Tower Foundations Ref: JN005/08

REPORT 5336

TITIRANGI NO.3 RESERVOIR
GEOTECHNICAL REPORT

For: Watercare Services Ltd
2 Nuffield Street
Newmarket, AUCKLAND

By: Tower Foundations Ltd
P O Box 20-294
Glen Eden,
Waitakere, 0641

Date: October 2008

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APPENDIX F Settlement Calculations

Executive Summary

1. Introduction

Tower Foundations have been engaged to investigate a possible site at Manuka Road for the proposed Titirangi No.3 Reservoir. This site was identified during the feasibility study as an alternative to the Konini Road site which required deep excavations into the hillside.

Due to some uncertainty regarding the stability of the Manuka Road site, an engineering geological assessment has been carried out which confirms that the underlying rock is stable, although a layer of colluvium or slope debris, originating from the high bluffs above, covers the site.

Following confirmation of site stability, a detailed investigation and laboratory testing programme was carried out to provide foundation design parameters. These site specific investigations have been combined with historical information. This has provided a good understanding of the classification of the foundation materials and the engineering performance in terms of the bearing capacity, estimated settlements and lateral earth pressures.

The findings of the investigation and analysis are:

- The site is stable and suitable for development of the reservoir.
- The foundation conditions are suitable for shallow foundations provided the foundation level is lower than RL128m. Ultimate and differential settlement estimates are provided.
- Although risk of settlement (and adverse aesthetic impact) can be reduced by lowering the reservoir invert level, this does impact on the ability to relieve ground-water pressures under the reservoir by gravity drainage.

- The historical information indicates that the new pump station can be built on the Huia Treatment Plant Site. Additional investigation is required to confirm foundation design parameters.

2. Site Description and Proposed Development

The site comprises the 4.2Ha parcel of Watercare land at the intersection of Manuka Road and Woodlands Park Road, approximately 250m uphill from the Huia Water Treatment Plant (WTP). The location is shown in **Figure 1**.

Both the Huia WTP and the proposed Reservoir site are located on gently to moderately sloping ground below a ridge of stronger and more resistant material forming an arc of steep and high bluffs from the intersection of Woodlands Park Rd and Scenic Drive, westwards to the head of the Lower Nihotupu Reservoir.

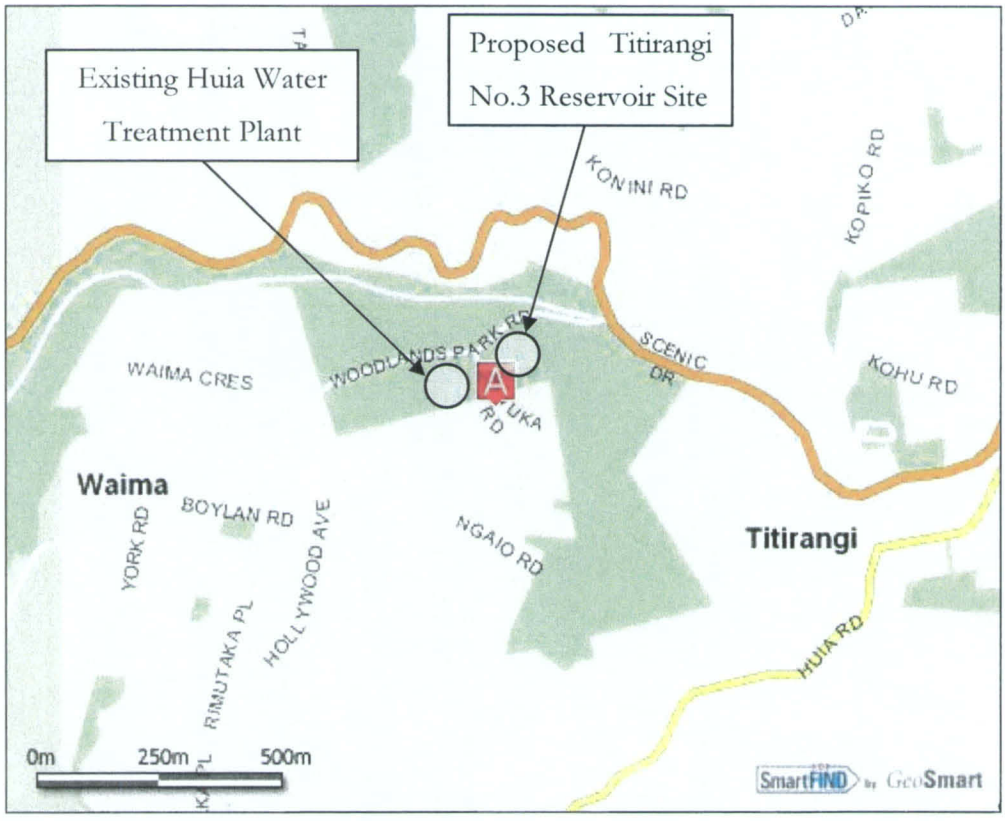

Figure 1. Locality Plan

It is proposed to construct a new treated water reservoir of approximately 20,000m^3 capacity. The approximate size and shape of the reservoir is shown in Drawings 2005523.017, sheets 1 and 2 attached.

The treated water will have to be pumped into the new No.3 reservoir from the Huia WTP before gravity feeding into the existing Huia No. 1 treated water main which runs directly beneath the proposed reservoir site.

3. Scope of Work

The investigation has been carried out in two stages in order to confirm the overall site suitability before proceeding with detailed analysis of foundation conditions. The scope of work has comprised:

- Stage 1. Engineering Geology
  - Interpretation of stereoscopic aerial photographs.
  - Review of available geological maps and reports.
  - Walkover survey and geological mapping
  - Inclinometer survey of cross-section.
  - Drilling three investigation boreholes.
- Stage 2. Geotechnical Engineering
  - Review of historical geotechnical data.
  - Development of geological cross-sections (model)
  - Laboratory testing of selected samples.
  - Post-processing test data and selecting design parameters.
  - Estimates of bearing capacity and settlement.
  - Estimates of lateral earth pressure coefficients.
- Compile Report.

NOTES

1: EXISTING CONTOURS FROM WSL SURVEY. DRAWINGS E3X144 DATED 10.10.05, E3X122 DATED 08.04.04, E3X123 DATED 04.05.04, E3X130 DATE 15.06.04 AND E3X132 DATED 23.06.04.
2: BOREHOLE POSITIONS FROM GHD REPORT No 2585 DATED SEPTEMBER 2002, BECA - FIG 1 DATED 17.11.05 AND TONKIN & TAYLOR REPORT DATED OCTOBER 2005

HUIA TREATMENT PLANT

30m x 15m
450m

PROPOSED PUMP STATION

WOODLANDS PARK ROAD

WOODLANDS PARK ROAD

MANUKA ROAD

Huia No1 Treated Water Flume

Huia No1 Treated Water Flume

MB01 MB02 MB03
BH3239 BH3174 BH3176 BH3175
BBH6 BH3240 BBH5 BBH3
HA4 HA2 HA3 HA1 BHA1
GH1 GH2
BH3264 BH3263 BH3265
NA94A / 355
Lot5 / DP156565
4.0105 Ha.
BBH4 BH3266
BB3 BH3267
BB2 BH3227 BH3228
BB1 BH2 BBH1 BH1
AH1
Sludge Lagoon
Sludge Lagoon
BH4328 BH4329 BH4796 BH4798 BH4797
BH5 AH4 AH5
BBH2 BH4 BH4A BH3
HA6 HA8 HA5 HA7
BH3229

MH1 MH2 MH3

PROPOSED 20,000m³ RESERVOIR No3 + 5000m³ CHLORINE CONTACT TANK SHOWN DASHED

Approximate Overall Size 85m x 40m x 8m high 27,200m³

Assumed Floor level RL. 128m & T.W.L. RL. 136m

Watercare Services Limited
NA94A / 356
Lot6 / DP156565
4.2027 Ha.

A 018
B 018

BOREHOLE LEGEND

- ARA CIRCA 1984-1988
- TONKIN & TAYLOR
- BECA
- TOWER FOUNDATIONS 2008
- HARRISON GRIERSON 2008

ISSUE	DATE	AMENDMENT	BY	APPD.
–	7:08	FOR CLIENT CONSIDERATION	G.B.	T.C.

		BY	DATE
DESIGNED	T.C.		7-08
DES. CHECKED	J.P.		7-08
DRAWN	G.B.		7-08
DWG. CHECKED	I.M.		7-08
PROJECT LEADER	T.C.		7-08
AM APPROVED	A.S.		7-08

OPERATIONS

ASSET MANAGEMENT

water Care services limited

PROPOSED TITIRANGI RESERVOIR No3
RESERVOIR SITING – SCHEME 11
BOREHOLE LOCATION PLAN – SHEET 1

CAD FILE 2005523.017	DATE 9-09-08
ORIGINAL SCALE A1 1:500 (A1)	CONTRACT No. –
DRAWING No. 2005523 .017	ISSUE –

NOTES

1: EXISTING CONTOURS FROM WSL SURVEY. DRAWINGS E3X144 DATED 10.10.05, E3X122 DATED 08.04.04, E3X123 DATED 04.05.04, E3X130 DATE 15.06.04 AND E3X132 DATED 23.06.04.
2: BOREHOLE POSITIONS FROM GHD REPORT No 2585 DATED SEPTEMBER 2002, BECA - FIG 1 DATED 17.11.05 AND TONKIN & TAYLOR REPORT DATED OCTOBER 2005

HUIA TREATMENT PLANT
HUIA TREATMENT PLANT
WOODLANDS PARK ROAD
30m x 15m 450m
PROPOSED PUMP STATION
MANUKA ROAD
Huia Not Treated Water Flume
NA94A / 355 Lot5 / DP156565 4.0105 Ha.
Sludge Lagoon
Sludge Lagoon
MH1
MH2
6m
MB01
MB02
MB03
GH1
GH2
HA1
HA2
HA3
HA4
HA5
HA6
HA7
HA8
BHA1
BBH1
BBH2
BBH3
BBH4
BBH5
BBH6
BH1
BH2
BH3
BH4
BH4A
BH5
BH3174
BH3175
BH3176
BH3187
BH3178
BH3179
BH3186
BH3188
BH3189
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BH3240
BH3229
BH3263
BH3265
BH3264
BH3267
BH3266
BH3227
BH3228
BB1
BB2
BB3
AH1
AH2
AH2A
AH3
AH4
AH5

BOREHOLE LEGEND

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- BECA
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OPERATIONS

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PROPOSED TITIRANGI RESERVOIR No3
RESERVOIR SITING - SCHEME 11
BOREHOLE LOCATION PLAN - SHEET 2

CAD FILE 2005523.017	DATE 9-09-08
ORIGINAL SCALE A1 1:500 (A1)	CONTRACT No. –
DRAWING No. 2005523 .017	ISSUE –

4. History of the Site

4.1 Development History of WTP Site

The Huia WTP was originally developed in the 1920s as the new raw-water sources in the Waitakere Ranges replaced Western Springs as the main source of water for Auckland City. The proposed reservoir site was formally used for housing the WTP staff. In fact the old driveway from Woodlands Park Road and the clearing where the houses were can still be seen on the borehole location plans.

A flurry of development activity took place in the 1970s and 1980s when the WTP was expanded and another more recent period of upgrade work has occurred since 2000. The history of investigation of the site has been summarised in "Huia Treatment Plant: Review of Historical Geotechnical Information", October 2008, a stand-alone report by Tower Foundations under a separate engagement. Although the proposed reservoir is sited 250m uphill of the WTP, both sites have the same underlying geology and the investigation, development and performance of the WTP structures is therefore relevant to the current proposal to develop a reservoir at Manuka Road.

Data from the review of historical information has been used, where appropriate and useful, as background information to the site specific data obtained during this investigation. The two-volume report can be accessed from Projectwise if required (Watercare reports 5330 and 5331).

Plate 1 shows the WTP as it is today with the areas of expansion and upgrade work annotated. The history of development is summarised as:

- Circa 1926; original building constructed in reinforced concrete on spread footings,
- 1972; chemical building extension constructed in reinforced concrete on spread footings,
- 1973; filter extension constructed in reinforced concrete on spread footings,

- 1973; the clarifiers were constructed in reinforced concrete on spread footings. Settlement monitoring indicated a maximum settlement of 39mm with an associated maximum differential of 30mm (rotational distortion 1:600),
- 2003; the wash-water tank was constructed in reinforced concrete on spread footings, although stone columns were installed below the footings.
- 2006: The lagoons below the treatment plant were expanded and upgraded to allow off-spec water to be released from the plant.

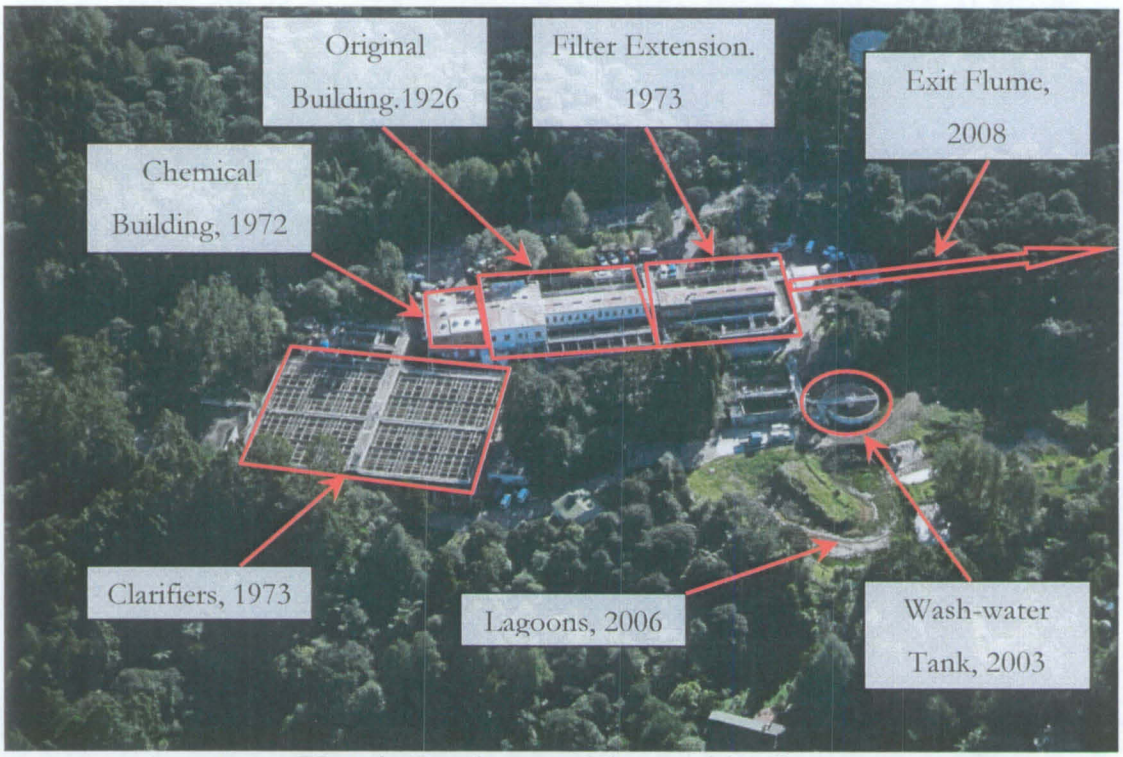


Plate 1. Development History of the Site

In addition to the Titirangi No.3 reservoir and pumping station an upgrade of the chlorination plant is being designed.

