained, rounded.
											8.25		Sandy GRAVEL with some cobbles grey, dense, wet, medium to coarse, rounded; sand, coarse.
								(4, 5, 9, 13, 11, 12) N = 45			9.20		GRAVEL with trace of sand, grey and brown, wet, medium to coarse, rounded.
				100							9.70		Sandy GRAVEL, brown and grey, wet, medium to coarse,

- Small Disturbed Sample
- Large Disturbed Sample
- SPT Liner Sample
- Thin Wall Undisturbed Sample
- U100 Undisturbed Sample
- Pocket Penetrometer Test
- Piston Sample
- Water Level
- Impression Packer Test
- Standard Penetration Test
- Permeability Test
- Piezometer / Standpipe Tip
- Packer Test
- In-situ Vane Shear Test

LOGGED **A. PEREIRA**

DATE **09/11/2012**

CHECKED **D. MAHONEY**

DATE **29/11/2012**

## REMARKS

2

GROUND-LEVEL m RL

AGS4 BOREHOLE RECORD BH.GPJ AGS 4.GDT 17/12/2012

- LOGGED A. PEREIRA  
DATE 09/11/2012  
CHECKED D. MAHONEY  
DATE 29/11/2012

REMARKS

# BOREHOLE RECORD

HOLE NO. **BH5**  
PROJECT NO. **200376**

PROJECT **Knights Stream Park. Stage 6&7  
Halswell Junction Road**

METHOD **Direct Push Drilling**

CO-ORDINATES ( )

SHEET **1** of **2**

MACHINE & NO. **9700-D Truck**

**E 1562694**

DATE from **05/11/2012** to **05/11/2012**

**N 5175452**

FLUSHING MEDIUM **Water**

ORIENTATION **VERTICAL**

GROUND-LEVEL m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	STRATA DESCRIPTION <small>SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION GRADING, BEDDING, PLASTICITY, ETC. (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)</small>
				90					Type Ref Depth		0.00		
											0.25		Silty SAND, brown, moist, fine to medium grained. (TOPSOIL)
											0.80		SAND, light grey brown, dry do moist, fine to medium.
											1.90		Silty SAND, light grey with orange mottling, moist, non plastic, fine to medium grained.
				63				(1, 0, 0, 1, 0, 0) N = 1			2.25		SAND with trace of silt, grey with orange brown mottling, non plastic, medium grained.
											3.00		SAND with some silt and trace of gravel, grey, moist to wet, fine to medium grained; gravel, fine to medium grained.
				80				(1, 0, 0, 1, 1, 2) N = 4			3.90		Sandy SILT, grey, soft, wet, low to high pasticity
											4.50		Silty SAND, grey with orange mottling, moist, fine to medium grained.
											4.70		SAND, grey, loose, wet, medium grained. Liquefies upon tapping
				87				(1, 0, 1, 2, 2, 2) N = 7			4.90		Clayey SAND, brown greyish, wet, medium grained; clay very soft, wet, highly plastic.
											5.10		SAND, grey, wet, medium grained.
											6.00		GRAVEL with some sand, grey, wet, fine to medium
								(12, 19, 20, 22, 20) N = 62/225 mm			7.00		GRAVEL with some sand and occasional cobble, grey, very dense, wet, medium to coarse, rounded; sand, medium to coarse.
													GRAVEL with traces of cobbles, grey, very dense, wet, rounded.
				73				(14, 15, 21, 22, 25) N = 68/225 mm					
								(6, 10, 22, 26, 29) N = 77/225 mm					9.00m with lenses gravelly sand, sand is fine to coarse
				87									

- Small Disturbed Sample
- Large Disturbed Sample
- SPT Liner Sample
- Thin Wall Undisturbed Sample
- U100 Undisturbed Sample
- Pocket Penetrometer Test
- Piston Sample
- Water Level
- Impression Packer Test
- Standard Penetration Test
- Permeability Test
- Piezometer / Standpipe Tip
- Packer Test
- In-situ Vane Shear Test

LOGGED **A. PEREIRA**

DATE **05/11/2012**

CHECKED **D. MAHONEY**

DATE **29/11/2012**

## REMARKS

# BOREHOLE RECORD

HOLE NO. **BH5**

PROJECT NO. **200376**

PROJECT **Knights Stream Park. Stage 6&7**  
**Halswell Junction Road**

METHOD **Direct Push Drilling**

CO-ORDINATES ( )

SHEET **2** of **2**

MACHINE & NO. **9700-D Truck**

**E 1562694**

DATE from **05/11/2012** to **05/11/2012**

**N 5175452**

FLUSHING MEDIUM **Water**

ORIENTATION **VERTICAL**

GROUND-LEVEL m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples Type Ref Depth	Reduced Level	Depth (m)	Legend	STRATA DESCRIPTION SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION, GRADING, BEDDING, PLASTICITY, ETC. (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)
				87				(9, 9, 8, 9, 10, 11) N = 38			10.00		
				73				(11, 11, 12, 12, 10, 11) N = 45					
				73				(11, 8, 9, 12, 13, 14) N = 48					
				60				(10, 12, 12, 14, 15, 15) N = 56			15.00		
													12.50m Becomes cobbly gravel
													End of DPD at 15.00m, on 05/11/2012 Termination Reason: Target depth reached

- Small Disturbed Sample
- Large Disturbed Sample
- SPT Liner Sample
- Thin Wall Undisturbed Sample
- U100 Undisturbed Sample
- Pocket Penetrometer Test
- Piston Sample
- Water Level
- Impression Packer Test
- Standard Penetration Test
- Permeability Test
- Piezometer / Standpipe Tip
- Packer Test
- In-situ Vane Shear Test

LOGGED **A. PEREIRA**

DATE **05/11/2012**

CHECKED **D. MAHONEY**

DATE **29/11/2012**

## REMARKS

# BOREHOLE RECORD

HOLE NO.

**BH6**

PROJECT NO.

**200376**

PROJECT **Knights Stream Park. Stage 6&7  
Halswell Junction Road**

METHOD **Direct Push Drilling**

CO-ORDINATES ( )

SHEET **1** of **2**

MACHINE & NO. **9700-D Truck**
**E 1562685**

DATE from **12/11/2012** to **12/11/2012**
**N 5175577**

FLUSHING MEDIUM **Water**

ORIENTATION **VERTICAL**

GROUND-LEVEL m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	STRATA DESCRIPTION SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION, GRADING, BEDDING, PLASTICITY, ETC. (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)
				73					Type Ref Depth		0.00		Silty SAND, brown, moist. (TOPSOIL).
											0.50		
				100				(7, 7, 8, 4, 5, 3) N = 20			2.05		Sandy GRAVEL, grey, medium dense, dry, medium to coarse, rounded; sand, medium.
											2.60		SAND, grey, moist medium to coarse.
				100				(2, 1, 2, 1, 0, 1) N = 4			2.95		Gravelly SAND, grey, moist, medium to coarse, rounded; sand, coarse.
											3.40		Sandy GRAVEL, grey, loose moist, medium to coarse rounded; sand, medium to coarse.
											3.65		Silty sandy GRAVEL, brown, wet, medium to coarse, rounded; sand, fine.
											4.00		Silty SAND, brownish grey with orange mottling, wet, fine to medium.
				100				(15, 12, 10, 10, 10, 9) N = 39			4.35		CLAY, grey with orange mottling, moist, very stiff.
											4.50		Sandy GRAVEL, grey, wet, fine to medium, rounded; sand, fine to medium.
											4.80		Gravelly SAND, grey, dense, wet, medium to coarse; gravel, medium to coarse, rounded.
								(11, 19, 22, 25, 19) N = 66/225 mm			6.00		Sandy GRAVEL with traces of cobbles and boulders, grey, wet, fine to coarse, rounded to subangular; sand, medium to coarse.
											6.55		GRAVEL, grey, very dense, wet, coarse.
											7.25		Sandy GRAVEL, grey, wet, medium to coarse, rounded to subangular; sand, medium to coarse.
				100				(9, 7, 9, 10, 11, 11) N = 41			7.50		SAND with some gravel, grey, wet, medium to coarse; gravel, fine to coarse.
											7.80		SAND, grey, dense, wet, medium to coarse.
													GRAVEL with trace of cobbles, brownish grey, wet, fine to coarse, rounded to subangular.
								(16, 18, 19, 18, 21) N = 58/225 mm			9.00		Gravelly SAND, grey, very dense, wet, coarse; gravel, medium to coarse.
				67							9.50		GRAVEL with trace of cobbles, grey, dense, wet, medium to coarse, rounded to subangular.

- Small Disturbed Sample
- Large Disturbed Sample
- SPT Liner Sample
- Thin Wall Undisturbed Sample
- U100 Undisturbed Sample
- Pocket Penetrometer Test
- Piston Sample
- Water Level
- Impression Packer Test
- Standard Penetration Test
- Permeability Test
- Piezometer / Standpipe Tip
- Packer Test
- In-situ Vane Shear Test

LOGGED **A. PEREIRA**

DATE **14/11/2012**

CHECKED **D. MAHONEY**

DATE **29/11/2012**

## REMARKS

# BOREHOLE RECORD

HOLE NO. **BH6**  
PROJECT NO. **200376**

PROJECT **Knights Stream Park. Stage 6&7  
Halswell Junction Road**

METHOD **Direct Push Drilling**

CO-ORDINATES ( )

SHEET **2** of **2**

MACHINE & NO. **9700-D Truck**
**E 1562685**

DATE from **12/11/2012** to **12/11/2012**
**N 5175577**

FLUSHING MEDIUM **Water**

ORIENTATION **VERTICAL**

GROUND-LEVEL m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples Type Ref Depth	Reduced Level	Depth (m)	Legend	STRATA DESCRIPTION SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION, GRADING, BEDDING, PLASTICITY, ETC. (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)
				67							10.00		
								(9, 12, 12, 11, 11, 10) N = 44			10.50		
<p>End of DPD at 10.50m, on 12/11/2012 Termination Reason: Target depth reached</p>													

- ☐ Small Disturbed Sample
- ☐ Large Disturbed Sample
- ☐ SPT Liner Sample
- ☐ Thin Wall Undisturbed Sample
- ☐ U100 Undisturbed Sample
- ☐ Pocket Penetrometer Test
- ☐ Piston Sample

- ☐ Water Level
- ☐ Impression Packer Test
- ☐ Standard Penetration Test
- ☐ Permeability Test
- ☐ Piezometer / Standpipe Tip
- ☐ Packer Test
- ☐ In-situ Vane Shear Test

LOGGED **A. PEREIRA**

DATE **14/11/2012**

CHECKED **D. MAHONEY**

DATE **29/11/2012**

**REMARKS**

# BOREHOLE RECORD

HOLE NO.

BH7

PROJECT NO.

200376

PROJECT **Knights Stream Park. Stage 6&7**  
**Halswell Junction Road**

METHOD **Direct Push Drilling**

CO-ORDINATES ( )

SHEET **1** of **2**

MACHINE & NO. **9700-D Truck**
**E 1562682**

DATE from **13/11/2012** to **13/11/2012**
**N 5175730**

FLUSHING MEDIUM **Water**

ORIENTATION **VERTICAL**

GROUND-LEVEL m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	STRATA DESCRIPTION SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION, GRADING, BEDDING, PLASTICITY, ETC. (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)
				87					Type Ref Depth		0.00		Silty SAND, brown, moist. (TOPSOIL)
											0.40		SAND, brownish grey, dry, moist, medium to coarse grained.
								(7, 4, 5, 3, 5, 5) N = 18			1.10		Sandy GRAVEL, grey, medium dense, dry, rounded, medium to coarse; sand, medium to coarse.  2.20m Becomes moist.
				73							3.00		SAND with trace of gravel, grey, medium dense, wet, medium to coarse grained; gravel, medium to coarse, rounded.
				70				(2, 3, 3, 3, 3, 3) N = 12			3.35		Sandy GRAVEL, grey, wet, medium to coarse, rounded; sand, coarse.
											4.60		SILT with some sand, grey, wet, low plasticity, soft to firm.
				100				(4, 3, 4, 4, 5, 5) N = 18			5.15		Gravelly SAND, yellowish brown, wet, medium, rounded; sand, coarse.
											5.75		Sandy GRAVEL with a trace of cobbles, grey, wet, fine to coarse, rounded to subrounded; sand, coarse.
				73				(4, 6, 5, 6, 5, 6) N = 22			6.00		SAND, brownish grey, medium dense, wet, fine to coarse.
											6.70		GRAVEL, grey, wet, medium to coarse, rounded.
											6.90		Sandy GRAVEL with trace of cobbles, brownish grey, wet, fine to coarse, rounded; sand, coarse.
								(7, 6, 5, 5, 5, 6) N = 21			7.50		SAND, grey, dense, wet, medium to coarse.
				93							8.05		Sandy GRAVEL with trace of cobbles, grey, wet, fine to coarse, rounded; sand, coarse.
								(7, 6, 6, 6, 8, 9) N = 29			9.00		SAND with some silt, brown, medium dense, wet to saturated, fine to medium grained.
				93							9.70		
											9.90		GRAVEL with some sand, grey, wet, medium to coarse,

- Small Disturbed Sample
- Large Disturbed Sample
- SPT Liner Sample
- Thin Wall Undisturbed Sample
- U100 Undisturbed Sample
- Pocket Penetrometer Test
- Piston Sample
- Water Level
- Impression Packer Test
- Standard Penetration Test
- Permeability Test
- Piezometer / Standpipe Tip
- Packer Test
- In-situ Vane Shear Test

LOGGED **A. PEREIRA**

DATE **14/11/2012**

CHECKED **D. MAHONEY**

DATE **29/11/2012**

## REMARKS



# BOREHOLE RECORD

HOLE NO.	<b>BH7</b>
PROJECT NO.	<b>200376</b>

PROJECT **Knights Stream Park. Stage 6&7**  
**Halswell Junction Road**

METHOD **Direct Push Drilling**

CO-ORDINATES ( )

SHEET **2** of **2**

MACHINE & NO. **9700-D Truck**

**E 1562682**

DATE from **13/11/2012** to **13/11/2012**

**N 5175730**

FLUSHING MEDIUM **Water**

ORIENTATION **VERTICAL**

GROUND-LEVEL m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples Type Ref Depth	Reduced Level	Depth (m)	Legend	STRATA DESCRIPTION SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION GRADING, BEDDING, PLASTICITY, ETC. (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)
				93				(11, 10, 11, 16, 19, 22) ↓ N = 68			10.00		rounded to subangular.
				63							10.50		Sandy GRAVEL with trace of cobbles, brownish grey, wet, fine to coarse, rounded to subangular; sand, coarse.
													Sandy GRAVEL, yellowish brown, very dense, wet, fine to medium, rounded; sand, coarse.
													10.65m Becomes coarse and with trace of cobbles.
								(14, 13, 13, 17, 19, 24) ↓ N = 73			12.00		End of DPD at 12.00m, on 13/11/2012 Termination Reason: Target depth reached

- |                              |                            |
|------------------------------|----------------------------|
| • Small Disturbed Sample     | ▼ Water Level              |
| Large Disturbed Sample       | Impression Packer Test     |
| SPT Liner Sample             | Standard Penetration Test  |
| Thin Wall Undisturbed Sample | Permeability Test          |
| U100 Undisturbed Sample      | Piezometer / Standpipe Tip |
| Pocket Penetrometer Test     | Packer Test                |
| Piston Sample                | ✓ In-situ Vane Shear Test  |

LOGGED **A. PEREIRA**

DATE **14/11/2012**

CHECKED **D. MAHONEY**

DATE **29/11/2012**

## REMARKS

# BOREHOLE RECORD

HOLE NO. **BH8**  
PROJECT NO. **200376**

PROJECT **Knights Stream Park. Stage 6&7  
Halswell Junction Road**

METHOD **Direct Push Drilling**

CO-ORDINATES ( )

SHEET **1** of **2**

MACHINE & NO. **9700-D Truck**
**E 1562744**

DATE from **15/11/2012** to **19/11/2012**
**N 5175892**

FLUSHING MEDIUM **Water**

ORIENTATION **VERTICAL**

GROUND-LEVEL m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	STRATA DESCRIPTION SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION, GRADING, BEDDING, PLASTICITY, ETC. (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)
									Type Ref Depth		0.00		
													Silty SAND, brown, wet, fine (TOPSOIL).
											0.40		SAND, grey, moist, fine to coarse.
											1.10		
								(6, 7, 8, 7, 7, 8) N = 30			2.05		Sandy GRAVEL with trace of cobbles, grey, medium dense, moist, medium to coarse, rounded to subangular; sand, medium to coarse.
											3.00		GRAVEL, grey, moist, medium to coarse, rounded to subrounded.
								(2, 1, 1, 1, 1, 1) N = 4			3.30		Silty CLAY, browns, wet, soft, low plasticity.
											3.80		SILT, grey with orange mottling, moist, very stiff, low plasticity, .
											4.40		SAND, grey, wet, medium to coarse.
								(2, 3, 1, 2, 1, 1) N = 5			5.43		Silty SAND, grey, loose, wet, fine.
											5.53		SAND, grey, wet, medium to coarse.
								(2, 2, 2, 3, 3, 4) N = 12					Silty SAND grey, medium dense, wet, fine.
											7.50		
								(1, 3, 7, 14, 18, 21) N = 60					Silty SAND with some gravel, grey, very dense, wet, fine to coarse; silt, non plastic; gravel, coarse.
											9.00		
								(19, 15, 11, 8, 6, 6) N = 31			9.50		Sandy GRAVEL, grey, dense, wet, fine to medium, rounded to subangular.
													GRAVEL with some sand, brownish grey, wet, medium to coarse. 9.80m becomes coarse with cobbles
<div> <div> <div>Small Disturbed Sample</div> <div>Large Disturbed Sample</div> <div>SPT Liner Sample</div> <div>Thin Wall Undisturbed Sample</div> <div>U100 Undisturbed Sample</div> <div>Pocket Penetrometer Test</div> <div>Piston Sample</div> </div> <div> <div>Water Level</div> <div>Impression Packer Test</div> <div>Standard Penetration Test</div> <div>Permeability Test</div> <div>Piezometer / Standpipe Tip</div> <div>Packer Test</div> <div>In-situ Vane Shear Test</div> </div> </div>													REMARKS  LOGGED <b>A. PEREIRA</b> DATE <b>21/11/2012</b> CHECKED <b>D. MAHONEY</b> DATE <b>29/11/2012</b>

# BOREHOLE RECORD

HOLE NO. **BH8**  
PROJECT NO. **200376**

PROJECT **Knights Stream Park. Stage 6&7  
Halswell Junction Road**

METHOD **Direct Push Drilling**

CO-ORDINATES ( )

SHEET **2** of **2**

MACHINE & NO. **9700-D Truck**
**E 1562744**

DATE from **15/11/2012** to **19/11/2012**
**N 5175892**

FLUSHING MEDIUM **Water**

ORIENTATION **VERTICAL**

GROUND-LEVEL m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/end	Water Recovery % Total core	Water Recovery % Solid core	R.Q.D.	Fracture Index	Tests	Samples			Reduced Level	Depth (m)	Legend	STRATA DESCRIPTION SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION GRADING, BEDDING, PLASTICITY, ETC.... (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)
								Type	Ref	Depth				
							(13, 20, 13, 12, 9, 9) ↓ N = 43				10.00		10.20m becomes redish brown	
											10.50		Sandy GRAVEL, brownish grey, dense, wet, medium ro coarse, rounded to subangular; sand, medium to coarse.	
											11.63		GRAVEL with some bolders, grey, wet, coarse.	
							(14, 10, 13, 15, 12, 12) ↓ N = 52				12.00		Sandy GRAVEL, grey, very dense, wet, medium to coarse, rounded to subangular; sand medium to coarse.	
											12.75		COBBLES with some bolders, grey, wet, rounded to subangular.	
											13.50		GRAVEL, grey, dense, wet, coarse, rounded.	
							(12, 13, 10, 11, 13, 16) ↓ N = 50				13.85		Sandy GRAVEL, brownish grey, very dense, wet, medium to coarse, rounded to subangular; sand, medium to coarse.	
							(17, 22, 20, 17, 50) ↓ N = 87/225 mm				15.00		End of DPD at 15.00m, on 19/11/2012 Termination Reason: Target depth reached	
<div><div><div><div>•</div><div>Small Disturbed Sample</div></div><div><div>▬</div><div>Large Disturbed Sample</div></div><div><div>▬</div><div>SPT Liner Sample</div></div><div><div>▬</div><div>Thin Wall Undisturbed Sample</div></div><div><div>▬</div><div>U100 Undisturbed Sample</div></div><div><div>▬</div><div>Pocket Penetrometer Test</div></div><div><div>▬</div><div>Piston Sample</div></div></div><div><div><div>▼</div><div>Water Level</div></div><div><div>▬</div><div>Impression Packer Test</div></div><div><div>▬</div><div>Standard Penetration Test</div></div><div><div>▬</div><div>Permeability Test</div></div><div><div>▬</div><div>Piezometer / Standpipe Tip</div></div><div><div>▬</div><div>Packer Test</div></div><div><div>▬</div><div>In-situ Vane Shear Test</div></div></div></div> <div>LOGGED <u>A. PEREIRA</u></div> <div>DATE <u>21/11/2012</u></div> <div>CHECKED <u>D. MAHONEY</u></div> <div>DATE <u>29/11/2012</u></div> <div>REMARKS</div>														

LOGGED **A. PEREIRA**  
DATE **21/11/2012**  
CHECKED **D. MAHONEY**  
DATE **29/11/2012**

REMARKS

# BOREHOLE RECORD

HOLE NO. **BH9**  
PROJECT NO. **200376**

PROJECT **Knights Stream Park. Stage 6&7  
Halswell Junction Road**

METHOD **Direct Push Drilling**

CO-ORDINATES ( )

SHEET **1** of **2**

MACHINE & NO. **9700-D Truck**

**E 1562634  
N 5175967**

DATE from **14/11/2012** to **15/11/2012**

FLUSHING MEDIUM **Water**

ORIENTATION **VERTICAL**

GROUND-LEVEL m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples Type Ref Depth	Reduced Level	Depth (m)	Legend	STRATA DESCRIPTION SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION, GRADING, BEDDING, PLASTICITY, ETC. (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)
				80							0.00		Silty SAND, brown, moist, fine to medium (TOPSOIL).
											0.70		
											1.00		Sandy GRAVEL, grey, moist, medium to coarse, rounded to subangular; sand, fine to coarse.
													GRAVEL, grey, very dense, moist, medium to coarse, rounded.
				100				(12, 15, 15, 17, 19) N = 51/225 mm			2.10		
											2.50		Sandy GRAVEL, grey, moist, fine to coarse, rounded to subangular; sand, coarse.
													GRAVEL, grey, loose, moist, medium to coarse, rounded to subangular.
				100				(3, 1, 3, 2, 2, 2) N = 9			3.40		
											3.52		Silty sandy GRAVEL, brownish grey with orange mottling, fine to medium rounded; sand, medium to coarse; silt, non plastic.
											3.95		CLAY with trace of sand, grey with orange mottling, moist, very stiff, low plasticity.
				100				(2, 1, 2, 2, 2, 2) N = 8			4.45		Silty SAND, grey with orange mottlin, moist, fine to medium; silt non plastic.
											5.00		SAND, brownish grey, loose, moist, fine to medium.
											5.60		Sandy SILT, grey with orange mottling, moist, non plastic; sand, fine.
				100				(1, 2, 1, 2, 1, 1) N = 5					SAND, grey with orange mottling, loose, moist, fine.
											7.65		6.00m Becomes grey and wet
				100				(1, 1, 1, 1, 1, 1) N = 4					CLAY, grey, moist, soft, high plasticity.
											8.20		SAND, grey, loose, wet, fine.
				100				(2, 2, 1, 1, 1, 1) N = 4					9.75m pieces of wood
<div> <ul style="list-style-type: none"> <li>Small Disturbed Sample</li> <li>Large Disturbed Sample</li> <li>SPT Liner Sample</li> <li>Thin Wall Undisturbed Sample</li> <li>U100 Undisturbed Sample</li> <li>Pocket Penetrometer Test</li> <li>Piston Sample</li> </ul> </div> <div> <ul style="list-style-type: none"> <li>Water Level</li> <li>Impression Packer Test</li> <li>Standard Penetration Test</li> <li>Permeability Test</li> <li>Piezometer / Standpipe Tip</li> <li>Packer Test</li> <li>In-situ Vane Shear Test</li> </ul> </div>													<div>LOGGED <b>A. PEREIRA</b></div> <div>DATE <b>21/11/2012</b></div> <div>CHECKED <b>D. MAHONEY</b></div> <div>DATE <b>29/11/2012</b></div>
REMARKS													

# BOREHOLE RECORD

HOLE NO. **BH9**  
PROJECT NO. **200376**

PROJECT **Knights Stream Park. Stage 6&7  
Halswell Junction Road**

METHOD **Direct Push Drilling**

CO-ORDINATES ( )

SHEET **2** of **2**

MACHINE & NO. **9700-D Truck**
**E 1562634**

DATE from **14/11/2012** to **15/11/2012**
**N 5175967**

FLUSHING MEDIUM **Water**

ORIENTATION **VERTICAL**

GROUND-LEVEL m RL

STRATA DESCRIPTION														
SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION, GRADING, BEDDING, PLASTICITY, ETC... (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)														
Drilling Progress	Casing depth/size	Water level (m) shift start/end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples			Reduced Level	Depth (m)	Legend
									Type	Ref	Depth			
				100									10.00	
				100				(3, 2, 2, 1, 2, 3) N = 8					10.90	
				67				(12, 9, 14, 10, 11, 8) N = 43					12.00	Sandy GRAVEL, grey, wet, coarse, rounded to subrounded. 11.10m becomes brownish grey and with cobbles
				100				(2, 2, 1, 2, 2, 1) N = 6					12.75	GRAVEL, grey, dense, wet, coarse, rounded to subrounded.
								(15, 19, 21, 26, 28) N = 75/225 mm					15.00	Sandy GRAVEL, grey, loose, wet, fine to coarse, rounded to subangular; sand, medium to coarse.  13.50m becomes dense
														End of DPD at 15.00m, on 15/11/2012 Termination Reason: Target depth reached
<div><div><div><div>Small Disturbed Sample</div><div>Large Disturbed Sample</div><div>SPT Liner Sample</div><div>Thin Wall Undisturbed Sample</div><div>U100 Undisturbed Sample</div><div>Pocket Penetrometer Test</div><div>Piston Sample</div></div><div><div>Water Level</div><div>Impression Packer Test</div><div>Standard Penetration Test</div><div>Permeability Test</div><div>Piezometer / Standpipe Tip</div><div>Packer Test</div><div>In-situ Vane Shear Test</div></div></div><div>LOGGED <b>A. PEREIRA</b> DATE <b>21/11/2012</b> CHECKED <b>D. MAHONEY</b> DATE <b>29/11/2012</b></div><div>REMARKS</div></div>														

# BOREHOLE RECORD

HOLE NO. **BH10**  
PROJECT NO. **200376**

PROJECT **Knights Stream Park. Stage 6&7  
Halswell Junction Road**

METHOD **Direct Push Drilling**

CO-ORDINATES ( )

SHEET **1** of **2**

MACHINE & NO. **9700-D Truck**

**E 1562482**

DATE from **13/11/2012** to **14/11/2012**

**N 5175765**

FLUSHING MEDIUM **Water**

ORIENTATION **VERTICAL**

GROUND-LEVEL m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples	Reduced Level	Depth (m)	Legend	STRATA DESCRIPTION <small>SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION GRADING, BEDDING, PLASTICITY, ETC. (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)</small>
				90					Type Ref Depth		0.00		Silty SAND, brown, moist, fine. (TOPSOIL)
											0.73		
											0.90		SAND, grey, dry, fine to medium
													GRAVEL with some sand and trace of cobbles, grey, dry, medium to coarse, rounded to subangular; sand, fine to coarse; cobbles, subangular.
				100				(11, 12, 13, 13, 11, 13) N = 50			1.50		Sandy GRAVEL, light grey, dense, dry, fine to coarse, rounded to subangular; sand, medium to coarse.
													2.10m Become moist
				93				(3, 4, 7, 10, 10, 9) N = 36					3.50m Become wet and medium dense
				100				(2, 5, 7, 9, 11, 11) N = 38					
											5.25		
											5.35		SAND, yellowish grey, wet, medium.
											5.50		Silty SAND, grey wet medium to coarse; silt grey with orange mottling, firm, low plasticity.
								(5, 4, 4, 4, 4, 5) N = 17					GRAVEL, grey, wet, medium to coarse, rounded.
													Sandy GRAVEL, grey, medium dense, wet, medium to coarse, rounded; sand brown, medium to coarse.
													5.70m Become with trace of cobbles
											7.50		
				70				(11, 12, 18, 19, 24) N = 61/225 mm			7.80		Gravelly SAND, grey, very dense, wet, medium to coarse; gravel, medium to coarse, rounded to subangular.
													GRAVEL, grey, wet, medium to coarse, rounded to subangular.
													8.15m Became cobbly
											9.00		
				100				(9, 11, 14, 18, 21) N = 53/225 mm			9.90		Sandy GRAVEL with trace of cobbles, grey, very dense, wet, medium to coarse, rounded to subangular; sand, coarse.

