REPORT

Nelson City Council

Tahunanui Liquefaction Assessment
Stage 2 - Assessment of Eastern Margin

Tonkin & Taylor

ENVIRONMENTAL AND ENGINEERING CONSULTANTS

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Stage **2** - Assessment of Eastern Margin

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Executive summary

This report presents the results of a two stage assessment of the Tahunanui Area in Nelson:

- The purpose of the current assessment is to further assess the liquefaction potential of sediments in the north-eastern part of the Tahunanui Area where the previous investigation indicated the presence of surficial gravel deposits and a reduced thickness of sediments with a high liquefaction potential.
- The findings of this Stage 2 assessment generally support the findings of T&T's Stage 1 assessment which was carried out in 2013.
- Machine auger, and CPT testing indicate that the Muritai gravel is a variable strength (though generally dense) mix of silty gravel, sandy, and gravelly sediments, occur in the Stage 2 area. The upper surface of the Muritai gravel deposits is inclined at <1° to the west, and extends up to 350 m to the west of Tahunanui Drive.
- CPT testing indicated that the Muritai gravel is underlain by up to 5.5 m of highly liquefiable sands consistent with the Tahunanui Sands. This layer thins to the east, and is expected to be largely absent immediately to the east of Tahunanui Drive.
- The Scala penetrometer investigations indicate very loose to loose material consistent with the Tahunanui Sands is present at the ground surface around the western edge of the Muritai gravel deposits (see T&T Figure 871023-F1). Beneath the upper Tahunanui Sands the western edge of the Muritai gravel appears to dip generally at between 1 and 2 degrees to the west.
- Preliminary (i.e. with no correction to account for soil plasticity) analyses of the Stage 2 CPT results indicate liquefaction induced settlements in the Muritai gravel deposits are likely to be between 0 and 10 mm during an 1/25 Annual Probability of Exceedence - AEP (Serviceability Limit State – SLS) seismic event, between 0 and 50 mm during an 1/100 AEP seismic event, and, between 0 and 100 mm during a 1/500 AEP (Ultimate Limit State – ULS) seismic event.
- The soils that are predicted to liquefy generally comprise sands to non-plastic silt materials. Visual assessment of samples recovered from the machine auger holes indicate that none of these potentially liquefiable soils are likely to have sufficient plasticity to resist liquefaction.
- Analysis of the Stage 2 CPT's carried out within the Muritai gravel using the recently developed Liquefaction Severity Number (LSN) earthquake event, and based on current groundwater levels indicated there is likely be minor localised sand boils and little to no damage to structures due to liquefaction in a Ultimate Limit State (ULS) seismic event (Assessed ULS LSN's ranged between 0 and 22).
- Assessed LSN's within both the Stage 1 and Stage 2 Study Areas are sensitive to rises in groundwater i.e. due to seasonal fluctuations, increases during near-field earthquakes, and predicted sea-level rise.
- During a ULS (Ultimate Limit State) seismic event lateral spread displacements are not predicted within the Muritai gravel.
- In terms of the guidance documents which have been issued to date by MBIE in support of the Canterbury Earthquake recovery, the geotechnical analysis which has been completed to date indicates, in general, the Stage 2 study area is likely to exhibit a "TC1" to "TC2" level of land performance during a future design seismic event.

1 Introduction

Tonkin & Taylor Ltd (T&T) has been engaged by Nelson City Council (NCC) to undertake an assessment of the eastern extent of liquefiable sediments underlying the Tahunanui residential area in Nelson City. Authority to proceed with this report was provided in writing by Chris Ward of NCC on 12 May 2014. T&T's Letter of Engagement dated 07 May 2014 sets out the scope of works and conditions of engagement for this report.

1.1 Previous assessment

This report is an addendum to our previous study on the liquefaction potential of soils across the wider area of Tahunanui - T&T report 'Tahunanui Area Liquefaction Assessment' dated November 2013 (T&T ref. 871023) hence-forth referred to as 'Stage 1' of the assessment.

The Stage 1 report was based on a site investigation comprising two (2) boreholes, ten (10) Cone penetrometer (CPT) tests, and; a MASW (Multi-channel Analysis of Surface Waves) geophysical survey. The Stage 1 report also broadly summarized the surface and subsurface geotechnical features of the area, and gave a detailed description of the process of liquefaction and its effects. The main conclusions from that report were:

- The Study Area (i.e. the flat land at Tahunanui) is underlain by silt and sand dominant sediments to depths of 8 m bgl (below existing ground level) in the south-east and up to 14 m depth in the north-west. In general, between 50% and 80% of this layer is assessed to be liquefaction susceptible.
- Preliminary (i.e. with no correction to account for soil plasticity) analyses of CPT results indicate total liquefaction induced settlements are likely to be between 5 and 25 mm during an SLS (Serviceability Limit State) seismic event, and, between 130 mm and 290 mm during an ULS seismic event.
- The soils that are predicted to liquefy generally comprise sands to non-plastic silts. Visual assessment of the core which was recovered from the machine boreholes indicates that none of these potentially liquefiable soils are likely to have sufficient plasticity to resist liquefaction.
- Analysis of the CPT results using the recently developed Liquefaction Severity Number (LSN) methodology indicates that collateral damage due to liquefaction is likely to vary across the Study Area.

1.2 Current assessment

The Stage 2 Study Area comprises the low-lying flat to gently sloping land at Tahunanui as shown on T&T Figure 871023-F1.

The purpose of the Stage 2 assessment is to further assess the liquefaction potential of sediments in the north-eastern part of the Stage 1 Study Area, where the previous investigation indicated the presence of surficial gravel deposits and a reduced thickness of sediments with a high liquefaction potential. The Stage 2 assessment utilises the investigations and conclusions from the November 2013 report, as well as further field investigations carried out in the Stage 2 Study Area comprising:

- Twenty-six (26) Scala penetrometer tests
- Twelve (12) Cone Penetrometer tests
- Four (4) logged machine auger holes

It must be appreciated that other areas in the Nelson urban area may also be subject to a liquefaction risk.

2 Liquefaction description

For a description of the process, triggering, and effects of liquefaction refer to Section 2 of the Stage 1 T&T Report 'Tahunanui Liquefaction Assessment' dated November 2013, T&T ref. 871023.

3 Site conditions

3.1 Surface features

The main surface features within the Stage 2 Study Area are as follows:

Muritai gravel

These deposits are situated within an area of land elevated at approximately RL 16.2 m and higher situated around Muritai Street, that for the purposes of this study have been termed the 'Muritai gravel'. This land is slightly inclined (< 1°) to the west, and is elevated slightly above the general surface level of the Stage 2 Study Area, which is sub-horizontal and generally elevated at RL 15 to 16 m apart from where relict and present day beach sand dunes are present.

This area extends westward from the Tahunanui Hills in the east, to west of Muritai St, and from the northern end of Muritai Street in the north to the eastern end of Parkers Road in the south.

A second area of gravelly sediments is also present within the commercial and industrial area to the south of the Muritai gravel associated with Jenkin's Creek. This study is focussed on the residential land in the north-east of the study area, and as such no investigations were carried out within the Jenkin's Creek Fan.

Relict sand dunes

The eastern end of a several rows of relict sand dunes is present to the west of the western edge of the Muritai gravel deposits, as shown on T&T Figure 871023-F1. Two of these features extend east to lie within the central part of the Muritai gravel deposits.

3.2 Subsurface geology

The geotechnical site investigations which were carried out for the purposes of this liquefaction assessment report comprised twenty-six (26) Scala penetrometer tests, four (4) Machine Auger holes, and twelve (12) Cone Penetrometer tests. The locations of these investigations are shown on T&T Figure 871023-F1 attached in Appendix A.

The results of the Stage 1 Investigation are summarised in Section 3 of the T&T report 'Tahunanui Liquefaction Assessment' dated November 2013 (T&T ref. 871023).

Machine auger holes

Machine Auger holes MA1 to MA4 were carried out within the Muritai gravel to check the composition and consistency of the gravel sediments, and, to check for the presence of the Tahunanui Sands beneath the gravel deposits. These tests encountered the following:

- MA1 to MA3 were carried out within Burrell Park and encountered a layered sequence of sandy gravels, silty gravels, and gravels, overlying sandy sediments consistent with the Tahunanui Sands at depths of between 2.5 m (MA1) and 3.0 m (MA2 and MA3).
- MA4 was located on the western side of Muritai Street, and encountered a sequence of sandy gravels, silty gravels, and gravels, to a depth of 3.0 m below ground level, overlying sands consistent with the Tahunanui Sands. These upper gravel materials were similar to those which were observed in to MA1- to MA3.
- The gravel sediments which were encountered between 2 and 3 m below ground level were generally denser and coarser than those encountered within the upper 2 m of the Muritai gravel deposits.
- Below the surficial topsoil layer these soils were non-plastic, and, generally contained only trace amounts of low plasticity silt.

CPT investigations

The CPT testing that was carried out as part of this Stage 2 assessment was undertaken to ascertain the presence and extent of Tahunanui Sands beneath the Muritai gravel.

The CPT testing indicated the following with regards to the subsurface geology in the Stage 2 Study Area:

- CPT1 to CPT24 penetrated to depths of between 4.0 and 8.2 m below ground level.
- CPT13, CPT14, CPT's 16-19, CPT 21, CPT23, and CPT24 all indicated the sub-soil profile comprises sandy sediments up to 5.5 m thick (CPT23) consistent with the Tahunanui Sands underlying an approximately 2.5 to 3.0 m thick layer of predominantly sandy gravel, gravelly sand, gravel and occasionally sandy sediments.
- These CPT's also locally indicated the presence of silty and organic sediments within the gravel deposits, particularly near the ground surface.
- Where the CPT tests indicated Muritai gravel deposits, the base of such deposits was generally elevated at approximately between RL 13.6 and 13.9 m
- CPT14, CPT20, and CPT22, which were located near the eastern edge of the study area, did not encounter sandy sediments consistent with the Tahunanui Sands and all terminated in very dense gravelly material at depths of between 3.2 m and 6.5 m.
- All CPT's carried out in Stage 2 of the investigation terminated within 1 m of the interpreted base of the Tahunanui Sands, in dense gravelly sand.
- The CPT's also indicated that beneath the Muritai gravel, the interpreted base of the Tahunanui Sands is generally inclined to the west at a greater angle than elsewhere in Tahunanui. The base of this layer is inferred to rise from RL 11.5 m in the east (CPT23) to RL 5 m in the west (CPT5 – location shown on T&T Figure 871023-F3).
- The minimum interpreted thickness's of Tahunanui Sands recorded were in CPT19 (2.2 m) and CPT23 (2.1) m.
- Along-side the results of the previous Stage 1 investigations, the Stage 2 CPT's indicate that sandy sediments of the Tahunanui Sands thin to the east, from nearly 15 m in CPT6 (location shown on T&T Figure 871023-F3) at the western end of Parkers Road, to approximately 2.5 m (CPT23) at a point located approximately 100 m to the east of Tahunanui Drive.

Scala Penetrometer investigations

Scala penetrometer tests SC1 to SC26 were carried out around the western edge of the Muritai gravel deposits (as shown on T&T Figure 871023-F1) where Tahunanui Sands overlie the upper surface of the gravel deposits, to ascertain the extent and strength of these weak sediments. The Scala penetrometer tests indicated the following:

- SC1 to SC26 penetrated to depths of between 0.45 and 2.55 m below ground level.
- Very loose to loose soils, extending from the ground surface up to 1.5 m depth and consistent with Tahunanui Sands were encountered in the majority of the Scala tests overlying moderately dense to dense soils.
- The depth of very loose to loose soils encountered is shown on T&T Figure 871023-F2, along with interpreted 0 m and 1 m thickness contours of very loose to loose soils overlying the western edge of the Muritai gravel deposits.
- Beneath the top surface of the Tahunanui Sands the western edge of the Muritai gravel appears to dip generally at between 1 and 2 degrees to the west.

3.3 Groundwater

Following completion of CPT tests, the resulting holes were dipped to confirm groundwater levels. From this data the following conclusions have been made regarding the site groundwater level:

- Groundwater levels across the wider Stage 1 Study Area are inferred to fall gently to the north-west, and generally appear to be a subdued reflection of the surface topography.
- Areas of elevated groundwater levels are present within the Stage 2 Study Area beneath areas of elevated topography, i.e. the gravel deposits in the north-east of the Study Area that are the focus of this report.
- The groundwater levels which were recorded in the CPTs that are located in the Stage 2 Study Area ranged between 0.8 m (CPT15) and 2.3 m (CPT23) depth below ground level (bgl).
- Groundwater levels measured in machine auger holes MA1 to MA4 indicated groundwater levels between 1.0 and 1.4 m depth below ground level.
- Comparison of groundwater levels from this study with historic data within the area of Muritai gravel indicates that groundwater levels vary seasonally in the order of 0.5 m on the eastern part of the Muritai gravel deposits adjacent to Tahunanui Drive. Seasonal groundwater variation is less to the west on the sub-horizontal plains to the east of the Muritai gravel deposits.
- Due to the layered nature of the Muritai gravel, and their proximity to the Tahunanui Hills, perched groundwater levels fed from the hills may be present within the gravel deposits.

3.4 Existing land use and infrastructure

The Stage 2 Study Area is predominantly developed residential properties, with open recreational spaces (Centennial and Burrell Parks) present on either side of Muritai Street. Tahunanui Primary School occupies the central part of the area between Tahunanui Drive and Muritai Street. An area of commercial and light industrial buildings is also present along the western side of Tahunanui Drive between Parkers Road and Rawhiti Street.

4 Earthquake scenarios

4.1 General

For a more detailed description of the earthquake scenarios utilised as part of this assessment please refer to Section 4 of the above report. For clarity the main points are summarised in Table 1 below.

Table **1** - Design earthquake scenarios*

Design Case	Peak Ground Acceleration (PGA) (g)	Earthquake Magnitude (M_W)	Annual Probability of exceedence
SLS	0.09g(1)	7.5 (2)	1/25
1/100 AEP	0.18g(1)	7.5 (2)	1/100
ULS	0.36g(1)	7.5 (2)	1/500

Notes:

(1) Assumes Seismic Subsoil Class C and

(2) Magnitude M_W = 7.5 reflects the magnitude weighting used for the calculation of PGA in NZS1170.5:2004.

PGA has been assessed based on the methodology outlined in NZS1170.5: 2004 assuming the following design criteria:

Building design life	50 years
Building importance level	2
Return period factor	1.0 for 500 years and 0.25 for 25 years.
Sub-soil class	C (Shallow soils)
Hazard factor	0.27 (Nelson)

* This table has been reproduced from Table 2 in T&T Report 'Tahunanui Liquefaction Assessment' dated November 2013 (T&T ref. 871023)

A Building Importance Level of 2 (IL2) as defined in NZS1170.5:2004 has been used for this study, as the large majority of buildings within the Study Area fall into this category (single family dwellings).

4.2 Groundwater sensitivity

Liquefaction is commonly associated with saturated soils. Hence the assessed or measured groundwater level is a critical factor in determining the liquefaction potential of a soil column.

The following issues and uncertainties which are associated with the site groundwater levels have been considered during the liquefaction assessment:

i. Groundwater level measurements assumed for the CPT tests are generally those taken by the CPT operator immediately following culmination of the test. As such they are subject to inaccuracies where for example the groundwater recovery is slower and levels may not have become static (this is more likely in less permeable soils such as within the dense silty gravel sediments within the Muritai gravel deposits.

ii. Groundwater levels fluctuate throughout the year within the Stage 2 Study Area, and as such they may at times be higher than those measured during our site investigation.

iii. Additionally, following near-field earthquake events generated on faults underlying or adjacent to Nelson City (such as those experienced in Christchurch) groundwater pressures often become elevated due to a rapid succession of aftershocks (an effect known as pore-pressure "ratcheting") saturating near surface soils, and depending on the level of shaking

can also cause artesian (above ground) water pressure – as was observed in Christchurch following the large earthquake events of 2010/2011. This can lead to liquefaction of soils above the measured groundwater levels during large aftershocks immediately following near-field earthquake events. This 'ratcheting' effect is not likely to be a factor for remote earthquakes that may affect the site. We stress that the critical earthquake for Nelson City is a remote earthquake generated on the Alpine Fault (as defined in NZS 1170.5). However, north-east trending active faults (such as the Waimea Fault) are mapped adjacent to Nelson City, and may also be present to the west of Nelson City in Tasman Bay.

iv. Perched groundwater maybe locally present within the gravel deposits above granular sediments that have a sufficient component of fine-grained materials to effectively reduce permeability.

v. Sea-levels are predicted to rise. According to the NCC Land Development Manual 2010, 30 mm of sea-level rise is currently predicted from 2010 to 2050. Further sea-level rise is also predicted beyond this date. Ministry for the Environment (MFE) figures are in the order of 10 mm of sea level rise per year. When setting out planning requirements for sites within low-lying areas such as Tahunanui (where groundwater levels are affected to a large degree by the sea level) consideration should be given to the effects of sea level rise on the liquefaction vulnerability of that site.

To quantify the sensitivity of the LSN estimates with respect to the groundwater levels, we have run the LSN calculations under a range of groundwater conditions as described below:

1. Measured groundwater level

   - *Scenario based on measured or assessed groundwater level.*

2. Measured groundwater level + 0.3 m

   - *Seasonal fluctuations in groundwater levels are likely to have an effect in the order of +/- 0.3 m.*

3. Measured groundwater level + 0.5 m

   - *Currently predicted sea-level rise to 2050 is likely to have an effect in the order of + 0.5 m on groundwater levels. We note that effects due to predicted sea level rise further out than this (i.e. to 2100) are likely to be greater than + 0.5 m.*

4. Measured groundwater level + 0.8 m

   - *Effects due to 'ratcheting' are difficult to predict and depend primarily on the size of the earthquake and its proximity to the Site, but could exceed +0.8 m in a near-field ULS event.*

The above groundwater issues do not operate in isolation and have the potential to occur concurrently and compound producing a greater variance in groundwater level. However, we consider there is a very low likelihood of such combinations occurring concurrently, and, do not consider it necessary to consider their combined effects for the purposes of planning for structures with a design life of 50 years.

The results of this groundwater sensitivity assessment are presented in Section 5.7 below.

5 Liquefaction assessment

For a full summary of the standards, and documents used in this study, as well as the methodologies used to assess the liquefaction hazard please refer to Section 5 of the Stage 1 T&T Report 'Tahunanui Liquefaction Assessment' dated November 2013 (T&T ref. 871023).

5.1 CPT Splicing

The CPT tests which were carried out within the Stage 2 Study Area encountered dense to very dense gravel deposits that, on occasion, necessitated the use of a solid, non-instrumented CPT cone to push through to the sandy deposits beneath, allowing testing of these materials.

For this reason several of the CPT's (CPT14 to CPT16, CPT19, CPT20 and CPT23) are composed of two different CPT 'pushes' that have been 'spliced' together to produce a full-depth trace.

Where incomplete CPT data is available at certain depths (i.e. where the solid cone was used), site observations made by T&T staff during the CPT testing and assessment of and available adjacent data was used to assess the nature of the material encountered. A skin friction co-efficient was then inferred and the CPT trace updated manually to artificially produce either a liquefiable or non-liquefiable soil as appropriate.

For example, where the solid cone encountered dense to very dense gravelly material, this was noted on the field investigation records and subsequently assessed to be non-liquefiable. In all other cases, where no other data was available to suggest that the material is non-liquefiable, a conservative approach was adopted and this material was assumed to be liquefiable.

5.2 SLS / ULS liquefaction induced settlements

5.2.1 General

The seismic settlement of the liquefiable layers identified was estimated using the methodology published by Ishihara and Yoshimini. These estimates were combined to provide an indication of the free-field liquefaction-induced settlement which could be expected at the ground surface. The results of this work is summarised below in Table 2.

For the purposes of the liquefaction assessment which is summarised below in Table 2, the three earthquake scenarios described previously in Section 4.1 were analysed in conjunction with the appropriate measured groundwater level of between 0.7 m and 2.3 m bgl.

Table 2 – Estimate of liquefaction-induced free-field settlement of the ground surface.

CPT No.	Earthquake Scenario			CPT No.	Earthquake Scenario		
	SLS M=7.5 PGA=0.09g	1/100 AEP M=7.5 PGA=0.18g	ULS M=7.5 PGA=0.36g		SLS M=7.5, PGA=0.09g	1/100 AEP M=7.5 PGA=0.18g	ULS M=7.5 PGA=0.36g
	Stage 1 CPT's (mm)				Stage 2 CPT's (mm)		
				13	3	32	44
				14	1	20	27
1	8	88	127	15	1	22	55
2	12	141	266	16	7	25	64
3	11	101	185	17	2	34	82
5	5	74	157	18	0	18	56
6	18	165	285	19	3	34	62
7	11	125	239	20	0	0	4
8	23	186	278	21	4	49	81
9	18	150	245	22	0	0	0
10	13	129	255	23	0	6	36
12	6	68	255	24	3	12	22
Range	5 – 23	68 – 186	127 – 285	Range	0 – 7	0 – 49	4 – 82

A detailed summary of the above liquefaction analysis results and output is presented in Appendix B.

The methodology used to obtain the total settlement estimates which are presented above may be conservative as no correction has been made for soil plasticity. Therefore the values given above in Table 2 are generally expected to represent an upper bound estimate of the total settlement likely at the test locations. Further investigation drilling and laboratory testing would need to be completed to enable an appropriate fines correction to be applied to the liquefaction analysis.

Examination of the drill core recovered from BH1 and BH2, which were carried out in 2013 as part of the Stage 1 assessment, indicates none of the liquefiable layers identified by the engineering assessment are likely to have sufficient plasticity to resist liquefaction. Tahunanui Sands material observed in Machine Augers MA1-MA4, which were carried during the Stage 2 assessment, is assessed to be similar in nature to that observed in BH1 and BH2, and this supports the above conclusion.

5.2.2 Infilled ditches/channels

Infilled channels and drainage ditches are present within the Stage 2 Study Area.

Shallow drainage ditches (up to 1.2 m deep) were originally excavated early in the 1900's to drain the low-lying land allowing human settlement, but in the 1960's these were filled in due to safety concerns. A former channel of the Waimea River forms the north-west boundary of the Muritai gravel.

These features are likely to be back-filled with a variable strength mix of loose sandy sediments that are likely to be subject to settlement and compression in a large seismic event.

Some localised differential settlements can be expected within a distance equivalent to 1 to 5 times the depth of the infilled channel/ditch, from the edge of such features, depending on the surrounding geology.

5.3 Assessed thickness of liquefaction and settlement

T&T Figure 871023-F2 "Liquefaction induced settlement", attached in Appendix A summarises the key findings from the Stage 2 liquefaction analysis, including:

- The estimated free-field liquefaction settlements for SLS, 1/100 AEP, and ULS events. These are reported for each Stage 2 CPT.
- The estimated total cumulative thickness of liquefied layers (CLT) for each Stage 2 CPT are reported for SLS, 1/100 AEP and ULS events.

The free-field settlements which were estimated as part of the Stage 1 assessment under SLS and ULS events are shown on T&T Figure 871023-A2 in the Stage 1 T&T Report 'Tahunanui Liquefaction Assessment' dated November 2013 (T&T ref. 871023).

In general, the conclusions of the Stage 1 and 2 liquefaction analysis (refer T&T Figures 871023-F2 and 871023-F3 in Appendix A) are as follows;

- The groundwater level above which liquefaction is not expected to occur is typically between 0.7 and 2.3 m below the existing ground surface level.
- During each of the design seismic events which have been analysed for the purposes of this report, liquefaction could be expected to occur beneath the Stage 2 Study Area with a total cumulative thickness of liquefied layers as follows:

  a) Serviceability limit state (1/25 AEP) earthquake (SLS)

  - Total cumulative liquefied layer thickness: 0.0 - 0.1 m

  b) Serviceability limit state (1/100 AEP) earthquake

  - Total cumulative liquefied layer thickness: 0.0 – 2.1 m

  c) Ultimate limit state (1/500 AEP) earthquake (ULS)

  - Total cumulative liquefied layer thickness: 0 – 4.5 m

- For each of the design seismic events which have been analysed for the purposes of this Stage 2 report, free-field settlement of the ground surface due to liquefaction is estimated to be:

  a) Serviceability limit state (1/25 AEP) earthquake (SLS 1): 0 mm to 10 mm

  b) 1/100 AEP earthquake: 0 mm to 50 mm

  c) Ultimate limit state (1/500 AEP) earthquake (ULS): 0 mm to 100 mm

5.4 Liquefaction severity number (LSN)

The Liquefaction Severity Number (LSN) assessment methodology was developed by T&T on the behalf of the Earthquake Commission (EQC). Its purpose is to enable a more robust assessment of the likely damage at the ground surface as a result of various seismic scenarios. The closer a liquefiable layer is to the ground surface, the more likely it is to cause damage to surface structures during liquefaction. The LSN assessment methodology takes into account the depth and thickness of liquefiable layers in addition to their proximity to the ground surface, as well as crust thickness, varying soil conditions, shaking intensity, shaking duration and groundwater levels. The assessment output is an overall "LSN" rating for each earthquake scenario.

The purpose of this assessment is to re-define the area for which additional building consent conditions will be required to minimise the effects of liquefaction.

In general, the LSN analysis methodology is an extremely useful tool to enable a pragmatic assessment of the likely degree of land damage which will be experienced at the ground surface as a result of a future design earthquake event.

As such we have presented the assessed LSN in a ULS earthquake event for all CPT's carried out as part of this assessment (Stages 1 and 2) in Figure 871023-F3, attached in Appendix A.

Table 3 below summarises the anticipated ground effects for each range of LSN.

Table **3** – Summary of LSN and anticipated damage at the ground surface

LSN Range	Expected ground surface damage
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 some sand boils and 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 settlements of structures
>50	Severe damage, extensive evidence of liquefaction as surface, severe total and differential settlements affecting structures, damage to services.

* Table based on Table 13.1 from T&T report 'Liquefaction Vulnerability Study'

Table 4 below summarises the LSN that has been calculated using the Twenty-two (22) CPT's that were analysed during both stages of this investigation for SLS1, 1/100 AEP, and ULS earthquake scenarios.

Table 4 –Estimate of LSN values

CPT No.	Earthquake Scenario			CPT No.		Earthquake Scenario	
	SLS PGA = 0.09g	1/100 AEP PGA = 0.18g	ULS PGA = 0.36g		SLS PGA = 0.09g	1/100 AEP PGA = 0.18g	ULS PGA = 0.36g
	Stage 1				Stage 2		
				13	1	10	13
				14	1	15	20
1	0	13	22	15	0	4	13
2	0	14	36	16	2	6	13
3	0	11	23	17	0	6	18
5	0	6	18	18	0	4	13
6	0	29	52	19	1	8	17
7	0	16	32	20	0	0	3
8	0	30	53	21	0	8	21
9	0	18	42	22	0	0	0
10	12	14	34	23	0	1	8
12	1	12	29	24	1	12	22
Range	0 to 12	6 to 30	13 to 53	Range	0 to 2	0 to 15	3 to 22

5.5 Liquefaction trigger

Analysis has been undertaken to assess the trigger Peak Horizontal Ground Acceleration (PGA_H) for liquefaction of susceptible soils in the Study Area. Published methods for liquefaction assessment (Idriss & Boulanger, 2008) and settlement (Zhang, Robertson, & Brachman, 2002) were used to complete this assessment, and an assessment of the likely effects at the ground surface (Van Ballegooy, 2013). Figure 1 below presents the assessed LSN for each CPT test for various return periods of earthquake shaking. More intense earthquake shaking will trigger liquefaction of more dense soils and thus result in a greater LSN.

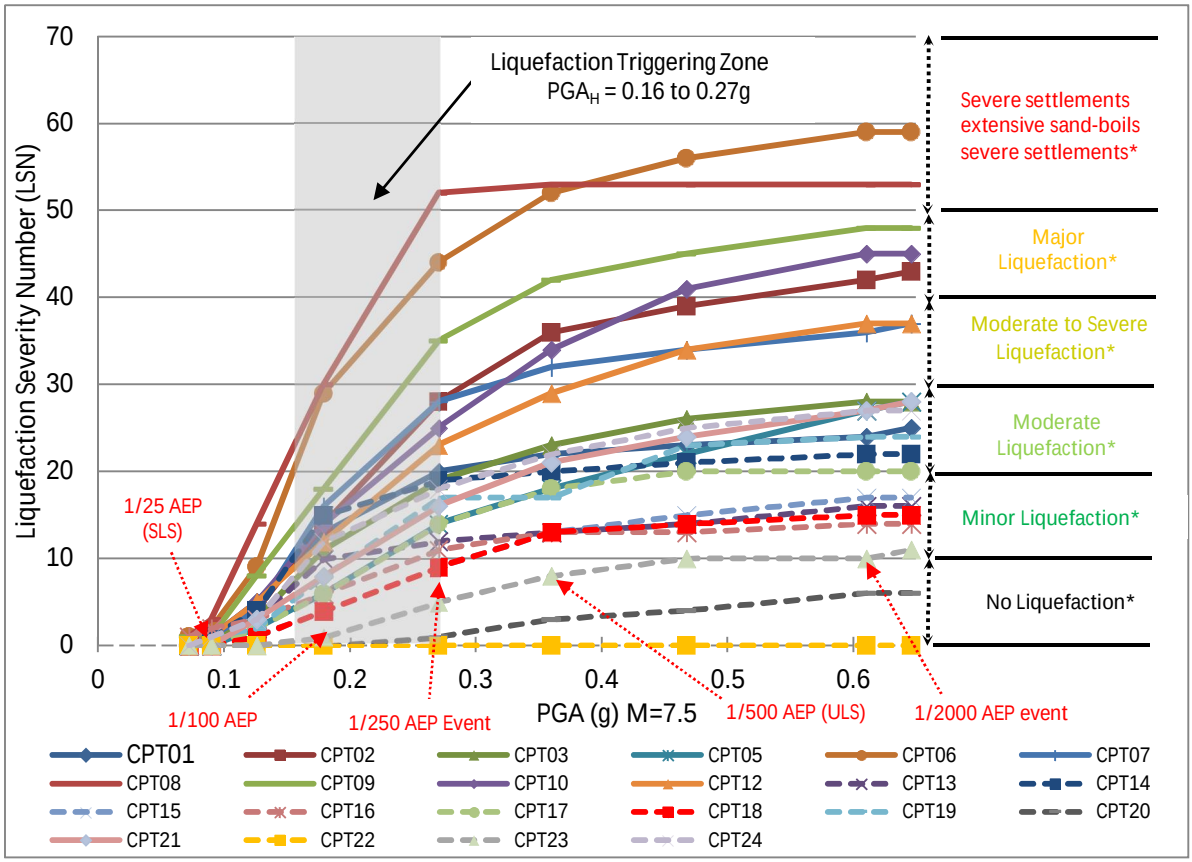

*Figure 1 - Assessed LSN sensitivity to PGA$_H$ (Stage **2** CPTs are dashed lines)*

* Refer to Table 3 for explanation.

With reference to Figure 1, the potential for liquefaction, and the total thickness of the potentially liquefied soil column, is relatively small for the SLS seismic event (0.09g). However, with a slightly higher level of seismic shaking (i.e. a 0.18g, 1/100 AEP event) the assessment indicates substantially more liquefaction is triggered. CPT6 and CPT8, which are located furthest to the west, indicate the highest LSN values, and CPT22, which is located further east shows the lowest LSN. This is likely due to a combination of the thinning and absence of highly liquefiable Tahunanui Sands in the west, the proximity of loose Tahunanui Sand deposits and the relatively shallow depth to the groundwater table at the location of CPT6 and CPT8.

5.6 Lateral spreading risk

Liquefaction induced lateral spreading can cause severe damage to buildings and infrastructure. In order for lateral spreading to be feasible for a particular area, a free-face, i.e. a river bank or coast-line must be present in the vicinity of the assessed area.

The following is relevant to the lateral spread risk within the Stage 2 Study Area:

- Effects due to lateral spreading usually occur within a distance of 20 to 50 times the height of the free-face from any particular free-face.
- There are no existing free-faces within 200 m of the Stage 2 Study Area. The nearest existing free-face is a drainage ditch within the Stage 1 Study Area situated 250 m to the south-west of the surface outcrop of the Muritai gravel.
- Shallow infilled drainage ditches and river channels are present across the Stage 2 Study Area, and are likely to be infilled with loose sediments that may allow minor localised

differential effects during a ULS seismic event, however the shallow nature of these features means they are unlikely to result in lateral spreading.

- The surface of the Muritai gravel sediments dips at less than 0.5° to the west. Lateral spreading risk generally occurs at locations where the ground surface is inclined at angles greater than 1° - 2°.

In consideration of the above factors we assess that here is likely to be a very low risk of lateral spreading in the Stage 2 Study Area during all seismic scenarios assessed as part of this report.

6 Conclusions

6.1 Groundwater sensitivity assessment

As discussed in Section 4 of this report, an assessment of the sensitivity of the LSN prediction's for the ULS (1/500 AEP event) with respect to groundwater variance has been carried out.

Table C.1, attached in Appendix C, summarises the predicted LSN for all CPT's that were carried out as part of this assessment under the various groundwater scenarios described in Section 4. This groundwater sensitivity assessment has highlighted the following:

- LSN is sensitive to small changes (+ 0.3 m) in the groundwater level (such as could be anticipated during seasonal fluctuations (over the majority of the Stage 2 Study Area, giving an average increase in LSN of approximately 6 for the Stage 1 CPT's, and 5 for the Stage 2 CPT's.
- An average increase in LSN of 13 is predicted for the Stage 1 CPT's with only a moderate (+ 0.5 m) increase in groundwater level – such as is predicted over the next 50 years due to sea level rise. A smaller average increase in LSN of 10 is predicted for the Stage 2 CPT's- due primarily to the presence of dense granular soils within the Muritai gravel.
- Under a significant increase in groundwater levels (+ 0.8 m) such as is possible due to pore-water pressure 'ratcheting' following a large near-field earthquake, the predicted increase in LSN's for the Stage 1 CPT's averaged 27. For the Stage 2 CPT's the average increase in LSN was 23.

Further refinement could be achieved by monitoring annual fluctuation in groundwater levels within the Stage 1 Study Area.

6.2 General

In terms of the guidance documents which have been issued to date by MBIE in support of the Canterbury Earthquake recovery, the geotechnical analysis which has been completed to date indicates, in general, the Stage 2 study area is likely to exhibit a "TC1" to "TC2" level of land performance during a future design seismic event.

The main findings of this Stage 2 liquefaction assessment of ground at Tahunanui are as follows:

- Machine auger, and CPT testing indicate that the Muritai gravel is made up of a variable strength (though generally dense) mix of silty gravel, sandy, sandy gravel, and gravel sediments.
- CPT testing indicates that the Muritai gravel is underlain by up to 5.5 m of highly liquefiable sand consistent with the Tahunanui Sands. This layer thins to the east, and appears to be largely absent immediately to the east of Tahunanui Drive.
- The Scala penetrometer investigations indicate very loose to loose material consistent with the Tahunanui Sands is present at the ground surface around the western edge of the Muritai gravel as shown in T&T Figure 871023-F1. Beneath the upper Tahunanui Sands the western edge of the Muritai gravel appears to dip generally at between 1 and 2 degrees to the west.
- Preliminary liquefaction analysis (i.e. with no correction to account for soil plasticity) indicates total liquefaction induced settlements in the Stage 2 Study Area are likely to be between:
    - 0 and 10 mm during an SLS1 seismic event,
    - 0 and 50 mm during an 1/100 AEP seismic event and,
    - 0 and 100 mm during an ULS seismic event.

The soils that are predicted to liquefy generally comprise sands to non-plastic silt materials. Visual assessment of samples recovered from the machine auger holes indicates that none of these potentially liquefiable soils are likely to have sufficient plasticity to resist liquefaction, as was the case in the preliminary Stage 1 assessment.

- Analysis using the Liquefaction Severity Number (LSN) methodology indicates within the Stage 2 area there is likely be minor localised sand boils and little to no damage to surface structures due to liquefaction in an Ultimate Limit State (ULS) seismic event (LSN prediction's range between 0 and 22 for an ULS seismic event).
- During an Ultimate Limit State seismic event lateral spread displacements are not predicted within the Muritai gravel / Stage 2 Study Area, which dips to the east at < 1°.

Table 5 below summarises the predicted effects within and surrounding the Muritai gravel / Stage 2 Study Area, based on currently measured groundwater levels, under the three earthquake scenarios described in Section 4 of this report.

Table 5 - Summary of potential liquefaction consequences within the Stage 2 Study Area

Liquefaction Consequence	*Likelihood** and Consequences within the Stage 2 Study Area		
	SLS	1/100 AEP	ULS
Sand Boils	*Rare*	*Unlikely* in Muritai gravel. Localised sand boils *possible* around the western edge of the Muritai gravel where Tahunanui Sands are present on top of the Muritai gravel sediments.	Localised sand boils across the Muritai gravel *possible*. Widespread sand boils *likely* around the edge of the Muritai gravel where Tahunanui Sands are present above the Muritai gravel sediments.
Buoyancy and uplift of buried pipes and manholes	*Rare*	*Unlikely* within Muritai gravel. Localised buoyancy and uplift *Possible* in saturated Tahunanui Sands (i.e. around the western edge of the Muritai gravel).	Some minor localised buoyancy and uplift of buried manholes and pipes is *possible* in the Muritai gravel, and *likely* around the western edge of the Muritai gravel where these works are constructed below the groundwater table.
Free-field settlement of the ground surface	*Barely credible*	*Likely* free-field liquefaction induced ground surface settlements of 0 - 50 mm are currently predicted under this seismic scenario. Larger settlements *likely* where building loads are applied at foundation locations. Differential settlements resulting in significant damage to underground services and paved surfaces is *Barely Credible* within Muritai gravel, and *Rare* around the edge of the Muritai gravel.	*Likely* free-field liquefaction induced ground surface settlements of typically 0 - 100 mm are currently predicted for the Muritai gravel and surrounding area. Larger settlements are *likely* to occur where building loads are applied at foundation locations. Differential settlements *possible* within Muritai gravel, and *likely* around its western edge, and could result in damage to underground services and paved surfaces (i.e. inadequate fall at some locations on pipelines) and to buildings.
Bearing capacity failure of shallow foundations	*Barely credible*	*Rare* on Muritai gravel. Localised bearing capacity failures *possible* where foundations bear in saturated Tahunanui Sands (i.e. around the western edge of the Muritai gravel).	Some bearing capacity failure of shallow foundations is *possible* within the Muritai gravel and *likely* around its western edge. *Likely* differential settlement of foundations of up to 50 mm is predicted within the Muritai gravel. Bearing capacity failures *possible* for heavily loaded foundations within the Muritai gravel, and *likely* around its western edge
Lateral spreading	*Barely credible* - The risk of lateral displacement is assessed to be *barely credible* within the Stage 2 Study Area under all design seismic events		

* Likelihood in general accordance with the 'Practice Note Guidelines for Landslide risk management 2007 – Appendix C

6.3 Statutory requirements for future development

In addition to the discussion in Section 6.3 of the Stage 1 T&T report 'Tahunanui Liquefaction Assessment' dated November 2013 (T&T ref. 871023), the following is relevant when considering potential statutory requirements for property owners and developers in the Study Area.

Comparison of the predicted LSN value's for CPTs carried out as part of this Stage 2 assessment with those predicted during the preliminary Stage 1 assessment (based on current assessed groundwater levels) indicates that LSN predictions within the Muritai gravel are generally lower (LSN = 0 to 22) than for the remainder of the Study Area to the west (LSN = 18 to 53).

Whilst we anticipate damage to surface structures as a result of a ULS earthquake event over the majority of the Stage 1 Study Area, we assess that where a non-liquefiable crust exists of sufficient thickness (such as within the Muritai gravel / Stage 2 Study Area) liquefaction is unlikely to result in significant damage to surface structures based on currently assessed groundwater levels.

Where saturated (i.e. below the water table) loose sands are present near the ground surface, such as around the edge of the Muritai gravel, there is an increased potential for damage to near surface structures in a future design seismic event. T&T Figure 871023-F2, attached in Appendix A, shows the inferred 1.0 m thick isopach contour of Tahunanui Sands overlying the edge of the Muritai gravel.

When considering planning requirements for future structures, the effects of uncertainty surrounding groundwater levels (particularly effects due to sea level rise) should be considered.

7 Applicability

This report has been prepared for the benefit of Nelson City Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

All recommendations and opinions which are contained in this report are based on a desk study of available information, and a subsurface data from a geophysical survey, boreholes, Machine augers, Scala penetrometer tests, and cone penetration tests. The nature and continuity of subsoil away from the test locations are inferred and it must be appreciated that actual conditions could vary from the assumed model.

The susceptibility analyses carried out represent probabilistic analyses of empirical liquefaction databases under various earthquakes. Earthquakes are unique and impose different levels of shaking in different directions on different sites. The results of the liquefaction susceptibility analyses and the estimates of consequences presented within this document are based on regional seismic demand and published analysis methods, but it is important to understand that the actual performance may vary from that calculated.

All recommendations and opinions which are contained in this report are preliminary in nature and subject to confirmation by detailed geotechnical investigation and engineering assessment.

Tonkin & Taylor LTD

Environmental and Engineering Consultants

Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
.....	.....
Marcus Lovell	Mark Foley
Senior Engineering Geologist	Project Director

mjl

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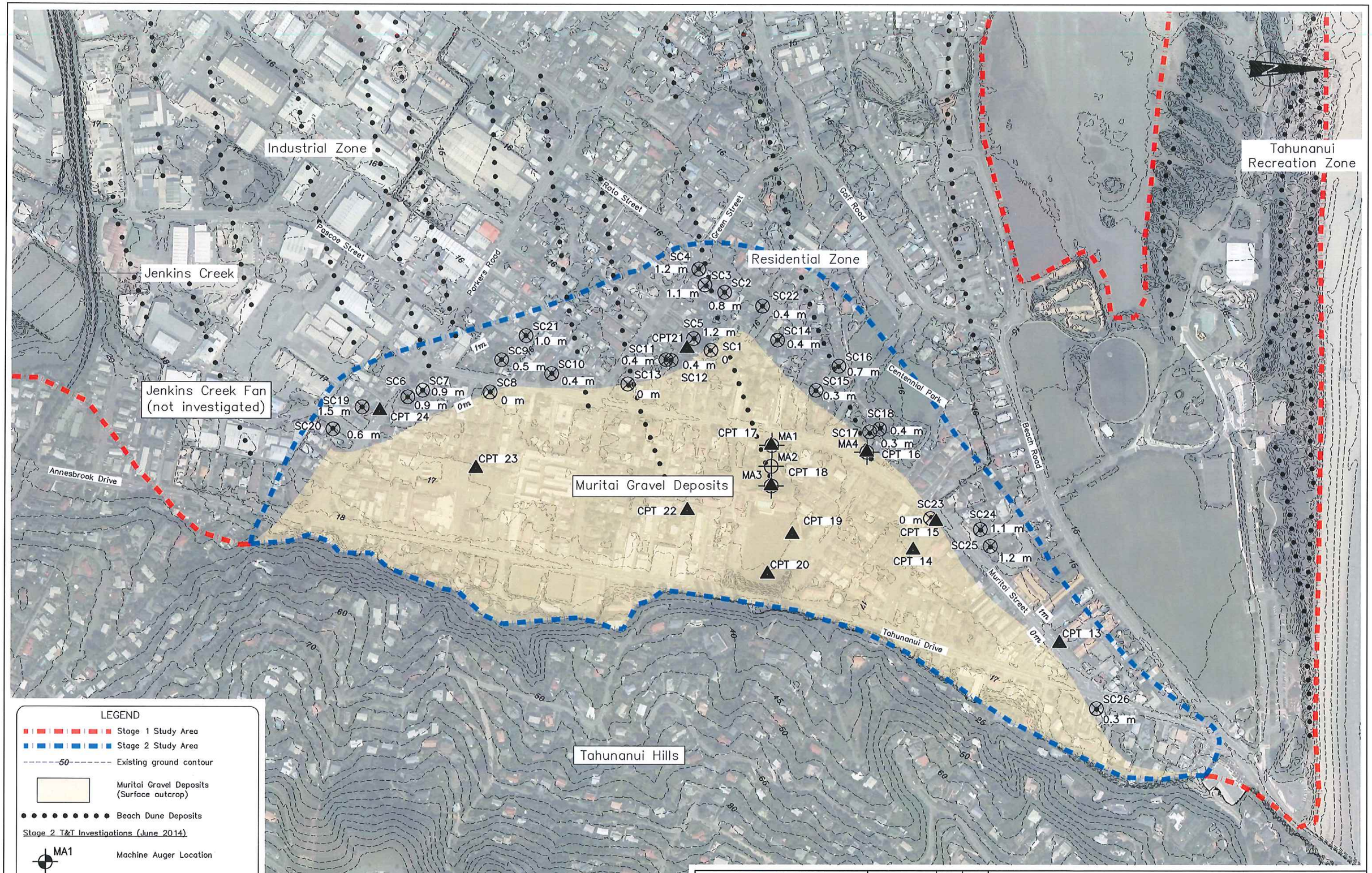
Appendix A: Tonkin & Taylor Figures

- Figure 871023-F1 – Stage 2 Site Investigation Plan
- Figure 871023-F2 – Stage 2 Liquefaction Settlement and Thickness
- Figure 871023-F3 – Stage 1 & 2 Liquefaction Susceptibility Number Values



LEGEND

- Stage 1 Study Area
- Stage 2 Study Area
- 50 Existing ground contour
- Muritai Gravel Deposits (Surface outcrop)
- Beach Dune Deposits

Stage 2 T&T Investigations (June 2014)

- MA1 Machine Auger Location
- SC8 Scala Penetrometer Location
- CPT 23 Cone Penetrometer Test Location (Perry Geotech)
- 0 m Assessed thickness of Tahunanui sands overlying the Muritai Gravel Deposits

A1263318

A3 SCALE 1:5000

0 50 100 150 200 250 (m)

Note: Aerial photo sourced from Nelson City Council

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DRAWN	AGI	Sep. 14
DRAFTING CHECKED	DMW	2/10/14
APPROVED	[illegible]	10/10/14
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PROJECT No. 87 1023		

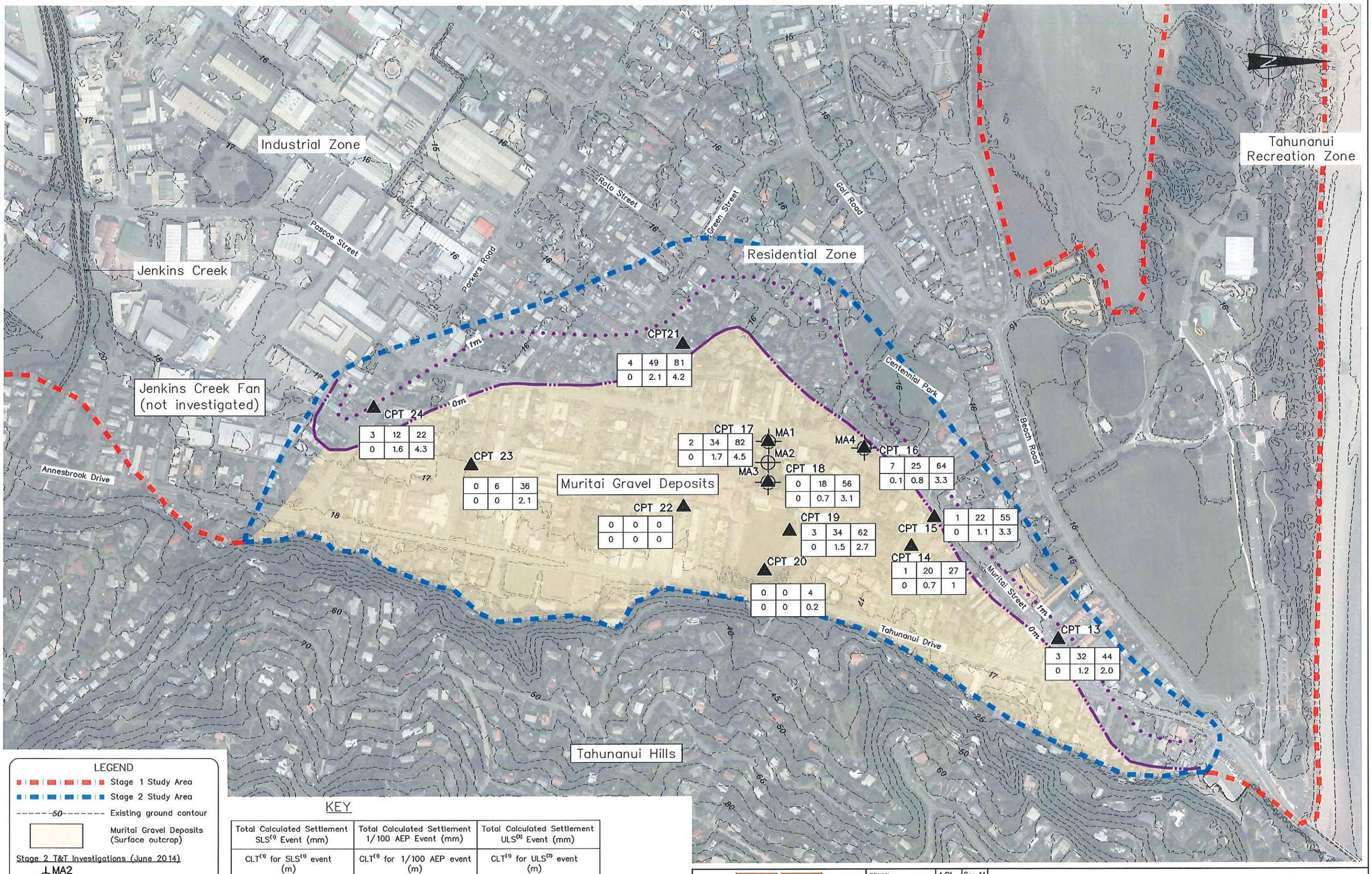
NELSON CITY COUNCIL

TAHUNANUI LIQUEFACTION STUDY

TAHUNANUI, NELSON

Stage 2 Site Investigation Plan

FIG. No. 87 1023-F 1 REV. 0



LEGEND

- Stage 1 Study Area
- Stage 2 Study Area
- 50 Existing ground contour
- Muritai Gravel Deposits (Surface outcrop)

Stage 2 T&T Investigations (June 2014)

- MA2 Machine Auger Location
- CPT 22 Cone Penetrometer Test Location (Perry Geotech)
- 0m / 1m Inferred Isopach thickness of Tahunanui sands overlying the Muritai Gravel Deposits
- A1263318

KEY

Total Calculated Settlement SLS(1) Event (mm)	Total Calculated Settlement 1/100 AEP Event (mm)	Total Calculated Settlement ULS(3) Event (mm)
CLT(1) for SLS(1) event (m)	CLT(1) for 1/100 AEP event (m)	CLT(1) for ULS(3) event (m)

NOTES:
(1) CLT = Cumulative Thickness of Liquefaction (m).
(2) SLS(1) event = PGA 0.09g, Mw=7.5.
(3) 1/100 AEP event = PGA 0.18g, Mw=7.5
(4) ULS event = PGA 0.36g, Mw=7.5.

Note:
Aerial photo sourced from Nelson City Council

A3 SCALE 1:5000
0 50 100 150 200 250 (m)

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TAHUNANUI LIQUEFACTION STUDY
TAHUNANUI, NELSON
Stage 2 Liquefaction Settlement and Thickness

FIG. No. 87 1023-F2 REV. 0

LEGEND

- Stage 1 Study Area
- Stage 2 Study Area
- Muritai Gravel Deposits (Surface outcrop)

T&T Investigation (April/May 2013)

- BH 1 — Borehole Location (Prodrill)
- CPT 12 — Cone Penetrometer Test Location (Geotechnics)

Stage 2 T&T Investigations (June 2014)

- MA3 — Machine Auger Location
- CPT 18 — Cone Penetrometer Test (Perry Geotech)

KEY

Liquefaction Susceptibility Number (LSN) under 1/100 AEP/ULS[3] earthquake scenario (refer Section 5.4 of report).

CPT No.

1 — Assessed LSN in SLS1 earthquake
12 — Assessed LSN in 1/100 AEP earthquake
22 — Assessed LSN in ULS earthquake

(Refer to Section 5.4 of report)

NOTES:
(1) SLS[1] event = PGA 0.09g, Mw=7.5.
(2) 1/100 AEP event = PGA 0.18g, Mw=7.5
(3) ULS event = PGA 0.36g, Mw=7.5.

Tahuna Recreation Zone
Tahuna Holiday Park
Residential Zone
Nelson Golf Course
Nelson Airport
Industrial Zone

CPT6 0 29 52
CPT9 0 18 42
CPT1 0 13 22
BH1
CPT 13 1 10 13
CPT 15 0 4 13
CPT 14 1 15 20
CPT 16 2 6 13
MA4
MA2
MA1
MA3
CPT 18
CPT 19 1 8 17
CPT 20 0 0 3
CPT 17 0 6 18
CPT 22 0 0 0
CPT5 0 6 18
CPT21 0 8 21
CPT7 0 16 32
BH2
CPT3 0 11 23
CPT12 1 12 29
CPT 23 0 1 8
CPT2 0 14 36
CPT 24 1 12 22
CPT10 12 14 34
CPT8 0 30 53
CPT4

Beach Road
Tahunanui Drive
Golf Road
Roto Street
Green Street
Parkers Road
Bolt Road
Pascoe Street
Annesbrook Drive
Quarantine Road
Whakatu Drive

Data on liquefaction potential from this test is not included in this assessment due to errors during testing (refer Section 1 of November 2013 report). However, results from CPT4 indicate that the liquefaction potential is consistent with the results of the other CPT tests carried out as part of this investigation.

A3 SCALE 1: 10000
0 0.1 0.2 0.3 0.4 0.5 (km)
A1266318

Note:
Aerial photo sourced from Nelson City Council

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APPROVED		10/14
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SCALES (AT A3 SIZE) 1: 10000		
PROJECT No. 87 1023		

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TAHUNANUI LIQUEFACTION STUDY
TAHUNANUI, NELSON
Stage 1 & 2 Liquefaction Susceptibility Number Values

FIG. No. 87 1023-F3 REV. 0

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Appendix B: Investigation results

- Machine Auger logs - MA1 to MA4
- Scala penetrometer logs - SC1 to SC26
- CPT Liquefaction Assessment Results - CPT13 to CPT24
- Engineering Terminology Log Sheet

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BOREHOLE LOG

BOREHOLE No: MA1

SHEET 1 OF 1

PROJECT: Tahuna Liquefaction | LOCATION: Burrell Park | JOB No: 871023

CO-ORDINATES 1620498.79, 5429424.39 | DRILL TYPE: Machine Auger | HOLE STARTED: 16/6/14

DRILL METHOD: Auger | HOLE FINISHED: 16/6/14

R.L. ≈ 16.4m | DRILLED BY: A+G

DATUM Nelson City | DRILL FLUID: Nil | LOGGED BY: MJL | CHECKED: MJL

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE / WEATHERING CONDITION	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
TOPSOIL									0				F				SILT: low plasticity organics, occasional fine to coarse rounded gravel and trace sand, brown/grey
MURITAI FAN GRAVEL (RECENT)	A / N		100%	AUGER	L / Z				0.5			m	D				GRAVEL: with sand, and trace low plasticity silt, sand fine to coarse, gravel fine to coarse, rounded and unweathered, brown/grey
									1.0								
									1.5			W	D				Sandy GRAVEL: with trace low plasticity silt, gravel is rounded fine to medium unweathered, blue/grey. silt % decreasing with depth.
									2.0								
									2.5								
TAHUNANUI SANDS (RECENT)									3.0				MD				SAND: with trace fine to medium, rounded, unweathered gravel, clasts sandstone/mudstone, sand is micaceous trace silt (<1%) blue/grey.
									3.5								End of hole at 3.0m. - target depth reached
									4.0								Notes: (1) Carried out adjacent to CPT-17.
									4.5								
									5.0								

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BOREHOLE LOG

BOREHOLE No: MA2

SHEET 1 OF 1

PROJECT: Tahunanui Liquefaction | LOCATION: Burrell Park | JOB No: 871023

CO-ORDINATES 1620527.50, 5429423.53 | DRILL TYPE: Machine Auger | HOLE STARTED: 16/6/14

DRILL METHOD: Auger | HOLE FINISHED: 16/6/14

R.L. | DRILLED BY: A+G

DATUM Nelson City | DRILL FLUID: Nil | LOGGED BY: MJL CHECKED: MJL

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY	METHOD	CASING	TESTS	SAMPLES	RL (m) / DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
TOPSOIL								0				F				SILT: low plasticity, organics occasional fine to coarse rounded gravel, and trace sand, brown/grey
MURITAI FAN GRAVEL (RECENT)								0.5			m	D				silty GRAVEL: with trace sand, low plasticity silt, gravel is fine to coarse, sub-rounded to rounded, unweathered sandstone, grey/brown.
								1.0								
								1.5								sandy GRAVEL: with some low plasticity silt, fine to coarse sand, fine to coarse sub-rounded to rounded, unweathered sandstone gravel. brown/grey. silt % decreasing with depth.
								2.0			W	D				
								2.5								
								3.0								
TAHUNANUI SANDS (RECENT)												MD				SAND: with occasional fine to medium sub angular unweathered gravels, blue/grey
								3.5								End of hole at 3.2m - target depth reached
								4.0								
								4.5								
								5.0								

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BOREHOLE LOG

BOREHOLE No: MA3

SHEET 1 OF 1

PROJECT: Tahunanui Liquefaction | LOCATION: Burrell Park | JOB No: 871023

CO-ORDINATES 1620 556.94, 5429 423.09 | DRILL TYPE: Machine Auger | HOLE STARTED: 16/6/14

DRILL METHOD: Auger | HOLE FINISHED: 16/6/14

R.L. ~16.5m | DRILLED BY: A+G

DATUM Nelson City | DRILL FLUID: Nil | LOGGED BY: MJL | CHECKED: MJL

GEOLOGICAL									ENGINEERING DESCRIPTION							
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY	METHOD	CASING	TESTS	SAMPLES	R.L. (m) / DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
TOPSOIL								0	wx			F				SILT: low plasticity, organics, occasional fine to coarse rounded gravel, trace sand, brown/grey
MURITAI FAN GRAVEL (RECENT)								0.5			m	D				silty GRAVEL: with trace sand, low plasticity silt, gravel is fine to coarse sub-rounded to rounded, unweathered sandstone, grey/brown.
								1.0								
	A / Z		100%	AUGER	CASING			1.5								sandy GRAVEL: with some low plasticity silt, fine to coarse sand, fine to coarse sub-rounded to rounded unweathered gravel, brown/grey. silt % decreasing with depth.
								2.0			W	D				
								2.5								
								3.0								
TAHUNANUI SANDS (RECENT)												MD				SAND: with occasional fine to medium sub-angular, unweathered gravels, blue/grey
								3.5								End of hole at 3.2m - target depth reached
								4.0								Notes: (i) Carried out adjacent to CPT-18.
								4.5								
								5.0								

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BOREHOLE LOG

BOREHOLE No: MA4

SHEET 1 OF 1

PROJECT: Tahunanui Liquefaction | LOCATION: 56 Muritai St. | JOB No: 871023

CO-ORDINATES 1620508.63, 5429561.81 | DRILL TYPE: Machine Auger | HOLE STARTED: 16/6/14

DRILL METHOD: Auger | HOLE FINISHED: 16/6/14

R.L. ~16.4m | DRILLED BY: A+G

DATUM Nelson City | DRILL FLUID: Nil | LOGGED BY: MJL CHECKED: M.M.