The Review of Geological Information compiled a range of geological reports and geotechnical information. The following reports provided valuable information on the site:

- Auckland Regional Authority Borehole Logs (1970s to 1980s)
- Engineering Geology Report (Mansergh for DSIR, Sept 1988)
- Engineering Geology Report (Works Consultancy, Oct 1995)
- Huia WTP Geotech Risk Assessment (GHD Sept 2002)
- Structural assessment of Sludge Lagoons (T&T Oct 2005)
- Geological Risk Assessment (Beca Infrastructure, Oct, 2006)
- Exit Flume Slope Stability (Beca Infrastructure, Nov 2006)
- Chlorination Plant Upgrade (Harrison Grierson, Sept, 2008)
- Titirangi No.3 Reservoir (Tower Foundations, Oct, 2008)

A total of 63 boreholes have now been drilled, distributed across the WTP and Manuka Road sites. The location of these boreholes is shown in the attached Borehole Location Plans (dwg 2005523.017 sheets 1 and 2. Although the historical boreholes on the WTP site do not assist with developing a geological model at the Manuka Rd site, the available test data does provide valuable information on the properties of the subsoils. The geology across both sites is consistent.

The following test historical test information has been used to supplememnyt the site specific testing;

- Atterberg limits
- Triaxial tests

5. Geological Setting

A detailed engineering geological assessment of the site has been carried. The findings are summarised here with extracts from the geological report, included in full, in **Appendix A.**

5.1 Geology of the Catchment

The geology of the catchment comprises sedimentary rocks of Miocene age with a sequence of rock comprising Nihotupu Formation underlain by Cornwallis Formation, interfingered and underlain by the East Coast Bays Formation. Alluvial deposits and colluvium are found filling the base of the valleys and in pockets on slopes throughout the catchment.

These geological units can be summarised as:

- The **East Coast Bays Formation (ECBF)** forms the basement rock. It is up to 100m thick in places and comprises alternating beds of sandstone and siltstone of varying thickness. Rocks of the East Coast Bays Formation vary in strength from extremely weak to weak. Thin bedding-parallel clay seams occur in this formation and are generally related to flexural slip during deformation.
- **Cornwallis Formation** overlies the East Coast Bays Formation. It is up to 60m thick in places and comprises massive coarse-grained sandstones with thin inter-bedded siltstones. Rocks of the Cornwallis formation also vary considerably in strength from extremely weak to moderately strong.
- The **Nihotupu Formation** overlies and inter-fingers with the Cornwallis Formation. It is up to 60m thick in places and comprises massive beds of fine to coarse Volcaniclastic sandstone. Volcaniclastic rocks of the Nihotupu Formation also vary considerably in strength.

These rock formations, where they are exposed at the surface are often intensely weathered to depths of up to 20m, resulting in residual soils typically comprising firm to very stiff clays, silts and sands of variable plasticity. East Coast Bays Formation.

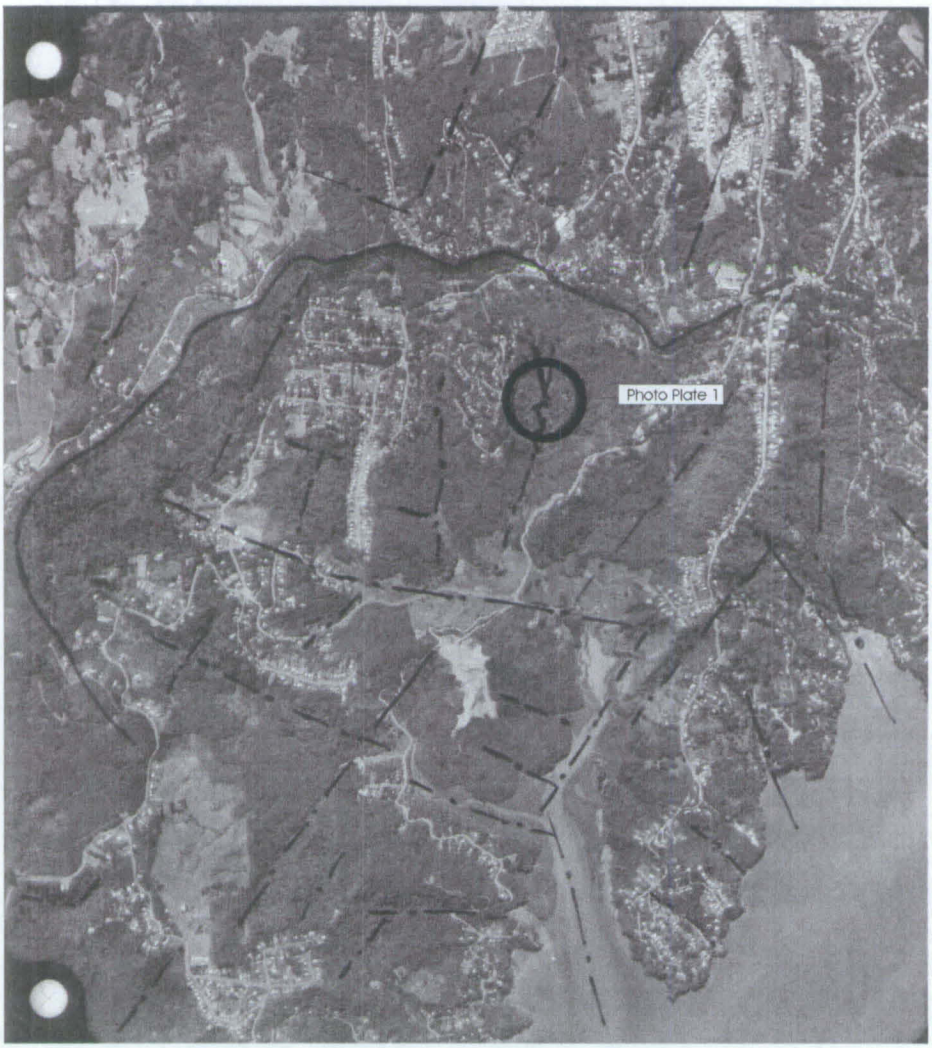
5.2 Aerial Photo Interpretation and Geomorphology

Review of stereoscopic aerial photographs shows the Little Muddy Creek basin draining south south-west to the Manukau harbour with a high arcuate ridge forming the north side of the basin. The basin is dissected by deeply incised valleys which follow the regional geological structure. **Figure 2** shows the drainage pattern where the streams follow the joint patterns in the rock and **Plate 1** illustrates the saw-toothed nature of the streams as they change direction following the orthogonal joint sets in the rock.

An area of large-scale movement, with resultant deformation of the geological units would not exhibit a drainage pattern that conforms so well to the unbroken geological structure. The geomorphology is not consistent with theories of a massive ancient landslide, but are consistent with the valley-within-a-valley formation formed by erosion at distinctly different sea levels as proposed by Mansergh. This is supported by overlaying the geological map onto the aerial photographs.

The Nihotupu formation is observed to follow the arcuate ridge around the head of the valleys (refer to the attached "Geological Map" plan no 2113/2950-1), forming the high crest-bluffs due to its greater resistance to erosion than the underlying softer ECBF and Cornwallis units which have undercut the Nihotupu formation as they have eroded. This arcuate feature has been interpreted by some parties as a large scale landslide headscarp.

ORMISTON ASSOCIATES LTD
CONSULTANTS IN GEOTECHNICAL ENGINEERING, GEOLOGY & ENGINEERING GEOLOGY
Level 1, 18 St Martins Lane, Auckland City
P O Box 47-822 Ponsonby, Auckland New Zealand
Ph (00649) 378 1081 Fax (00649) 378 9834



CLIENT:	**Watercare Services Ltd**
LOCATION:	Reservoir No 3
TITLE:	**Lineament Study**

SCALE: Not To Scale
DRAWN: BXH
DATE: September 2008
CHECKED: AWO

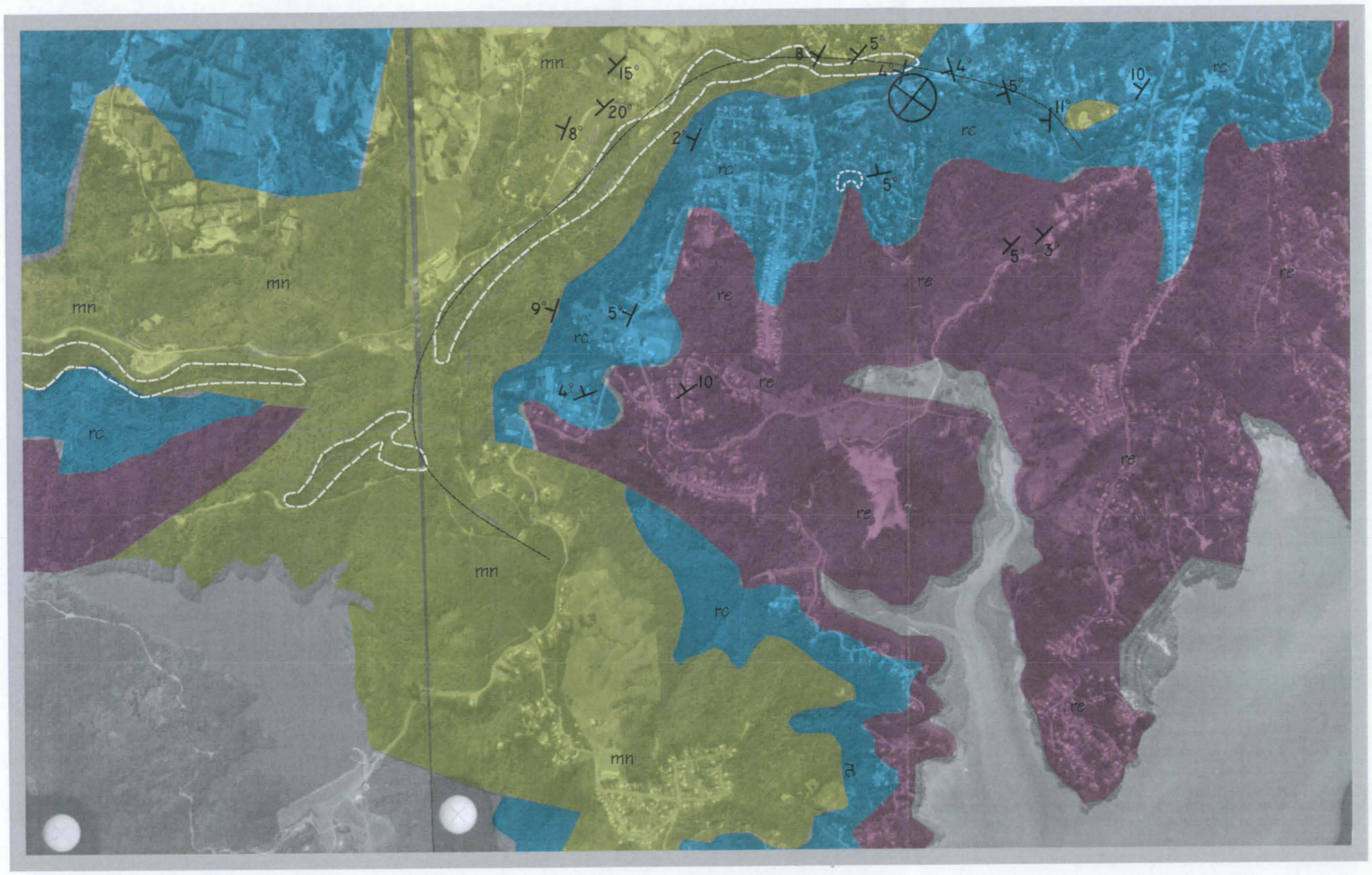
Figure 2. Lineaments showing drainage pattern of the catchment

Plate 1 – Stream following regional structure. (Note sharp right angles in stream alignment)

Mounds observed around the existing filter station and reservoir are interpreted to be colluvial remnants of the bluff forming process and can be observed throughout the Waitakere Ranges.

5.3 Field Mapping and Geological Structure

Lithologies in the area are observed to have a general north to northwest dip, into the general slope of the Little Muddy Creek Basin, in the order of 5° to 8°. This is consistent throughout the catchment with the exception of discrete locations along Scenic Drive where a south-westerly to westerly dip occurs. This could be due to intra-formation slumping that occurred at the time of deposition resulting in localised folded bedding.



Legend

- mn — Waitakere Formation (Nihotupu Fm) - Alternating Mudstone & Sandstone
- rc — Cornwallis Formation - Volcanic grit and Alternating Siltstones & Sandstones
- re — East Coast Bays Formation - Alternating Siltstones & Sandstones
- 10° — Strike & Dip
- Approximate extent of Major Bluff
- Approximate location of Reservoir No 3
- Approximate extent of arcuate feature

Note: Geologic interpretation is approximate only being based on field observations and Sheet N42/7, Cornwallis, Industrial Map Series

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CONSULTANTS IN GEOTECHNICAL ENGINEERING, GEOLOGY & ENGINEERING GEOLOGY
18 St Martins Lane, Auckland City
P O Box 47-822 Ponsonby, Auckland New Zealand
Ph (00649) 378 1081 Fax (00649) 378 9834

waterCare services limited

TOWER FOUNDATIONS

CLIENT: Watercare Services Ltd
LOCATION: Titirangi No 3 Reservoir
TITLE: Geological Map

SCALE: 1:24000 @ A3
DRAWN: BXH
DATE: 17th Sept 2008
CHECKED: LGD

DRAWING NO
2113/2950-1
SHEET 1 OF 1

We would expect to see an inconsistency or large variations in bedding dip throughout the catchment if it had been subject to a massive landslide. Observations of the bluff and waterfall below Ngaio Road indicate that the rock belongs to the Cornwallis Formation. It is massively bedded and exhibits only minor fracturing with a north-west dip of approximately 5° (i.e into the bluff) consistent with the regional dip. The rock mass does not show any evidence of having been subject to deep seated movement (ref **Plate 2**).