- Small Disturbed Sample
- Large Disturbed Sample
- SPT Liner Sample
- Thin Wall Undisturbed Sample
- U100 Undisturbed Sample
- Pocket Penetrometer Test
- Piston Sample
- Water Level
- Impression Packer Test
- Standard Penetration Test
- Permeability Test
- Piezometer / Standpipe Tip
- Packer Test
- In-situ Vane Shear Test

LOGGED **A. PEREIRA**

DATE **20/11/2012**

CHECKED **D. MAHONEY**

DATE **29/11/2012**

## REMARKS

# BOREHOLE RECORD

HOLE NO. **BH10**

PROJECT NO. **200376**

PROJECT **Knights Stream Park. Stage 6&7  
Halswell Junction Road**

METHOD **Direct Push Drilling**

CO-ORDINATES ( )

SHEET **2** of **2**

MACHINE & NO. **9700-D Truck**
**E 1562482**

DATE from **13/11/2012** to **14/11/2012**
**N 5175765**

FLUSHING MEDIUM **Water**

ORIENTATION **VERTICAL**

GROUND-LEVEL m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples <small>Type Ref Depth</small>	Reduced Level	Depth (m)	Legend	STRATA DESCRIPTION <small>SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION GRADING, BEDDING, PLASTICITY, ETC. (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)</small>
				100							10.00		
								(9, 11, 8, 7, 8, 8) N = 31			10.50		Cobbly GRAVEL with trace of sand, grey, dense, wet, medium to coarse, rounded, to subangular; cobbles subrounded to subangular; sand, coarse.
													End of DPD at 10.50m, on 14/11/2012 Termination Reason: Target depth reached

- Small Disturbed Sample
- Large Disturbed Sample
- SPT Liner Sample
- Thin Wall Undisturbed Sample
- U100 Undisturbed Sample
- Pocket Penetrometer Test
- Piston Sample
- Water Level
- Impression Packer Test
- Standard Penetration Test
- Permeability Test
- Piezometer / Standpipe Tip
- Packer Test
- In-situ Vane Shear Test

LOGGED **A. PEREIRA**

DATE **20/11/2012**

CHECKED **D. MAHONEY**

DATE **29/11/2012**

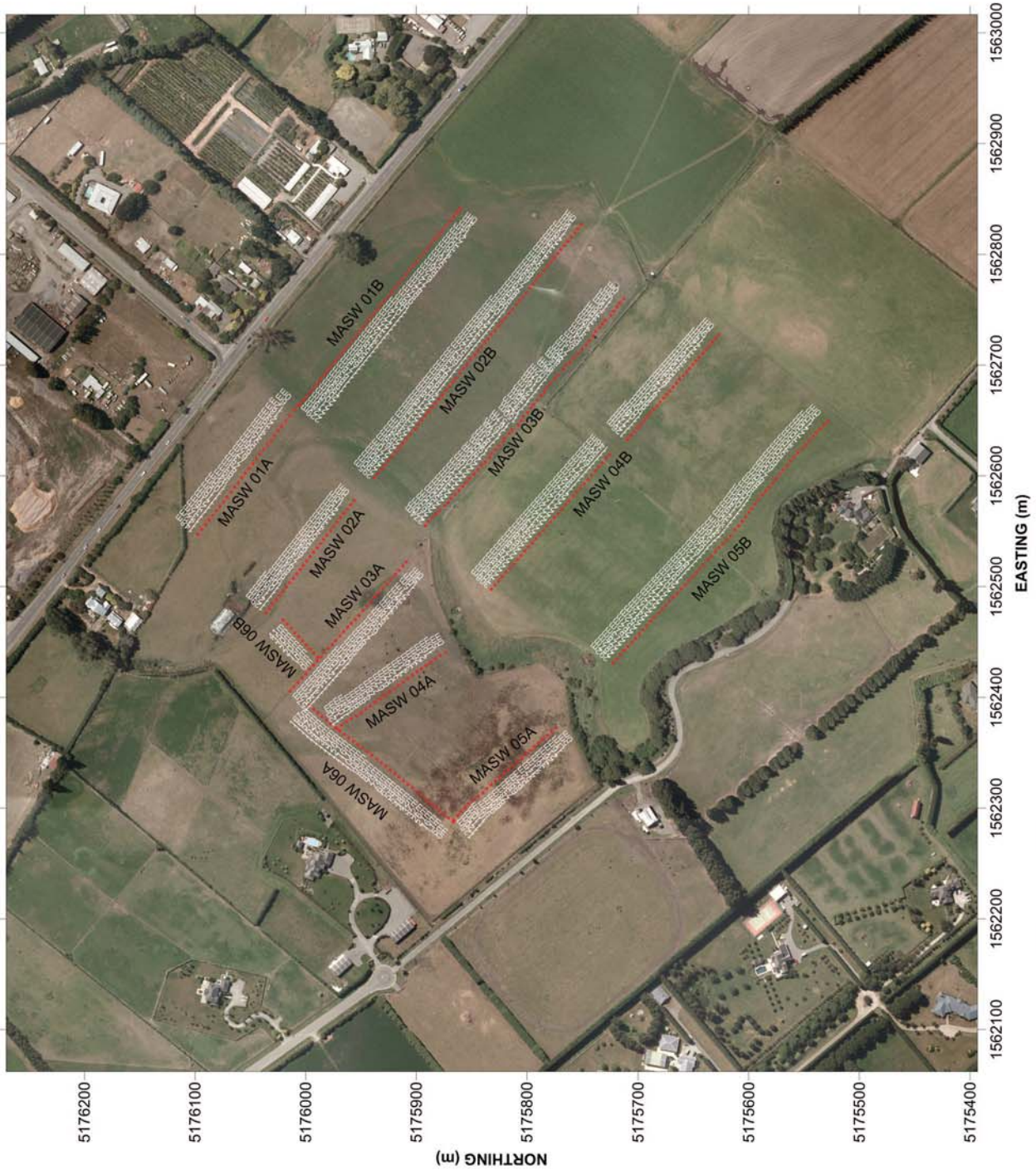
## REMARKS



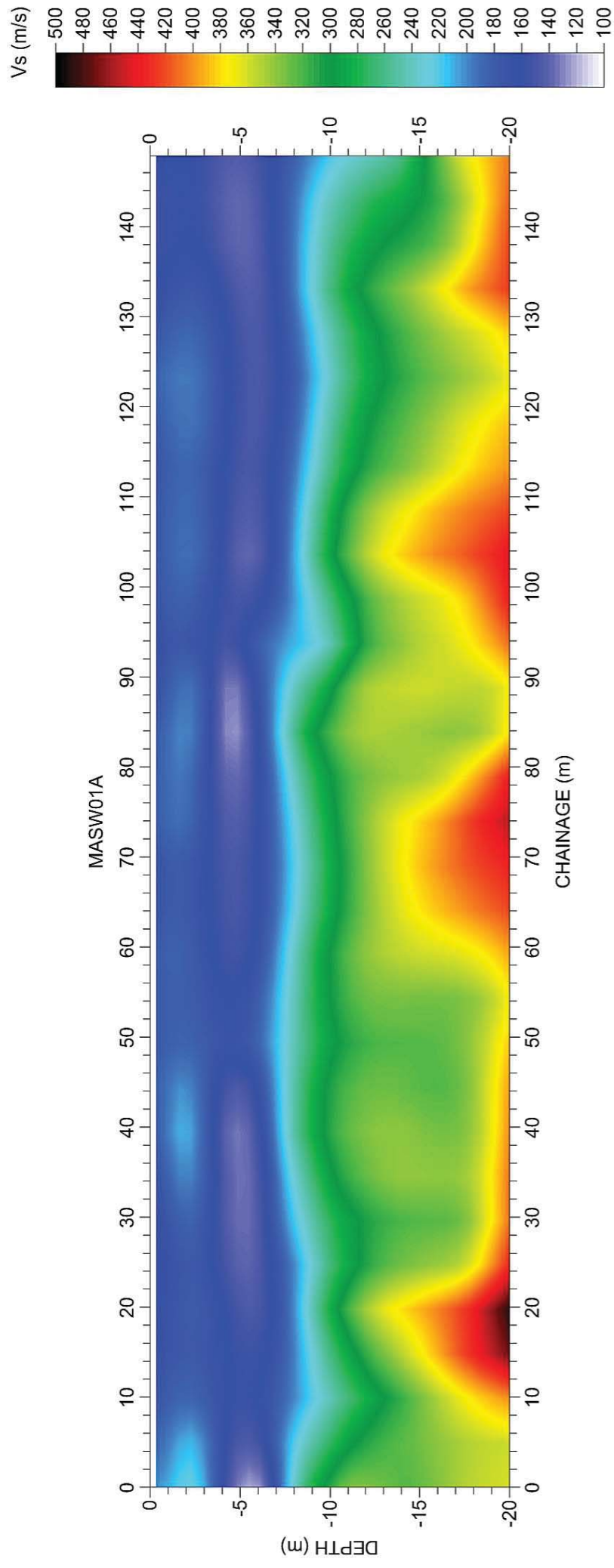
# Appendix F

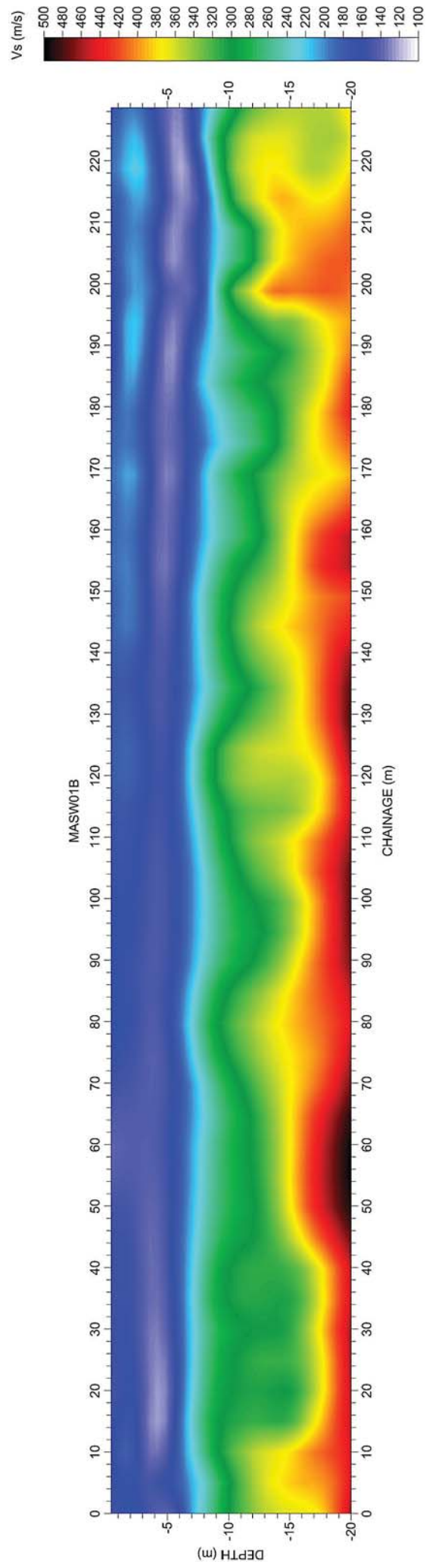
## MASW Cross-Sections



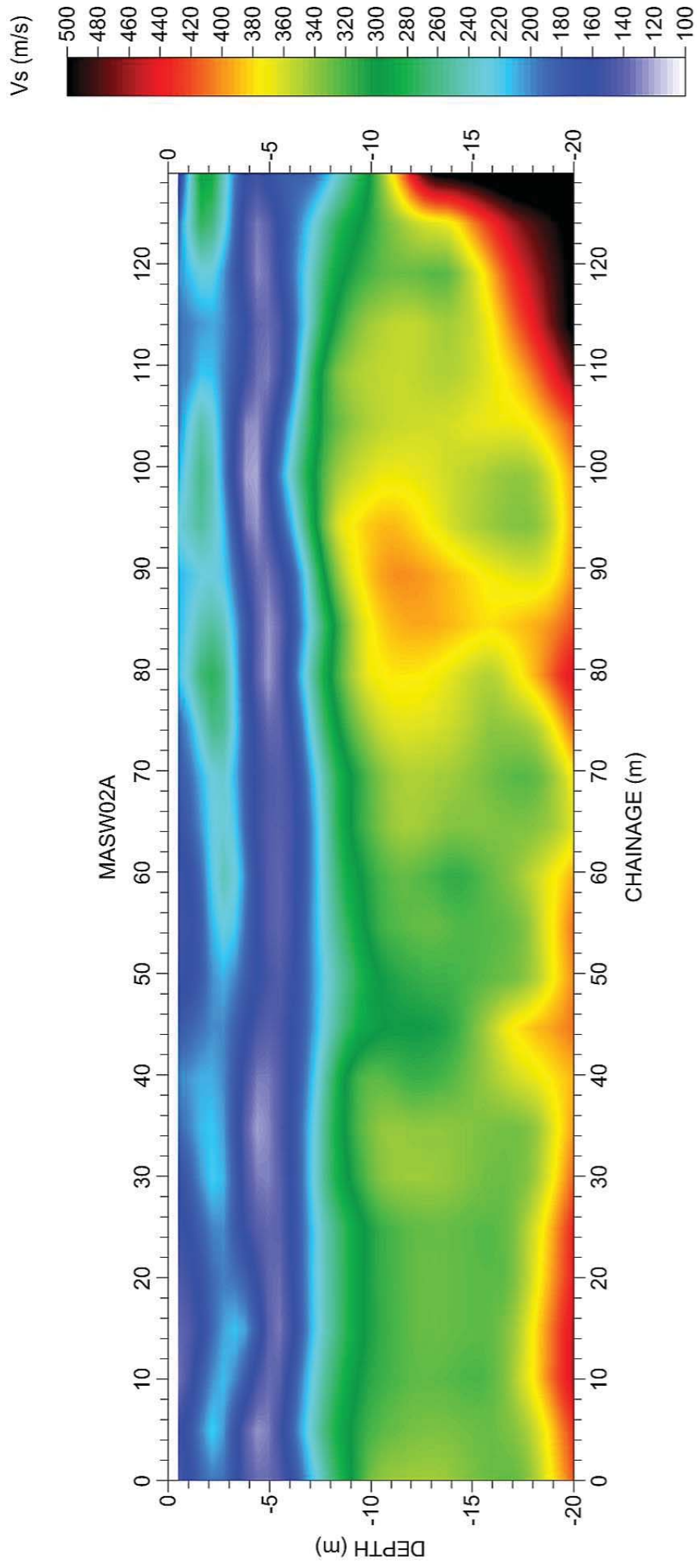


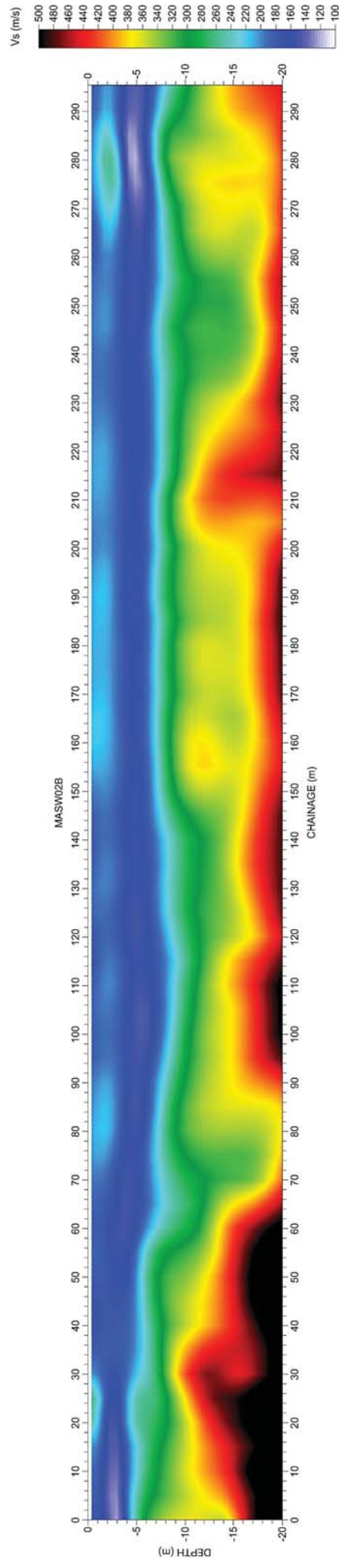
TITLE-	KNIGHT STREAM STAGE 6 & 7	
	MASW LINE LOCATIONS	
LOCATION-	HALSWELL, CHRISTCHURCH	
NOTES-	Coordinates NZ2000 TM Grid.	
	Aerial photograph post February 2011.	
	Line labels show the chainage along the line.	
	Each point represents the midpoint of the 24m MASW array.	
		A3
		<div><a href="http://www.southerngeophysical.com">www.southerngeophysical.com</a></div>

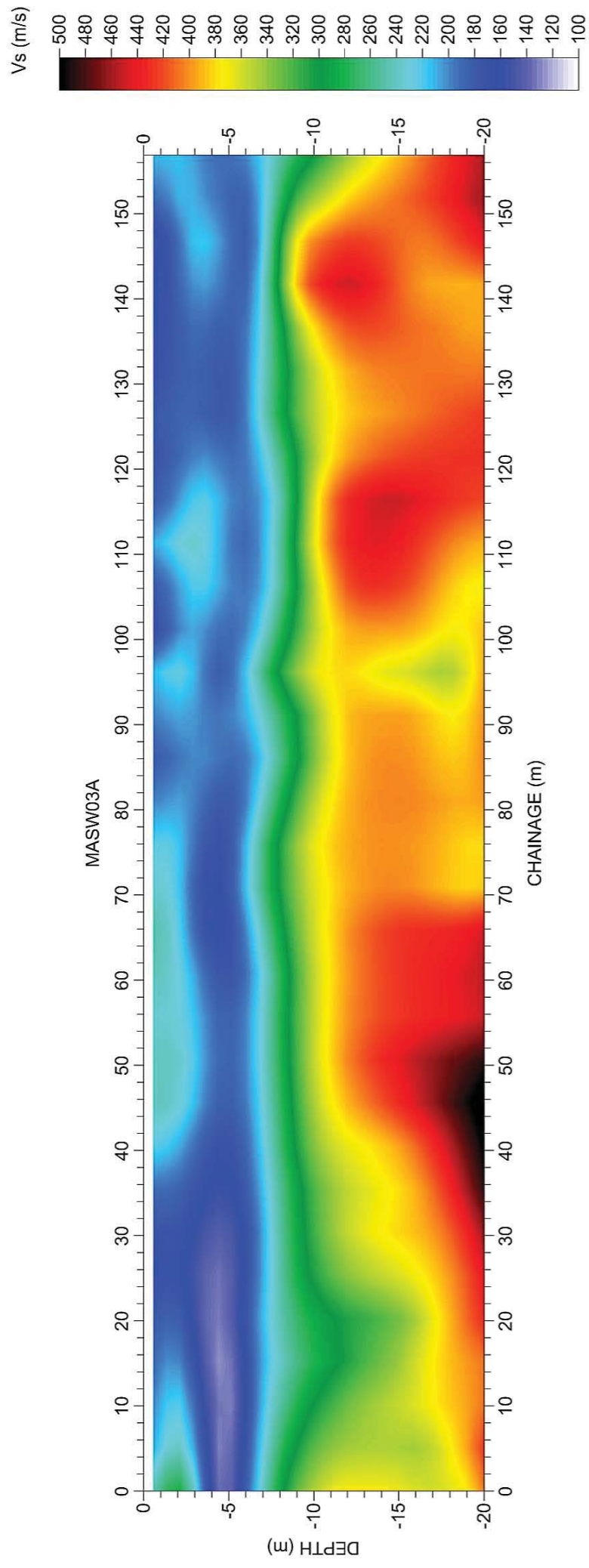


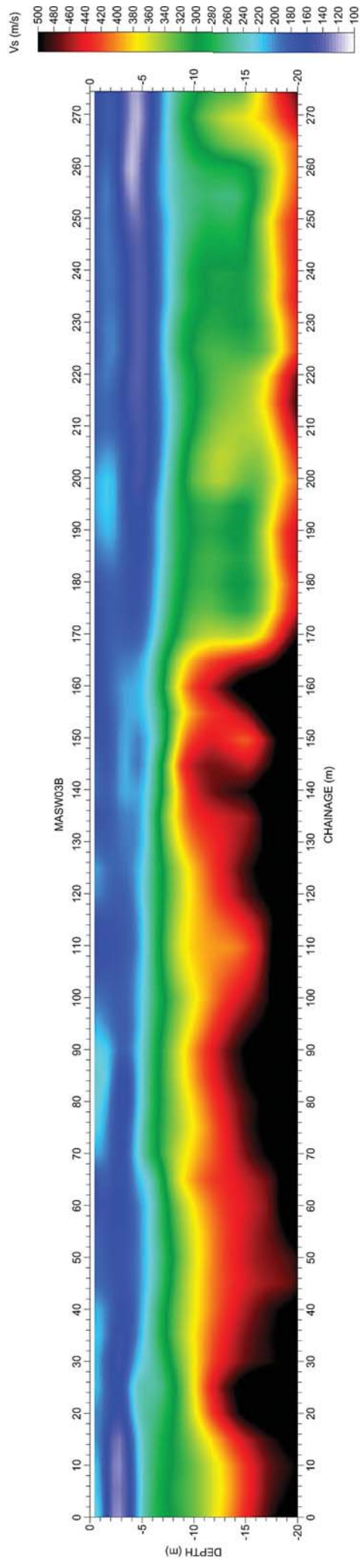


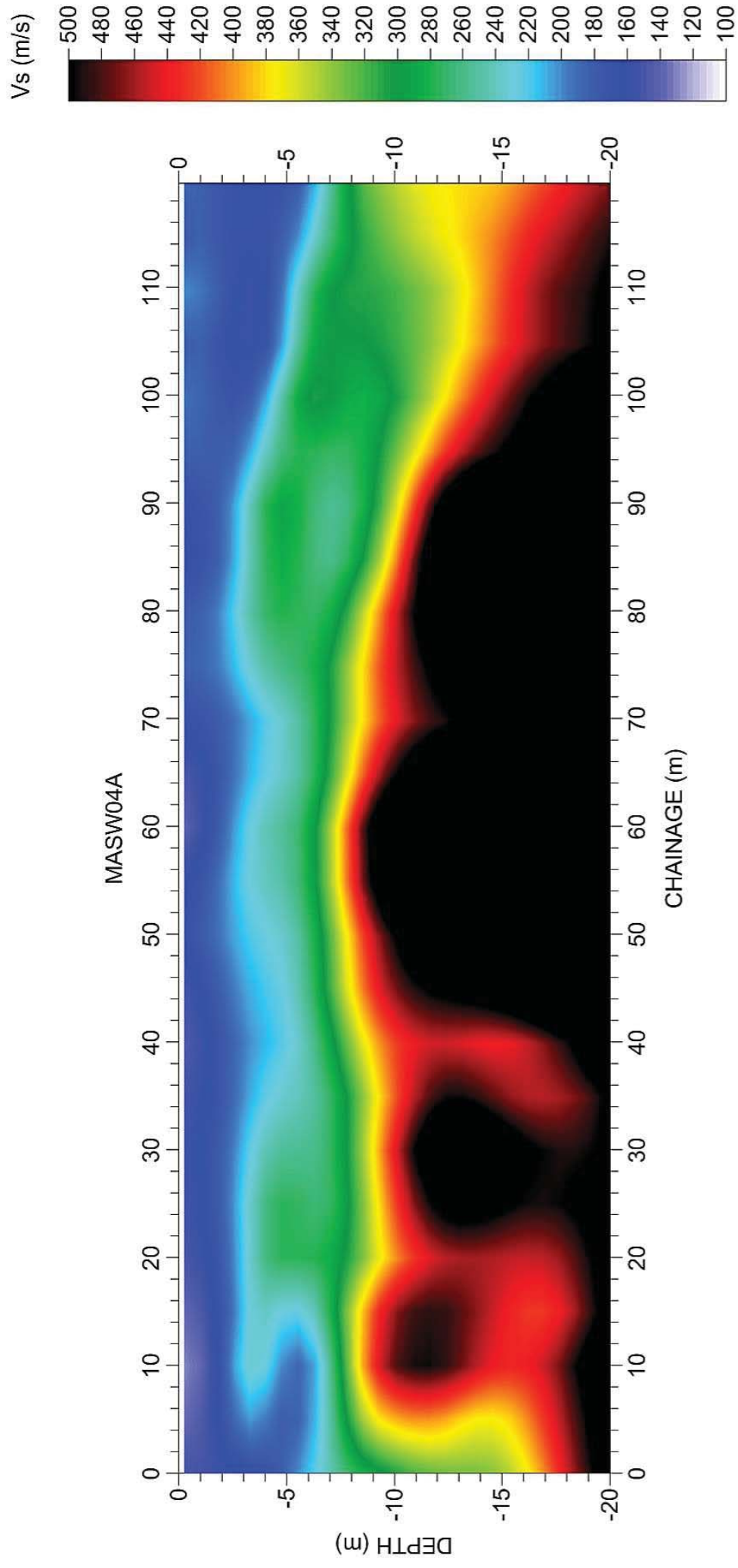




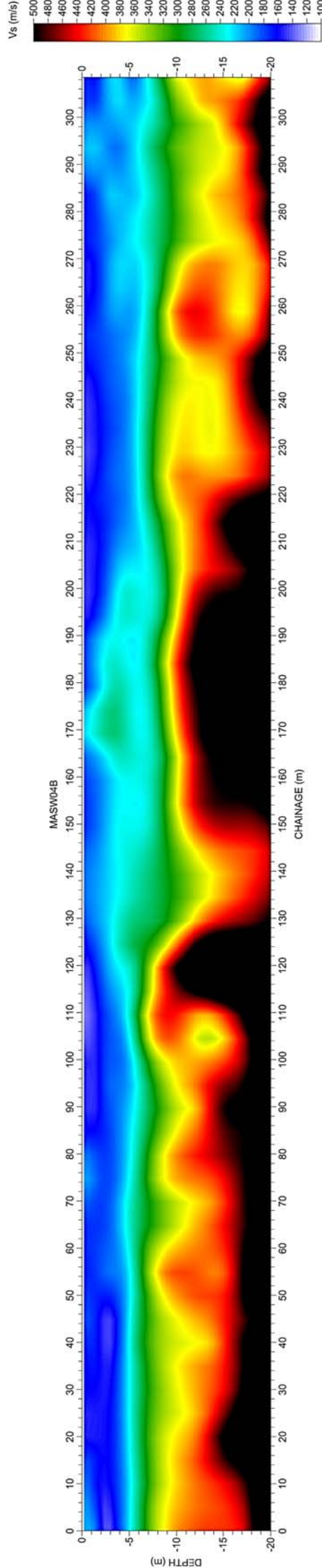


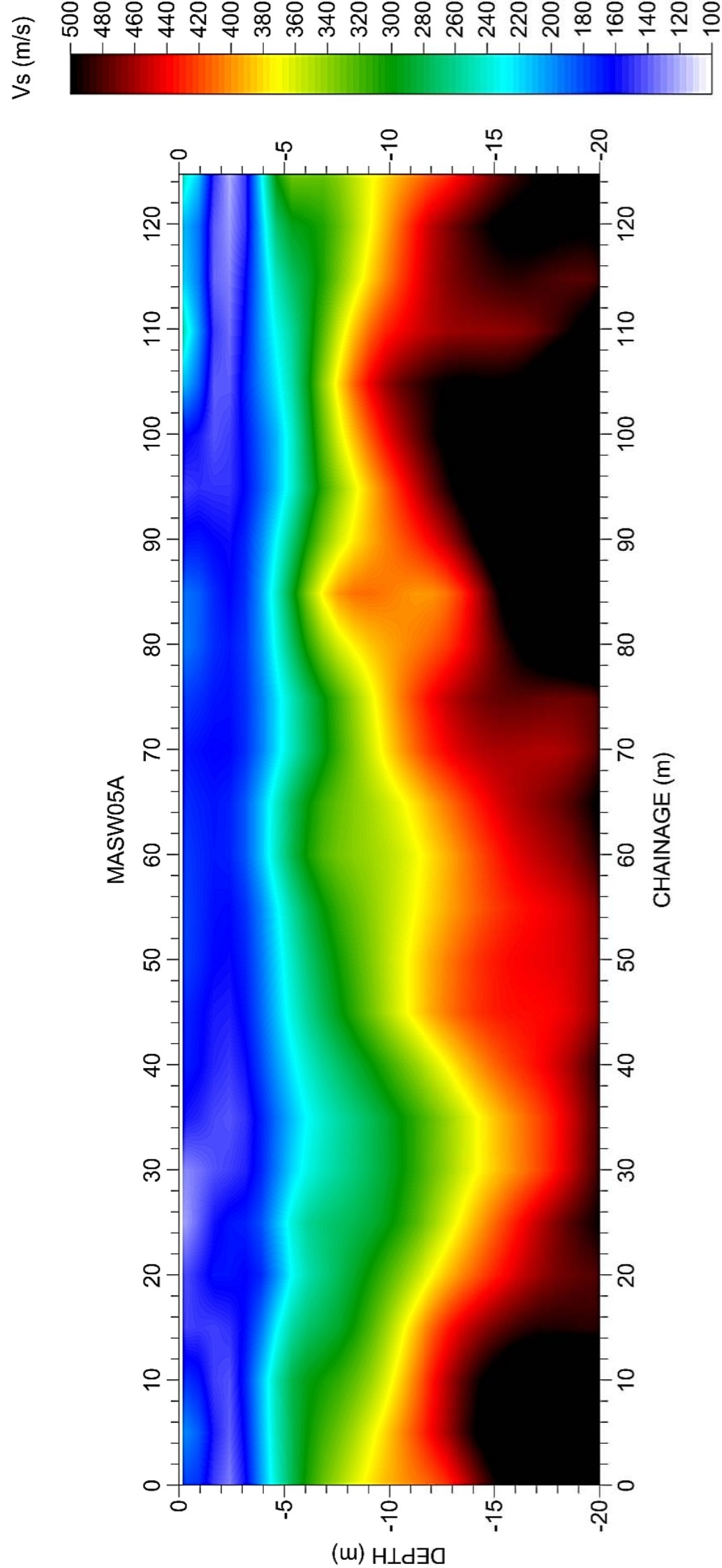


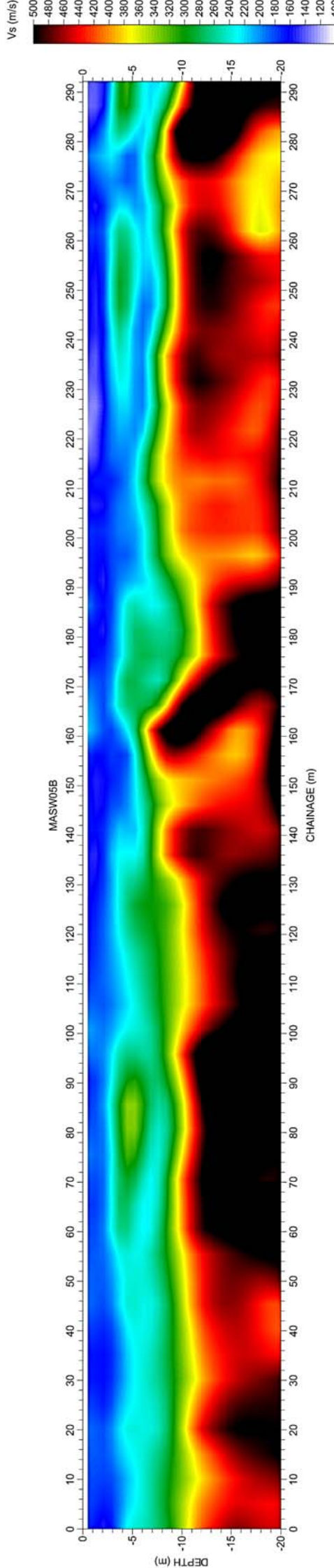


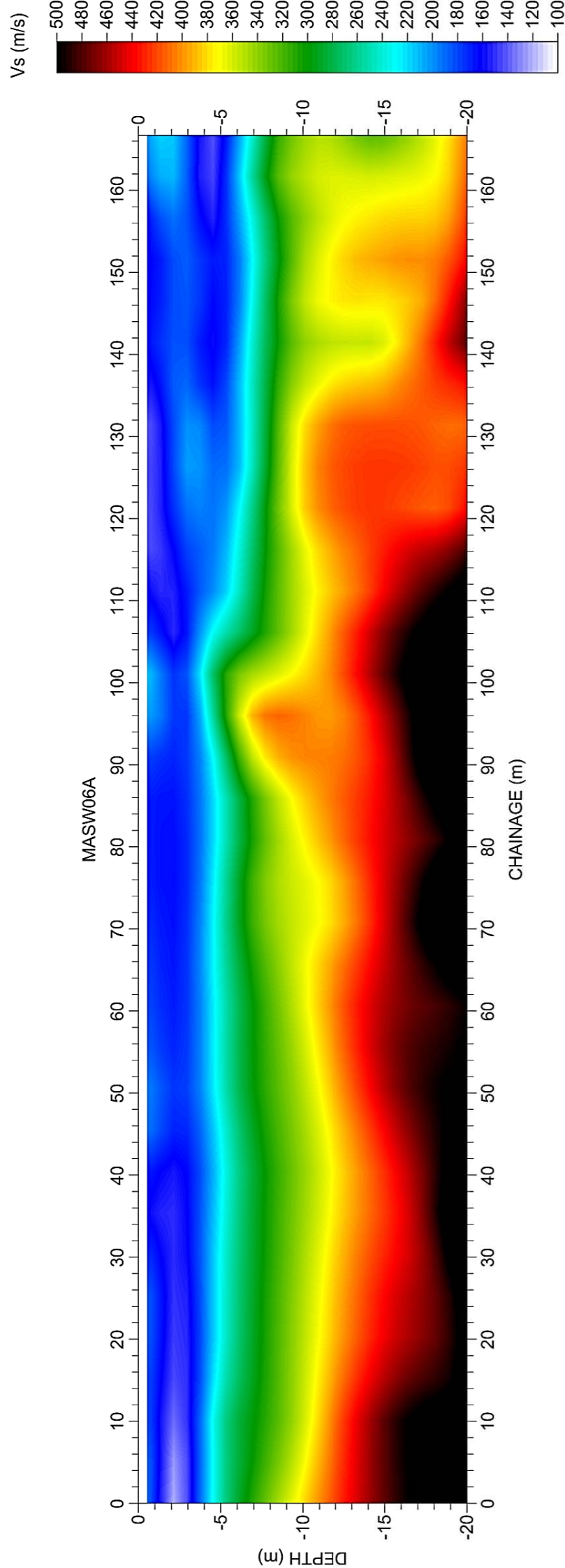






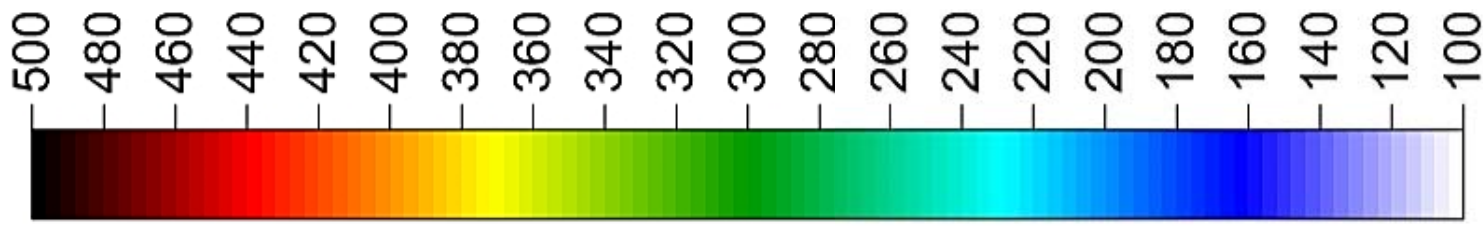




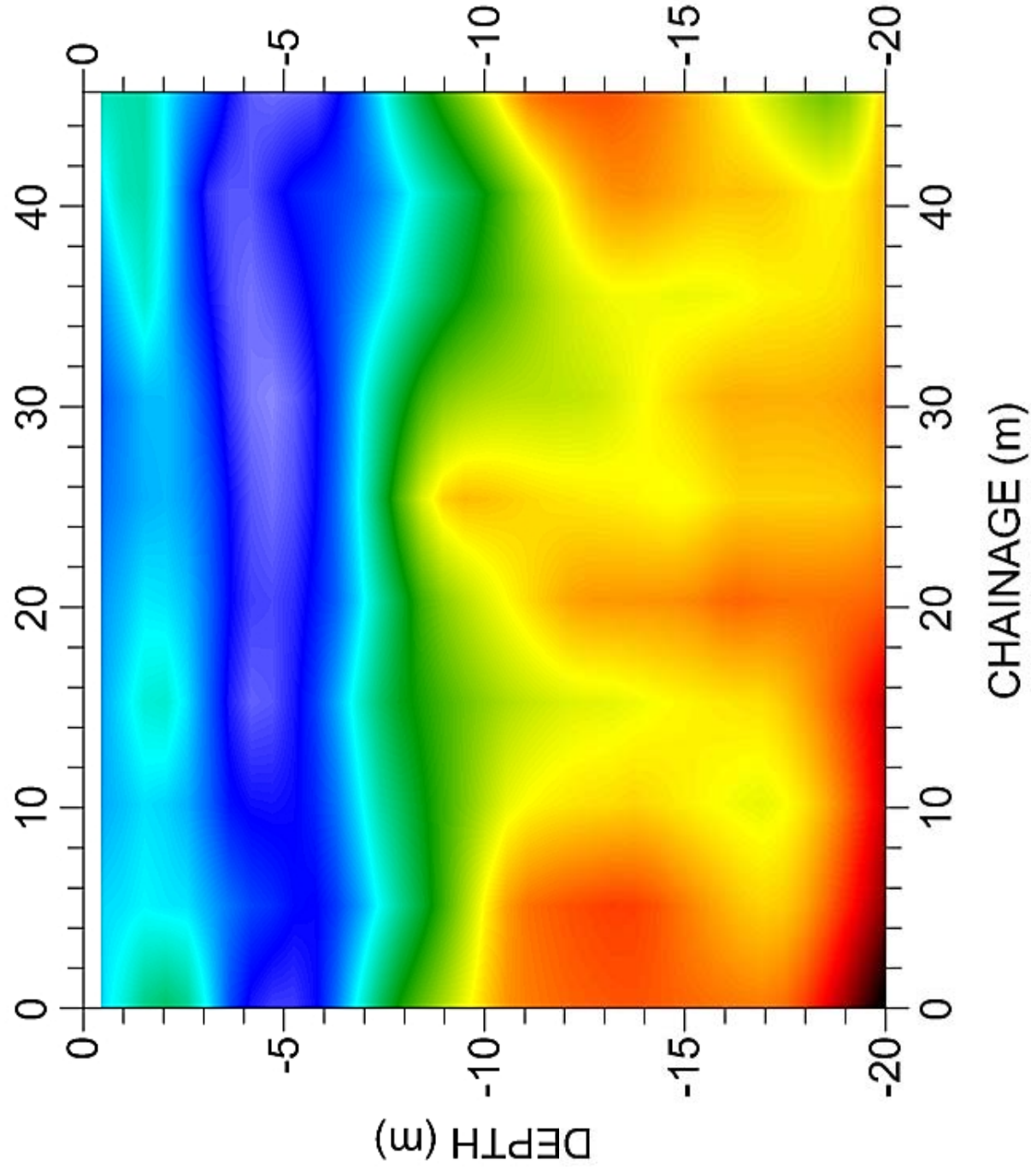




$V_s$  (m/s)