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	FLUID LOSS	WATER	CORE RECOVERY	METHOD	CASING	TESTS	SAMPLES	R.L. (m) / DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION / ROCK DESCRIPTION
TOPSOIL								0				F				SILT: low plasticity, organics occasional fine to coarse rounded gravel and trace sand, brown/grey
MURITAI FAN GRAVEL (RECENT)	A / Z	▽	100%	AUGER	CASING			0.5			m	D				silty GRAVEL: with trace sand, gravel is fine to coarse sub-rounded to rounded unweathered gravel, grey/brown.
								1.0								
								1.5								sandy GRAVEL: sand fine to coarse, gravel fine to coarse, rounded, unweathered, trace low plasticity silt, dark grey
								2.0			W	D				2.4m coarse rounded gravel
								2.5								2.5m defined layer of sand ~100mm thick.
TAHUNANUI SANDS (RECENT)								3.0				MD				SAND: fine to medium, occasional pondered unweathered gravel, trace silt, blue/grey
								3.5								End of hole at 3.2m - target reached.
								4.0								Notes: (1) Carried out adjacent to CPT-16.
								4.5								
								5.0								

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43 Halifax Street
P O Box 1009
NELSON
Tel: (03) 546 6339
Fax: (03) 546 7619

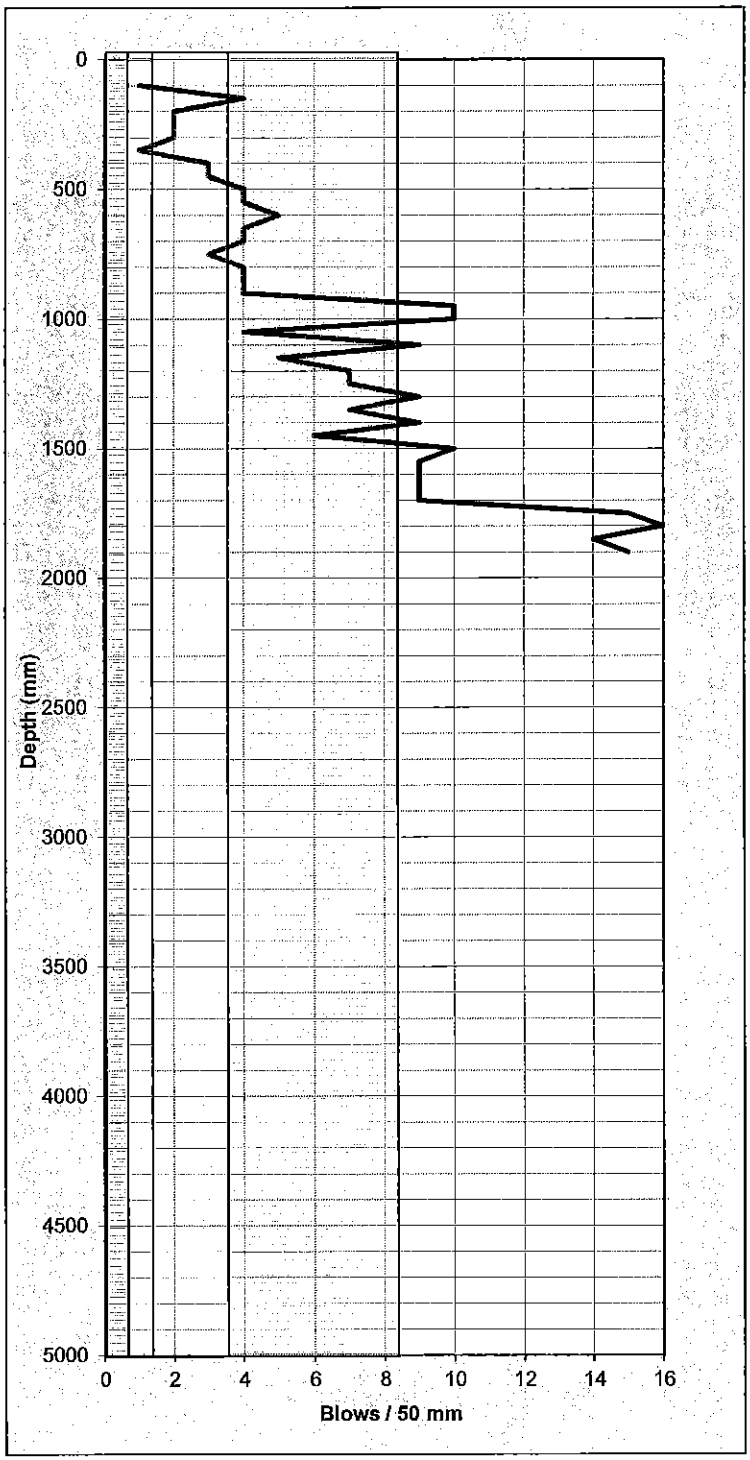
SCALA PENETROMETER LOG

Job No: *871023*
Project: *Tahuna - Liquefaction*
Location:
Position: **See plan** Latitude Longitude

Date: *8/05/2014*
Operated by: *WWD/MJL*
Logged by: *WWD/MJL*
Checked by: *mjl*

Test No. *SC1*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50		2550	
100	1	2600	
150	4	2650	
200	2	2700	
250	2	2750	
300	2	2800	
350	1	2850	
400	3	2900	
450	3	2950	
500	4	3000	
550	4	3050	
600	5	3100	
650	4	3150	
700	4	3200	
750	3	3250	
800	4	3300	
850	4	3350	
900	4	3400	
950	10	3450	
1000	10	3500	
1050	4	3550	
1100	9	3600	
1150	5	3650	
1200	7	3700	
1250	7	3750	
1300	9	3800	
1350	7	3850	
1400	9	3900	
1450	6	3950	
1500	10	4000	
1550	9	4050	
1600	9	4100	
1650	9	4150	
1700	9	4200	
1750	15	4250	
1800	16	4300	
1850	14	4350	
1900	15	4400	
1950		4450	
2000		4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

TONKIN & TAYLOR
43 Halifax Street
P O Box 1009
NELSON
Tel: (03) 546 6339
Fax: (03) 546 7619

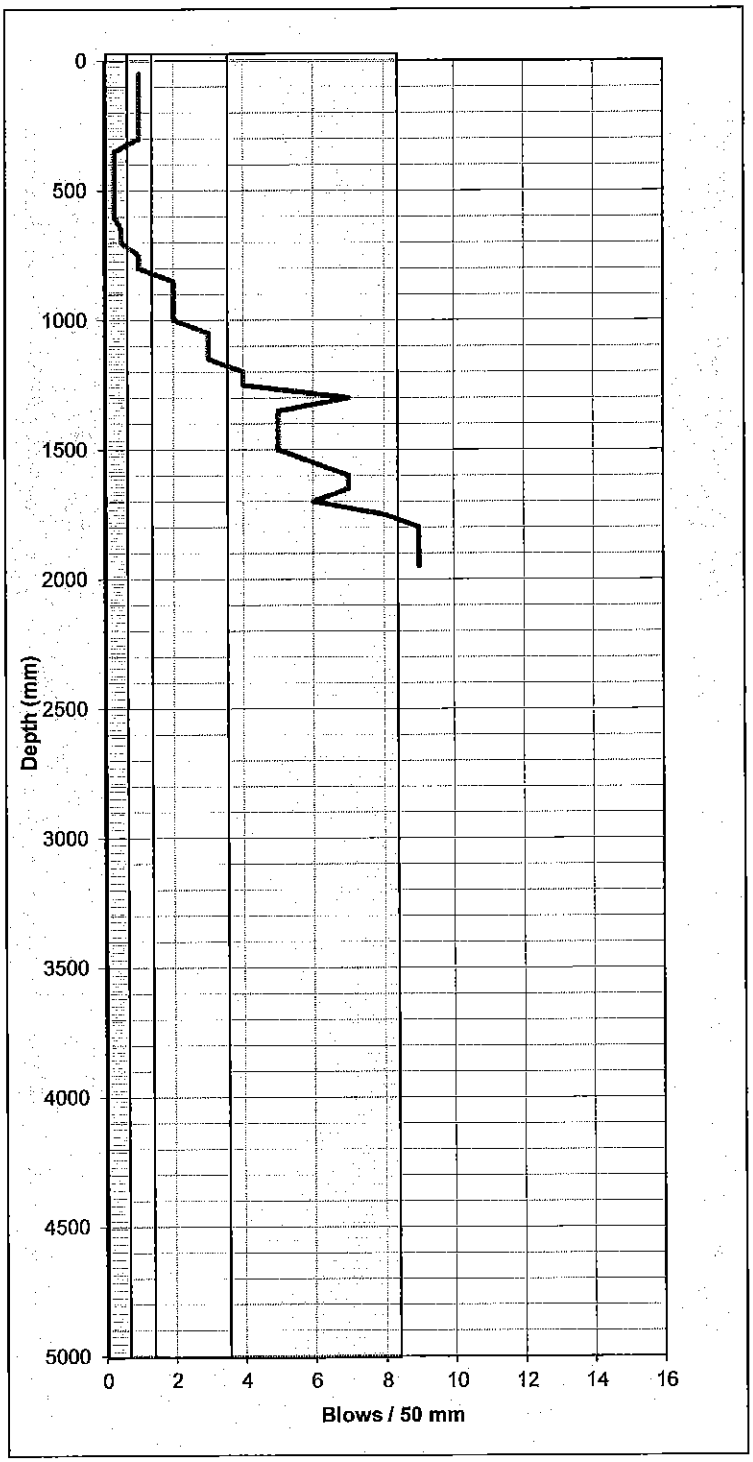
SCALA PENETROMETER LOG

Job No: **871023**
Project: **Tahuna - Liquefaction**
Location:
Position: **See plan** Latitude Longitude

Date: **8/05/2014**
Operated by: **WWD/MJL**
Logged by: **WWD/MJL**
Checked by: MJL

Test No. SC2
Sheet 1
of 1

mm Driven	No. of Blows	mm Driven	No. of Blows
50	1	2550	
100	1	2600	
150	1	2650	
200	1	2700	
250	1	2750	
300	1	2800	
350	0.3	2850	
400	0.3	2900	
450	0.3	2950	
500	0.3	3000	
550	0.3	3050	
600	0.3	3100	
650	0.5	3150	
700	0.5	3200	
750	1	3250	
800	1	3300	
850	2	3350	
900	2	3400	
950	2	3450	
1000	2	3500	
1050	3	3550	
1100	3	3600	
1150	3	3650	
1200	4	3700	
1250	4	3750	
1300	7	3800	
1350	5	3850	
1400	5	3900	
1450	5	3950	
1500	5	4000	
1550	6	4050	
1600	7	4100	
1650	7	4150	
1700	6	4200	
1750	8	4250	
1800	9	4300	
1850	9	4350	
1900	9	4400	
1950	9	4450	
2000		4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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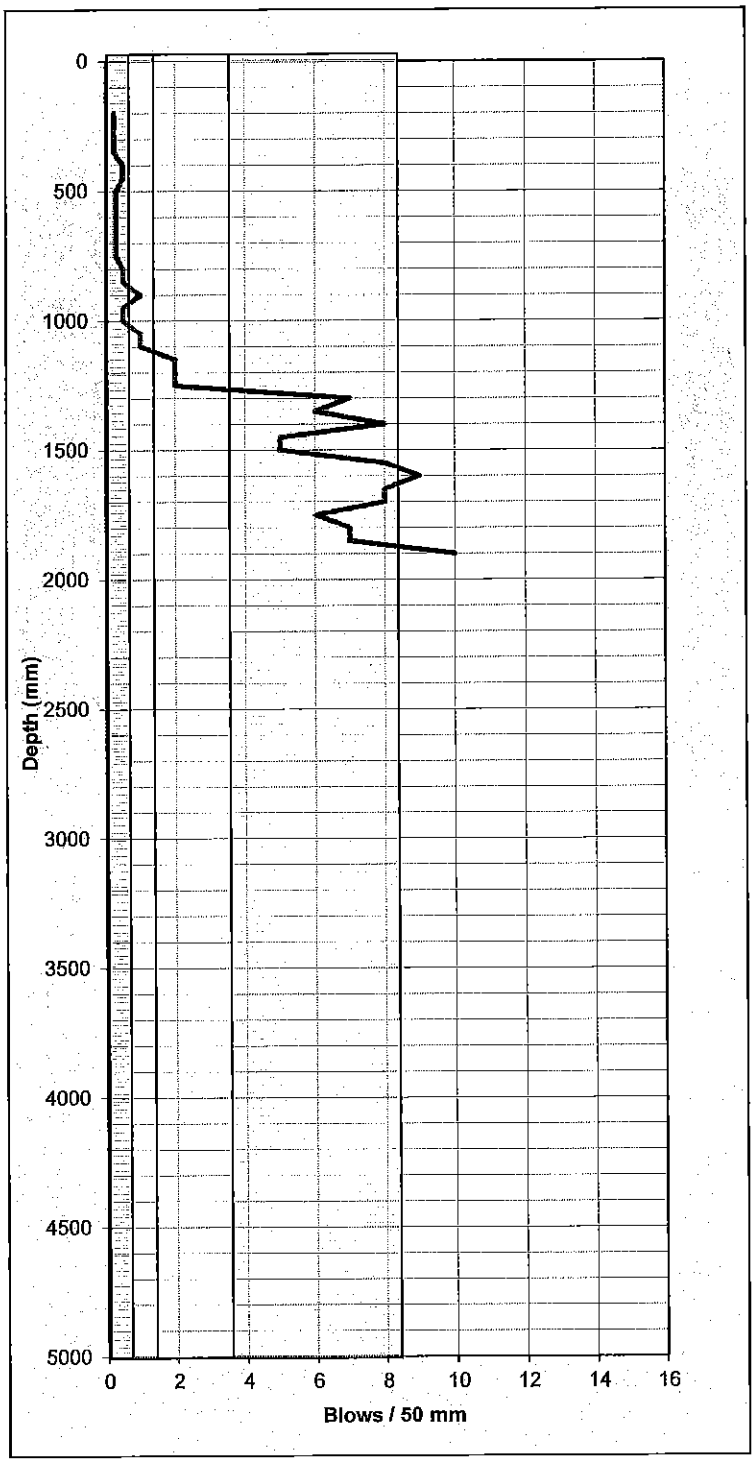
SCALA PENETROMETER LOG

Job No: *871023*
Project: *Tahuna - Liquefaction*
Location:
Position: **See plan** Latitude Longitude

Date: *8/05/2014*
Operated by: *WWD/MJL*
Logged by: *WWD/MJL*
Checked by: *mjl*

Test No. *SC3*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50		2550	
100		2600	
150		2650	
200	0.25	2700	
250	0.25	2750	
300	0.25	2800	
350	0.25	2850	
400	0.5	2900	
450	0.5	2950	
500	0.3	3000	
550	0.3	3050	
600	0.3	3100	
650	0.3	3150	
700	0.3	3200	
750	0.3	3250	
800	0.5	3300	
850	0.5	3350	
900	1	3400	
950	0.5	3450	
1000	0.5	3500	
1050	1	3550	
1100	1	3600	
1150	2	3650	
1200	2	3700	
1250	2	3750	
1300	7	3800	
1350	6	3850	
1400	8	3900	
1450	5	3950	
1500	5	4000	
1550	8	4050	
1600	9	4100	
1650	8	4150	
1700	8	4200	
1750	6	4250	
1800	7	4300	
1850	7	4350	
1900	10	4400	
1950		4450	
2000		4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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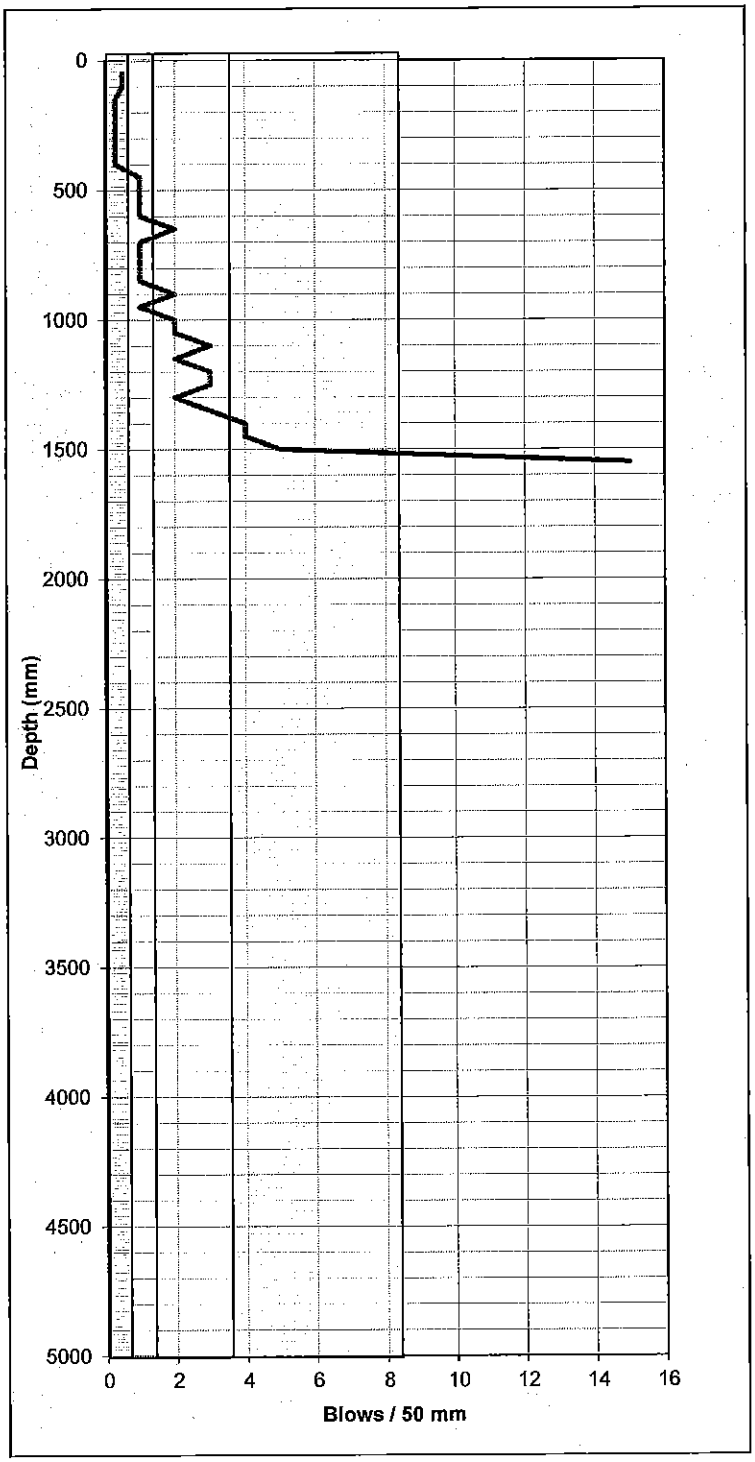
SCALA PENETROMETER LOG

Job No: **871023**
Project: **Tahuna - Liquefaction**
Location:
Position: **See plan** Latitude Longitude

Date: **8/05/2014**
Operated by: **WWD/MJL**
Logged by: **WWD/MJL**
Checked by: MJL

Test No. SC4
Sheet 1
of 1

mm Driven	No. of Blows		mm Driven	No. of Blows
50	0.5		2550	
100	0.5		2600	
150	0.3		2650	
200	0.3		2700	
250	0.3		2750	
300	0.3		2800	
350	0.3		2850	
400	0.3		2900	
450	1		2950	
500	1		3000	
550	1		3050	
600	1		3100	
650	2		3150	
700	1		3200	
750	1		3250	
800	1		3300	
850	1		3350	
900	2		3400	
950	1		3450	
1000	2		3500	
1050	2		3550	
1100	3		3600	
1150	2		3650	
1200	3		3700	
1250	3		3750	
1300	2		3800	
1350	3		3850	
1400	4		3900	
1450	4		3950	
1500	5		4000	
1550	15	+	4050	
1600			4100	
1650			4150	
1700			4200	
1750			4250	
1800			4300	
1850			4350	
1900			4400	
1950			4450	
2000			4500	
2050			4550	
2100			4600	
2150			4650	
2200			4700	
2250			4750	
2300			4800	
2350			4850	
2400			4900	
2450			4950	
2500			5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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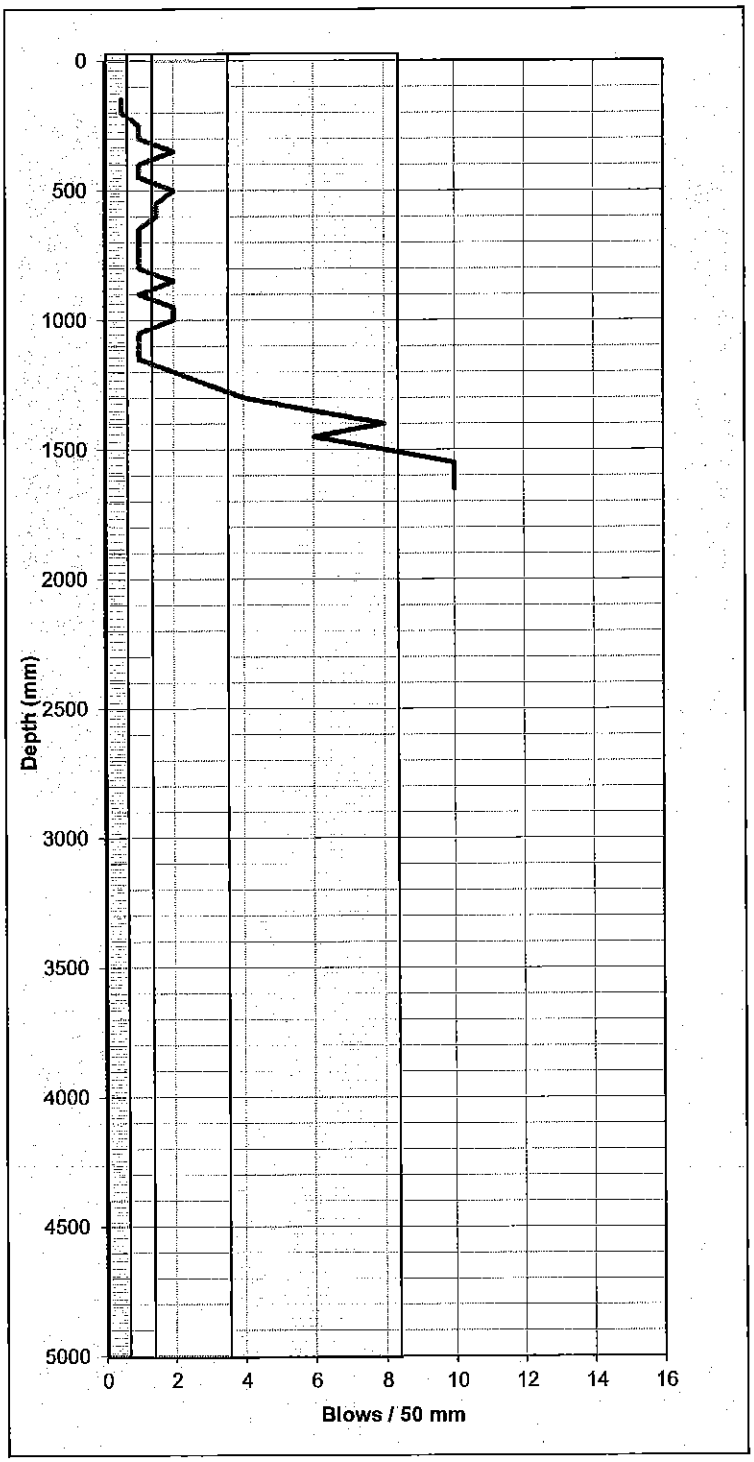
SCALA PENETROMETER LOG

Job No: *871023*
Project: *Tahuna - Liquefaction*
Location:
Position: **See plan** Latitude Longitude

Date: *8/05/2014*
Operated by: *WWD/MJL*
Logged by: *WWD/MJL*
Checked by: *mjl*

Test No. *SC5*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50		2550	
100		2600	
150	0.5	2650	
200	0.5	2700	
250	1	2750	
300	1	2800	
350	2	2850	
400	1	2900	
450	1	2950	
500	2	3000	
550	1.5	3050	
600	1.5	3100	
650	1	3150	
700	1	3200	
750	1	3250	
800	1	3300	
850	2	3350	
900	1	3400	
950	2	3450	
1000	2	3500	
1050	1	3550	
1100	1	3600	
1150	1	3650	
1200	2	3700	
1250	3	3750	
1300	4	3800	
1350	6	3850	
1400	8	3900	
1450	6	3950	
1500	8	4000	
1550	10	4050	
1600	10	4100	
1650	10	4150	
1700		4200	
1750		4250	
1800		4300	
1850		4350	
1900		4400	
1950		4450	
2000		4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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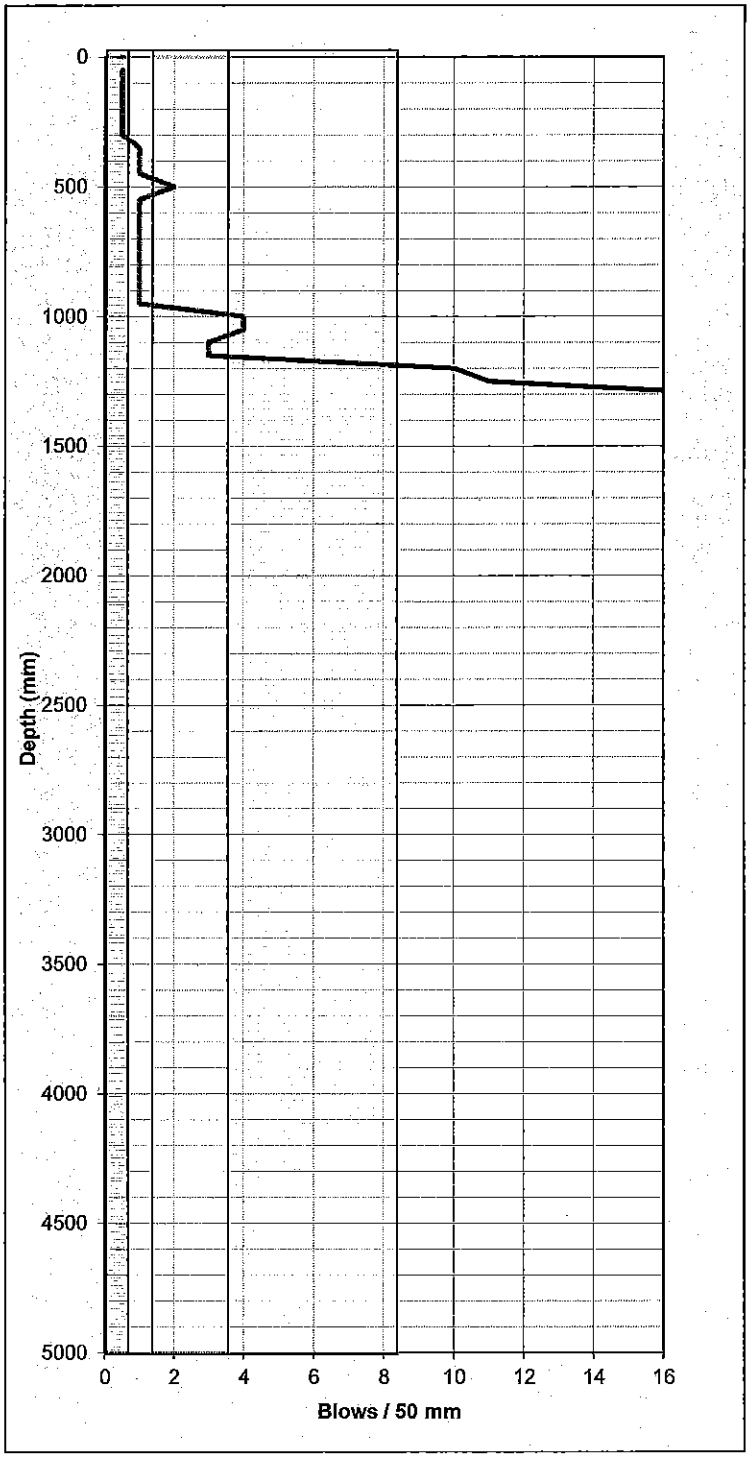
SCALA PENETROMETER LOG

Job No:	*871023*	Date:	*14/05/2014*
Project:	***Tahuna - Liquefaction***	Operated by:	*WWD*
Location:		Logged by:	*WWD*
Position:	**See plan** Latitude Longitude	Checked by:	

Test No.	*SC6*
Sheet	*1*
of	*1*

mm Driven	No. of Blows		mm Driven	No. of Blows
50	*0.5*		2550	
100	*0.5*		2600	
150	*0.5*		2650	
200	*0.5*		2700	
250	*0.5*		2750	
300	*0.5*		2800	
350	*1*		2850	
400	*1*		2900	
450	*1*		2950	
500	*2*		3000	
550	*1*		3050	
600	*1*		3100	
650	*1*		3150	
700	*1*		3200	
750	*1*		3250	
800	*1*		3300	
850	*1*		3350	
900	*1*		3400	
950	*1*		3450	
1000	*4*		3500	
1050	*4*		3550	
1100	*3*		3600	
1150	*3*		3650	
1200	*10*		3700	
1250	*11*		3750	
1300	*18*	+	3800	
1350			3850	
1400			3900	
1450			3950	
1500			4000	
1550			4050	
1600			4100	
1650			4150	
1700			4200	
1750			4250	
1800			4300	
1850			4350	
1900			4400	
1950			4450	
2000			4500	
2050			4550	
2100			4600	
2150			4650	
2200			4700	
2250			4750	
2300			4800	
2350			4850	
2400			4900	
2450			4950	
2500			5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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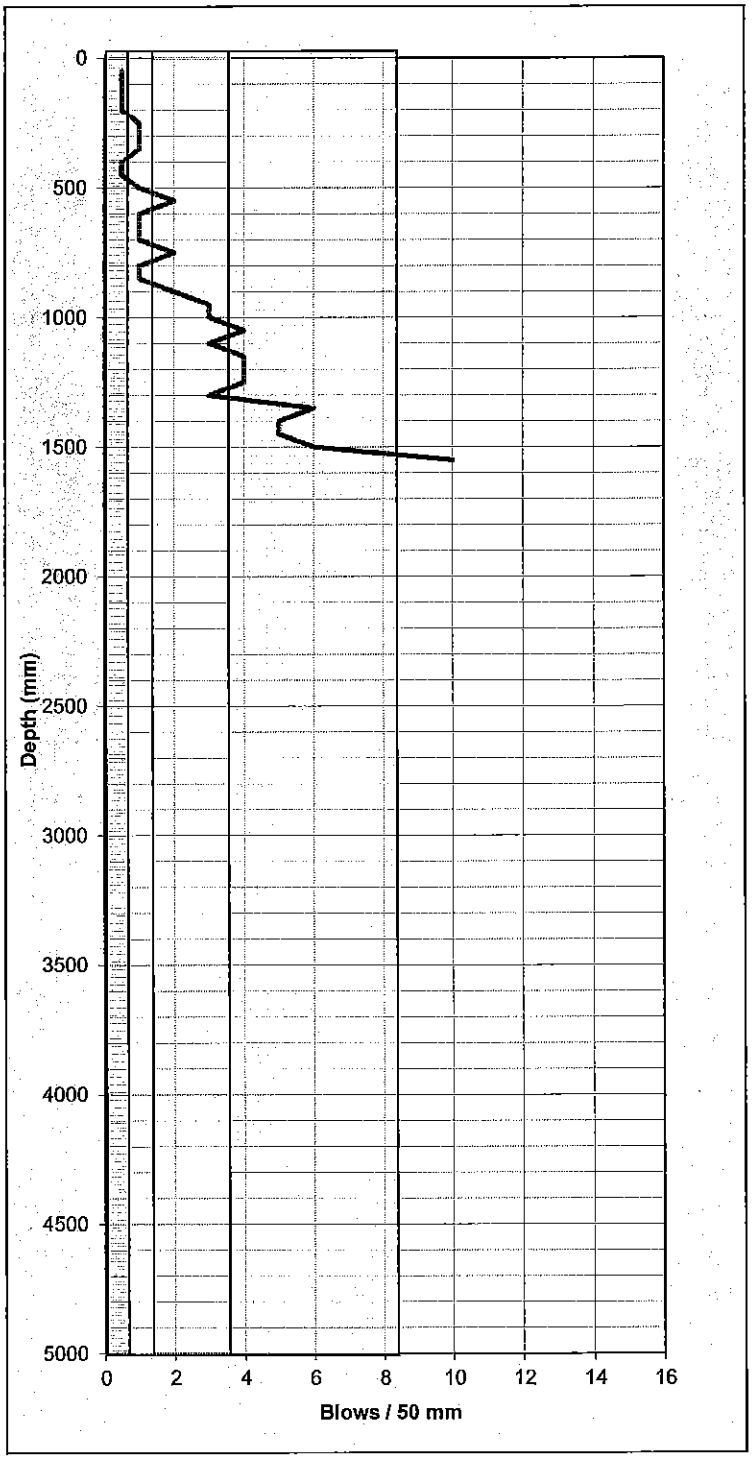
SCALA PENETROMETER LOG

Job No: *871023*
Project: *Tahuna - Liquefaction*
Location:
Position: **See plan** Latitude Longitude

Date: *14/05/2014*
Operated by: *WWD*
Logged by: *WWD*
Checked by: *mpl*

Test No. *SC7*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50	0.5	2550	
100	0.5	2600	
150	0.5	2650	
200	0.5	2700	
250	1	2750	
300	1	2800	
350	1	2850	
400	0.5	2900	
450	0.5	2950	
500	1	3000	
550	2	3050	
600	1	3100	
650	1	3150	
700	1	3200	
750	2	3250	
800	1	3300	
850	1	3350	
900	2	3400	
950	3	3450	
1000	3	3500	
1050	4	3550	
1100	3	3600	
1150	4	3650	
1200	4	3700	
1250	4	3750	
1300	3	3800	
1350	6	3850	
1400	5	3900	
1450	5	3950	
1500	6	4000	
1550	10	4050	
1600		4100	
1650		4150	
1700		4200	
1750		4250	
1800		4300	
1850		4350	
1900		4400	
1950		4450	
2000		4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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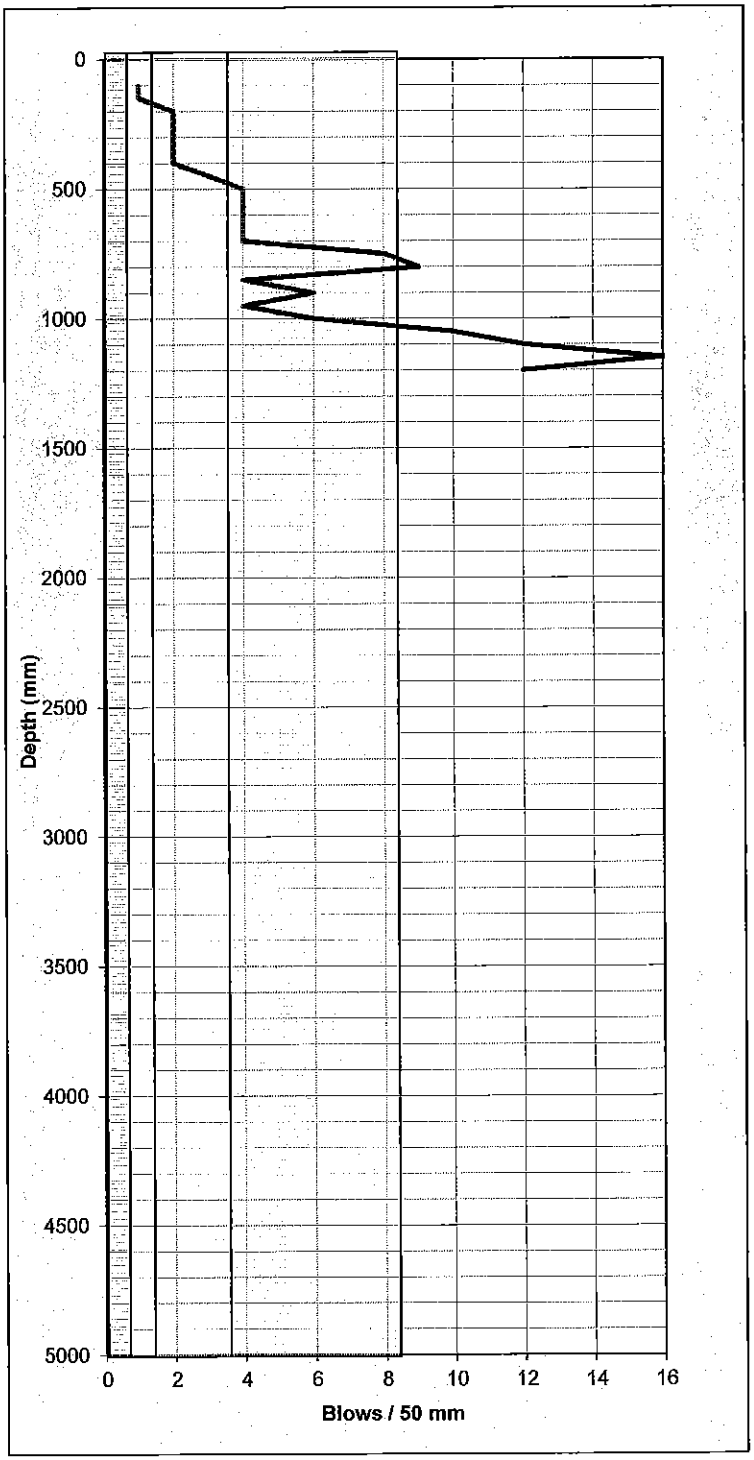
SCALA PENETROMETER LOG

Job No: *871023*
Project: *Tahuna - Liquefaction*
Location:
Position: **See plan** Latitude Longitude

Date: *14/05/2014*
Operated by: *WWD*
Logged by: *WWD*
Checked by: *mp*

Test No. *SC8*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50		2550	
100	1	2600	
150	1	2650	
200	2	2700	
250	2	2750	
300	2	2800	
350	2	2850	
400	2	2900	
450	3	2950	
500	4	3000	
550	4	3050	
600	4	3100	
650	4	3150	
700	4	3200	
750	8	3250	
800	9	3300	
850	4	3350	
900	6	3400	
950	4	3450	
1000	6	3500	
1050	10	3550	
1100	12	3600	
1150	16	3650	
1200	12	3700	
1250		3750	
1300		3800	
1350		3850	
1400		3900	
1450		3950	
1500		4000	
1550		4050	
1600		4100	
1650		4150	
1700		4200	
1750		4250	
1800		4300	
1850		4350	
1900		4400	
1950		4450	
2000		4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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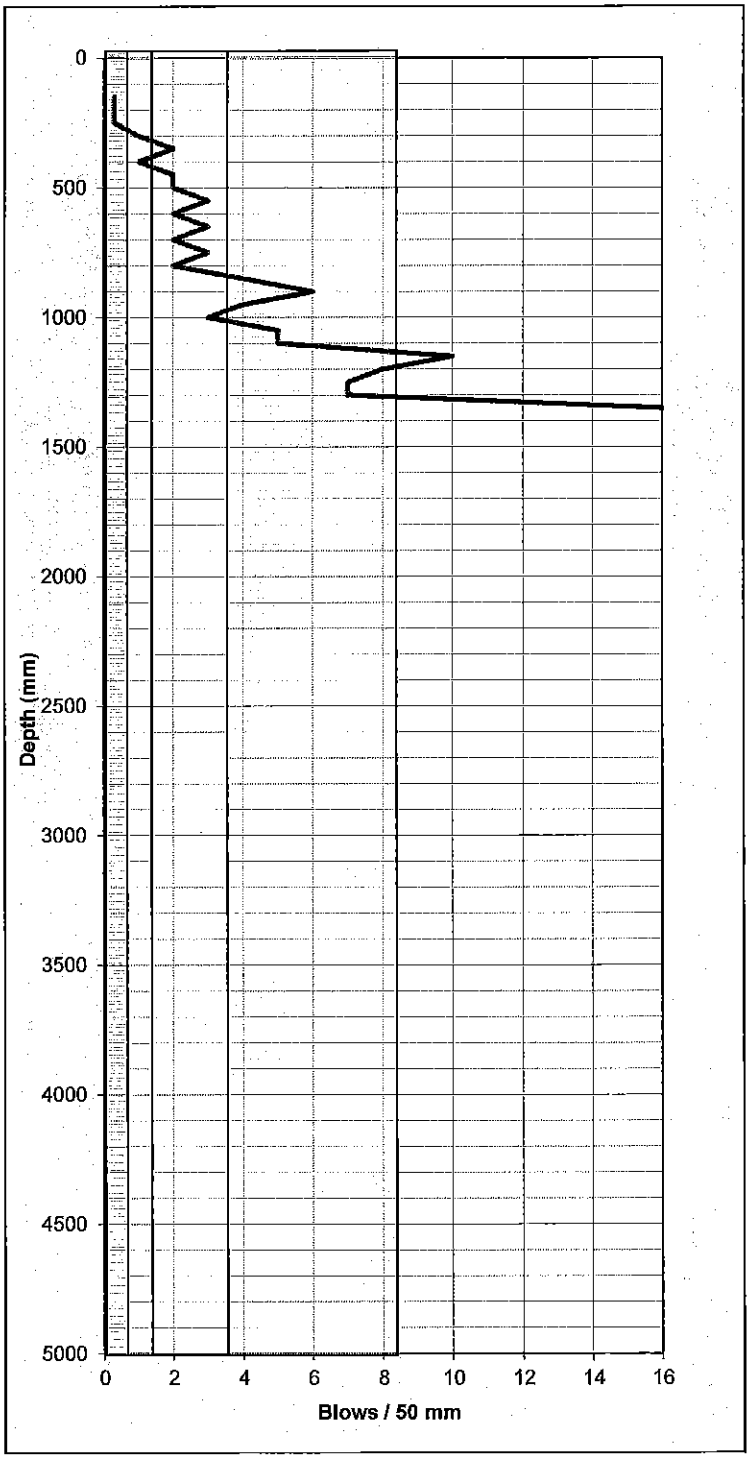
SCALA PENETROMETER LOG

Job No: *871023*
Project: *Tahuna - Liquefaction*
Location:
Position: **See plan** Latitude Longitude

Date: *14/05/2014*
Operated by: *WWD*
Logged by: *WWD*
Checked by: *mjt*

Test No. *SC9*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50		2550	
100		2600	
150	*0.3*	2650	
200	*0.3*	2700	
250	*0.3*	2750	
300	*1*	2800	
350	*2*	2850	
400	*1*	2900	
450	*2*	2950	
500	*2*	3000	
550	*3*	3050	
600	*2*	3100	
650	*3*	3150	
700	*2*	3200	
750	*3*	3250	
800	*2*	3300	
850	*4*	3350	
900	*6*	3400	
950	*4*	3450	
1000	*3*	3500	
1050	*5*	3550	
1100	*5*	3600	
1150	*10*	3650	
1200	*8*	3700	
1250	*7*	3750	
1300	*7*	3800	
1350	*16*	3850	
1400		3900	
1450		3950	
1500		4000	
1550		4050	
1600		4100	
1650		4150	
1700		4200	
1750		4250	
1800		4300	
1850		4350	
1900		4400	
1950		4450	
2000		4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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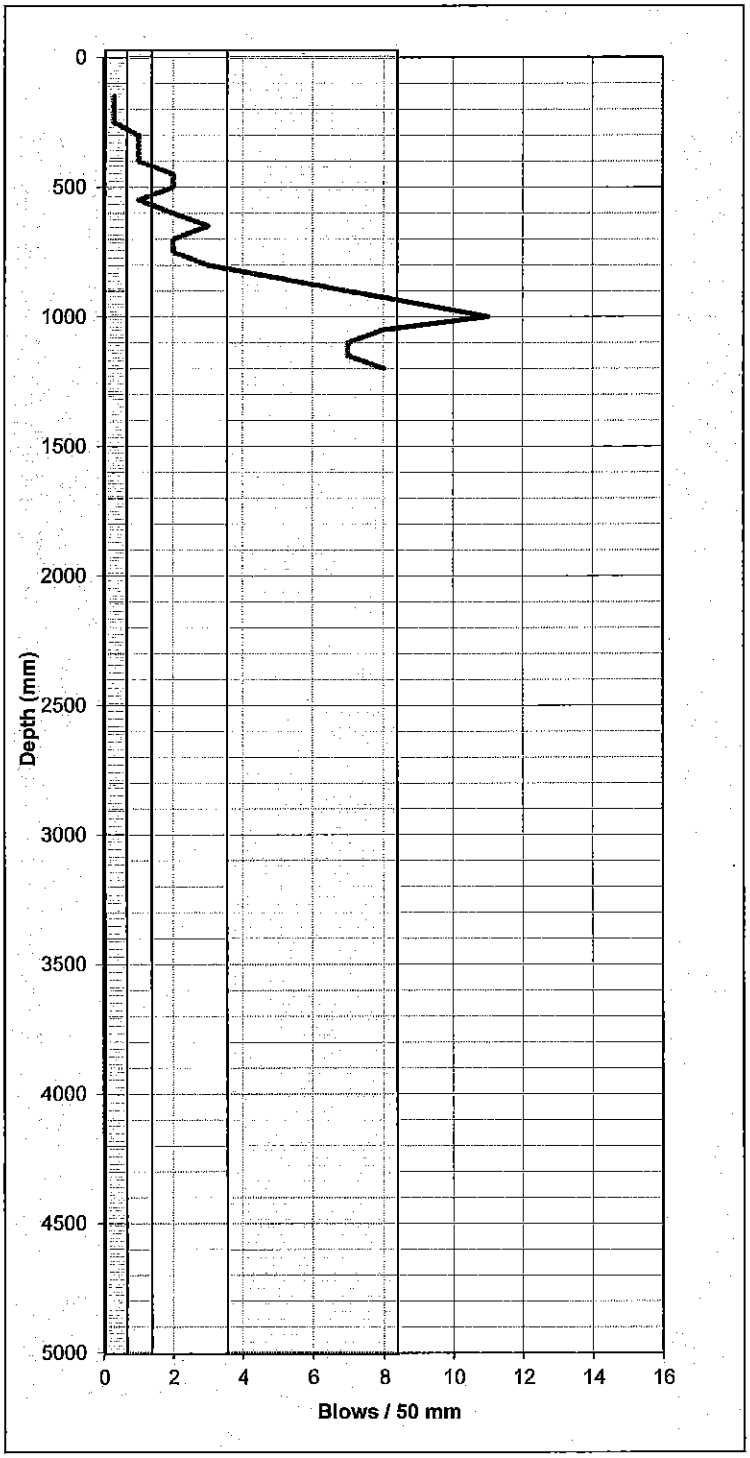
SCALA PENETROMETER LOG

Job No: *871023*
Project: *Tahuna - Liquefaction*
Location:
Position: **See plan** Latitude Longitude

Date: *14/05/2014*
Operated by: *WWD*
Logged by: *WWD*
Checked by: *mjr*

Test No. *SC10*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50		2550	
100		2600	
150	0.3	2650	
200	0.3	2700	
250	0.3	2750	
300	1	2800	
350	1	2850	
400	1	2900	
450	2	2950	
500	2	3000	
550	1	3050	
600	2	3100	
650	3	3150	
700	2	3200	
750	2	3250	
800	3	3300	
850	5	3350	
900	7	3400	
950	9	3450	
1000	11	3500	
1050	8	3550	
1100	7	3600	
1150	7	3650	
1200	8	3700	
1250		3750	
1300		3800	
1350		3850	
1400		3900	
1450		3950	
1500		4000	
1550		4050	
1600		4100	
1650		4150	
1700		4200	
1750		4250	
1800		4300	
1850		4350	
1900		4400	
1950		4450	
2000		4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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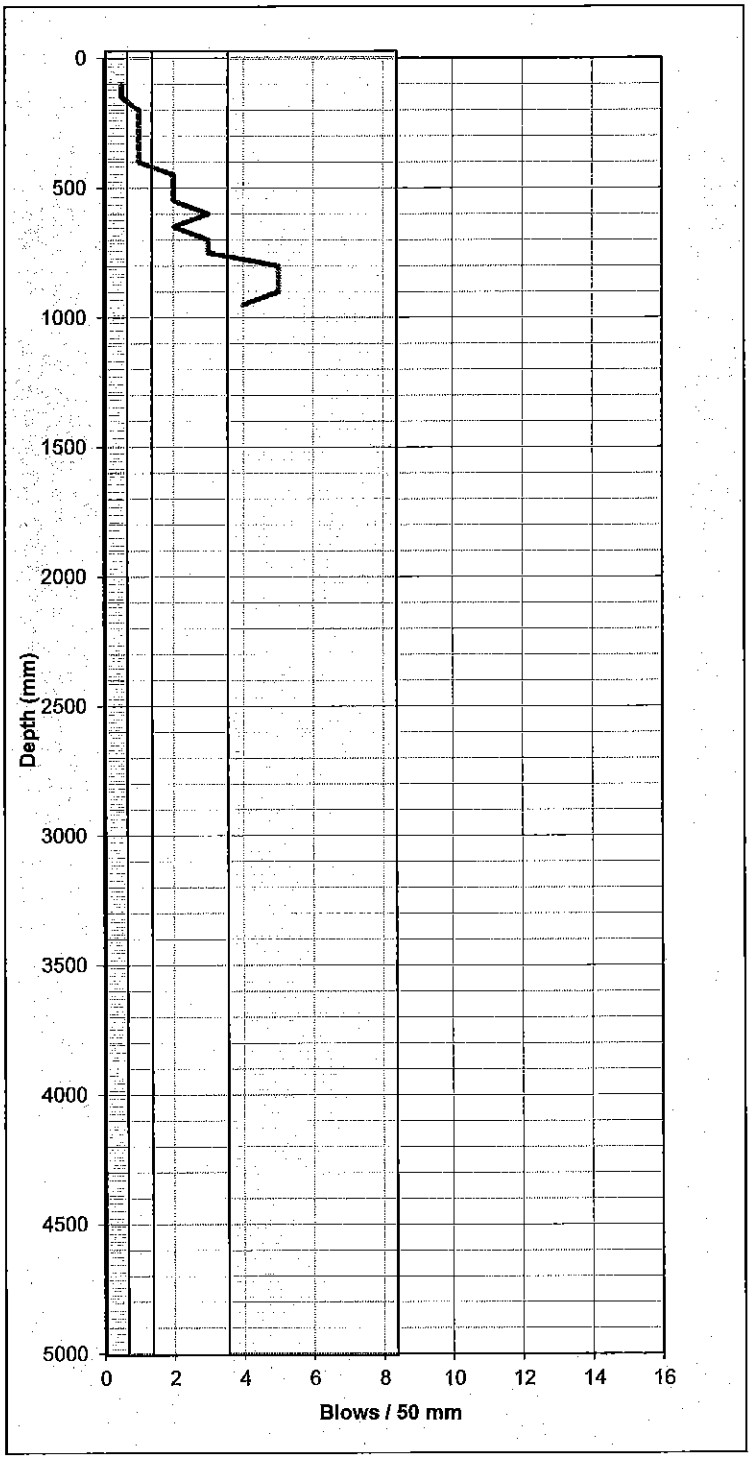
SCALA PENETROMETER LOG

Job No: *871023*
Project: *Tahuna - Liquefaction*
Location:
Position: **See plan** Latitude Longitude

Date: *14/05/2014*
Operated by: *WWD*
Logged by: *WWD*
Checked by: *mjl*

Test No. *SC11*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50		2550	
100	0.5	2600	
150	0.5	2650	
200	1	2700	
250	1	2750	
300	1	2800	
350	1	2850	
400	1	2900	
450	2	2950	
500	2	3000	
550	2	3050	
600	3	3100	
650	2	3150	
700	3	3200	
750	3	3250	
800	5	3300	
850	5	3350	
900	5	3400	
950	4	3450	
1000		3500	
1050		3550	
1100		3600	
1150		3650	
1200		3700	
1250		3750	
1300		3800	
1350		3850	
1400		3900	
1450		3950	
1500		4000	
1550		4050	
1600		4100	
1650		4150	
1700		4200	
1750		4250	
1800		4300	
1850		4350	
1900		4400	
1950		4450	
2000		4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

TONKIN & TAYLOR
43 Halifax Street
P O Box 1009
NELSON
Tel: (03) 546 6339
Fax: (03) 546 7619

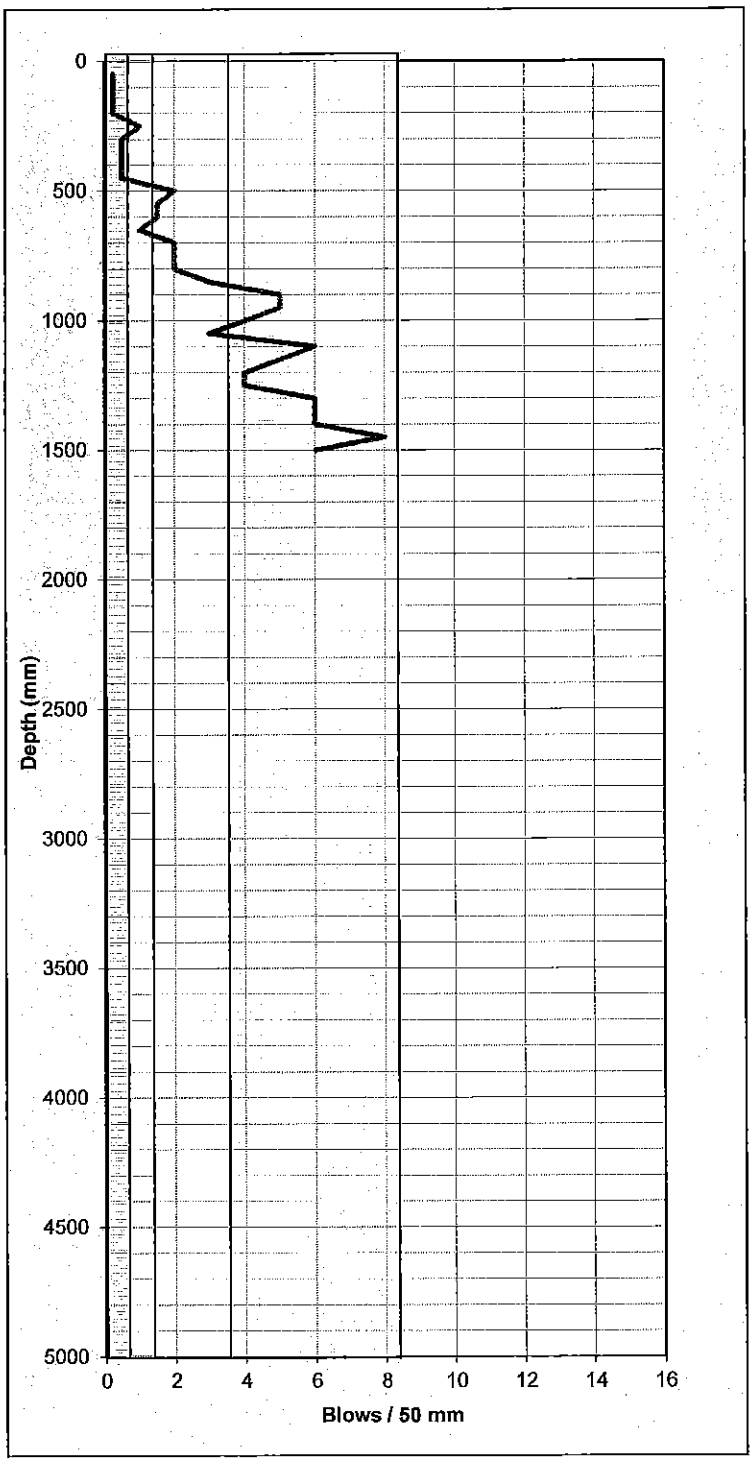
SCALA PENETROMETER LOG

Job No: **871023**
Project: **Tahuna - Liquefaction**
Location:
Position: **See plan** Latitude Longitude