Plate 2 Waterfall below Ngaio Road

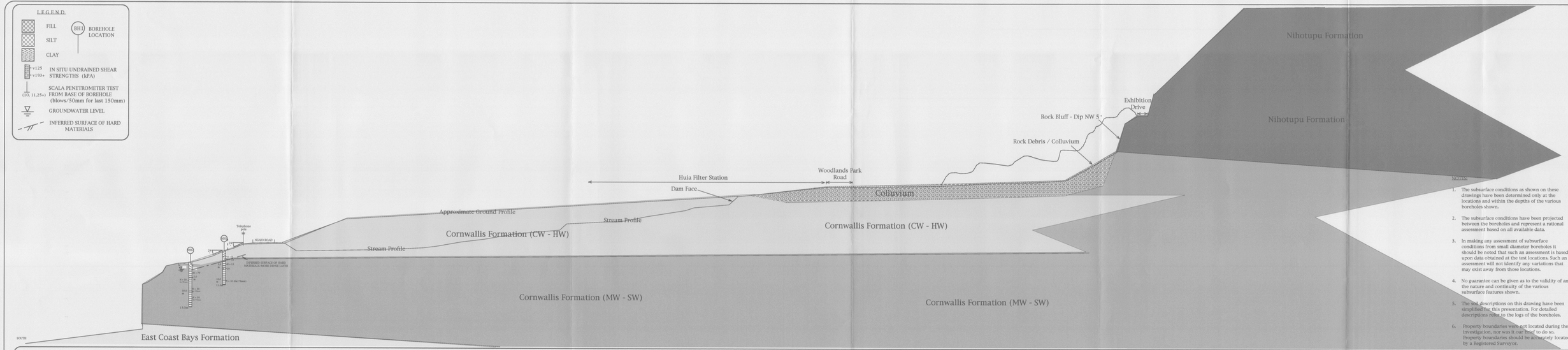
These observations support Mansergh's theory of a valley-in-a-valley erosion feature as there is an unbroken sequence of rock from the older ECBF to the younger Cornwallis to the Nihotupu formations.

The Beca Infrastructure report "Huia Filter Station Geological Risk Assessment (October 2006) concludes that the Huia Filter Station is located on a deep ancient landslide with another shallower slip which daylights at the approximate elevation of the Ngaio Road waterfall. There seems to be little credible geological evidence to support this conclusion. The theory seems to be based on the appearance of the bluffs as a slip scarp and some

observations of localised jointing in test pits and bedding dips inferred from drilling core (whithout any discussion of the correct orientation of the core). The theory is then supported by the graphical output from a numerical stability programme, showing a slip surface. The wider geological picture contradicts this theory.

There is no evidence of large blocks of the Nihotupu formation at lower elevations which would support the theory of a large scale landslide. Furthermore, the Beca Infrastructure geological model does not include the 15m high waterfall exposure of the Cornwallis Formation below Ngaio Rd (refer Figure 1), which is where the postulated slip surface shown in their output would exit. There is no evidence of either south-westerly dipping defects or an exit point at the 15m high waterfall exposure. In reality, it comprises competent rock with very little fracturing and a northerly dip.

The investigation and analysis of the catchment geology provides compelling evidence that confirms the earlier work by the DSIR, concluding that there is no large scale landslide encompassing the Little Muddy Creek catchment (and the subject site). There is no evidence of structural geological features providing kinematic mechanisms for large-scale slope failures and the site is suitable for the proposed reservoir. The attached geological cross section shows the unbroken sequence of rock interpreted from the investigation.



NOTES:

1. The subsurface conditions as shown on these drawings have been determined only at the locations and within the depths of the various boreholes shown.
2. The subsurface conditions have been projected between the boreholes and represent a rational assessment based on all available data.
3. In making any assessment of subsurface conditions from small diameter boreholes it should be noted that such an assessment is based upon data obtained at the test locations. Such an assessment will not identify any variations that may exist away from those locations.
4. No guarantee can be given as to the validity of and the nature and continuity of the various subsurface features shown.
5. The soil descriptions on this drawing have been simplified for this presentation. For detailed descriptions refer to the logs of the boreholes.
6. Property boundaries were not located during the investigation, nor was it our brief to do so. Property boundaries should be accurately located by a Registered Surveyor.

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CONSULTING GEOTECHNICAL ENGINEERS, GEOLOGISTS & ENGINEERING GEOLOGISTS
Level 1, 18 St Martins Lane, Auckland City
PO Box 47 922 Ponsonby, Auckland, New Zealand
Ph (09) 376 1061 & 827 7726 Fax (09) 376 9854

CLIENT : WaterCare Services Ltd
LOCATION : Huia Filter Station, Titirangi
TITLE : Schematic Geologic Cross-section

SCALES	Approx
DRAWN	BXH
DATE	18 Sept 2008
CHECKED	AWO

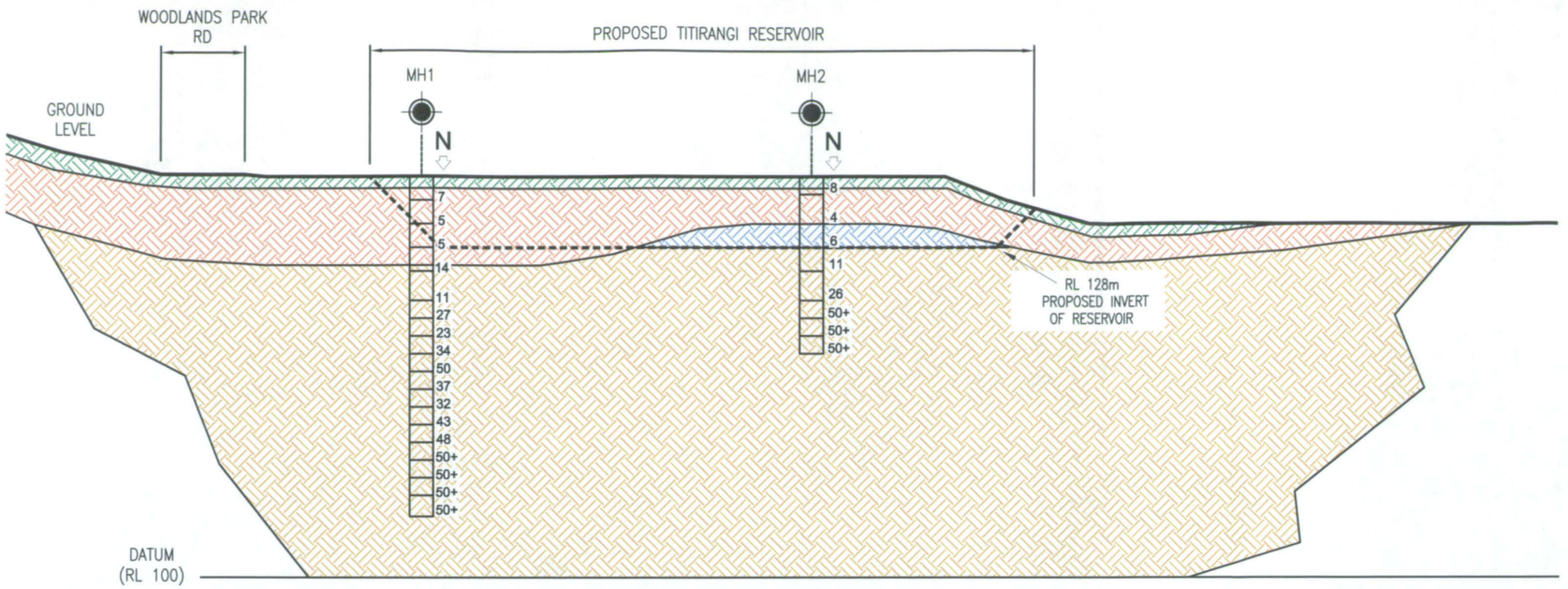
DRAWING NO
Figure 1
SHEET 1 OF 1

6. Foundation Conditions

6.1 Geological Model

The investigation boreholes confirm the reported geology, with the site underlain by a layer of colluvial material overlying the Cornwallis Formation. A lense of alluvium is sandwiched between the colluvium and the weathered Cornwallis formation.
Detailed borehole logs are attached in **Appendix B** and borelog photos are attached in **Appendix C**.

Geological Cross-sections A and B (Watercare Drawing 2005523.018) show the depth and distribution of the geological units with summary boreholes and SPT results for an indication of material strength. The proposed invert of the reservoir is shown on the cross-sections. **Figure 3** shows the profiles of SPT N-count versus mRL. It provides a good indication of the strength of the subsoils in relation to the proposed reservoir invert.



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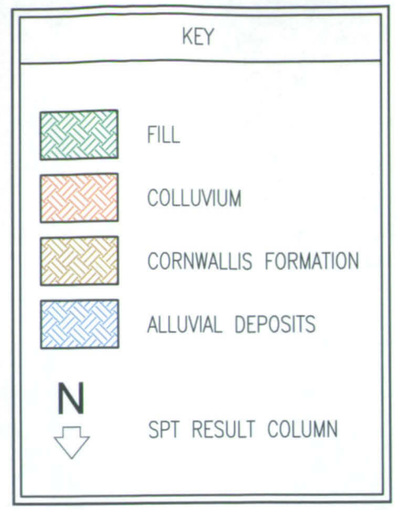

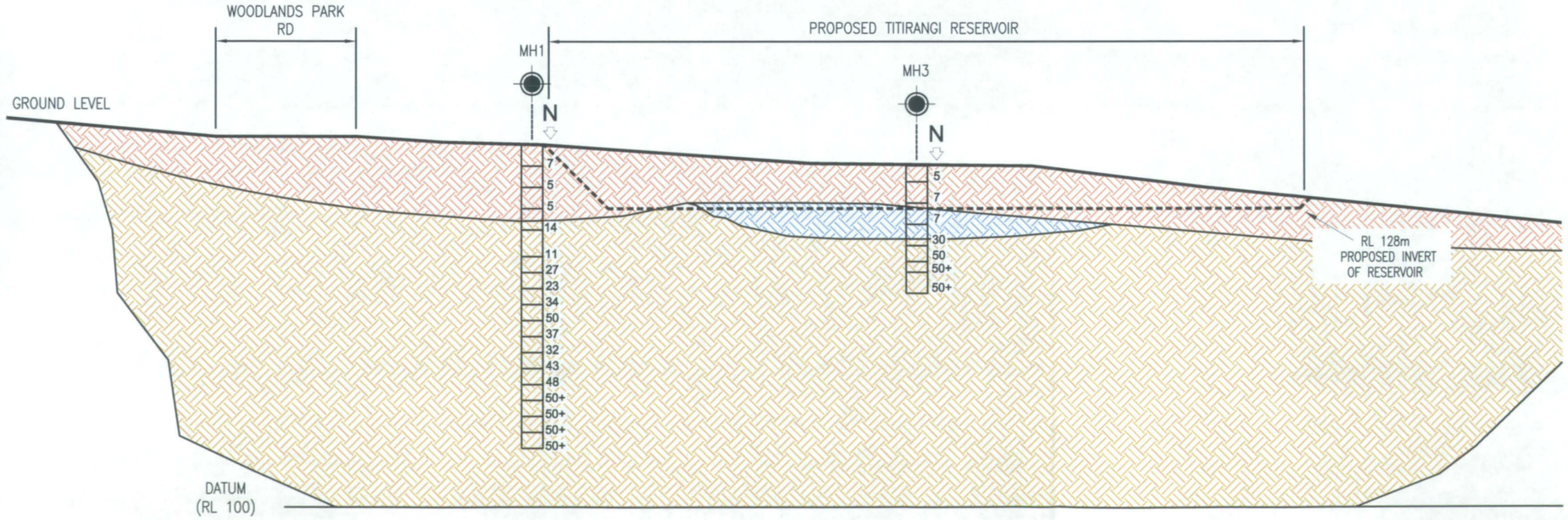

SECTION B
SCALE 1:1000 (A3) 017

ISSUE	DATE	AMENDMENT	BY	APPD.
–	–	FOR CLIENT CONSIDERATION	G.B.	T.C.

DESIGNED	T.C.	9-08
DES. CHECKED	J.P.	9-08
DRAWN	G.B.	9-08
DWG. CHECKED	I.M.	9-08
PROJECT LEADER	T.C.	9-08
AM APPROVED	A.S.	9-08
	BY	DATE

OPERATIONS

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PROPOSED TITIRANGI RESERVOIR No3
RESERVOIR SITING – SCHEME 11
GEOLOGICAL CROSS SECTIONS

CAD FILE 2005523.018	DATE 10-09-08
ORIGINAL SCALE A1 AS SHOWN	CONTRACT No. –
DRAWING No. 2005523 .018	ISSUE –

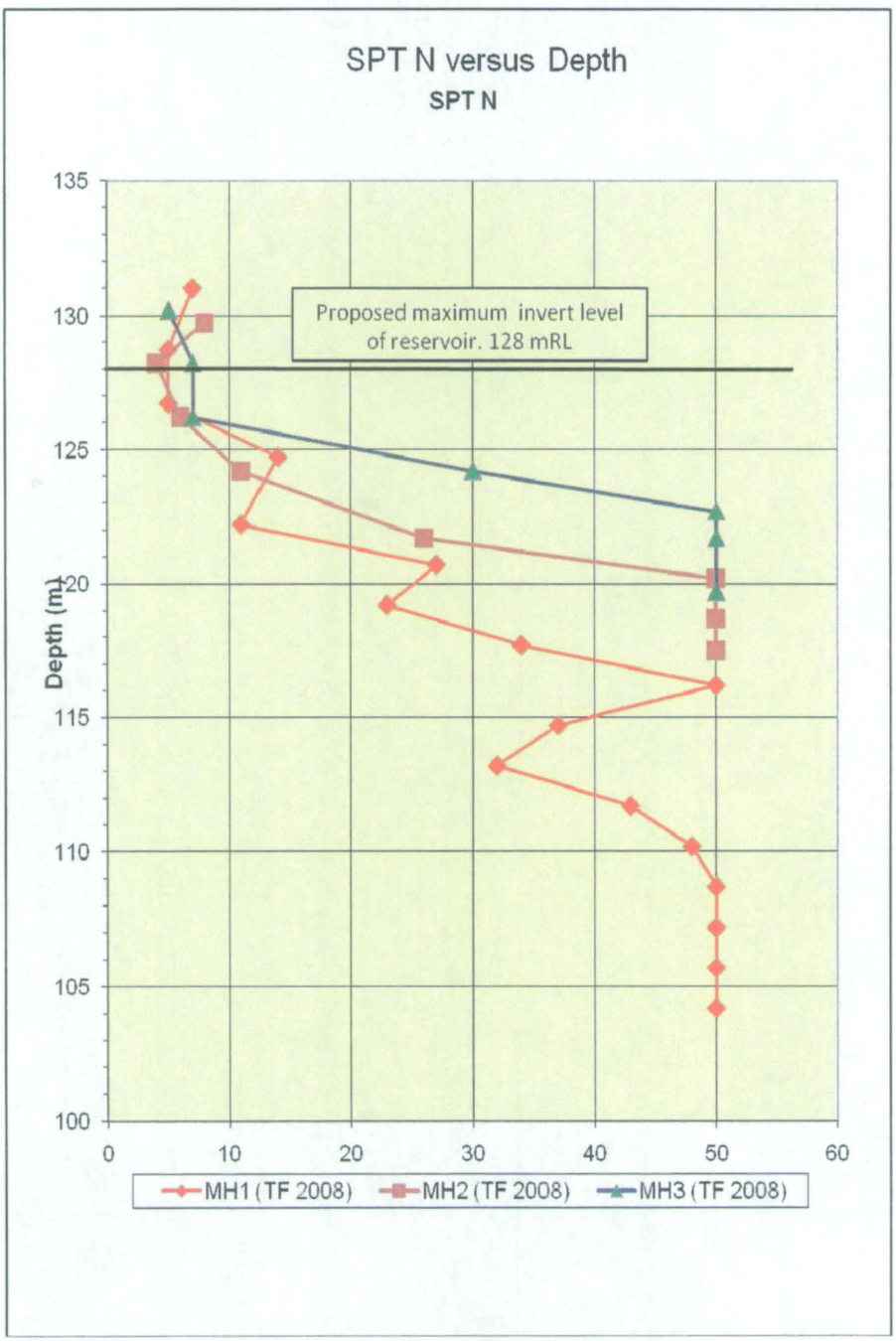


Figure 3 SPT N-count Profiles

For the purposes of bearing capacity estimates, the capacity is conservatively calculated based on the strength of the colluvial material, despite the cross sections and the above profile indicating that the layer of colluvium remaining beneath the reservoir is very thin.