MASW06B





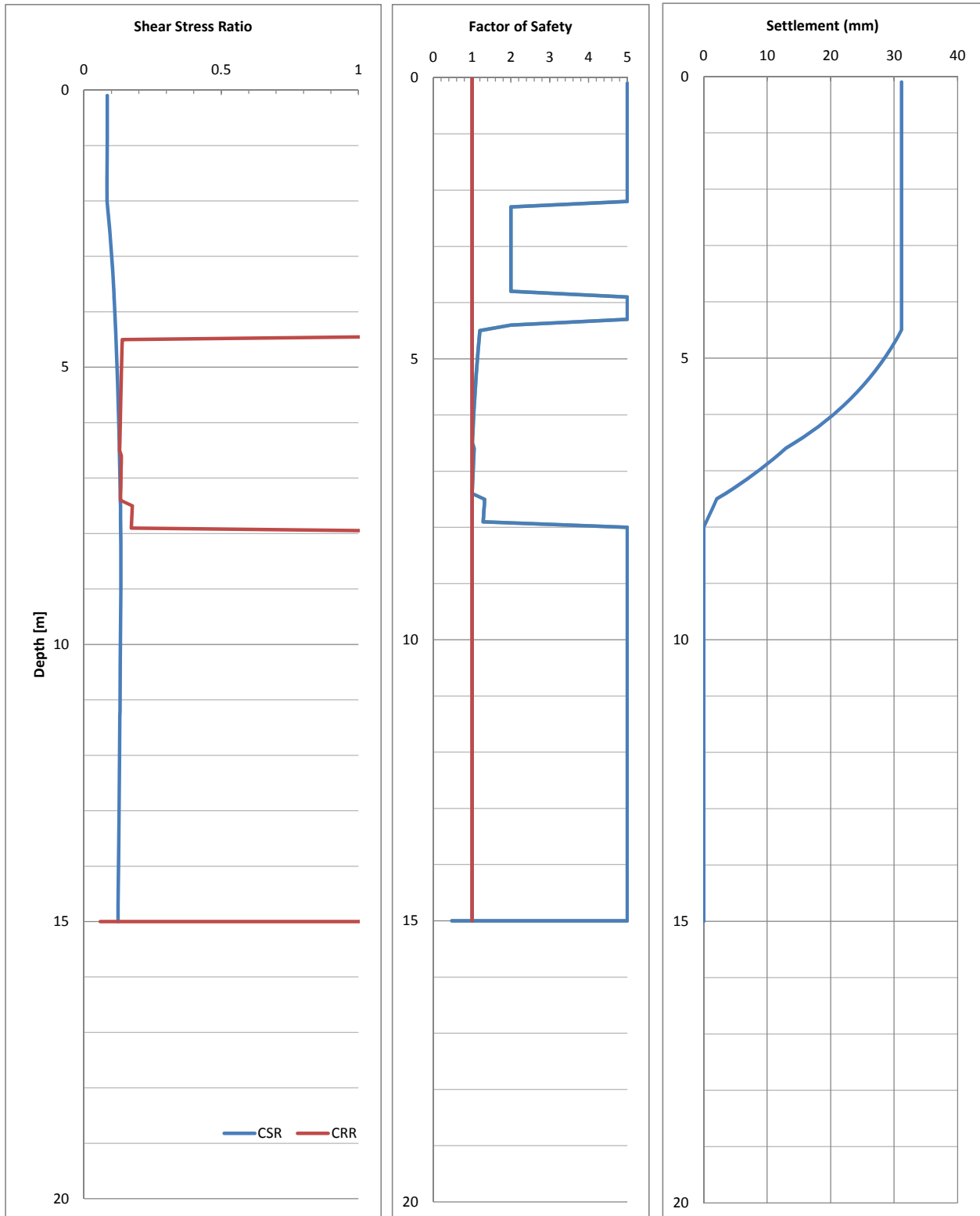
# Appendix G

## Liquefaction Assessment

### Outputs

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 31  
LSN: 5

**aurecon**

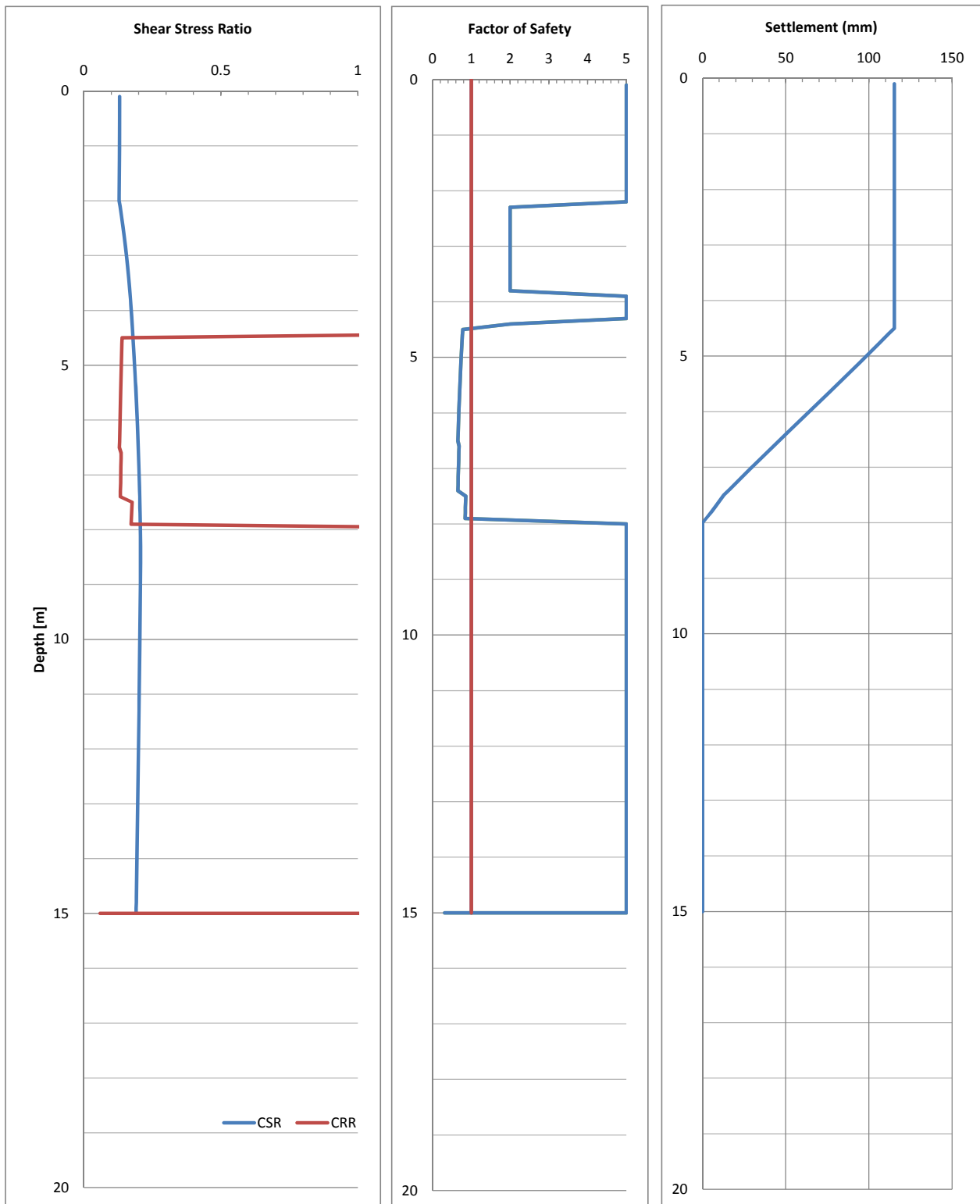
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH1
Design Event	SLS	Magnitude	7.5
Water Table [m]	2.0	Acceleration [g]	0.13

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 115

LSN: 19

**aurecon**

Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

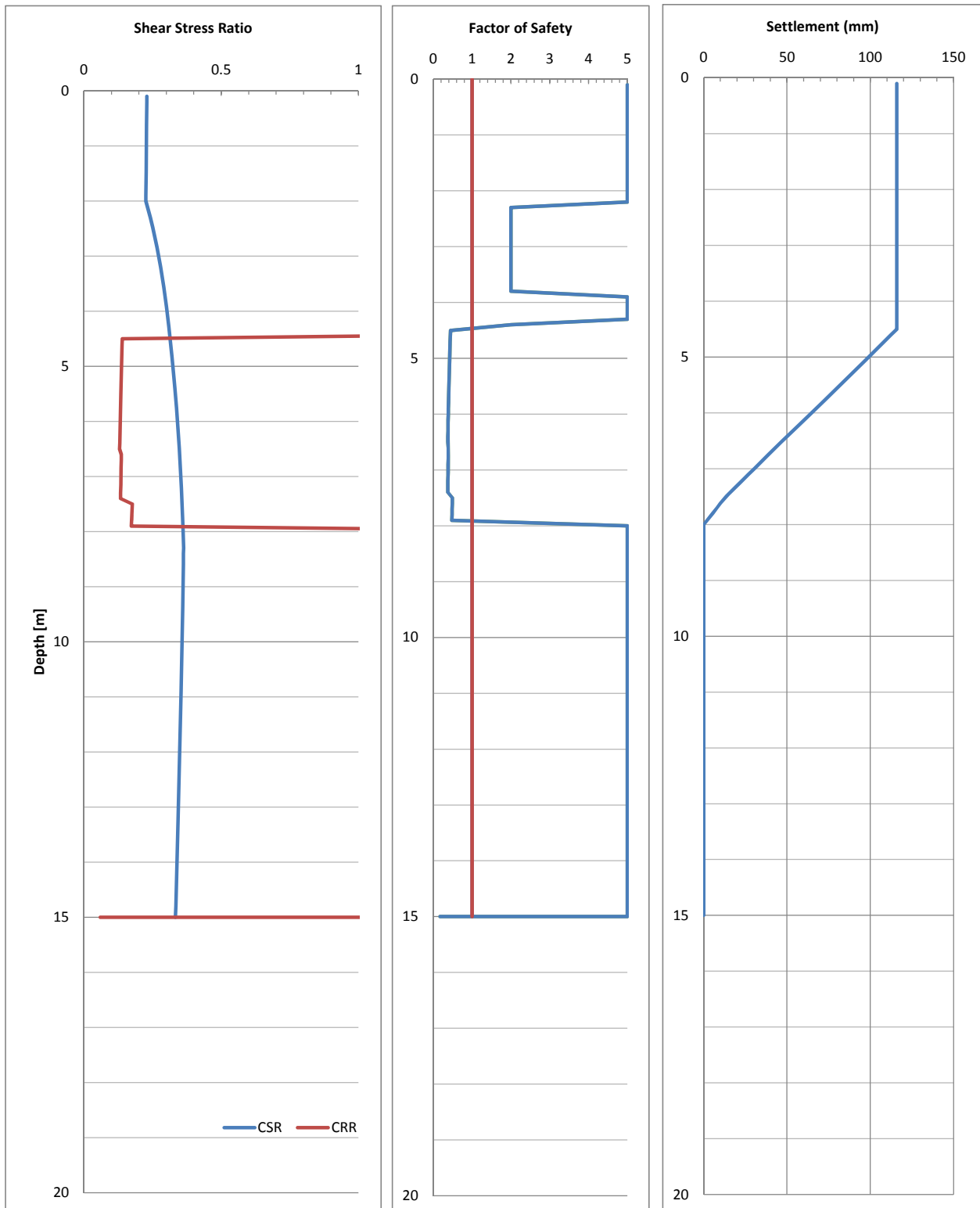
Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH1
Design Event	INT	Magnitude	7.5
Water Table [m]	2.0	Acceleration [g]	0.20



# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 116

LSN: 19

**aurecon**

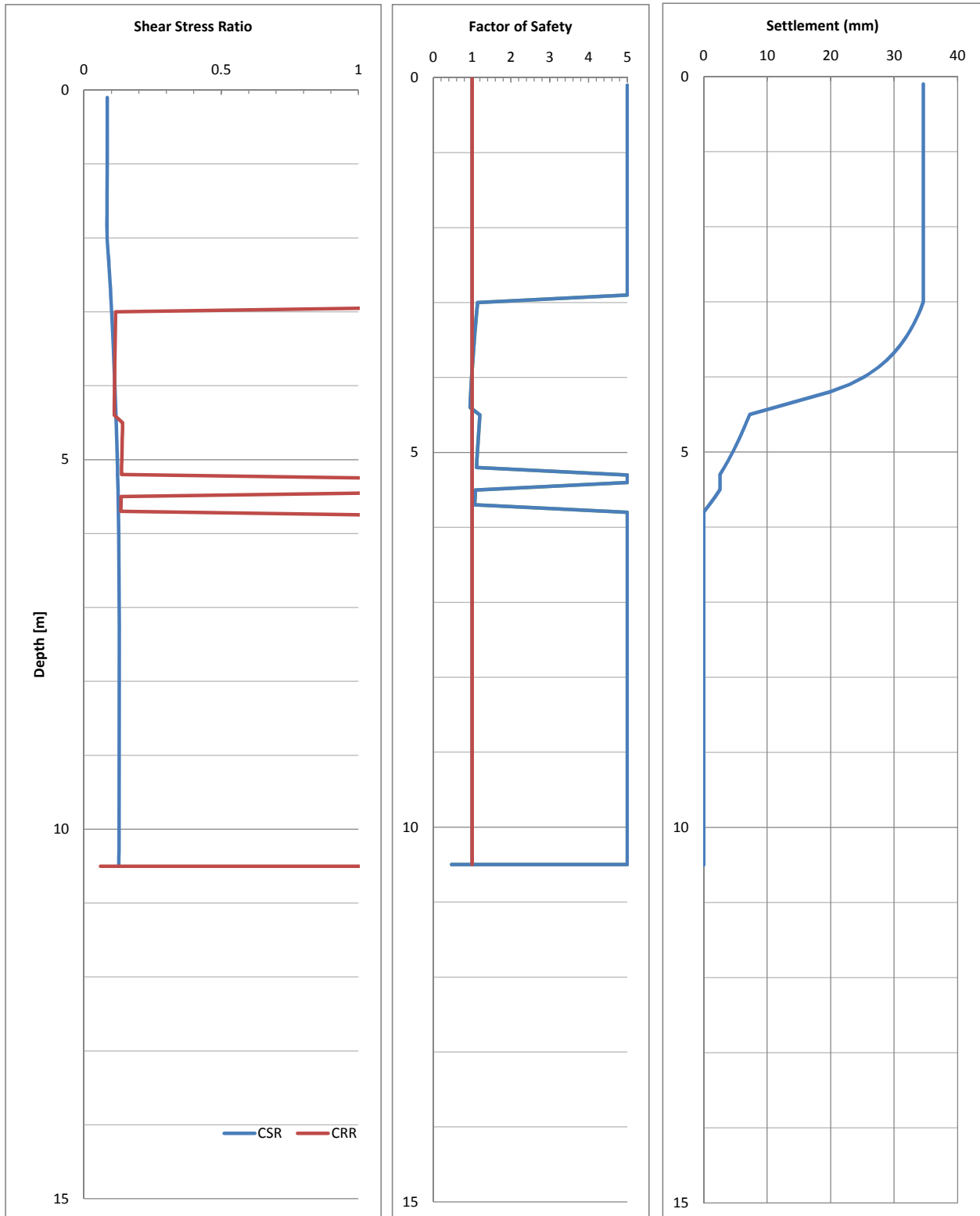
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH1
Design Event	ULS	Magnitude	7.5
Water Table [m]	2.0	Acceleration [g]	0.35

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 35  
LSN: 8

**aurecon**

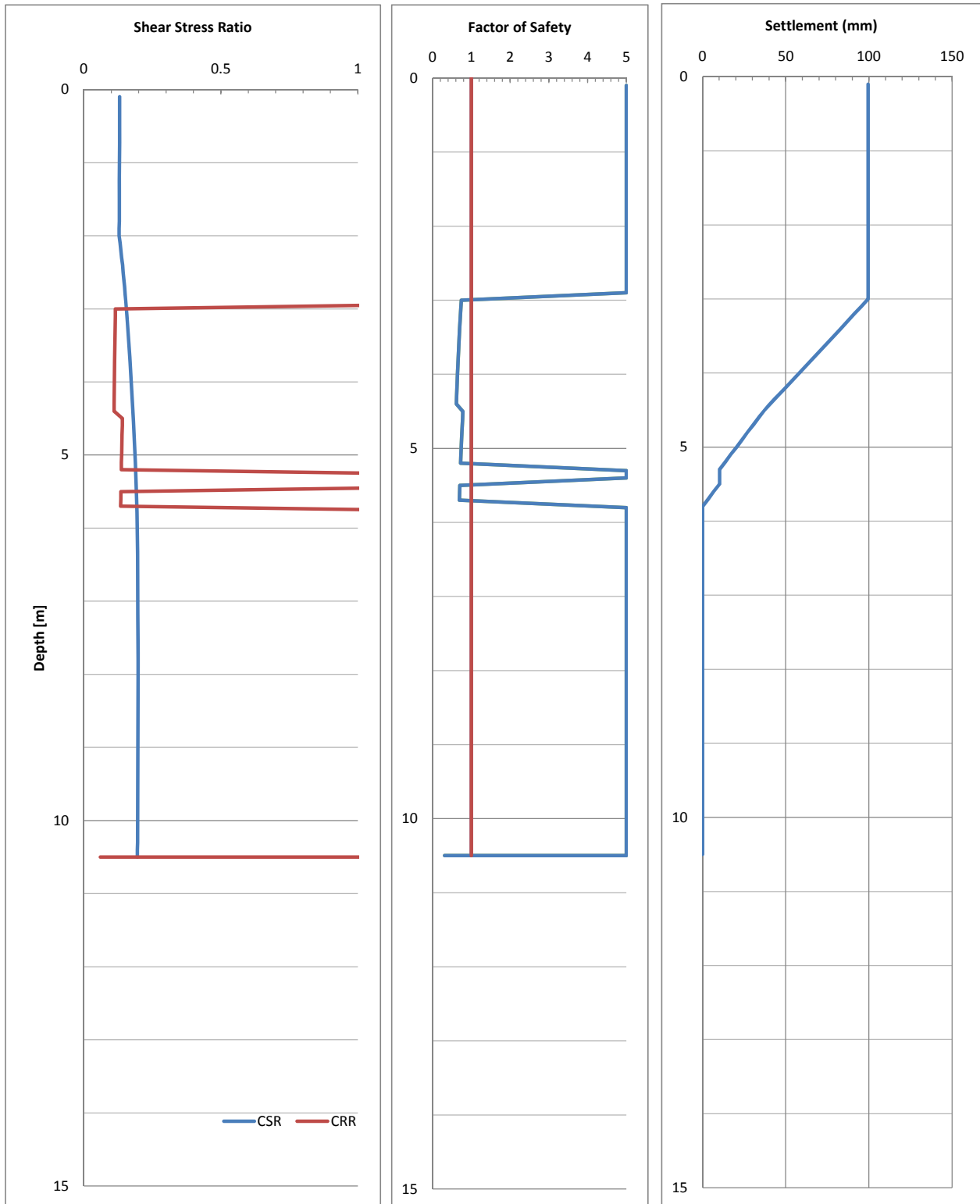
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH2
Design Event	SLS	Magnitude	7.5
Water Table [m]	2.0	Acceleration [g]	0.13

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 100

LSN: 25

**aurecon**

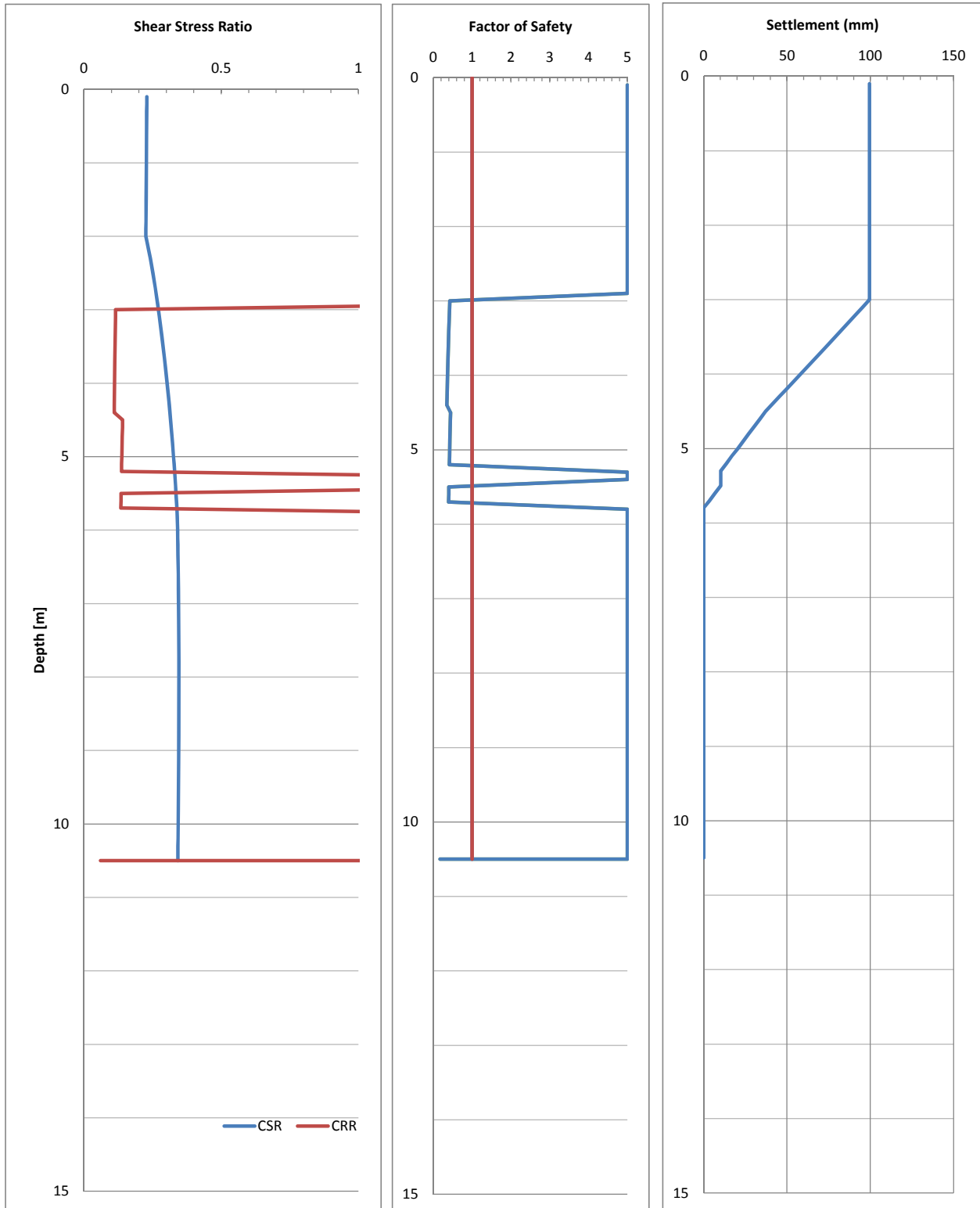
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH2
Design Event	INT	Magnitude	7.5
Water Table [m]	2.0	Acceleration [g]	0.20

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 100  
LSN: 25

**aurecon**

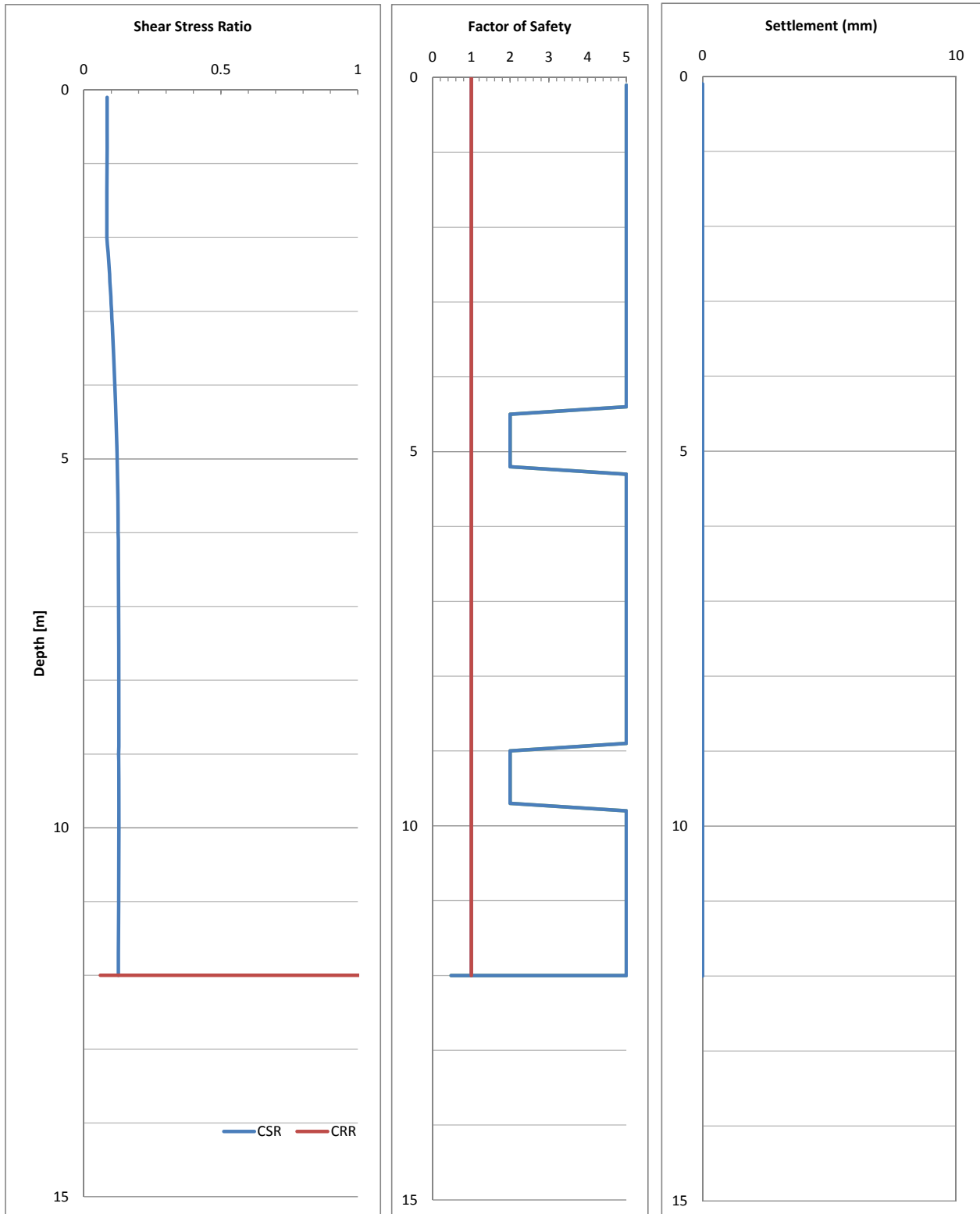
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH2
Design Event	ULS	Magnitude	7.5
Water Table [m]	2.0	Acceleration [g]	0.35

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 0  
LSN: 0

**aurecon**

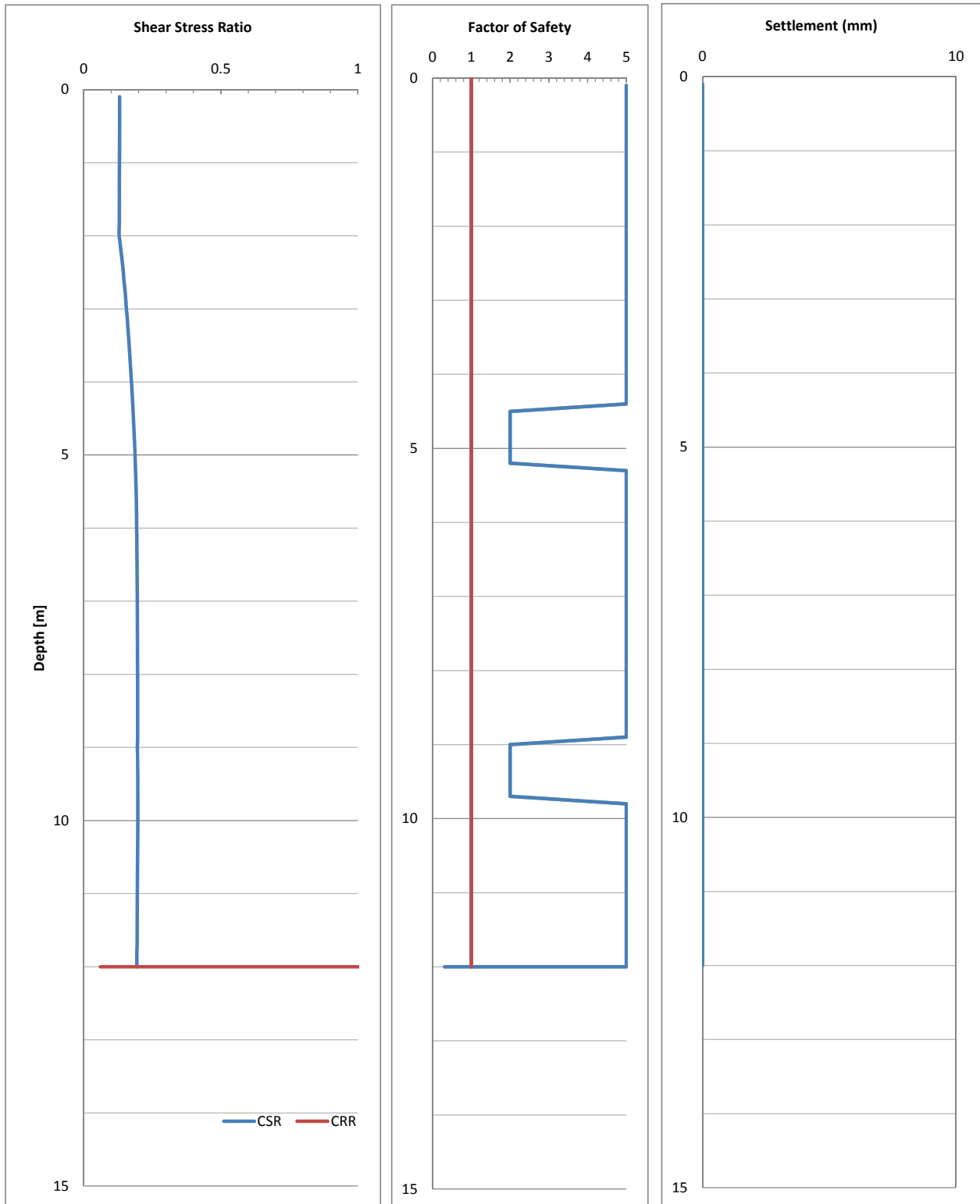
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH3
Design Event	SLS	Magnitude	7.5
Water Table [m]	2.0	Acceleration [g]	0.13