Date: **15/05/2014**
Operated by: **WWD**
Logged by: **WWD**
Checked by: mpl

Test No. **SC12**
Sheet **1**
of **1**

mm Driven	No. of Blows	mm Driven	No. of Blows
50	0.25	2550	
100	0.25	2600	
150	0.25	2650	
200	0.25	2700	
250	1	2750	
300	0.5	2800	
350	0.5	2850	
400	0.5	2900	
450	0.5	2950	
500	2	3000	
550	1.5	3050	
600	1.5	3100	
650	1	3150	
700	2	3200	
750	2	3250	
800	2	3300	
850	3	3350	
900	5	3400	
950	5	3450	
1000	4	3500	
1050	3	3550	
1100	6	3600	
1150	5	3650	
1200	4	3700	
1250	4	3750	
1300	6	3800	
1350	6	3850	
1400	6	3900	
1450	8	3950	
1500	6	4000	
1550		4050	
1600		4100	
1650		4150	
1700		4200	
1750		4250	
1800		4300	
1850		4350	
1900		4400	
1950		4450	
2000		4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

TONKIN & TAYLOR
43 Halifax Street
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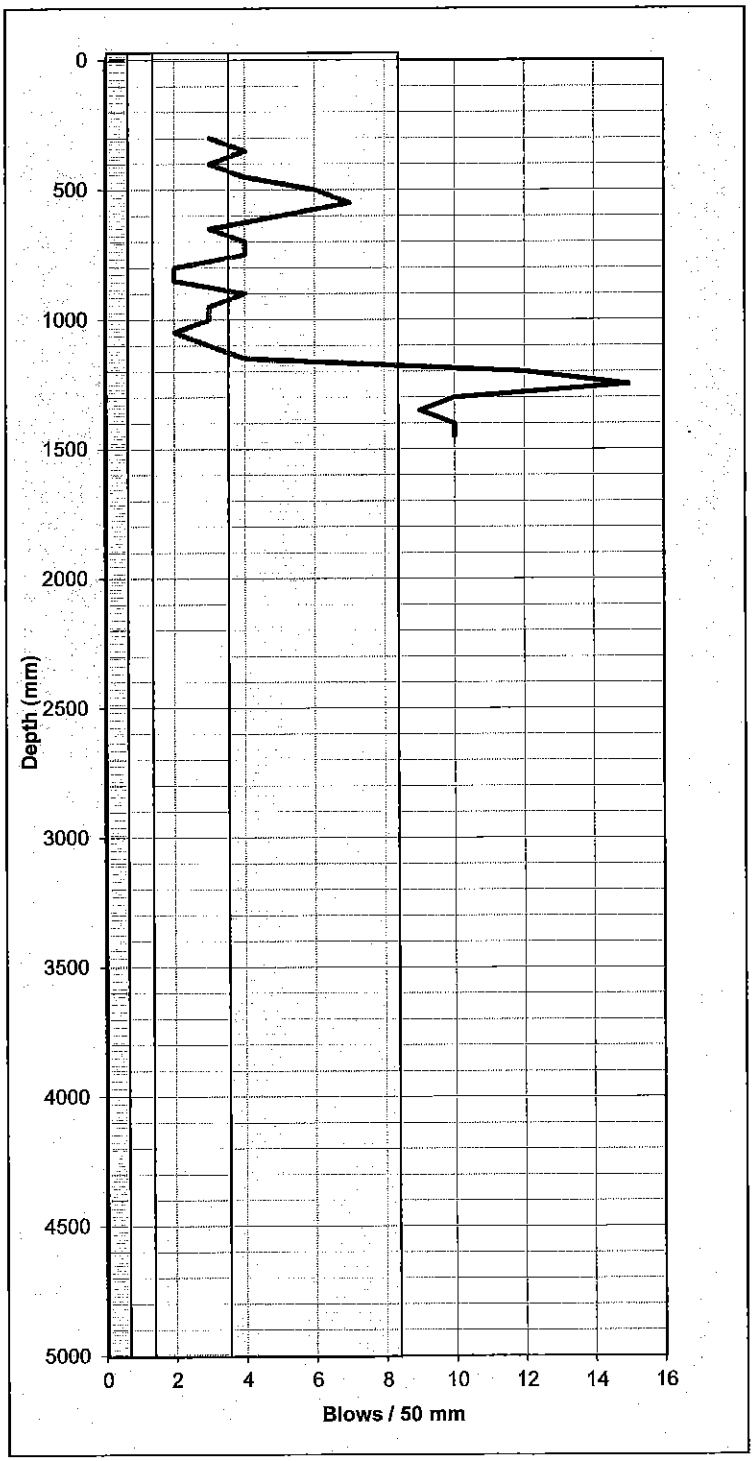
SCALA PENETROMETER LOG

Job No: **871023**
Project: **Tahuna - Liquefaction**
Location:
Position: **See plan** Latitude Longitude

Date: **15/05/2014**
Operated by: **WWD**
Logged by: **WWD**
Checked by:

Test No. SC13
Sheet 1
of 1

mm Driven	No. of Blows		mm Driven	No. of Blows
50			2550	
100			2600	
150			2650	
200			2700	
250			2750	
300	3		2800	
350	4		2850	
400	3		2900	
450	4		2950	
500	6		3000	
550	7		3050	
600	5		3100	
650	3		3150	
700	4		3200	
750	4		3250	
800	2		3300	
850	2		3350	
900	4		3400	
950	3		3450	
1000	3		3500	
1050	2		3550	
1100	3		3600	
1150	4		3650	
1200	12		3700	
1250	15		3750	
1300	10		3800	
1350	9		3850	
1400	10		3900	
1450	10	+	3950	
1500			4000	
1550			4050	
1600			4100	
1650			4150	
1700			4200	
1750			4250	
1800			4300	
1850			4350	
1900			4400	
1950			4450	
2000			4500	
2050			4550	
2100			4600	
2150			4650	
2200			4700	
2250			4750	
2300			4800	
2350			4850	
2400			4900	
2450			4950	
2500			5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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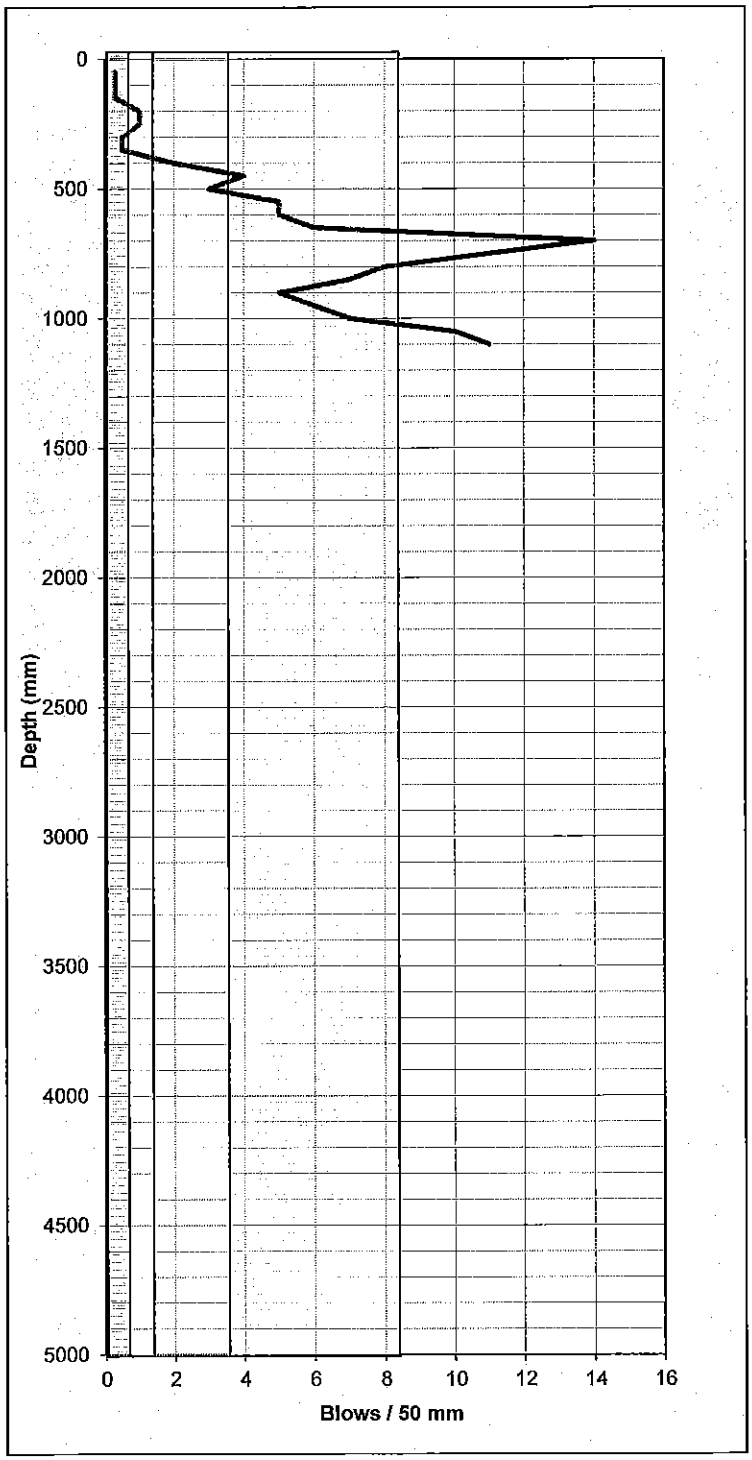
SCALA PENETROMETER LOG

Job No: *871023*
Project: *Tahuna - Liquefaction*
Location:
Position: **See plan** Latitude Longitude

Date: *15/05/2014*
Operated by: *WWD*
Logged by: *WWD*
Checked by: *mjt*

Test No. *SC14*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50	0.3	2550	
100	0.3	2600	
150	0.3	2650	
200	1	2700	
250	1	2750	
300	0.5	2800	
350	0.5	2850	
400	2	2900	
450	4	2950	
500	3	3000	
550	5	3050	
600	5	3100	
650	6	3150	
700	14	3200	
750	11	3250	
800	8	3300	
850	7	3350	
900	5	3400	
950	6	3450	
1000	7	3500	
1050	10	3550	
1100	11	3600	
1150		3650	
1200		3700	
1250		3750	
1300		3800	
1350		3850	
1400		3900	
1450		3950	
1500		4000	
1550		4050	
1600		4100	
1650		4150	
1700		4200	
1750		4250	
1800		4300	
1850		4350	
1900		4400	
1950		4450	
2000		4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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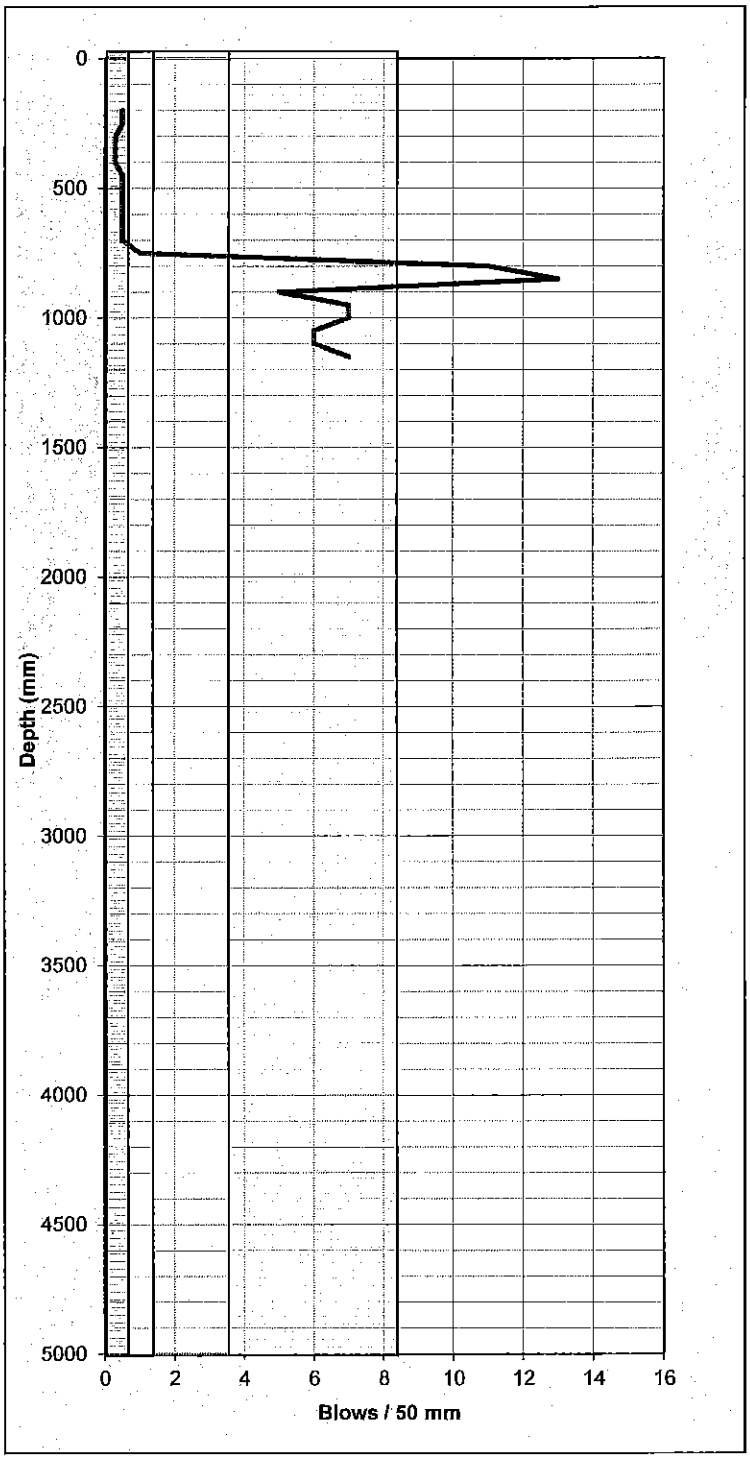
SCALA PENETROMETER LOG

Job No: *871023*
Project: *Tahuna - Liquefaction*
Location:
Position: **See plan** Latitude Longitude

Date: *15/05/2014*
Operated by: *WWD*
Logged by: *WWD*
Checked by: *mjl*

Test No. *SC15*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50		2550	
100		2600	
150		2650	
200	0.5	2700	
250	0.5	2750	
300	0.3	2800	
350	0.3	2850	
400	0.3	2900	
450	0.5	2950	
500	0.5	3000	
550	0.5	3050	
600	0.5	3100	
650	0.5	3150	
700	0.5	3200	
750	1	3250	
800	11	3300	
850	13	3350	
900	5	3400	
950	7	3450	
1000	7	3500	
1050	6	3550	
1100	6	3600	
1150	7	3650	
1200		3700	
1250		3750	
1300		3800	
1350		3850	
1400		3900	
1450		3950	
1500		4000	
1550		4050	
1600		4100	
1650		4150	
1700		4200	
1750		4250	
1800		4300	
1850		4350	
1900		4400	
1950		4450	
2000		4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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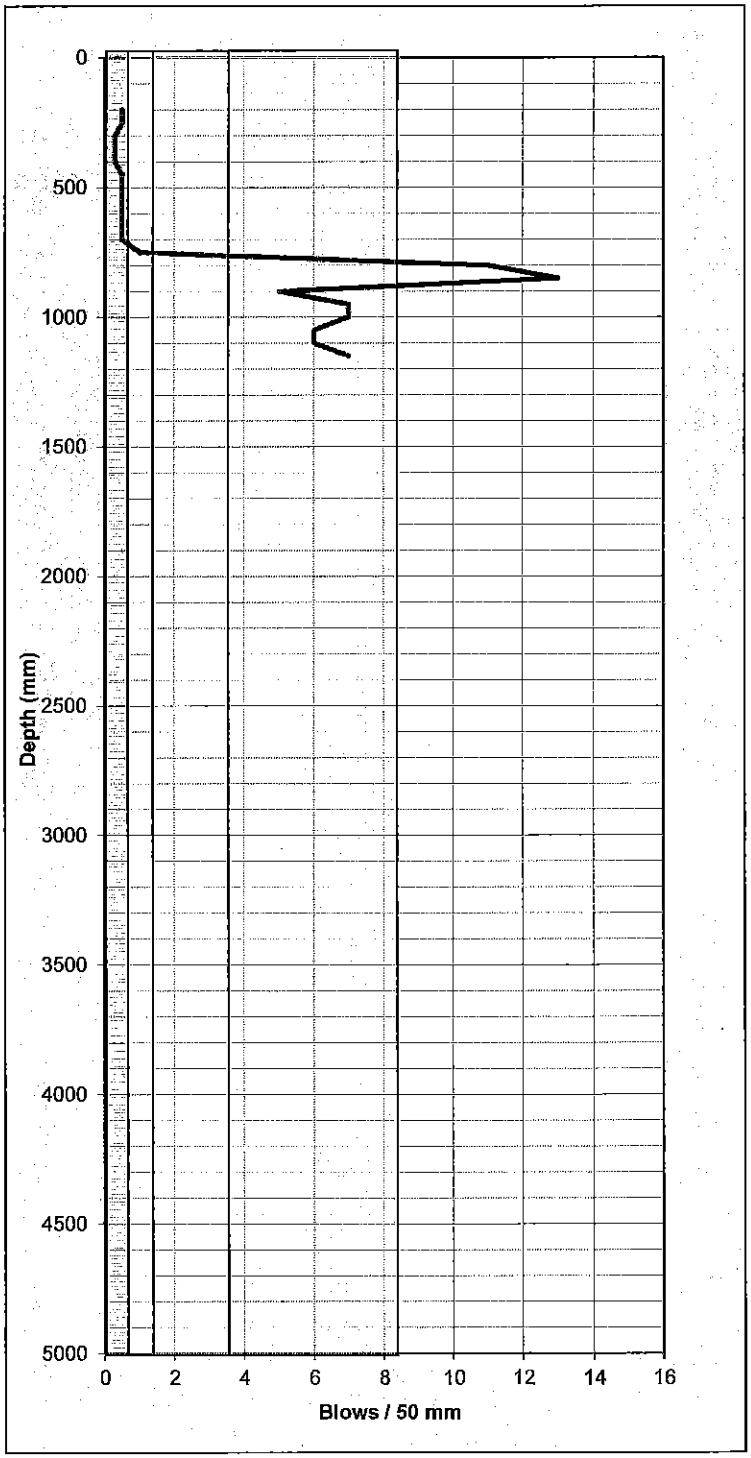
SCALA PENETROMETER LOG

Job No:	*871023*	Date:	*15/05/2014*
Project:	***Tahuna - Liquefaction***	Operated by:	*WWD*
Location:		Logged by:	*WWD*
Position:	**See plan** Latitude Longitude	Checked by:	

Test No.	***SC16***
Sheet	***1***
of	***1***

mm Driven	No. of Blows	mm Driven	No. of Blows
50		2550	
100		2600	
150		2650	
200	*0.5*	2700	
250	*0.5*	2750	
300	*0.3*	2800	
350	*0.3*	2850	
400	*0.3*	2900	
450	*0.5*	2950	
500	*0.5*	3000	
550	*0.5*	3050	
600	*0.5*	3100	
650	*0.5*	3150	
700	*0.5*	3200	
750	*1*	3250	
800	*11*	3300	
850	*13*	3350	
900	*5*	3400	
950	*7*	3450	
1000	*7*	3500	
1050	*6*	3550	
1100	*6*	3600	
1150	*7*	3650	
1200		3700	
1250		3750	
1300		3800	
1350		3850	
1400		3900	
1450		3950	
1500		4000	
1550		4050	
1600		4100	
1650		4150	
1700		4200	
1750		4250	
1800		4300	
1850		4350	
1900		4400	
1950		4450	
2000		4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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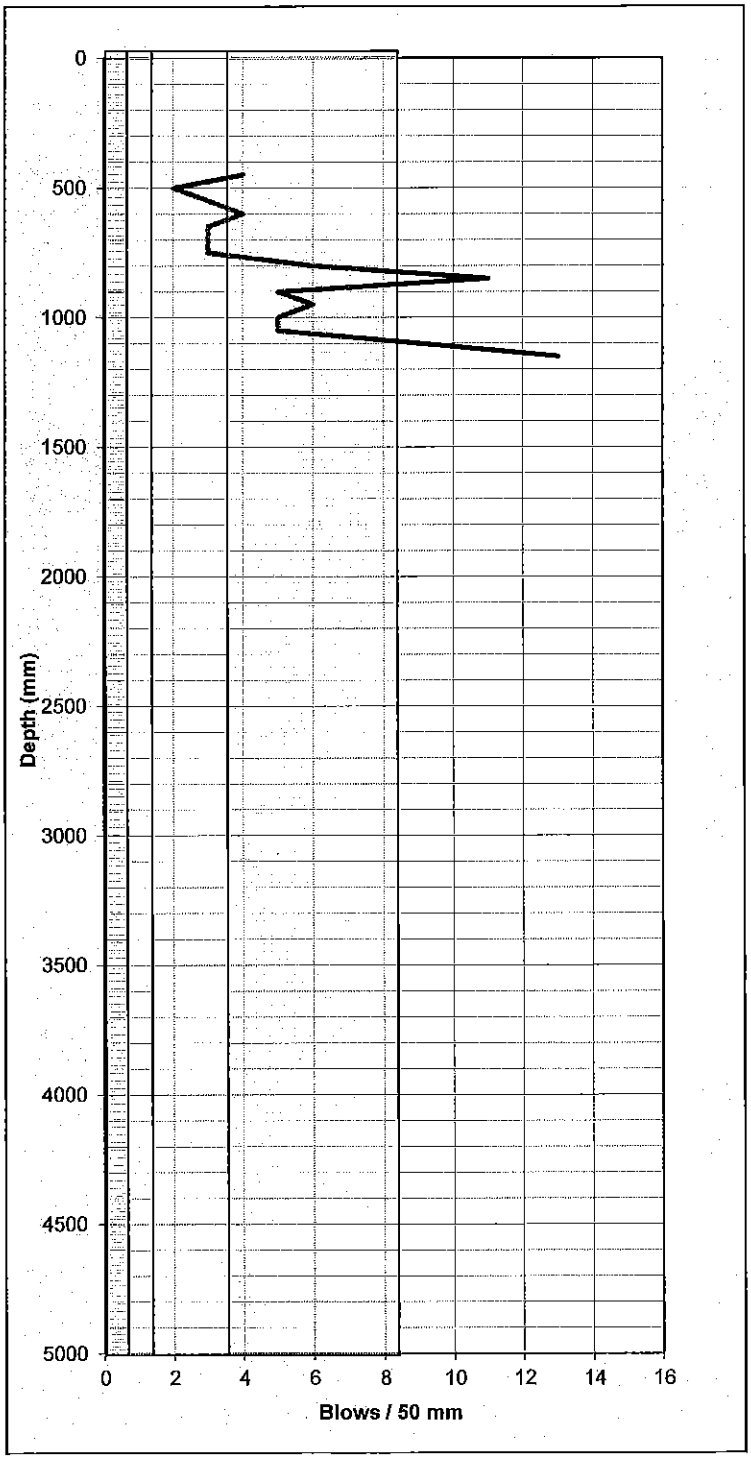
SCALA PENETROMETER LOG

Job No: *871023*
Project: *Tahuna - Liquefaction*
Location:
Position: **See plan** Latitude Longitude

Date: *15/05/2014*
Operated by: *WWD*
Logged by: *WWD*
Checked by: *mjt*

Test No. *SC17*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50		2550	
100		2600	
150		2650	
200		2700	
250		2750	
300		2800	
350		2850	
400		2900	
450	4	2950	
500	2	3000	
550	3	3050	
600	4	3100	
650	3	3150	
700	3	3200	
750	3	3250	
800	6	3300	
850	11	3350	
900	5	3400	
950	6	3450	
1000	5	3500	
1050	5	3550	
1100	9	3600	
1150	13	3650	
1200		3700	
1250		3750	
1300		3800	
1350		3850	
1400		3900	
1450		3950	
1500		4000	
1550		4050	
1600		4100	
1650		4150	
1700		4200	
1750		4250	
1800		4300	
1850		4350	
1900		4400	
1950		4450	
2000		4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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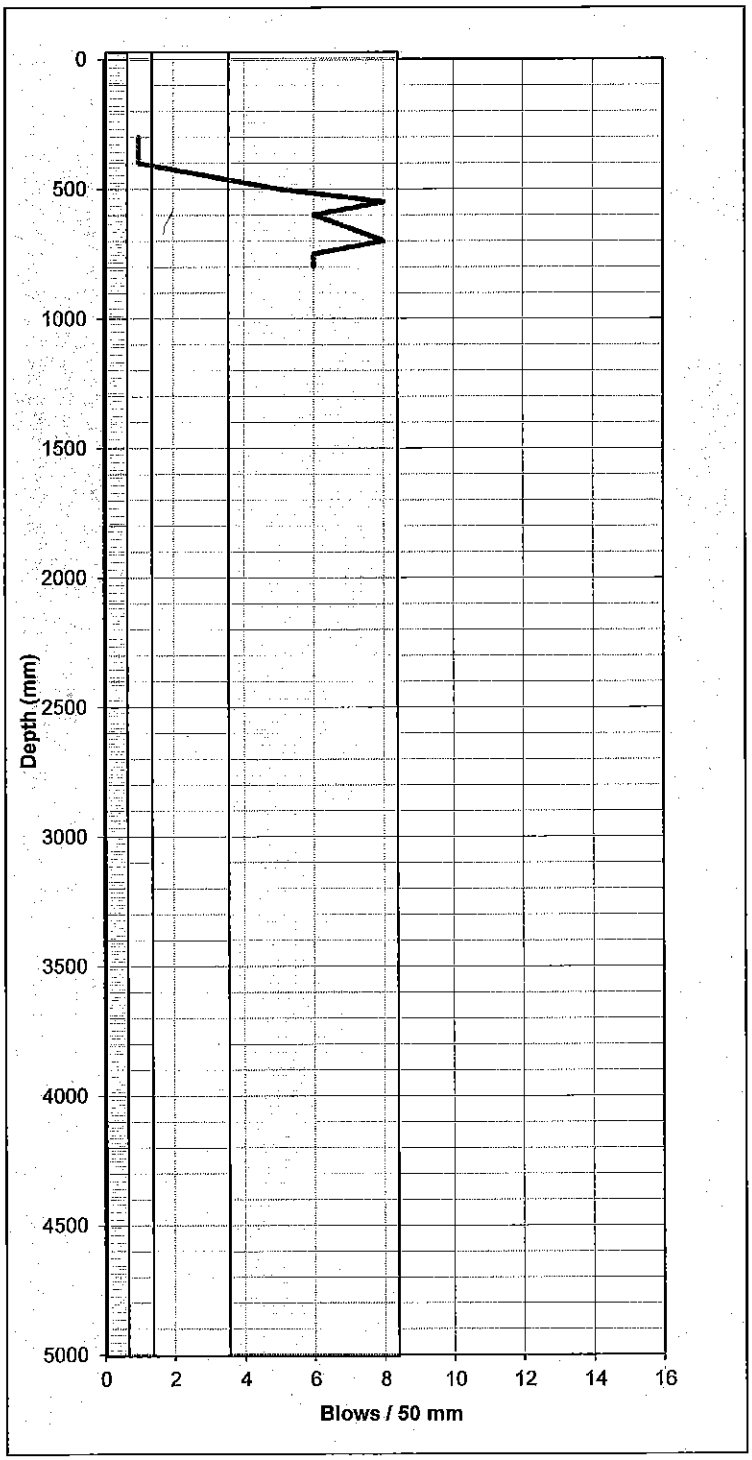
SCALA PENETROMETER LOG

Job No: *871023*
Project: *Tahuna - Liquefaction*
Location:
Position: **See plan** Latitude Longitude

Date: *15/05/2014*
Operated by: *WWD*
Logged by: *WWD*
Checked by: *mp*

Test No. *SC18*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50		2550	
100		2600	
150		2650	
200		2700	
250		2750	
300	1	2800	
350	1	2850	
400	1	2900	
450	3	2950	
500	5	3000	
550	8	3050	
600	6	3100	
650	7	3150	
700	8	3200	
750	6	3250	
800	6	3300	
850		3350	
900		3400	
950		3450	
1000		3500	
1050		3550	
1100		3600	
1150		3650	
1200		3700	
1250		3750	
1300		3800	
1350		3850	
1400		3900	
1450		3950	
1500		4000	
1550		4050	
1600		4100	
1650		4150	
1700		4200	
1750		4250	
1800		4300	
1850		4350	
1900		4400	
1950		4450	
2000		4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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Tel: (03) 546 6339
Fax: (03) 546 7619

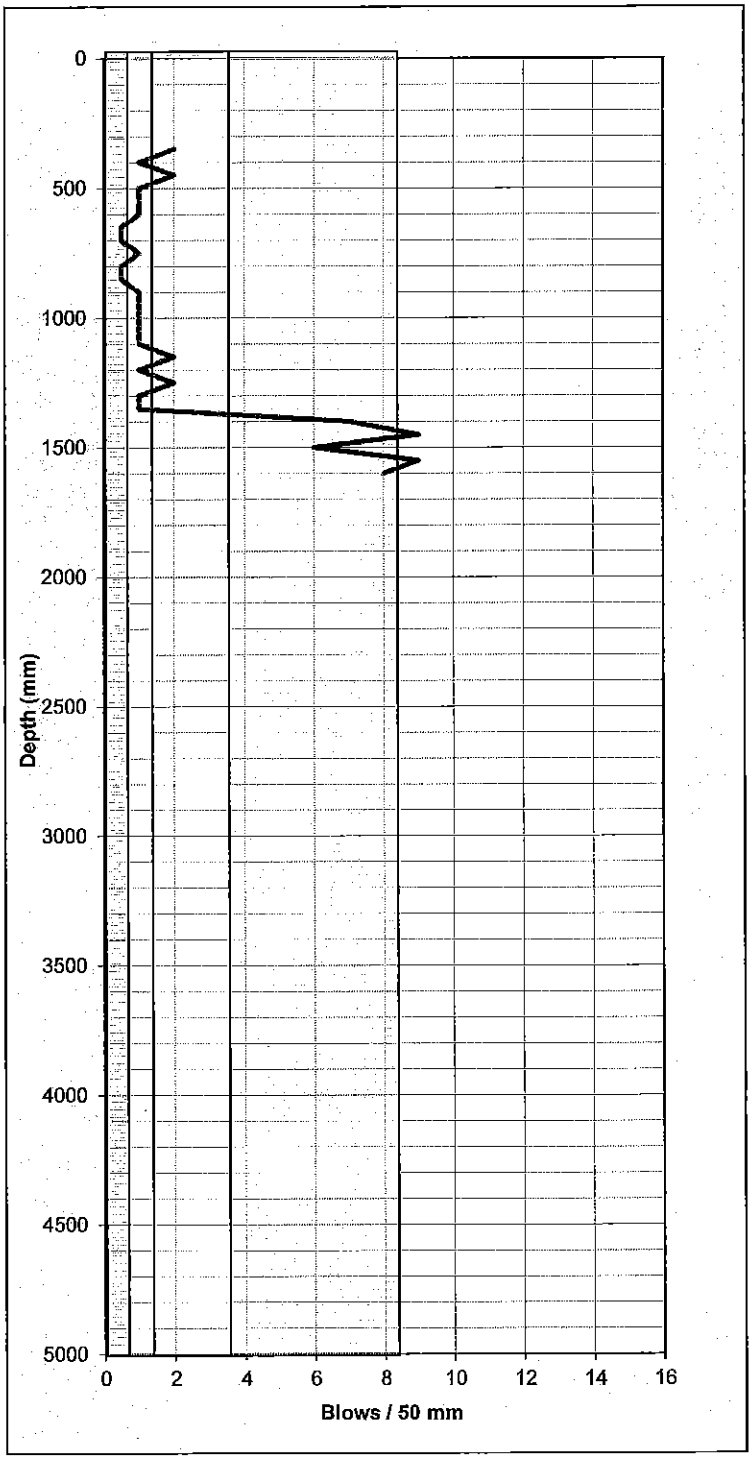
SCALA PENETROMETER LOG

Job No: *871023*
Project: *Tahuna - Liquefaction*
Location:
Position: **See plan** Latitude Longitude

Date: *21/05/2014*
Operated by: *WWD*
Logged by: *WWD*
Checked by: *mp*

Test No. *SC19*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50		2550	
100		2600	
150		2650	
200		2700	
250		2750	
300		2800	
350	2	2850	
400	1	2900	
450	2	2950	
500	1	3000	
550	1	3050	
600	1	3100	
650	0.5	3150	
700	0.5	3200	
750	1	3250	
800	0.5	3300	
850	0.5	3350	
900	1	3400	
950	1	3450	
1000	1	3500	
1050	1	3550	
1100	1	3600	
1150	2	3650	
1200	1	3700	
1250	2	3750	
1300	1	3800	
1350	1	3850	
1400	7	3900	
1450	9	3950	
1500	6	4000	
1550	9	4050	
1600	8	4100	
1650		4150	
1700		4200	
1750		4250	
1800		4300	
1850		4350	
1900		4400	
1950		4450	
2000		4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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Tel: (03) 546 6339
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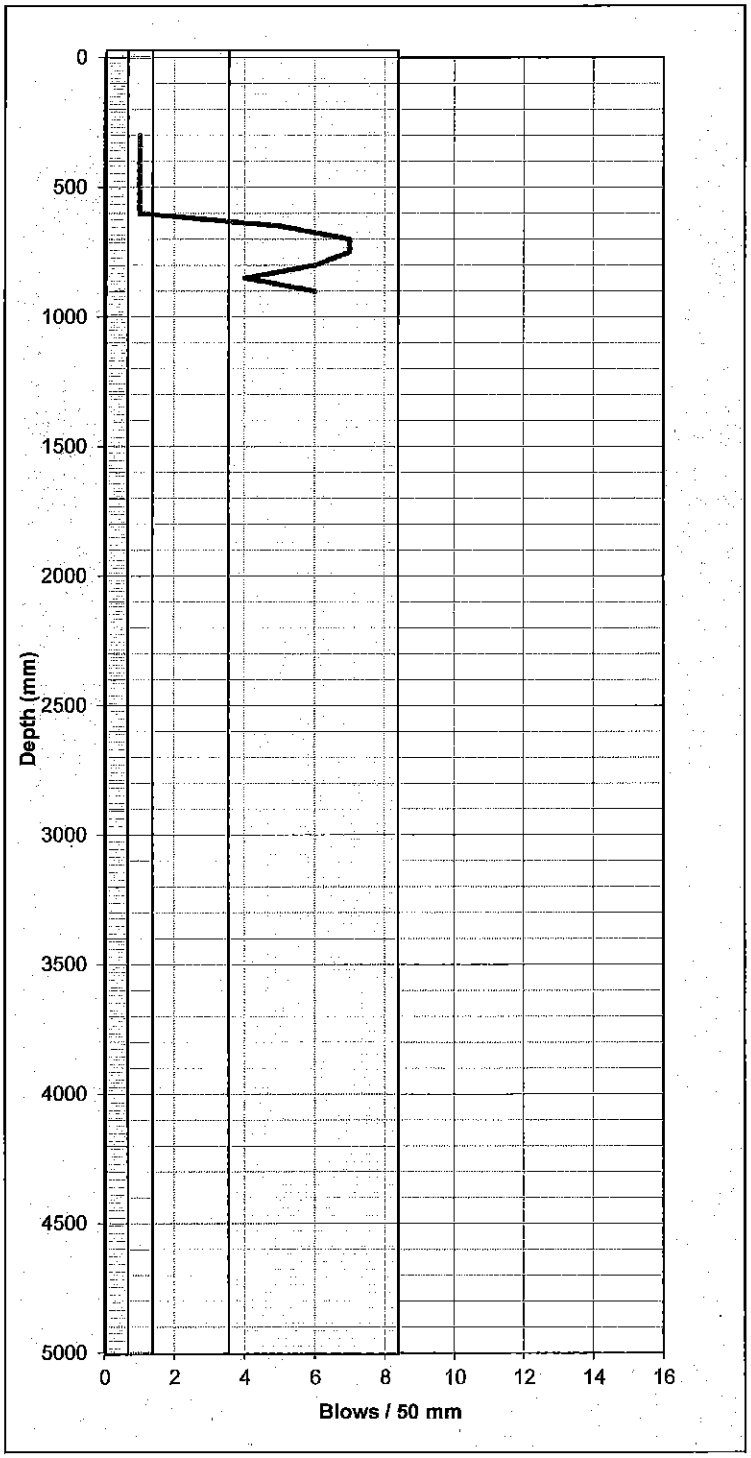
SCALA PENETROMETER LOG

Job No: *871023*
Project: *Tahuna - Liquefaction*
Location:
Position: **See plan** Latitude Longitude

Date: *21/05/2014*
Operated by: *WWD*
Logged by: *WWD*
Checked by: *mp*

Test No. *SC20*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50		2550	
100		2600	
150		2650	
200		2700	
250		2750	
300	1	2800	
350	1	2850	
400	1	2900	
450	1	2950	
500	1	3000	
550	1	3050	
600	1	3100	
650	5	3150	
700	7	3200	
750	7	3250	
800	6	3300	
850	4	3350	
900	6	3400	
950		3450	
1000		3500	
1050		3550	
1100		3600	
1150		3650	
1200		3700	
1250		3750	
1300		3800	
1350		3850	
1400		3900	
1450		3950	
1500		4000	
1550		4050	
1600		4100	
1650		4150	
1700		4200	
1750		4250	
1800		4300	
1850		4350	
1900		4400	
1950		4450	
2000		4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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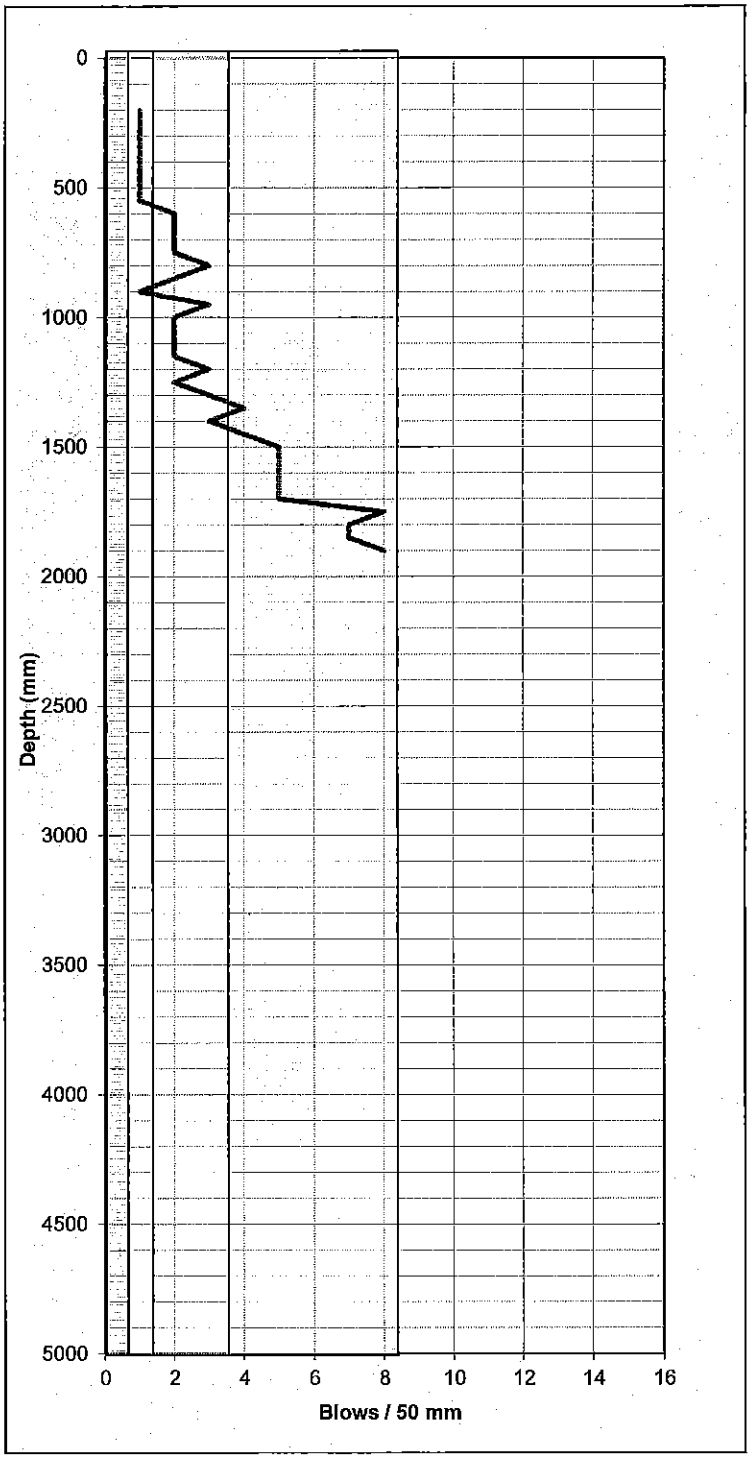
SCALA PENETROMETER LOG

Job No:	*871023*	Date:	*21/05/2014*
Project:	*Tahuna - Liquefaction*	Operated by:	*WWD*
Location:		Logged by:	*WWD*
Position:	**See plan** Latitude Longitude	Checked by:	*mjl*

Test No.	*SC21*
Sheet	*1*
of	*1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50		2550	
100		2600	
150		2650	
200	*1*	2700	
250	*1*	2750	
300	*1*	2800	
350	*1*	2850	
400	*1*	2900	
450	*1*	2950	
500	*1*	3000	
550	*1*	3050	
600	*2*	3100	
650	*2*	3150	
700	*2*	3200	
750	*2*	3250	
800	*3*	3300	
850	*2*	3350	
900	*1*	3400	
950	*3*	3450	
1000	*2*	3500	
1050	*2*	3550	
1100	*2*	3600	
1150	*2*	3650	
1200	*3*	3700	
1250	*2*	3750	
1300	*3*	3800	
1350	*4*	3850	
1400	*3*	3900	
1450	*4*	3950	
1500	*5*	4000	
1550	*5*	4050	
1600	*5*	4100	
1650	*5*	4150	
1700	*5*	4200	
1750	*8*	4250	
1800	*7*	4300	
1850	*7*	4350	
1900	*8*	4400	
1950		4450	
2000		4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

TONKIN & TAYLOR
43 Halifax Street
P O Box 1009
NELSON
Tel: (03) 546 6339
Fax: (03) 546 7619

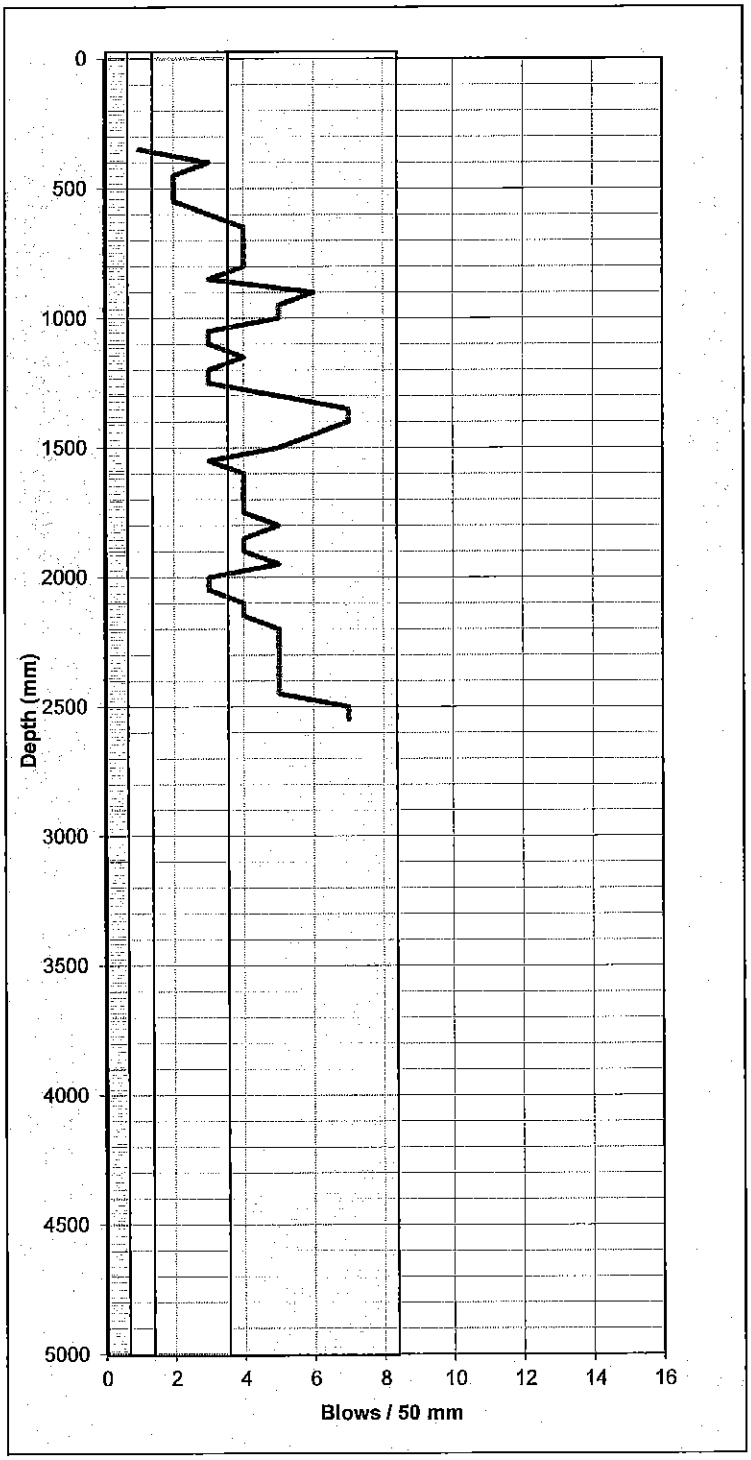
SCALA PENETROMETER LOG

Job No: *871023*
Project: *Tahuna - Liquefaction*
Location:
Position: **See plan** Latitude Longitude

Date: *21/05/2014*
Operated by: *WWD*
Logged by: *WWD*
Checked by: *mjl*

Test No. *SC22*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50		2550	7
100		2600	
150		2650	
200		2700	
250		2750	
300		2800	
350	1	2850	
400	3	2900	
450	2	2950	
500	2	3000	
550	2	3050	
600	3	3100	
650	4	3150	
700	4	3200	
750	4	3250	
800	4	3300	
850	3	3350	
900	6	3400	
950	5	3450	
1000	5	3500	
1050	3	3550	
1100	3	3600	
1150	4	3650	
1200	3	3700	
1250	3	3750	
1300	5	3800	
1350	7	3850	
1400	7	3900	
1450	6	3950	
1500	5	4000	
1550	3	4050	
1600	4	4100	
1650	4	4150	
1700	4	4200	
1750	4	4250	
1800	5	4300	
1850	4	4350	
1900	4	4400	
1950	5	4450	
2000	3	4500	
2050	3	4550	
2100	4	4600	
2150	4	4650	
2200	5	4700	
2250	5	4750	
2300	5	4800	
2350	5	4850	
2400	5	4900	
2450	5	4950	
2500	7	5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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Tel: (03) 546 6339
Fax: (03) 546 7619

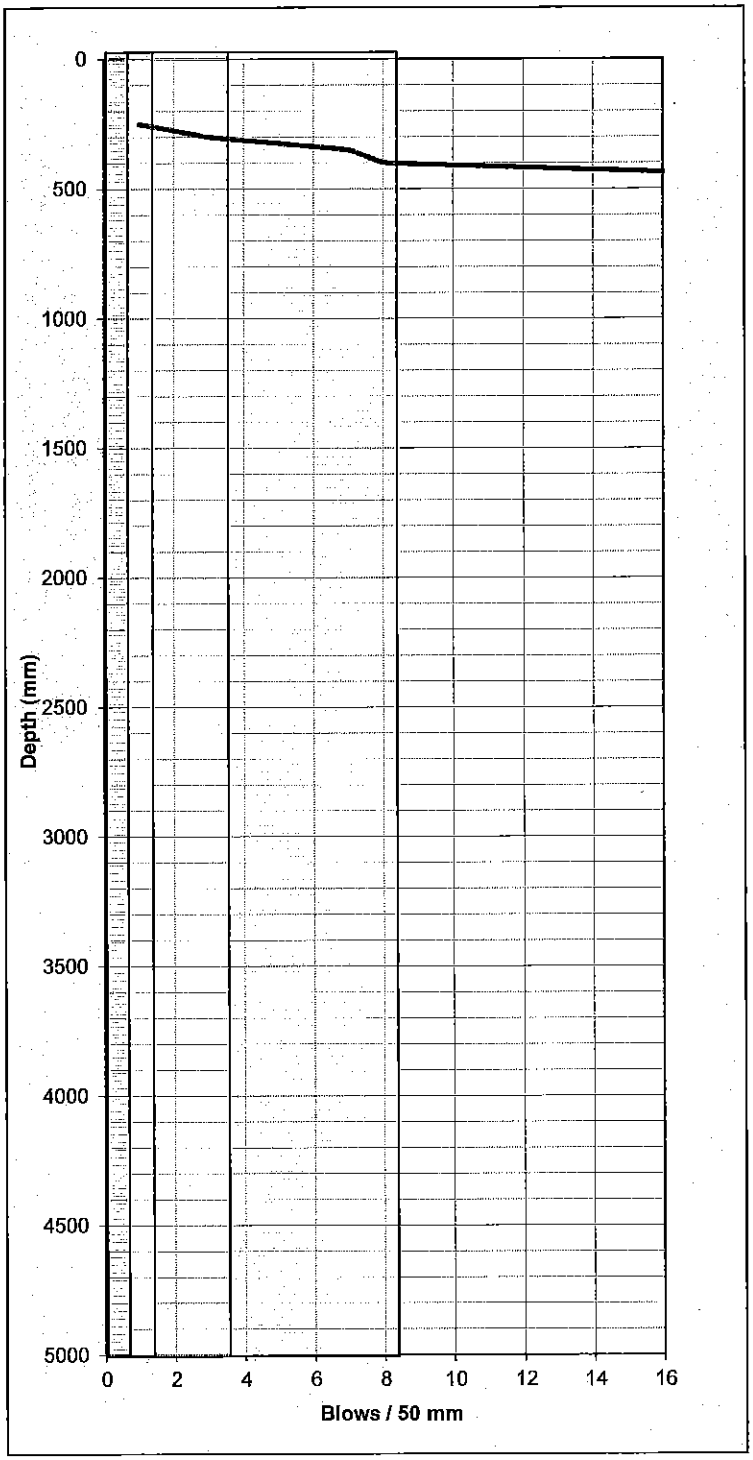
SCALA PENETROMETER LOG

Job No: *871023*
Project: *Tahuna - Liquefaction*
Location:
Position: **See plan** Latitude Longitude

Date: *21/05/2014*
Operated by: *WWD*
Logged by: *WWD*
Checked by: *mp*

Test No. *SC23*
Sheet *1*
of *1*

mm Driven	No. of Blows		mm Driven	No. of Blows
50			2550	
100			2600	
150			2650	
200			2700	
250	*1*		2750	
300	*3*		2800	
350	*7*		2850	
400	*8*		2900	
450	*19*		2950	
500		R	3000	
550			3050	
600			3100	
650			3150	
700			3200	
750			3250	
800			3300	
850			3350	
900			3400	
950			3450	
1000			3500	
1050			3550	
1100			3600	
1150			3650	
1200			3700	
1250			3750	
1300			3800	
1350			3850	
1400			3900	
1450			3950	
1500			4000	
1550			4050	
1600			4100	
1650			4150	
1700			4200	
1750			4250	
1800			4300	
1850			4350	
1900			4400	
1950			4450	
2000			4500	
2050			4550	
2100			4600	
2150			4650	
2200			4700	
2250			4750	
2300			4800	
2350			4850	
2400			4900	
2450			4950	
2500			5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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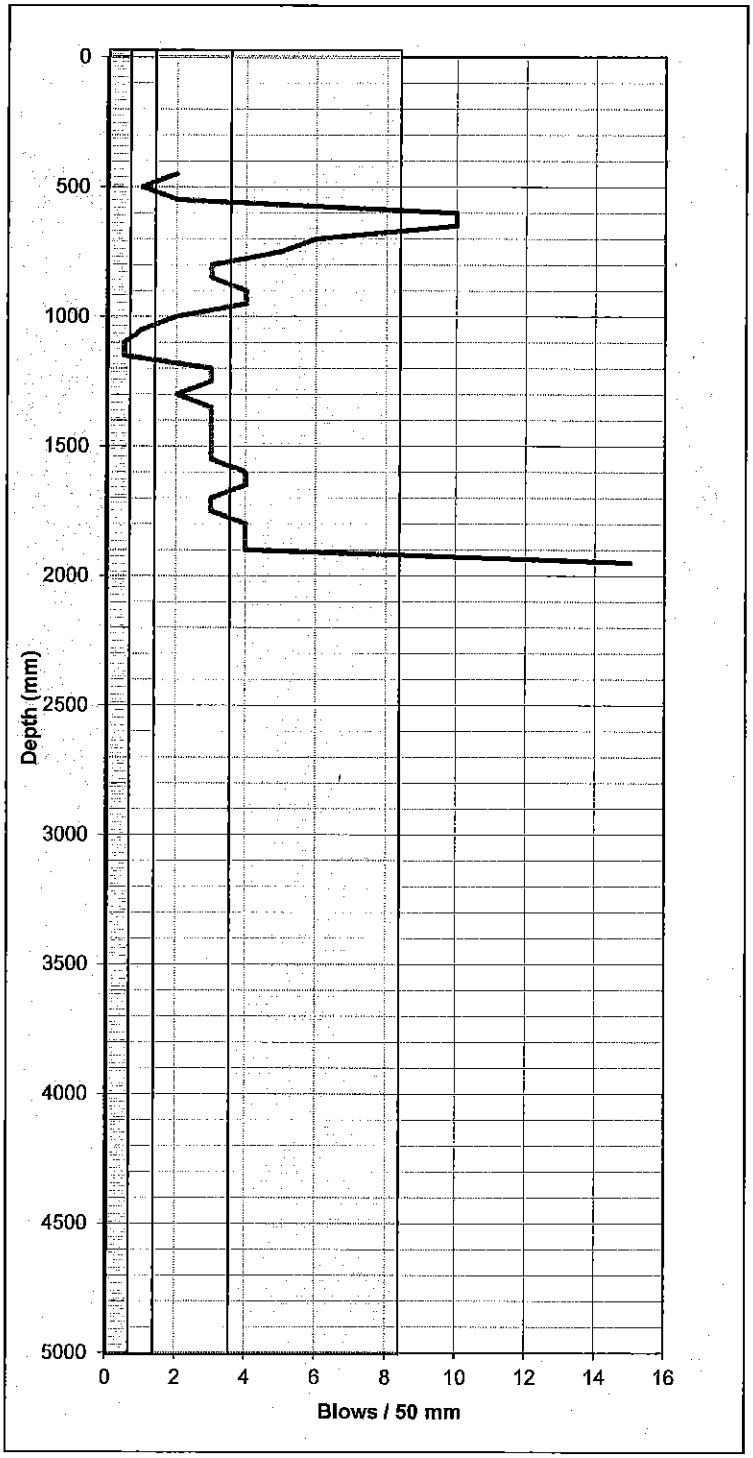
SCALA PENETROMETER LOG

Job No: *871023*
Project: *Tahuna - Liquefaction*
Location:
Position: **See plan** Latitude Longitude