For the purposes of settlement estimates, colluvium and weathered Cornwallis formation down to RL120m is considered as compressible and material below RL120m is considered incompressible. Based on the SPT profile in **Figure 3** this is a conservative approach.

6.2 Materials Characterisation

6.2.1 Plasticity

Three sets of Atterberg limit tests were carried out on undisturbed samples of cohesive colluvial materials in order to classify the materials and understand their behaviour (all laboratory test results are attached in **Appendix D)**.

The Casagrande chart shown in **Figure 4** (extracted from the historical review of geotechnical information) shows the three test results from this investigation as well as historical test results. There is some uncertainty as to whether the historical test samples were from Colluvium or the weathered Cornwallis Formation. Given the similarity in composition of the Nihotupu and the Cornwallis formations the liquid and plastic limits (and consequently the plasticity index) would probably be similar, and for this exercise, the differentiation between the two is not necessary.

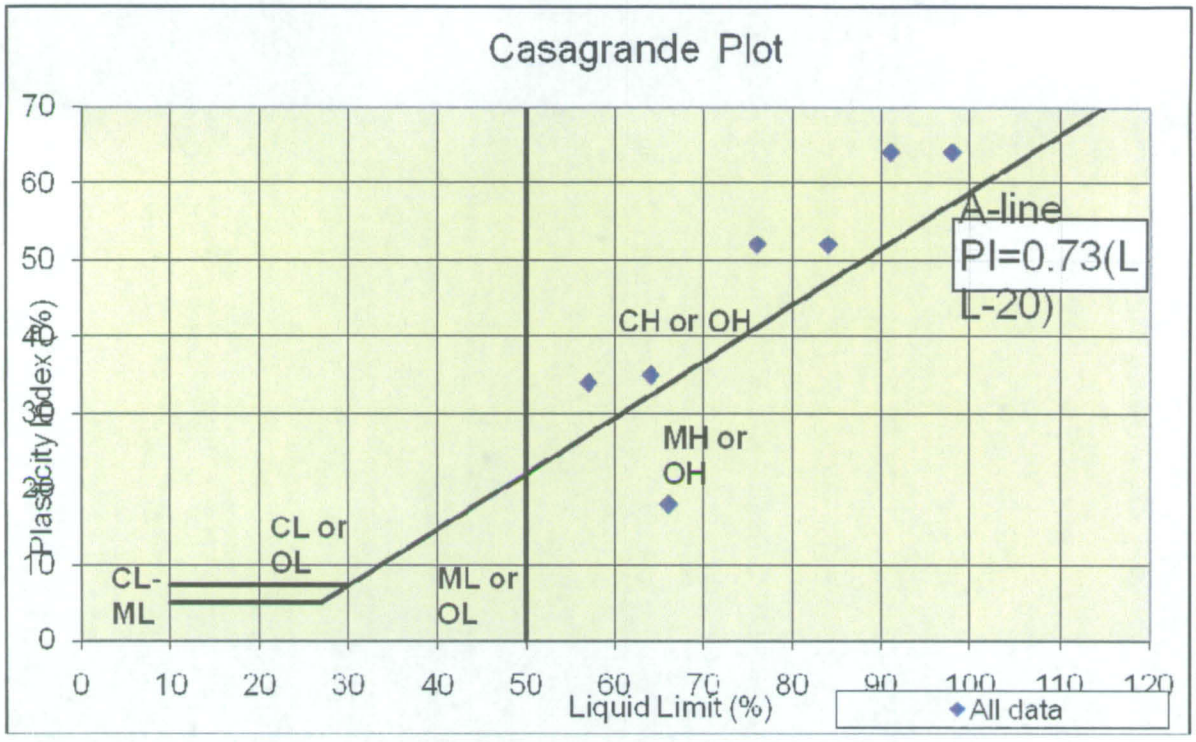


Figure 4: Casagrande Chart

Figure 4 shows quite variable plasticity materials from medium plasticity silts to high plasticity clays and reflects the variability of the parent material (coarse sandstone to siltstone). The chart indicates that the weathered materials exhibit plastic behaviour over a fairly large range of water contents (18% to 65%) and can sustain fairly high water contents before changing phase to the liquid state.

The natural water content and bulk density of the foundation materials are consistent with the profiles of water content and bulk density illustrated in the review of historical geotechnical information. There is little to be inferred from those profiles, so they are not reproduced here.

In summary, the tests and historical information indicate that the colluvial and alluvial subsoil materials comprise moderate to highly plastic silts and clays capable of sustaining high moisture contents.

6.2.2 Strength Parameters

Despite having numerous historical SPT tests (150 tests) and insitu vane shear tests (245) they are unfortunately of limited value. Both sets of data show extreme variability with no discernible trend. This is due in part to the existence of large blocks of unweathered sandstone embedded in a matrix of weathered material. Given the lack of reliable data and the weak correlations between SPT and undrained shear strength, combined with the absence of a load case requiring an undrained analysis, there seems to be little value in estimating undrained shear strength.

The recovery and testing of good quality undisturbed samples provides an accurate picture of the effective strength properties of the subsoil materials. Three samples of the weakest materials were tested in consolidated undrained triaxial tests. These test results are attached in **Appendix D**.

These tests, combined with the historical data provides a total of 18 consolidated-undrained triaxial tests carried out on materials from the upper on 7m of the ground profile. The major and minor stresses at failure have been used to develop the p-q plot shown in **Figure 5**. The results show a definite trend with high correlation to the best fit linear regression line shown.

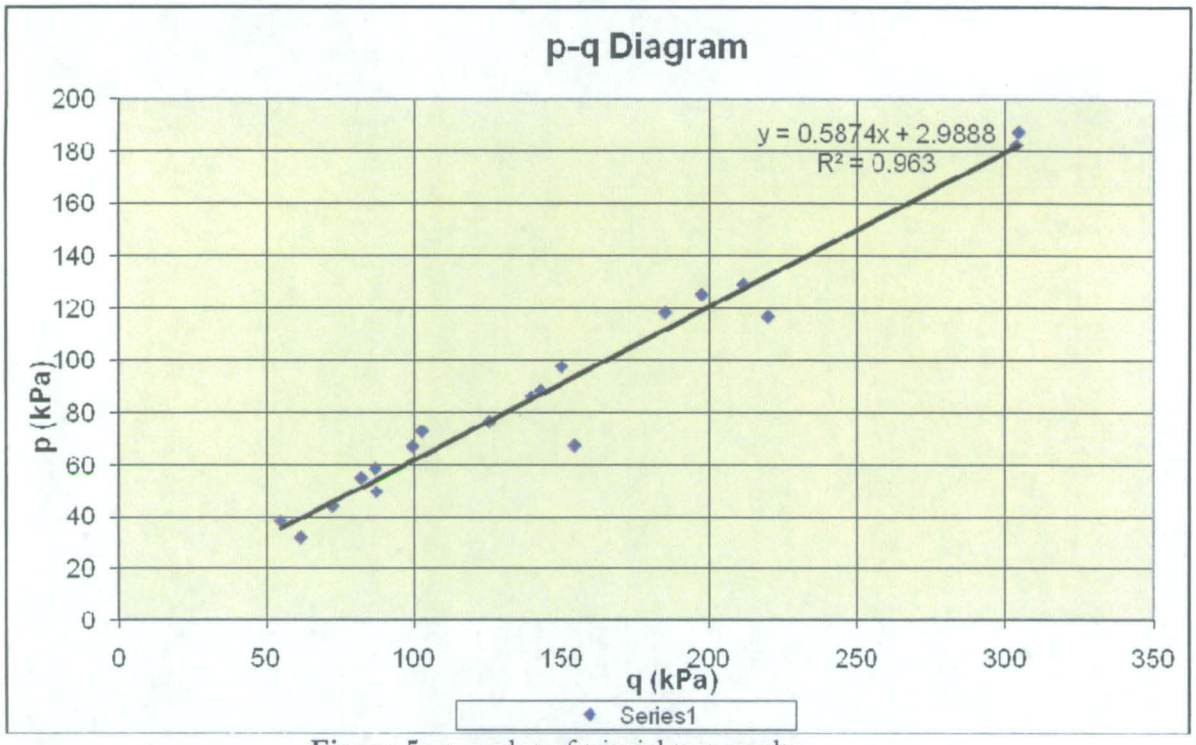


Figure 5: p-q plot of triaxial test results.

The slope and intersection of the best-fit line from the p-q plot has been transformed to the effective strength failure envelope (tangent to the mohrs circles) by the following formulae:

Effective friction angle $\phi = \sin^{-1} \psi$, where ψ = the angle from the p-q plot

Effective cohesion $c' = d/\cos \phi$, where δ = the intercept on the p-axis

The above transformations have been applied to the best-fit curve shown in **Figure 5** as well as the estimated upper and lower-bound limits. The results are presented in **Table 1**.

	Analysis of effective strength parameters		
	lower bound	best fit	Upper bound
y-intercept "d" (kPa)	0.0	3	12
TAN ψ	0.5	0.587	0.6
effective friction "ϕ" (kPa)	32.2	36.0	36.9
effective cohesion "c" (kPa)	0.0	3.7	15.0

Table 1. Range of Effective strength Parameters

For the purposes of design, effective strength parameters between the best estimate and the lower bound have been used.

6.2.3 Deformation Parameters

Most of the structures built at the Huia WTP have been built on spread footings. Monitoring data from the clarifiers indicates a maximum settlement of 36mm with a maximum differential of 30mm. The resulting 1:600 rotational distortion has not affected the structure and it appears from the condition of the rest of the existing structures that they have also performed well in regards to settlement.

Three one-dimensional consolidation tests have been carried out on the weakest colluvial materials recovered from the investigation.

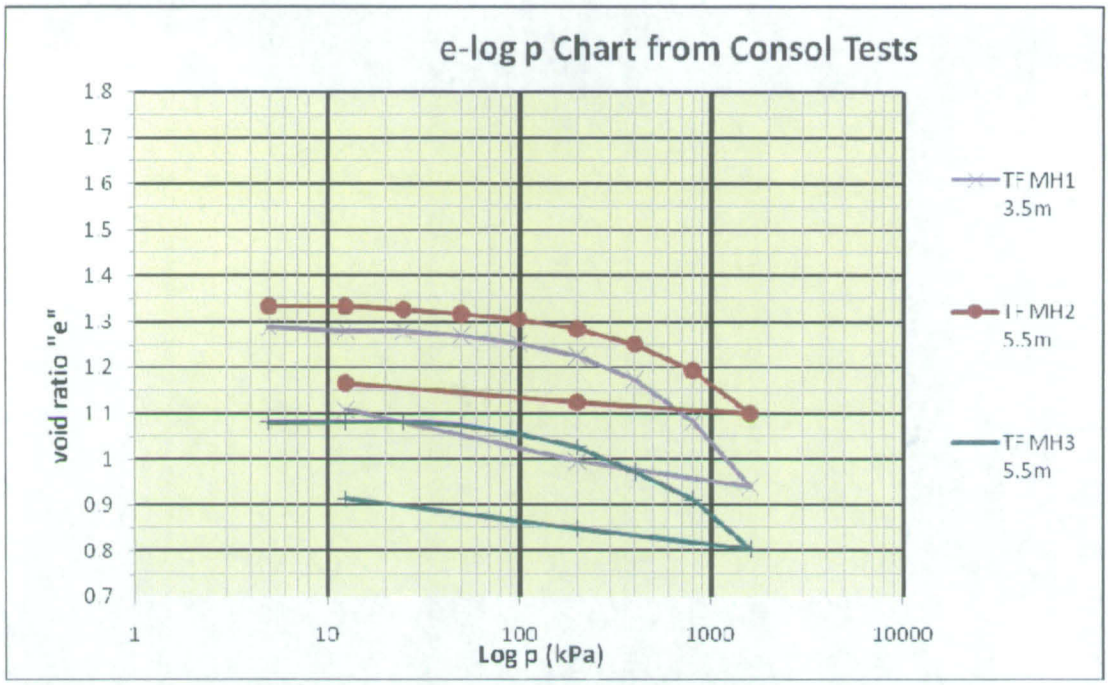


Figure 6: e-log p plot of consolidation test results.

Figure 6 shows relatively consistent consolidation curves for all three samples. There is some variation in the magnitude of the void ratio although the rate of change of the void ratio is very consistent. One point to note is that there is no distinct pre-consolidation point which is expected given that the materials are disturbed residual soils.

The compression index over the stages of loading from 50kPa to 400kPa are calculated as

- MH1 3.5m; C_c=0.9
- MH2 5.5m; C_c=0.6
- MH3 5.5m; C_c=0.9

For analysis purposes a value of compression index Cc = 0.9 has been selected.