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 0  
LSN: 0



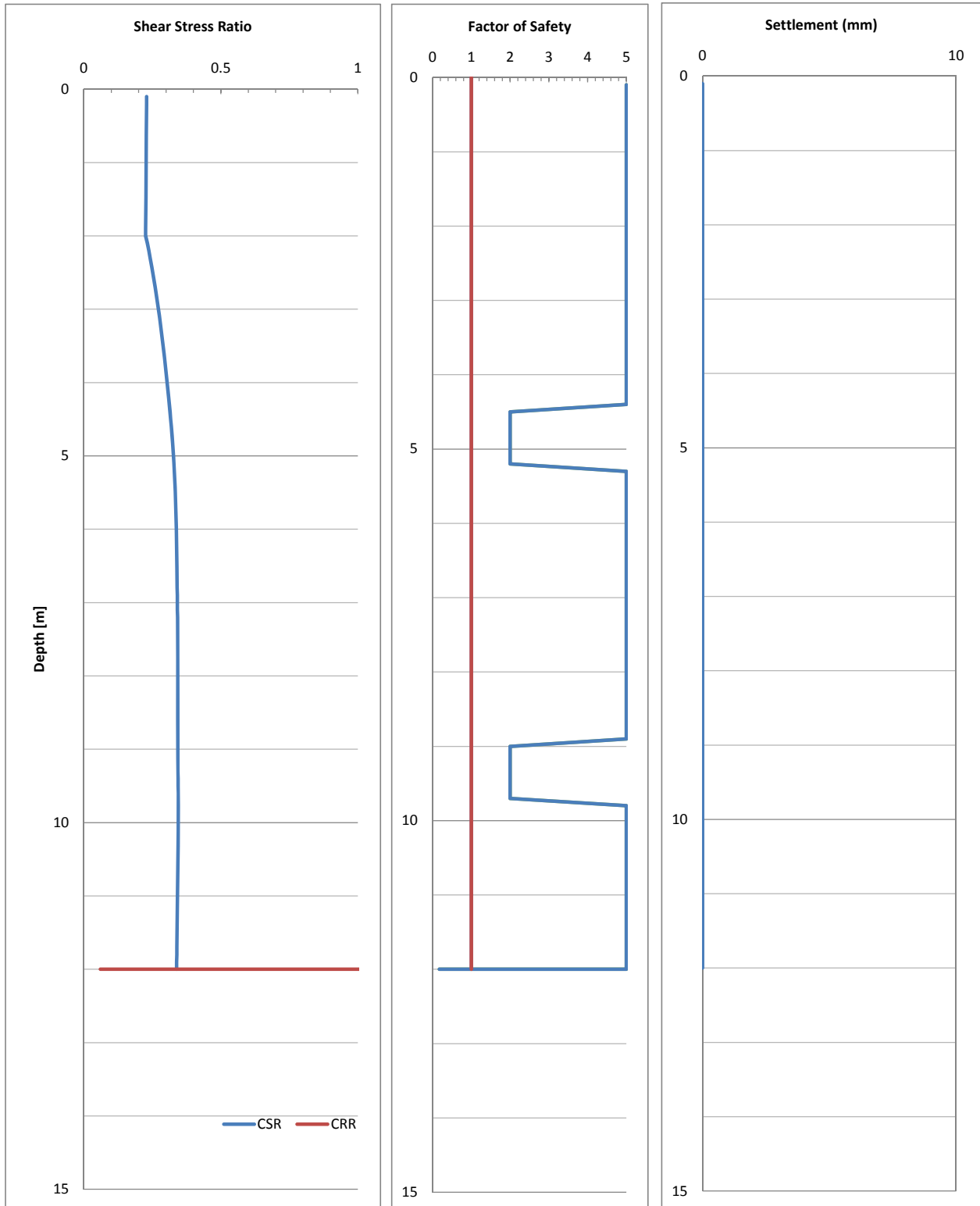
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH3
Design Event	INT	Magnitude	7.5
Water Table [m]	2.0	Acceleration [g]	0.20

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 0  
LSN: 0

**aurecon**

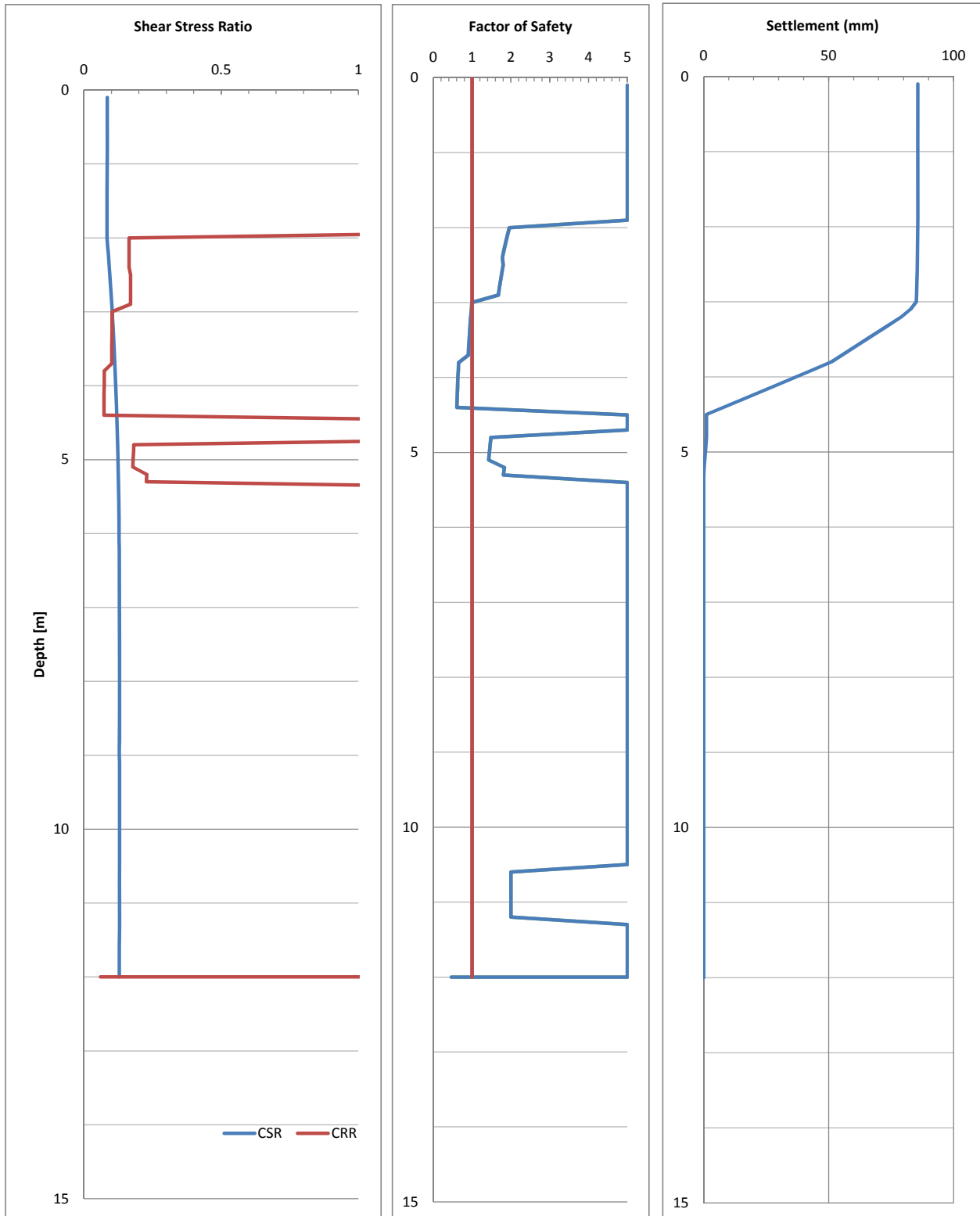
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH3
Design Event	ULS	Magnitude	7.5
Water Table [m]	2.0	Acceleration [g]	0.35

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 86  
LSN: 23

**aurecon**

Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

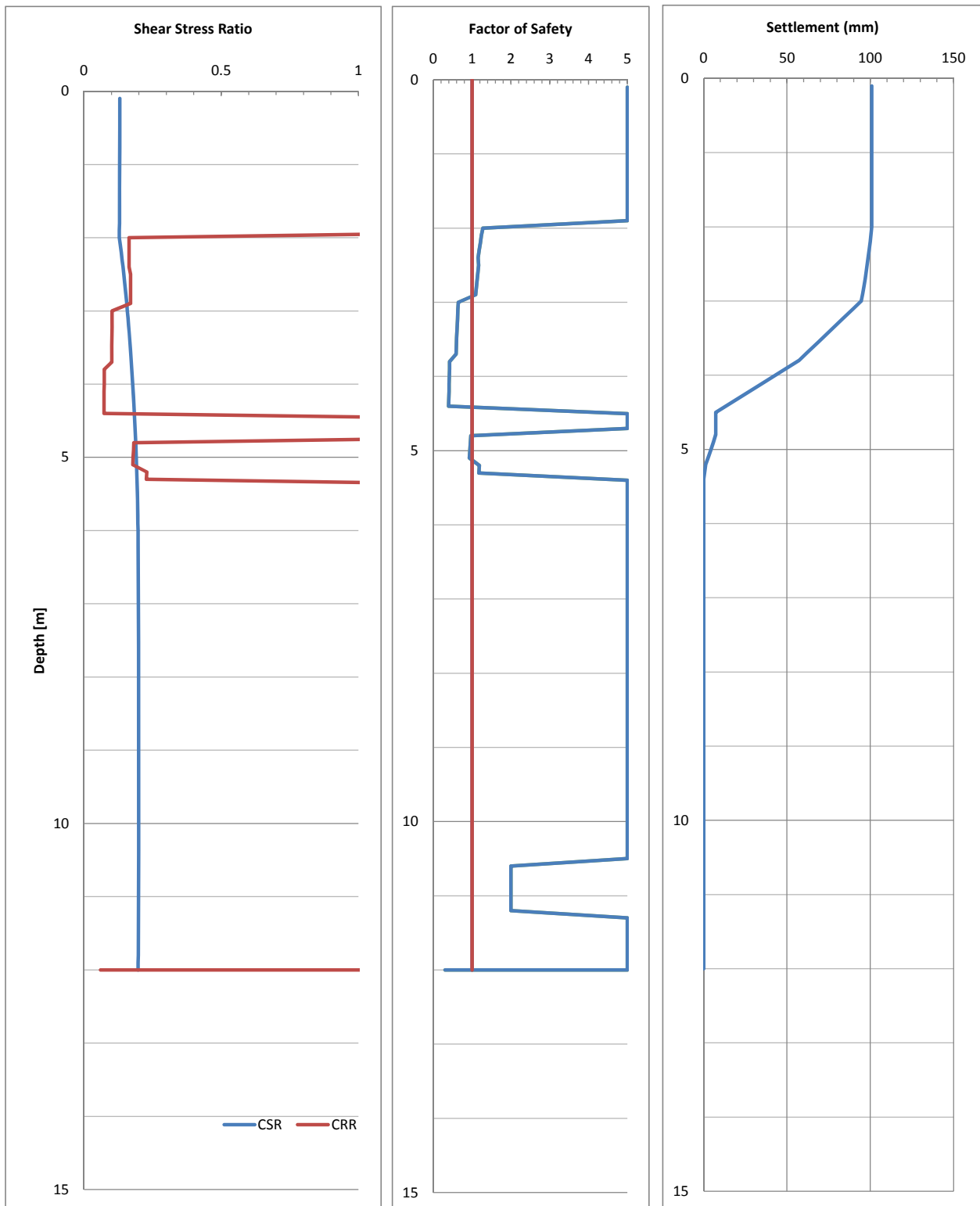
Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH4
Design Event	SLS	Magnitude	7.5
Water Table [m]	2.0	Acceleration [g]	0.13



# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 101  
LSN: 28



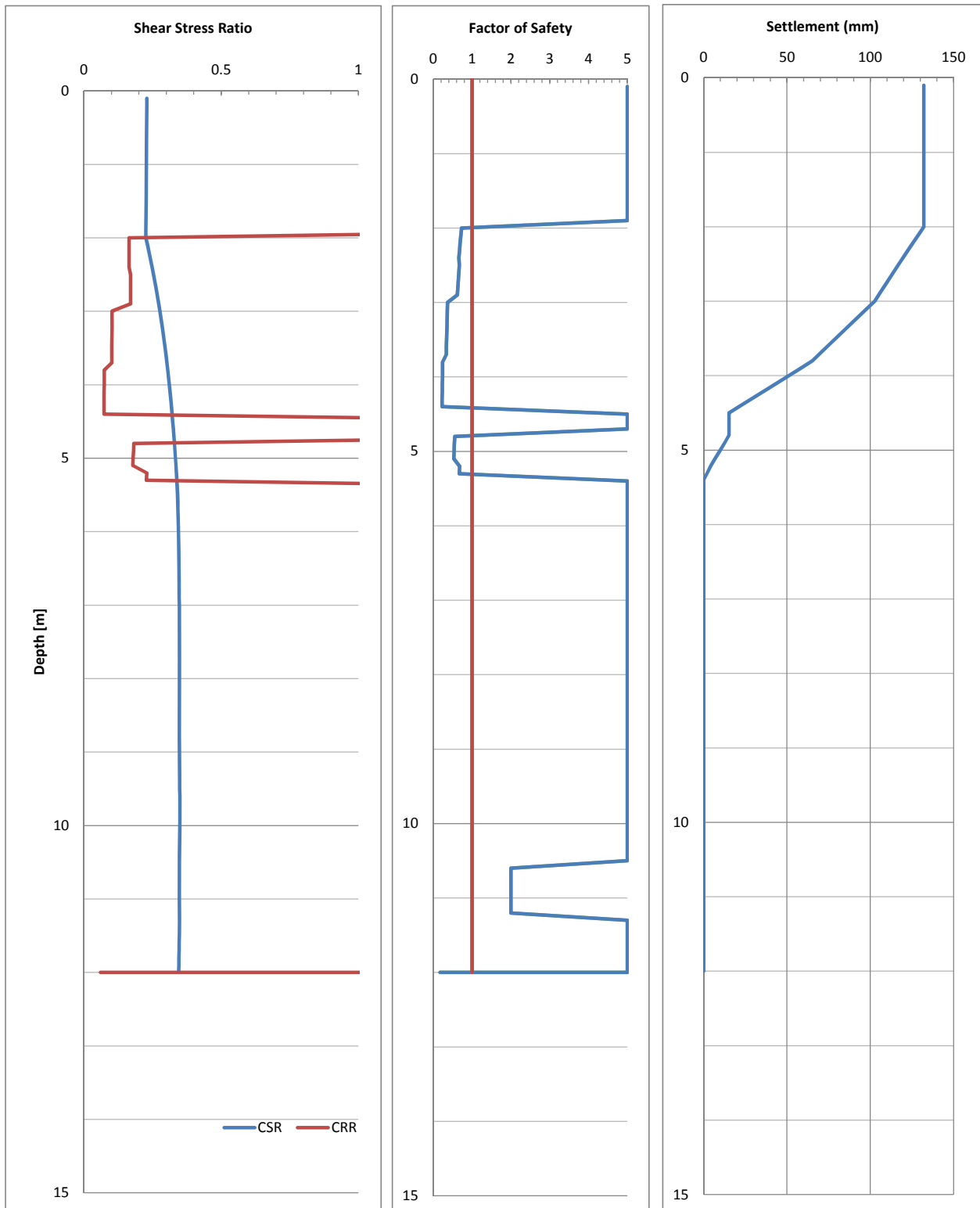
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH4
Design Event	INT	Magnitude	7.5
Water Table [m]	2.0	Acceleration [g]	0.20

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 132  
LSN: 39

**aurecon**

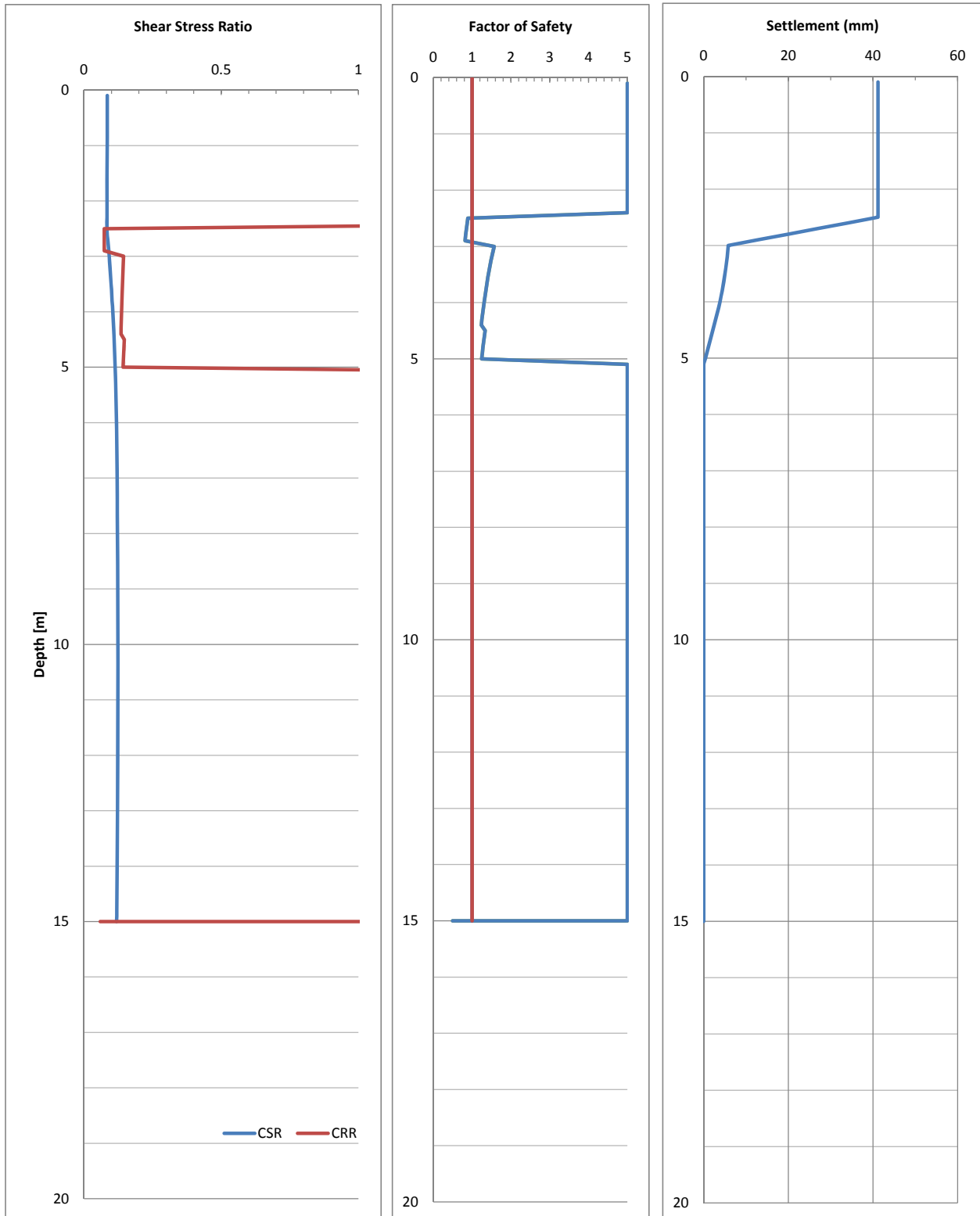
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH4
Design Event	ULS	Magnitude	7.5
Water Table [m]	2.0	Acceleration [g]	0.35

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 41  
LSN: 15

**aurecon**

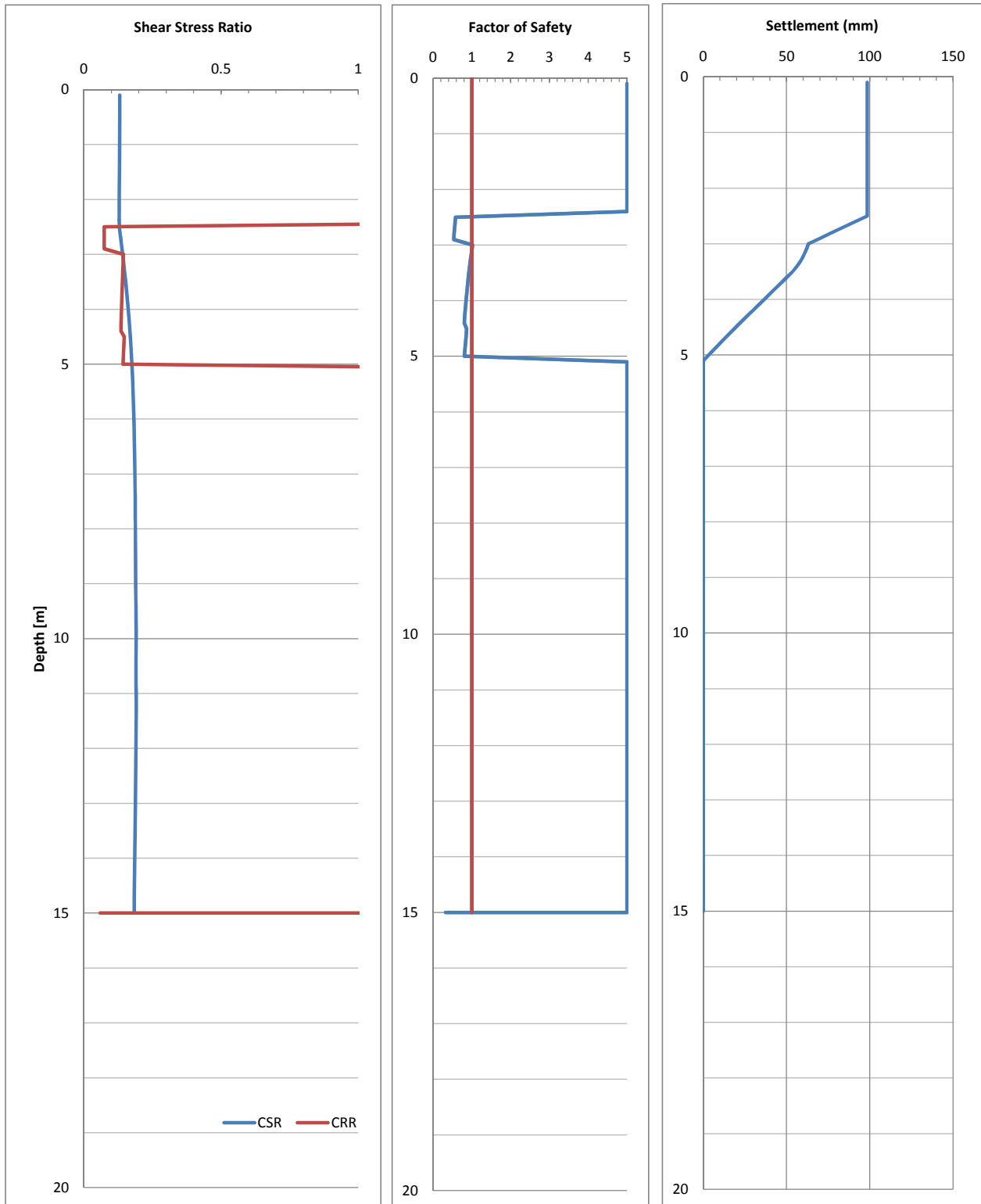
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH5
Design Event	SLS	Magnitude	7.5
Water Table [m]	2.5	Acceleration [g]	0.13

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 98

LSN: 29

**aurecon**

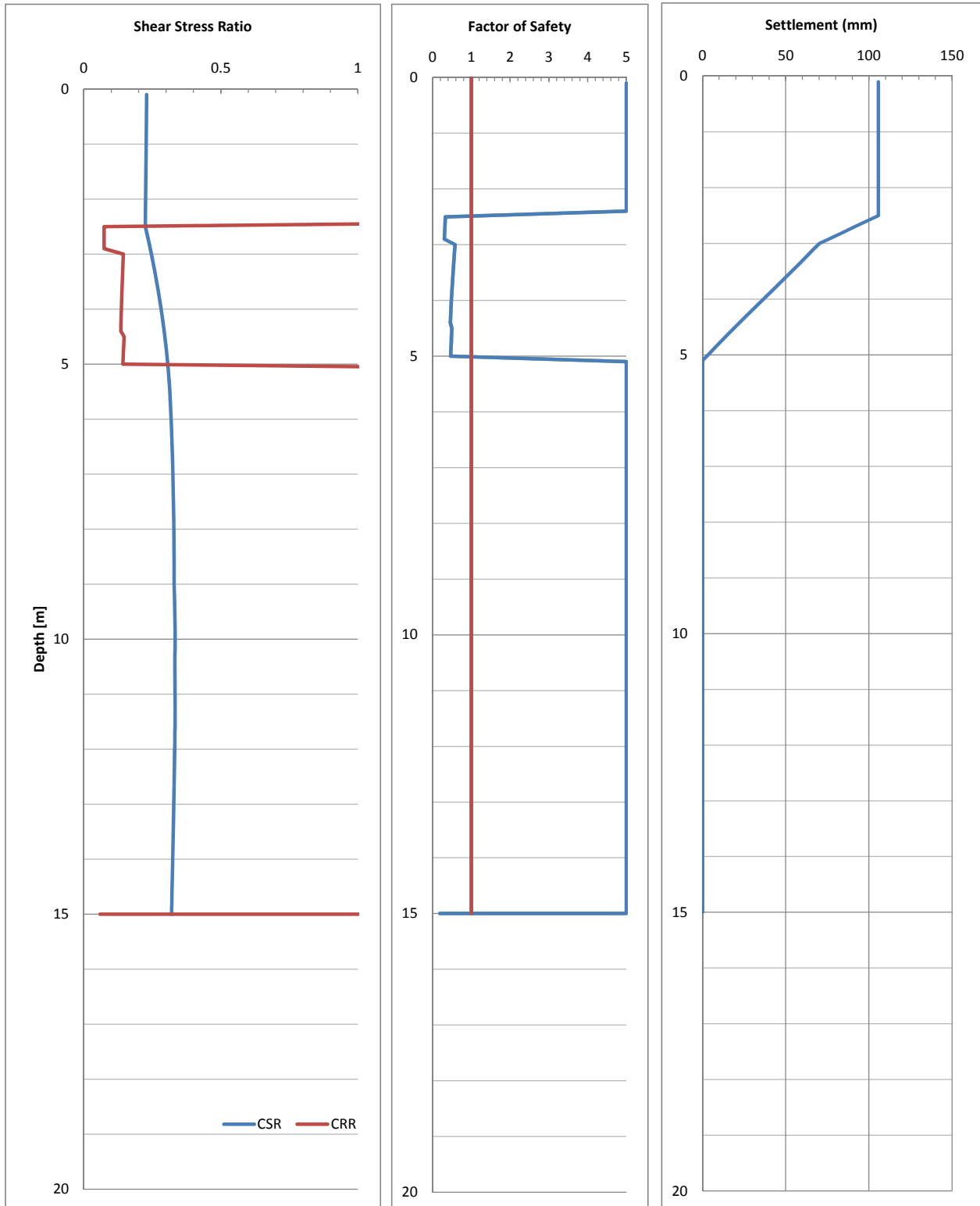
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH5
Design Event	INT	Magnitude	7.5
Water Table [m]	2.5	Acceleration [g]	0.20

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 106

LSN: 32

**aurecon**

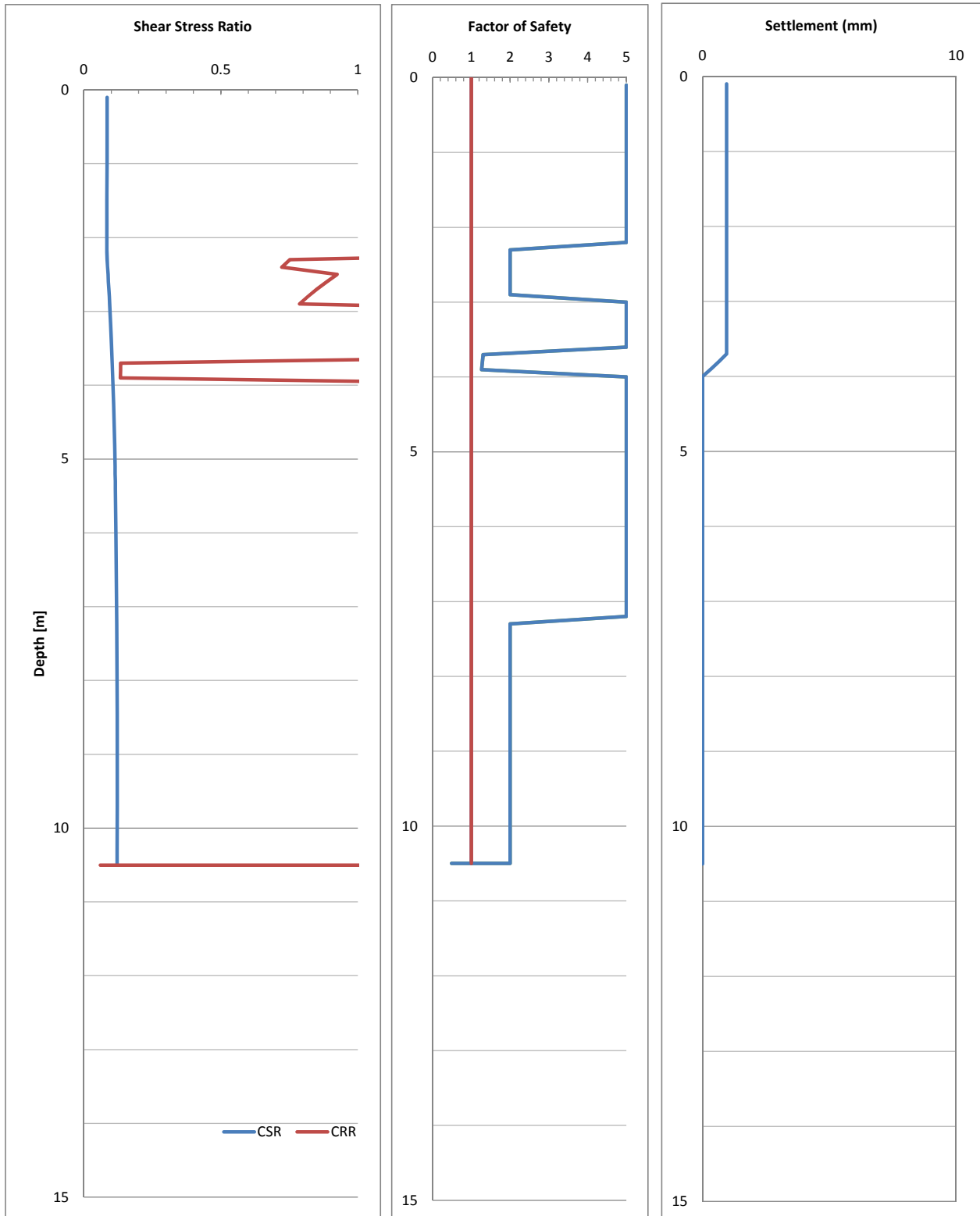
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH5
Design Event	ULS	Magnitude	7.5
Water Table [m]	2.5	Acceleration [g]	0.35

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 1  
LSN: 0

**aurecon**

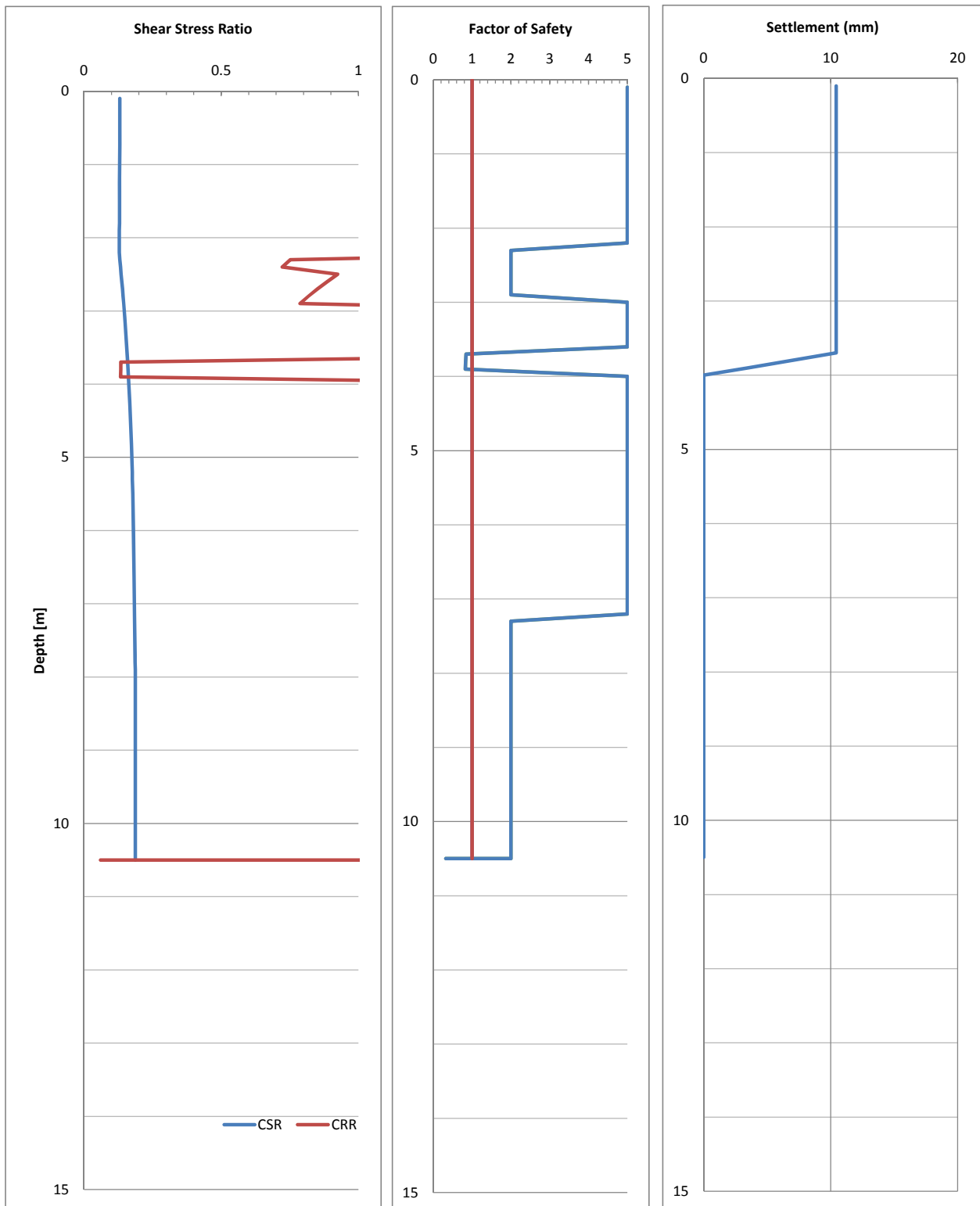
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH6
Design Event	SLS	Magnitude	7.5
Water Table [m]	2.3	Acceleration [g]	0.13