Date: *21/05/2014*
Operated by: *WWD*
Logged by: *WWD*
Checked by: *mjl*

Test No. *SC24*
Sheet *1*
of *1*

mm Driven	No. of Blows		mm Driven	No. of Blows
50			2550	
100			2600	
150			2650	
200			2700	
250			2750	
300			2800	
350			2850	
400			2900	
450	2		2950	
500	1		3000	
550	2		3050	
600	10		3100	
650	10		3150	
700	6		3200	
750	5		3250	
800	3		3300	
850	3		3350	
900	4		3400	
950	4		3450	
1000	2		3500	
1050	1		3550	
1100	0.5		3600	
1150	0.5		3650	
1200	3		3700	
1250	3		3750	
1300	2		3800	
1350	3		3850	
1400	3		3900	
1450	3		3950	
1500	3		4000	
1550	3		4050	
1600	4		4100	
1650	4		4150	
1700	3		4200	
1750	3		4250	
1800	4		4300	
1850	4		4350	
1900	4		4400	
1950	15		4450	
2000		R	4500	
2050			4550	
2100			4600	
2150			4650	
2200			4700	
2250			4750	
2300			4800	
2350			4850	
2400			4900	
2450			4950	
2500			5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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43 Halifax Street
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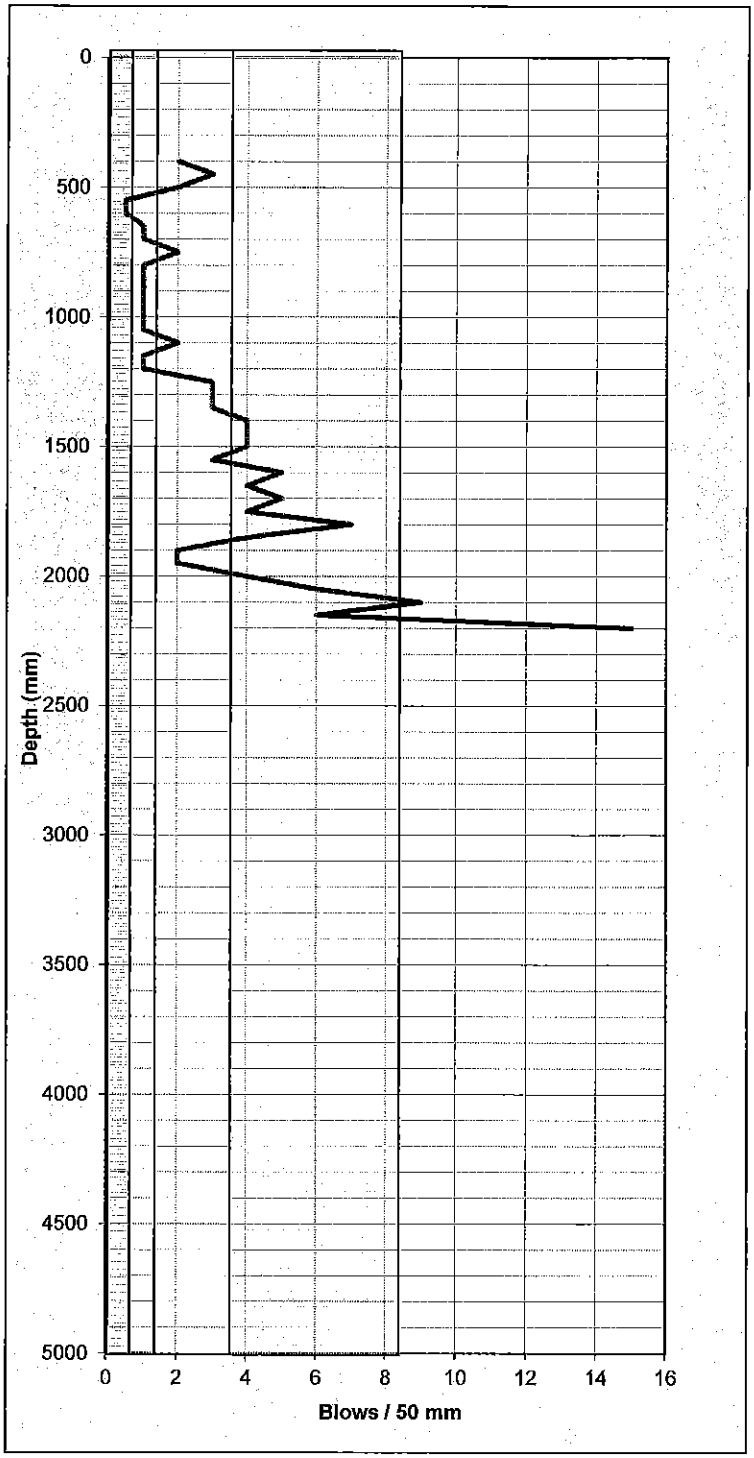
SCALA PENETROMETER LOG

Job No:	*871023*	Date:	*21/05/2014*
Project:	*Tahuna - Liquefaction*	Operated by:	*WWD*
Location:		Logged by:	*WWD*
Position:	**See plan** Latitude Longitude	Checked by:	*mjp*

Test No.	*SC25*
Sheet	*1*
of	*1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50		2550	
100		2600	
150		2650	
200		2700	
250		2750	
300		2800	
350		2850	
400	2	2900	
450	3	2950	
500	2	3000	
550	0.5	3050	
600	0.5	3100	
650	1	3150	
700	1	3200	
750	2	3250	
800	1	3300	
850	1	3350	
900	1	3400	
950	1	3450	
1000	1	3500	
1050	1	3550	
1100	2	3600	
1150	1	3650	
1200	1	3700	
1250	3	3750	
1300	3	3800	
1350	3	3850	
1400	4	3900	
1450	4	3950	
1500	4	4000	
1550	3	4050	
1600	5	4100	
1650	4	4150	
1700	5	4200	
1750	4	4250	
1800	7	4300	
1850	4	4350	
1900	2	4400	
1950	2	4450	
2000	4	4500	
2050	6	4550	
2100	9	4600	
2150	6	4650	
2200	15 +	4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

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43 Halifax Street
P O Box 1009
NELSON
Tel: (03) 546 6339
Fax: (03) 546 7619

SCALA PENETROMETER LOG

Job No: *871023*
Project: *Tahuna - Liquefaction*
Location:
Position: **See plan** Latitude Longitude

Date: *21/05/2014*
Operated by: *WWD*
Logged by: *WWD*
Checked by: *mjl*

Test No. *SC26*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50		2550	
100		2600	
150		2650	
200		2700	
250		2750	
300		2800	
350		2850	
400		2900	
450		2950	
500	3	3000	
550	4	3050	
600	2	3100	
650	3	3150	
700	3	3200	
750	2	3250	
800	5	3300	
850	3	3350	
900	5	3400	
950	6	3450	
1000	9	3500	
1050	10	3550	
1100	7	3600	
1150	4	3650	
1200	4	3700	
1250	3	3750	
1300	3	3800	
1350	3	3850	
1400	3	3900	
1450	7	3950	
1500	10	4000	
1550	9	4050	
1600	14	4100	
1650		4150	
1700		4200	
1750		4250	
1800		4300	
1850		4350	
1900		4400	
1950		4450	
2000		4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
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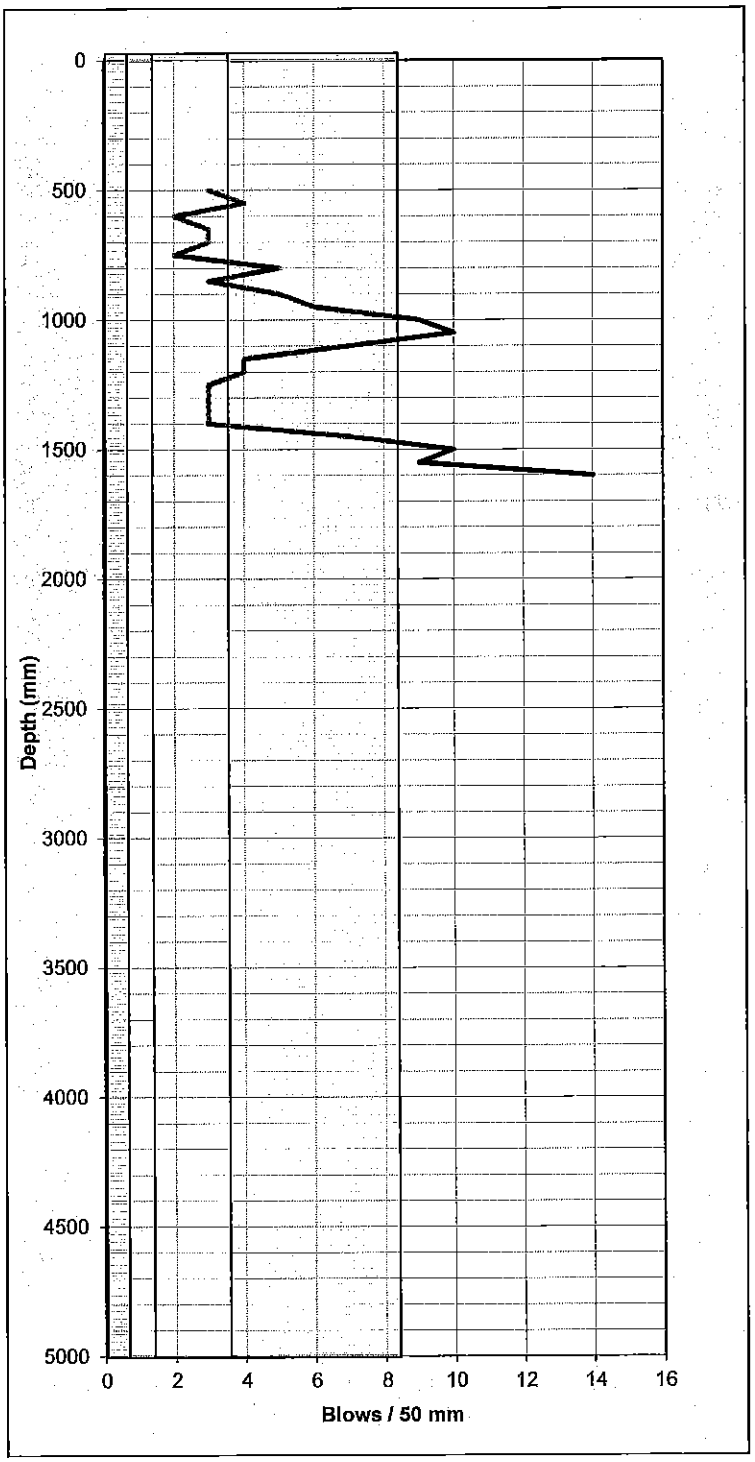
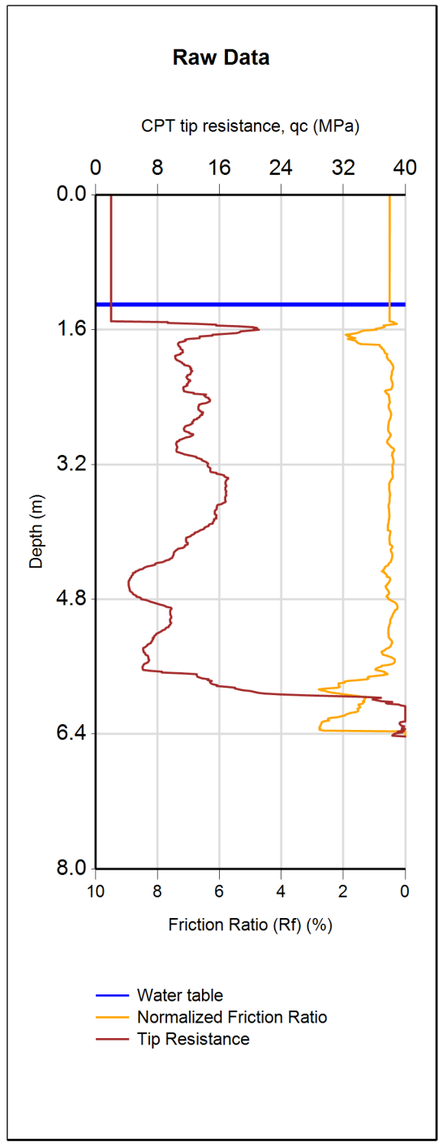
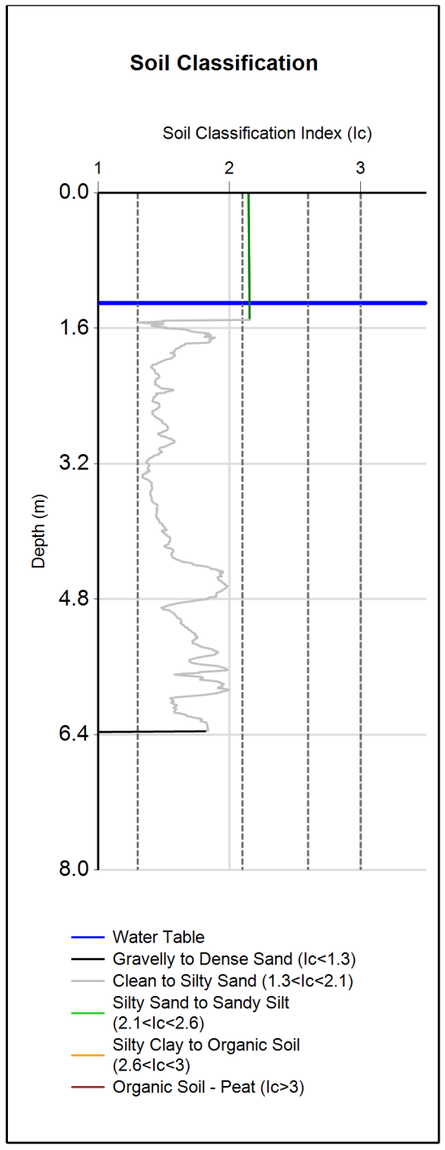
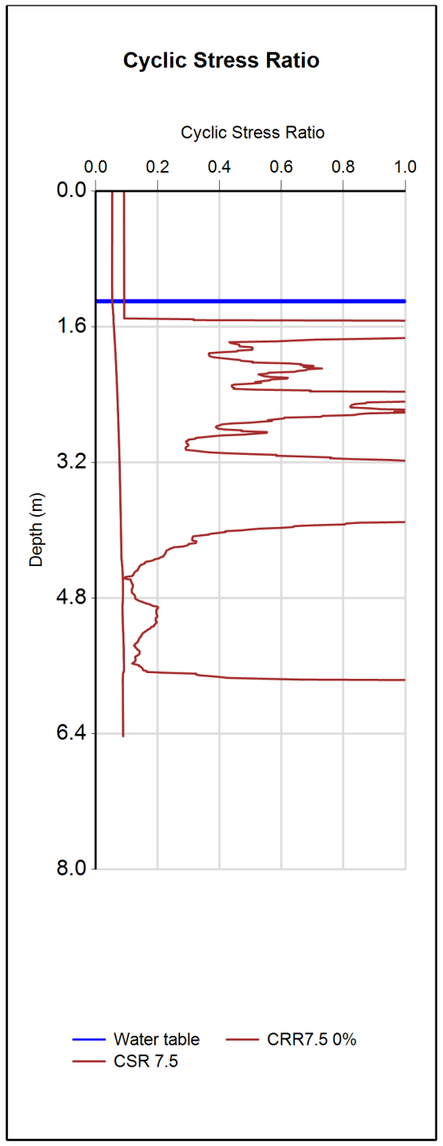
2400		4900	
2450		4950	
2500		5000	

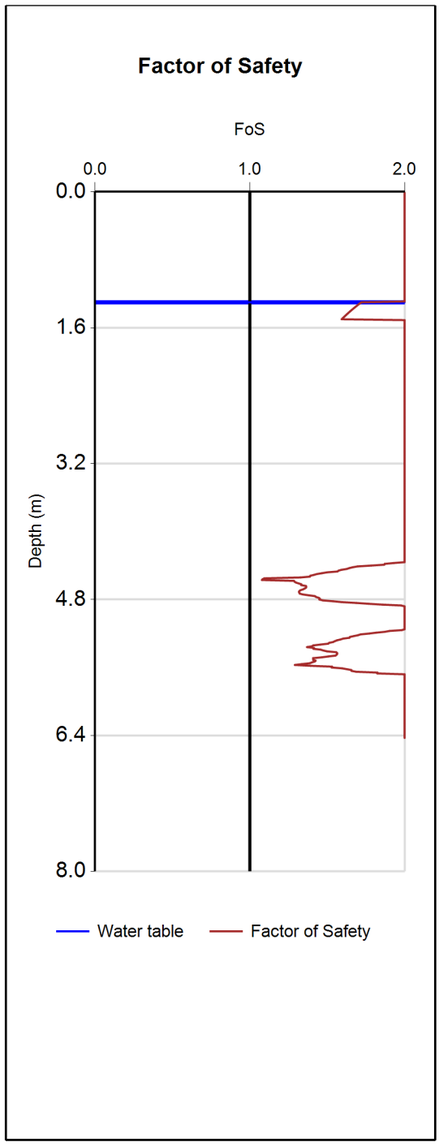


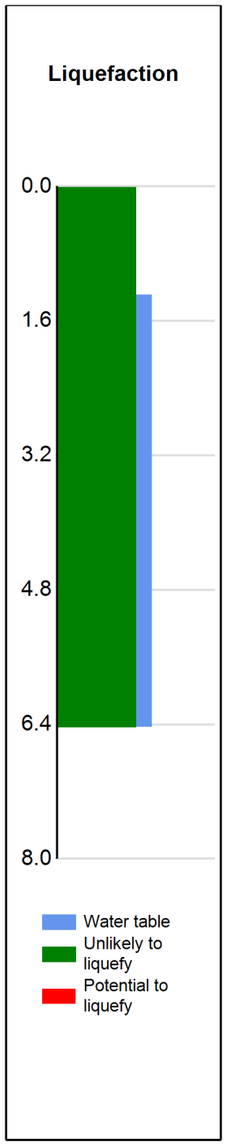
Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer









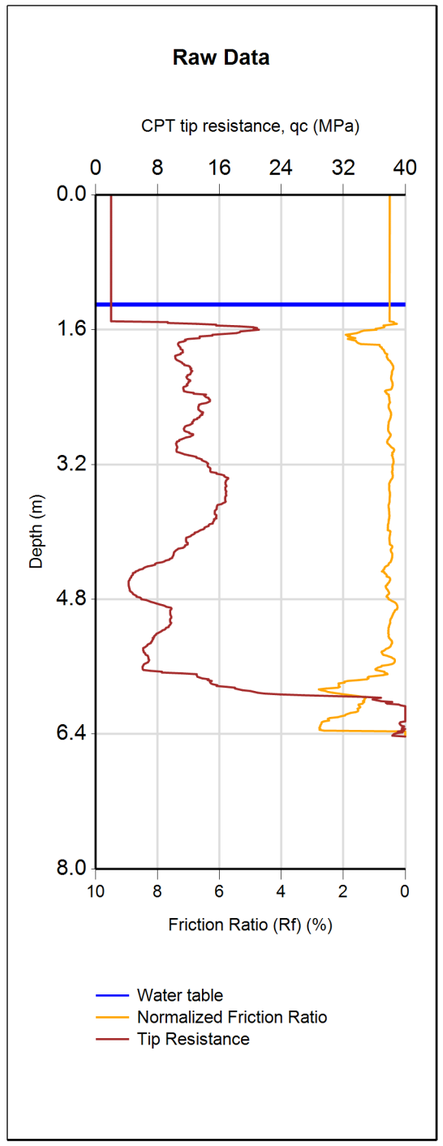


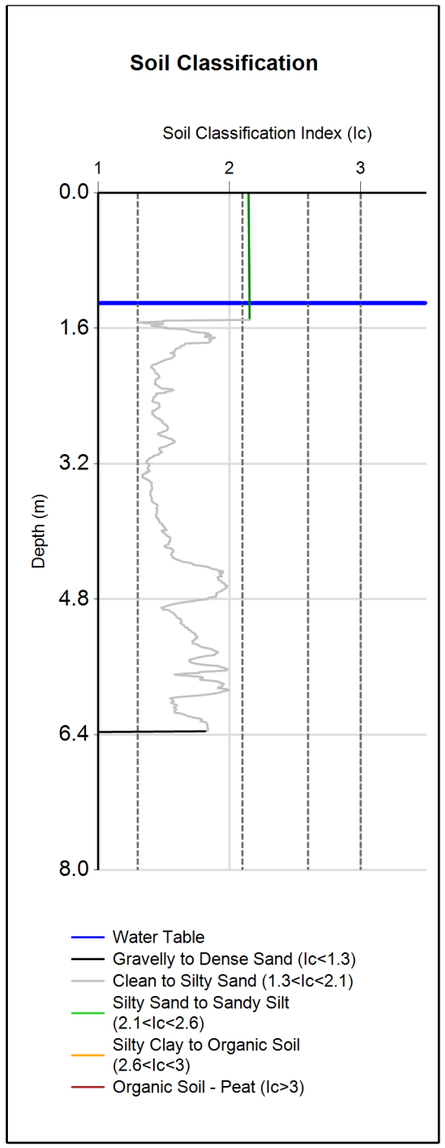
Surcharge used.

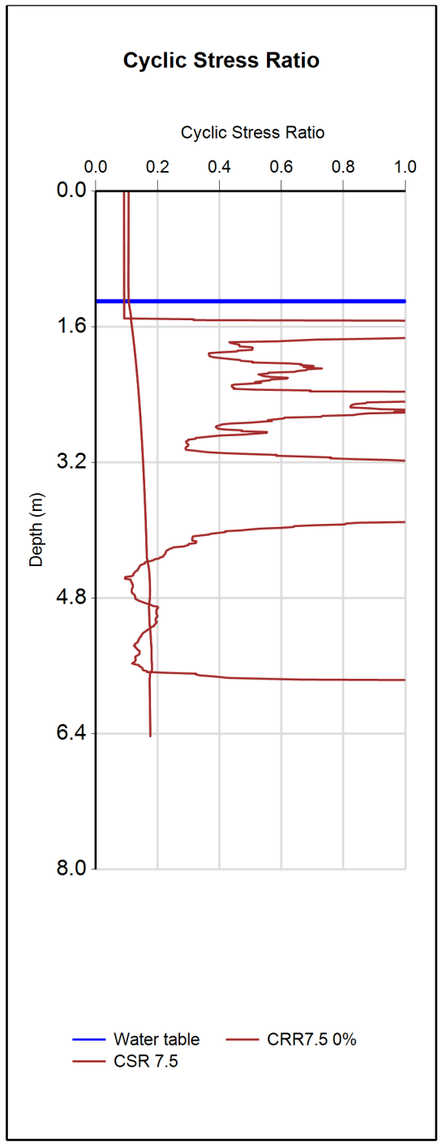
(Assumed pre-drill values)

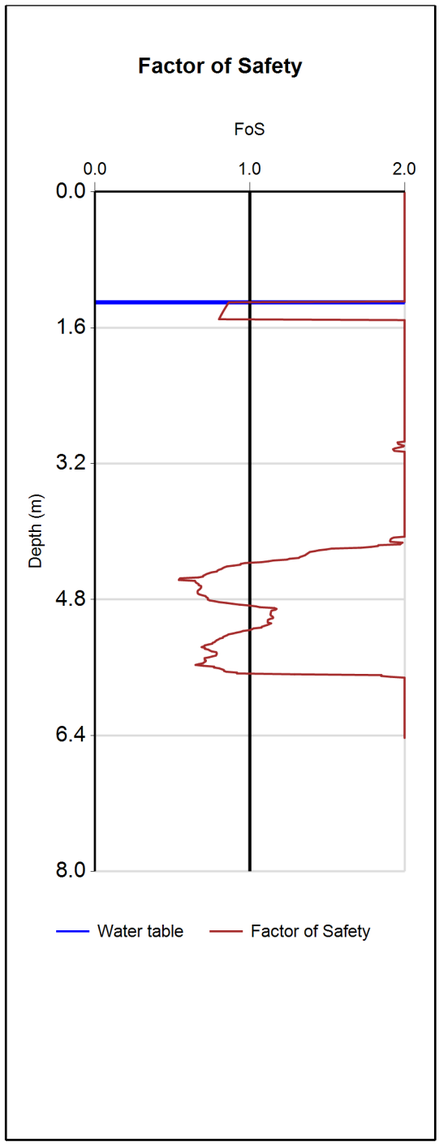
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 13	42398	20/06/2014	User Specified	7.5	0.09	1.3	IB	ZRB	1.5	2	0.01	18

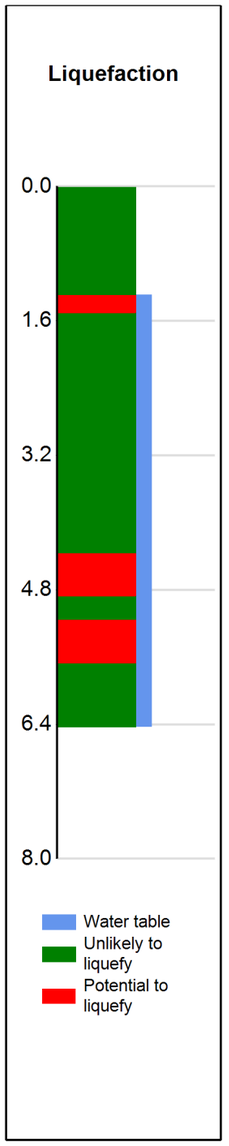
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	3	0	0	1	6.4











(Assumed pre-drill values)

	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 13	42398	20/06/2014	User Specified	7.5	0.179	1.3	IB	ZRB	1.5	2	0.01	18

	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	32	1.2	2	10	4.5

Tonkin & Taylor	Tonkin & Taylor Environmental and Engineering consultants V1.2	CLIENT, PROJECT **Nelson City Council** **Tahunanui Liquefaction**	LOCATION Nelson	DATE	10/07/2014
				ANALYSED	mjl
		TITLE **Stage 2**	JOB NUMBER **871023**	CHECKED	
				PAGE	1 of 7 pages

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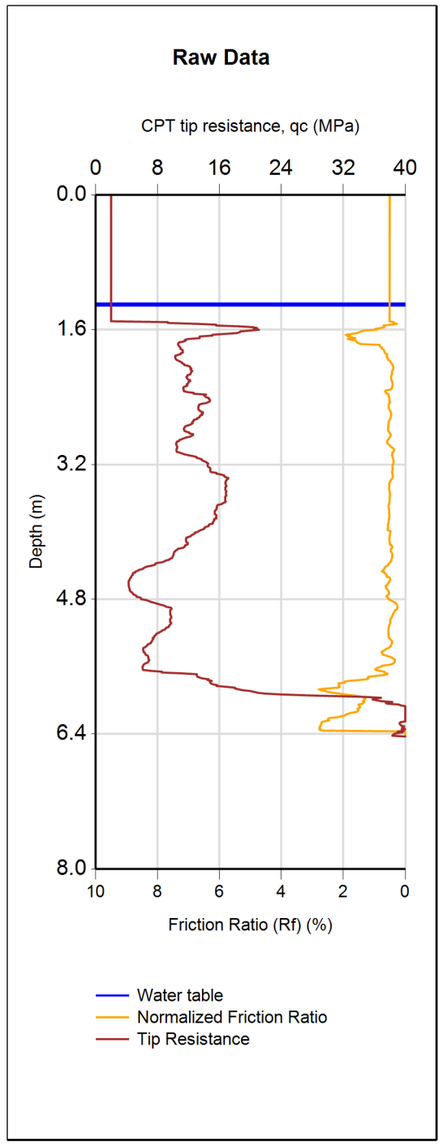
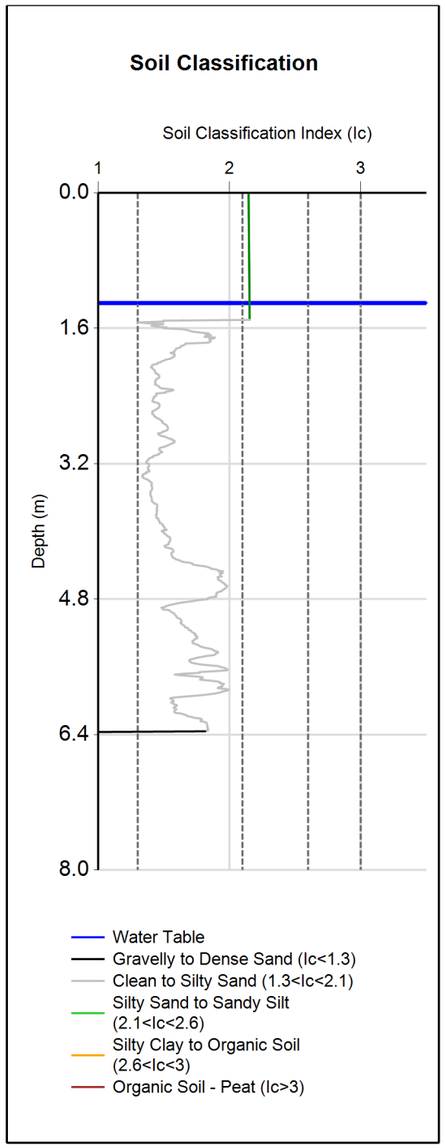
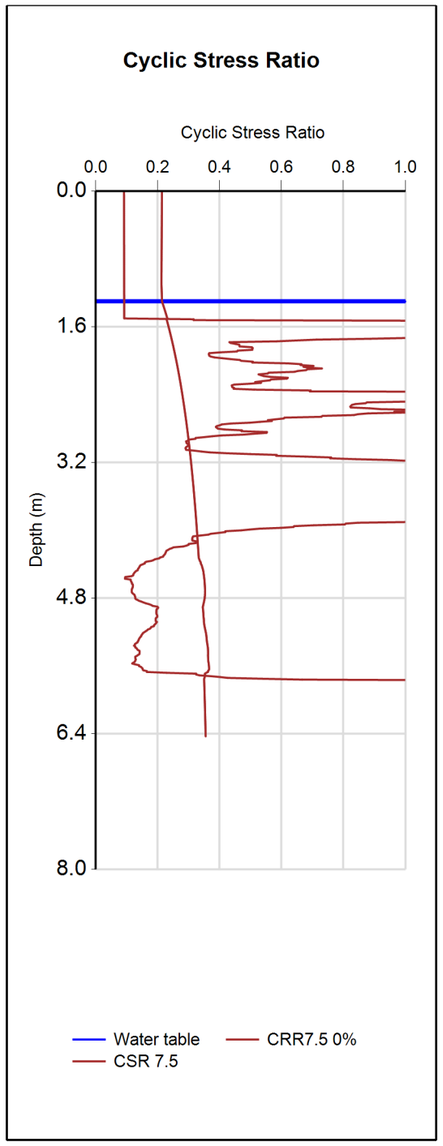
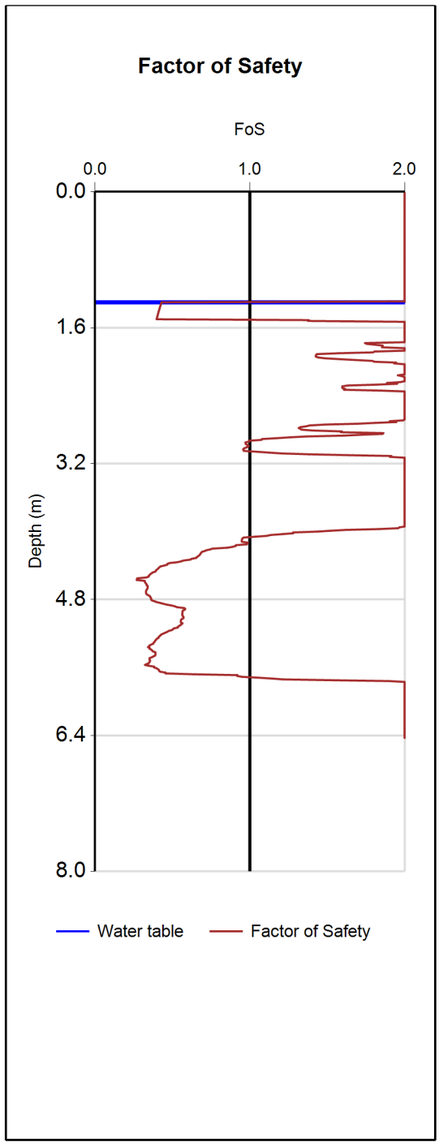
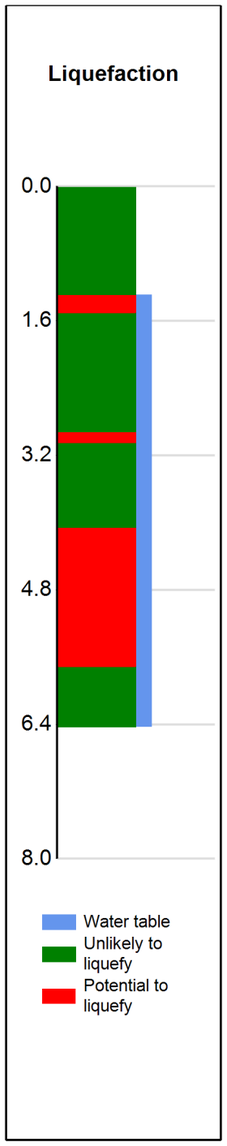








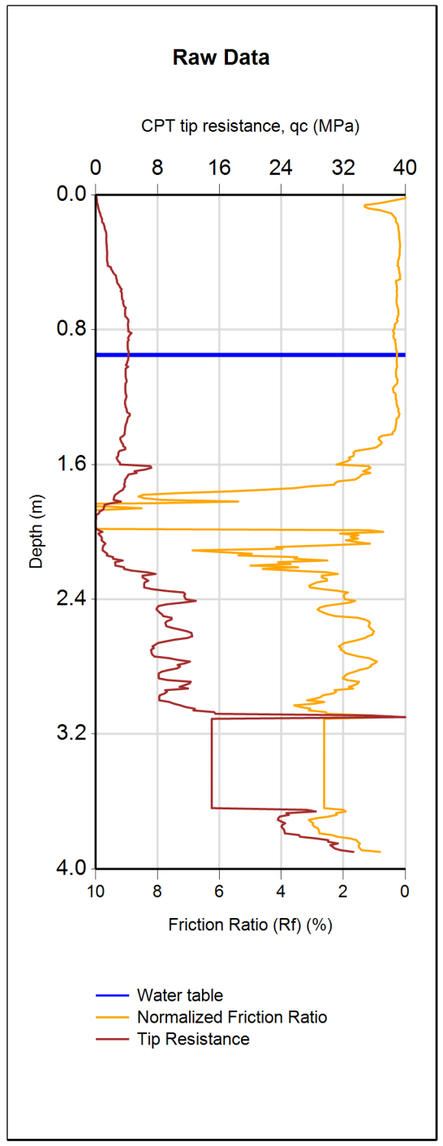


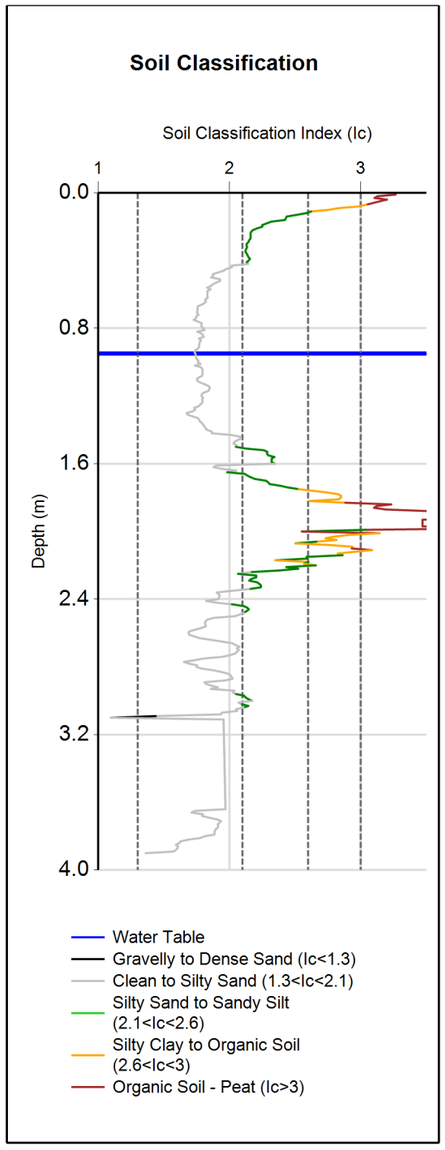
Surcharge used.

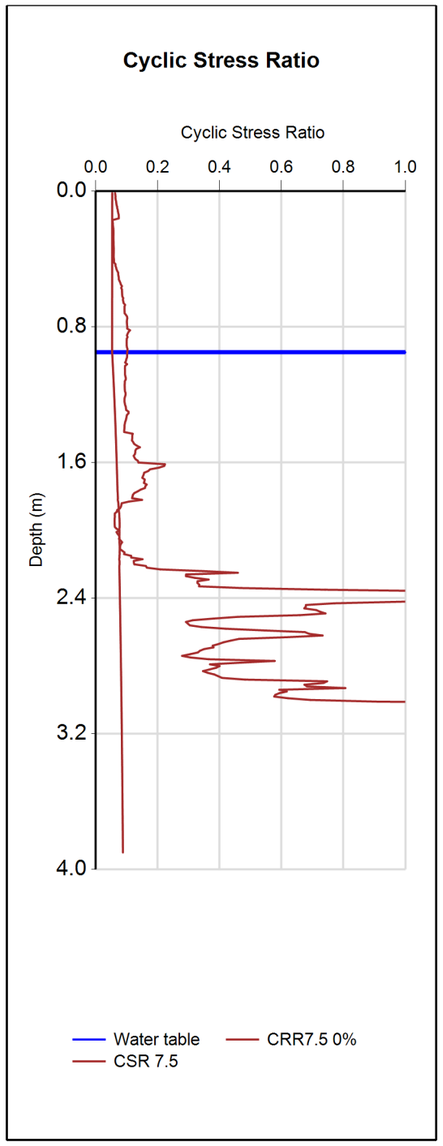
(Assumed pre-drill values)

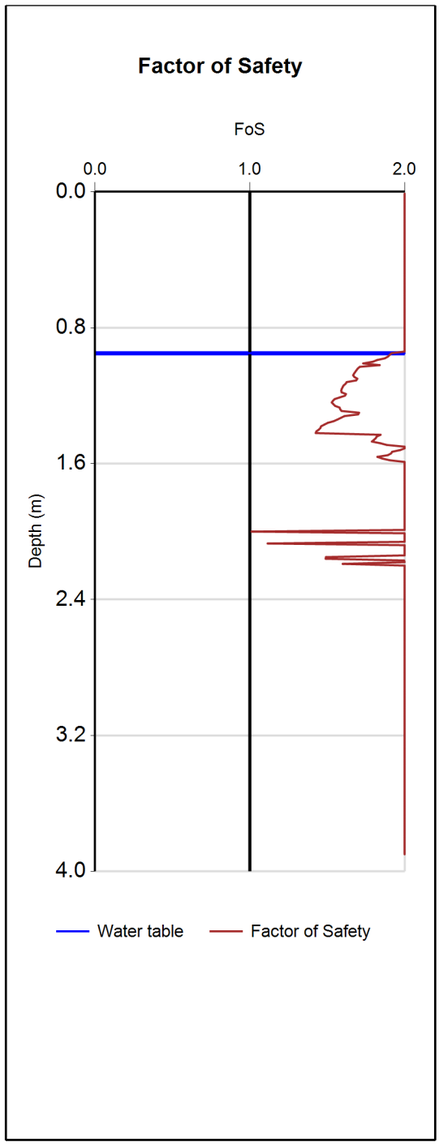
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 13	42398	20/06/2014	User Specified	7.5	0.36	1.3	IB	ZRB	1.5	2	0.01	18

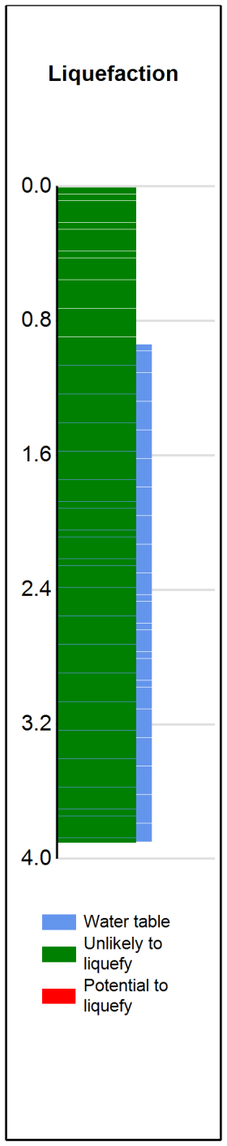
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	44	2	7	13	3











Surcharge used.

(Assumed pre-drill values)

	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 14 - Spliced	42591	19/06/2014	User Specified	7.5	0.09	1.0	IB	ZRB	0	2	0.01	18

	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	1	0	0	1	3.9

Tonkin & Taylor	Tonkin & Taylor Environmental and Engineering consultants V1.2	CLIENT, PROJECT **Nelson City Council** **Tahunanui Liquefaction** TITLE **Stage 2**	LOCATION Nelson JOB NUMBER **871023**	DATE ANALYSED CHECKED PAGE	10/07/2014 mjl 1 of 7 pages

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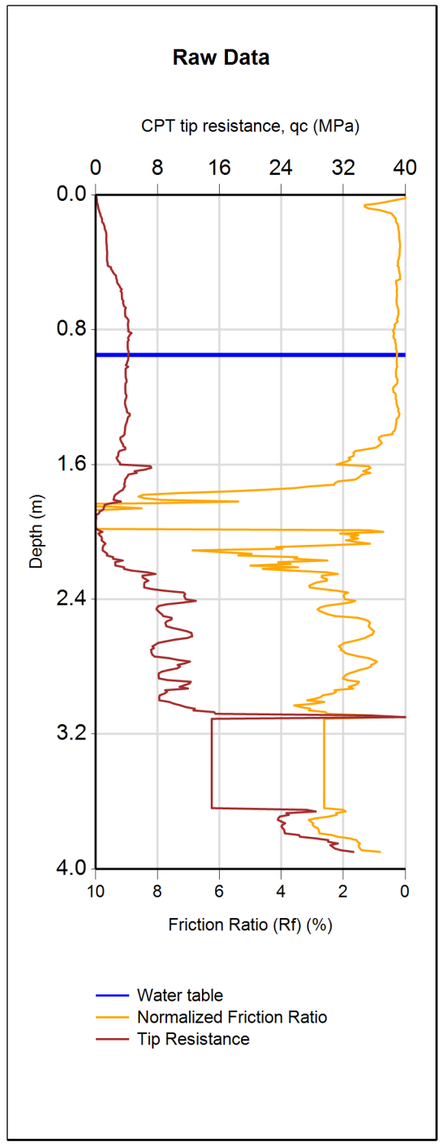
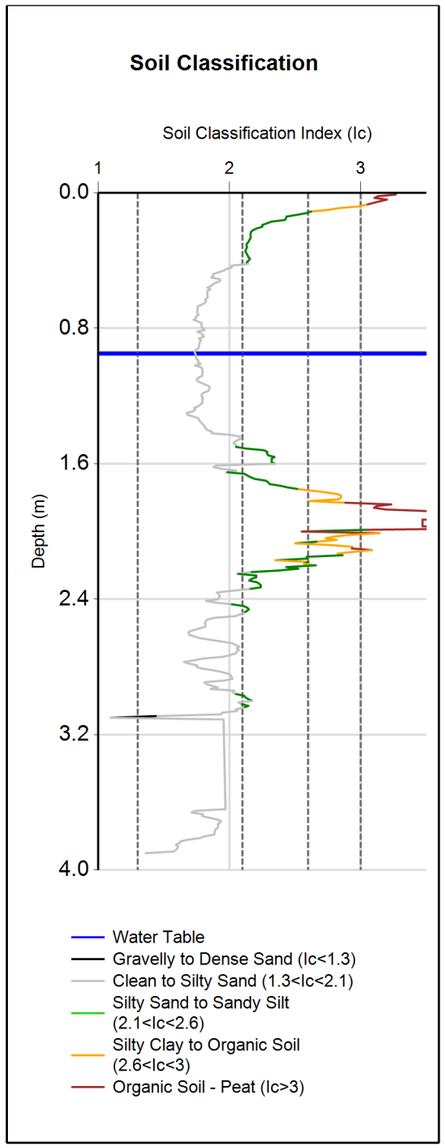
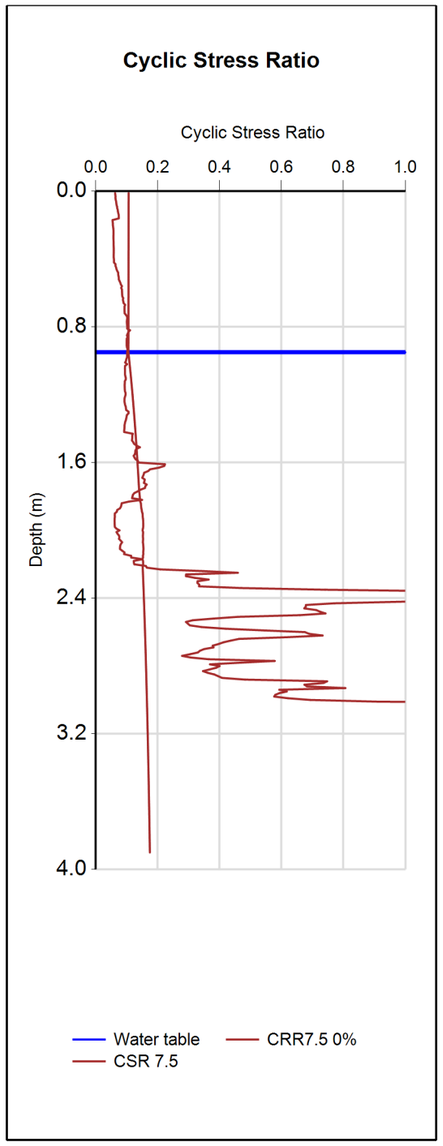
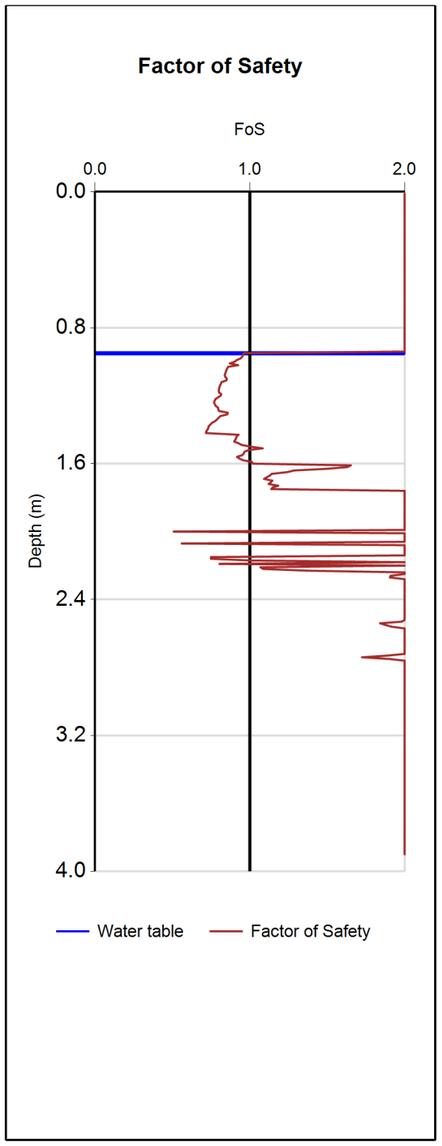
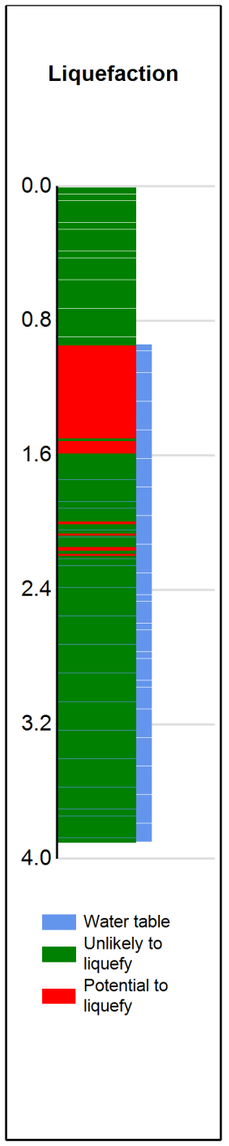










Surcharge used.

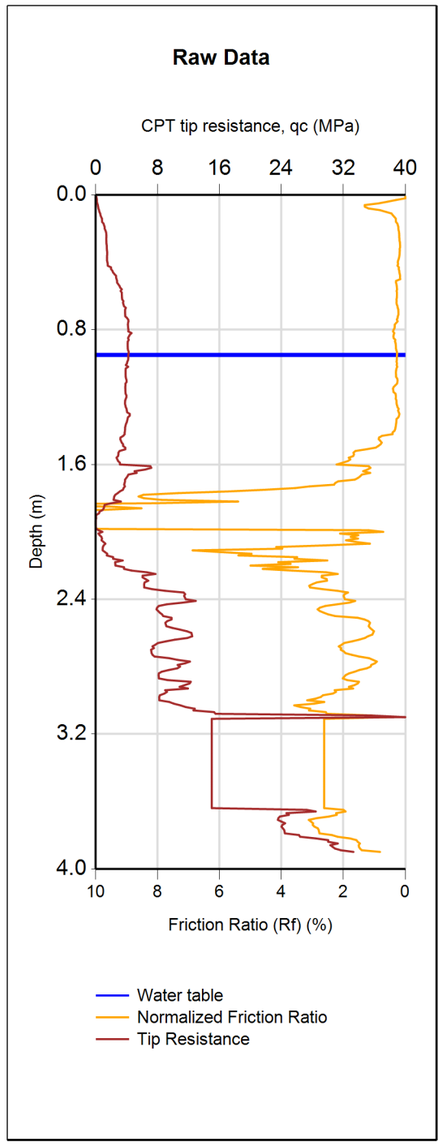
(Assumed pre-drill values)

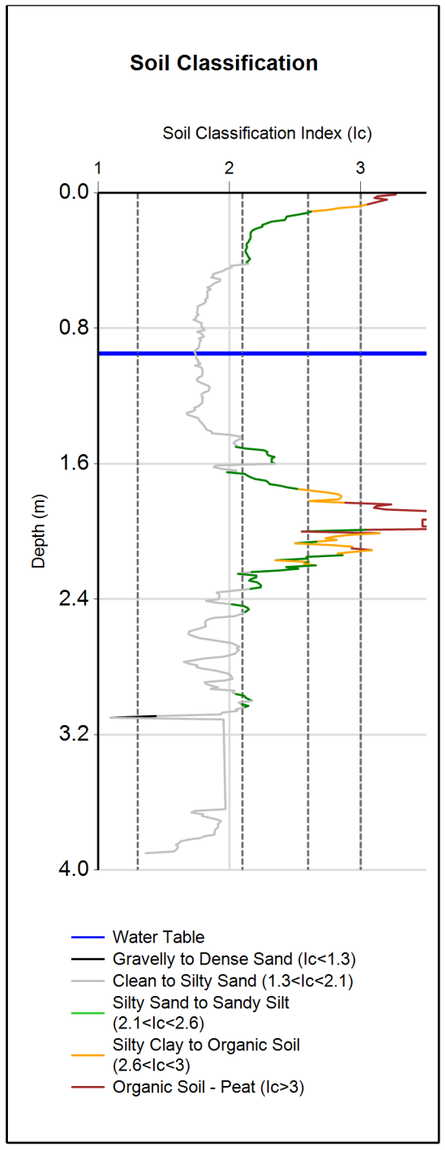
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 14 - Spliced	42591	19/06/2014	User Specified	7.5	0.179	1.0	IB	ZRB	0	2	0.01	18

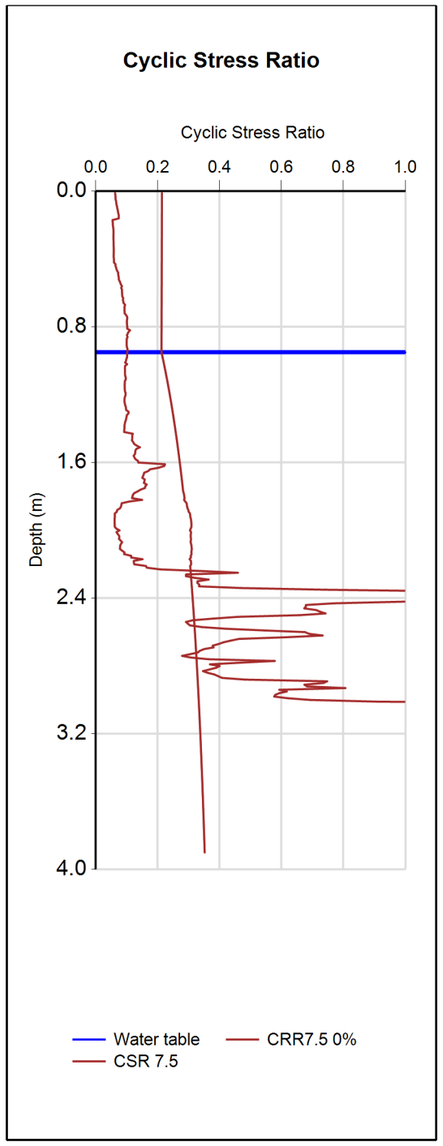
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	20	0.7	1	15	1

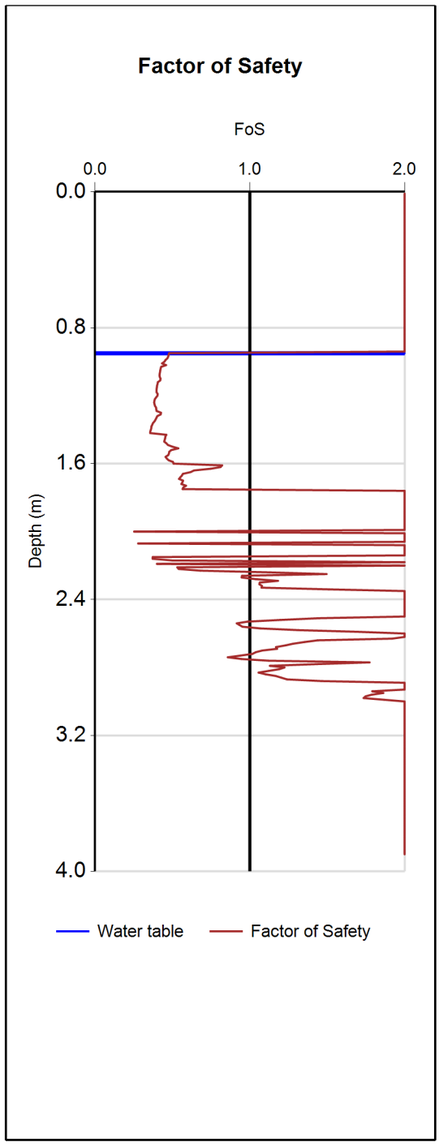
Tonkin & Taylor	Tonkin & Taylor Environmental and Engineering consultants V1.2	CLIENT, PROJECT **Nelson City Council** **Tahunanui Liquefaction**	LOCATION Nelson	DATE	10/07/2014
				ANALYSED	mjl
		TITLE **Stage 2**	JOB NUMBER **871023**	CHECKED	
				PAGE	1 of 7 pages

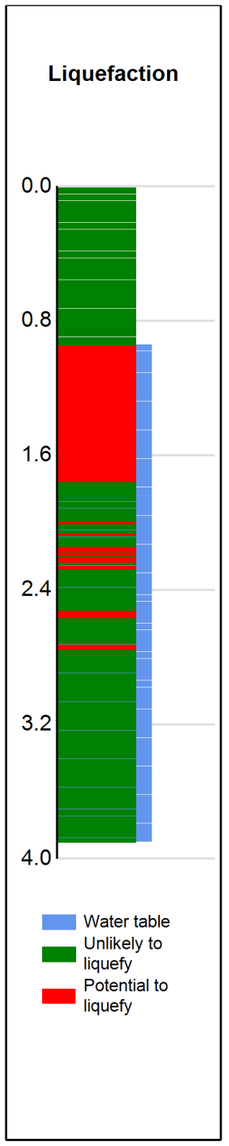
A1263318









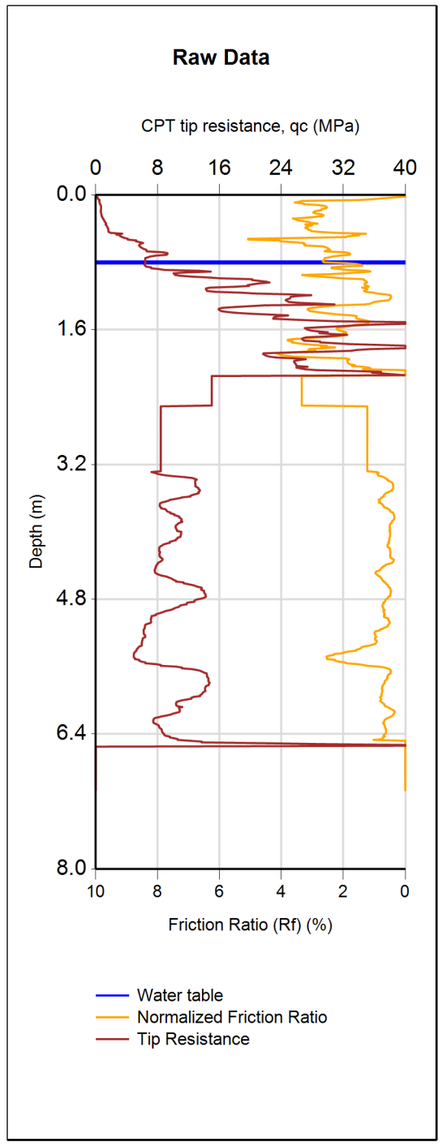


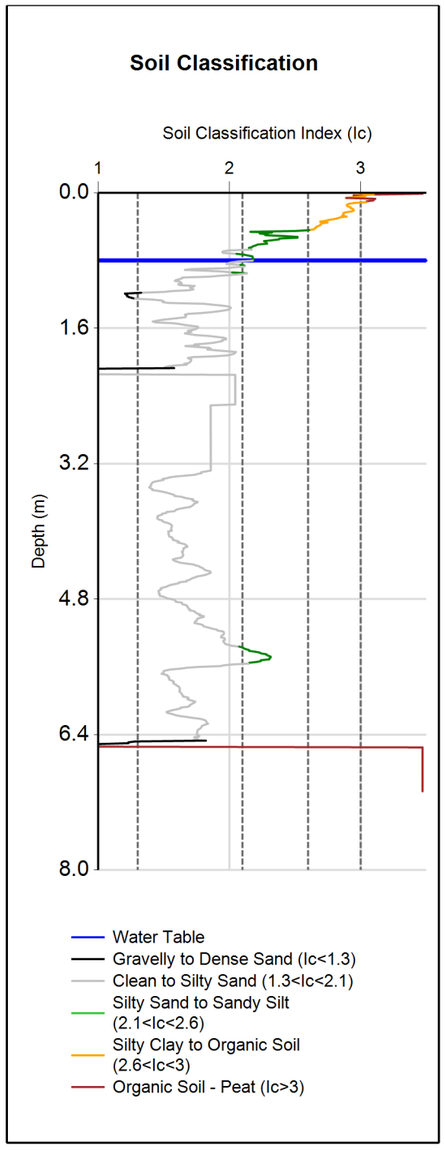
Surcharge used.