The other material parameter required for settlement calculation is the initial void ratio. The test pressures from the consolidation tests have been transformed from pressure to an equivalent depth. The minimum, mean and maximum void ratio have then been plotted versus depth as shown in **Figure 7**

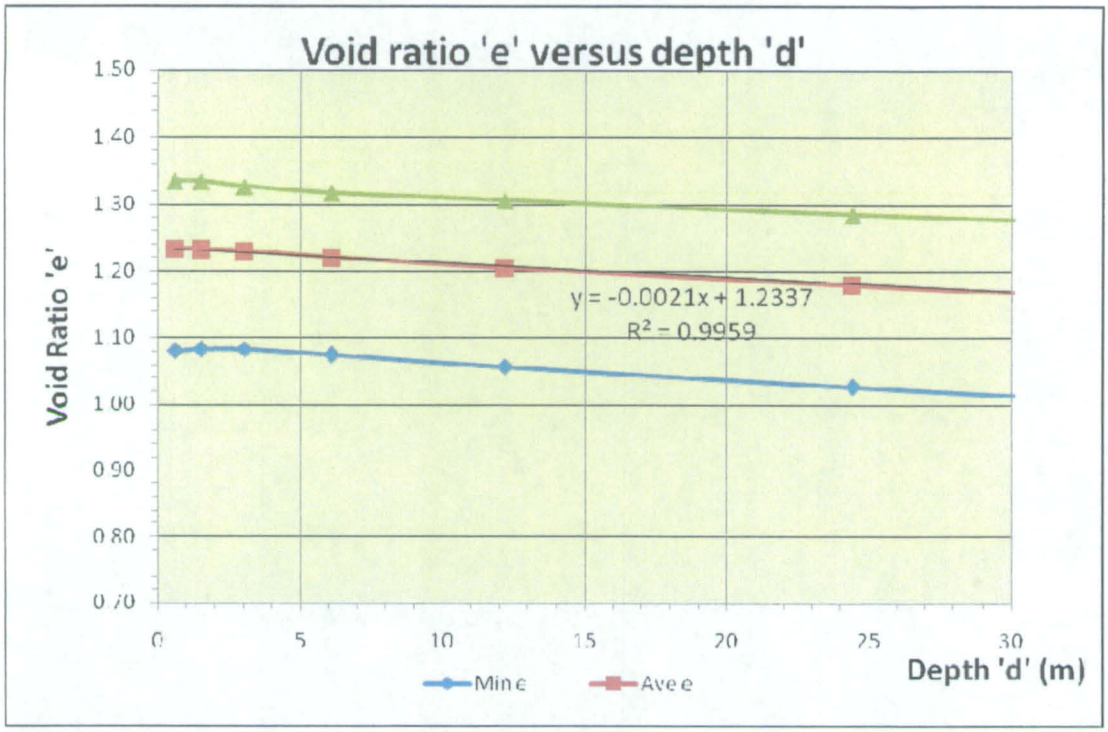


Figure 7 Void Ratio versus depth

It can be seen from **Figure 7** that the average void ratio over the depth of interest at the site is almost linear with a best-fit line of e=0.0021d +1.2337 where e=void ratio and d=depth. This relationship has been used to define the initial void ratio in settlement calculations.

7. Foundation Design

7.1 Reservoir Foundation

The geological cross-sections indicate that the reservoir will be founded on a thin layer of colluvial material overlying weathered Cornwallis sandstone. This material becomes less weathered or compressible within about 8m to 10m depth. These conditions are suitable for using a shallow raft foundation comprising a slab integrated with a grid of ground beams to distribute loads arising from minor differential settlements.

The settlement of the raft has been analysed using Terzaghi's theory of one dimensional consolidation. Consolidation settlements have been estimated at the three following critical locations:

- The NW-corner where the deepest excavation to reservoir invert occurs. The low vertical stresses beneath the corner of the tank combined with the subsoils at this corner consolidating and expanding within the unload-reload range when the reservoir loads are applied, will cause the settlements at this location to be the least in comparison to other locations.
- The centre of the tank where the vertical stresses beneath the tank are most concentrated and extend to the deepest influence. This means that the settlements here are the largest.
- The SE-corner where the minimum amount of soil is excavated. Although the stresses beneath this corner are the same as those in the opposite corner, the minimum excavation will result in the subsoils consolidating within the virgin compression range. Settlements at this corner will be slightly more than in the NW.

The vertical stresses beneath each of the above critical points have been estimated by Westergard's stress distribution for a uniformly loaded rectangular area on an elastic half-space. The influence curves are attached in **Appendix E**. The resulting profiles of vertical stress influence are shown in **Figure 8** The profiles show the difference in the vertical stress distribution between the corner and the centre of the tank.

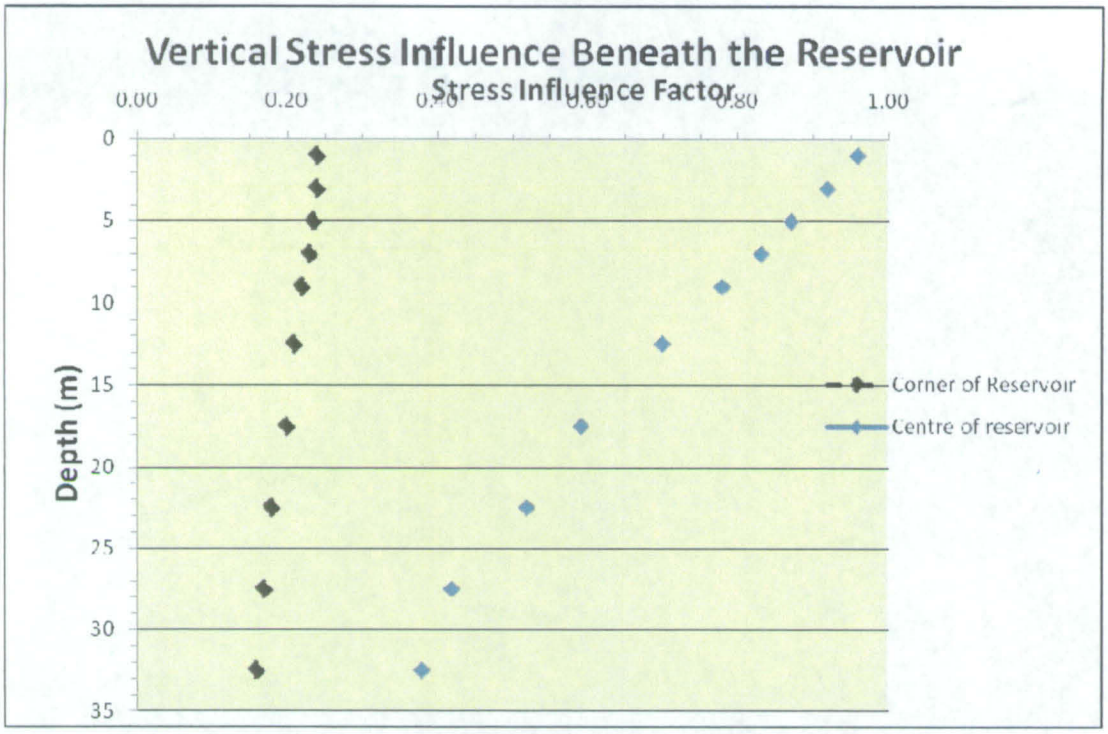


Figure 8 Vertical Stress profiles beneath the reservoir.

A uniform load of 90kPa has been applied to the stress influence profiles in **Figure 8** to represent a reservoir of approximately 8m height. The resulting stress distributions have been used in the calculation of settlement.

The vertical soil profile at each of the three locations has been separated into layers so that discrete vertical stresses, initial void ratios, and compression indexes can be applied. The consolidation of each layer has then been calculated using Terzaghi's theory of one-dimensional consolidation and the layers summed to produce an integrated estimate of settlement.

The tabulated calculation sheets are attached in **Appendix F**. It can be seen that the compression index varies between 0.009 and 0.006 for the upper 6m depth (128mRL to 122mRL). The 0.09 value represents the virgin compression index and the 0.006 represents the unload-reload index. A compression index of 0.003 has been applied to the weathered Cornwallis material between RL122m and RL 118m. The material below this will effectively be incompressible under these low pressures. The SPT versus mRL profile supports this assumption.

Figure 9 shows the estimated settlement profile. The maximum settlement is estimated at 145mm and the maximum angular distortion is estimated at 1:600. This should be tolerable with the correct structural detailing. Settlements could be reduced further by lowering the reservoir floor and driving more of the consolidation under the reservoir loads into the unload-reload region.

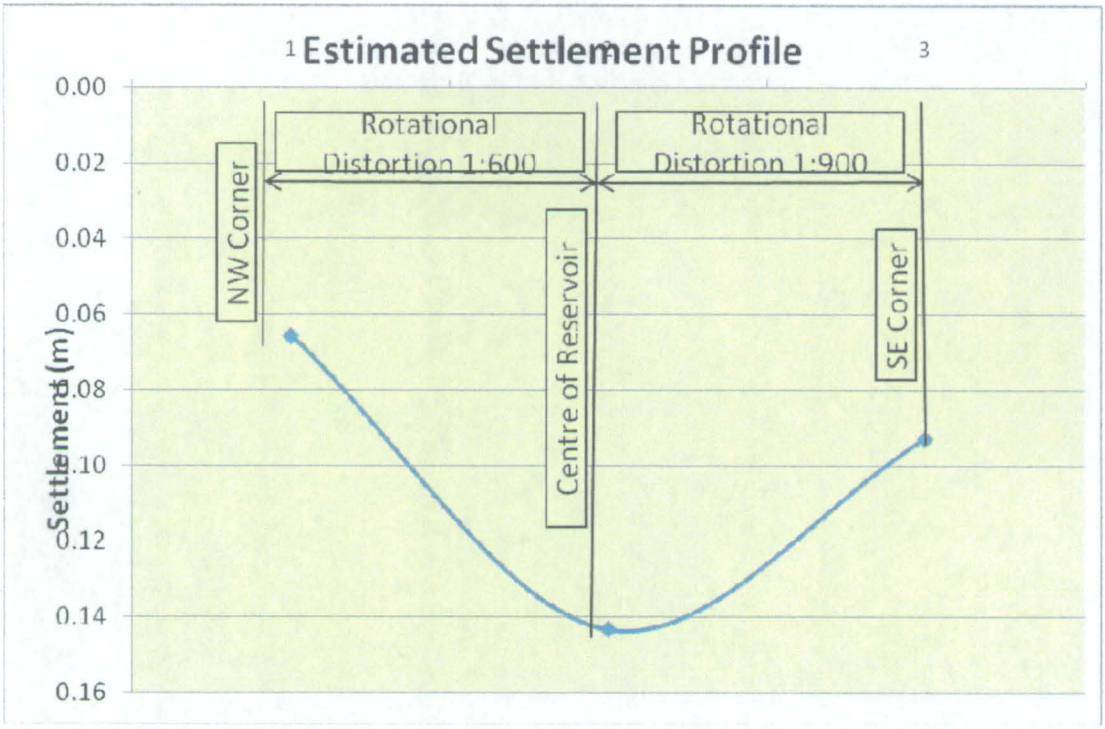


Figure 9 Estimated Settlement Profile.

7.2 Bearing Capacity of Shallow Footings

There will undoubtedly be some ancilliary structures requiring foundation design. Foundation bearing capacity of shallow footings has been calculated using effective strength parameters (**Figure ?**) by Terzaghi's Bearing Capacity formula:

$$q = c N_c + qN_q + 0.5\,\gamma B\, N_\gamma \qquad \text{where:}$$

- q = ultimate bearing capacity
- c = effective cohesion
- γ = unit weight

- B = footing width, and
- N_c N_q and N_γ = bearing capacity factors for cohesion, overburden and friction respectively.

Analysis indicates that after applying a strength reduction factor of 0.5, the safe load capacity of a 0.5m wide footing in these materials is in excess of 200kPa. For design purposes a strength reduced capacity of 200kPa should be assumed for limit state design. This capacity can be safely extrapolated out to wider foundations.

7.3 Soil Retention Structures

Based on an effective strength friction angle of 35 degrees, the following lateral earth loads can be applied in design:

- Active earth pressure coefficient K_a = 0.27
- At-rest earth pressure coefficient K_0 = 0.42

Appropriate partial load factors should be applied to these in design.

7.4 Temporary Excavations

Temporary excavations are likely to be as high as four to five metres. These excavations should be no steeper than 1:1 (H:V).

7.5 Pump Station Foundations

The pump station is located on the WTP site. Although the bearing capacity recommendations presented should be applicable for the pump station, there is some indication in the historic boreholes of filled ground in the upper areas of the WTP site. An additional borehole should be carried out in this area to confirm the ground conditions.

8. Summary

An investigation of the Manuka Road site for the Titirangi No.3 reservoir has been carried out. The scope of work comprised both a review of past information and site specific investigations. The investigation findings can be summarised as:

- There are no evidence of a large scale landslide encompassing the site and the site is therefore considered suitable for locating the proposed reservoir.
- Drilling investigations indicate that the site is underlain by a layer of colluvium or slope debris overlying weathered Cornwallis Sandstone. A layer of alluvium is sandwiched between the colluvium and Cornwallis Formation.
- Settlement of a raft foundation under the likely loads of the reservoir will cause settlements ranging from 65mm to 145mm.
- Angular distortions are likely to be in the region of 1:600.

Based on characterisation of the materials and analysis of the foundation performance we make the following recommendations:

- The proposed reservoir can be founded on a raft foundation comprising a floor slab integrated with a grid of ground beams.
- The lense of alluvium should be subexcavated and replaced with compacted hardfill when the foundations are exposed.
- Settlement of the foundations should be monitored as the walls are constructed and continue after first-filling until settlements stop.
- A safe bearing capacity of 200kPa can be used in design of ancilliary structures. This includes a strength reduction factor of 0.5 in accordance with limit state design.
- At-rest and active earth pressure coefficients of 0.42 and 0.27 can be used respectively with appropriate partial load factors applied.
- Temporary excavations should be no steeper than 1:1.

9. Limitation

This report has been prepared for the sole benefit of ***Watercare Services Ltd*** as our client with respect to the brief for the proposed development. It is not to be relied upon or used out of context by any other person without reference to Tower Foundations Ltd. The reliance by other parties on the information or opinions contained in the report shall, without prior review and agreement in writing, be at such parties sole risk.

We trust the above meets your present requirements. If there are any further queries, please do not hesitate to contact the undersigned.

Yours faithfully,
TOWER FOUNDATIONS LTD.

N. K. Jacka

Neil K Jacka Be (Hons)
Principal Engineer

Appendix A

Engineering Geology Report by Ormiston Associates

ORMISTON ASSOCIATES LTD

CONSULTANTS IN GEOTECHNICAL ENGINEERING, GEOLOGY & ENGINEERING GEOLOGY

Level 1 18 St Martins Lane Auckland City
PO Box 47-822 Ponsonby Auckland 1144 New Zealand
Telephone 09-302 2193 Facsimile 09-302 2197
Email: mail@ormiston.co.nz

Your Ref:

Our Ref: 2113/2950

ENGINEERING GEOLOGICAL ASSESSMENT OF THE LITTLE MUDDY CREEK CATCHMENT FOR PROPOSED TITIRANGI NO 3 RESERVOIR

For: Watercare Services Ltd
c/- Tower Foundations Ltd,
Level 1, 18 St Martins Lane,
Grafton, AUCKLAND

By: Ormiston Associates Ltd
P O Box 47-822
Ponsonby
AUCKLAND

Date: September 2008

TABLE OF CONTENTS

1. Introduction

Ormiston Associates Ltd have been commissioned by Watercare Services Ltd to undertake an engineering geological assessment of the proposed Titirangi No 3 Water Reservoir with particular emphasis on the broader Little Muddy Creek Catchment and inferred large-scale landslide postulated by Beca Infrastructure and Tonkin & Taylor.