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 10  
LSN: 3

**aurecon**

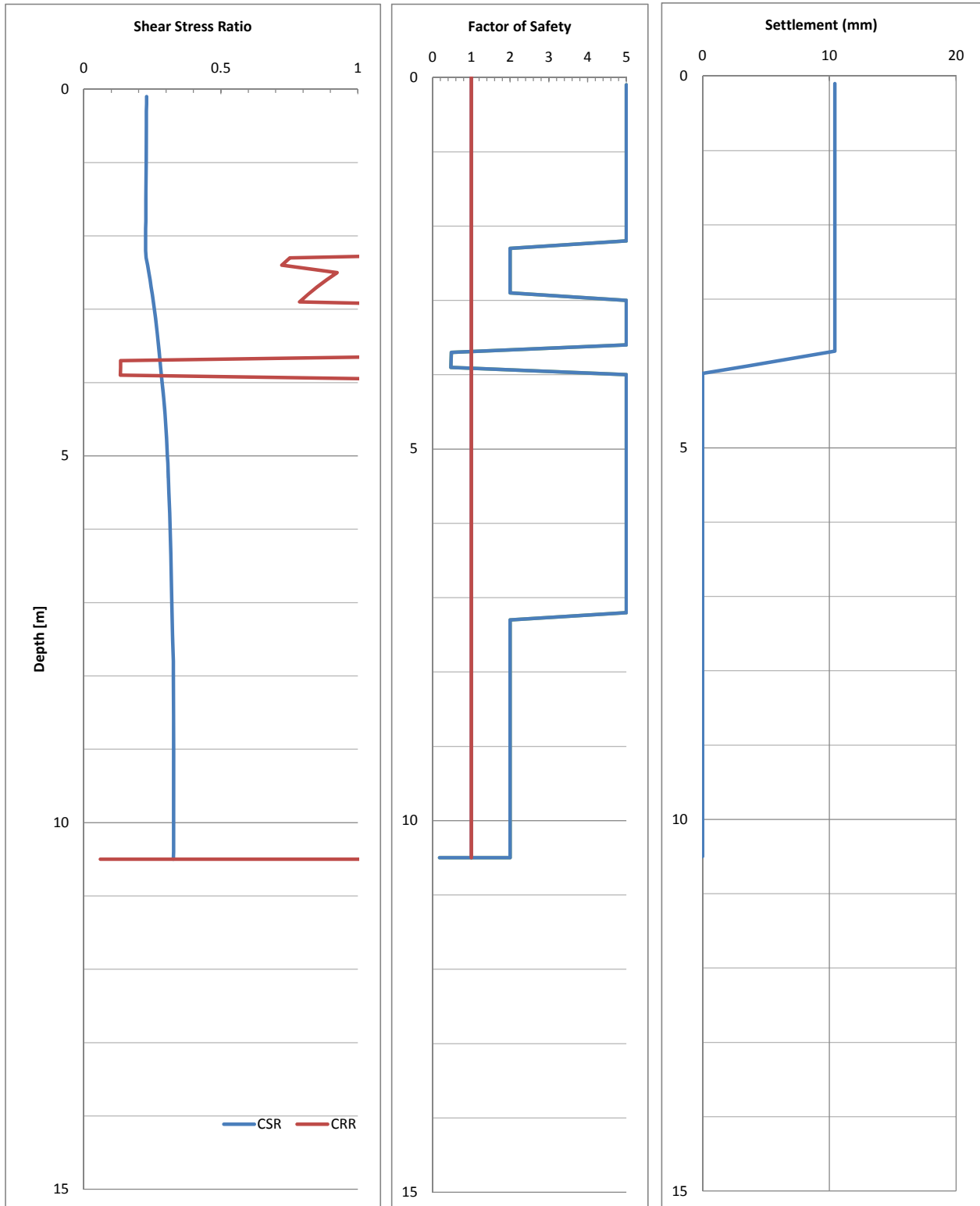
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH6
Design Event	INT	Magnitude	7.5
Water Table [m]	2.3	Acceleration [g]	0.20

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 10  
LSN: 3

**aurecon**

Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

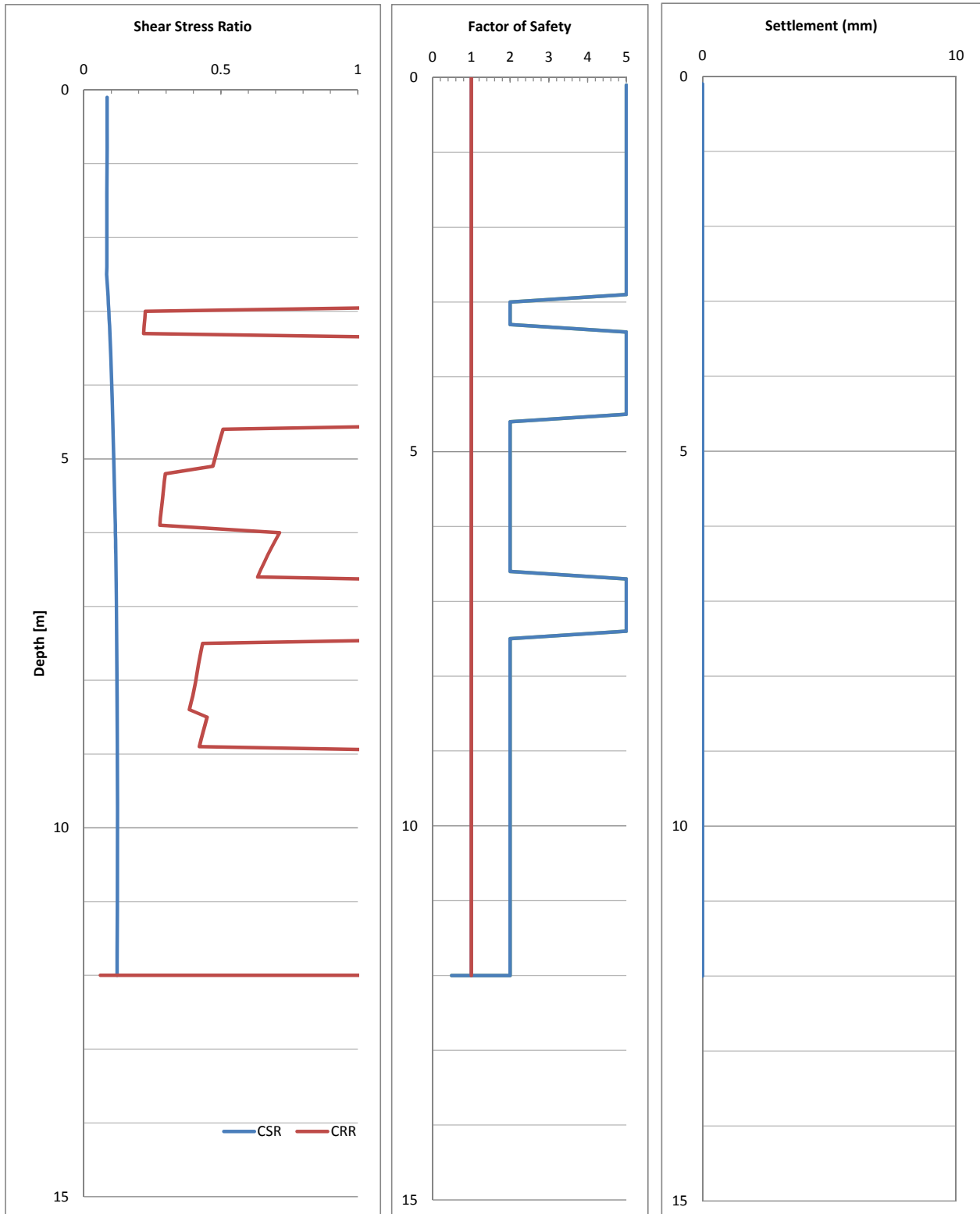
Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH6
Design Event	ULS	Magnitude	7.5
Water Table [m]	2.3	Acceleration [g]	0.35



# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 0  
LSN: 0

**aurecon**

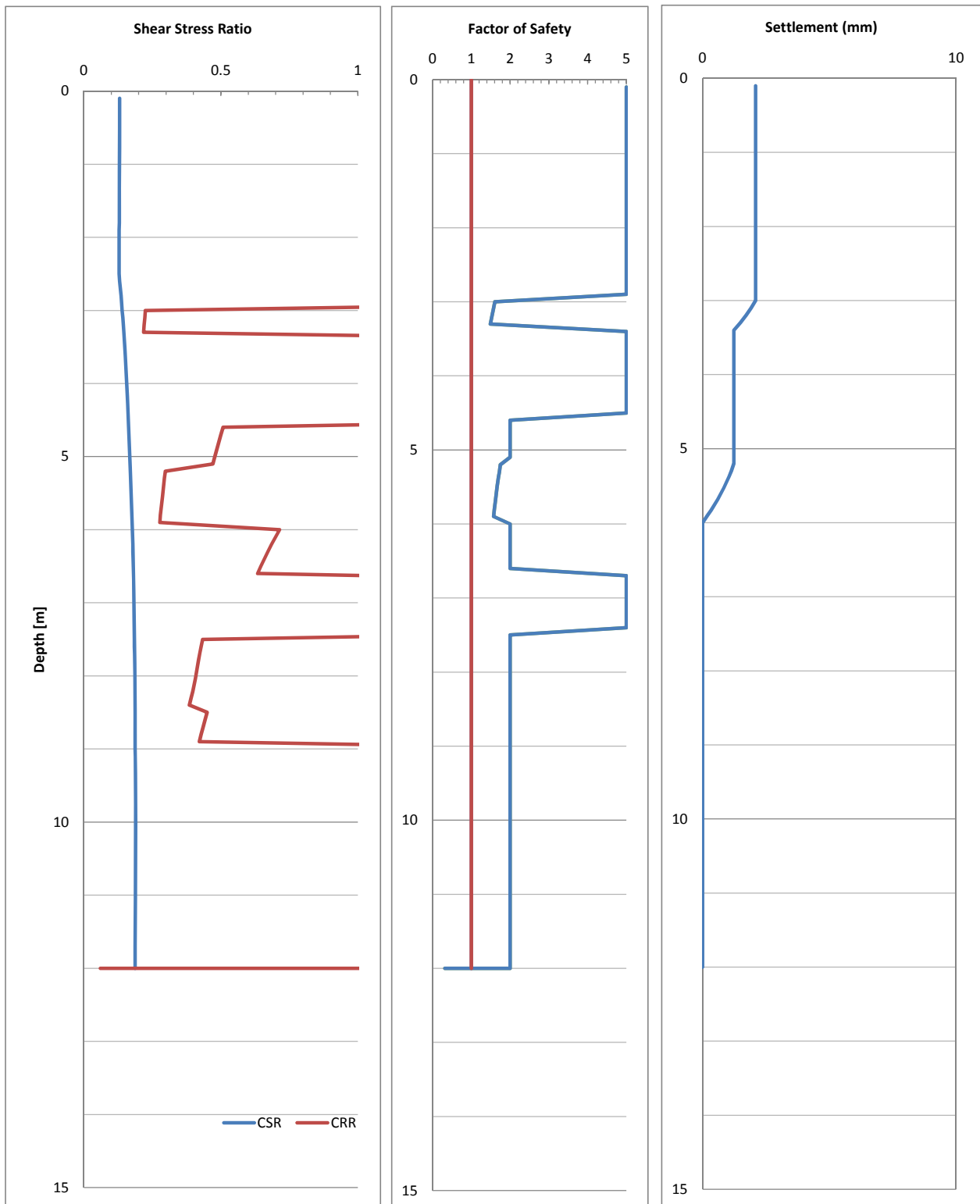
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH7
Design Event	SLS	Magnitude	7.5
Water Table [m]	2.5	Acceleration [g]	0.13

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 2  
LSN: 0

**aurecon**

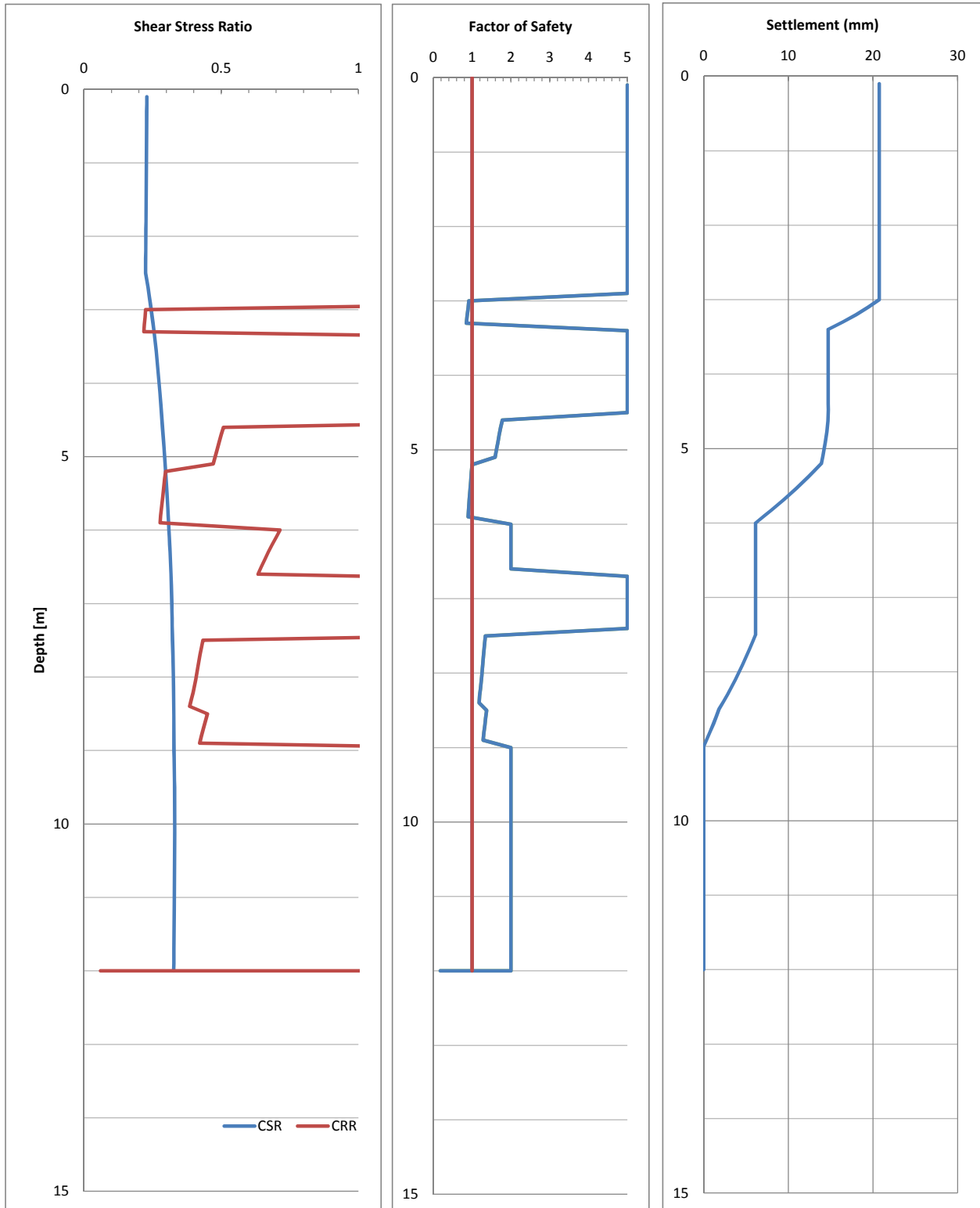
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH7
Design Event	INT	Magnitude	7.5
Water Table [m]	2.5	Acceleration [g]	0.20

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 21  
LSN: 4

**aurecon**

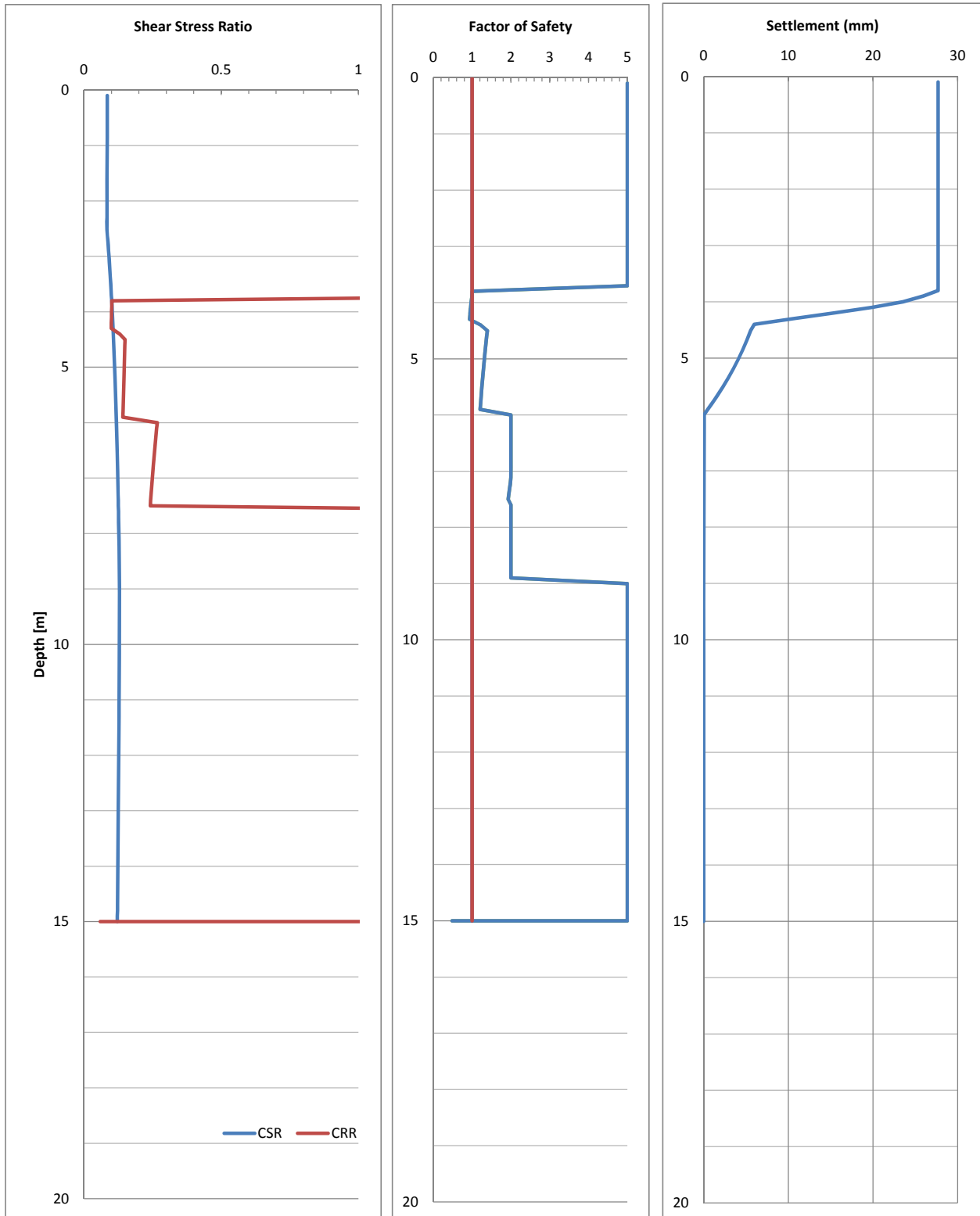
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH7
Design Event	ULS	Magnitude	7.5
Water Table [m]	2.5	Acceleration [g]	0.35

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 28  
LSN: 7

**aurecon**

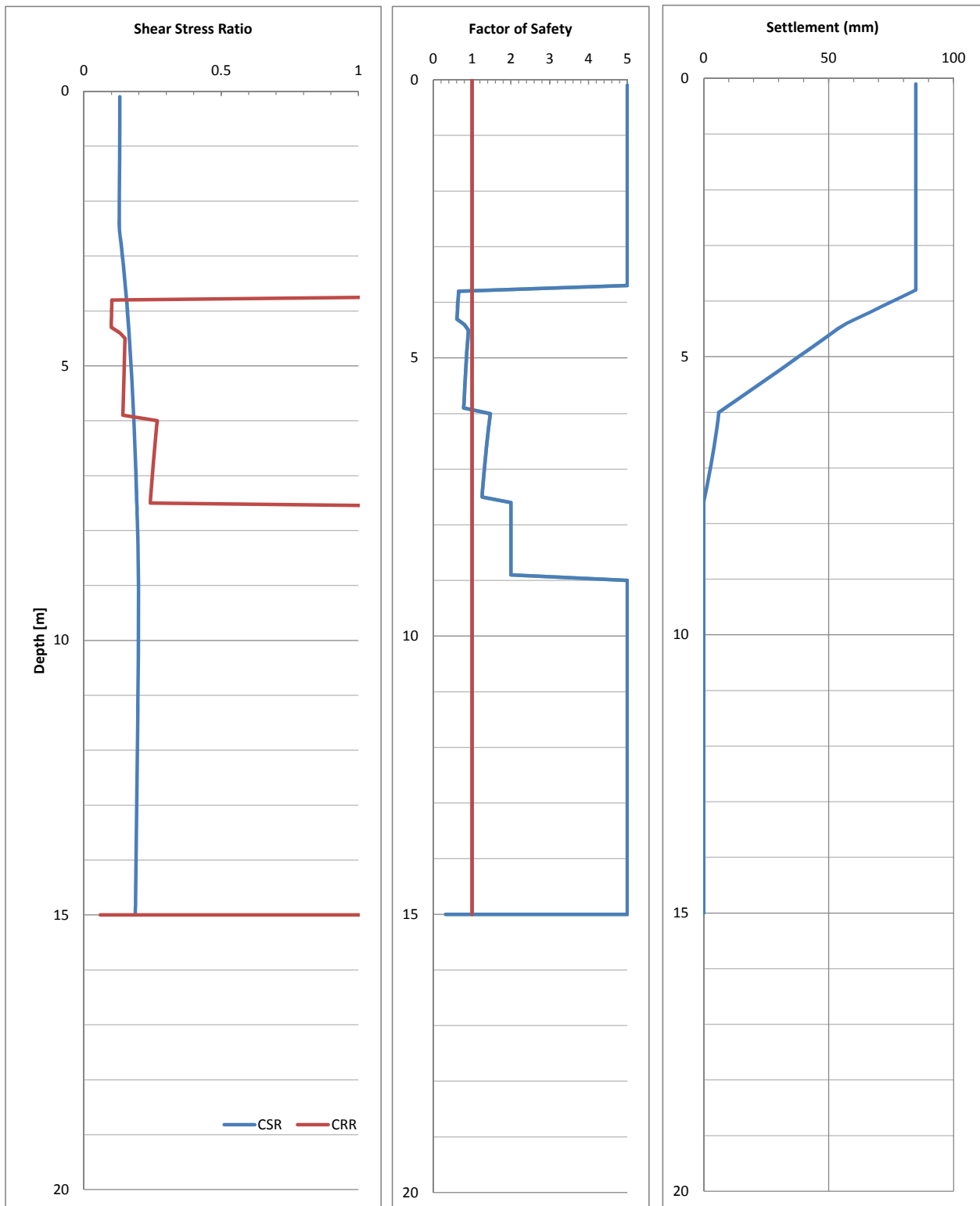
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH8
Design Event	SLS	Magnitude	7.5
Water Table [m]	2.5	Acceleration [g]	0.13

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 85

LSN: 18

**aurecon**

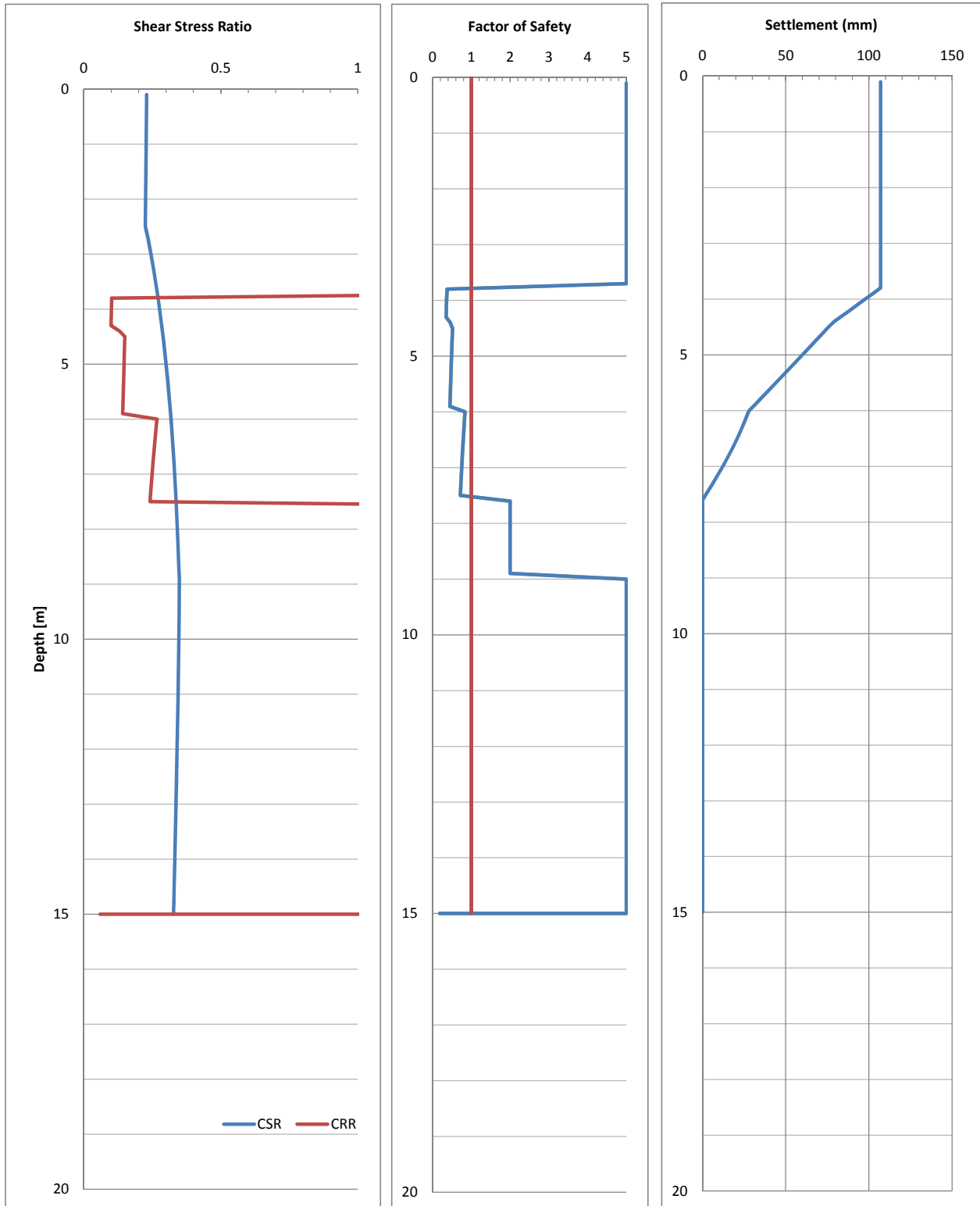
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH8
Design Event	INT	Magnitude	7.5
Water Table [m]	2.5	Acceleration [g]	0.20

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 107  
LSN: 21

**aurecon**

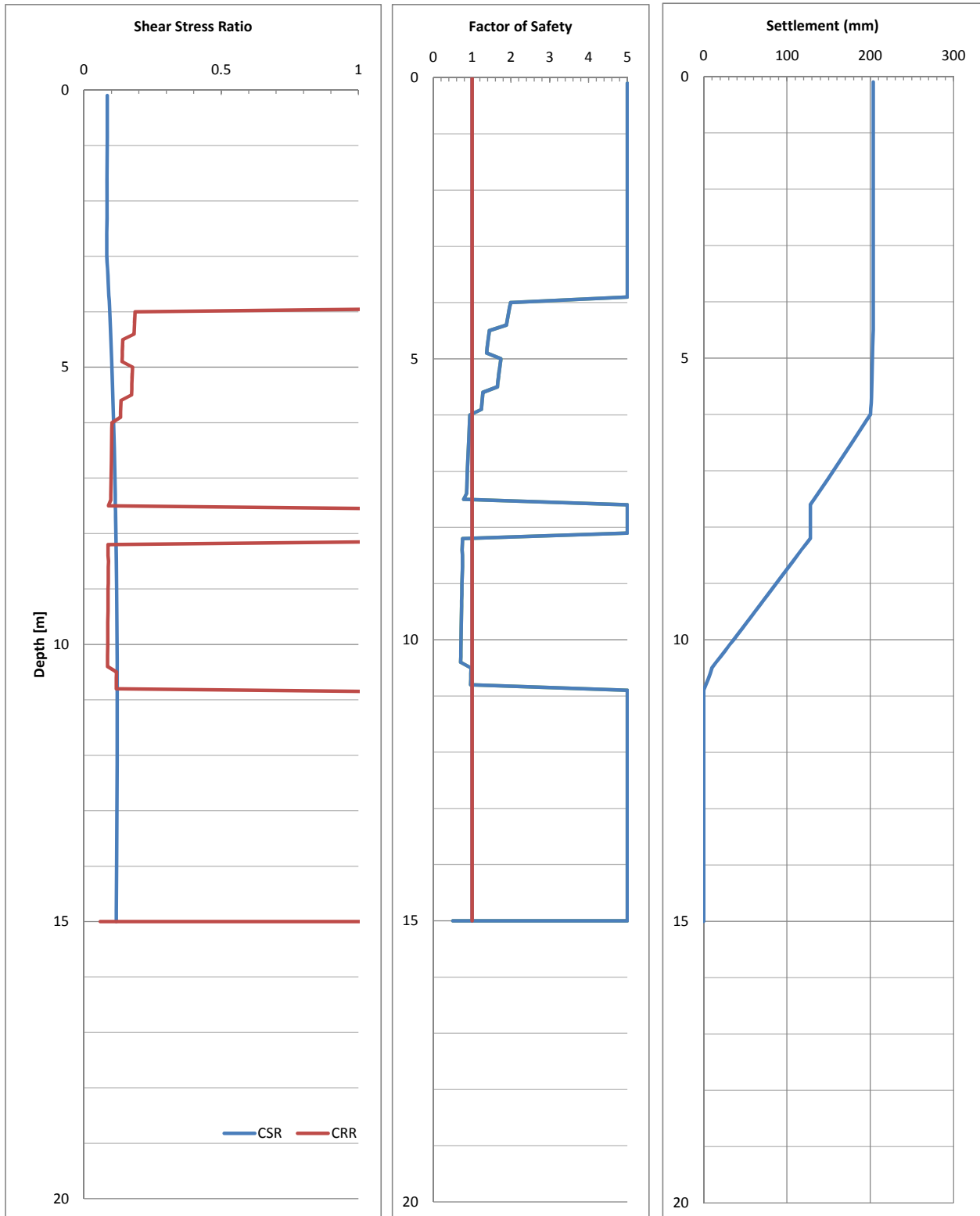
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH8
Design Event	ULS	Magnitude	7.5
Water Table [m]	2.5	Acceleration [g]	0.35