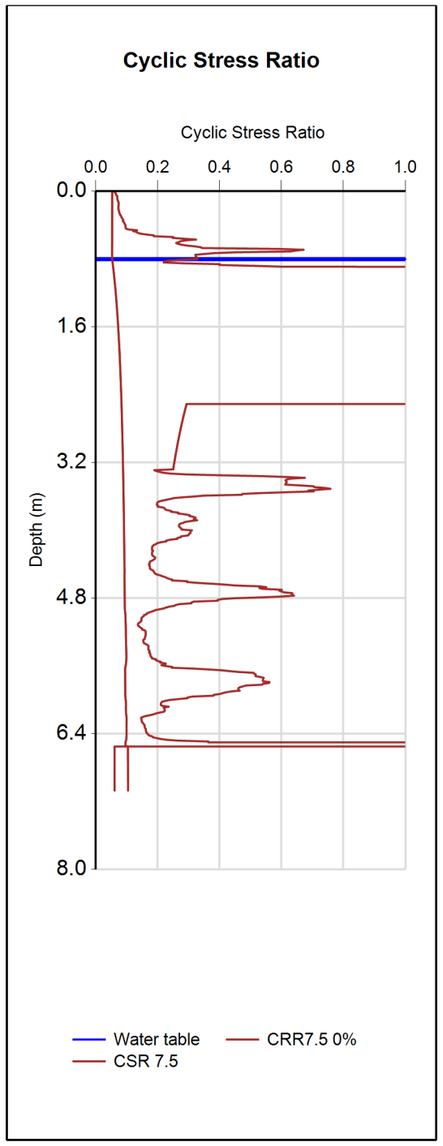
(Assumed pre-drill values)

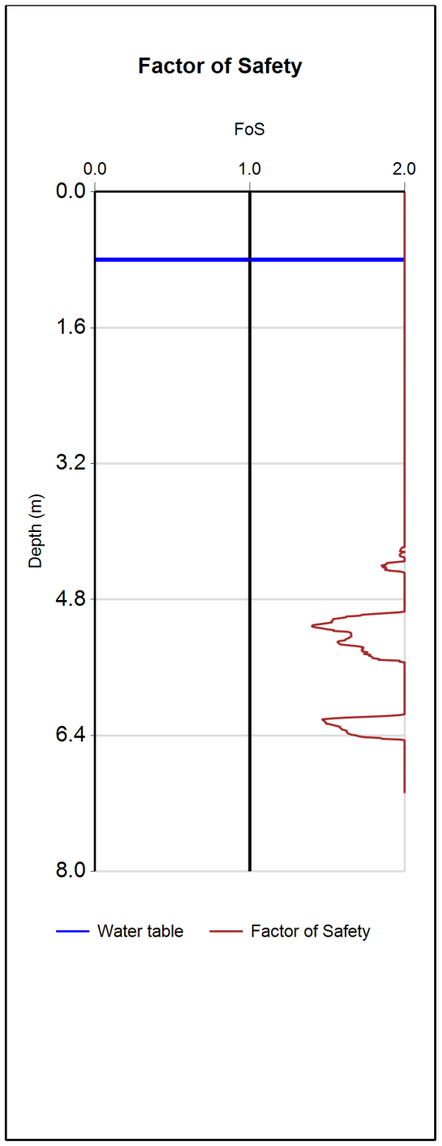
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 14 - Spliced	42591	19/06/2014	User Specified	7.5	0.36	1.0	IB	ZRB	0	2	0.01	18

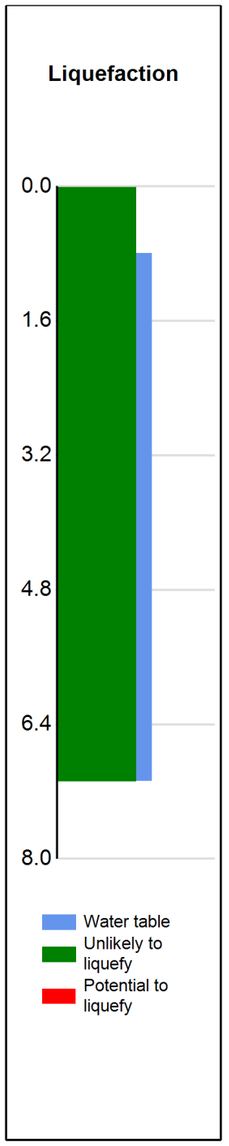
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	27	1	5	20	1









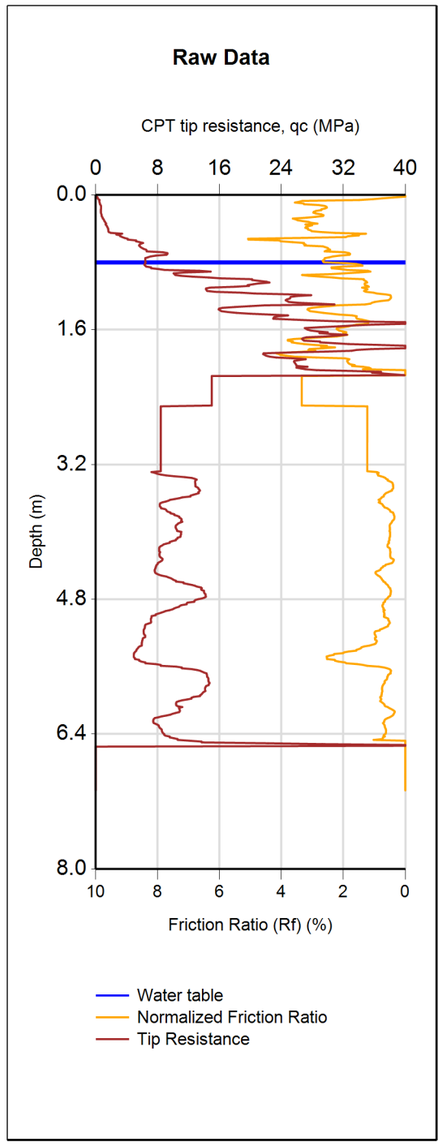


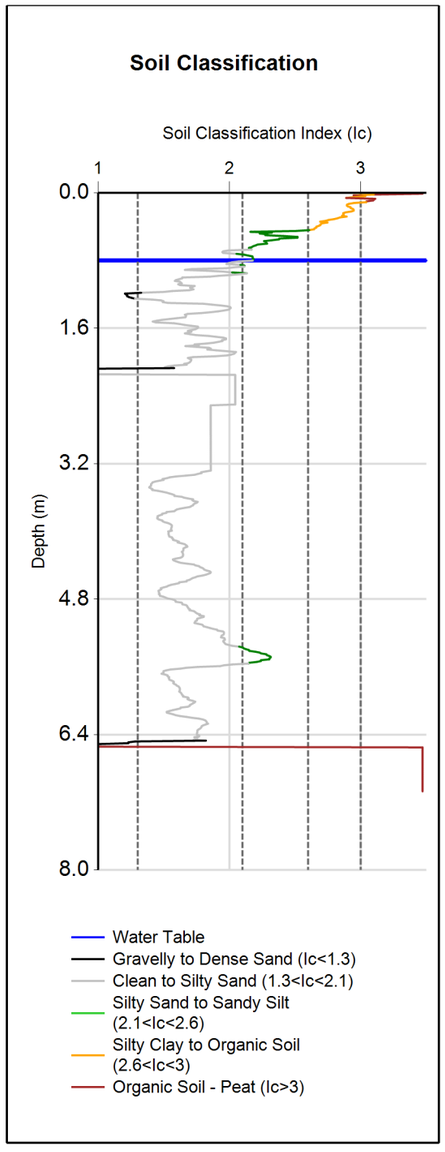
Surcharge used.

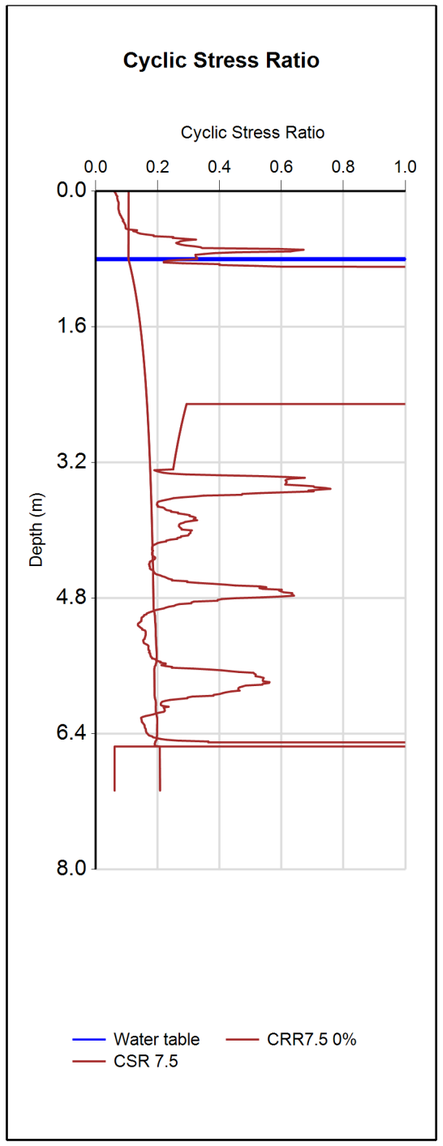
(Assumed pre-drill values)

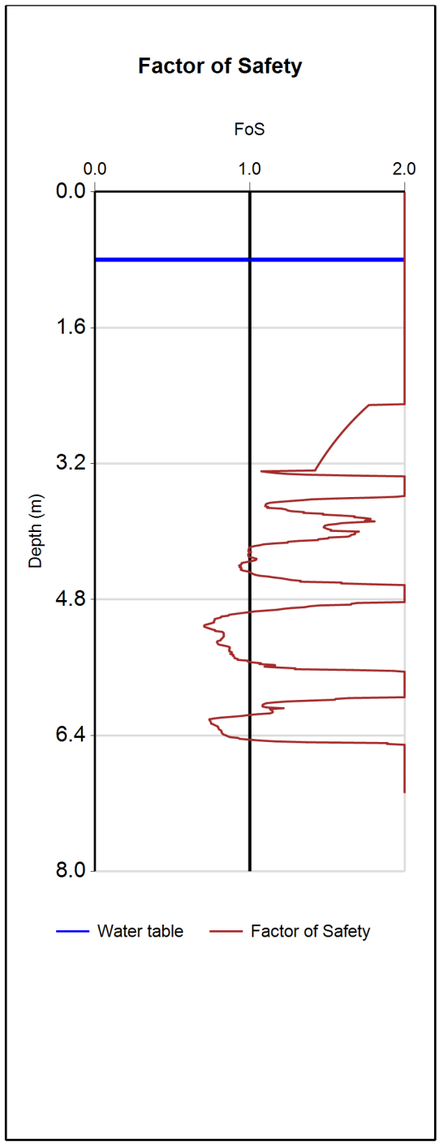
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 15 - Spliced	42592	19/06/2014	User Specified	7.5	0.09	0.8	IB	ZRB	0	2	0.01	18

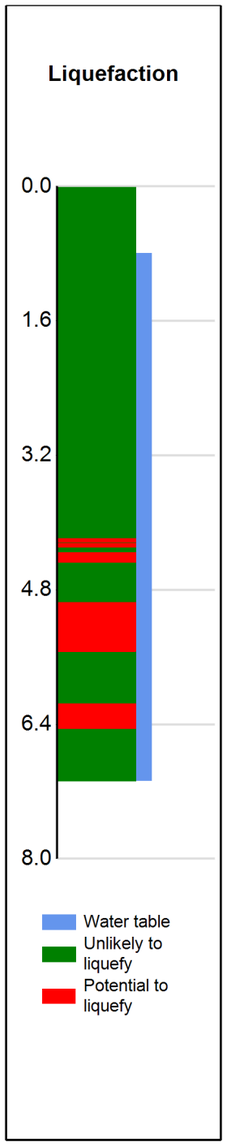
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	1	0	0	0	7.1









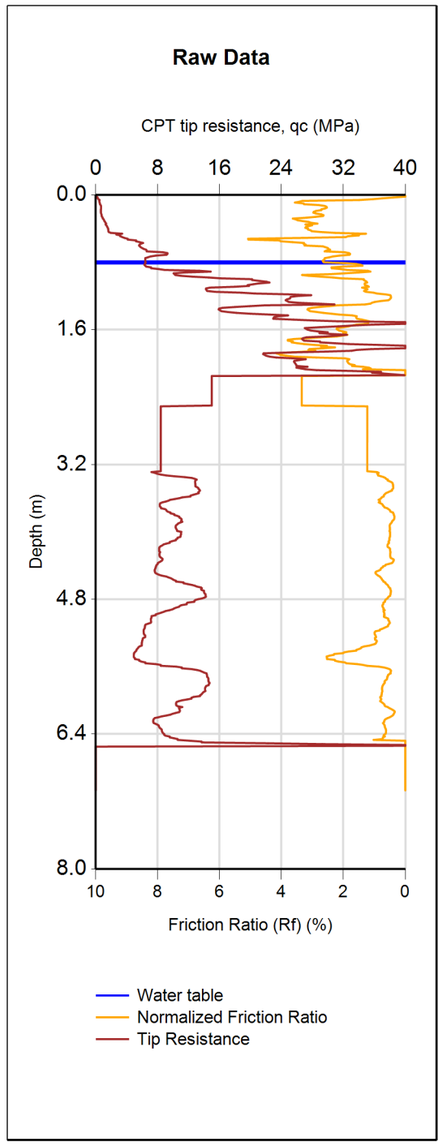


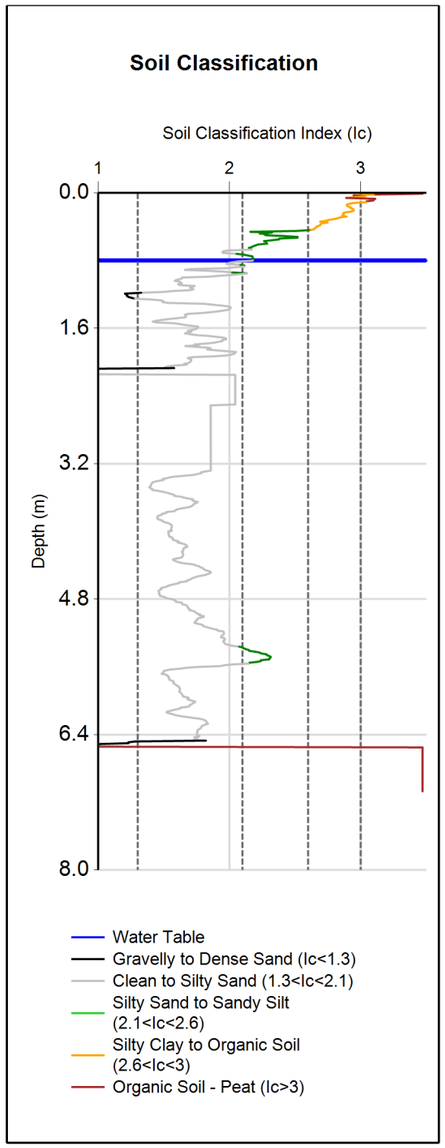
Surcharge used.

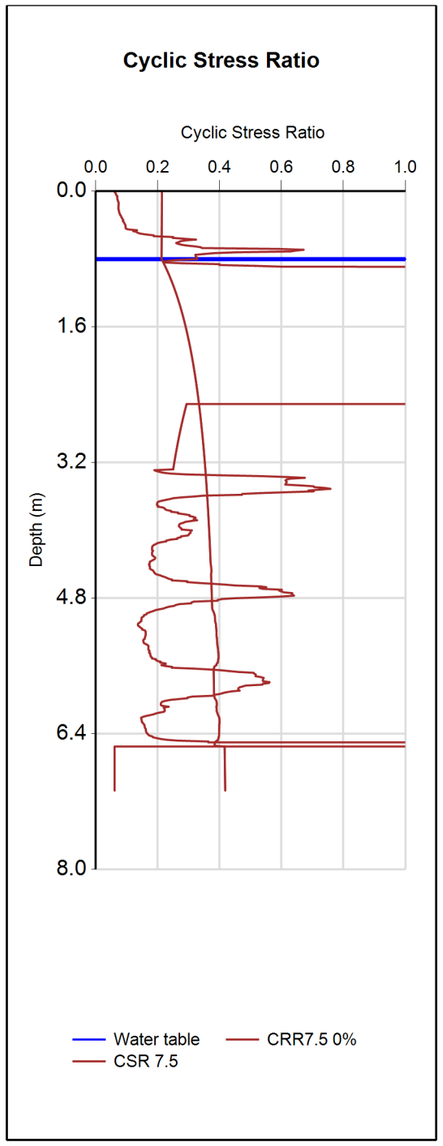
(Assumed pre-drill values)

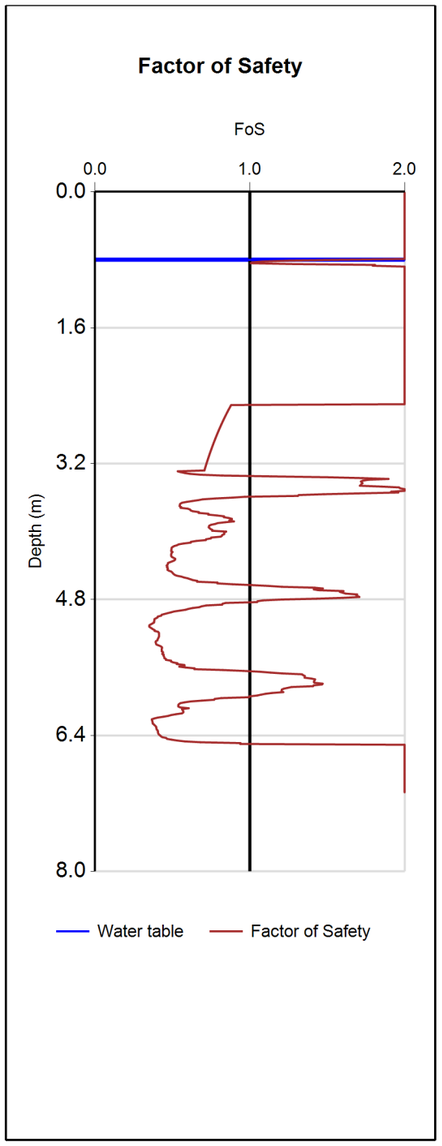
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 15 - Spliced	42592	19/06/2014	User Specified	7.5	0.179	0.8	IB	ZRB	0	2	0.01	18

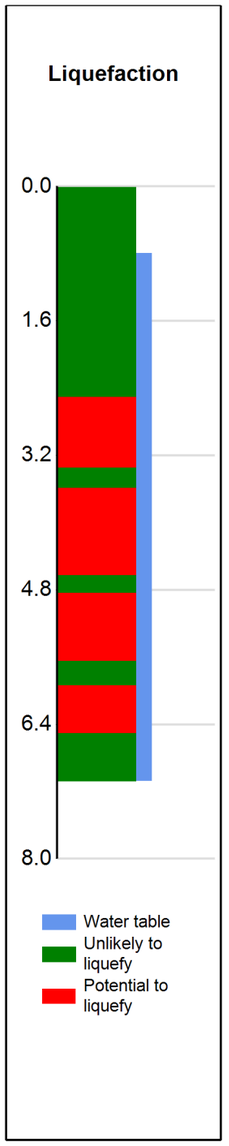
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	22	1.1	1	4	4.3









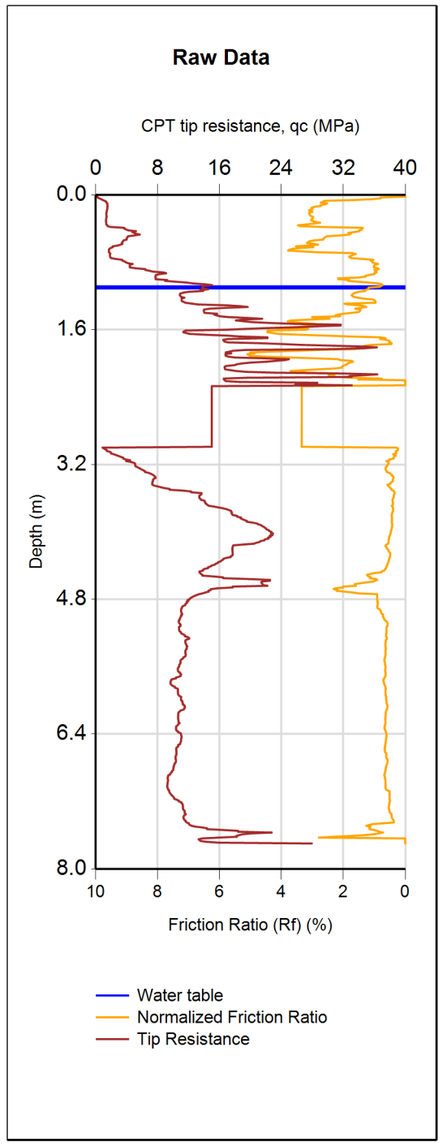


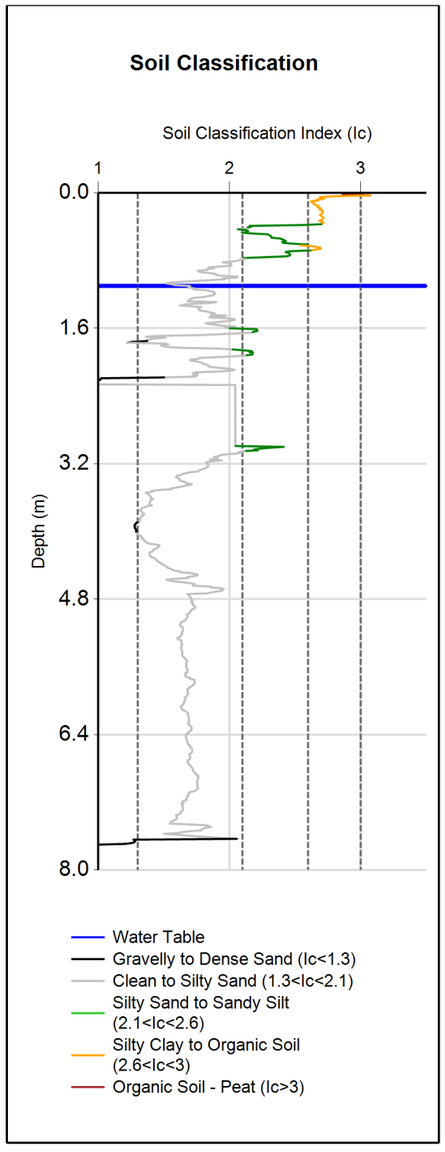
Surcharge used.

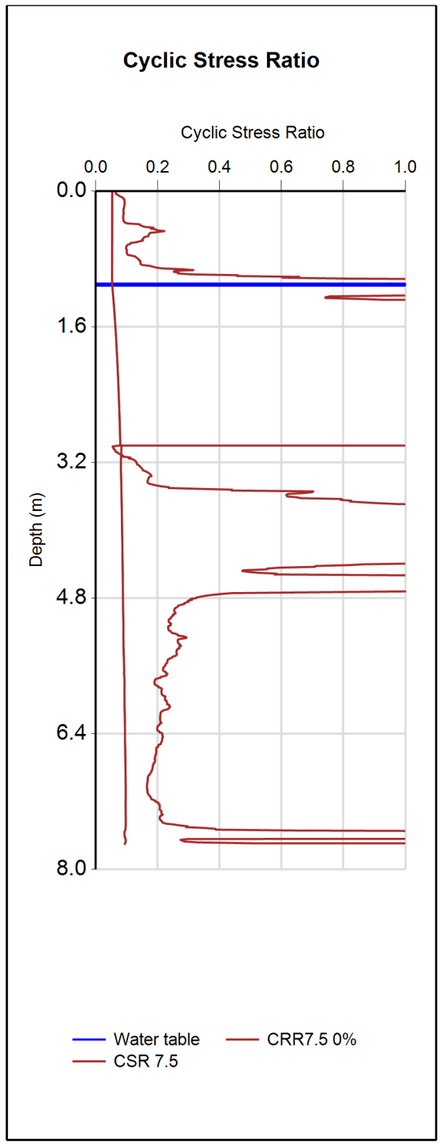
(Assumed pre-drill values)

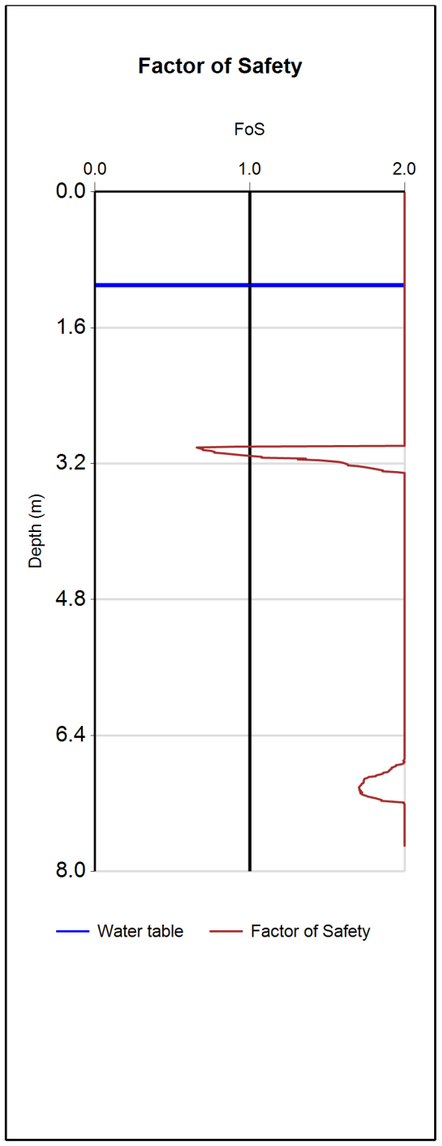
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 15 - Spliced	42592	19/06/2014	User Specified	7.5	0.36	0.8	IB	ZRB	0	2	0.01	18

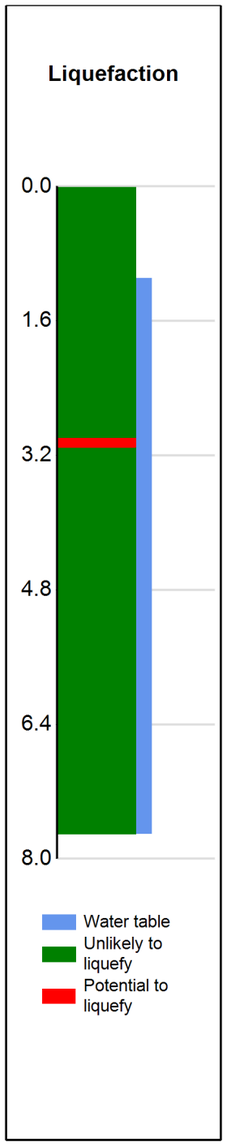
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	55	3.3	10	13	2.6









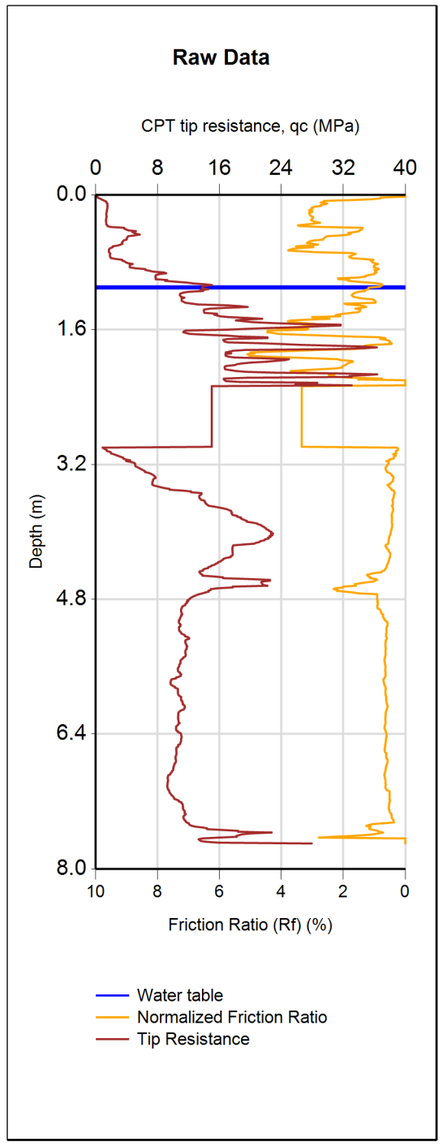


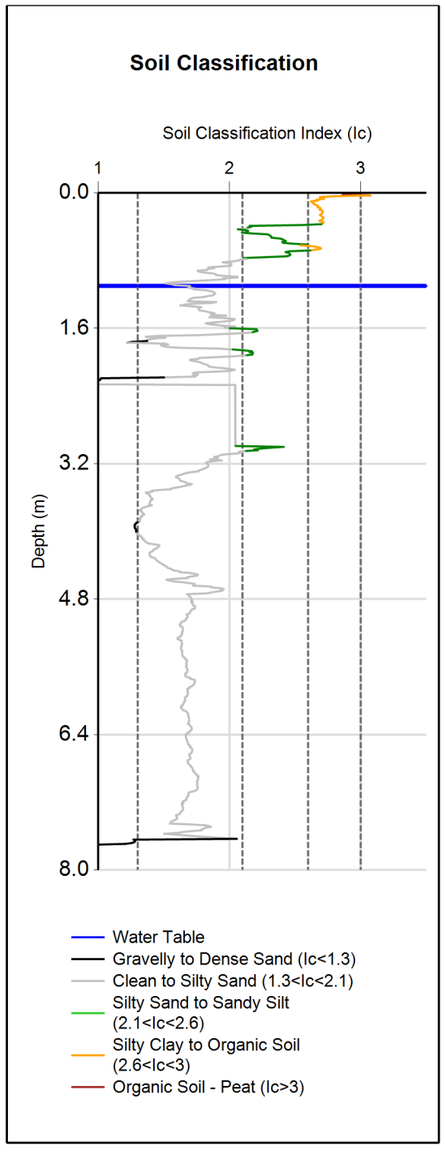
Surcharge used.

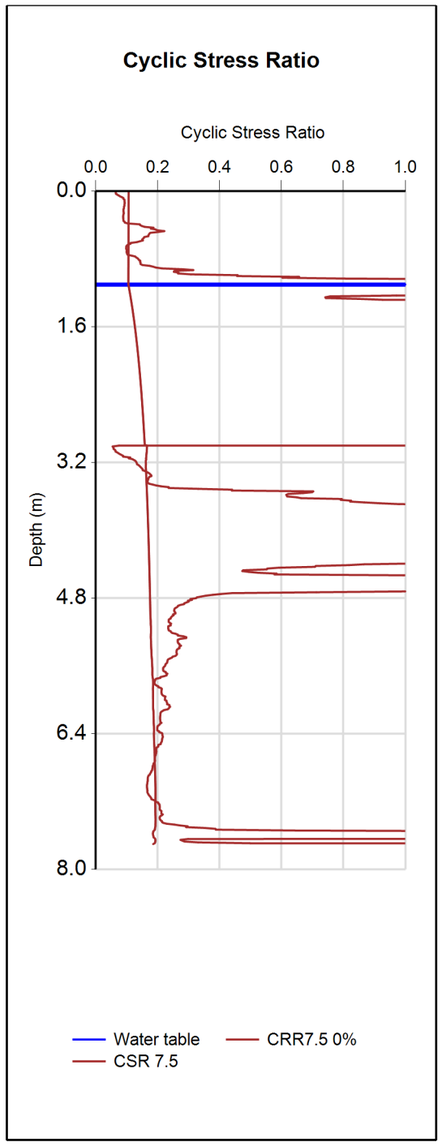
(Assumed pre-drill values)

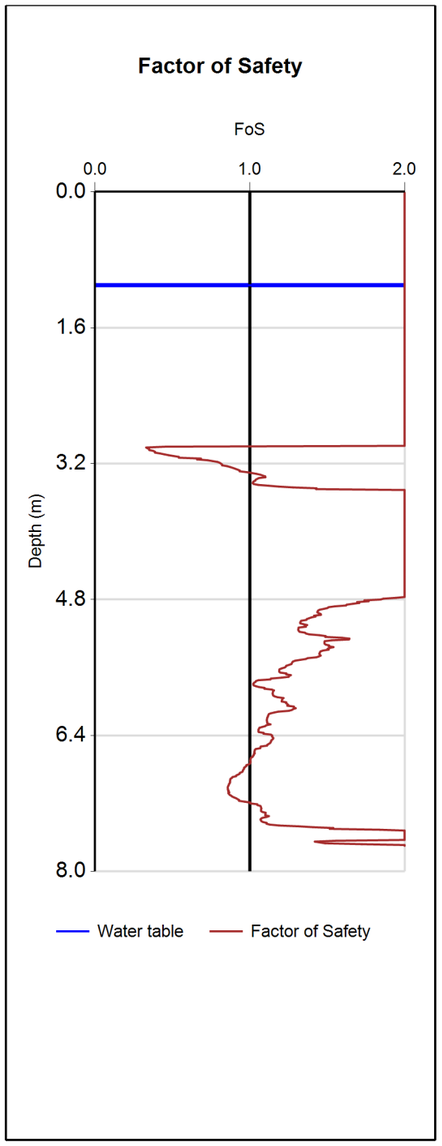
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 16 - Spliced	42594	20/06/2014	User Specified	7.5	0.09	1.1	IB	ZRB	0	2	0.01	18

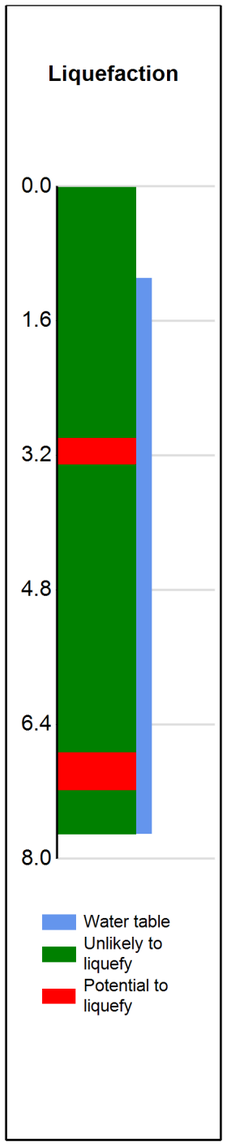
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	7	0.1	0	2	3.1









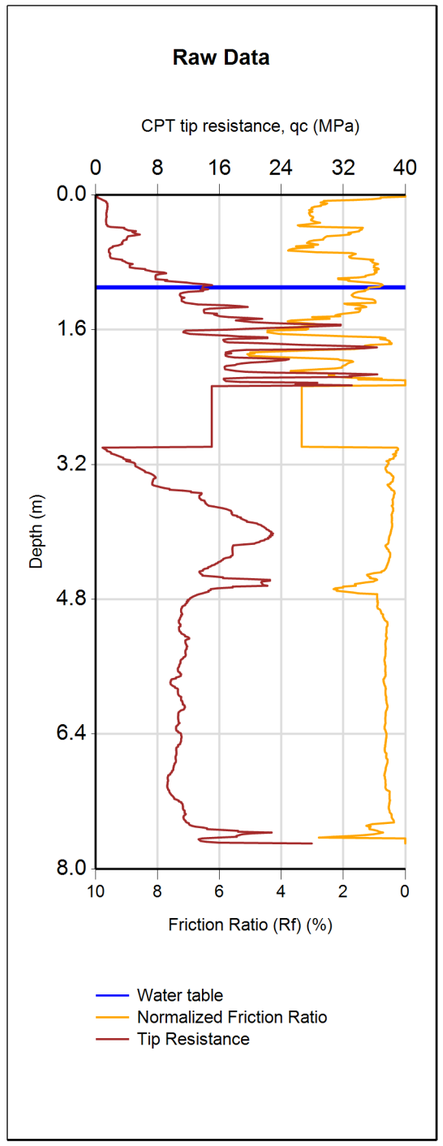


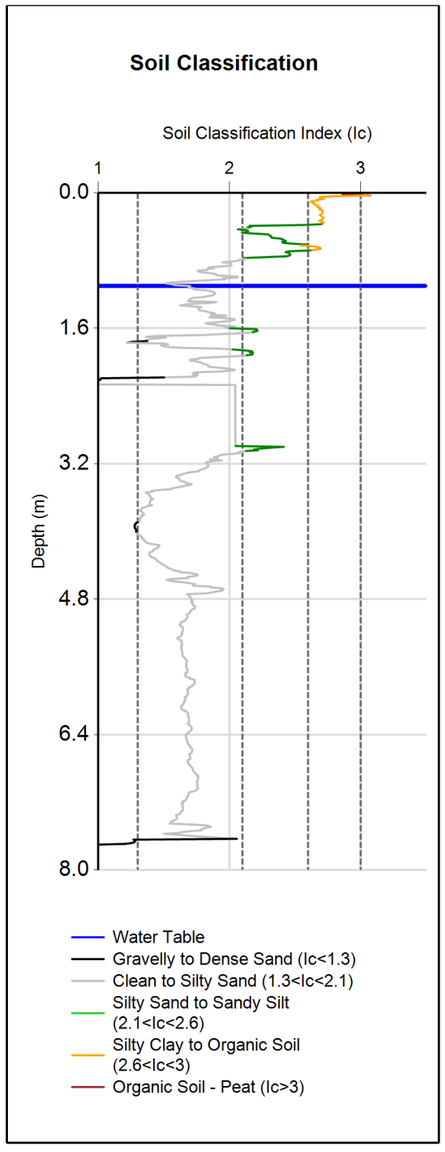
Surcharge used.

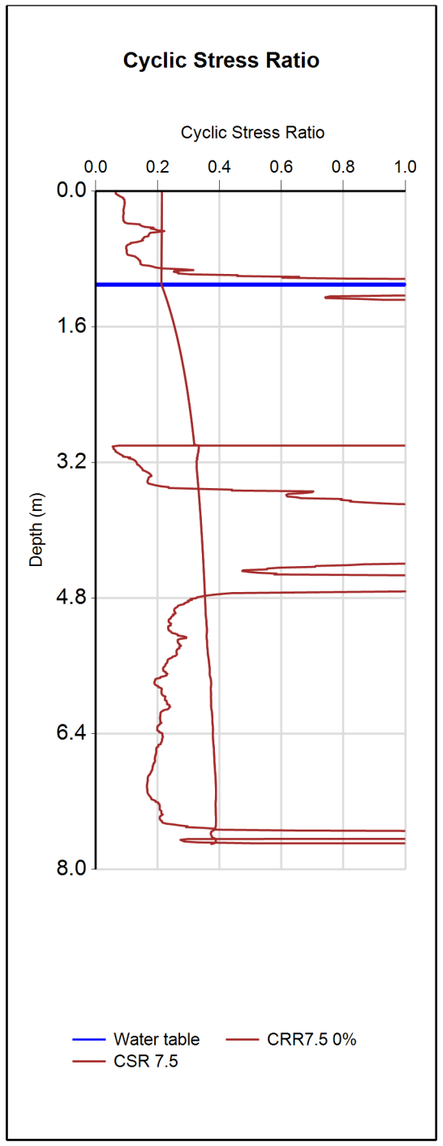
(Assumed pre-drill values)

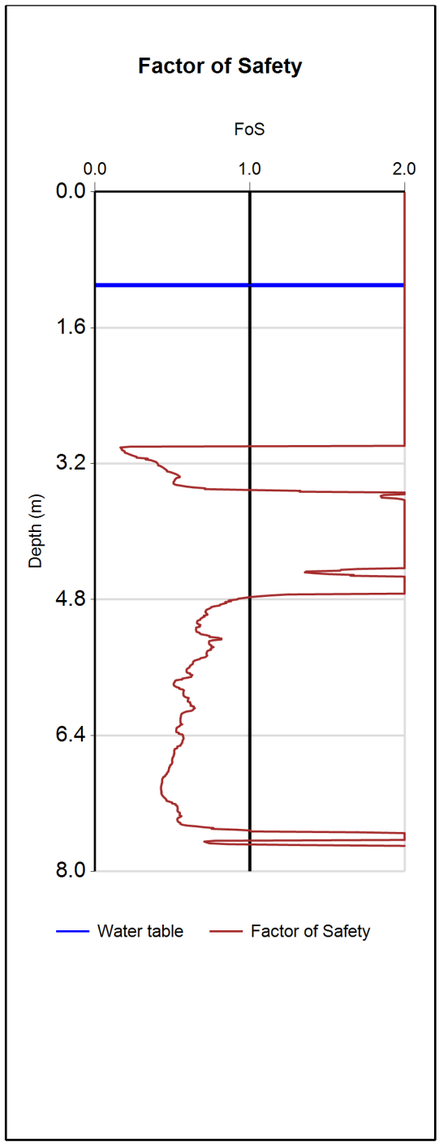
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	γ (kN/m³)
INPUT:	CPT 16 - Spliced	42594	20/06/2014	User Specified	7.5	0.179	1.1	IB	ZRB	0	2	0.01	18

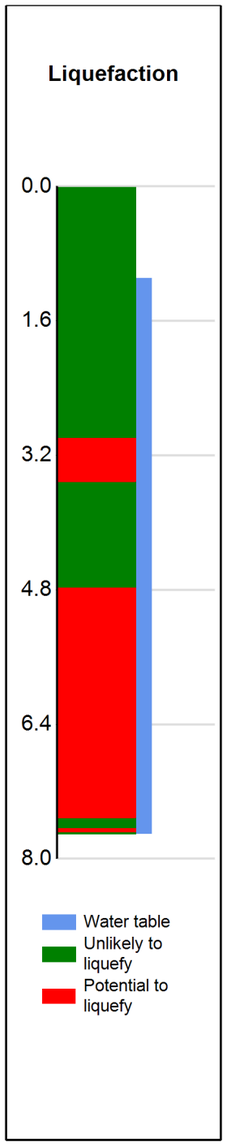
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	25	0.8	1	6	3.1









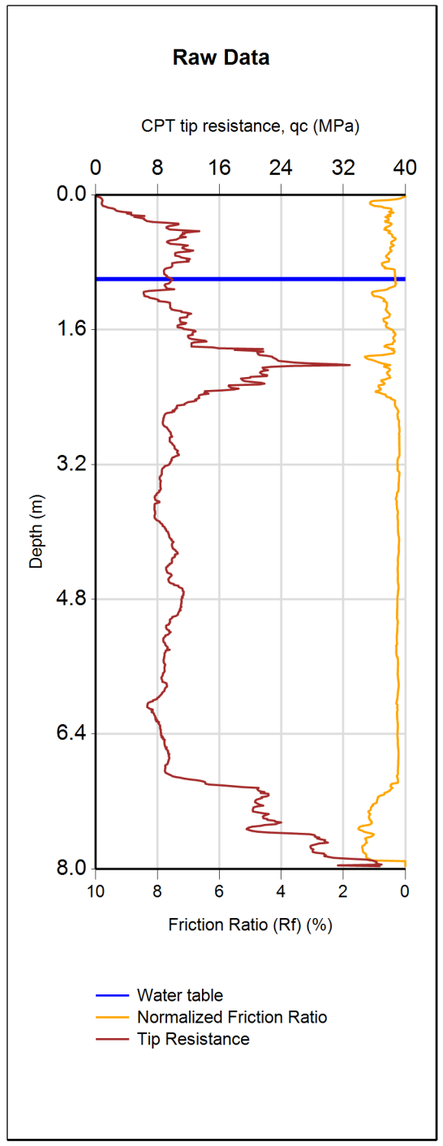


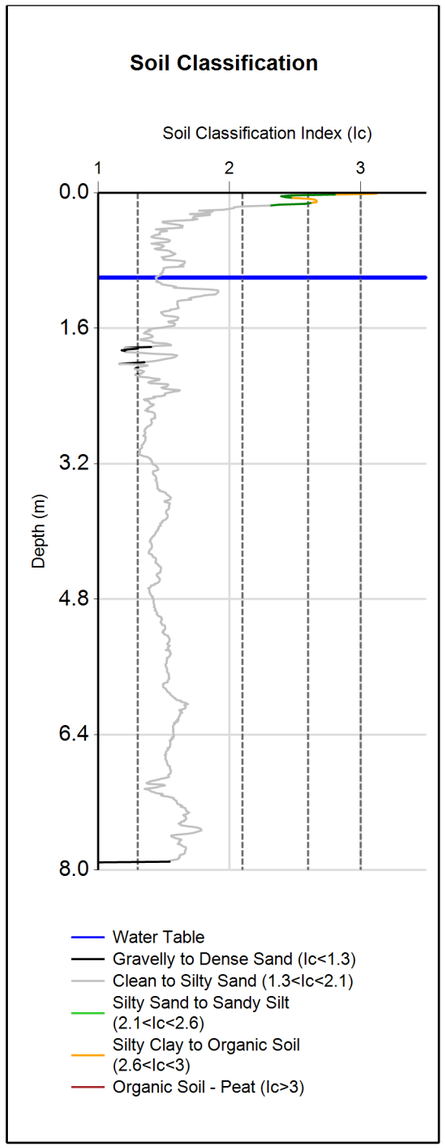
Surcharge used.

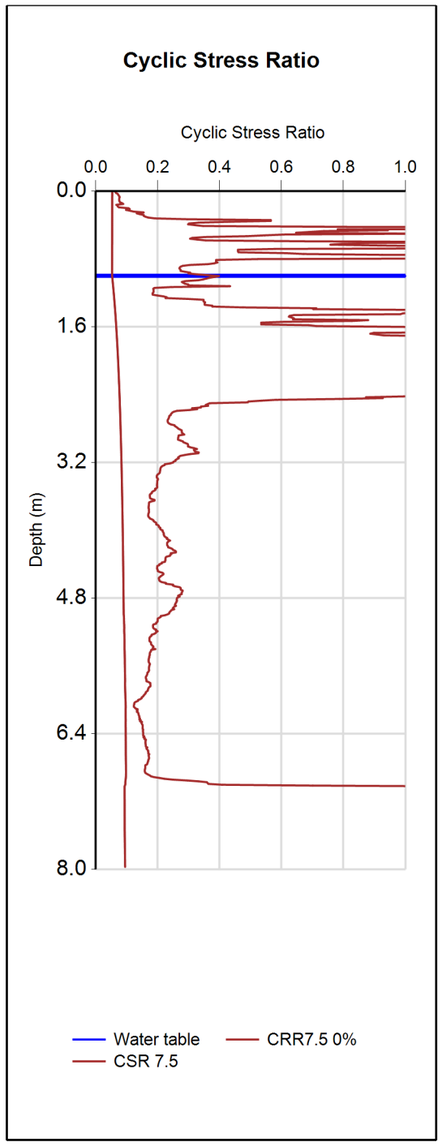
(Assumed pre-drill values)

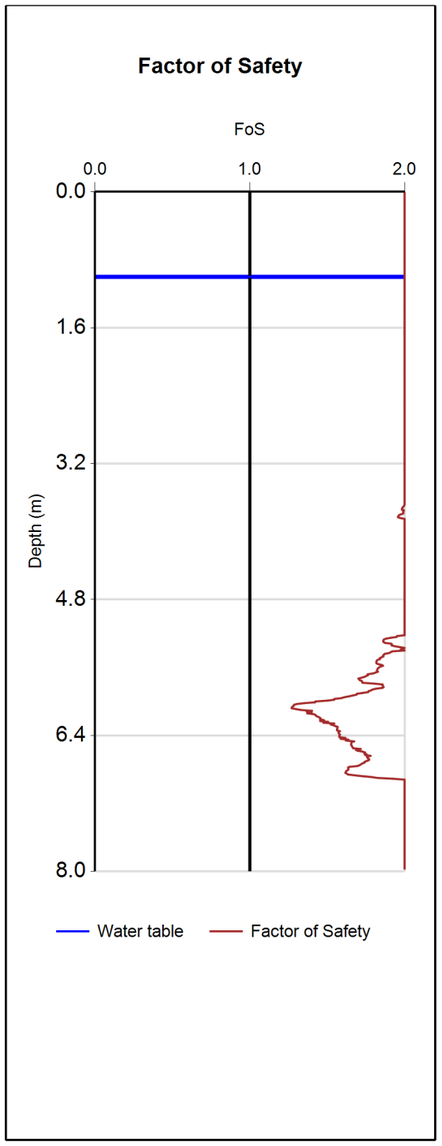
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 16 - Spliced	42594	20/06/2014	User Specified	7.5	0.36	1.1	IB	ZRB	0	2	0.01	18

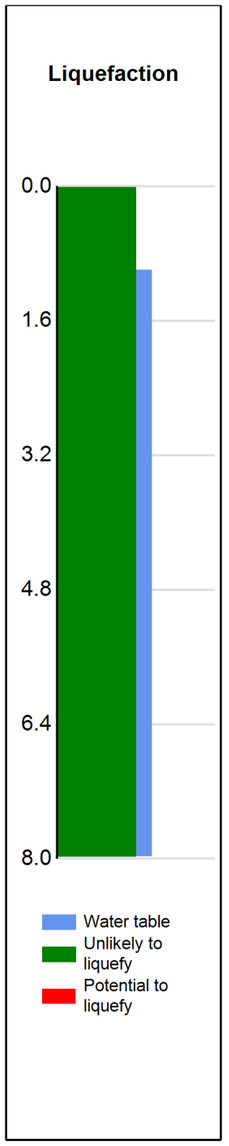
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	64	3.3	10	13	3.1











Surcharge used.

(Assumed pre-drill values)

	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 17 - 02TT14_CPT1	42431	20/06/2014	User Specified	7.5	0.09	1.0	IB	ZRB	0	2	0.01	18

	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	2	0	0	0	8

Tonkin & Taylor	Tonkin & Taylor Environmental and Engineering consultants V1.2	CLIENT, PROJECT **Nelson City Council** **Tahunanui Liquefaction**	LOCATION Nelson	DATE	10/07/2014
				ANALYSED	mjl
		TITLE **Stage 2**	JOB NUMBER **871023**	CHECKED	
				PAGE	1 of 8 pages

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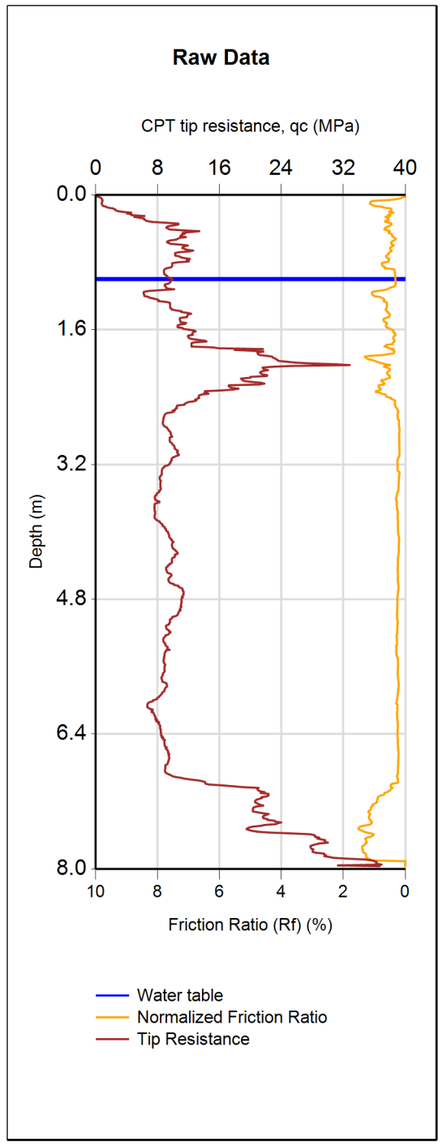
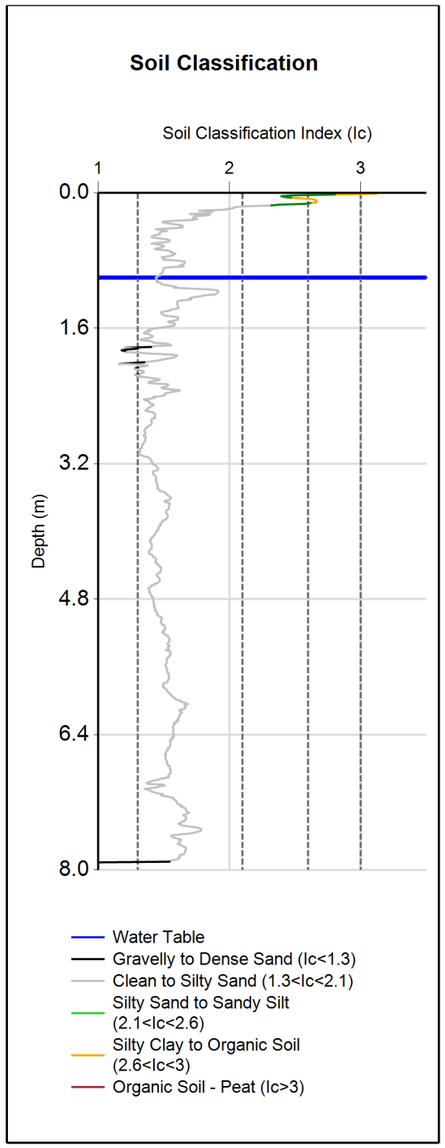
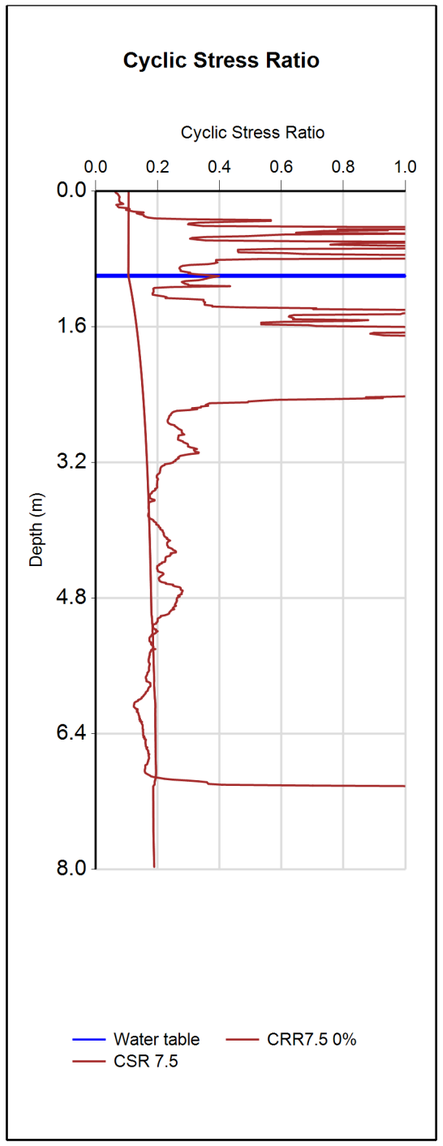
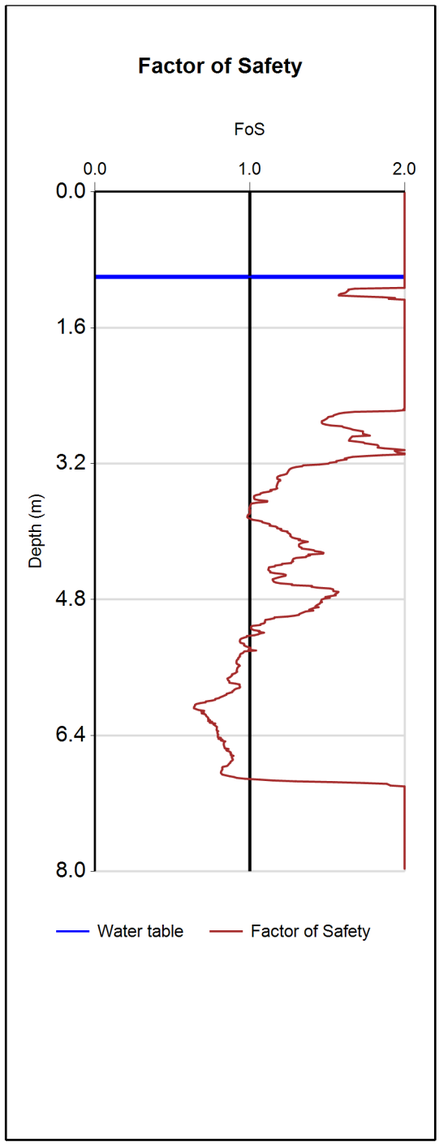
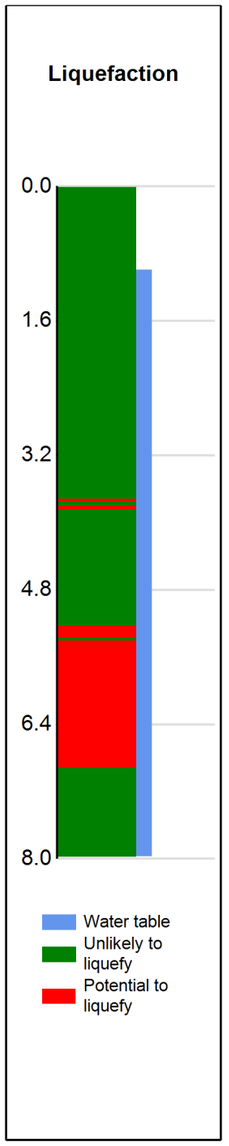








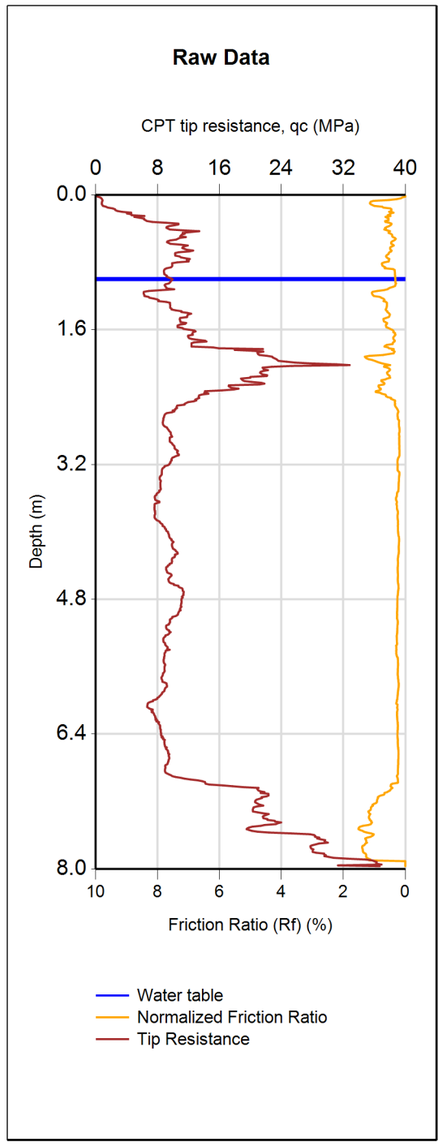


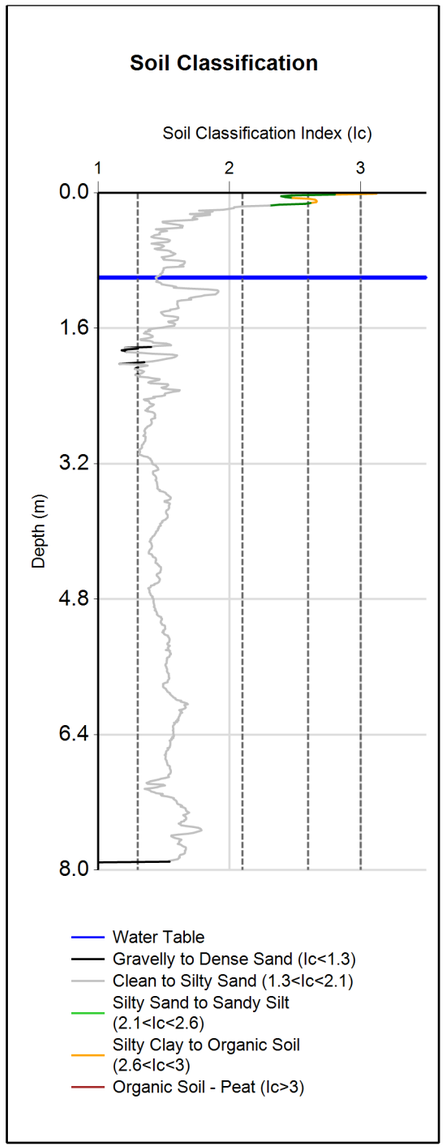
Surcharge used.