2. Site Description

The Little Muddy Creek Catchment is characterised by an arcuate ridge bluff forming the north side of the basin with prominent ridges descending generally to the south south-west to the Manukau Harbour. The basin is dissected by deeply incised valleys which follow the regional geologic structure and are drowned to the south by the Manukau Harbour. The streams feeding into the drowned lower reaches become less incised to the north but are broken by a series of waterfalls and prominent bluffs.

3. Scope of Work

In order to prepare our present report we have undertaken the following;

1. A review of geological maps
2. Reviewed stereo aerial photographs
3. Reviewed Machine Borehole information from other sites in the area
4. Reviewed previous reports as discussed previously
5. Undertaken a detailed walkover of the catchment including streams, tracks, and several key private properties.
6. Surveyed using tape and abney an approximate cross-section through the Huia Filter Station from above Exhibition Drive to Ngaio Road in order to investigate the presence of an unbroken rock sequence as described by Mansergh (DSIR 1988).
7. We have mapped outcrops to confirm the published geologic maps

4. Previous Work

We have been provided with a series of previous reports relating to various Watercare projects in the area. We outline the key findings, relevant to the current proposal, of each of the reports below.

4.1 G.D Mansergh – DSIR (September 1988)

- Arcuate bluffs are interpreted to be an erosional feature due to undercutting rather than a major landslide as previously interpreted by a previous investigator whom is not named.
- The existence of an unbroken rock sequence beneath the Huia Filter Station to the waterfall below Ngaio Road is evidence that the area does not comprise a massive landslide.
- Rock units all have a similar dip (around 4°) with a northerly component. Beds in the bluffs along Exhibition Drive dip into the face (north to northwest) at 2° to 5°.
- Mounds encountered at the toe of the bluffs and slopes below represent remnants of debris from the bluffs above.
- Recognises local geology as residual however colluvial deposits are expected.
- No active faults are recognised in the Waitakere Ranges and therefore ground deformation due to seismic movement is not considered to be a significant hazard.
- Large scale failure of the bluffs considered possible during a seismic event however probability of a large enough seismic event considered low.

4.2 Works Consultancy (October 1995)

- The escarpment is considered to be an erosional feature created by preferential erosion of the Waitemata Group causing undercutting of the Waitakere Group.
- The escarpment is not considered to be a slip scarp however, historic earthslides are inferred to have occurred at several locations.

4.3 GHD (September 2002)

- GHD agree with the findings of the 1988 DSIR report and base their report on the conclusion that the site is not underlain by a deep seated landslide but rather is encompassed within an erosional feature.

4.4 Tonkin & Taylor October 2005

- The area of the Huia Water Treatment Plant is believed to have undergone pre-historic movement with Scenic Drive forming the headscarp to the north and South Titirangi Road to the east.
- The rock mass is fractured resulting in a greater depth of weathering.
- No basis or explanation is given for the conclusion regarding a large scale landslide.
- We note that they interpret the geology underlying the Filer Station as Nihotupu Formation rather than Cornwallis Formation as recognised and reported by all other parties. No explanation for this interpretation is given.

4.5 Beca Infrastructure Ltd - Huia Filter Station Geological Risk Assessment (October 2006)

- Considers the arcuate feature reflects a headscarp and that the slide debris has moved in a southerly direction and is possibly not controlled by the west to south-west dip of bedding planes of the rock (mapped at 5° to 25°). They do not explain what in their opinion controls the landslide.
- It appears that a large proportion of the slide material has been eroded and that a more resistant erosional surface is left as indicated by the N-S trending ridgelines.
- Beca concur with the DSIR report that the debris mounds are likely to be erosional remnants from the large landslide although we note that the DSIR report does not recognise a large landslide. We are therefore unclear as to this finding.
- The geological risk posed by the landslide is considered to be low given the buttressing effect of the sandstone ridges on either side of the Armstrong Gully and at the toe of the slope.
- The current surface is considered to be a weathered erosional surface
- The filter station site is located at the head of the Armstrong Gully which in the area below Ngaio Road is very steep (~30°) and actively eroding.

4.6 Beca Infrastructure Ltd – Huia Filter Station – Exit Flume Slope Stability (November 2006)

- Nearest inferred fault 2km to south-west with no active faults within the Huia Filter Station site.
- Refers to the geological map indicating bedding orientations of the Cornwallis Formation on Scenic Drive as gently dipping to the southwest at 5° to 10°.
- Slickensided surfaces were encountered at a relatively shallow depth (<15m) in the boreholes with an approximate 10° to 20° west to south-west dip similar to the published and observed bedding dip. It is not stated whether or not the core was orientated however, if the core was not orientated then the dip direction cannot be relied on.

- Slickensided surfaces indicate planes of movement and therefore that past instability has occurred.
- An ancient large-scale headscarp feature is identified forming the upstanding steep side slopes along Scenic Drive.
- Slide debris is observed on the slopes immediately below the headscarp
- Basal failure surface inferred to be in the order of 70m deep with movement along a bedding parallel clay seam.
- Boreholes were drilled to 38m and did not encounter a deep basal sliding surface.
- Investigation revealed several shallow steeply dipping slickensided surfaces within the upper 14m of the soil profile.
- The slickensided surfaces could result from a series of smaller scale failures accounting for a lack of continuity between the observed surfaces.
- It is considered that the large-scale feature and smaller associated slide planes are a result of a historical earthquake.
- An inclinometer was installed to monitor the shallow slickensided surfaces and long term monitoring was recommended. No monitoring results have been provided.

5. Ormiston Associates Ltd Engineering Geological Assessment of the Little Muddy Creek Catchment

5.1 Regional Geology

The geology of the site and greater catchment comprises East Coast Bays Formation rocks (interbedded sandstone and siltstone) overlain by the Cornwallis Formation and Nihotupu Formation rocks all being of Miocene Age. Alluvial deposits and colluvium are found filling the base of the valleys and in pockets on slopes throughout the catchment. We have referred to Map Sheet 2, Geology of the Auckland Urban Area 1:50 000 scale by Kermode dated 1992 and Industrial Series Map Sheet N42/7, 1:25 000 scale dated 1982 by the DSIR.

These rock formations, where they are exposed at the surface are often intensely weathered to depths of up to 20m, resulting in residual soils typically comprising firm to very stiff clays, silts and sands of variable plasticity. East Coast Bays Formation

5.1.1 East Coast bays Formation (ECBF)

The East Coast Bays Formation (ECBF) forms the basement rock in this catchment. The ECBF is up to 100m thick in places and comprises alternating beds of sandstone and siltstone of varying thickness. Rocks of the East Coast Bays Formation vary in strength from extremely weak to weak. Thin bedding parallel clay seams occur in this formation and are generally related to flexural slip during deformation.

5.1.2 Cornwallis Formation

The Cornwallis Formation overlies and inter-fingers the East Coast Bays Formation. It is up to 60m thick in places and comprises massive coarse-grained sandstones with thin interbedded siltstones. Rocks of the Cornwallis formation also vary considerably in strength from extremely weak to moderately strong.

5.1.3 Waitakere Group (Nihotupu Formation)

The Nihotupu Formation overlies and inter-fingers with the Cornwallis Formation. It is up to 60m thick in places and comprises massive beds of fine to coarse Volcaniclastic sandstone. Volcaniclastic rocks of the Nihotupu Formation vary considerably in strength.

5.2 Aerial Photograph Interpretation

Review of stereoscopic aerial photographs shows the Little Muddy Creek basin draining south south-west to the Manukau harbour with a high arcuate ridge forming the north side of the basin. The basin is dissected by deeply incised valleys which follow the regional geologic structure and are drowned to the south by the Manukau Harbour. The streams feeding into the drowned lower reaches become less incised to the north but are broken by a series of waterfalls and prominent bluffs.

Observations of aerial photographs covering the area indicate that the three main valleys from Little Muddy Creek west to Huia have formed in a similar manner following the regional geological structure. A lineament study (**refer following page**) indicates that the drainage pattern of the incised valleys follows the general regional structure and is therefore considered to be unaltered. Photo plate 1 below illustrates the 'saw toothed' nature of the streams following the regional structure.

Photo Plate 1 – Stream following regional structure

(Note sharp right angles in stream alignment)

ORMISTON ASSOCIATES LTD
CONSULTANTS IN GEOTECHNICAL ENGINEERING, GEOLOGY & ENGINEERING GEOLOGY
Level 1, 18 St Martins Lane, Auckland City
P O Box 47-822 Ponsonby, Auckland New Zealand
Ph (00649) 378 1081 Fax (00649) 378 9834

CLIENT: **Watercare Services Ltd**
LOCATION: Reservoir No 3
TITLE: **Lineament Study**

SCALE: Not To Scale
DRAWN: BXH
DATE: September 2008
CHECKED: AWO

We would not expect an area of large-scale movement, with resultant deformation of the geological units to show a drainage pattern that conforms so well to the unbroken geological structure. The geomorphology is more consistent with the valley-within-a-valley formation formed by erosion at distinctly different sea levels as proposed by Mansergh. This is supported by overlaying the geological map onto the aerial photographs.

The Nihotupu formation is observed to follow the arcuate ridge around the head of the valleys forming the high crest-bluffs due to its greater resistance to erosion than the underlying softer ECBF and Cornwallis units which have undercut the Nihotupu formation as they have eroded.

The bluffs occurring at the head of the Little Muddy Creek Catchment are not confined to this catchment but also follow the Nihotupu Formation outcrop into adjacent catchments (refer attached Plan No 2113/2950-1), particularly those occurring at the head of the lower Nihotupu reservoir and catchment to the west.

The ridge located between Little Muddy Creek Catchment and the Lower Nihotupu Reservoir comprises more resistant Nihotupu formation and therefore completes the arcuate feature interpreted by some parties as a large scale landslide headscarp (refer attached plan no 2113/2950-1).

As observed in stream channels downslope of Ngaio Road and in other parts of the catchment, the Cornwallis Formation is also observed to be a bluff forming unit (refer Photo Plate 2 below), albeit on a smaller scale, explaining the continuation of the bluffs along Scenic Drive extending east towards Mt Atkinson and Titirangi.

Mounds observed around the existing filter station and reservoir are interpreted to be colluvial remnants of the bluff forming process and can be observed throughout the Waitakere Ranges.

Photo Plate 2 – Bluff/Cliff below Ngaio Road

(note massive un-fractured nature of the Cornwallis Formation)

5.3 Structure

Lithologies in the area are observed to have a general north to northwest dip, into the general slope of the Little Muddy Creek Basin, in the order of 5° to 8°. Only discrete locations along Scenic drive have a south-westerly to westerly dip component and this could be due to intra-formation slumping that occurred at the time of deposition resulting in localised folded bedding. This general north to northwest dip does not support the theory of a large scale landslide along bedding parallel clay seams as proposed by Beca.

Furthermore the north-west dip component appears to be consistent though-out the catchment and the wider area adjacent to the catchment (refer attached Plan No 2113/2950-1). We would expect to see an inconsistency or large variations in bedding dip throughout the catchment if it had been subject to large scale movement.

5.4 Field Mapping

Observations of geological structures, bedding, rock strength and drill core (refer attached logs/photos 17 Ngaio Road) of the bluff and waterfall below Ngaio Road indicate that the rock belongs to the Cornwallis Formation. It is massively bedded and exhibits only minor fracturing with a north-west dip of approximately 5° (i.e into the bluff) consistent with the dip measured within the Nihotupu Formation forming the bluffs above Exhibition Drive. The rock mass does not show any evidence of having been subject to deep seated movement.

These observations support Mansergh's theory of erosion as there is an unbroken sequence of rock from the older ECBF to the younger Cornwallis to the Nihotupu formations.

The Beca Infrastructure report concludes that the Huia Filter Station is located on a deep ancient landslide with another shallower slip beneath the Huia Filter Station. There seems to be little credible geological evidence to support this conclusion. The theory seems to be based on the appearance of the bluffs as a slip scarp and some observations of localised jointing in test pits and bedding dips inferred from drilling core (without any discussion of the correct orientation of the core). The theory is then supported by the graphical output from a numerical stability programme, showing a slip surface. The wider geological picture contradicts this theory.

There is no evidence of large blocks of the Nihotupu formation at lower elevations which would support the theory of a large scale landslide. Furthermore, the Beca Infrastructure geological model does not include the 15m high waterfall exposure of the Cornwallis Formation below Ngaio Rd (refer Figure 1), which is where the postulated slip surface shown in their output would exit. There is no evidence of either south-westerly dipping defects or an exit point at the 15m high waterfall exposure. In reality, it comprises competent rock with very little fracturing and a northerly dip.

6. Titirangi No 3 Reservoir Site

The site is located adjacent to Manuka Road and Woodlands Park Road and is essentially flat to gently sloping. A swampy area and small stream descend to the east from the site towards the head of a gully located in excess of 100m from the proposed building platform.

To the south, slopes descend gently for a significant distance before reaching the slope crest of a broad valley descending below and to the east of Manuka Road.

Machine boreholes drilled at the site by Pro-Drill on the 9th September 2008 indicate that the site is overlain by approximately 3.5m to 7.0m of colluvium. At the location of Boreholes MH 2 & MH 3 the colluvium is underlain by 2.0m to 2.5m of alluvial deposits with frequent decomposed rootlets. The presence of the swampy alluvial deposits confirms the presence of the surface colluvium and that the bluff has been eroded over time with the colluvium deposited in its present location over the alluvial deposits probably by shallow landslides derived off the bluffs. Borehole MH1 encountered 1.0m of fill.

Beneath the fill, colluvium and alluvial deposits the boreholes encountered completely weathered Cornwallis Formation to a depth of between 9.5m (MH3) and 18.0m (MH1). Below this the boreholes encountered moderately to slightly weathered Cornwallis Formation. **It should be noted that we did not identify slickensided or polished surfaces in the drill core from the site.**

There are no local slopes immediately below the proposed site that would pose a hazard from the stability view point.

The site is considered to be set back a sufficient distance from the toe of the bluffs that the risk of inundation due to a rock collapse is considered to be low.

7. Conclusions

We are in agreement with Mansergh (DSIR 1988) that the arcuate bluffs and gentle terraces of the Little Muddy Creek Catchment are erosional features rather than the result of a large scale landslide. Our observations, as discussed, do not support the theory of a large scale movement and we therefore support the theory of a geologically controlled erosional feature. We provide the following conclusions based on our investigation.