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 204  
LSN: 25

**aurecon**

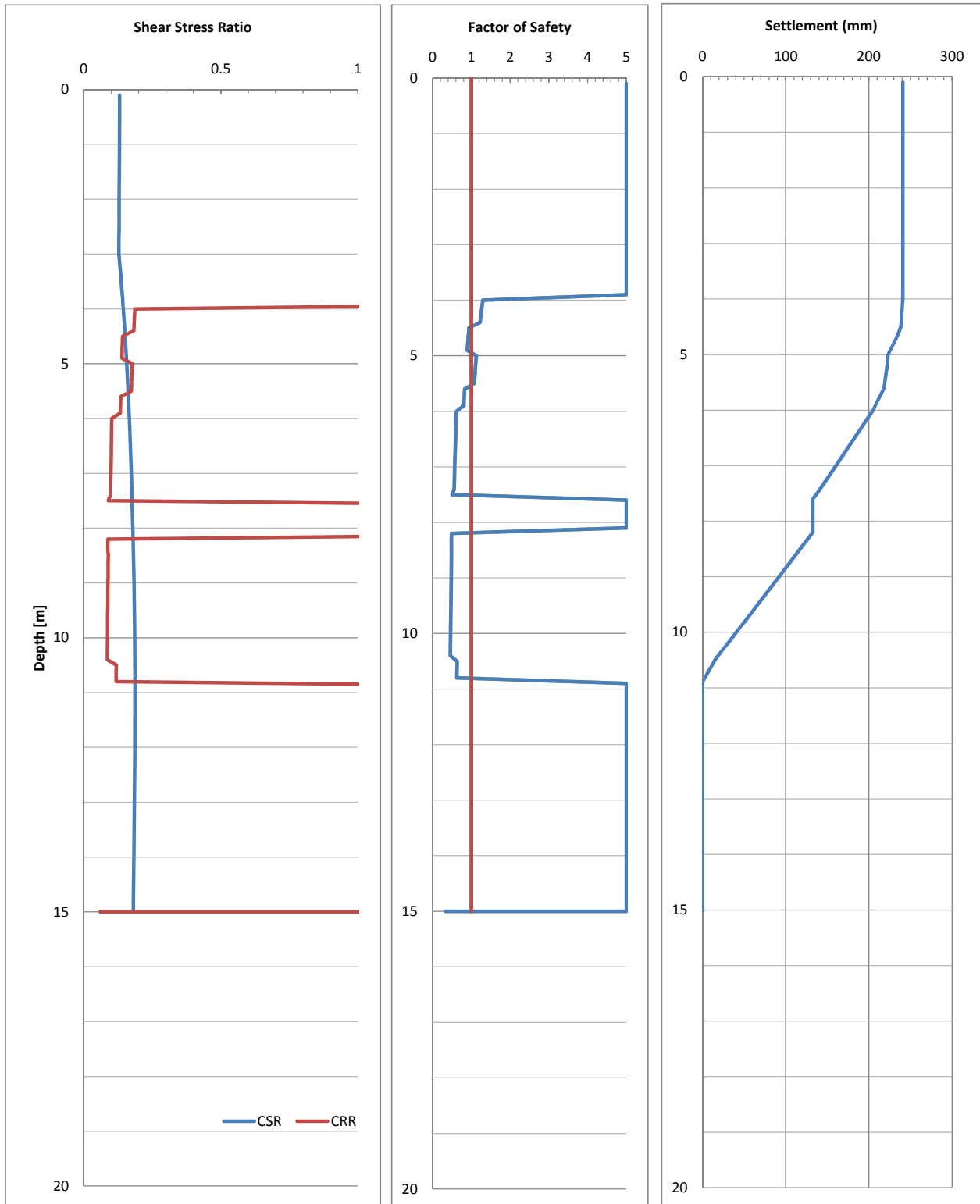
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH9
Design Event	SLS	Magnitude	7.5
Water Table [m]	3.0	Acceleration [g]	0.13

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 241

LSN: 32

**aurecon**

Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

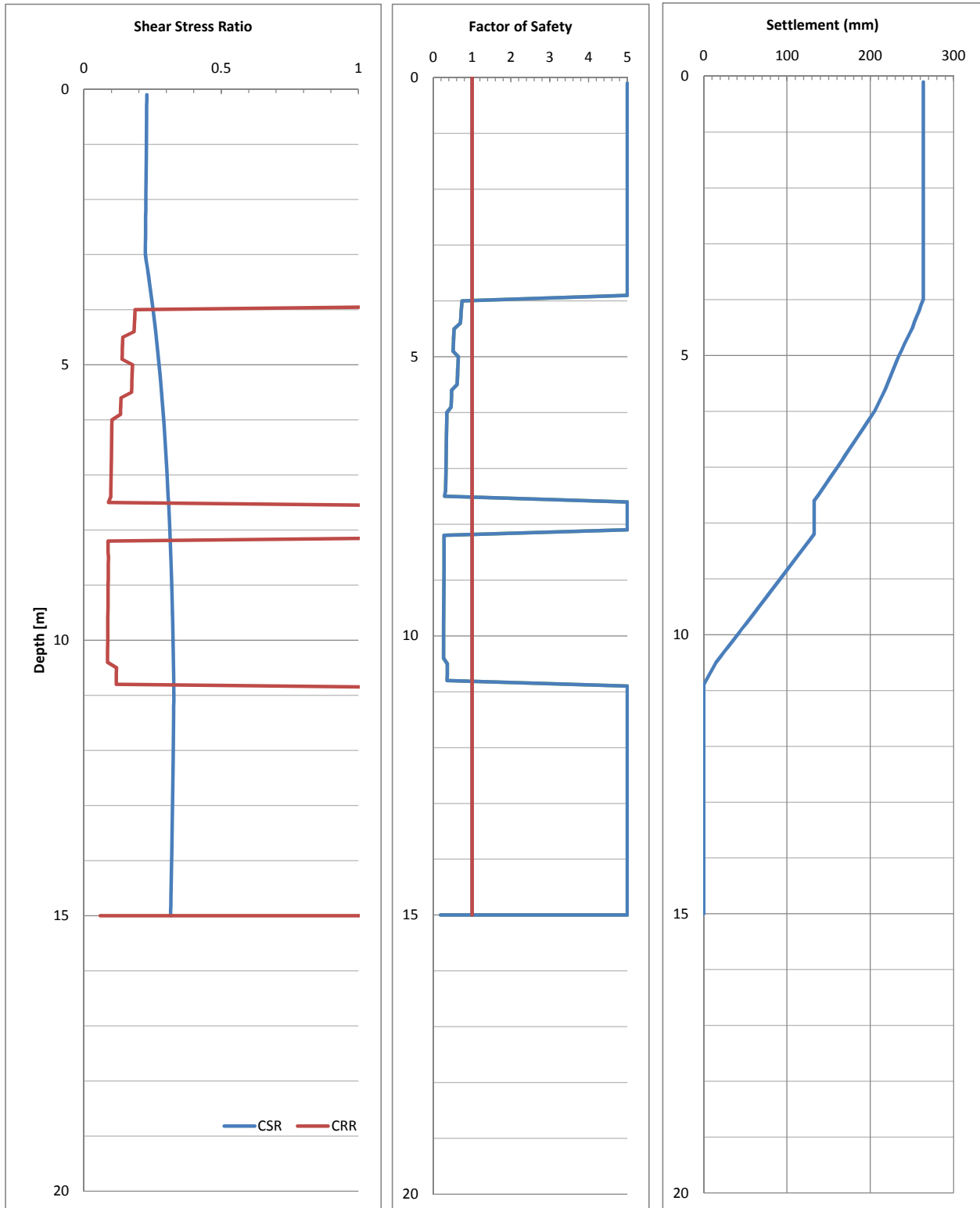
Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH9
Design Event	INT	Magnitude	7.5
Water Table [m]	3.0	Acceleration [g]	0.20



# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 264

LSN: 37

**aurecon**

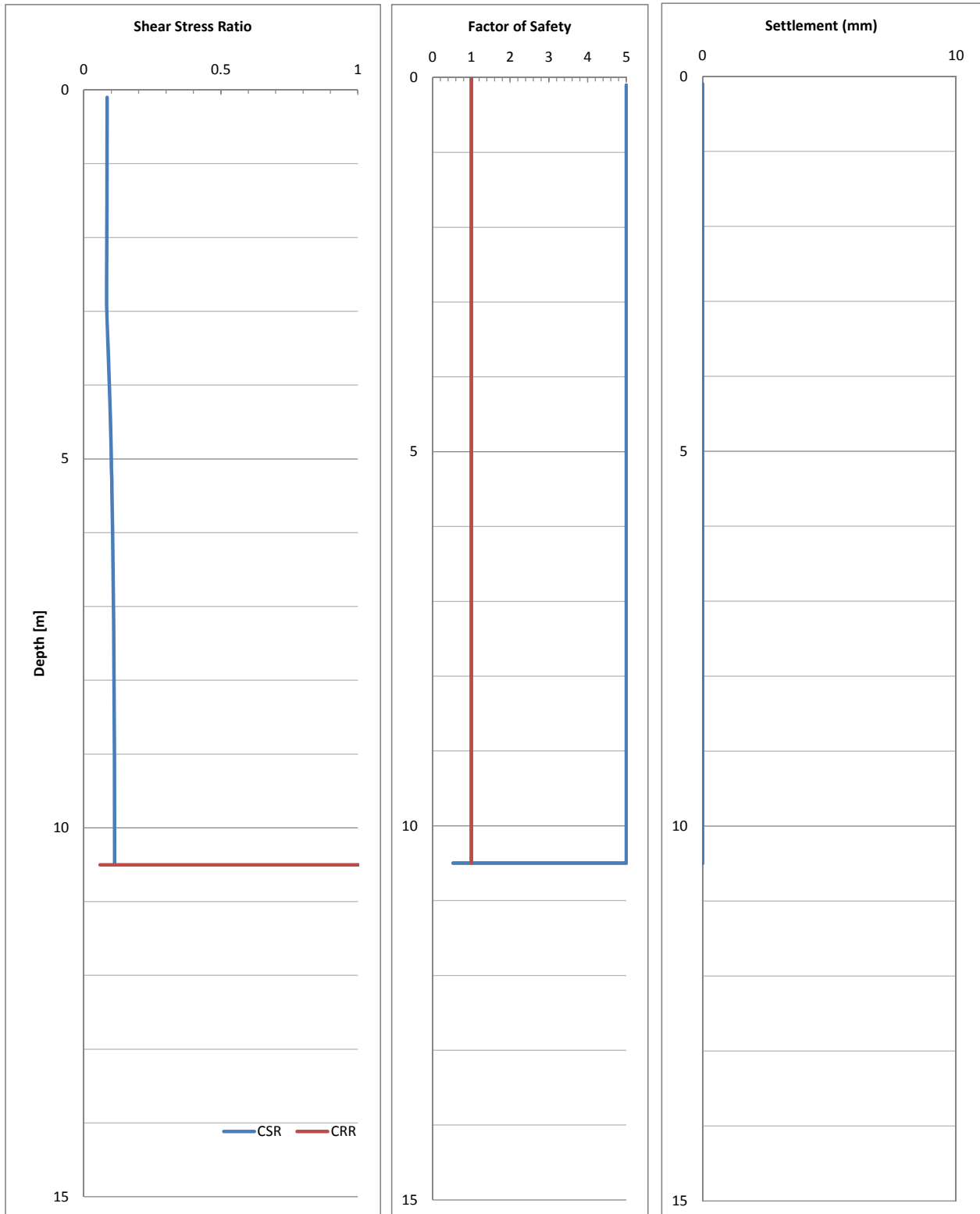
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH9
Design Event	ULS	Magnitude	7.5
Water Table [m]	3.0	Acceleration [g]	0.35

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 0  
LSN: 0

**aurecon**

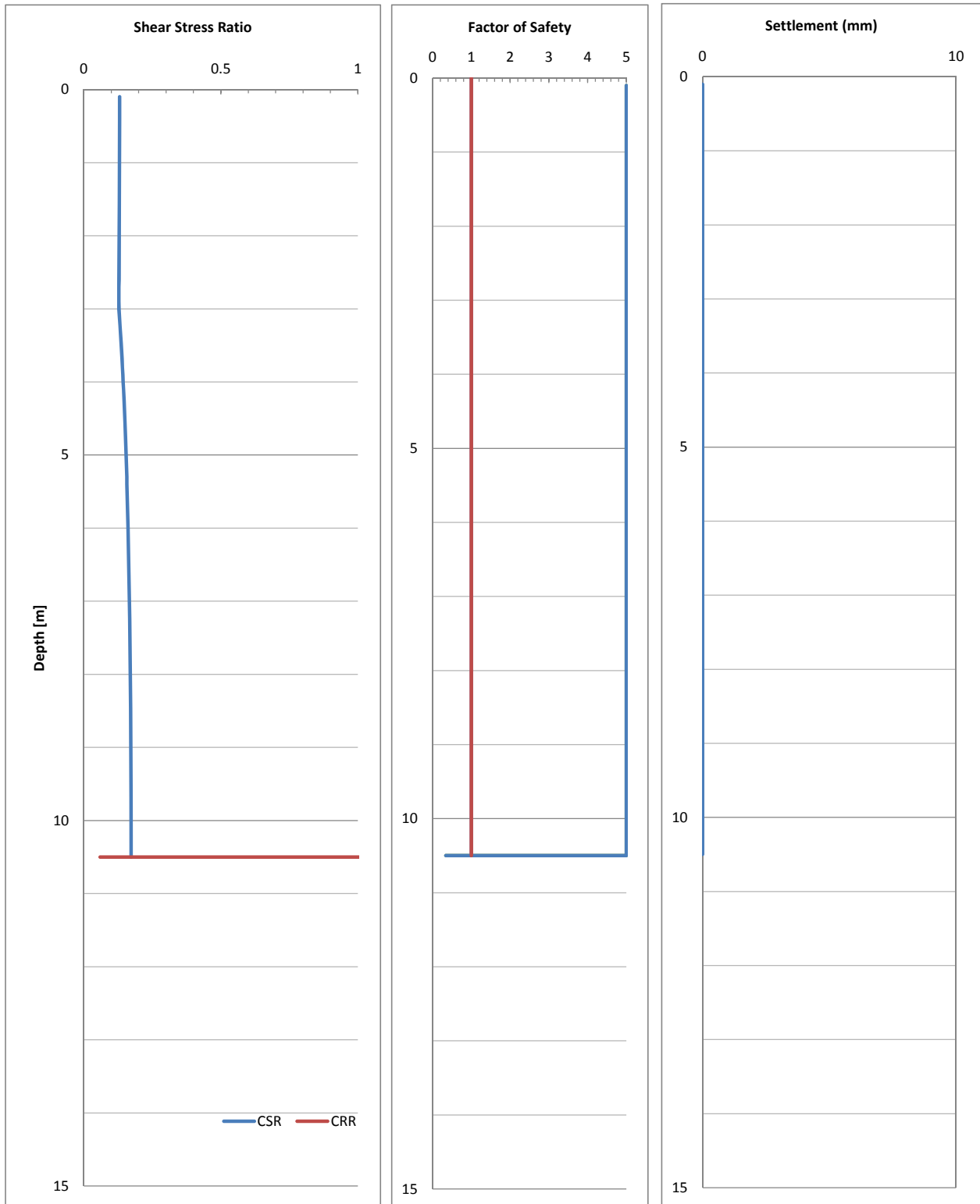
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH10
Design Event	SLS	Magnitude	7.5
Water Table [m]	3.0	Acceleration [g]	0.13

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 0

LSN: 0



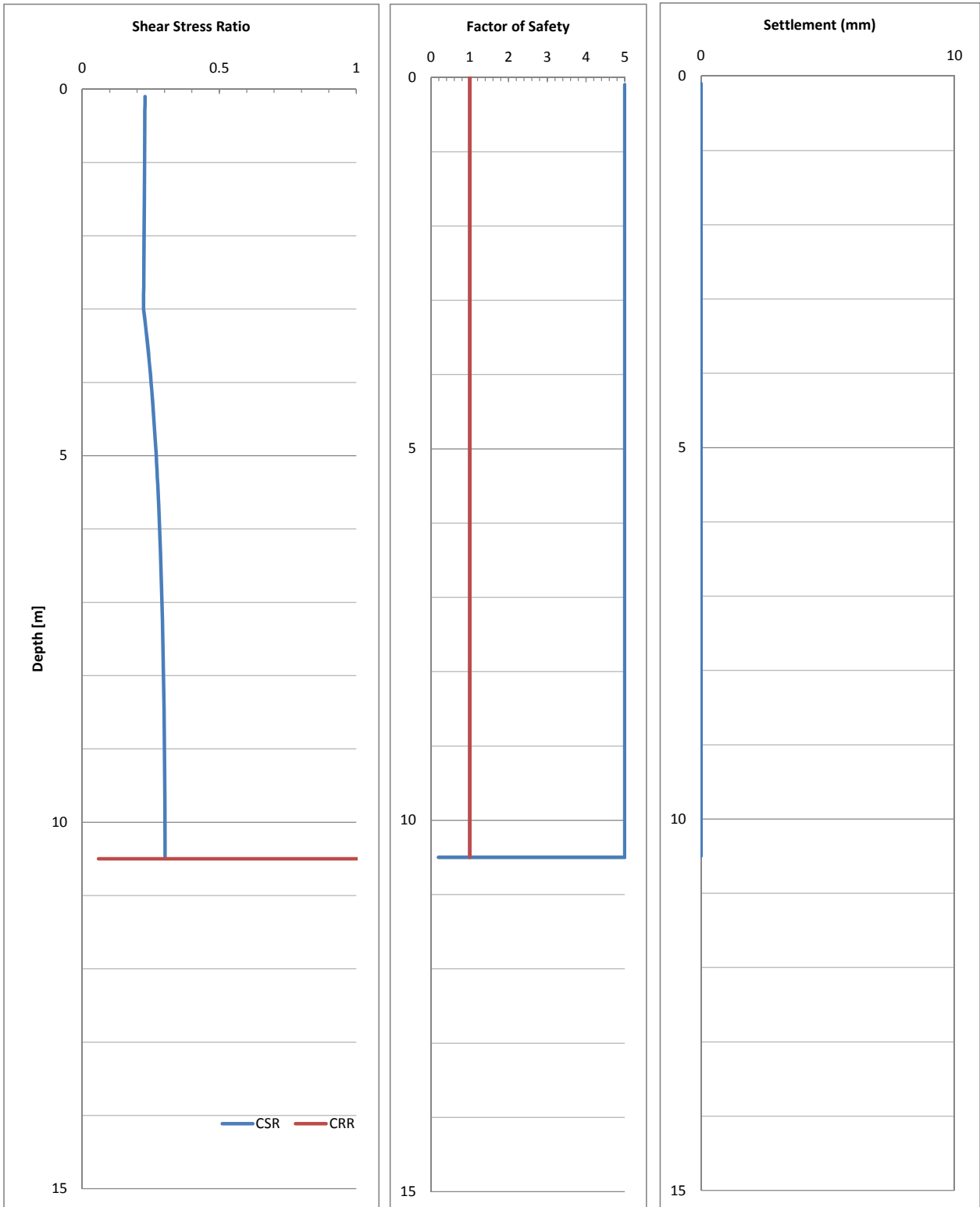
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com

Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH10
Design Event	INT	Magnitude	7.5
Water Table [m]	3.0	Acceleration [g]	0.20

# LIQUEFACTION ANALYSIS

Based upon method outlined in Idris and Boulanger (2008)



Settlement (mm): 0  
LSN: 0

**aurecon**

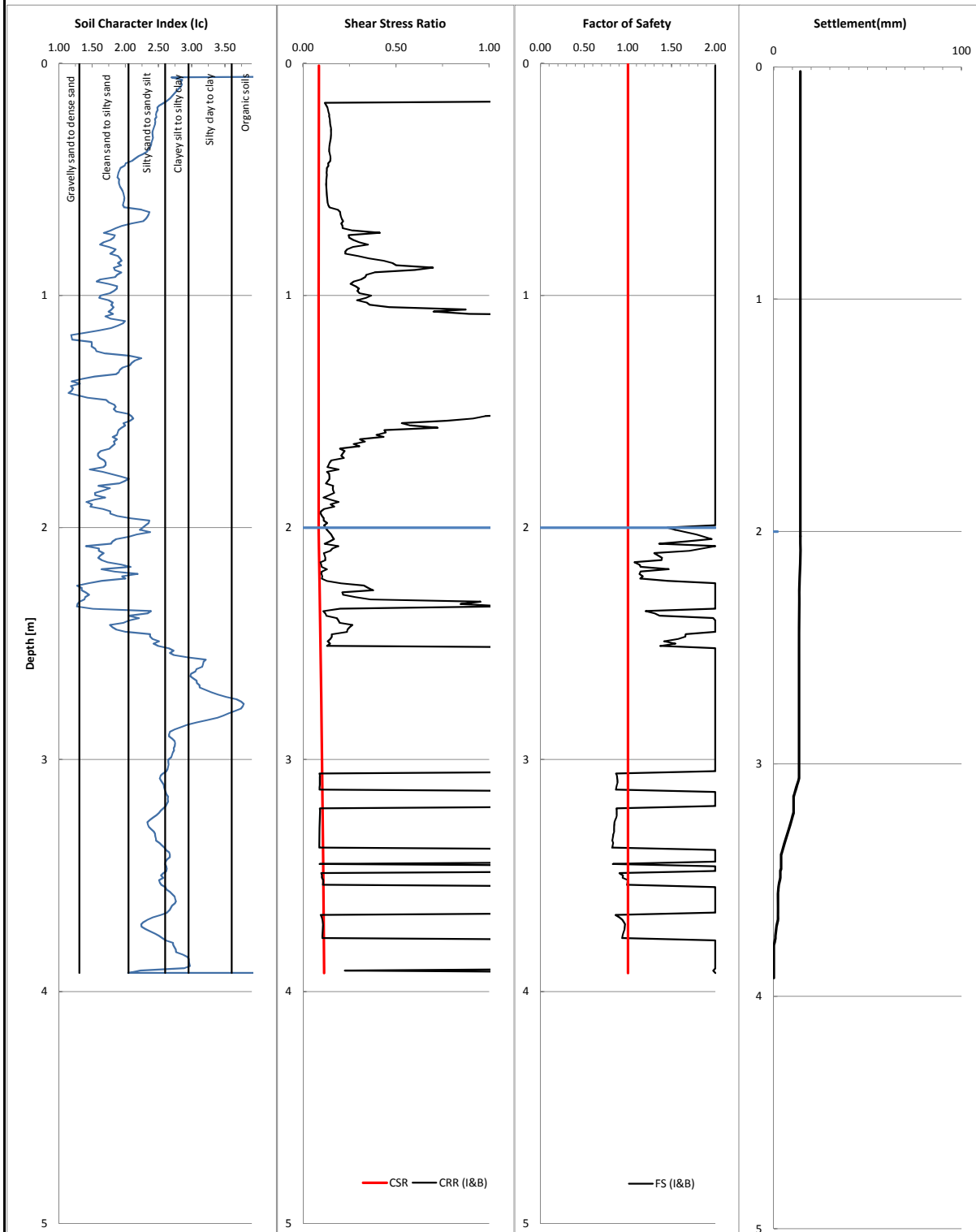
Aurecon New Zealand Limited  
Unit 1, 150 Cavendish Road  
Casebrook  
PO Box 1061  
Christchurch - New Zealand

Telephone: +64 3 366 0821  
Facsimile: +64 3 379 6955  
Email: christchurch@ap.aurecongroup.com  
Website: www.aurecongroup.com


Client	FHLD	Location	KSP Stage 7 & 8
Job No.	200376	Test No.	BH10
Design Event	ULS	Magnitude	7.5
Water Table [m]	3.0	Acceleration [g]	0.35

**LIQUEFACTION ANALYSIS**

Water Table [m] 2.00  
 Magnitude 7.50  
 Acceleration [g] 0.13

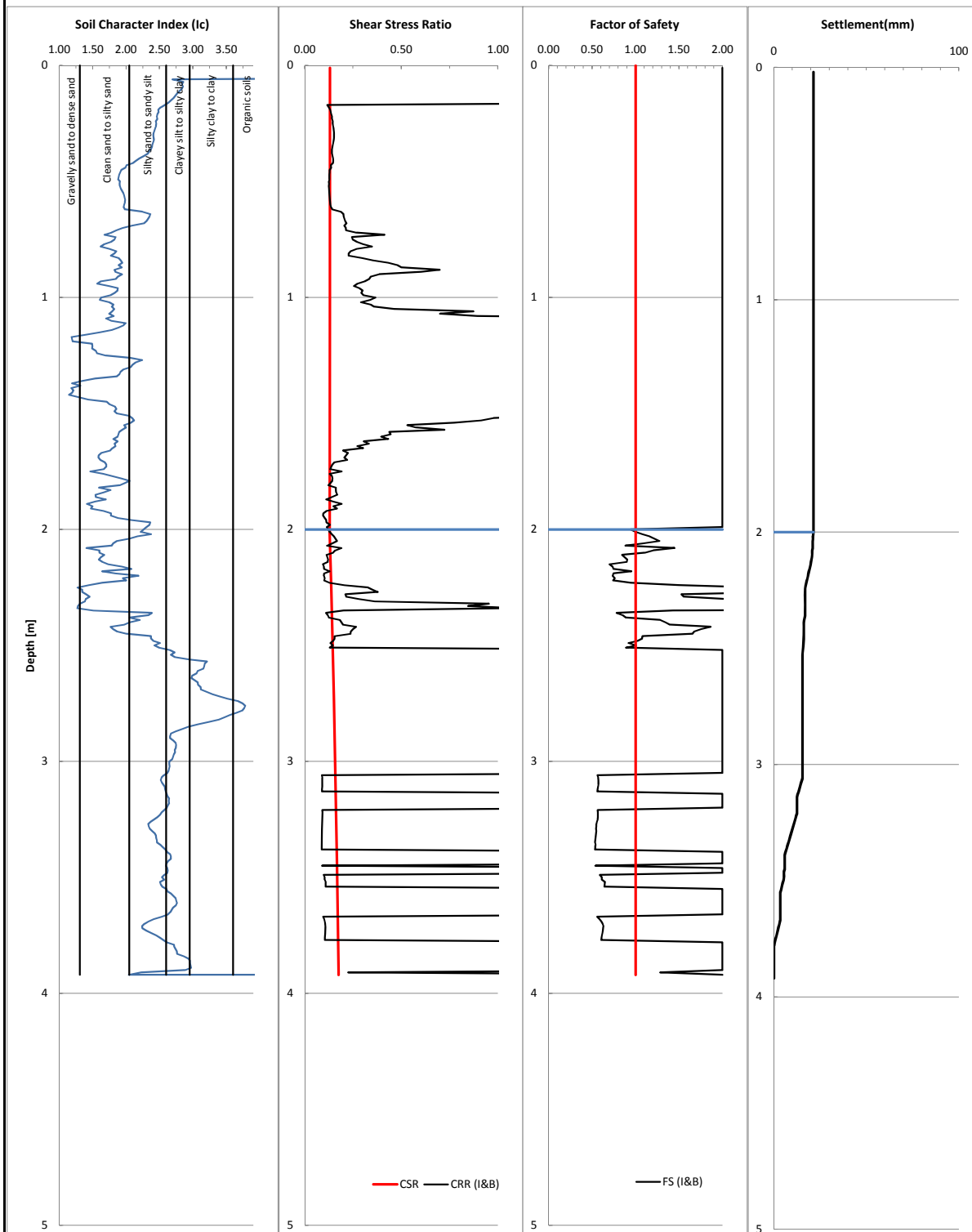


**Total Settlement (mm): 14**  
**LSN: 4**


 <small>           Aurecon New Zealand Limited            Unit 1, 150 Cavendish Road            Cashtown            PO Box 1061            Christchurch - New Zealand         </small>	Client	FHLD	Location	KSP 7 & 8
	Project No.	200376	Test No.	CPT143
	Design Event	SLS EQ	Date	26 November 2013

**LIQUEFACTION ANALYSIS**

Water Table [m] 2.00  
 Magnitude 7.50  
 Acceleration [g] 0.20

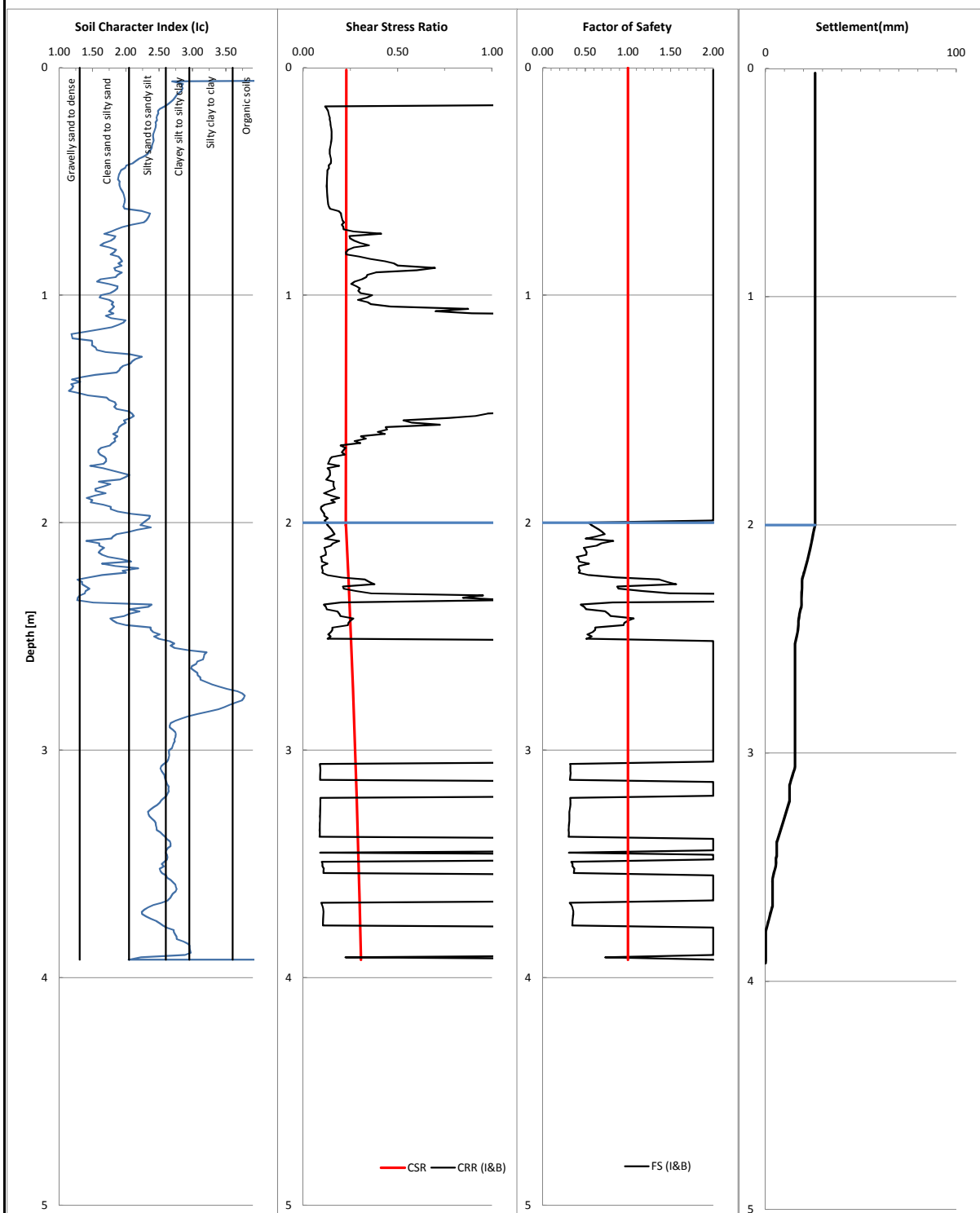


Total Settlement (mm): 21  
 LSN: 7

 <p>Aurecon New Zealand Limited        Unit 1, 150 Cavendish Road        Cashtown        PO Box 1061        Christchurch - New Zealand</p> <p>Telephone: +64 3 366 0821        Facsimile: +64 3 379 6955        Email: christchurch@ap.aurecongroup.com        Website: www.aurecongroup.com</p>	Client	FHLD	Location	KSP 7 & 8
	Project No.	200376	Test No.	CPT143
	Design Event	INT EQ	Date	26 November 2013