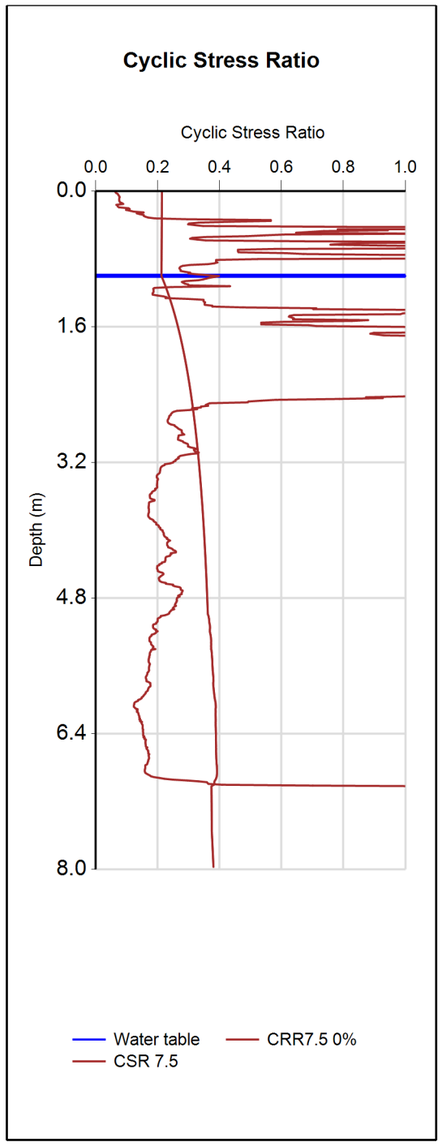
(Assumed pre-drill values)

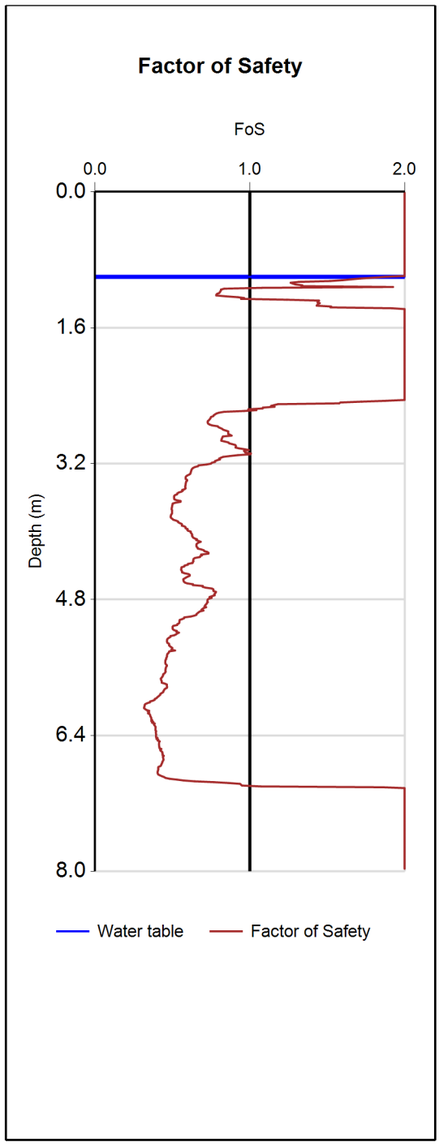
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 17 - 02TT14_CPT1	42431	20/06/2014	User Specified	7.5	0.179	1.0	IB	ZRB	0	2	0.01	18

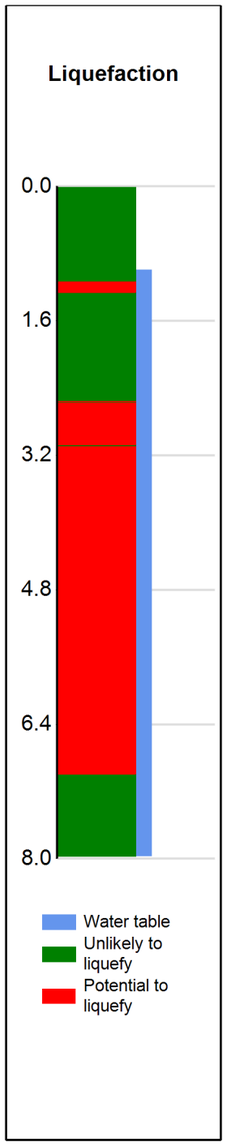
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	35	1.7	2	7	5.2









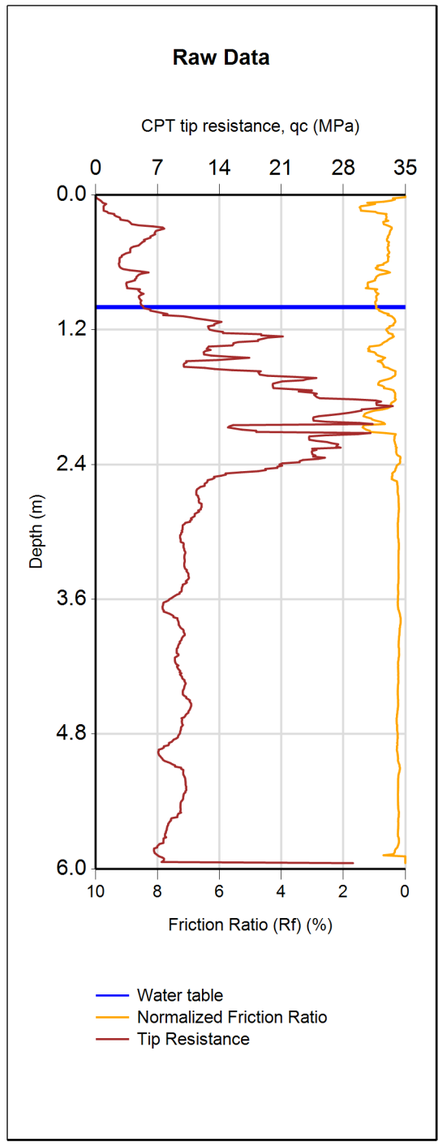


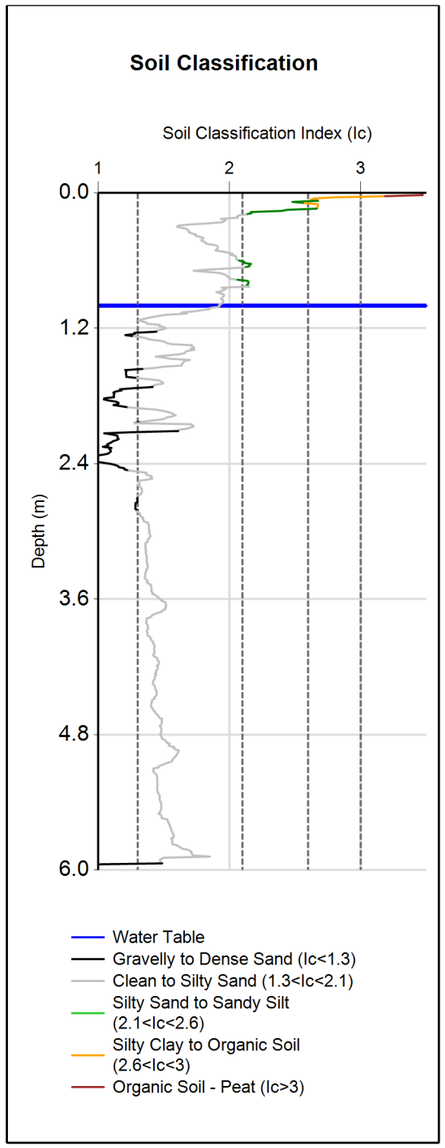
Surcharge used.

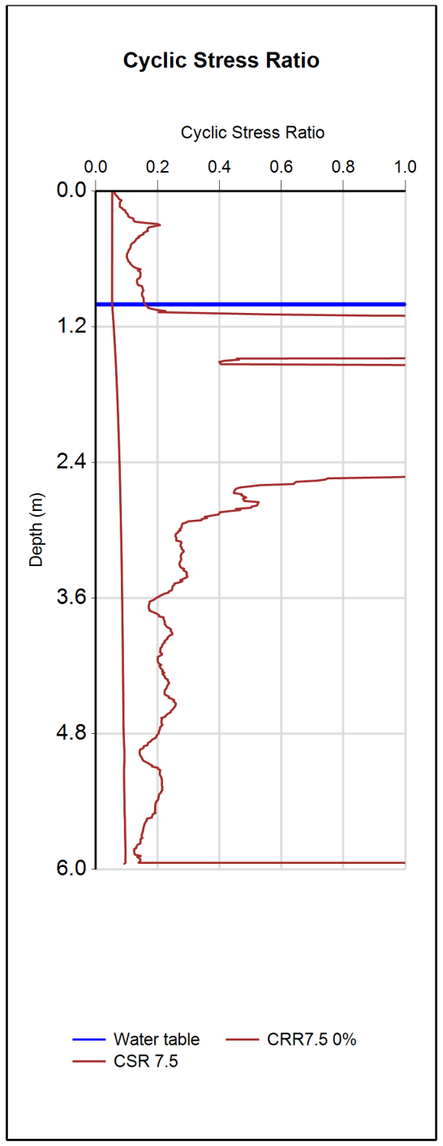
(Assumed pre-drill values)

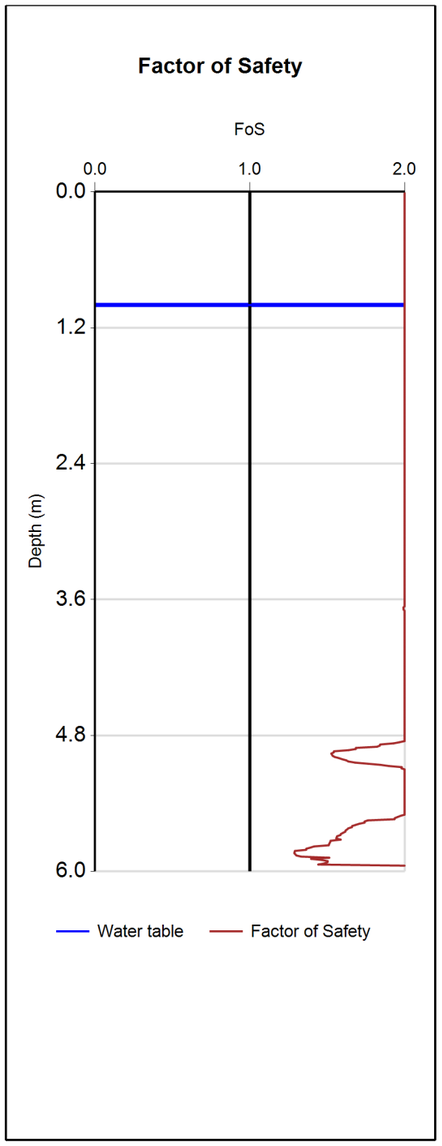
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 17 - 02TT14_CPT1	42431	20/06/2014	User Specified	7.5	0.36	1.0	IB	ZRB	0	2	0.01	18

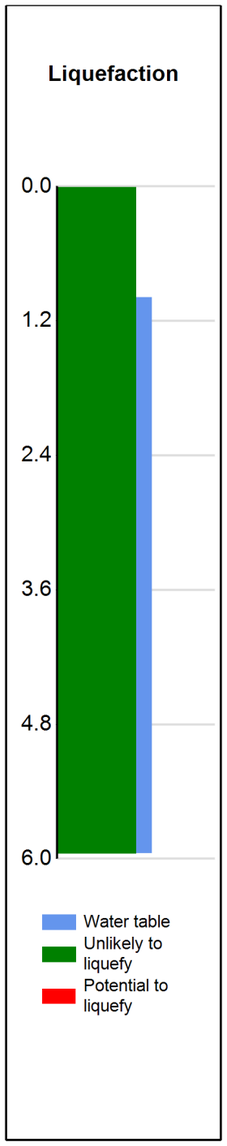
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	82	4.5	14	19	1.2









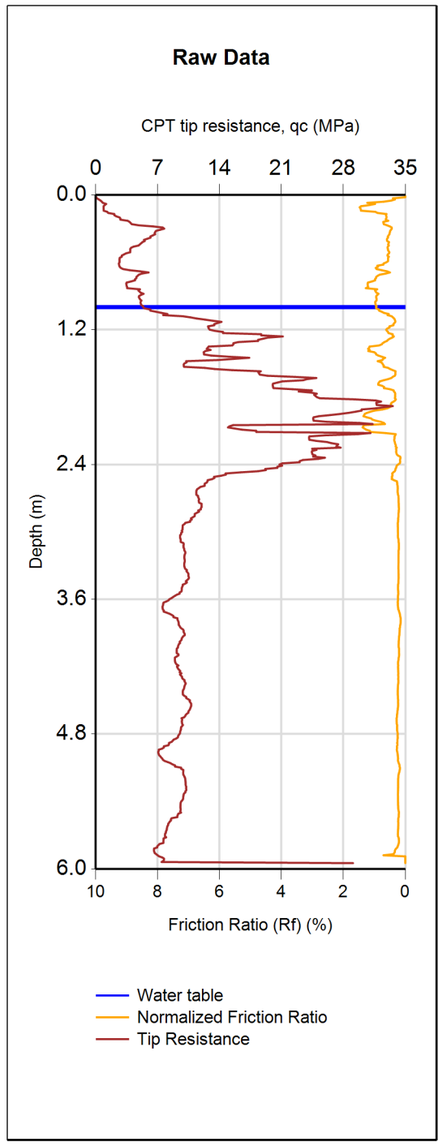


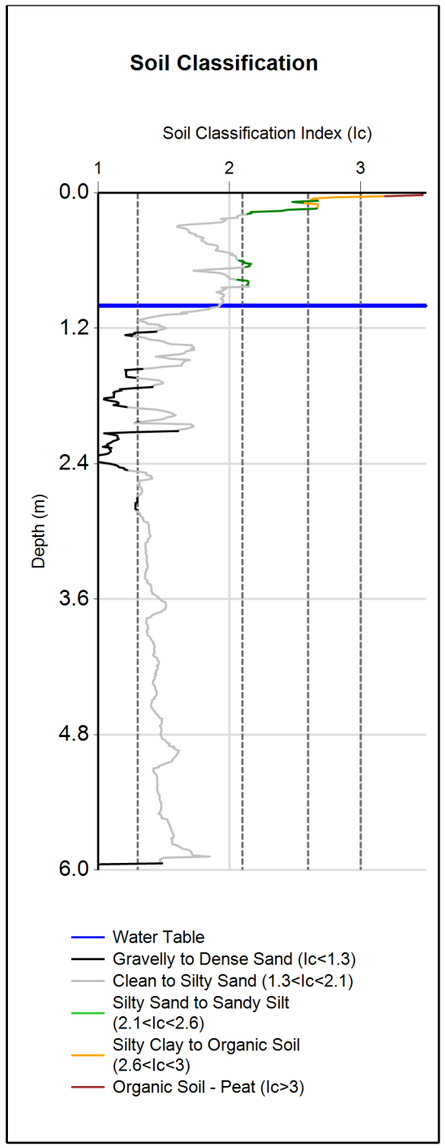
Surcharge used.

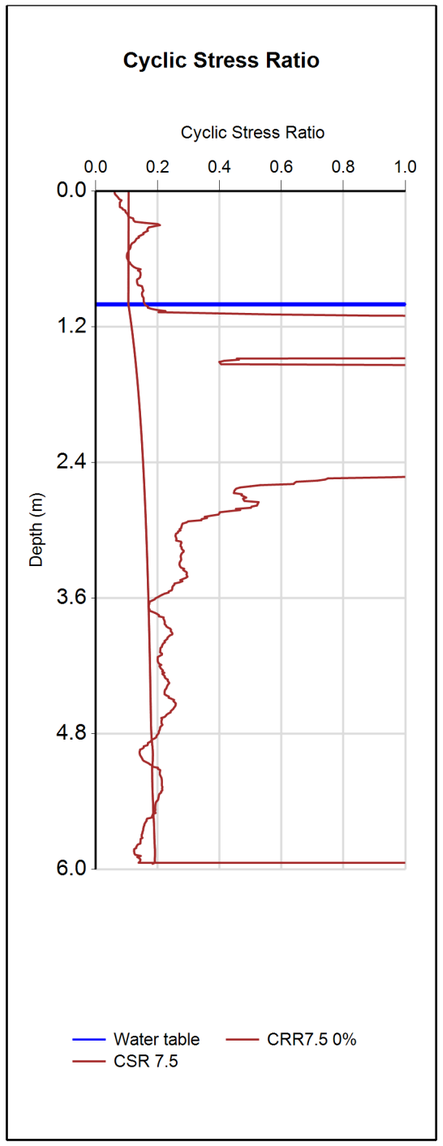
(Assumed pre-drill values)

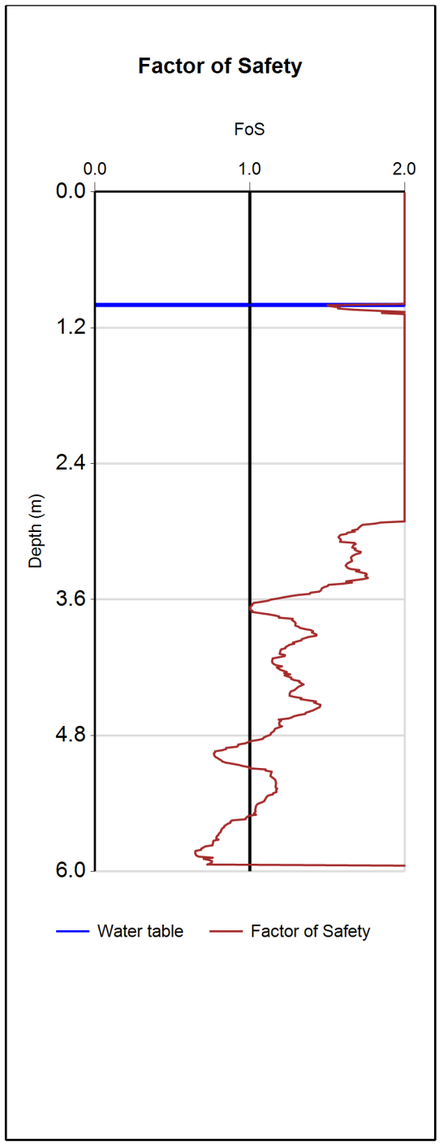
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 18 - 02TT14_CPT2	42432	20/06/2014	User Specified	7.5	0.09	1.0	IB	ZRB	0	2	0.01	18

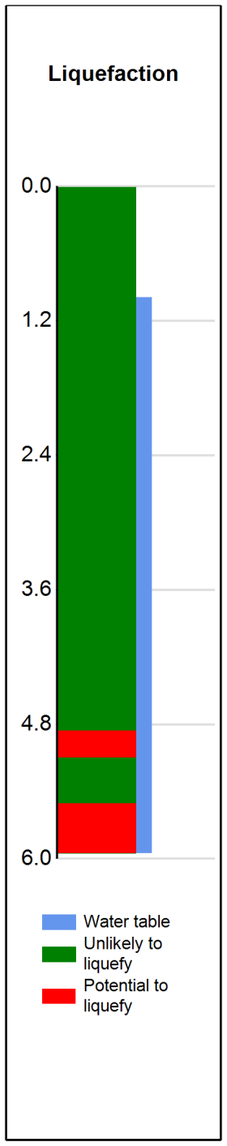
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	1	0	0	0	6









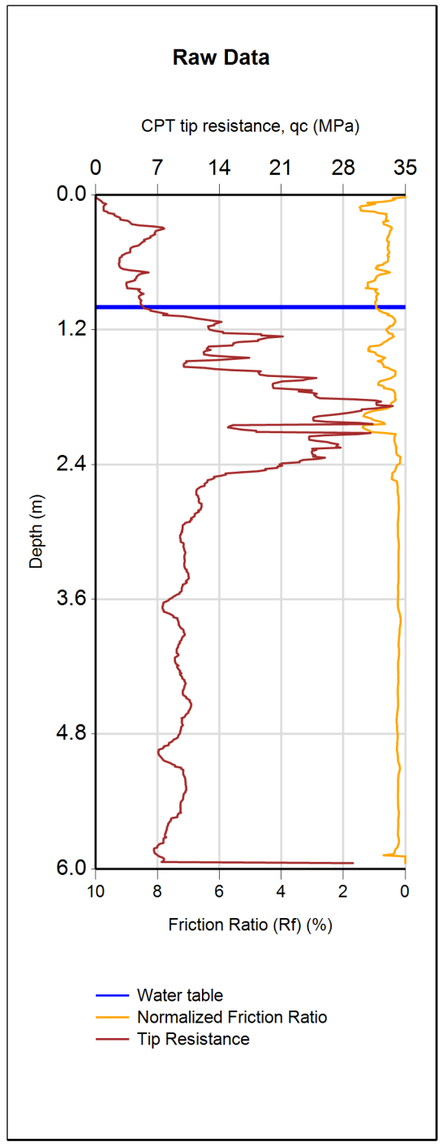


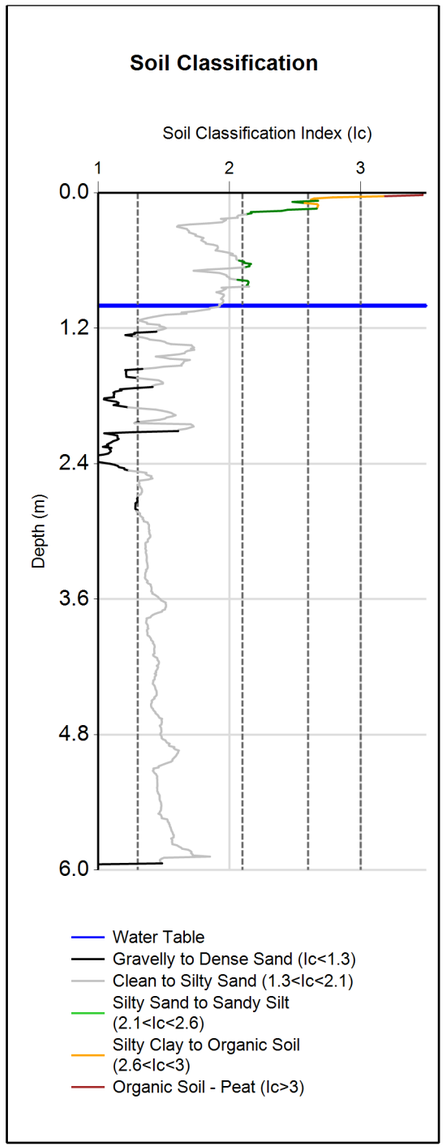
Surcharge used.

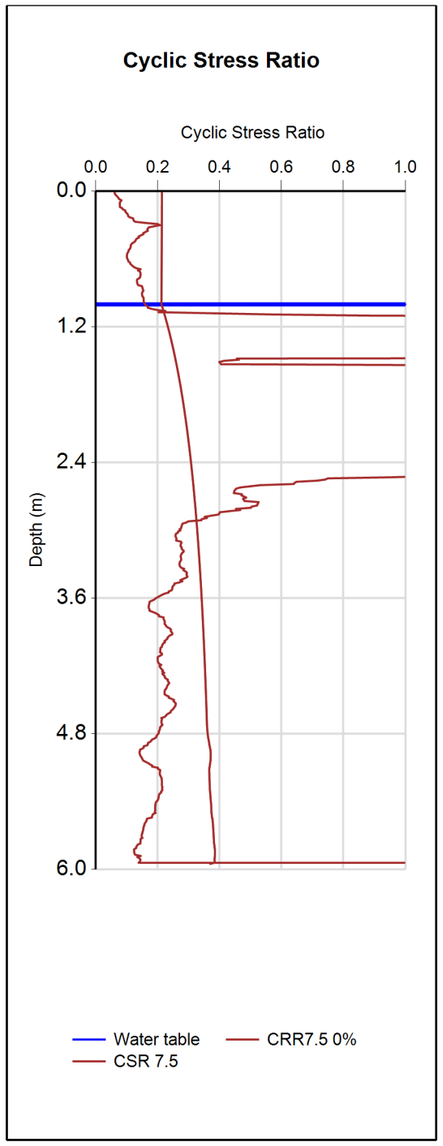
(Assumed pre-drill values)

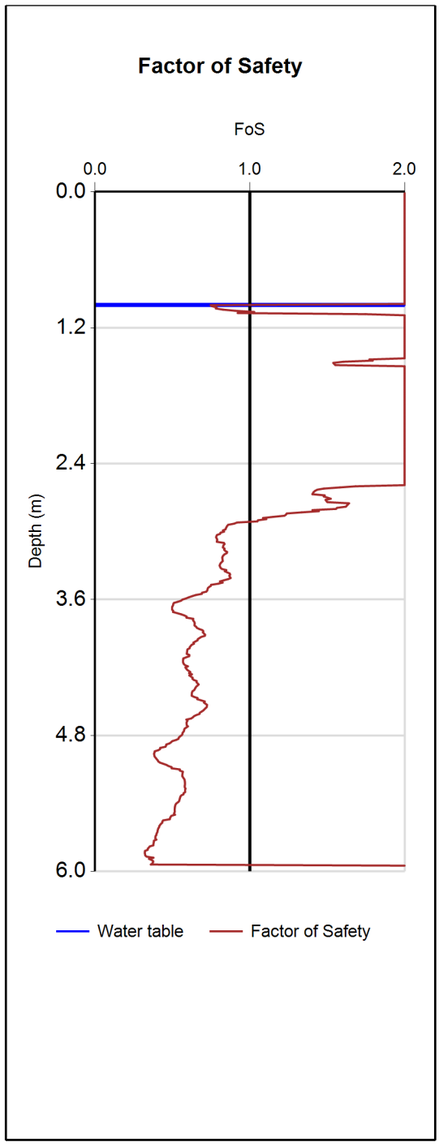
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 18 - 02TT14_CPT2	42432	20/06/2014	User Specified	7.5	0.179	1.0	IB	ZRB	0	2	0.01	18

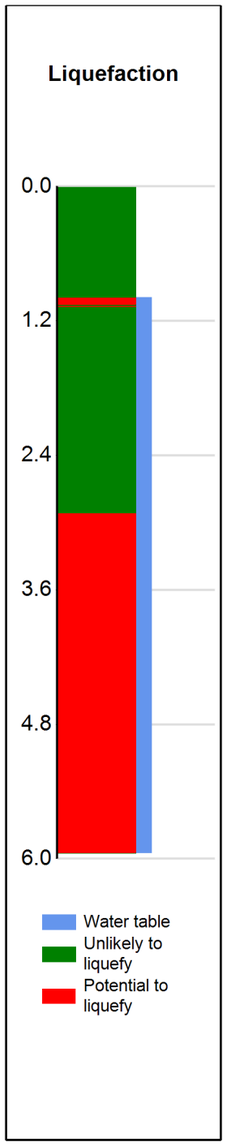
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	19	0.7	1	4	5









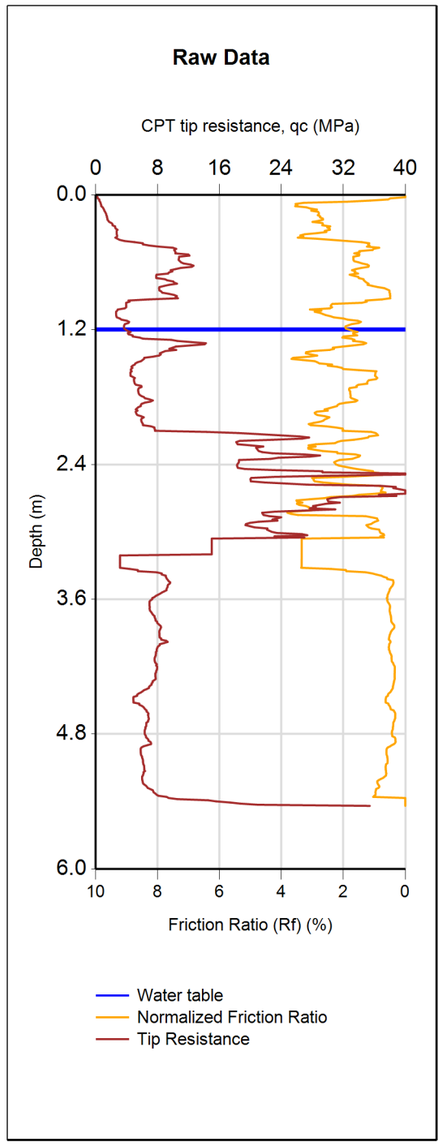


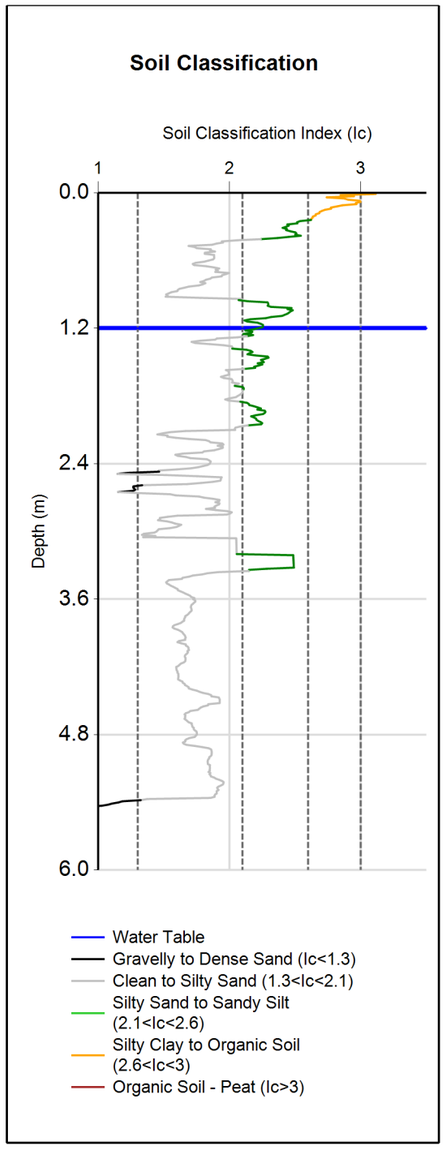
Surcharge used.

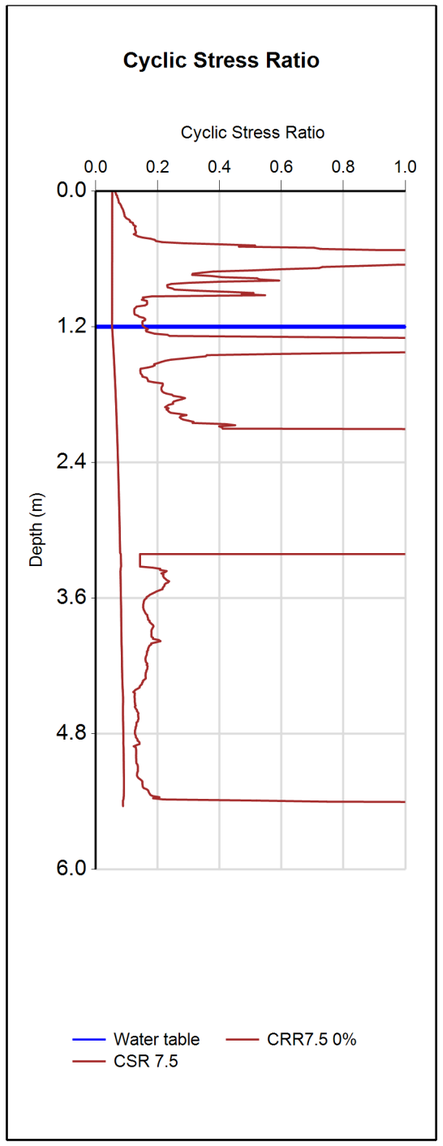
(Assumed pre-drill values)

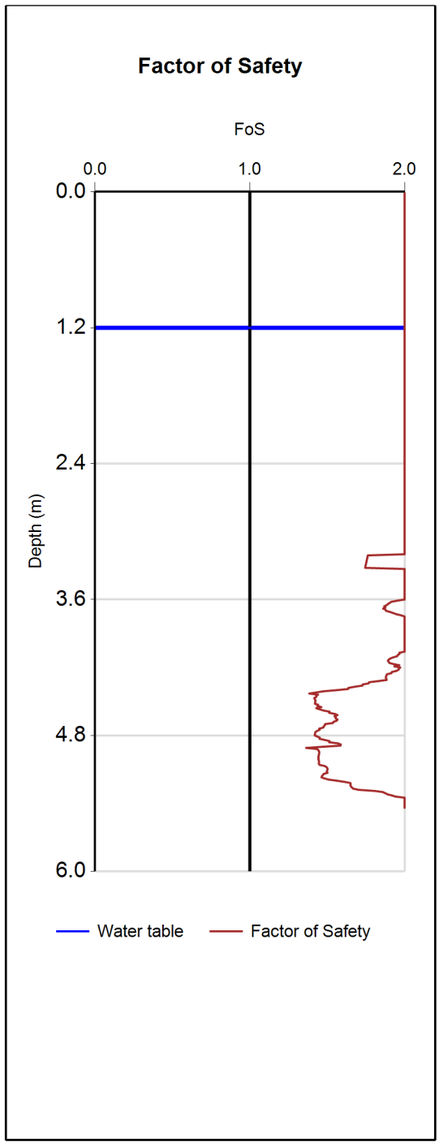
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	γ (kN/m³)
INPUT:	CPT 18 - 02TT14_CPT2	42432	20/06/2014	User Specified	7.5	0.36	1.0	IB	ZRB	0	2	0.01	18

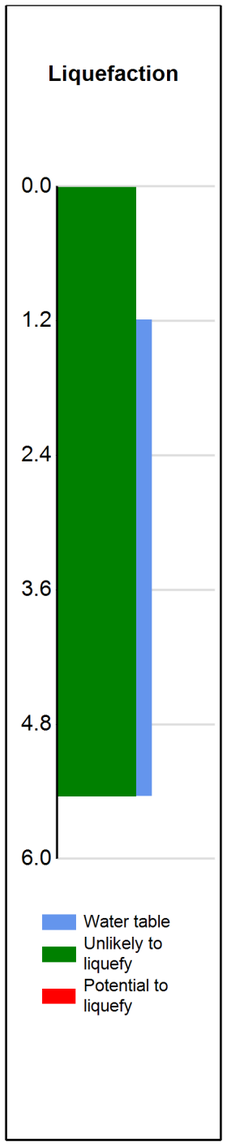
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	55	3.1	9	13	2.9







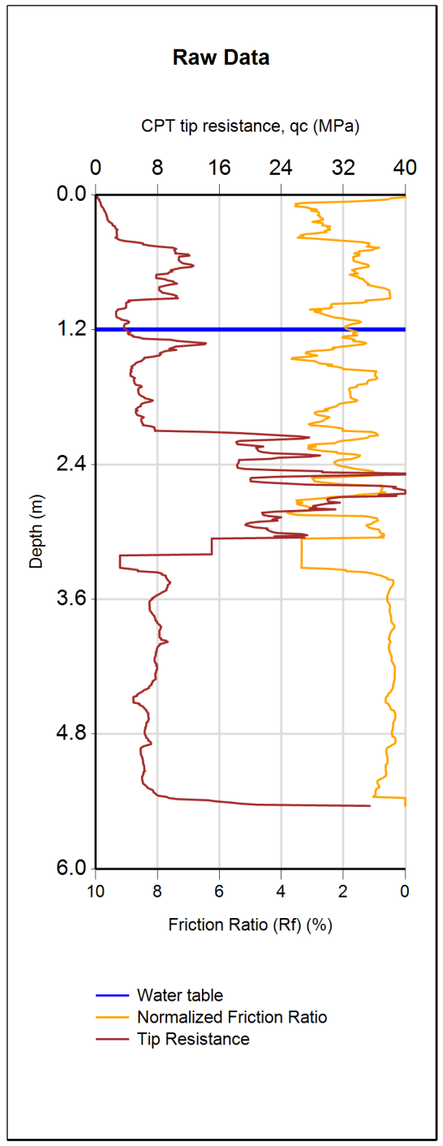


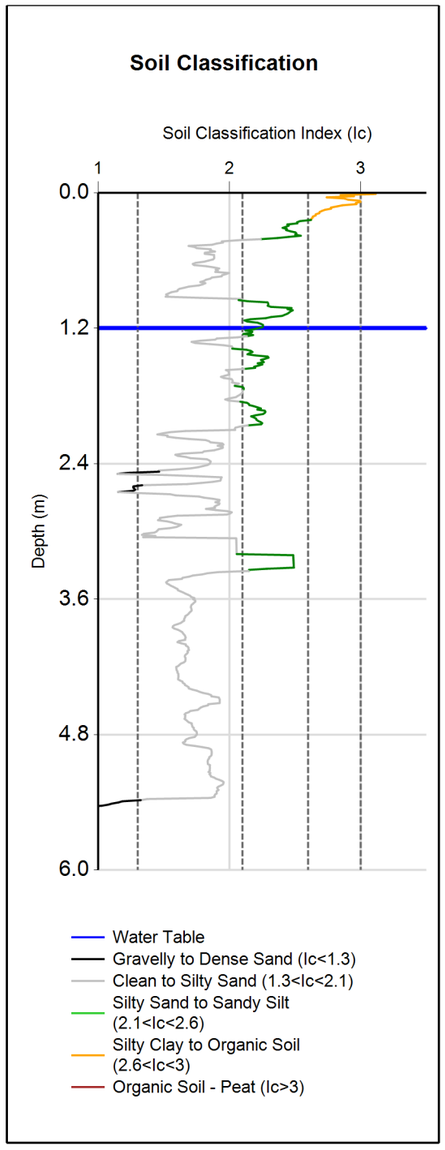


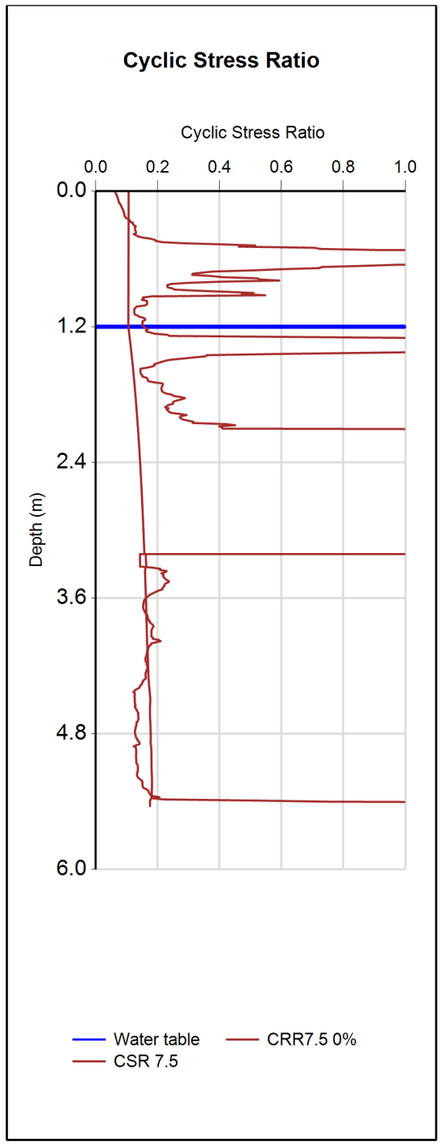
(Assumed pre-drill values)

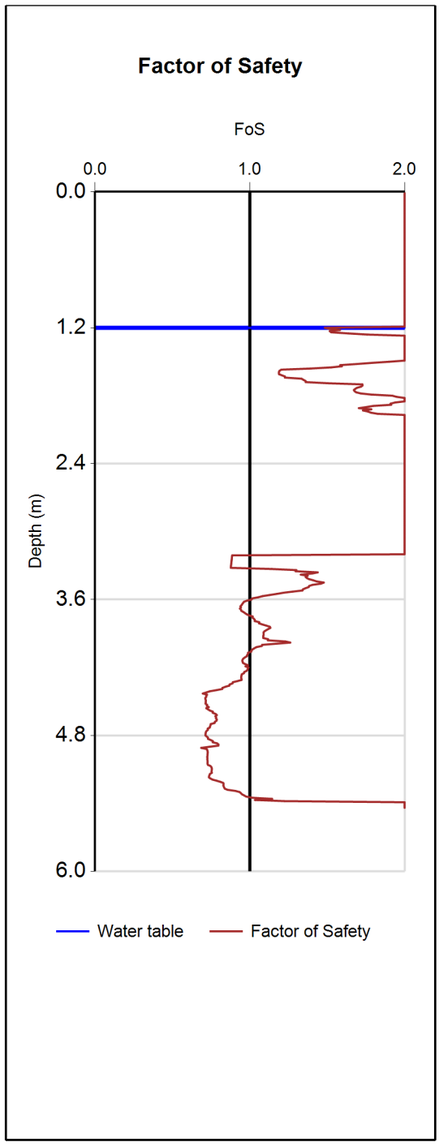
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 19 Tahunanui School - Spliced	42614	20/06/2014	User Specified	7.5	0.09	1.2	IB	ZRB	0	2	0.01	18

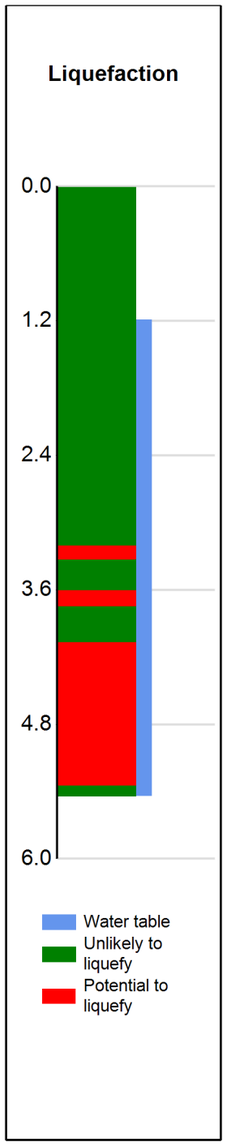
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	2	0	0	1	5.4









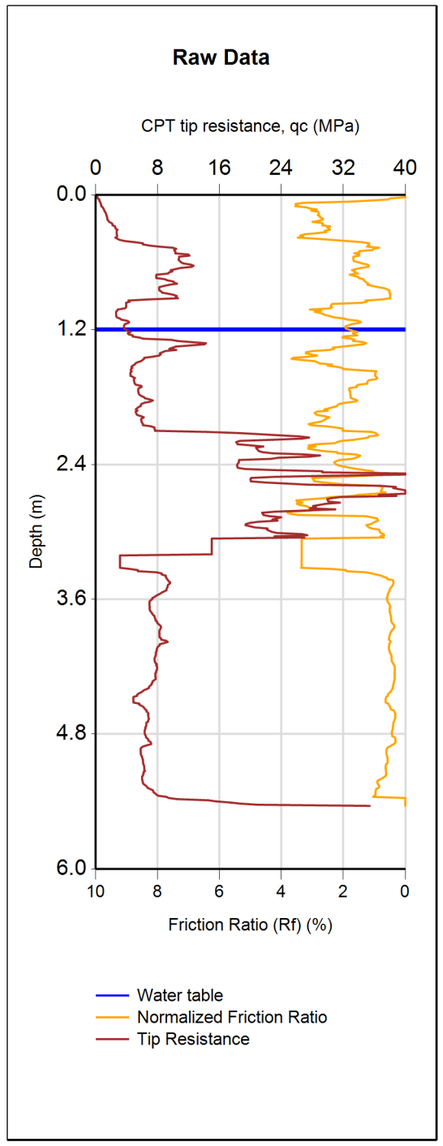


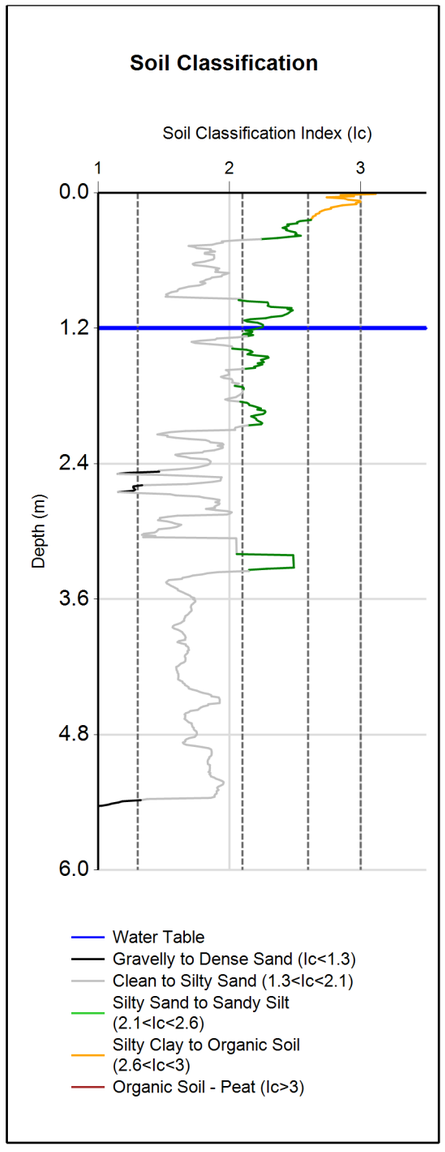
Surcharge used.

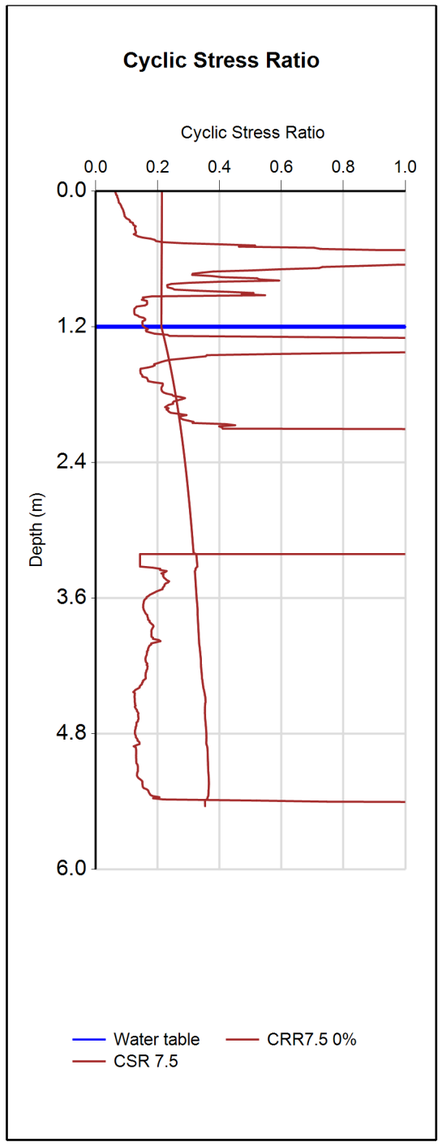
(Assumed pre-drill values)

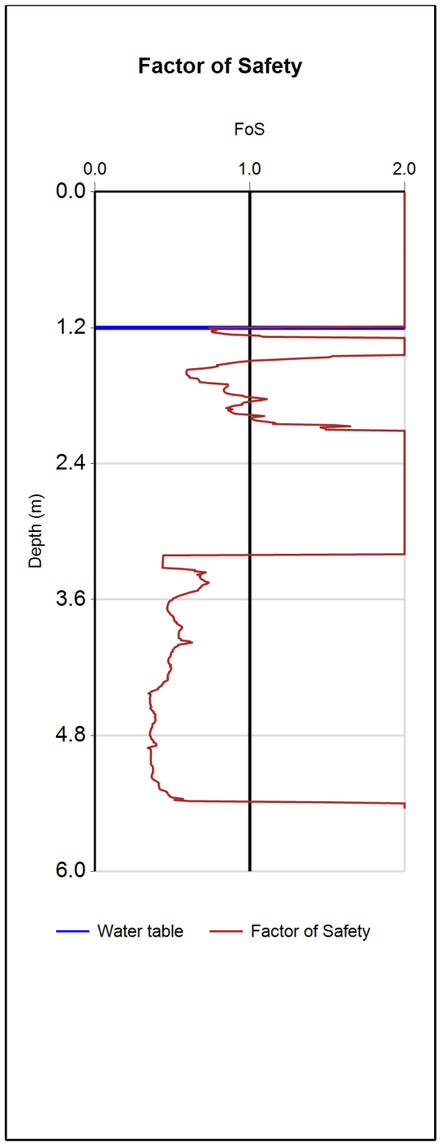
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 19 Tahunanui School - Spliced	42614	20/06/2014	User Specified	7.5	0.179	1.2	IB	ZRB	0	2	0.01	18

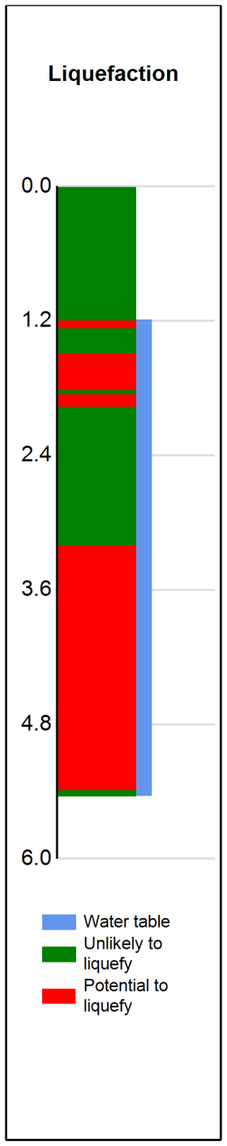
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	33	1.5	2	8	3.3







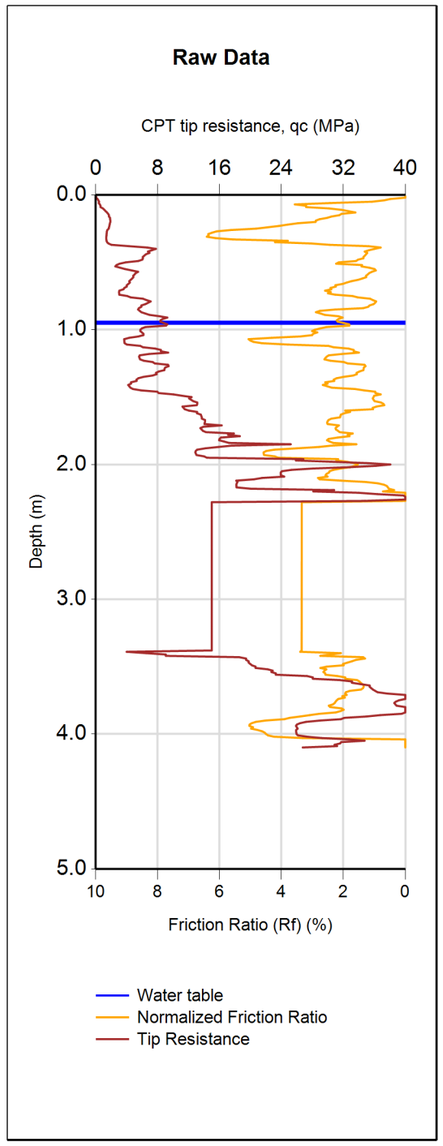


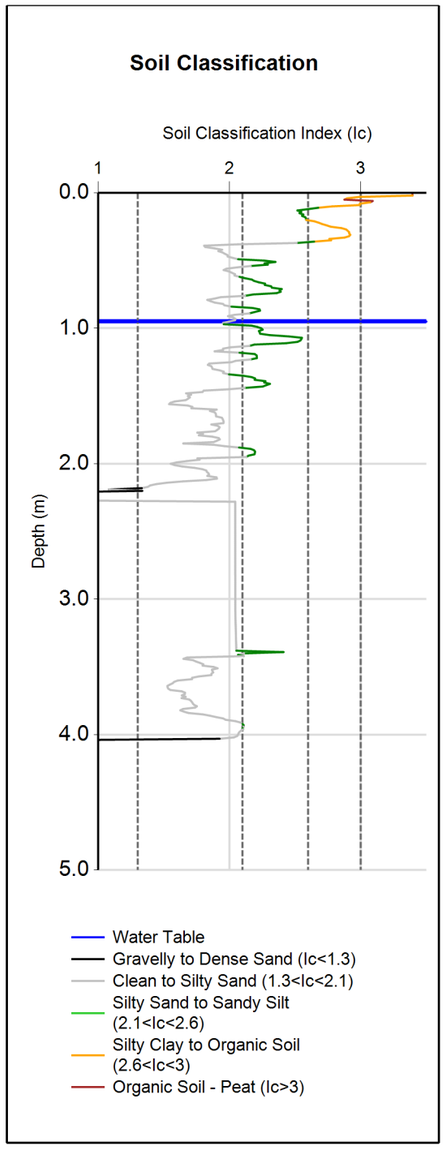


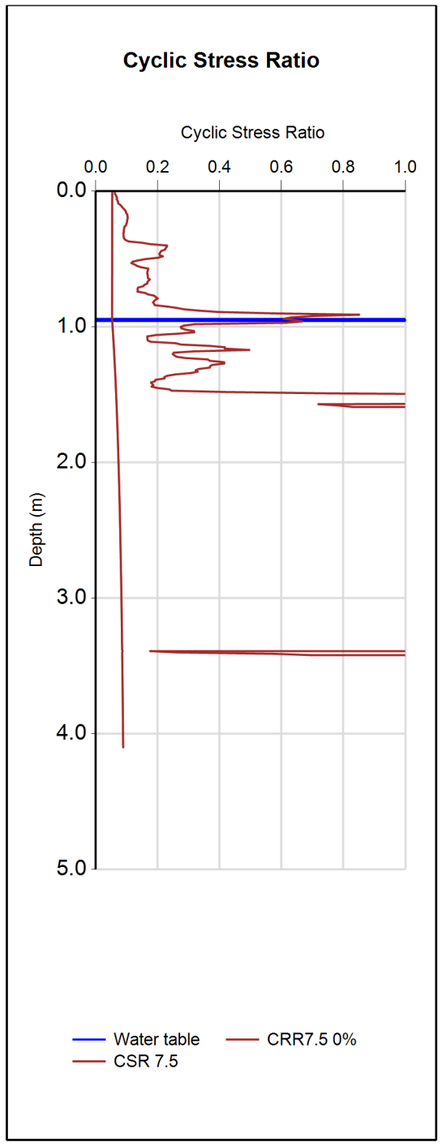
(Assumed pre-drill values)

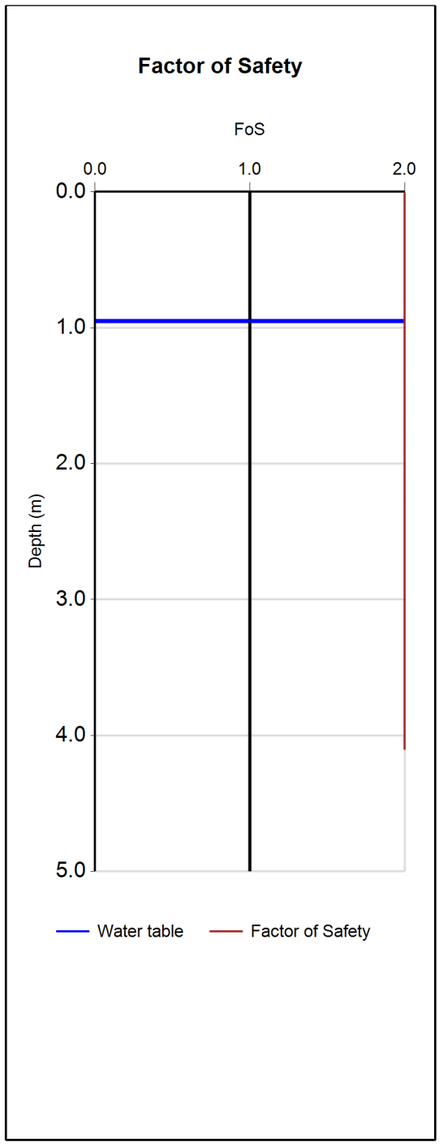
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 19 Tahunanui School - Spliced	42614	20/06/2014	User Specified	7.5	0.36	1.2	IB	ZRB	0	2	0.01	18