1. We are in agreement with Mansergh's theory of valley formation in contrast to a large scale landslide.
2. It is our opinion that the Little Muddy Creek Catchment has formed as a result of preferential weathering of the softer East Coast Bays Formation causing undercutting of the Cornwallis Formation and in turn the Nihotupu Formation to form the bluffs and topography observed at present. The steep sided ridge crest bluffs are concluded to result in part from the erosion resistant nature of this geologic unit and its location at the ridge crest.
3. As discussed above, we can find no evidence to support the presence of a large scale landslide other than the geomorphic feature of an arcuate shaped bluff at the head of a large catchment.
4. We can find no evidence to support a shallow landslide extending below the Huia Filter Station exiting below Ngaio Road. In our opinion, the risk of such a failure would be very low given the competent state and northwest direction of bedding dip of the Cornwallis Formation at depth below the site and exposed below Ngaio Road.
5. It is our opinion that local and catchment wide geologic hazards affecting the site of the proposed Titirangi No 3 Reservoir are low and that the site is suitable for the construction of the proposed reservoir provided adequate foundations are designed to take into account local soft colluvial and alluvial deposits encountered in the boreholes.

8. Limitation

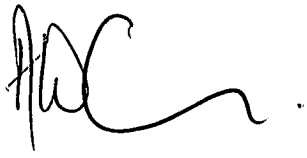
This report has been prepared for the sole benefit of ***Watercare Services Ltd*** as our client with respect to the brief for the proposed development. It is not to be relied upon or used out of context by any other person without reference to Ormiston Associates Ltd. The reliance by other parties on the information or opinions contained in the report shall, without prior review and agreement in writing, be at such parties sole risk.

We trust the above meets your present requirements. If there are any further queries, please do not hesitate to contact the undersigned.

Yours faithfully,

ORMISTON ASSOCIATES LTD.

Bevan X Hill MSc (Hons)
Senior Engineering Geologist, Associate



A W Ormiston MSc
Engineering Geologist, Director

TITIRANGI
RESERVOIR NO 3 BOREHOLE LOGS AND PHOTOS

ORMISTON ASSOCIATES LTD

CONSULTANTS IN GEOTECHNICAL ENGINEERING, GEOLOGY & ENGINEERING GEOLOGY

Prepared for: Tower Foundations Ltd.
Job No: 2113/2950
Project: Manuka Road Water Reservoir
Borehole Location:
Surface Elevation: Datum:
Surface Conditions:

LOG OF BOREHOLE MH1

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery (20 40 60 80)	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
FILL		GRAVEL SILT, clayey, stiff, wet, highly plastic, brownish orange, frequent manganese lenses.								
COLLUVIUM		SILT, clayey, stiff, wet, highly plastic, light grey mottled orange occasional gravels up to 20mm and manganese staining.	1	TRIPLE TUBE		PUSH TUBE		112 r45		2 3 4 N=7
		Orange mottled grey.	2					70 r40		
		SILT, slightly clayey, very stiff, moist, slightly plastic, greenish grey, occasional clasts (1-5mm), blocky structure	3			PUSH TUBE		75 r25		2 2 3 N=5
		Lense of SAND, dark brown, cemented.	4					30 r9		
			5							

Date Started ..... 8th September 2008
Date Finished ..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... Uncorrected
Logged by ..... BXH/RM

ORMISTON ASSOCIATES LTD
CONSULTING GEOTECHNICAL ENGINEERS,
GEOLOGISTS
& ENGINEERING GEOLOGISTS

Prepared for: Tower Foundations Ltd.
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Borehole Location:
Surface Elevation: Datum:
Surface Conditions:

LOG OF BOREHOLE MH1

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery (20 40 60 80)	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
COLLUVIUM		Lense of SAND, dark brown, cemented.		TRIPLE TUBE				68 r24		
		SANDSTONE boulder, completely weathered, brown becoming grey/orange.				PUSH TUBE				
		SILT, clayey, very stiff, wet, highly plastic, brownish orange and grey, freq. sandstone gravels (20-80mm dia.).	6							2 2 3 N=5
			7					102 r10		
CORNWALLIS FORMATION		SILT, very stiff, moist, non plastic, light yellowish orange & brown.						108 r14		
			8			PUSH TUBE				3 6 8 N=14
		Completely weathered siltstone, blocky, orange & brown. Limonite band (10mm).								
		Becomes mottled pink, white, orange, brown & grey.	9					58 r12		
								100 r10		
			10							

Date Started ..... 8th September 2008
Date Finished ..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorrected
Logged by ..... BXH/RM

ORMISTON ASSOCIATES LTD
CONSULTING GEOTECHNICAL ENGINEERS,
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Prepared for:	Tower Foundations Ltd.
Job No:	2113/2950
Project:	Manuka Road Water Reservoir
Borehole Location:	Refer Site Plan
Surface Elevation:	Datum:
Surface Conditions:	

LOG OF BOREHOLE MH1

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery (20 40 60 80)	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
CORNWALLIS FORMATION		Completely weathered siltstone, blocky, mottled pink, white, orange, brown & grey. Occasional gravels.	11	TRIPLE TUBE		PUSH TUBE				3 4 7 N=11
		SILT, very stiff, moist, non plastic, orange & brown, freq. completely weathered lithic fragments up to 20mm dia., freq. brown clay lenses (1-2mm).	12					UTP		6 12 15 N=27
		SANDSTONE(CW), SAND (fine), dense, moist, non plastic, brown. Occasional well cemented lithic fragments up to 50mm.	13							
		SAND (med-coarse), dense, moist, brown, freq. fine gravels.	14							5 13 10 N=23
			15							

Date Started ..... 8th September 2008
Date Finished ..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorrected
Logged by ..... BXH/RM

ORMISTON ASSOCIATES LTD
CONSULTING GEOTECHNICAL ENGINEERS,
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& ENGINEERING GEOLOGISTS

Prepared for:	Tower Foundations Ltd.
Job No:	2113/2950
Project:	Manuka Road Water Reservoir
Borehole Location:	Refer Site Plan.
Surface Elevation:	Datum:
Surface Conditions:	

LOG OF BOREHOLE MH1

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery (20 40 60 80)	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
CORNWALLIS FORMATION		SAND (med-coarse), dense, moist, brown, freq. fine gravels.	16	TRIPLE TUBE				UTP		12 13 21 N=34
			17					UTP		50 (For 150 N=50)
		Slightly to mod. weathered, very weak, massive, Sandstone, brown. Defect 60° to core axis, rough, tight. (drilling induced). Defect 45° to core axis, rough, tight. (drilling induced).	18							8 16 21 N=37
		Rock fabric destroyed by drilling from 19.5m - 21.0m.	19							8 16 16 N=32
			20							

Date Started ..... 8th September 2008
Date Finished..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorrected
Logged by ..... BXH/RM

ORMISTON ASSOCIATES LTD
CONSULTING GEOTECHNICAL ENGINEERS,
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& ENGINEERING GEOLOGISTS

Prepared for: Tower Foundations Ltd.
Job No: 2113/2950
Project: Manuka Road Water Reservoir
Borehole Location: Refer Site Plan
Surface Elevation: Datum:
Surface Conditions:

LOG OF BOREHOLE MH1

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
CORNWALLIS FORMATION		Slightly to mod. weathered, very weak, massive, Sandstone, brown.		TRIPLE TUBE						
		Becomes highly fractured from 21.0 - 22.5m	21							6 18 25 N=43
		SANDSTONE (band), very fine grained (Boulder). Defect 70° to core axis, limonite coated, tight.	22							15 20 28 N=48
		Defect 90° to core axis, rough, tight. (drilling induced).								
		Defect parallel to core axis (300mm length), rough, calcite coated.	23							
		Slightly weathered, greenish grey, massive, SANDSTONE (fine grained), very weak to extremely weak.								
		Fine grained grading to coarse grained, becomes very weak from 24.0 - 25.7m (highly fractured).	24							50 (for 110 N=50+)
		Angular gravels in a clay matrix.								
		Slightly weathered, greenish grey, massive, SANDSTONE (coarsely grained), very weak, highly fractured.	25							

Date Started ..... 8th September 2008
Date Finished ..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorrected
Logged by ..... BXH/RM

ORMISTON ASSOCIATES LTD
CONSULTING GEOTECHNICAL ENGINEERS,
GEOLOGISTS
& ENGINEERING GEOLOGISTS

Prepared for:	Tower Foundations Ltd.
Job No:	2113/2950
Project:	Manuka Road Water Reservoir
Borehole Location:	Refer Site Plan
Surface Elevation:	Datum:
Surface Conditions:	

LOG OF BOREHOLE MH1

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
CORNWALLIS FORMATION		Slightly weathered, greenish grey, massive, SANDSTONE (coarsely grained), very weak, highly fractured.	26	TRIPLE TUBE			20 40 60 80 100			50 (for 120 N=50+)
		Becomes slightly fractured. Defects 90° to core axis. (drill induced). From 27.3-28.5m becomes slightly fractured. Defect 90° to core axis. (drill induced).	27							50 (for 100 N=50+)
		End of Borehole 28.5m (Target Depth)	28							50 (for 140 N=50+)
			29							
			30							

Date Started ..... 8th September 2008
Date Finished ..... 8th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorrected
Logged by ..... BXH/RM

ORMISTON ASSOCIATES LTD
CONSULTING GEOTECHNICAL ENGINEERS,
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& ENGINEERING GEOLOGISTS

Prepared for: Tower Foundations Ltd.
Job No: 2113/2950
Project: Manuka Road Water Reservoir
Borehole Location:
Surface Elevation: Datum:
Surface Conditions:

LOG OF BOREHOLE MH2

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery (20 40 60 80)	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
COLLUVIUM		TOPSOIL, moist, firm, dark brown.	0	TRIPLE TUBE		PUSH TUBE		73 r32		2 4 4 N=8
		SILT, clayey, very stiff, wet, highly plastic, orange mottled grey, frequent topsoil inclusions.								
		SILT, very stiff, moist to wet, non plastic, orange mottled grey, relict rock fabric visible.	1					82 r32		
			2							
		SILT, clayey, very stiff, wet, highly plastic, light greyish brown mottled orange.	3			PUSH TUBE		25 r8 44 r15		
ALLUVIAL DEPOSITS		CLAY, very soft, wet, highly plastic, light grey.	4							1 2 2 N=4
		Frequent partly decomposed rootlets (8-10mm dia.)	5					40 r16		

Date Started ..... 8th September 2008
Date Finished ..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... Uncorrected
Logged by ..... BXH/RM

ORMISTON ASSOCIATES LTD
CONSULTING GEOTECHNICAL ENGINEERS,
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& ENGINEERING GEOLOGISTS

Prepared for: Tower Foundations Ltd.
Job No: 2113/2950
Project: Manuka Road Water Reservoir
Borehole Location:
Surface Elevation: Datum:
Surface Conditions:

LOG OF BOREHOLE MH2

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery (20 40 60 80)	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
ALLUVIAL DEPOSITS		CLAY, very soft, wet, highly plastic, light grey.								
		Becomes slightly sandy (fine).				PUSH TUBE		53 r26		
		SILT, very stiff, moist to wet, non to slightly plastic, greenish grey, trace clay in lenses.	6							1 3 3 N=6
CORNWALLIS FORMATION				TRIPLE TUBE				UTP		
		Occasional angular gravels up to 5mm dia.				PUSH TUBE		50 r10		
		Occasional lithic fragments up to 80mm dia.	8							3 5 6 N=11
			9					UTP		
								90 r29		
			10							

Date Started ..... 8th September 2008
Date Finished..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorrected
Logged by ..... BXH/RM

ORMISTON ASSOCIATES LTD
CONSULTING GEOTECHNICAL ENGINEERS,
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& ENGINEERING GEOLOGISTS

Prepared for:	Tower Foundations Ltd.
Job No:	2113/2950
Project:	Manuka Road Water Reservoir
Borehole Location:	Refer Site Plan
Surface Elevation:	Datum:
Surface Conditions:	

LOG OF BOREHOLE MH2

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery (20 40 60 80)	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
CORNWALLIS FORMATION		SILT, very stiff, moist to wet, non to slightly plastic, greenish grey, frequent lithic fragments oup to 80mm dia.	11	TRIPLE TUBE		PUSH TUBE		UTP		8 12 14 N=26
		Frequent limonite inclusions.								
		Relic rock fabric (completely weathered), brown & grey. Frequent bands of sandstone (50mm), very weak, grey. (Boulder).								
		SILT, stiff, moist to wet, non plastic, brownish grey, frequent lithic fragments of sandstone & siltstone.	12							14 25 25 (for 110mm) N=50+
			13							
		Weathered, brown, SANDSTONE (fine to medium grained), very weak to extremely weak.	14							17 26 24 (for 100mm) N=50+
		Fractures at 45° and 90° to core axis.								
		Defect at 45° to core axis, rought, tight.								
			15							

Date Started ..... 8th September 2008
Date Finished ..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorrected
Logged by ..... BXH/RM

ORMISTON ASSOCIATES LTD
CONSULTING GEOTECHNICAL ENGINEERS,
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& ENGINEERING GEOLOGISTS

Prepared for:	Tower Foundations Ltd.
Job No:	2113/2950
Project:	Manuka Road Water Reservoir
Borehole Location:	Refer Site Plan.
Surface Elevation:	Datum:
Surface Conditions:	

LOG OF BOREHOLE MH2

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery (20 40 60 80)	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
CORNWALLIS FORMATION		End of Borehole 15.0m (Target Depth)	15	TRIPLE TUBE						20 50 (for 130mm) N=50+

Date Started ..... 8th September 2008
Date Finished ..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorreted
Logged by ..... BXH/RM

ORMISTON ASSOCIATES LTD
CONSULTING GEOTECHNICAL ENGINEERS,
GEOLOGISTS
& ENGINEERING GEOLOGISTS

Prepared for:	Tower Foundations Ltd.
Job No:	2113/2950
Project:	Manuka Road Water Reservoir
Borehole Location:	
Surface Elevation:	Datum:
Surface Conditions:	

LOG OF BOREHOLE MH3

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery (20 40 60 80)	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
COLLUVIUM		TOPSOIL, moist, firm, dark brown.		TRIPLE TUBE		PUSH TUBE		80 r40		2 2 3 N=5
		SILT, slightly clayey, very stiff, moist, moderately plastic, orange mottled light grey.	1							
		SILT, stiff, wet, non plastic, brown mottled orange & grey, frequent limonite staining. Occasional cream mottles. Interbedded layers of cream clay. (100mm).	2							
			3			PUSH TUBE				
ALLUVIAL DEPOSITS		CLAY, silty, soft, wet, highly plastic, frequent minor organics.	4							2 3 4 N=7
		100mm layer of sand (fine to medium), manganese staining, brown. Occasional lenses of sand.	5					50 r16		

Date Started ..... 8th September 2008
Date Finished ..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... Uncorrected
Logged by ..... BXH/RM