**LIQUEFACTION ANALYSIS**

Water Table [m] 2.00  
 Magnitude 7.50  
 Acceleration [g] 0.35



Total Settlement (mm): 26  
 LSN: 9

**aurecon**

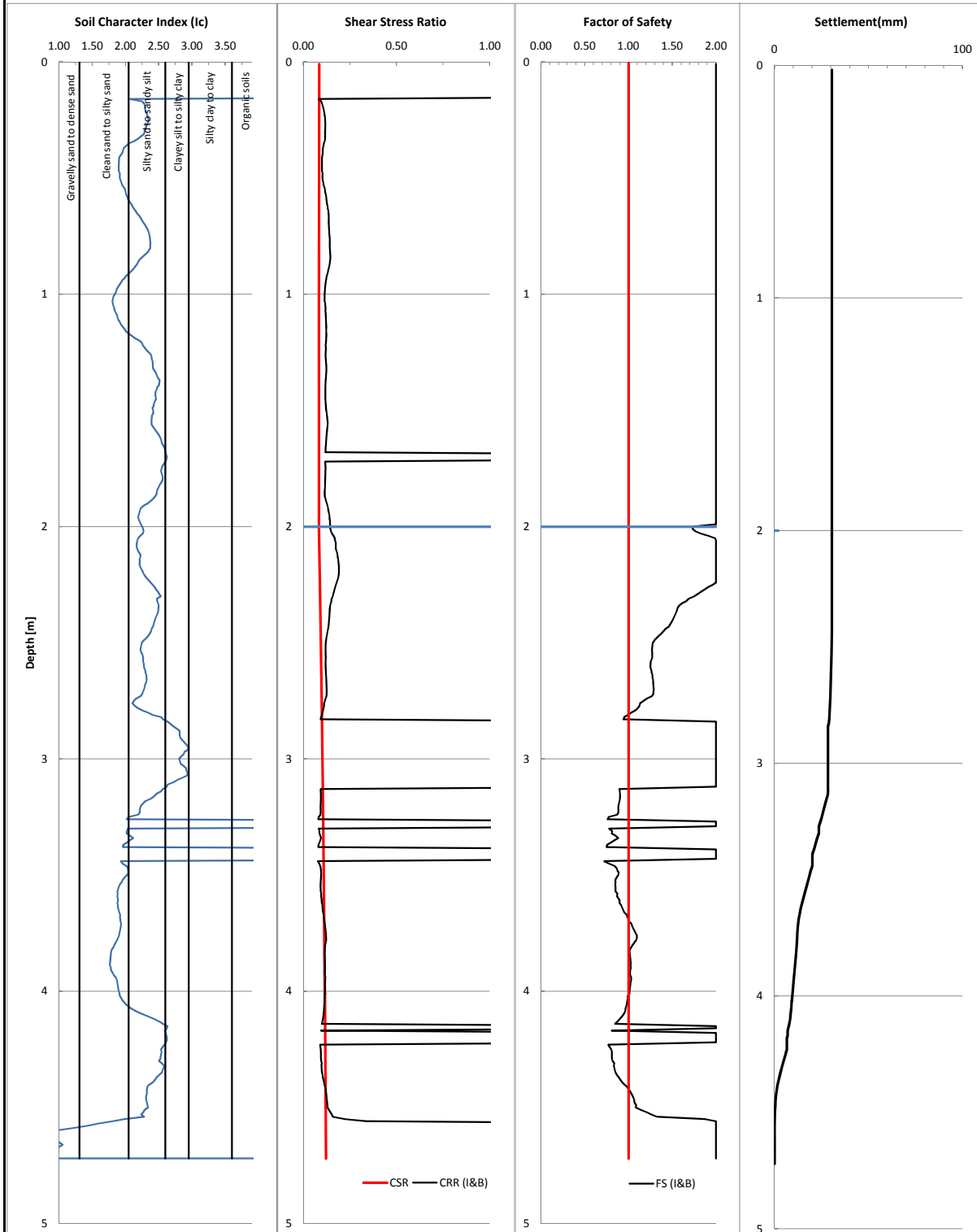
Aurecon New Zealand Limited  
 Unit 1, 150 Cavendish Road  
 Cessnock  
 PO Box 1061  
 Christchurch - New Zealand

Telephone: +64 3 366 0821  
 Facsimile: +64 3 379 8955  
 Email: christchurch@nz.aurecongroup.com  
 Website: www.aurecongroup.com


Client	FHLD	Location	KSP 7 & 8
Project No.	200376	Test No.	CPT143
Design Event	ULS EQ	Date	26 November 2013

**LIQUEFACTION ANALYSIS**

Water Table [m] 2.00  
 Magnitude 7.50  
 Acceleration [g] 0.13



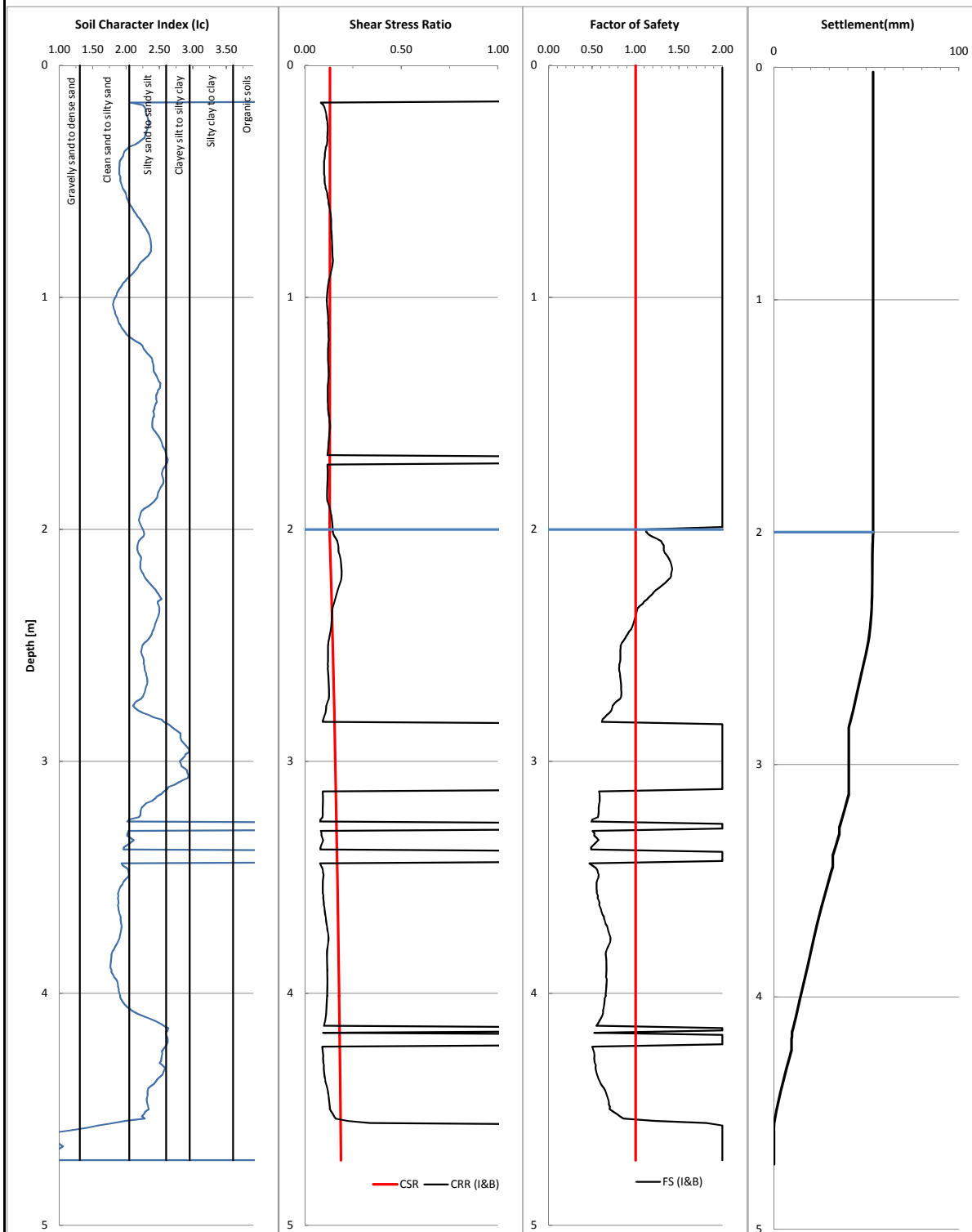
**Total Settlement (mm): 31**  
 LSN: 8

 <p><small>Aurecon New Zealand Limited  Unit 1, 150 Cavendish Road  Cashmere  PO Box 1061  Christchurch - New Zealand</small></p>	Client	FHLD	Location	KSP 7 & 8
	Project No.	200376	Test No.	CPT154
	Design Event	SLS EQ	Date	26 November 2013




**LIQUEFACTION ANALYSIS**

Water Table [m] 2.00  
 Magnitude 7.50  
 Acceleration [g] 0.20

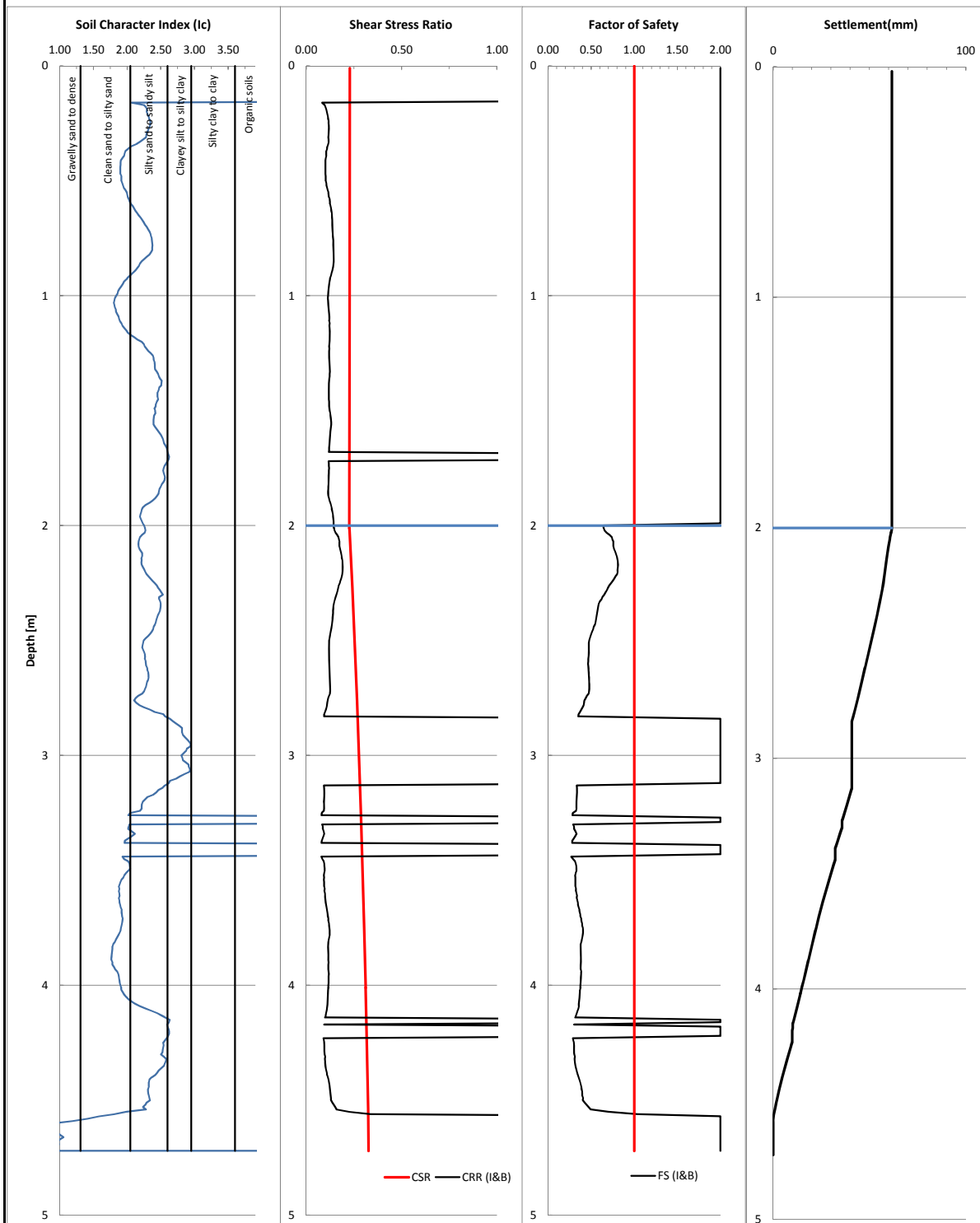


**Total Settlement (mm): 54**  
**LSN: 16**

 <p><small>Aurecon New Zealand Limited Unit 1, 150 Cavendish Road Cashmere PO Box 1061 Christchurch - New Zealand</small></p> <p><small>Telephone: +64 3 366 0821 Facsimile: +64 3 379 6955 Email: christchurch@ap.aurecongroup.com Website: www.aurecongroup.com</small></p>	Client	FHLD	Location	KSP 7 & 8
	Project No.	200376	Test No.	CPT154
	Design Event	INT EQ	Date	26 November 2013

**LIQUEFACTION ANALYSIS**

Water Table [m] 2.00  
 Magnitude 7.50  
 Acceleration [g] 0.35



**Total Settlement (mm): 62**  
 LSN: 19

**aurecon**

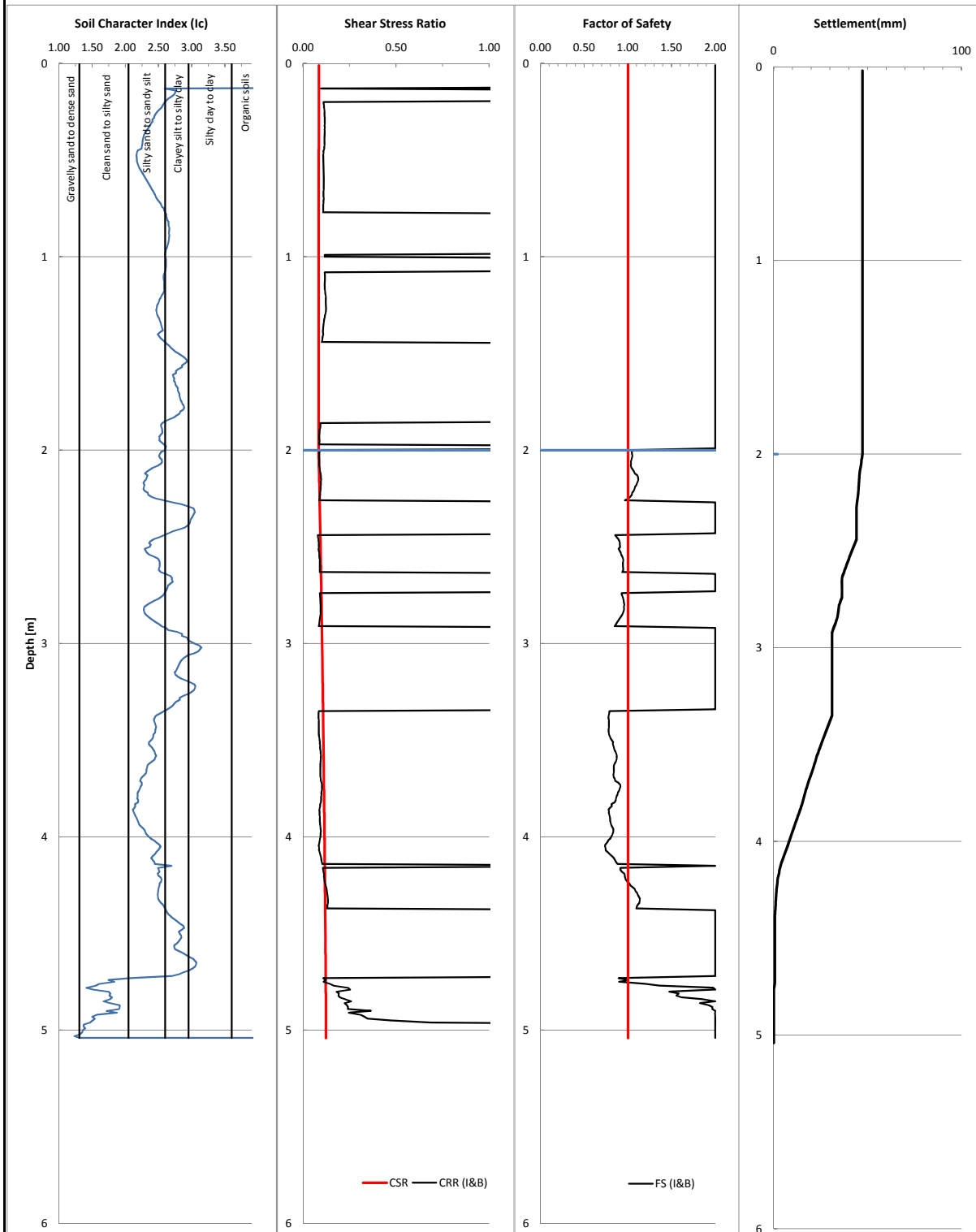
Aurecon New Zealand Limited  
 Unit 1, 150 Cavendish Road  
 Christchurch  
 PO Box 1061  
 Christchurch - New Zealand

Telephone: +64 3 366 0821  
 Facsimile: +64 3 379 8955  
 Email: christchurch@nz.aurecongroup.com  
 Website: www.aurecongroup.com


Client	FHLD	Location	KSP 7 & 8
Project No.	200376	Test No.	CPT154
Design Event	ULS EQ	Date	26 November 2013

**LIQUEFACTION ANALYSIS**

Water Table [m] 2.00  
 Magnitude 7.50  
 Acceleration [g] 0.13

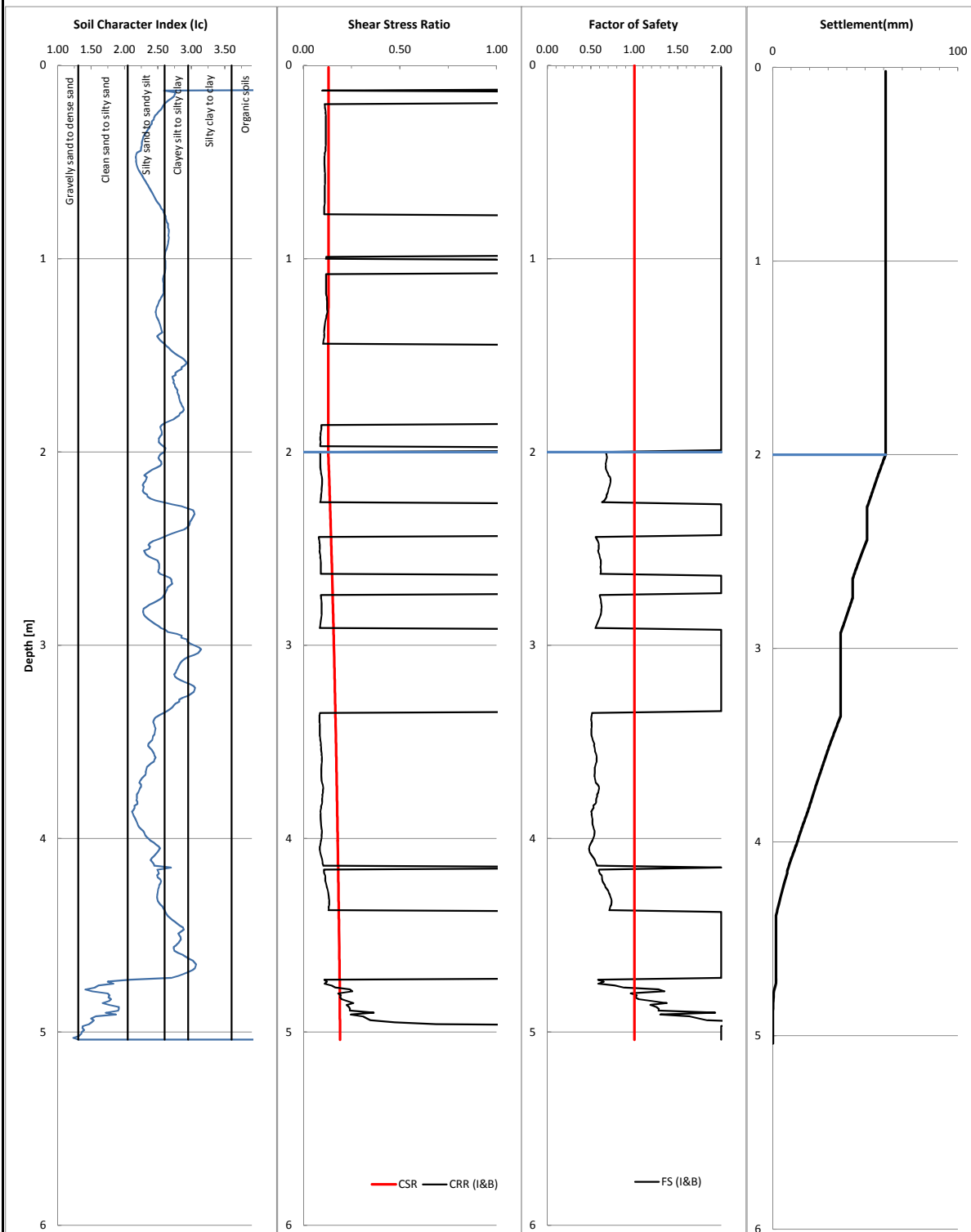


**Total Settlement (mm): 47**  
**LSN: 15**


 <small>Aurecon New Zealand Limited          Unit 1, 150 Cavendish Road          Cashtown          PO Box 1061          Christchurch - New Zealand</small>	Client	FHLD	Location	KSP 7 & 8
	Project No.	200376	Test No.	CPT158
	Design Event	SLS EQ	Date	26 November 2013

**LIQUEFACTION ANALYSIS**

Water Table [m] 2.00  
 Magnitude 7.50  
 Acceleration [g] 0.20

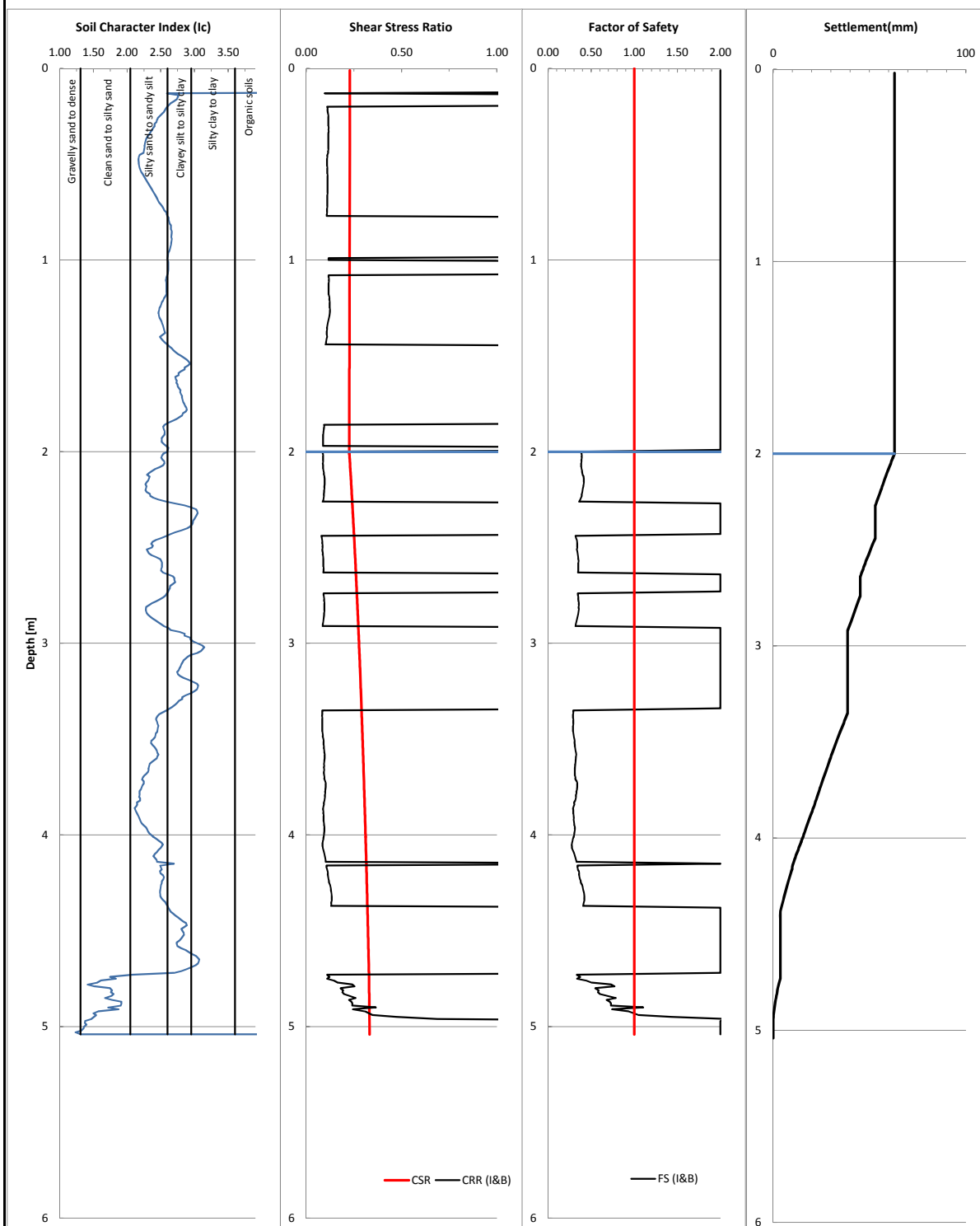


**Total Settlement (mm): 61**  
 LSN: 20

 <small>Aurecon New Zealand Limited          Unit 1, 150 Cavendish Road          Cashtown          PO Box 1061          Christchurch - New Zealand</small>	Client	FHLD	Location	KSP 7 & 8
	Project No.	200376	Test No.	CPT158
	Design Event	INT EQ	Date	26 November 2013

**LIQUEFACTION ANALYSIS**

Water Table [m] 2.00  
 Magnitude 7.50  
 Acceleration [g] 0.35



**Total Settlement (mm): 63**  
 LSN: 20

**aurecon**

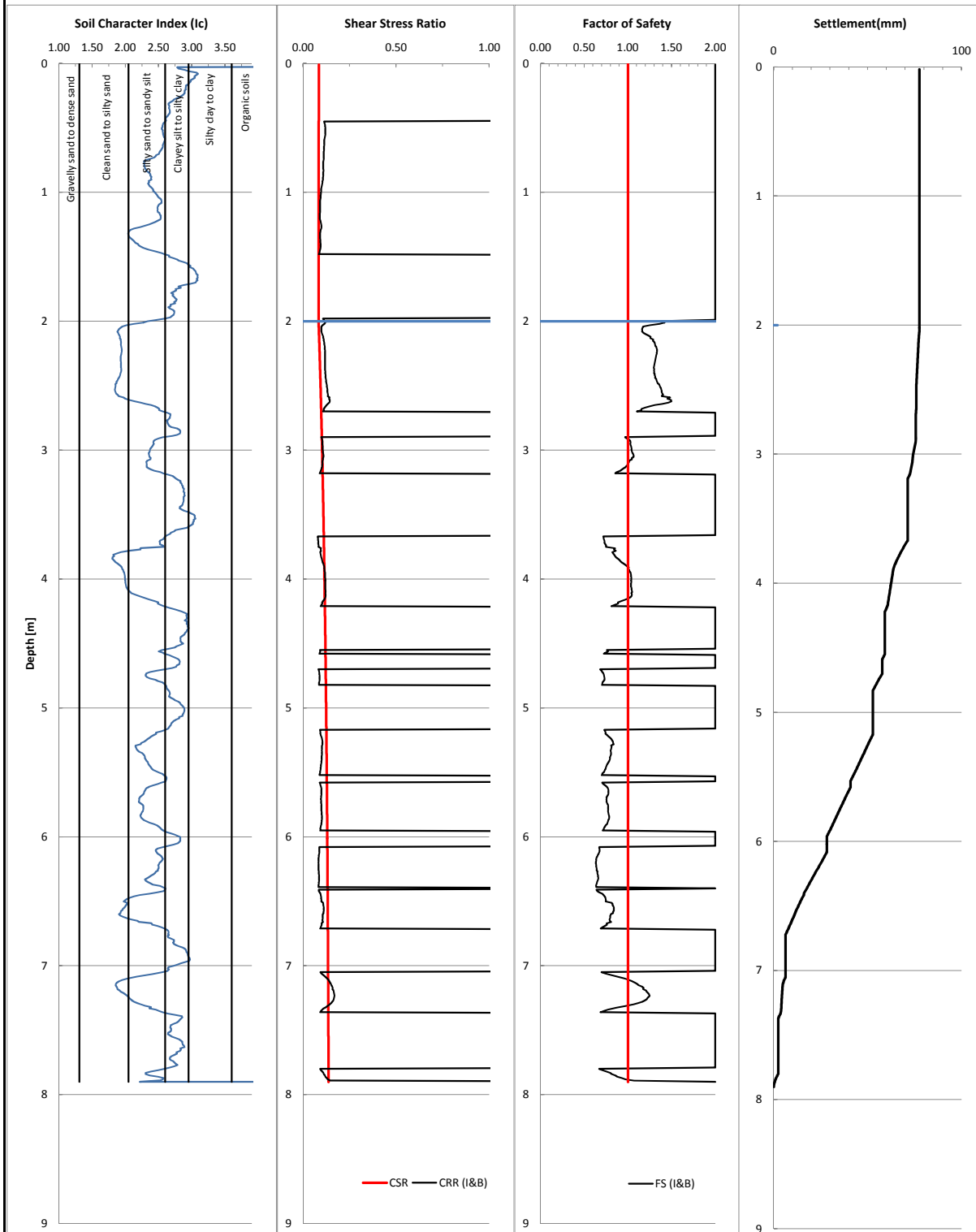
Aurecon New Zealand Limited  
 Unit 1, 150 Cavendish Road  
 Christchurch  
 PO Box 1061  
 Christchurch - New Zealand

Telephone: +64 3 366 0821  
 Facsimile: +64 3 379 8955  
 Email: christchurch@nz.aurecongroup.com  
 Website: www.aurecongroup.com


Client	FHLD	Location	KSP 7 & 8
Project No.	200376	Test No.	CPT158
Design Event	ULS EQ	Date	26 November 2013

**LIQUEFACTION ANALYSIS**

Water Table [m] 2.00  
 Magnitude 7.50  
 Acceleration [g] 0.13

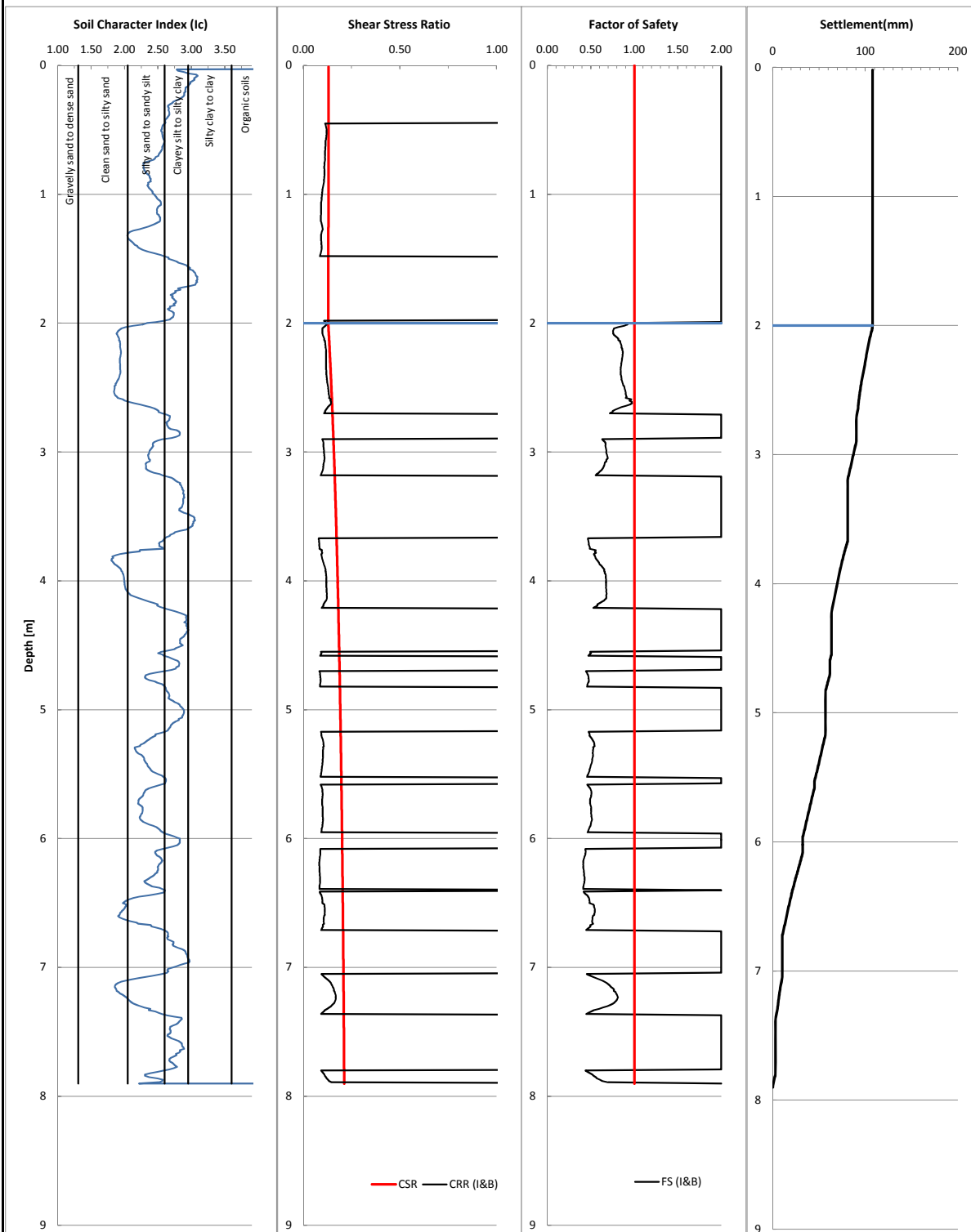


**Total Settlement (mm): 78**  
 LSN: 16


 <small>Aurecon New Zealand Limited          Unit 1, 150 Cavendish Road          Cashtown          PO Box 1061          Christchurch - New Zealand          Telephone: +64 3 366 0821          Facsimile: +64 3 379 6955          Email: christchurch@ap.aurecongroup.com          Website: www.aurecongroup.com</small>	Client	FHLD	Location	KSP 7 & 8
	Project No.	200376	Test No.	CPT501
	Design Event	SLS EQ	Date	26 November 2013