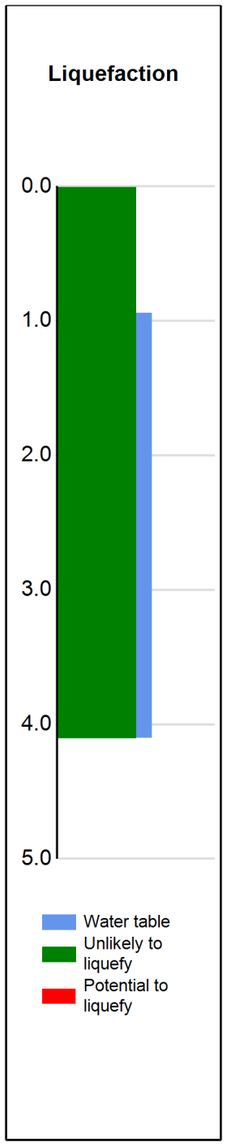
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	57	2.7	10	17	1.5







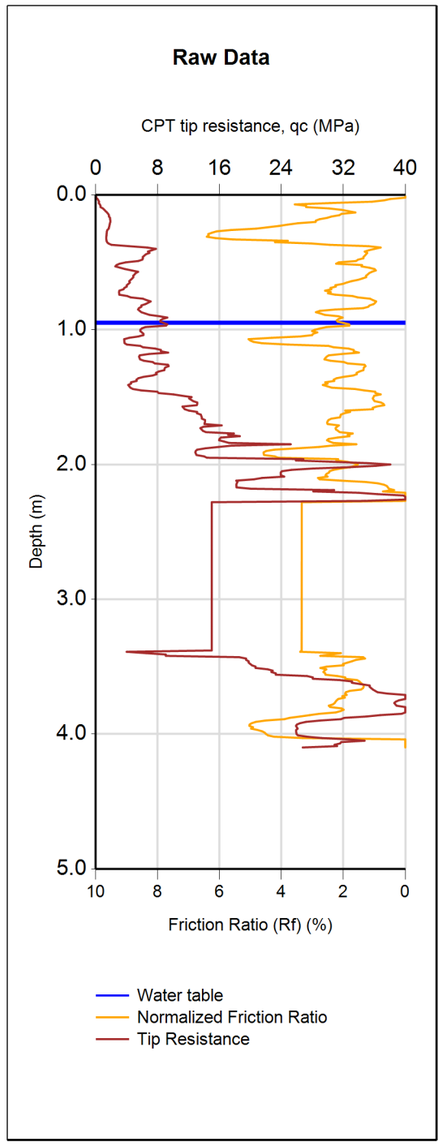


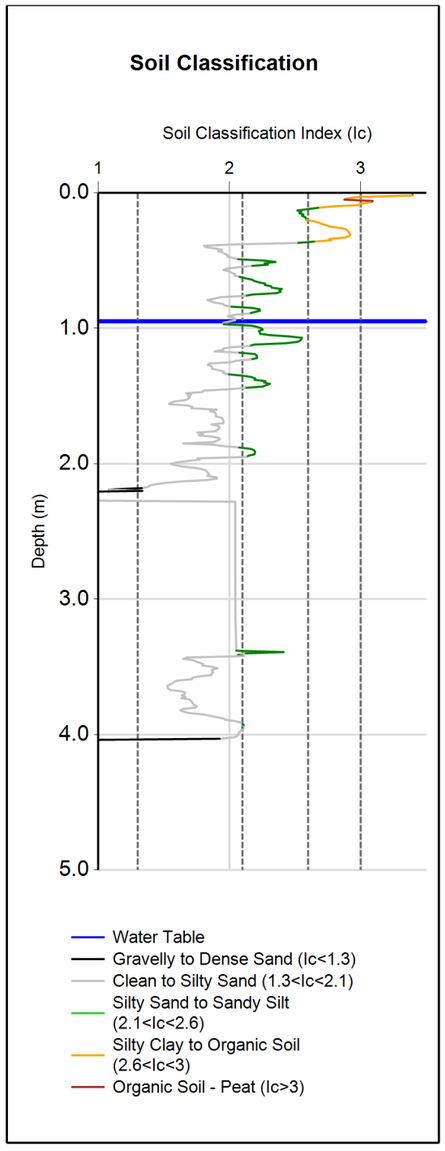


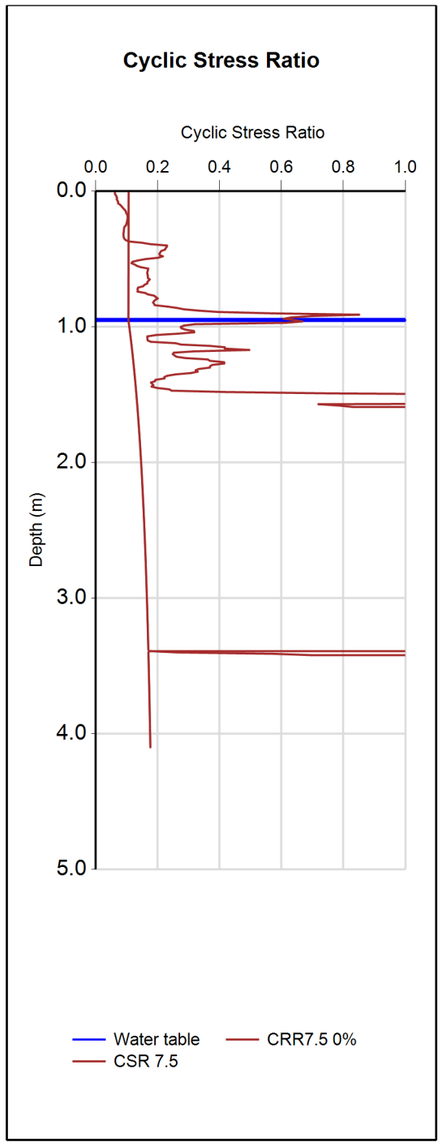
Surcharge used. (Assumed pre-drill values)

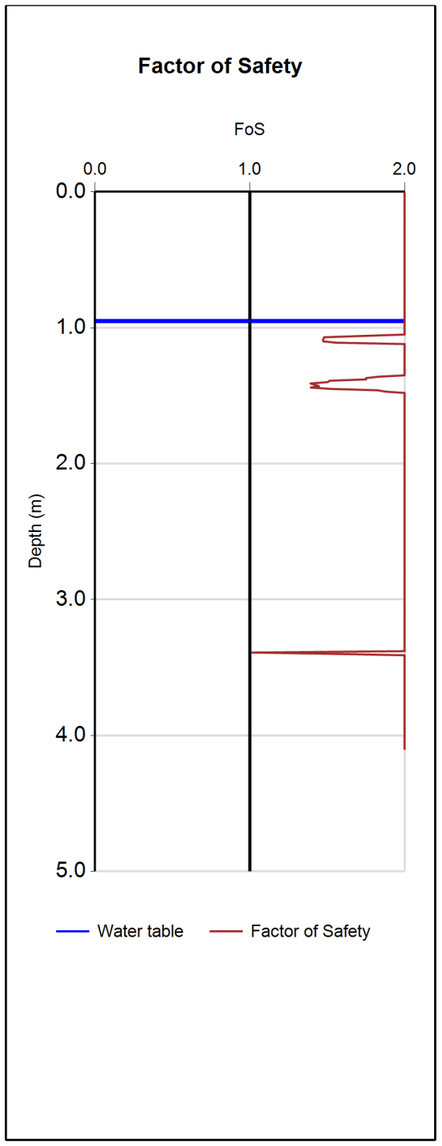
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 20 Tahunanui School - Spliced	42615	20/06/2014	User Specified	7.5	0.09	1.0	IB	ZRB	0	2	0.01	18

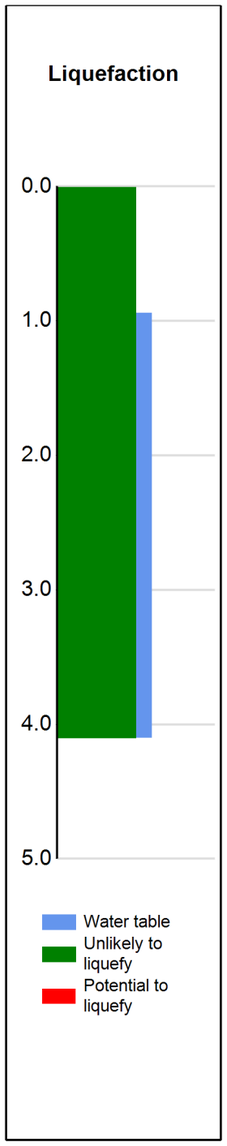
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	0	0	0	0	4.1









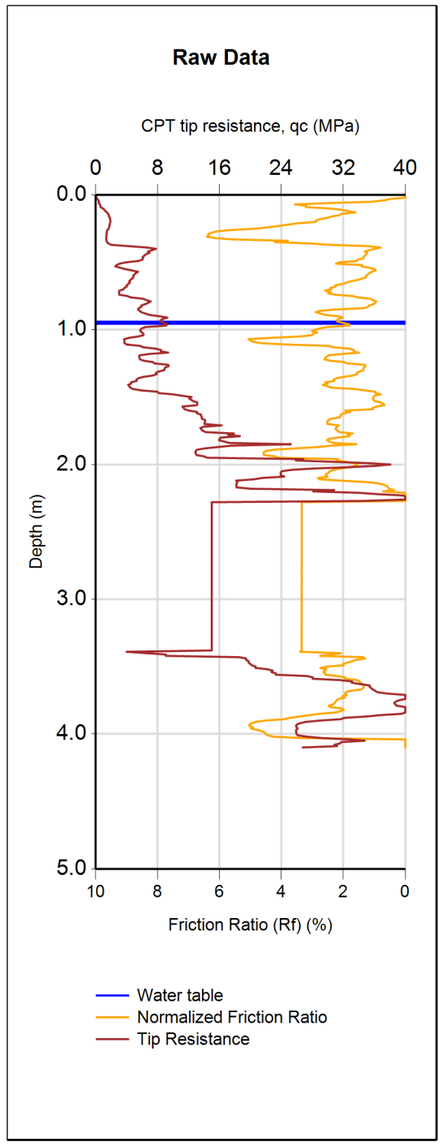


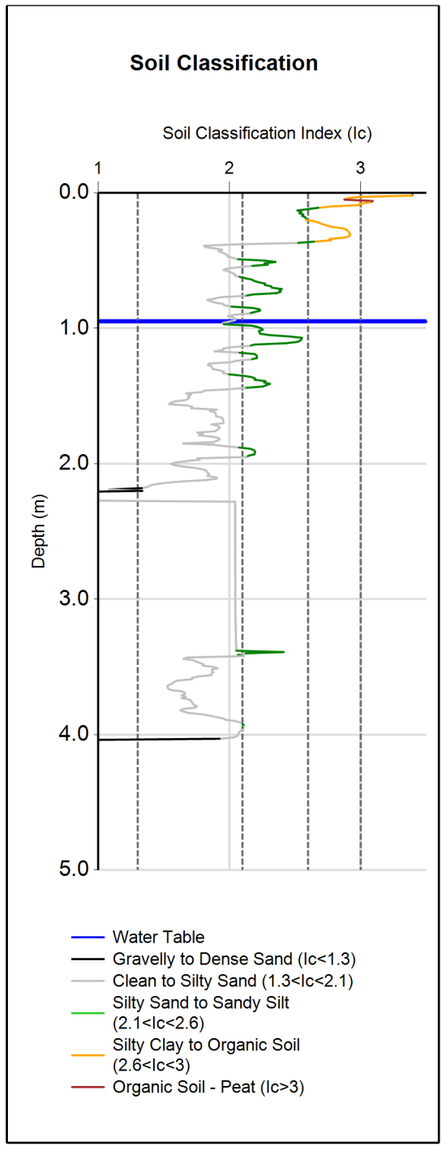
Surcharge used.

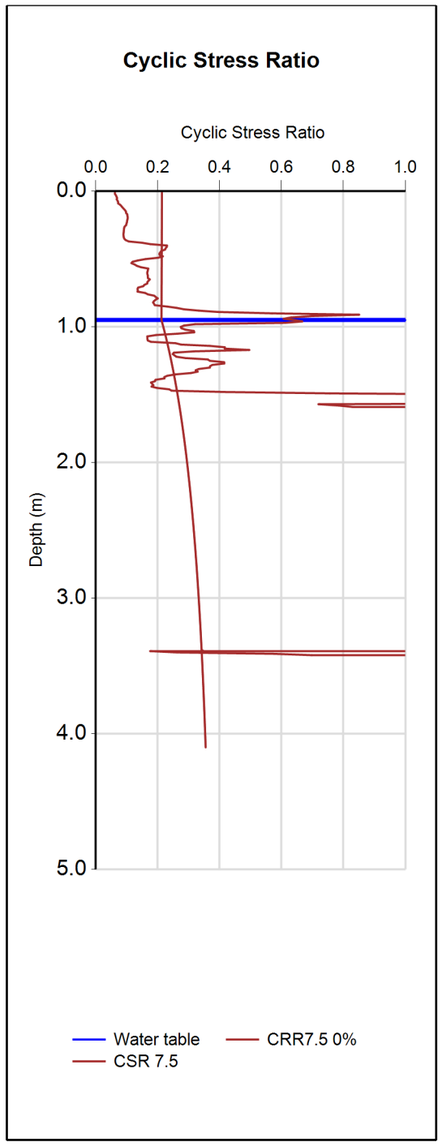
(Assumed pre-drill values)

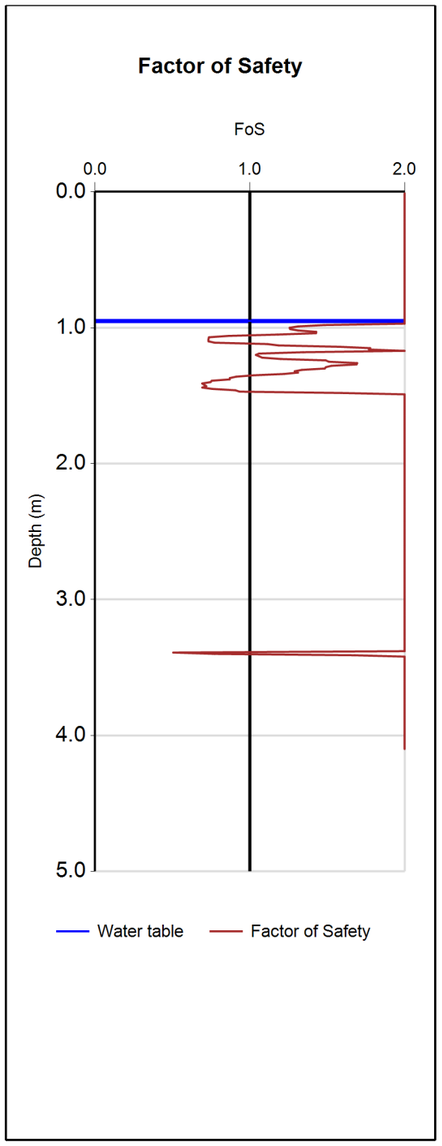
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 20 Tahunanui School - Spliced	42615	20/06/2014	User Specified	7.5	0.179	1.0	IB	ZRB	0	2	0.01	18

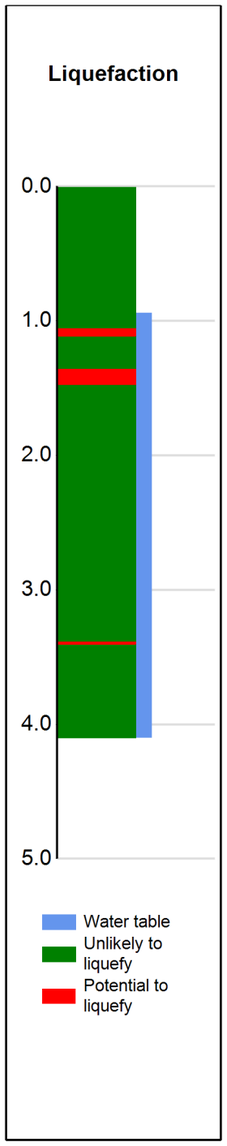
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	0	0	0	0	4.1









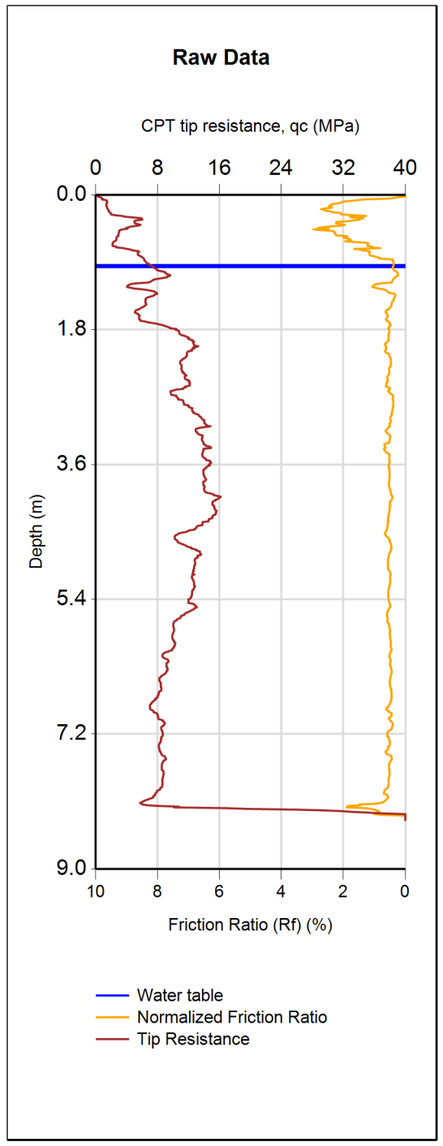


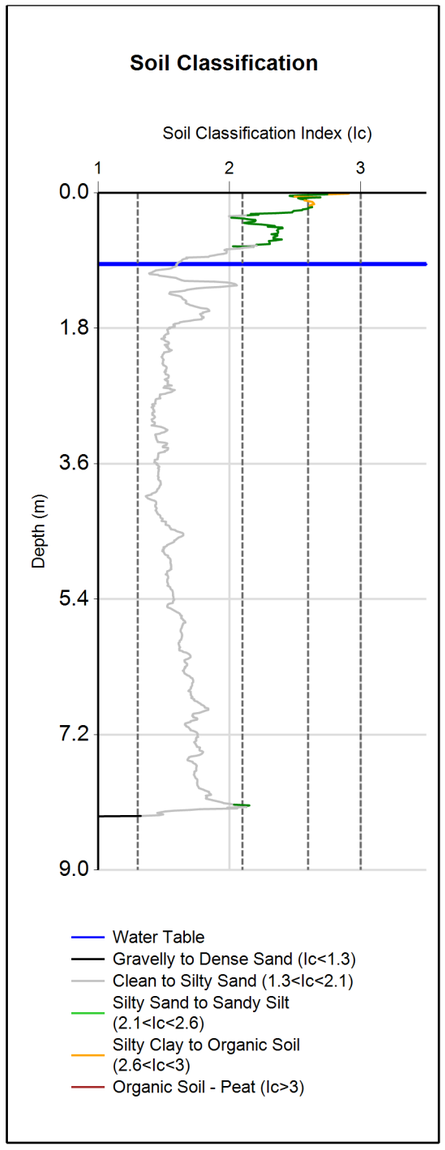
Surcharge used.

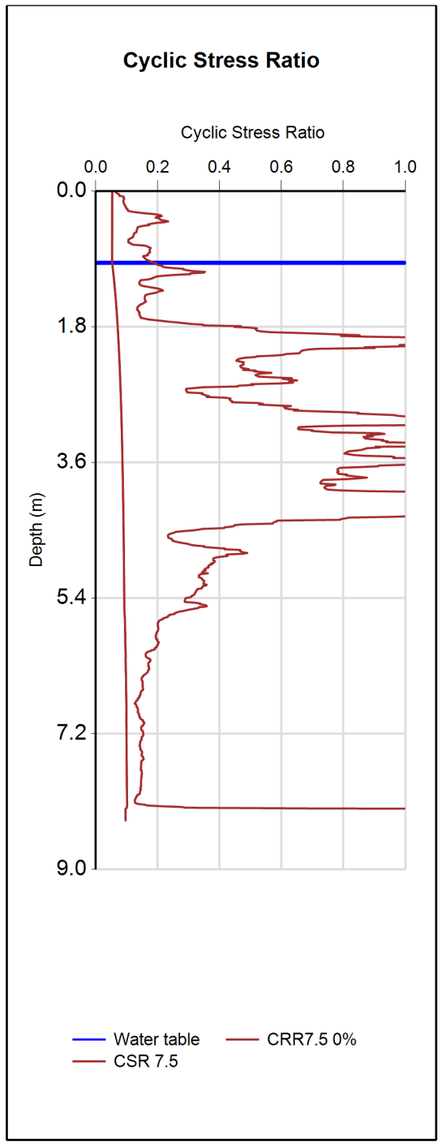
(Assumed pre-drill values)

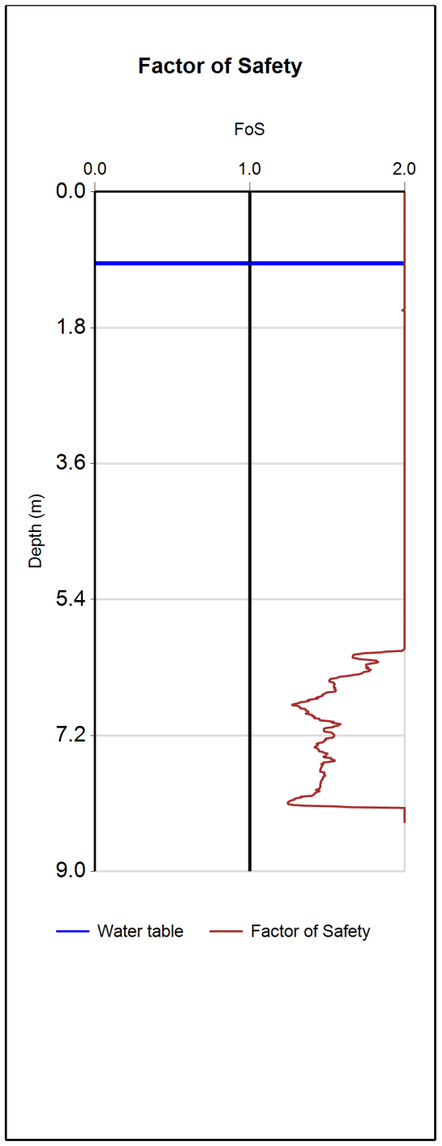
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 20 Tahunanui School - Spliced	42615	20/06/2014	User Specified	7.5	0.36	1.0	IB	ZRB	0	2	0.01	18

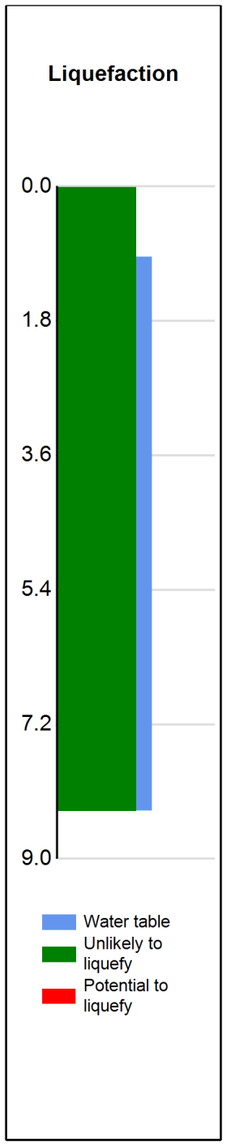
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	4	0.2	0	3	1.4









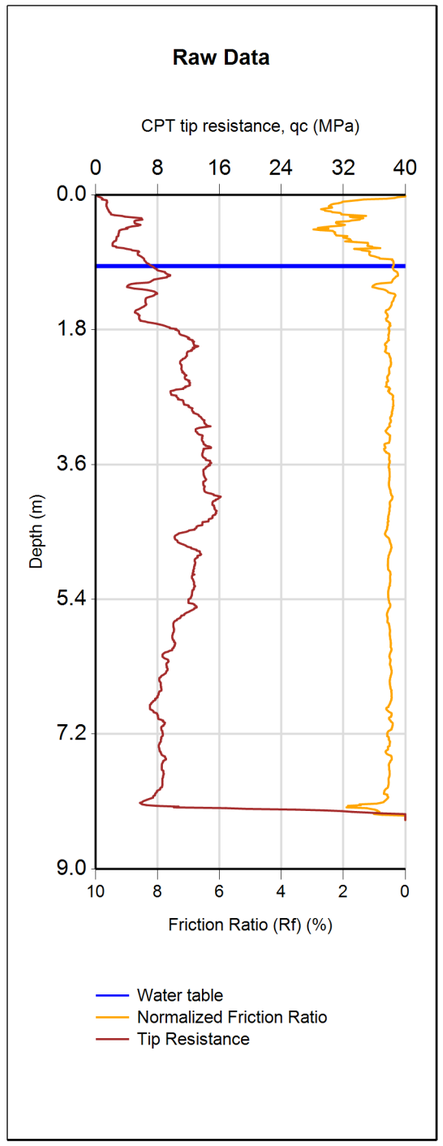


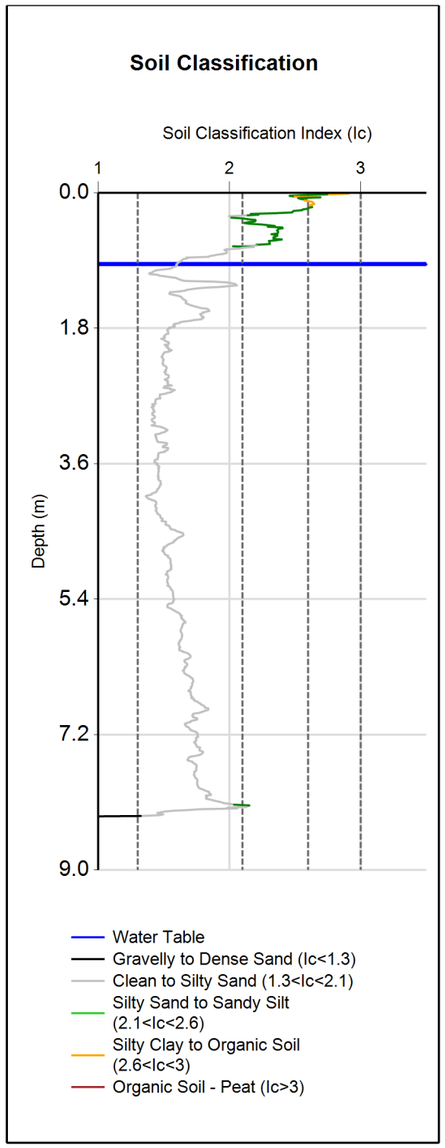
Surcharge used.

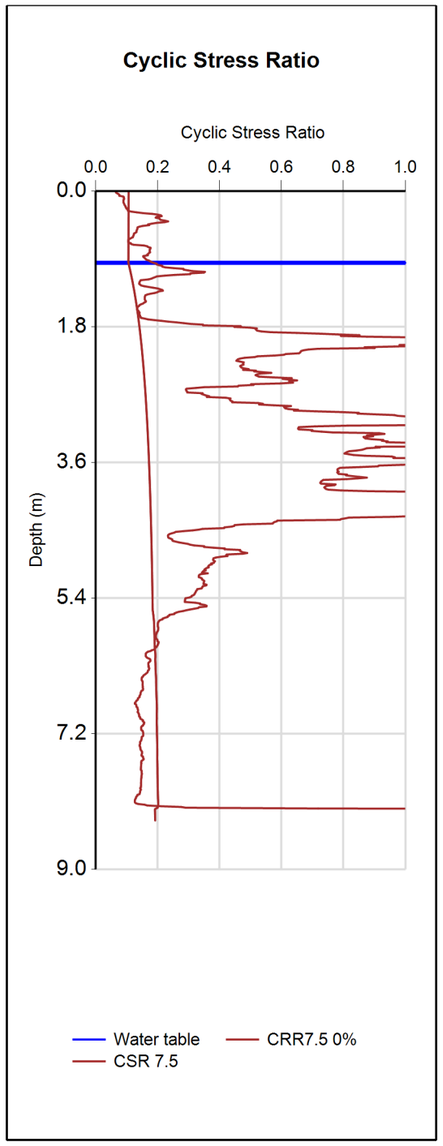
(Assumed pre-drill values)

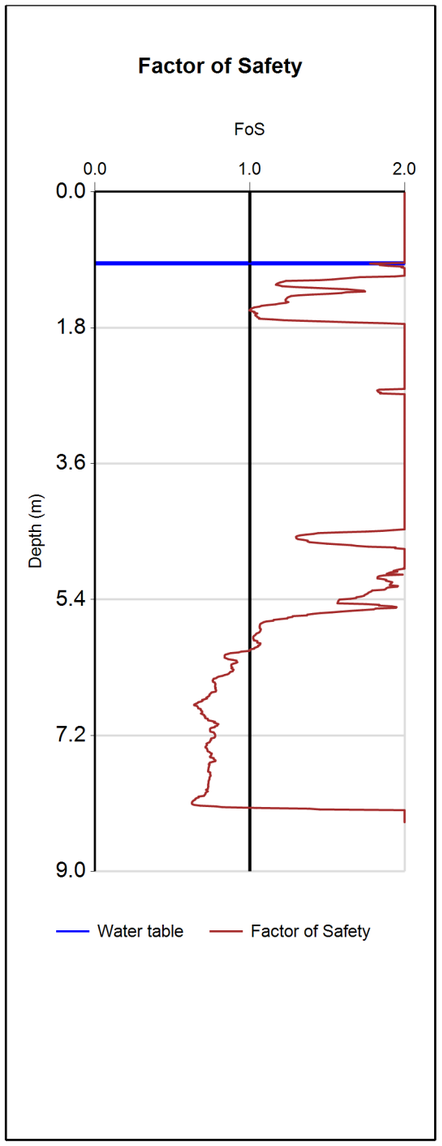
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 21 - 16-06 -14_02TT7	42437	20/06/2014	User Specified	7.5	0.09	1.0	IB	ZRB	0	2	0.01	18

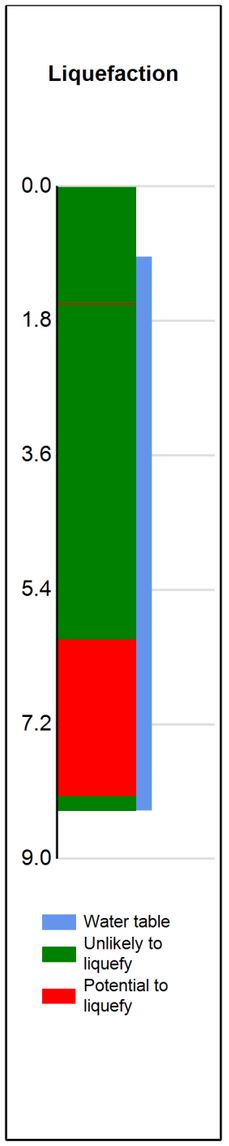
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	4	0	0	1	8.4







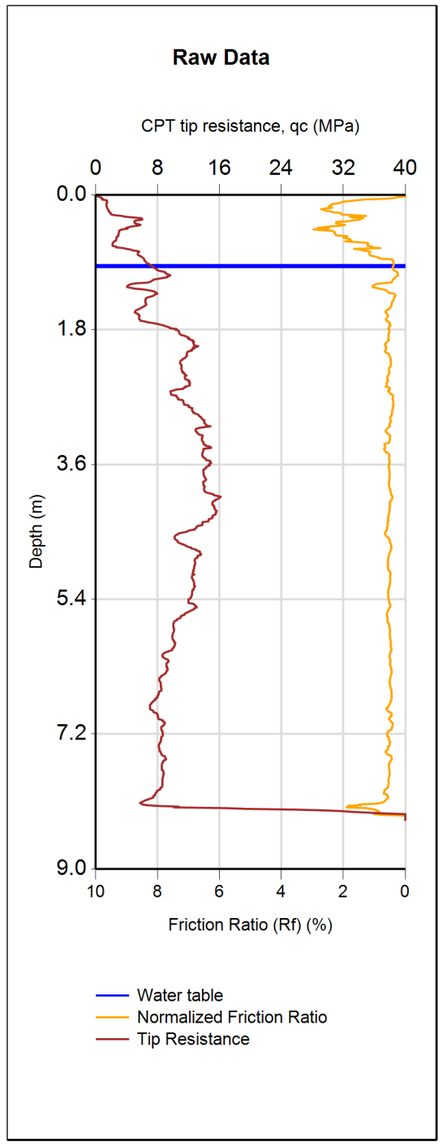


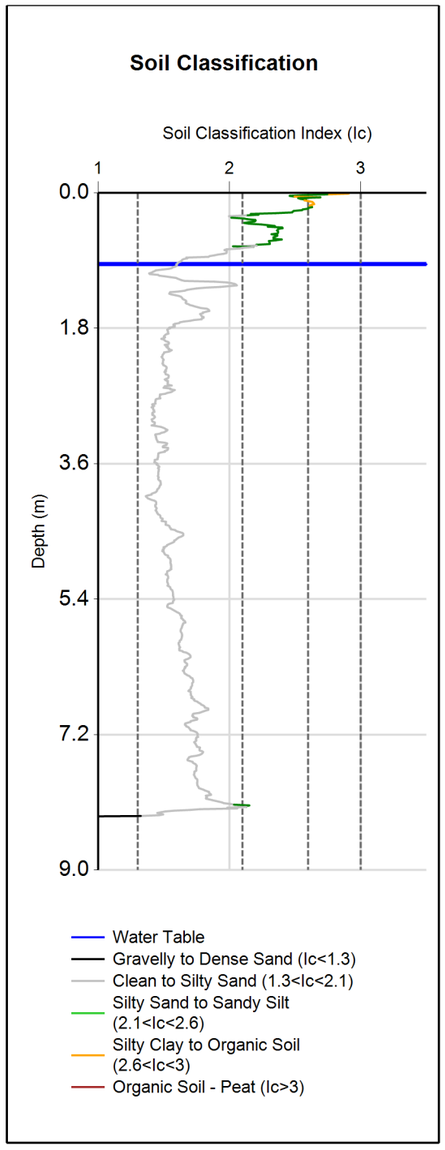


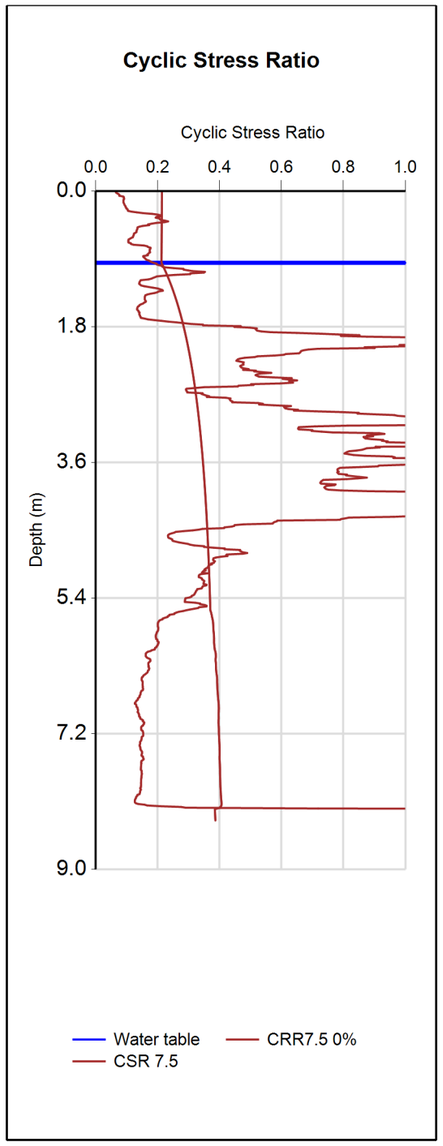
(Assumed pre-drill values)

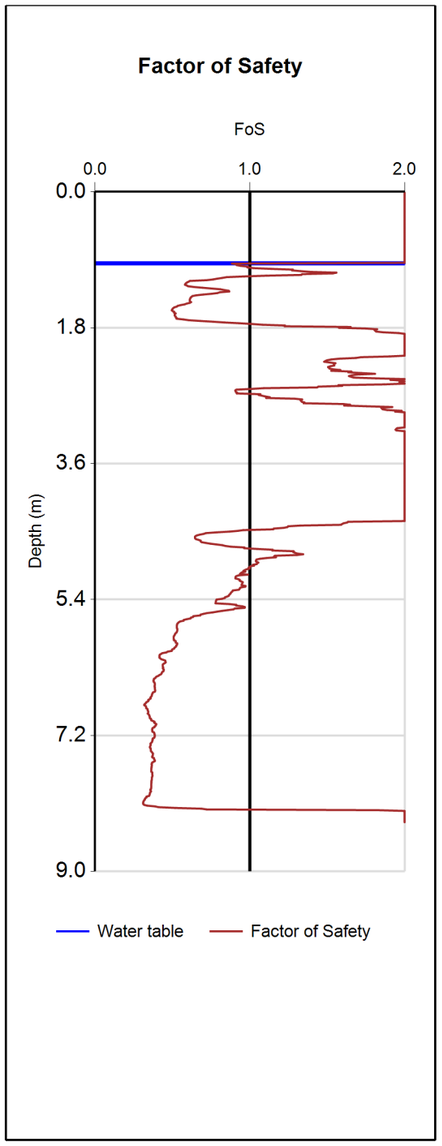
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 21 - 16-06 -14_02TT7	42437	20/06/2014	User Specified	7.5	0.179	1.0	IB	ZRB	0	2	0.01	18

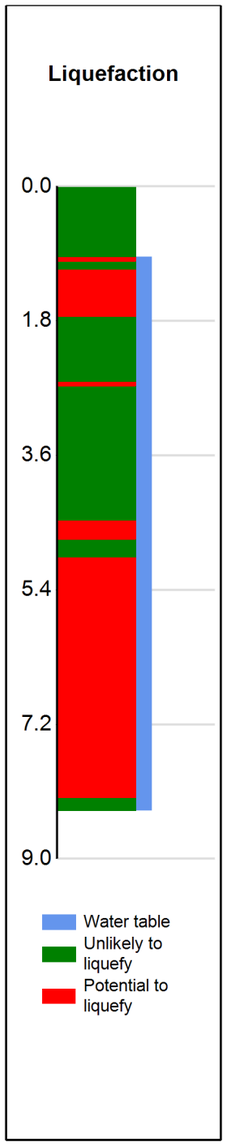
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	49	2.1	3	8	6.2









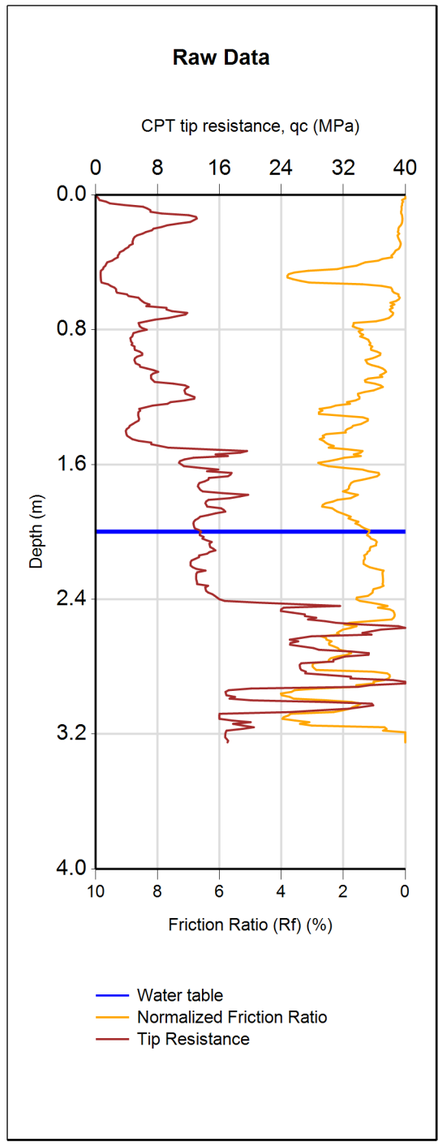


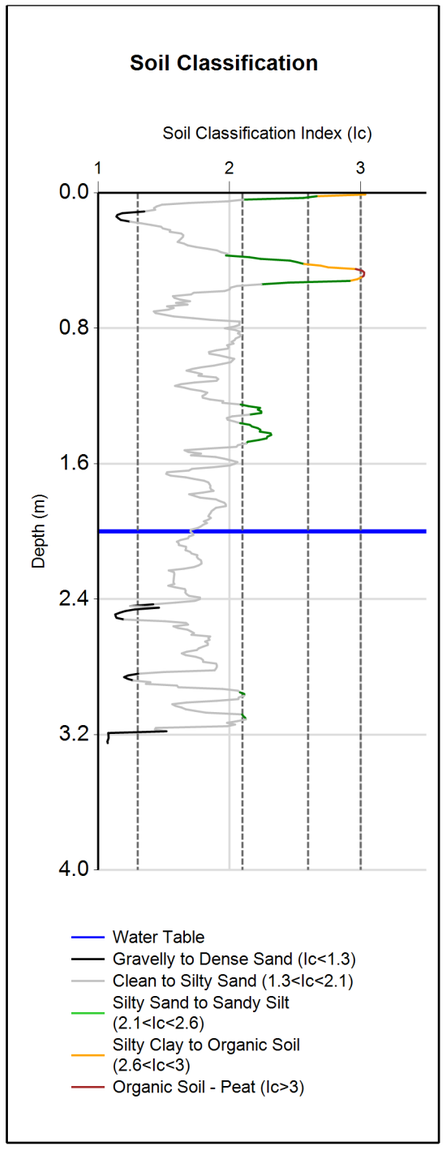
Surcharge used.

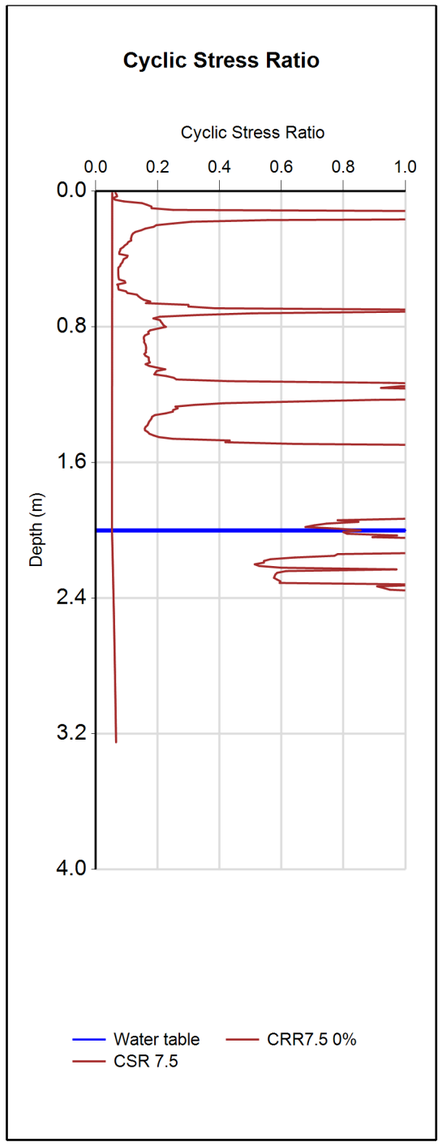
(Assumed pre-drill values)

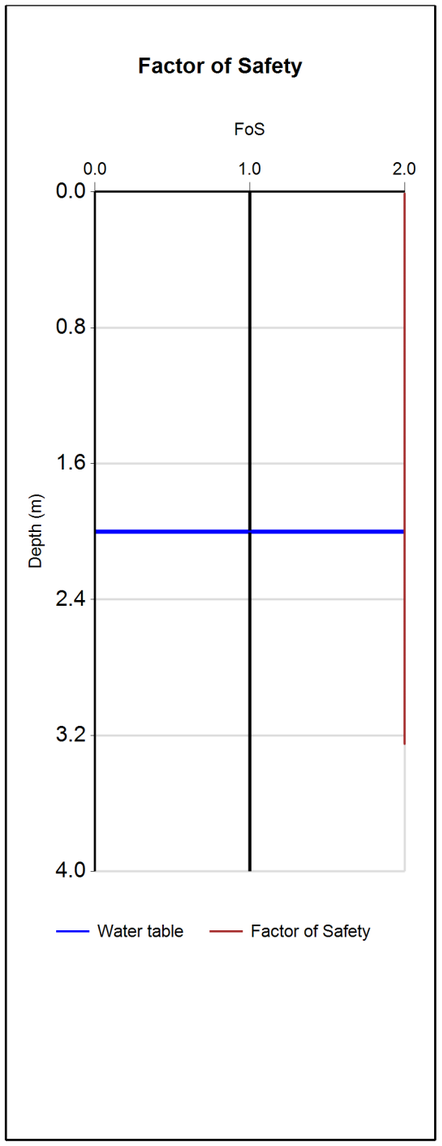
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 21 - 16-06 -14_02TT7	42437	20/06/2014	User Specified	7.5	0.36	1.0	IB	ZRB	0	2	0.01	18

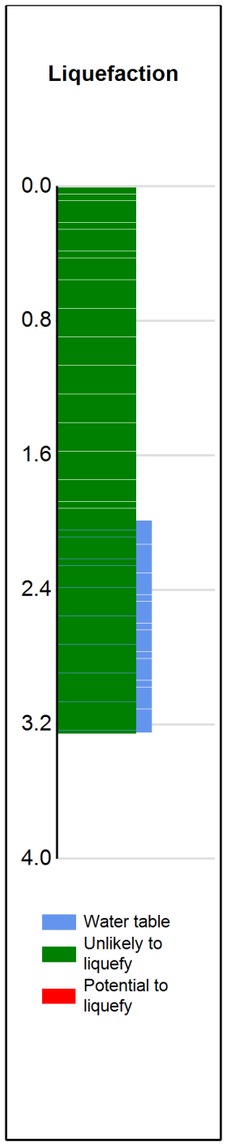
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	81	4.2	13	21	1.2









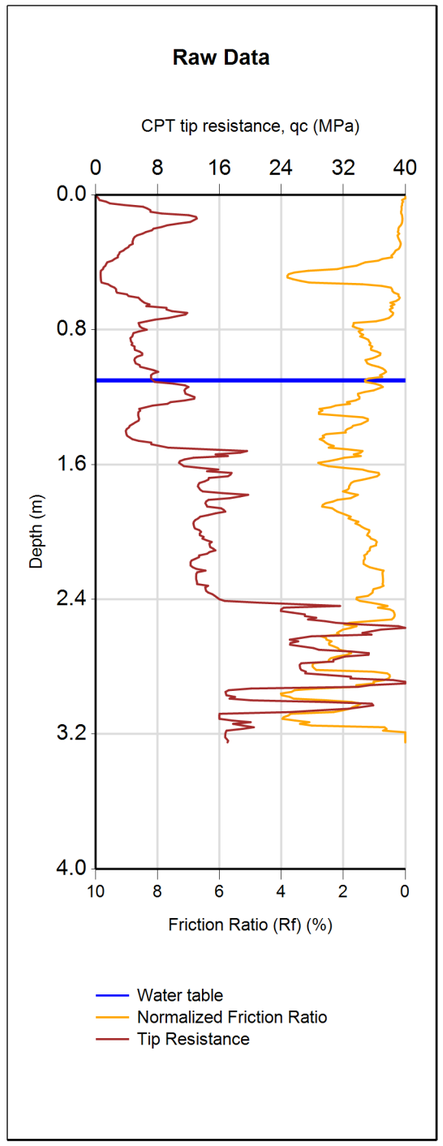


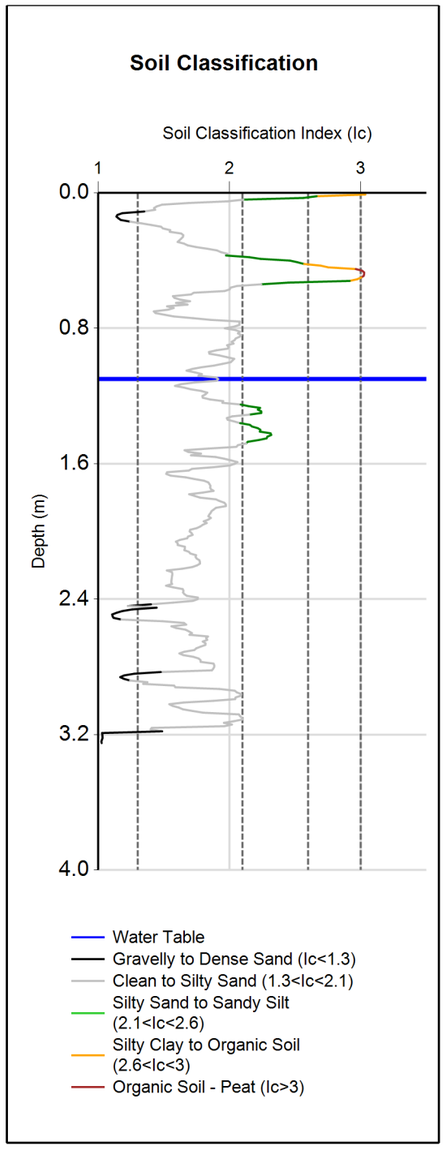
Surcharge used.

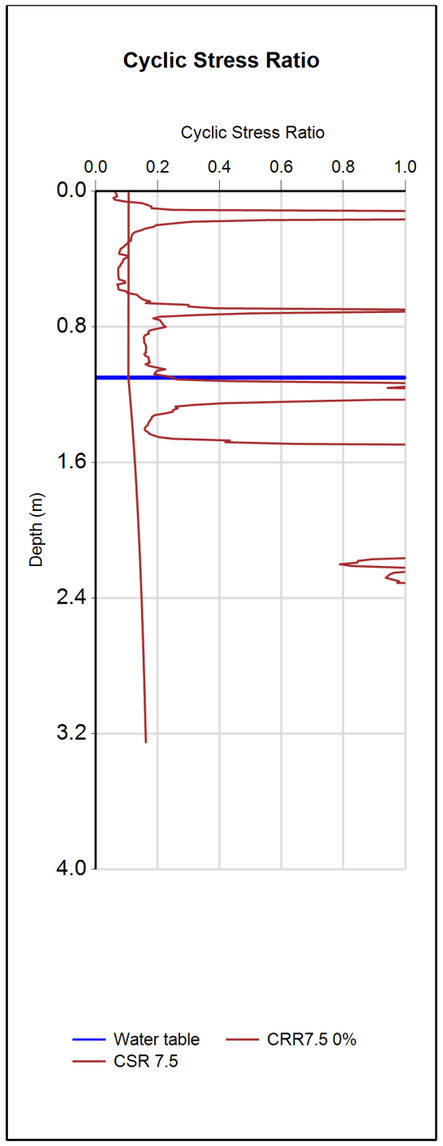
(Assumed pre-drill values)

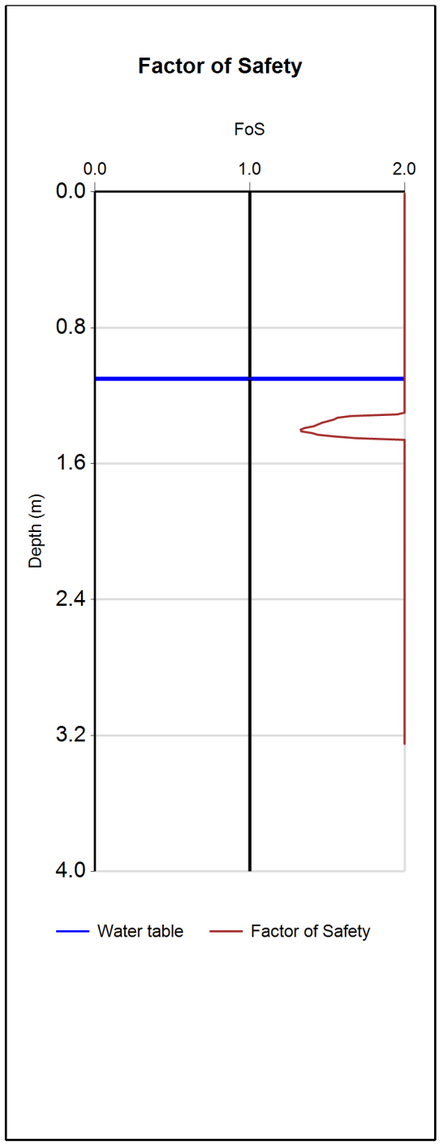
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 22 - 20-06 -14_02TT16	42442	20/06/2014	User Specified	7.5	0.09	2.0	IB	ZRB	0	2	0.01	18

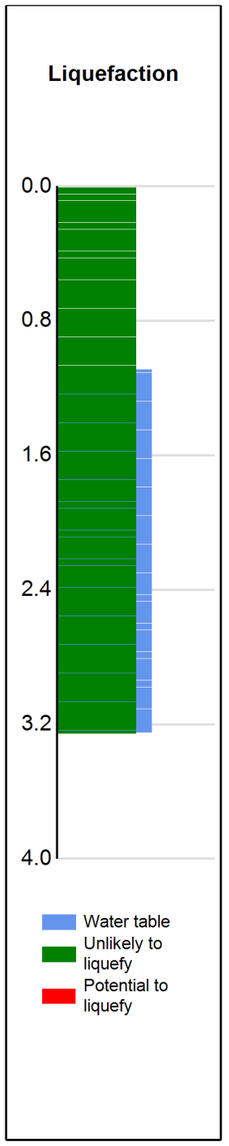
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	0	0	0	0	3.2











(Assumed pre-drill values)

	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 22 - 20-06 -14_02TT16	42442	20/06/2014	User Specified	7.5	0.179	1.1	IB	ZRB	0	2	0.01	18

	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	0	0	0	0	3.2

Tonkin & Taylor	Tonkin & Taylor Environmental and Engineering consultants V1.2	CLIENT, PROJECT **Nelson City Council** **Tahunanui Liquefaction**	LOCATION Nelson	DATE	10/07/2014
				ANALYSED	mjl
		TITLE **Stage 2**	JOB NUMBER **871023**	CHECKED	
				PAGE	1 of 4 pages

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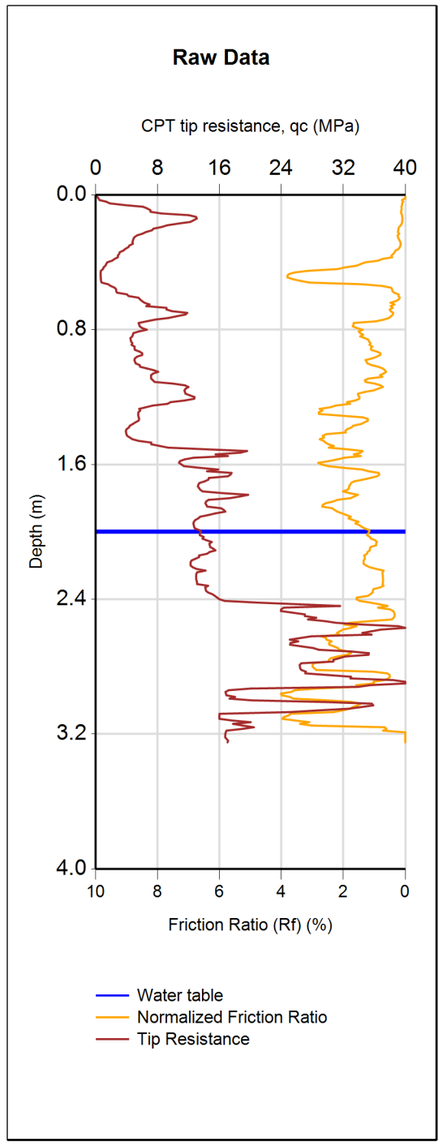
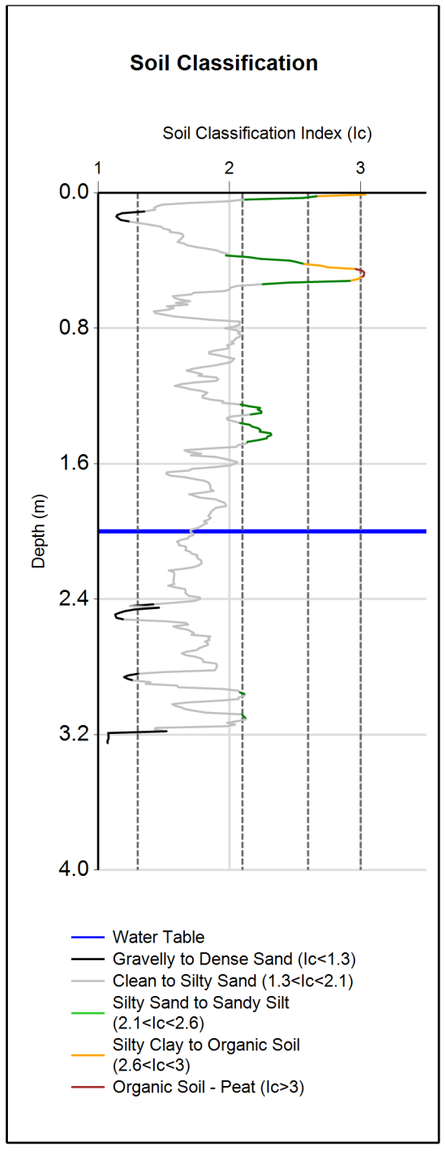
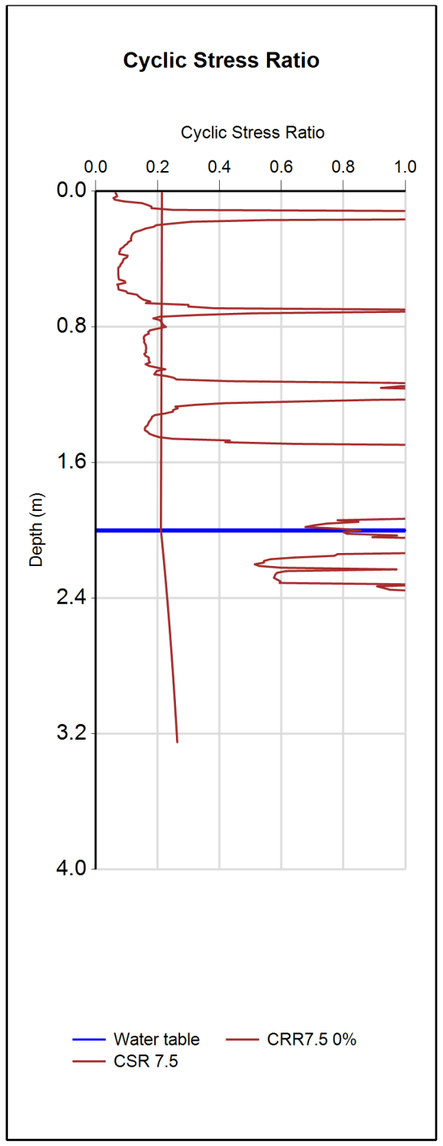
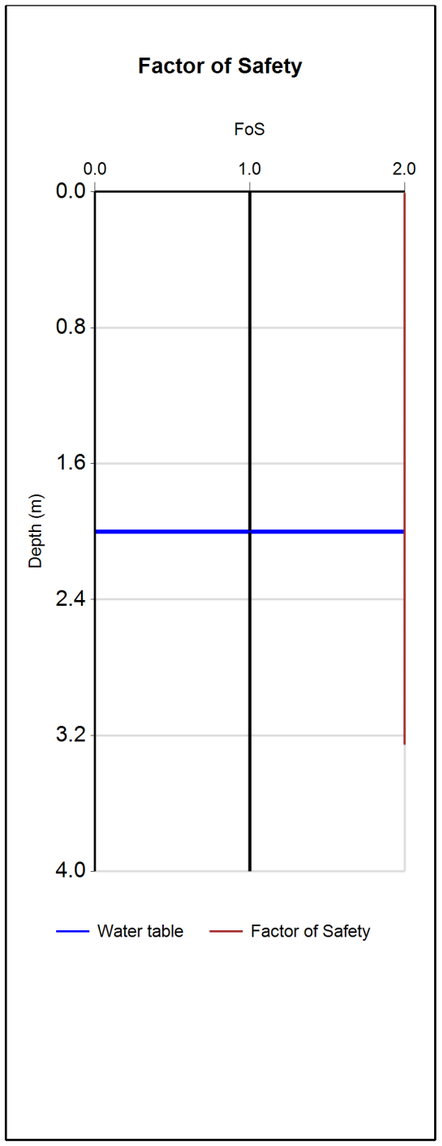
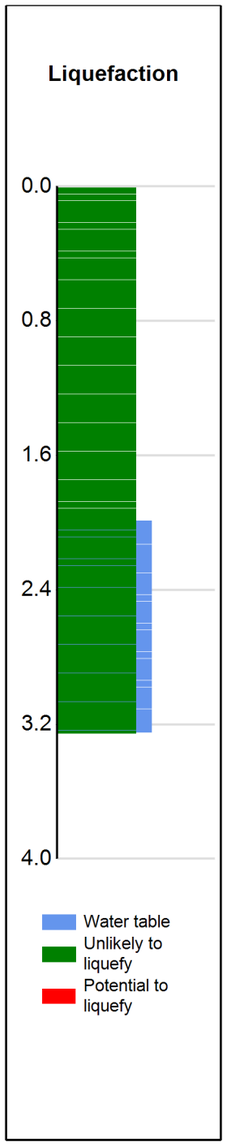








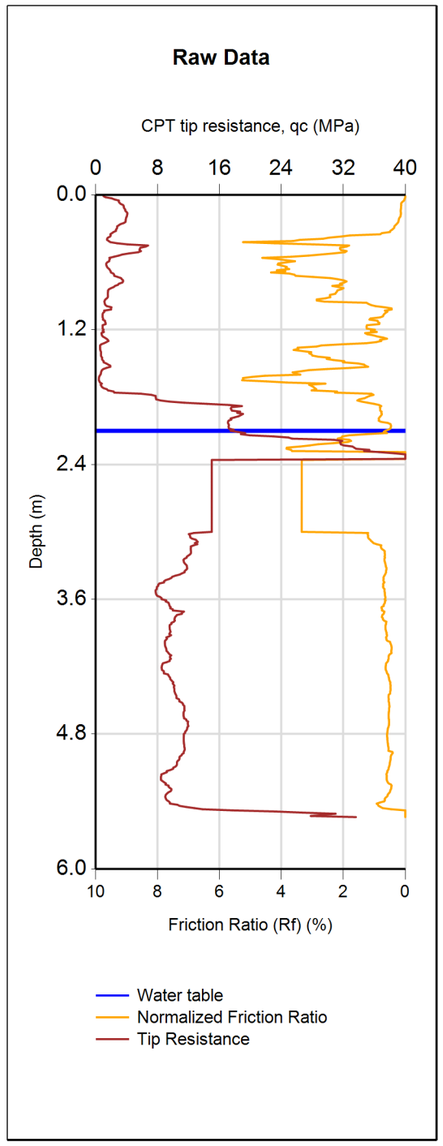


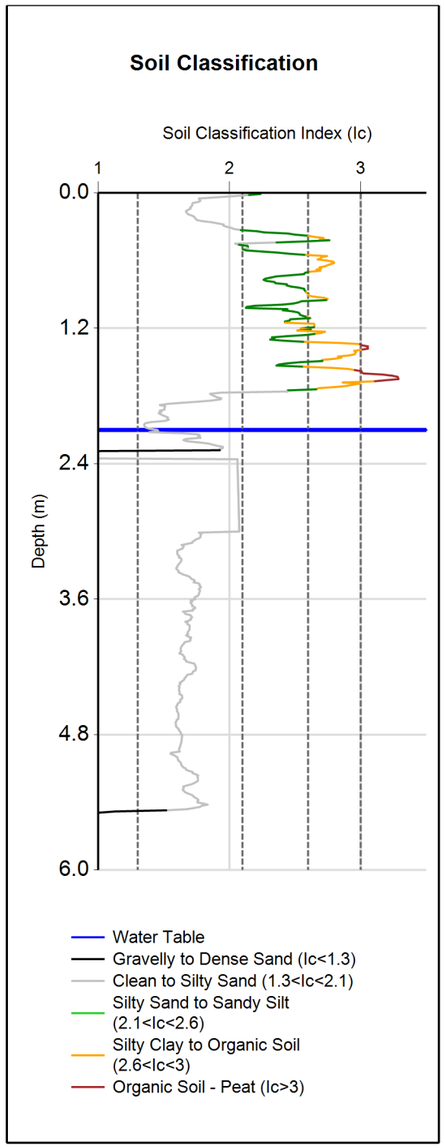
Surcharge used.