**LIQUEFACTION ANALYSIS**

Water Table [m] 2.00  
 Magnitude 7.50  
 Acceleration [g] 0.20

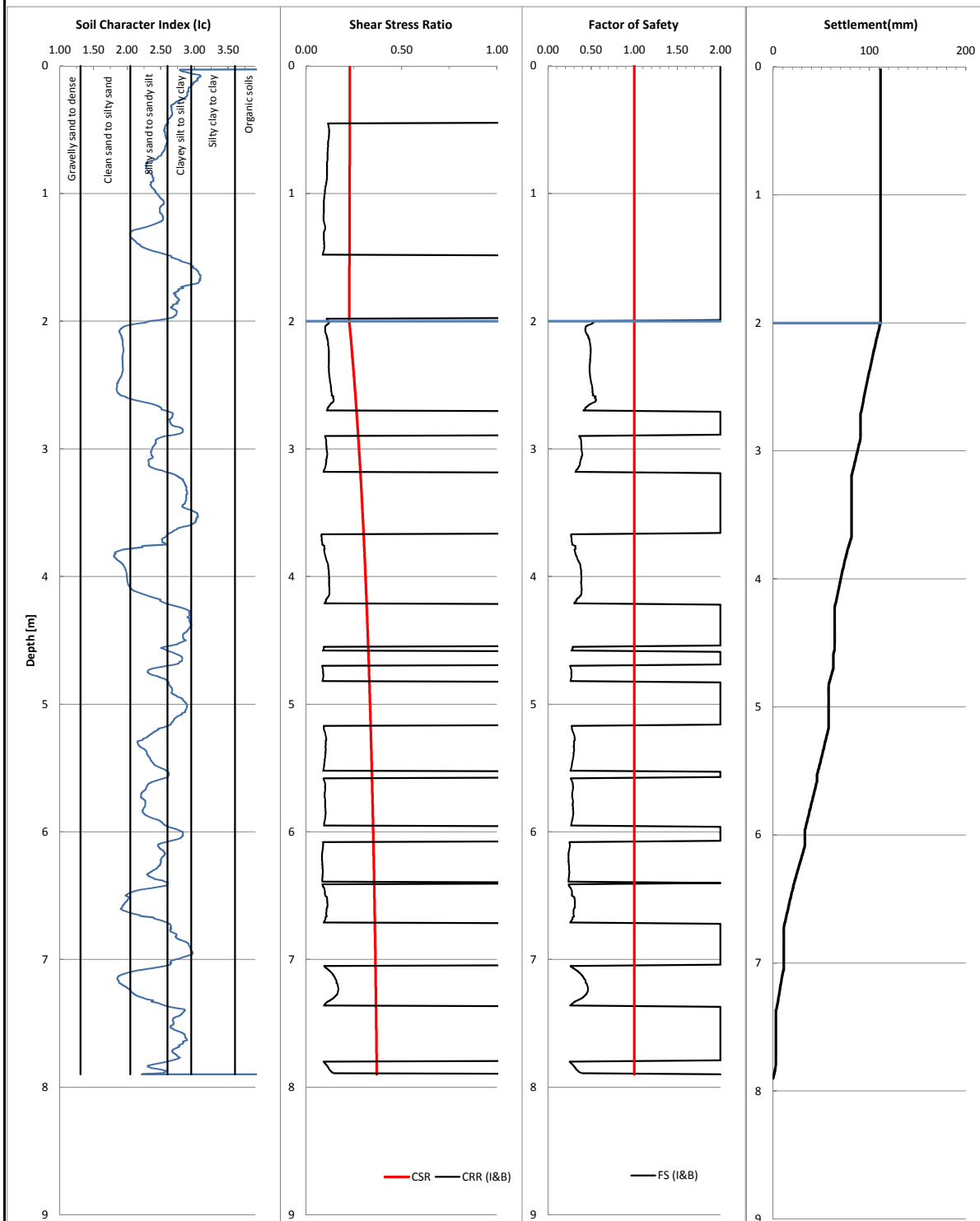


**Total Settlement (mm): 108**  
 LSN: 26

 <small>Aurecon New Zealand Limited          Unit 1, 150 Cavendish Road          Cashtown          PO Box 1061          Christchurch - New Zealand          Telephone: +64 3 366 0821          Facsimile: +64 3 379 6955          Email: christchurch@ap.aurecongroup.com          Website: www.aurecongroup.com</small>	Client	FHLD	Location	KSP 7 & 8
	Project No.	200376	Test No.	CPT501
	Design Event	INT EQ	Date	26 November 2013

**LIQUEFACTION ANALYSIS**

Water Table [m] 2.00  
 Magnitude 7.50  
 Acceleration [g] 0.35



Total Settlement (mm): 111  
 LSN: 27

**aurecon**

Aurecon New Zealand Limited  
 Unit 1, 150 Cavendish Road  
 Christchurch  
 PO Box 1061  
 Christchurch - New Zealand

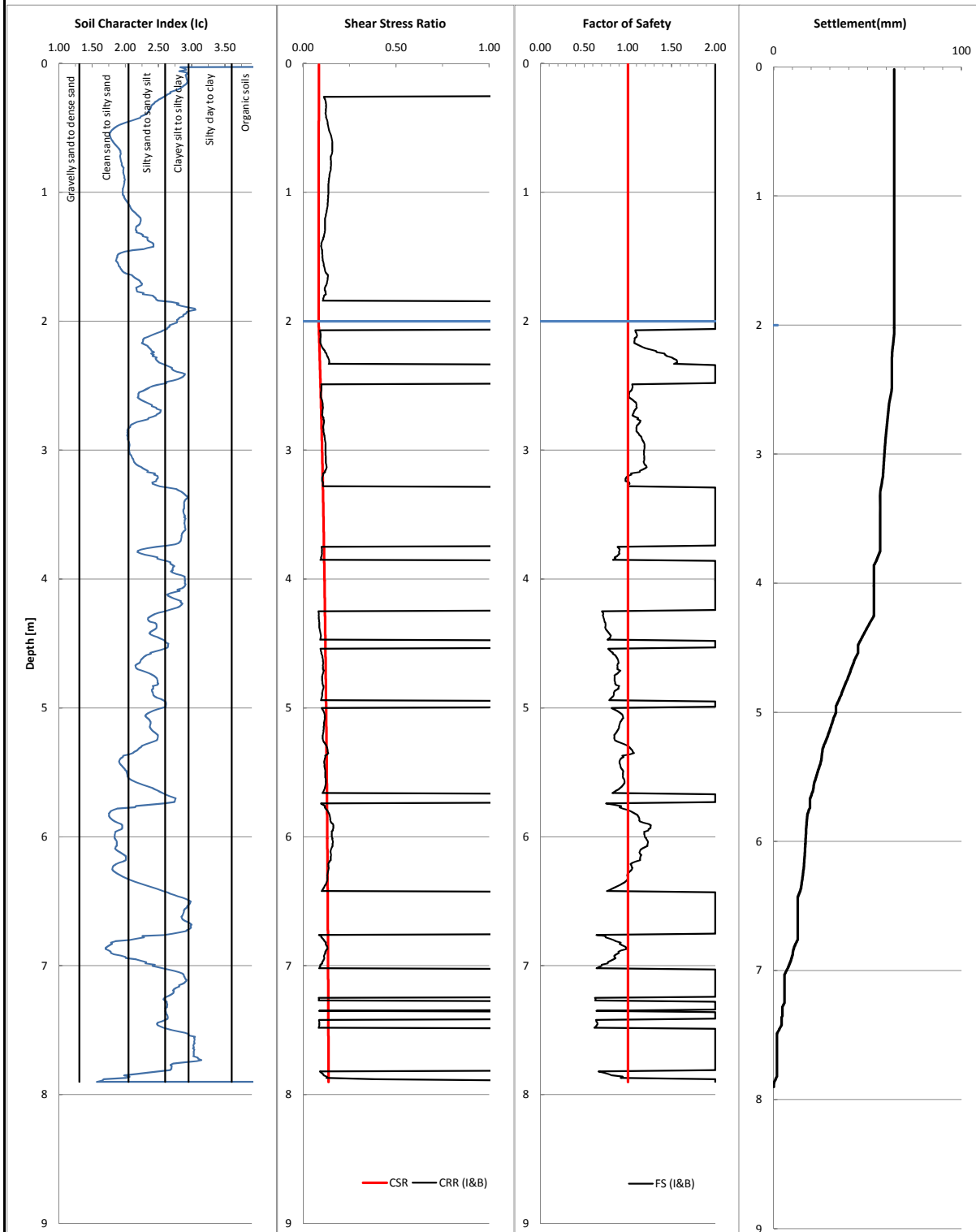
Telephone: +64 3 366 0821  
 Facsimile: +64 3 379 8955  
 Email: christchurch@nz.aurecongroup.com  
 Website: www.aurecongroup.com

Client	FHLD	Location	KSP 7 & 8
Project No.	200376	Test No.	CPT501
Design Event	ULS EQ	Date	26 November 2013




**LIQUEFACTION ANALYSIS**

Water Table [m] 2.00  
 Magnitude 7.50  
 Acceleration [g] 0.13

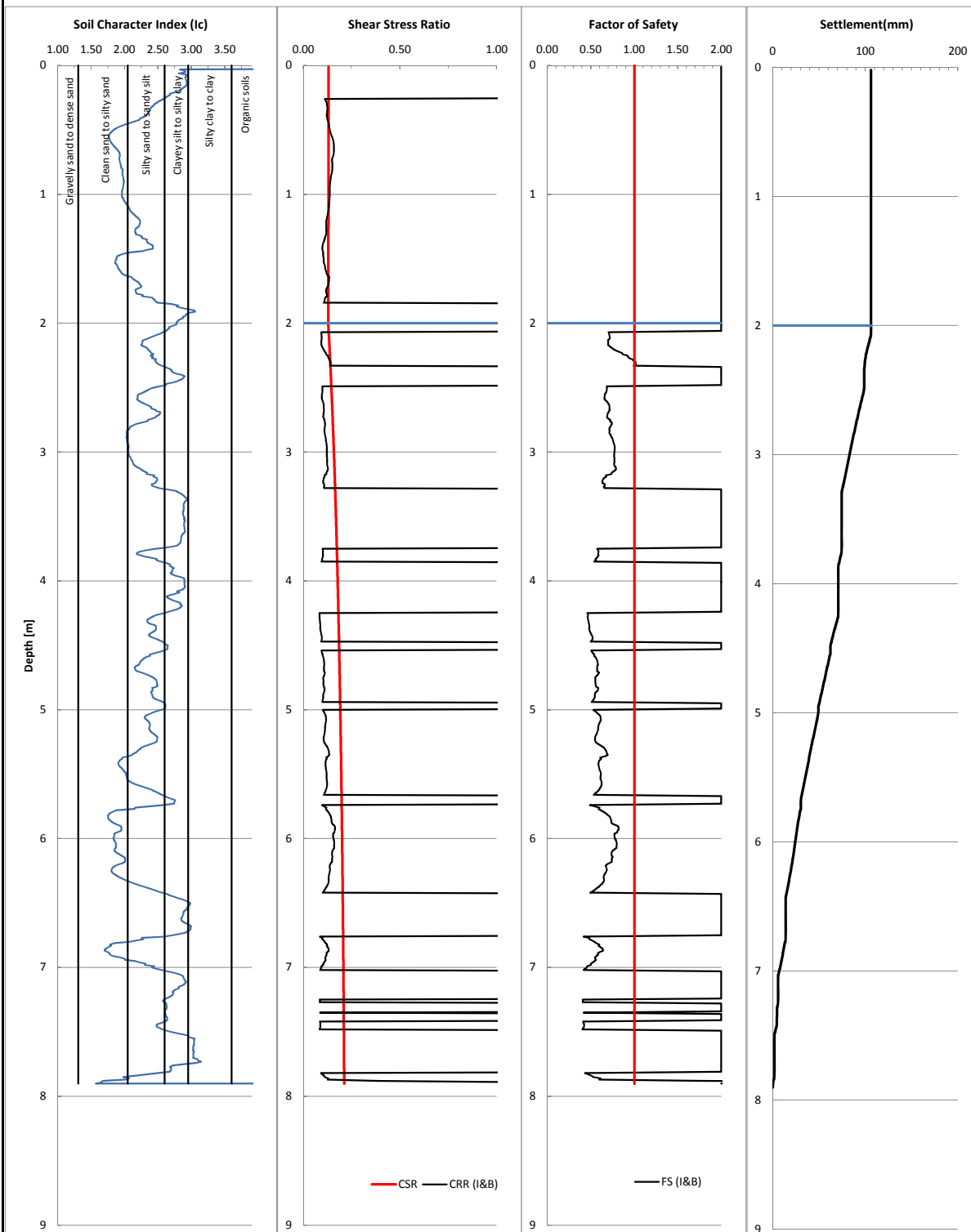


**Total Settlement (mm): 64**  
**LSN: 14**


 <small>Aurecon New Zealand Limited          Unit 1, 150 Cavendish Road          Cashtown          PO Box 1061          Christchurch - New Zealand          Telephone: +64 3 366 0821          Facsimile: +64 3 379 6955          Email: christchurch@ap.aurecongroup.com          Website: www.aurecongroup.com</small>	Client	FHLD	Location	KSP 7 & 8
	Project No.	200376	Test No.	CPT504
	Design Event	SLS EQ	Date	26 November 2013

**LIQUEFACTION ANALYSIS**

Water Table [m] 2.00  
 Magnitude 7.50  
 Acceleration [g] 0.20

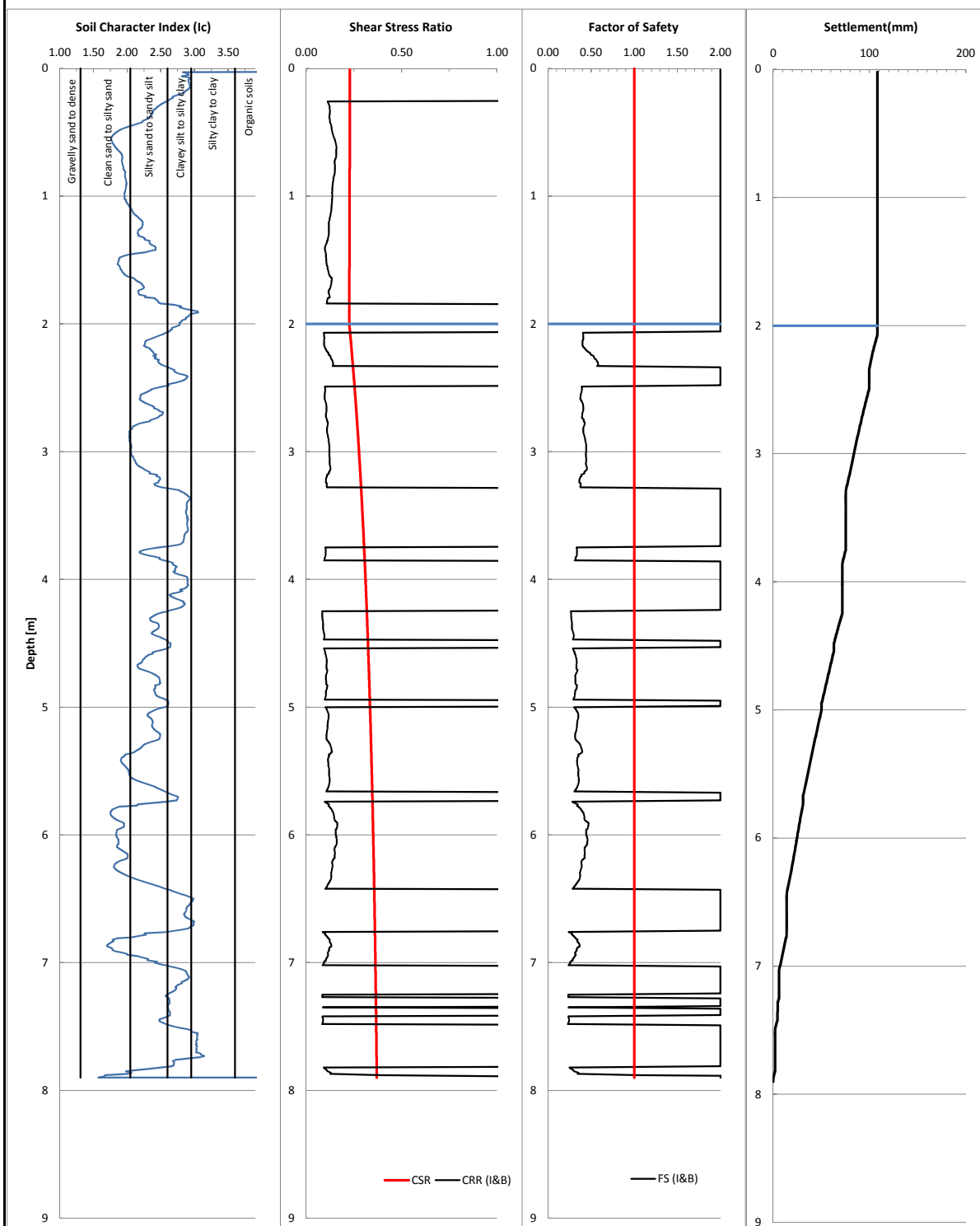


Total Settlement (mm): 106  
 LSN: 26

 <p>Aurecon New Zealand Limited        Unit 1, 150 Cavendish Road        Cashmere        PO Box 1061        Christchurch - New Zealand</p> <p>Telephone: +64 3 366 0821        Facsimile: +64 3 379 6955        Email: christchurch@ap.aurecongroup.com        Website: www.aurecongroup.com</p>	Client	FHLD	Location	KSP 7 & 8
	Project No.	200376	Test No.	CPT504
	Design Event	INT EQ	Date	26 November 2013

**LIQUEFACTION ANALYSIS**

Water Table [m] 2.00  
 Magnitude 7.50  
 Acceleration [g] 0.35



Total Settlement (mm): 108  
 LSN: 27

**aurecon**

Aurecon New Zealand Limited  
 Unit 1, 150 Cavendish Road  
 Christchurch  
 PO Box 1061  
 Christchurch - New Zealand

Telephone: +64 3 366 0821  
 Facsimile: +64 3 379 8955  
 Email: christchurch@nz.aurecongroup.com  
 Website: www.aurecongroup.com

Client	FHLD	Location	KSP 7 & 8
Project No.	200376	Test No.	CPT504
Design Event	ULS EQ	Date	26 November 2013

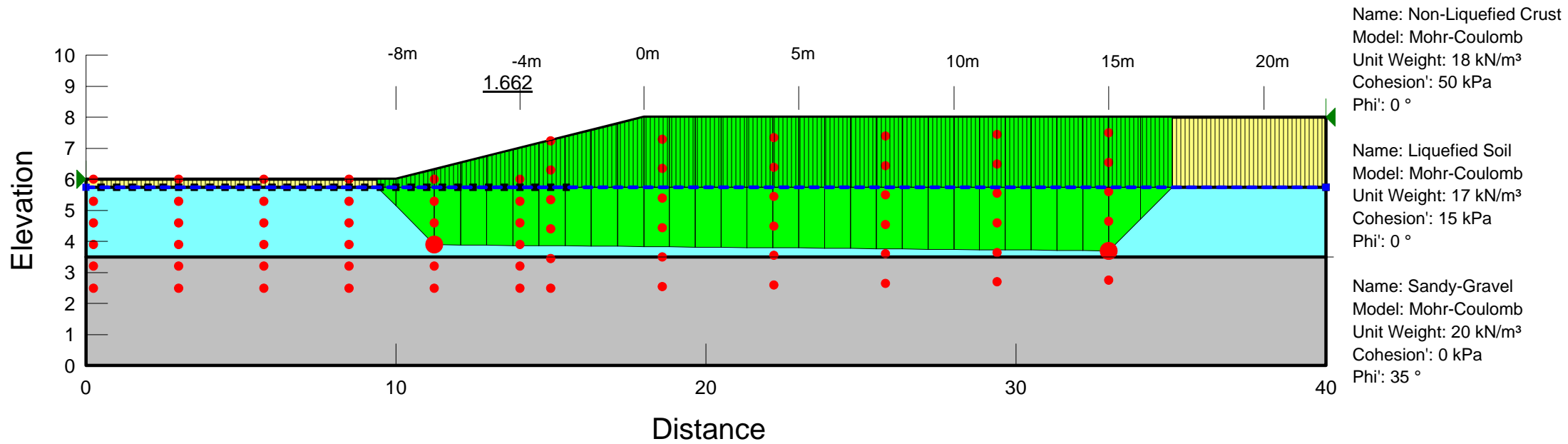


# Appendix H

## Slope/W Outputs

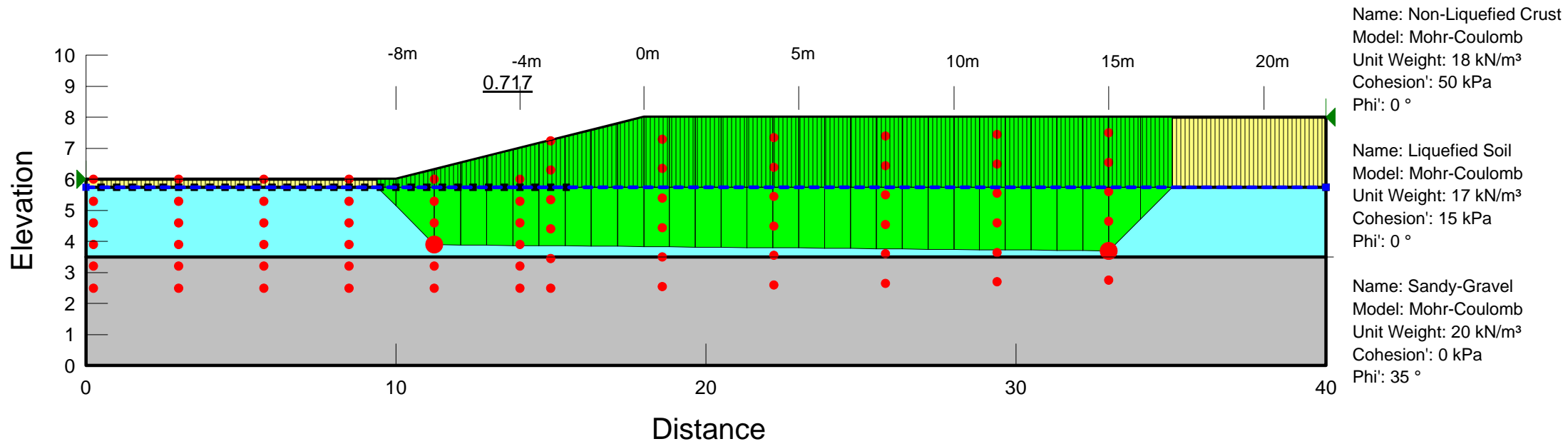
Knights Stream Park (200376)  
Stormwater Basin Lateral Spreading Modelling

SLS Design Case - 0.13g



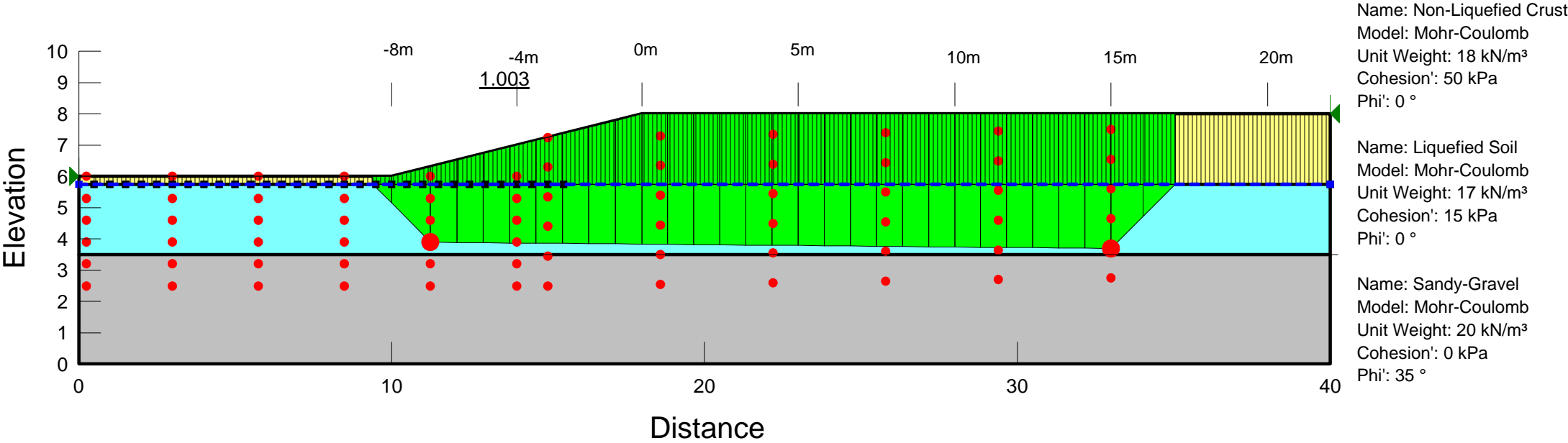
Knights Stream Park (200376)  
Stormwater Basin Lateral Spreading Modelling

ULS Design Case - 0.35g

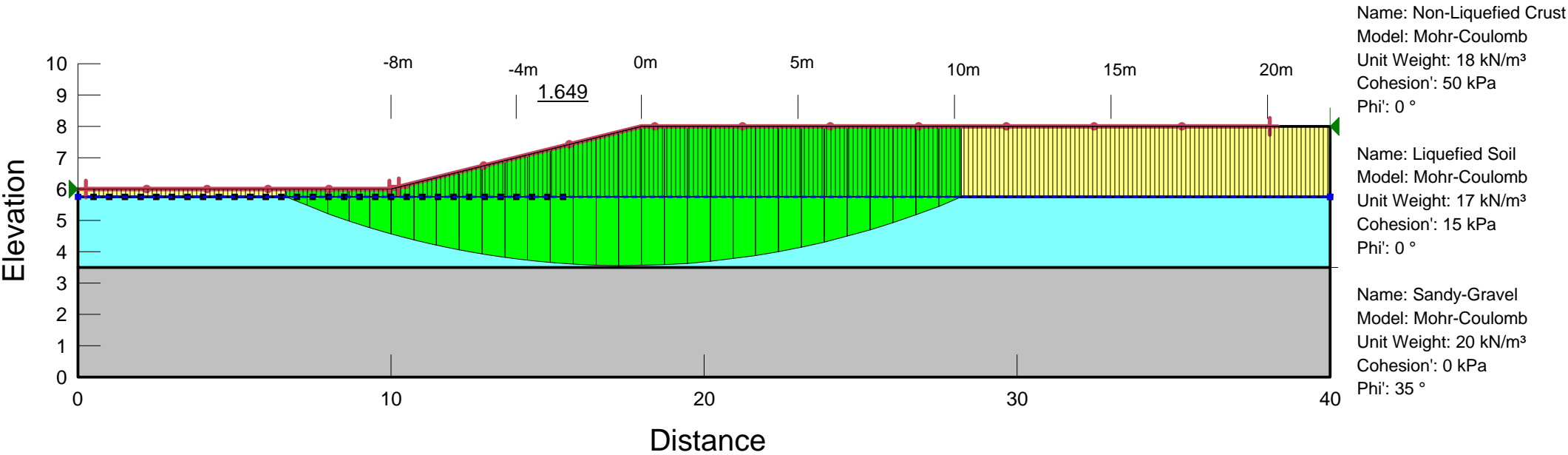


Knights Stream Park (200376)  
Stormwater Basin Lateral Spreading Modelling

Yeild Acceleration (FoS=1) - Horz Seismic Load: 0.24g



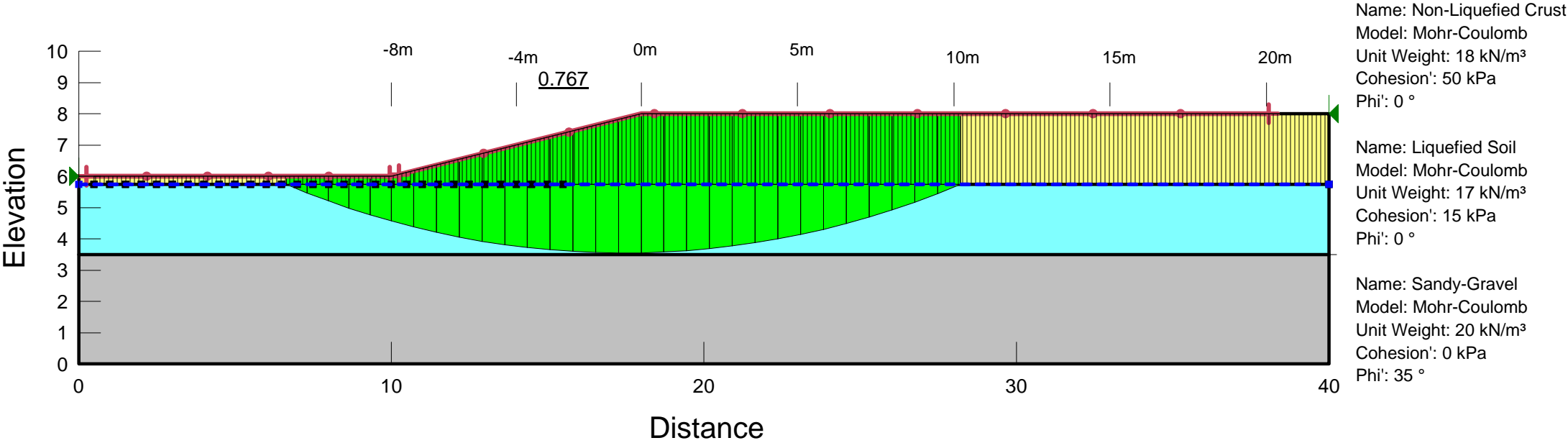
Knights Stream Park (200376)  
Stormwater Basin Lateral Spreading Modelling  
  
SLS Design Case - 0.13g





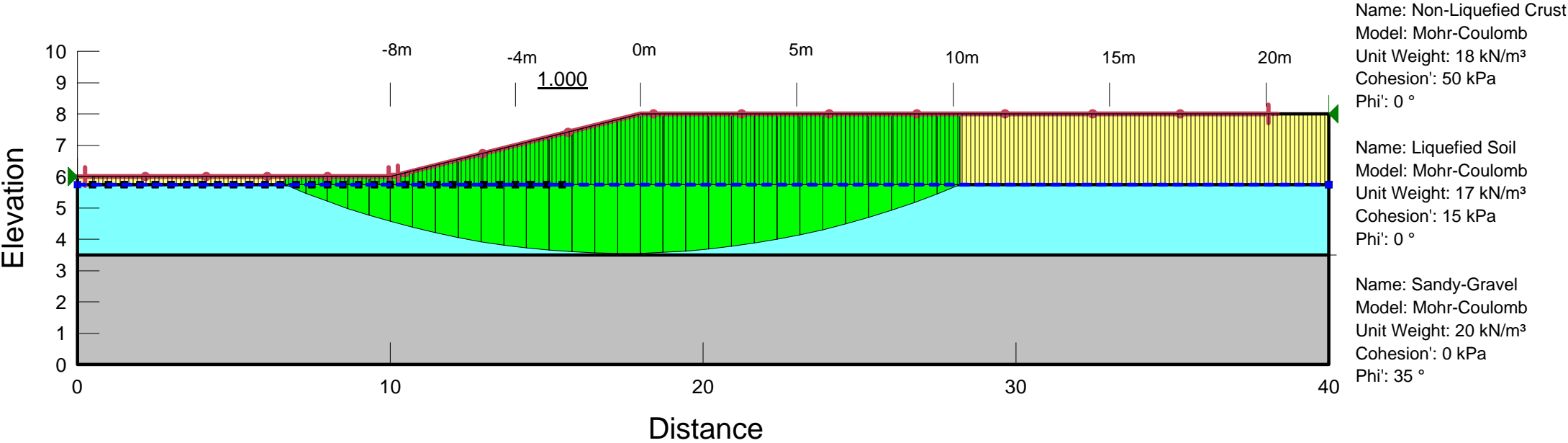
Knights Stream Park (200376)  
Stormwater Basin Lateral Spreading Modelling

ULS Design Case - 0.35g



Knights Stream Park (200376)  
Stormwater Basin Lateral Spreading Modelling

Yeild Acceleration (FoS=1) - Horz Seismic Load: 0.254g





**Aurecon New Zealand Limited**

Unit 1, 150 Cavendish Road  
Casebrook Christchurch 8051  
PO Box 1061  
Christchurch 8140  
New Zealand

**T** +64 3 366 0821

**F** +64 3 379 6955

**E** [christchurch@aurecongroup.com](mailto:christchurch@aurecongroup.com)

**W** [aurecongroup.com](http://aurecongroup.com)

**Aurecon offices are located in:**

Angola, Australia, Botswana, China,  
Ethiopia, Hong Kong, Indonesia,  
Lesotho, Libya, Malawi, Mozambique,  
Namibia, New Zealand, Nigeria,  
Philippines, Singapore, South Africa,  
Swaziland, Tanzania, Thailand, Uganda,  
United Arab Emirates, Vietnam.