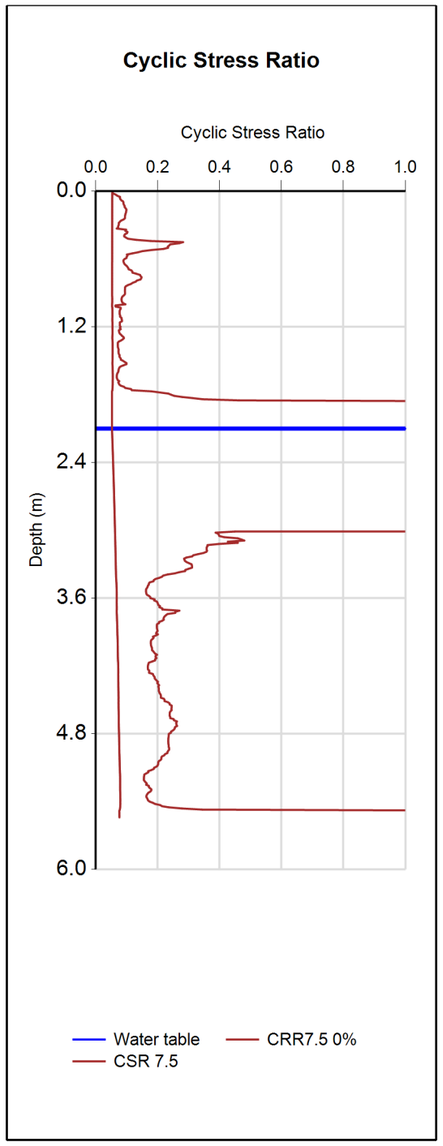
(Assumed pre-drill values)

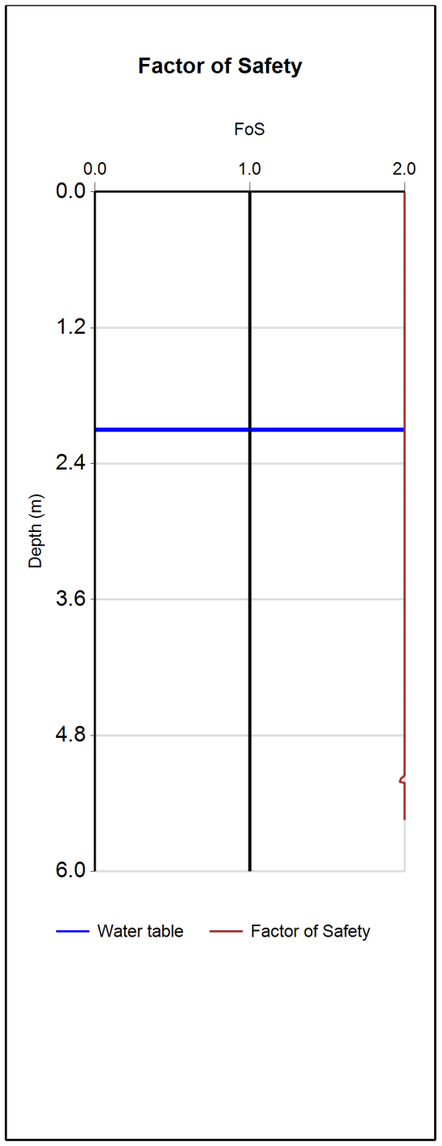
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 22 - 20-06 -14_02TT16	42442	20/06/2014	User Specified	7.5	0.36	2.0	IB	ZRB	0	2	0.01	18

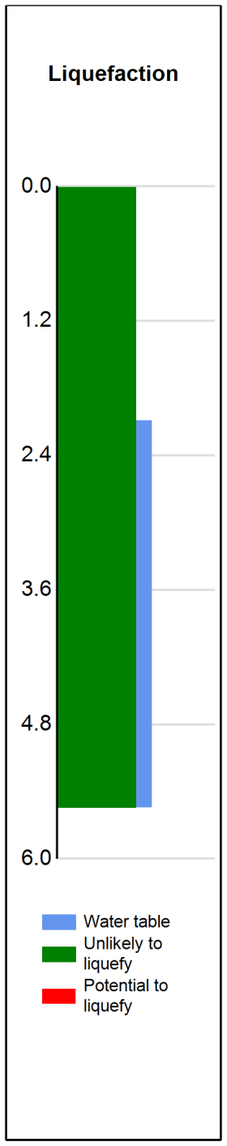
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	0	0	0	0	3.2







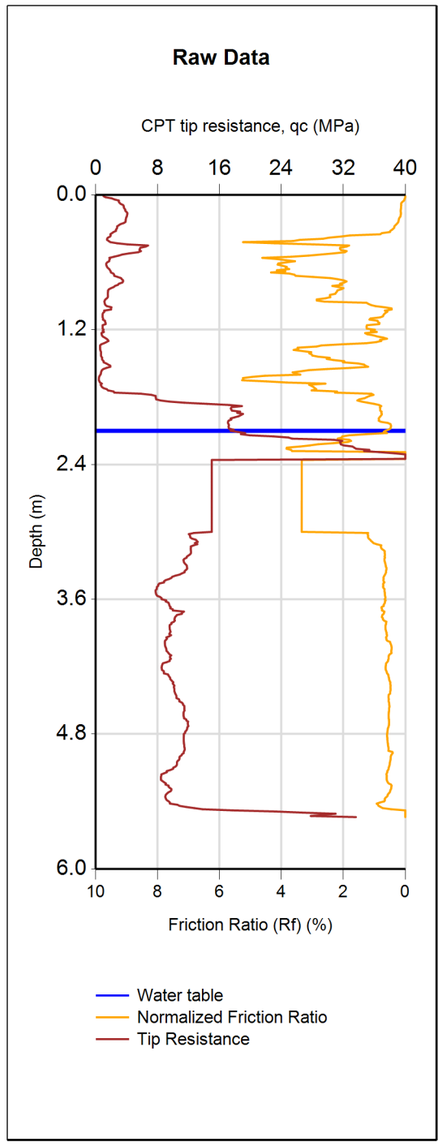


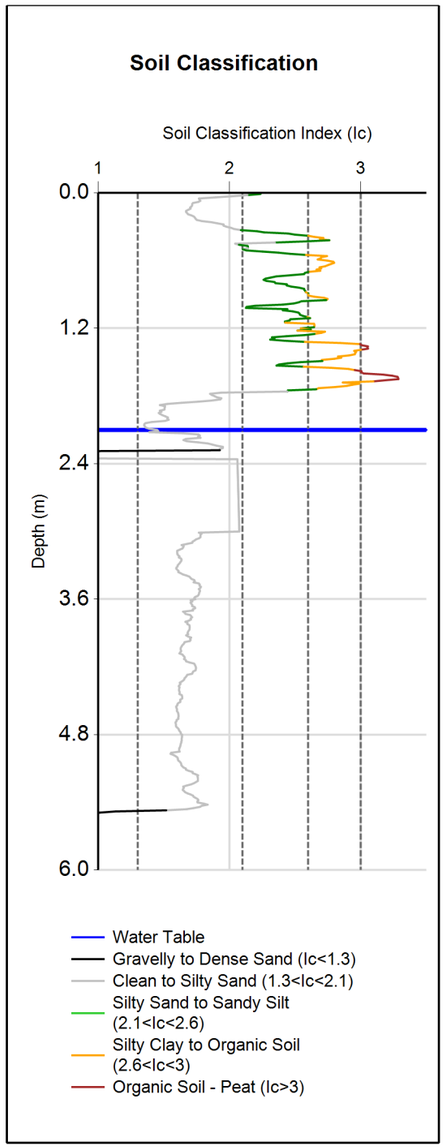


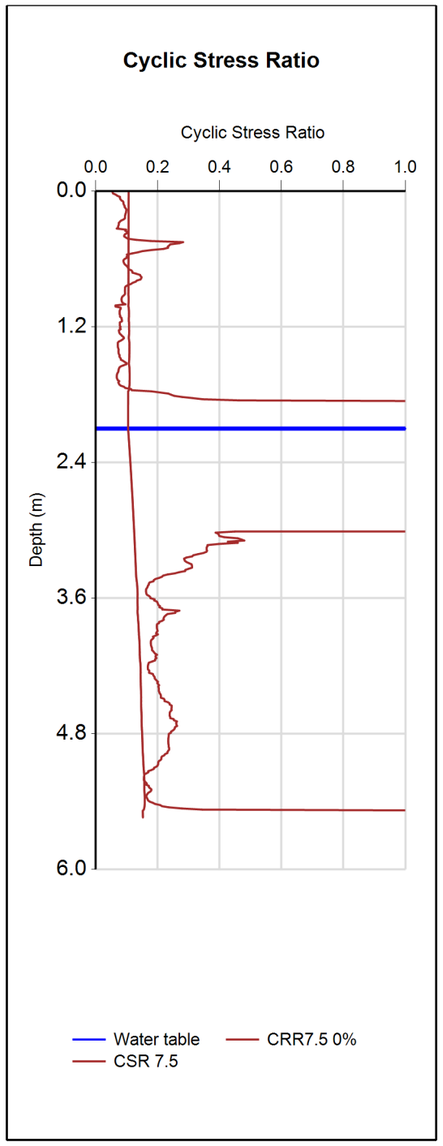
(Assumed pre-drill values)

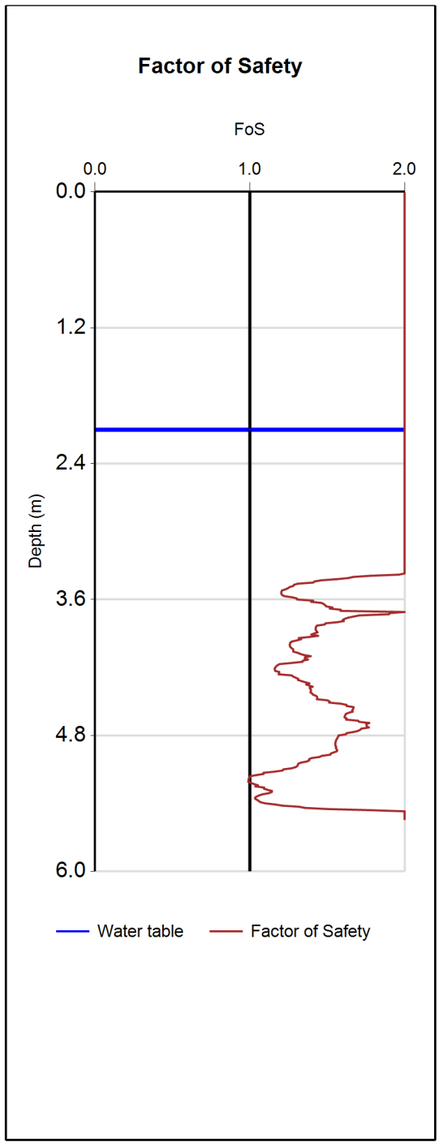
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	γ (kN/m³)
INPUT:	CPT 23 - Spliced	42616	20/06/2014	User Specified	7.5	0.09	2.1	IB	ZRB	0	2	0.01	18

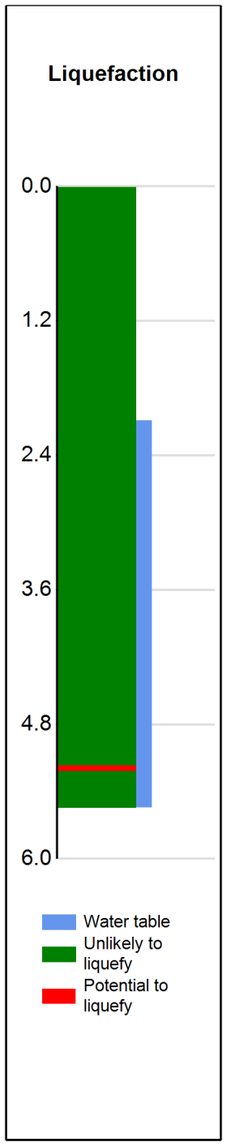
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	0	0	0	0	5.5







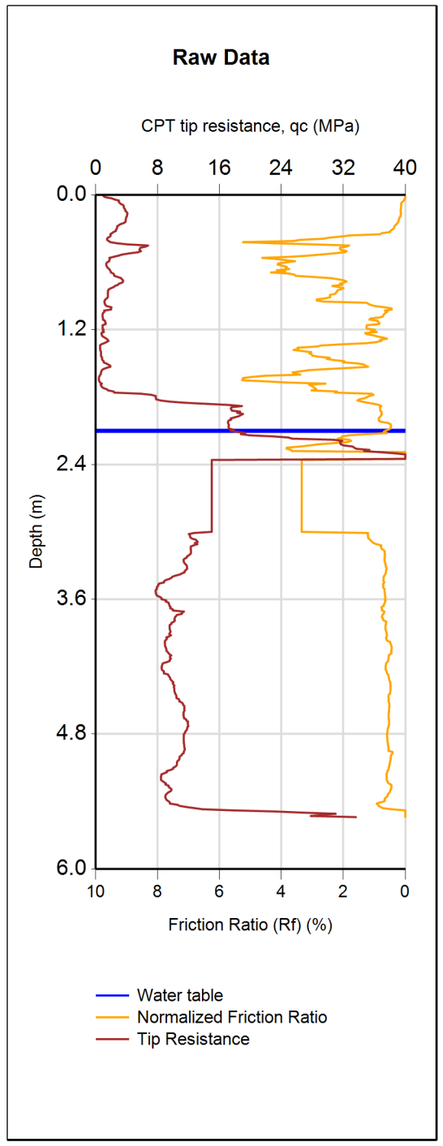


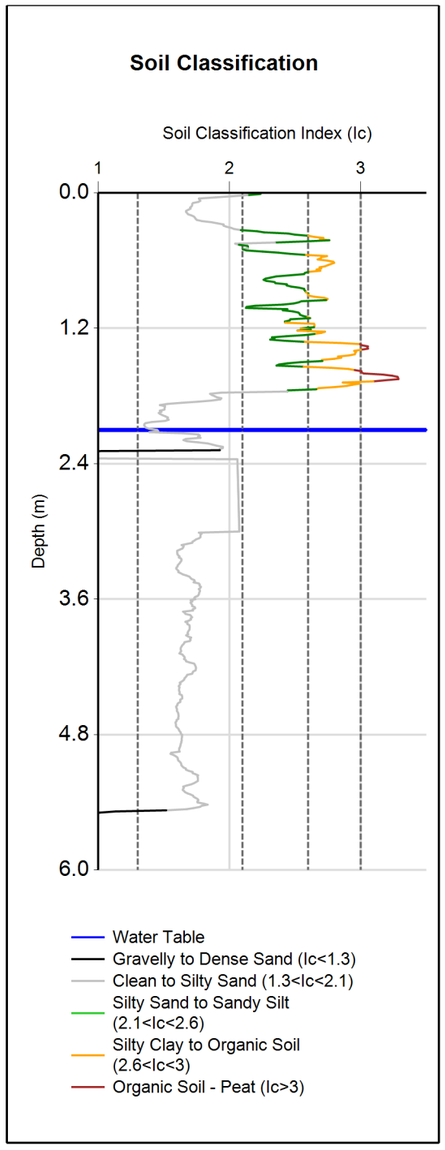


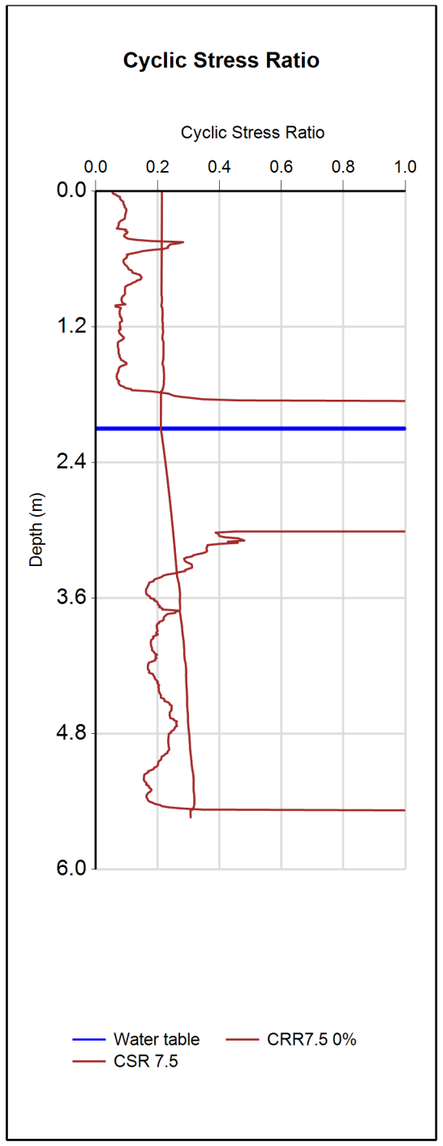
(Assumed pre-drill values)

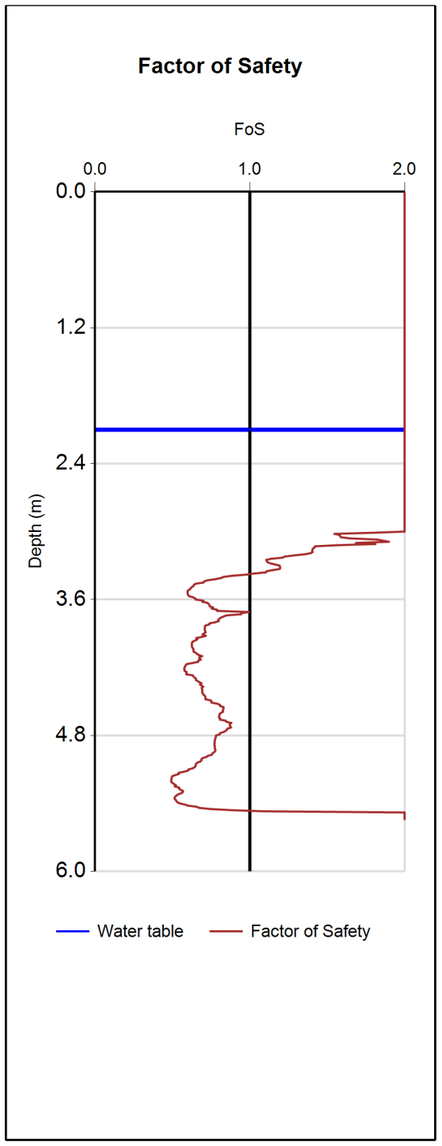
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 23 - Spliced	42616	20/06/2014	User Specified	7.5	0.179	2.1	IB	ZRB	0	2	0.01	18

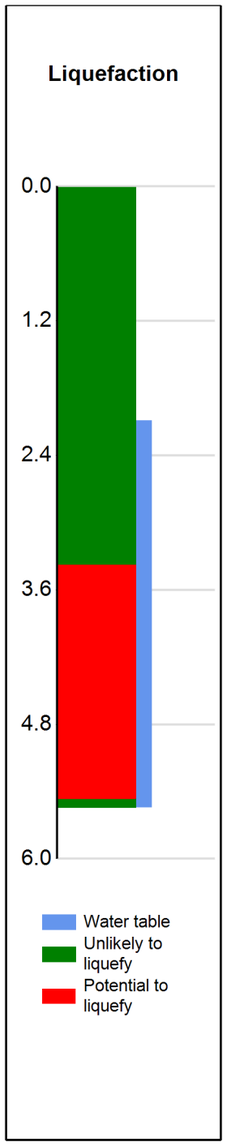
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	6	0	0	1	5.5







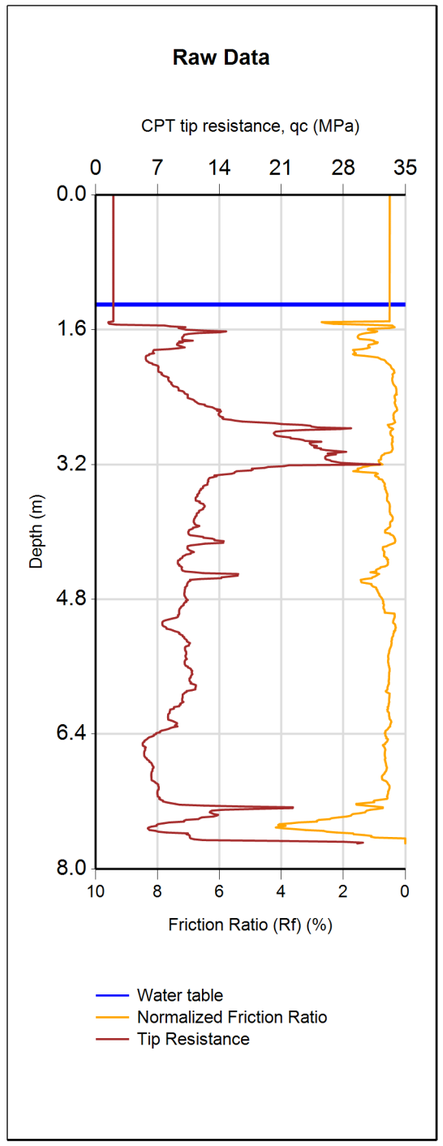


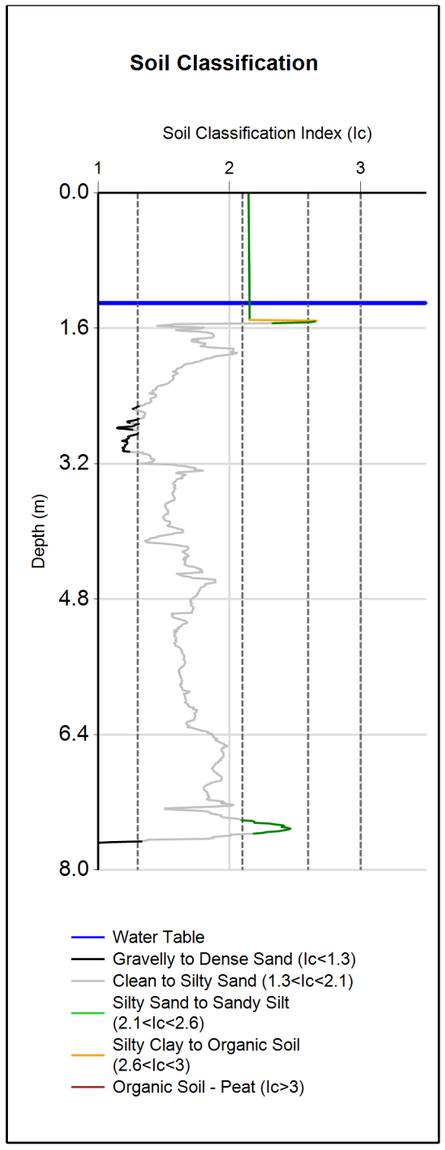


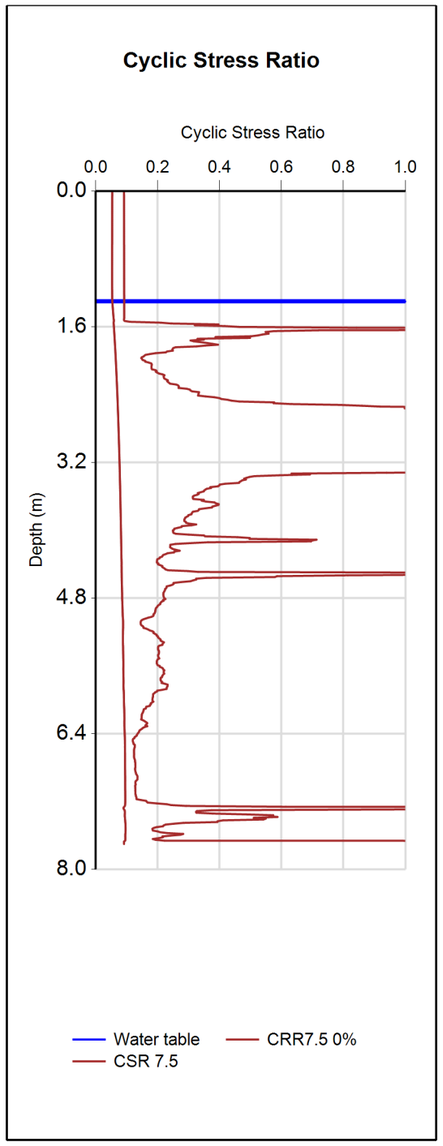
(Assumed pre-drill values)

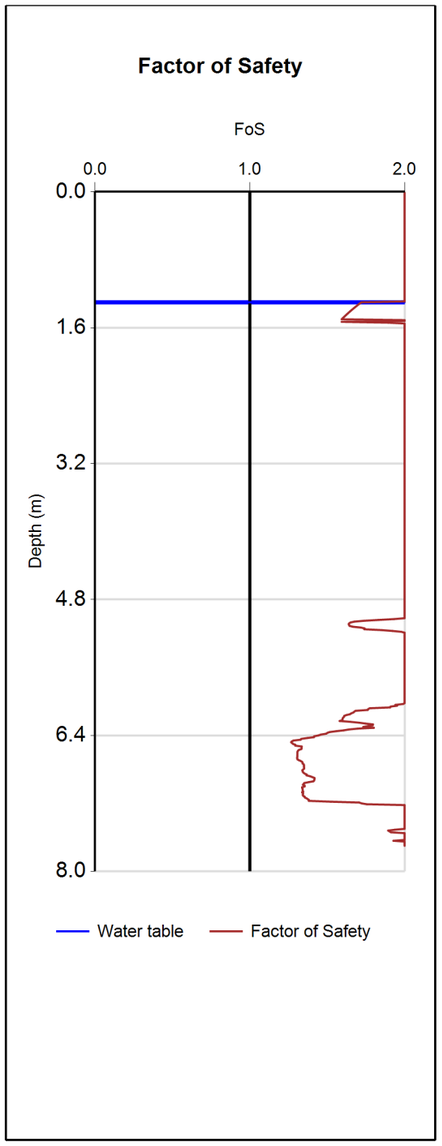
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 23 - Spliced	42616	20/06/2014	User Specified	7.5	0.36	2.1	IB	ZRB	0	2	0.01	18

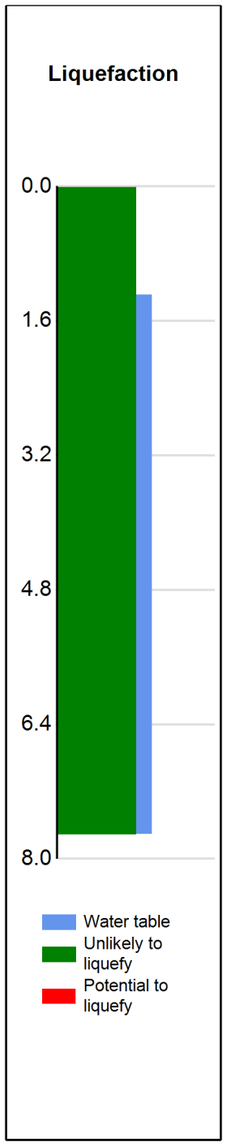
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	36	2.1	5	8	3.5









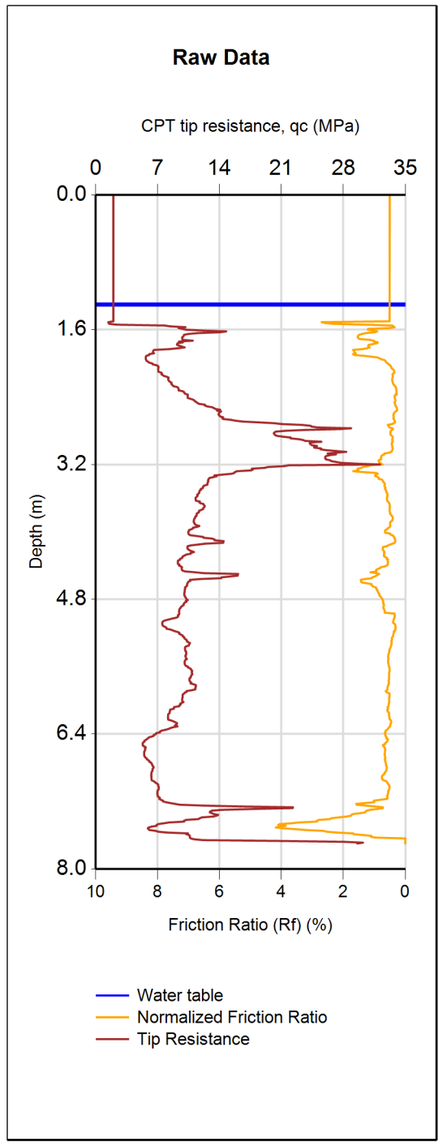


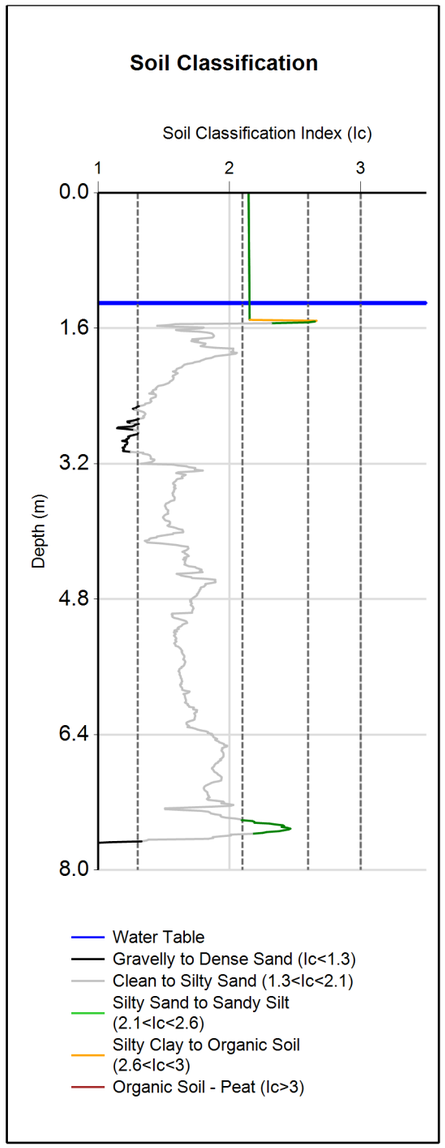
Surcharge used.

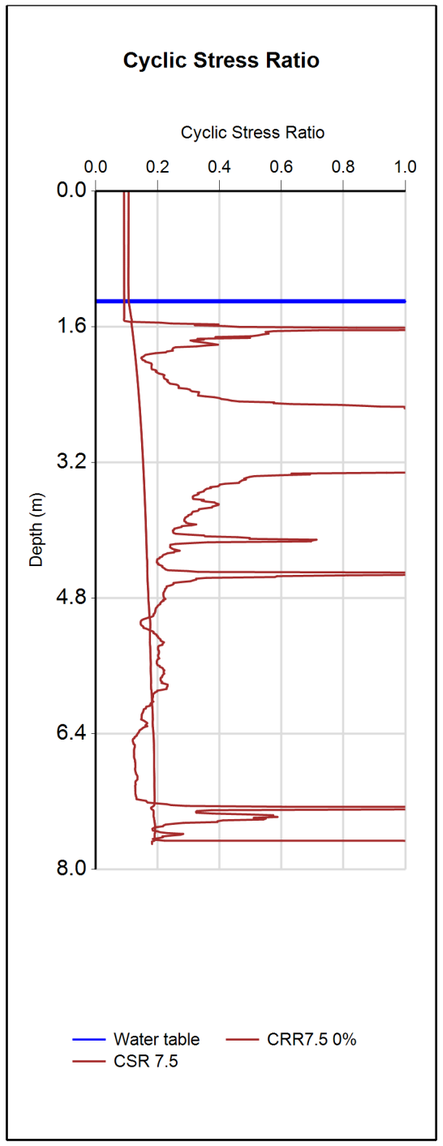
(Assumed pre-drill values)

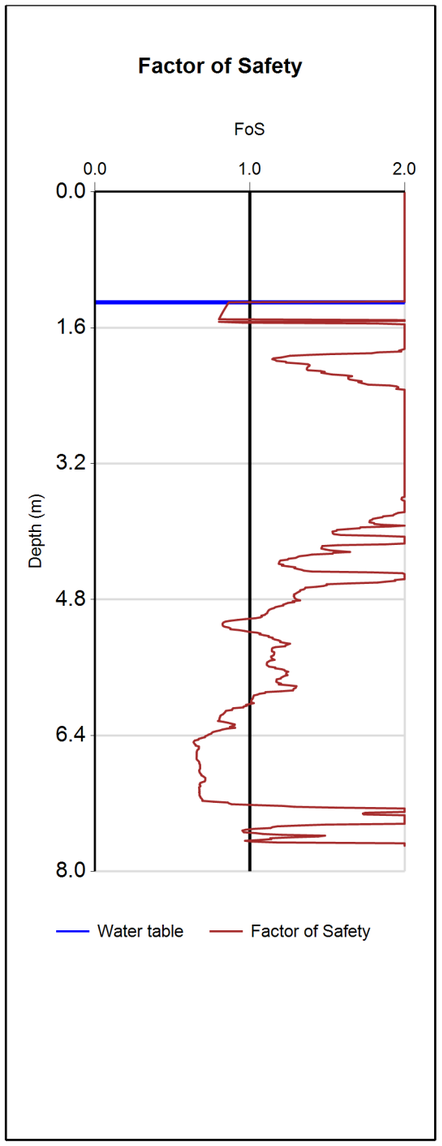
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 24 - 17-06 -14_02TT11	42478	20/06/2014	User Specified	7.5	0.09	1.3	IB	ZRB	1.5	2	0.01	18

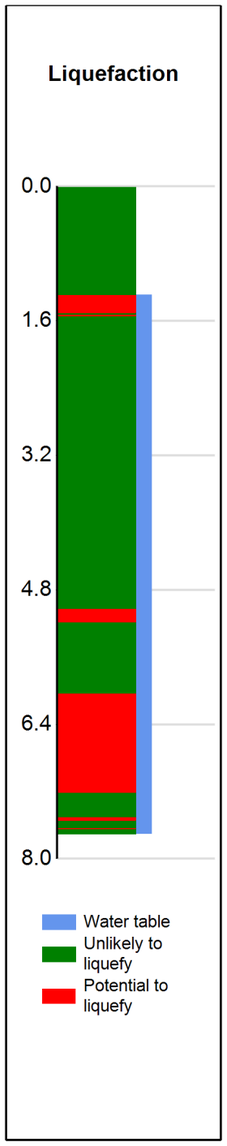
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	3	0	0	1	7.7







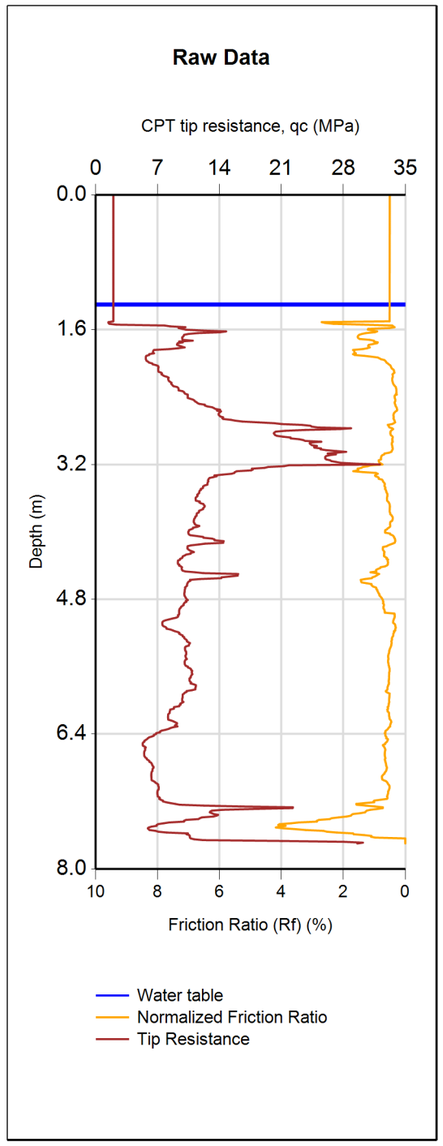


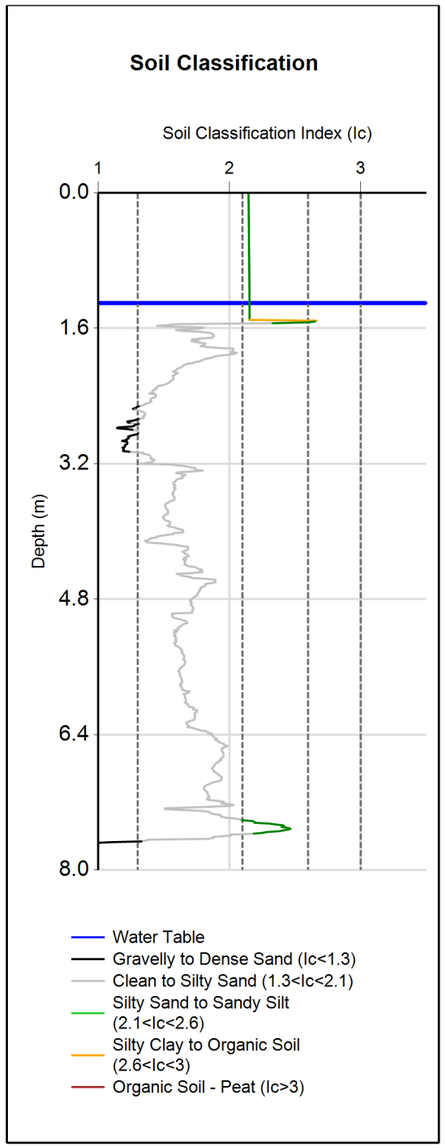


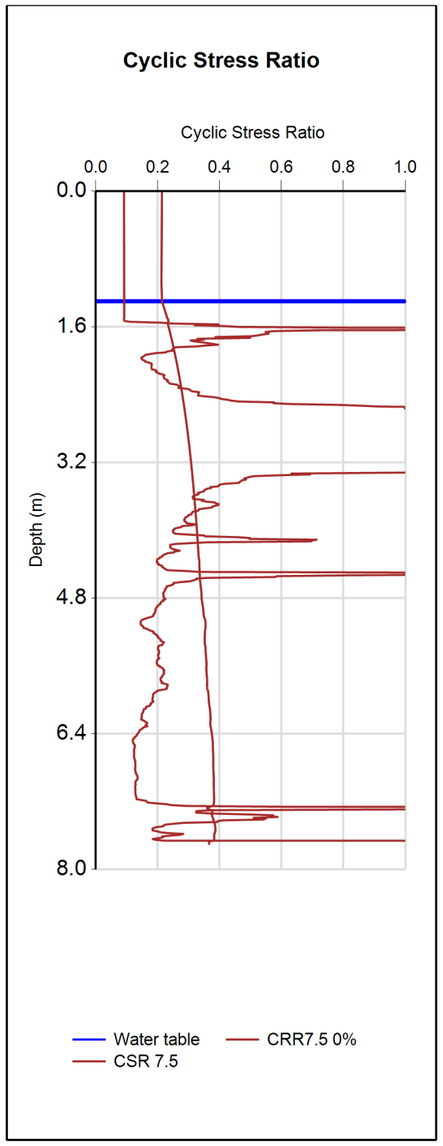
(Assumed pre-drill values)

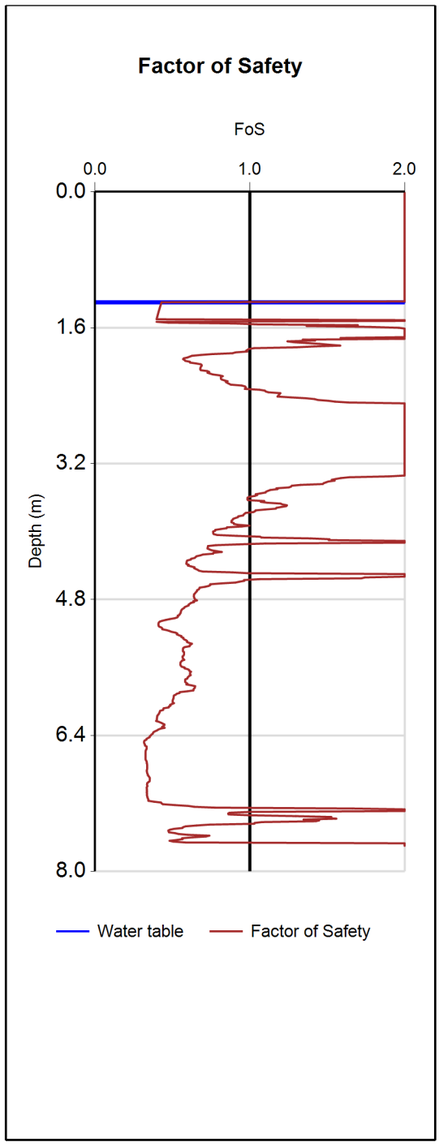
	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 24 - 17-06 -14_02TT11	42478	20/06/2014	User Specified	7.5	0.179	1.3	IB	ZRB	1.5	2	0.01	18

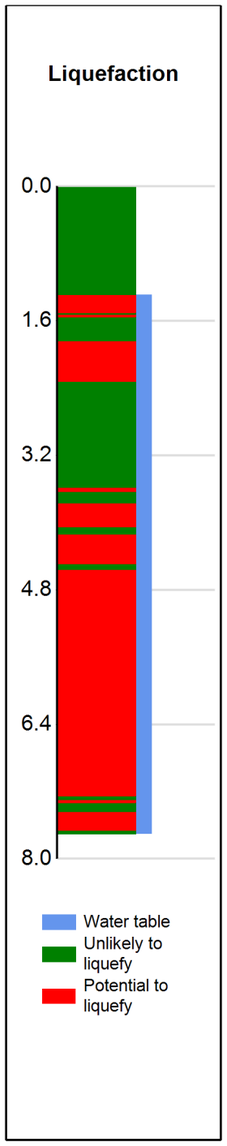
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	44	1.6	3	12	5.1











Surcharge used.

(Assumed pre-drill values)

	CPT Name	Database ID	Investigation Date	Event and PGA	Magnitude	PGA (g)	GWD (m)	Trigger Method	Settlement Method	Pre-drill Depth (m)	Qc (MPa)	Fs (MPa)	ɣ (kN/m³)
INPUT:	CPT 24 - 17-06 -14_02TT11	42478	20/06/2014	User Specified	7.5	0.36	1.3	IB	ZRB	1.5	2	0.01	18

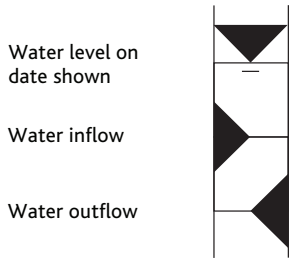
	Exceedance Probability	S - Calculated Settlement (mm)	CTL - Cumulative Thickness of Liquefaction (m)	LPI - Liquefaction Potential Index	LSN - Liquefaction Severity Number	CT - Crust Thickness (m)
OUTPUT:	15%	86	4.3	14	22	1.9

Engineering Log Terminology

GENERAL

Soil and rock descriptions follow the "Guidelines for the field classification and description of soil and rock for engineering purposes" by the New Zealand Geotechnical Society (2005). Refer to this document for methods of field determination.

Water



Core recovery

Expressed as percentage of the length of the core run recovered.

Drilling method/casing

Shows drilling method and depth of casing.

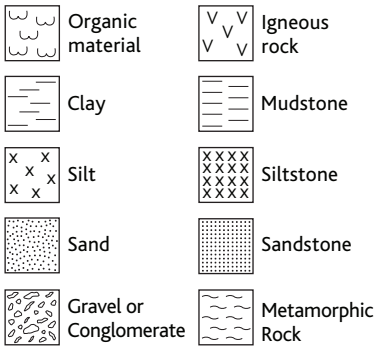
Common types:

OB	Open barrel
W	Wash
HQ3	HQ triple tube
PQ3	PQ triple tube coring
HSA	Hollow Stem Auger
WS	Window Sampler

Graphic logs

The graphic log shows soil and rock types. The defect log indicates the location, orientation and abundance of defects of all types.

Typical material symbols:



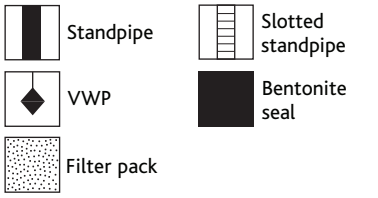
Tests

- **N=22:**SPT uncorrected blow count for 300 mm
- **75/12:**Undrained shear strength (peak /residual as measured by field vane.

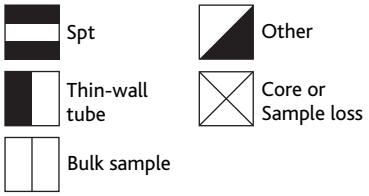
Laboratory test(s) carried out:

PMT	Pressuremeter test
LT	Lugeon test
LV	Laboratory vane
AL	Atterburg limits
UU	Undrained triaxial
PSD	Particle size
c' Ø'	Effective stress
CONS	Consolidation
DS	Direct shear
COMP	Compaction
UCS	Unconfined compression
IS	Point load

Installation type



Sample type



SOIL DESCRIPTION

Moisture content

D	Dry, looks and feels dry
M	Moist, no free water on hand when remoulding
W	Wet, free water on hand when remoulding
S	Saturated, free water present on sample

Consistency/undrained shear strength

		S_u (kPa)
VS	Very soft	< 12
S	Soft	12 to 25
F	Firm	25 to 50
St	Stiff	50 to 100
VSt	Very stiff	100 to 200
H	Hard	> 200

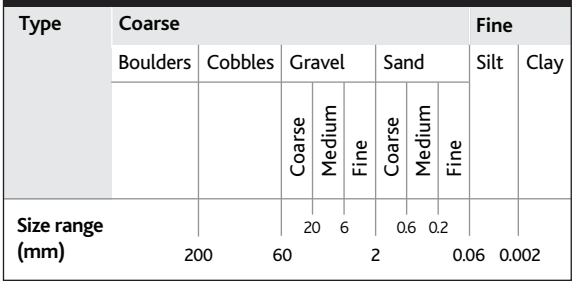
Density index

		SPT(N) - uncorrected
VL	Very loose	0 to 4
L	Loose	4 to 10
MD	Medium dense	10 to 30
D	Dense	30 to 50
VD	Very dense	> 50

Proportional terms definition (Coarse soils)

Fraction	Term	% of soil mass	Example
Major	(UPPER CASE)	Major constituent	Gravel
Subordinate	(lower case)	> 20	Sandy
Minor	with some... with minor...	12 - 20 5 - 12	with some sand with minor sand
	with trace of... (or slightly)...	< 5	with trace of sand (slighly sandy)

Grain size criteria

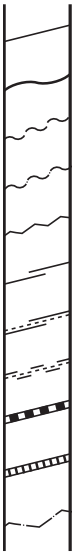


Engineering Log Terminology

ROCK DESCRIPTION

Signifcant defects

B	Bedding
J	Joint
Sc	Schistosity
Cl	Cleavage
Bz	Broken zone/crushed zone
Ft	Fault
Fg	Fault with gauge
SZ	Shear zone
Iz	Infilled seam
XD	Extremely weathered seam
DD	Drilling - induced defect



Weathering

UW	Unweathered
SW	Slightly weathered
MW	Moderately weathered
HW	Highly weathered
CW	Completely weathered
RW	Residual soil

Defect shape

ST	Stepped
UN	Undulating
PL	Planar

Roughness of defect surface

R	Rough
SM	Smooth
SL	Slickensided

Field strength

		UCS (MPa)	$I_{S(50)}$ (MPa)
EW	Extremely weak	< 1	N/A
VW	Very weak	1 - 5	N/A
W	Weak	5 - 20	N/A
MS	Moderately strong	20 - 50	1 - 2
S	Strong	50 - 100	2 - 5
VS	Very strong	100 - 250	5 - 10
ES	Extremely strong	> 250	> 10

Aperture

		Apperture (mm)
T	Tight	nil
VN	Very narrow	0 - 2
N	Narrow	2 - 6
MN	Moderately narrow	6 - 20
MW	Moderately wide	20 - 60
W	Wide	60 - 200
VW	Very wide	> 200

Defect coding

Type
Angle (perpendicular to core axis)
Infilling description (as per soil description)

J 60˚, PL, SL, T CV, STIFF GREEN CLAY

- Infilling/coating type
- Aperture
- Roughness
- Shape

Defect Orientation: for vertical unoriented boreholes defect orientation is measured normal to core axis e.g horizontal = 0˚. For angled boreholes defect orientation is measured relative to core axis e.g parallel to core axis = 0˚.

Infillings and coatings

CG	Clay gouge	Joints have openings between opposing faces of intact rock substance in excess of 1 mm filled with clay gouge. Clay is generally described in terms os soil properties.
CV	Clay veneers	Joints contain clay coating whose maximum thickness does not exceed 1 mm. Note: Describe clay in terms of soil properties.
PL	Penetrative limonite	Joint traces are marked in terms of well defined zones of slightly to moderately weathered ferruginised rock-substance within the adjacent rock.
FeSt	Limonite stained	Joint surfaces are stained or coated with limonite, although the rock substance immediately adjacent to the joints is fresh.
CT, SC	Coated	Joints exhibit coatings other than clay or limonite, e.g. Carbonate (CT) or Silica (SC).
CL, CS, CC	Cemented	Joints are cemented with limonite (CL), Silica (CS), or Carbonates (CC).
CN	Clean	Joint surface show no trace of clay, limonite, or other coatings.

Appendix C: Groundwater Sensitivity Assessment

- Table C.1 Groundwater sensitivity assessment for ULS seismic event

Table C.1 – Groundwater sensitivity assessment for ULS seismic event

CPT No.	Increasing Groundwater Level ---------->			
	Actual	+ 0.3 m	+ 0.5 m	+ 0.8 m
	Assessed LSN Value (ULS - 0.36 PGA)			
Stage 1 CPT's				
CPT1	22	25	28	29
CPT2	36	41	47	75
CPT3	23	23	24	28
CPT5	18	19	31	51
CPT6	52	61	71	100
CPT7	32	37	43	52
CPT8	53	60	67	77
CPT9	42	55	70	84
CPT10	34	37	41	56
CPT12	29	39	49	59
Stage 2 CPT's				
CPT13	13	22	28	44
CPT14*	20	32	49	108
CPT15	13	16	19	23
CPT16	13	17	22	30
CPT17	18	18	19	20
CPT18	13	13	14	16
CPT19	17	24	25	43
CPT20	3	8	18	35
CPT21	21	29	40	60
CPT22	0	0	0	2
CPT23	8	9	10	11
CPT24	22	31	39	56

* CPT-14 was carried out in the road verge adjacent to Rui Street, and as such the strength and liquefaction potential of shallow soils may be affected by shallow earthworks related to road formation. This may explain why this CPT is more sensitive to groundwater rise than others within the Stage 2 Study Area (LSN = 108 under +0.8 m scenario).

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ENVIRONMENTAL AND ENGINEERING CONSULTANTS

A1263318