ORMISTON ASSOCIATES LTD
CONSULTING GEOTECHNICAL ENGINEERS,
GEOLOGISTS
& ENGINEERING GEOLOGISTS

Prepared for:	Tower Foundations Ltd.
Job No:	2113/2950
Project:	Manuka Road Water Reservoir
Borehole Location:	
Surface Elevation:	Datum:
Surface Conditions:	

LOG OF BOREHOLE MH3

Sheet 2 of 3

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery (20 40 60 80)	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
ALLUVIAL DEPOSITS		CLAY, silty, soft, wet, highly plastic, frequent minor organics & occasional lenses of sand.	6	TRIPLE TUBE		PUSH TUBE		85 r10		3 3 4 N=7
								42 r4		
CORNWALLIS FORMATION		SAND (fine to medium), dense, brown. (completely weathered sandstone). Vertical clay filled joint (50mm).	7			PUSH TUBE		85 r28		11 6 24 N=30
		Extremely weak (CW Sandstone).	8					UTP		
			9					UTP		20 23 27 N=50
		Moderately to highly weathered, brown, massive, SANDSTONE, very weak. Defect at 70° to core axis, clay filled. (3mm).	10							

Date Started ..... 8th September 2008
Date Finished ..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorrected
Logged by ..... BXH/RM

ORMISTON ASSOCIATES LTD
CONSULTING GEOTECHNICAL ENGINEERS,
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& ENGINEERING GEOLOGISTS

Prepared for:	Tower Foundations Ltd.
Job No:	2113/2950
Project:	Manuka Road Water Reservoir
Borehole Location:	Refer Site Plan
Surface Elevation:	Datum:
Surface Conditions:	

LOG OF BOREHOLE MH3

Sheet 3 of 3

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery (20 40 60 80)	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
CORNWALLIS FORMATION		Moderately to highly weathered, brown, massive, SANDSTONE, very weak.		TRIPLE TUBE						21 50 (for 145mm) N=50+
		Very weak, grey, SANDSTONE.								
		Defect 90° to core axis, rough, tight, limonite coated surfaces.	11							
		Slightly weathered, blue grey, massive, SANDSTONE (fine to medium grained), weak. (Boulder).								
		Highly fractured from 12.0m - 12.3m.	12							50/80 N=50+
		Highly fractured, slightly weathered, fractures limonite stained from 12.3-3.0m.								
		End of Borehole 13.0m (Target Depth)	13							
			14							
			15							

Date Started ..... 8th September 2008
Date Finished ..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorrected
Logged by ..... BXH/RM

ORMISTON ASSOCIATES LTD
CONSULTING GEOTECHNICAL ENGINEERS,
GEOLOGISTS
& ENGINEERING GEOLOGISTS

Titirangi No 3 Reservoir

Borehole MH1

Box 1 - 0.0m to 5.0m

Box 2 - 5.0m to 8.6m

water Care services limited

TOWER FOUNDATIONS

ORMISTON ASSOCIATES LTD

Titirangi No 3 Reservoir

Borehole MH1

Box 3 - 8.6m to 11.5m

Box 4 - 11.5m to 14.9m

waterCare services limited

TOWER FOUNDATIONS

ORMISTON ASSOCIATES LTD

Titirangi No 3 Reservoir

Borehole MH1

Box 5 - 14.9m to 18.5m

Box 6 - 18.5m to 24.0m

waterCare services limited

TOWER FOUNDATIONS

ORMISTON ASSOCIATES LTD

CONSULTANTS IN GEOTECHNICAL ENGINEERING, GEOLOGY & ENGINEERING GEOLOGY

Titirangi No 3 Reservoir

Borehole MH1

Box 7 - 24.0m to 28.5m

End Of Bore

waterCare services limited

TOWER FOUNDATIONS

ORMISTON ASSOCIATES LTD

Titirangi No 3 Reservoir

Borehole MH2

Box 1 - 0.0m to 3.2m

Box 2 - 3.2m to 7.2m

waterCare services limited

TOWER FOUNDATIONS

ORMISTON ASSOCIATES LTD

Titirangi No 3 Reservoir

Borehole MH2

Box 3 - 7.2m to 10.7m

Box 4 - 10.7m to 13.5m

water Care services limited

TOWER FOUNDATIONS

ORMISTON ASSOCIATES LTD

Titirangi No 3 Reservoir

Borehole MH2

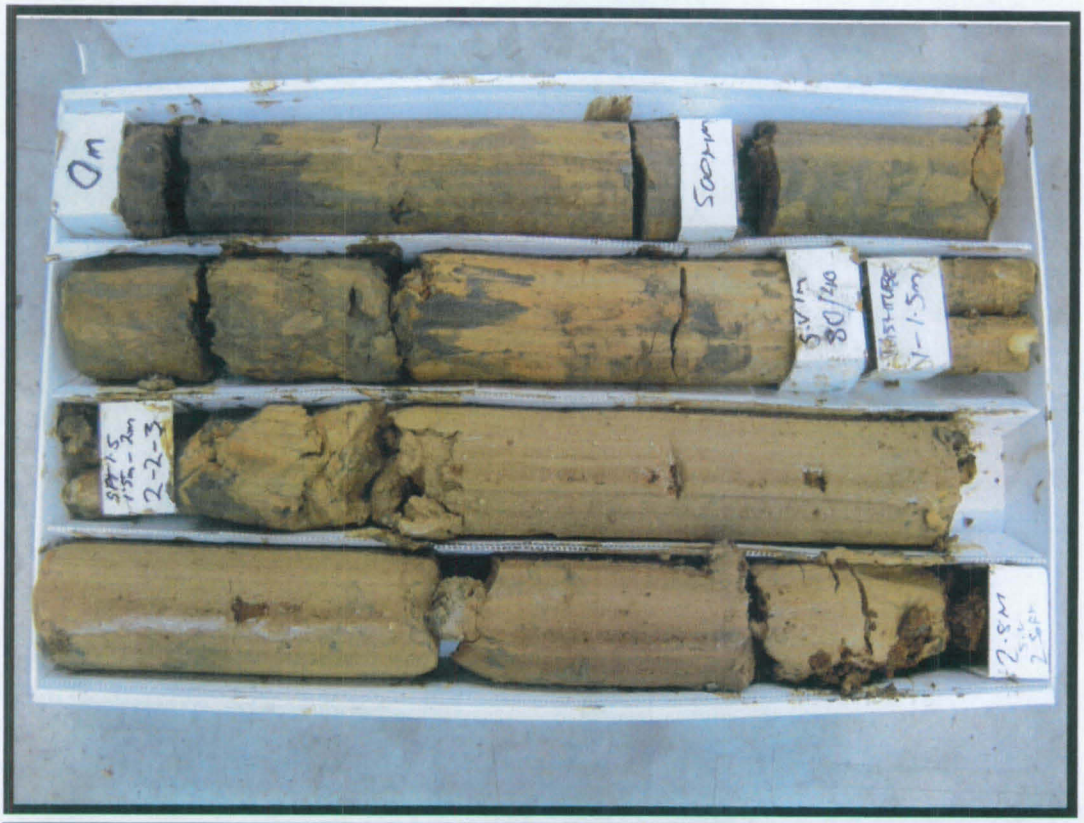
Box 5 - 13.5m to 15.0m

End Of Bore

waterCare services limited

TOWER FOUNDATIONS

ORMISTON ASSOCIATES LTD



Titirangi No 3 Reservoir

Borehole MH3

Box 1 - 0.0m to 2.8m

Box 2 - 2.8m to 6.7m

waterCare services limited

TOWER FOUNDATIONS

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Titirangi No 3 Reservoir

Borehole MH3

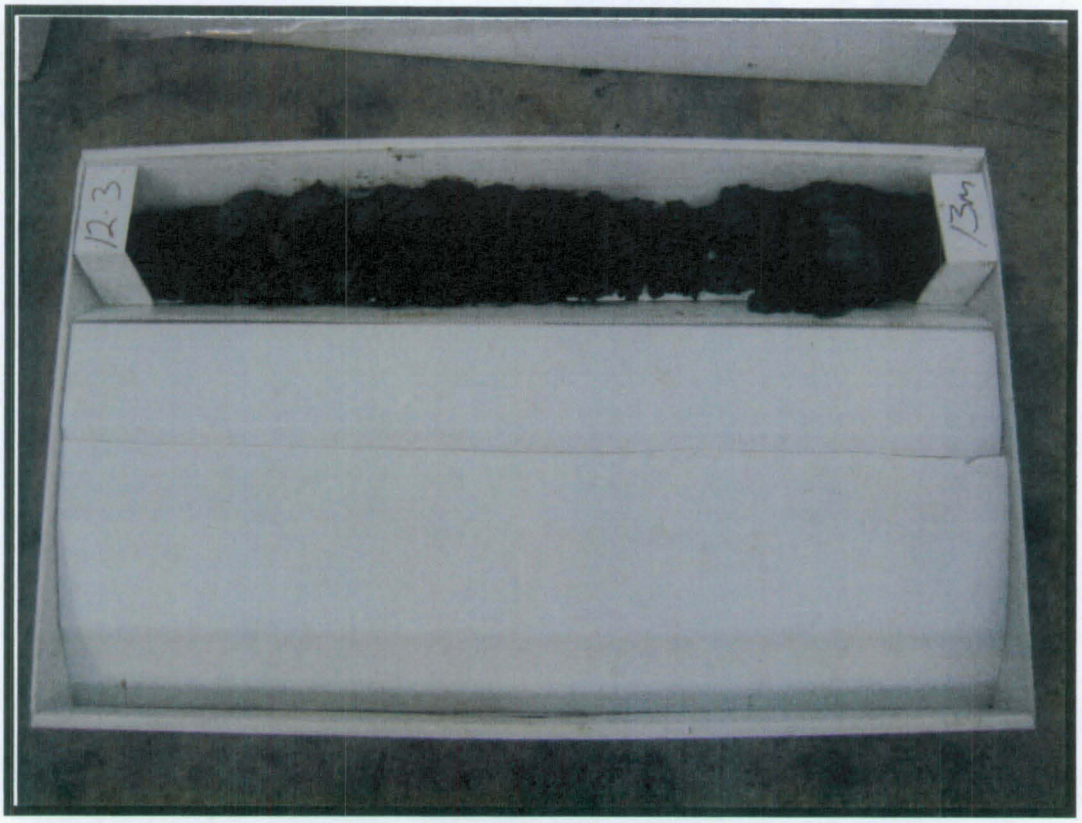
Box 3 - 6.7m to 9.6m

Box 4 - 9.6m to 12.3m

waterCare services limited

TOWER FOUNDATIONS

ORMISTON ASSOCIATES LTD



Titirangi No 3 Reservoir

Borehole MH3

Box 5 - 12.3m to 13.0m

End Of Bore

waterCare services limited

TOWER FOUNDATIONS

ORMISTON ASSOCIATES LTD

NGAIO ROAD
BOREHOLE LOGS AND PHOTOS

ORMISTON ASSOCIATES LTD

CONSULTANTS IN GEOTECHNICAL ENGINEERING, GEOLOGY & ENGINEERING GEOLOGY

Prepared for:

Job No:

Project: 17 Ngaio Road

Borehole Location: Refer to site plan

Surface Elevation: Datum:

Surface Conditions: Gently sloping, Bush Clad

LOG OF BOREHOLE MH1

Sheet 1 of 3

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery	FIELD TESTS: Strength	FIELD TESTS: Groundwater	FIELD TESTS: SPT
WAITEMATA GROUP SOILS		TOPSOIL, clayey, soft, wet, highly plastic, dark brown		TRIPLE TUBE			20 40 60 80	EW VW W S VS ES		
		CLAY, slightly silty, soft, wet, highly plastic, dark brown, occasional rootlets						25kpa		
		At 0.4m becomes orange								
		SILT, slightly clayey, sandy, stiff, moist, moderately plastic orange, occasional inclusions of red angular gravels	1					75kpa		
		SILT, clayey, slightly sandy, soft, moist, slightly plastic								
		SILT, sandy, slightly clayey, soft, wet, slightly plastic, orange, light brown, inclusions of gravels	2						26 March 2007	0 0 0 N=0
		SAND, slightly silty, loose, fine grained, stiff, wet, non plastic, dark brown						225kpa		
		Becomes coarse grained	3					225kpa		3 4 4 N=8
		Brown, Grey, completely to highly weathered, extremely weak, SILTSTONE, SANDSTONE, bedded (SILT, sandy, (fine to medium grained, very stiff, wet, non plastic, grey)						125kpa		
		At 4m gravel inclusions, band of highly weathered gravels, black , red brown	4							
		Dark grey, brown, highly weathered, very weak, SANDSTONE, bedded (SAND, fine to medium grained, stiff, wet, non plastic)						225 kpa		2 4 5 N=9
			5							

Date Started ..... 26 March 2007

Date Finished ..... 26 March 2007

Driller ..... Pro-Drill

Type of Rig ..... Rotary

Shear Vane No. .....

Logged by ..... RMM

ORMISTON ASSOCIATES LTD
CONSULTING GEOTECHNICAL ENGINEERS,
GEOLOGISTS
& ENGINEERING GEOLOGISTS

Prepared for:

Job No:

Project: 17 Ngaio Road

Borehole Location: Refer to site plan

Surface Elevation: Datum:

Surface Conditions: Gently sloping, bush clad

LOG OF BOREHOLE MH1

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery	FIELD TESTS: Strength	FIELD TESTS: Groundwater	FIELD TESTS: SPT
WAITEMATA GROUP		At 5m becomes coarse grained	6	TRIPLE TUBE			20 40 60 90	EW VW W S VS HS >350 kpa		6 6 8 N= 14
		Grey, moderately to highly weathered, SILTSTONE, (fine grained), sub horizontal, very weak, bedded	7							
		At 7m SILTSTONE, gravel inclusions	8							
		Grey, slightly to un-weathered, SILTSTONE, homogenous	9							
		Grey, unweathered, very weak, SILTSTONE, SANDSTONE, sand (fine - med grained), (very stiff, wet, non plastic)	10							50 N=50 for 75mm
		At 9m becomes weak								
		At 9.5m becomes medium to coarse grained, very dense SANDSTONE								

Date Started ..... 26 March 2007

Date Finished ..... 26 March 2007

Driller ..... Pro-Drill

Type of Rig ..... Rotary

Shear Vane No. .....

Logged by ..... RMM

ORMISTON ASSOCIATES LTD
CONSULTING GEOTECHNICAL ENGINEERS,
GEOLOGISTS
& ENGINEERING GEOLOGISTS

Prepared for:

Job No:

Project: 17 Ngaio Road

Borehole Location: Refer Site Plan

Surface Elevation: Datum:

Surface Conditions: Gently sloping, bus clad

LOG OF BOREHOLE MH1

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery	FIELD TESTS: Strength	FIELD TESTS: Groundwater	FIELD TESTS: SPT
WAITEMATA GROUP		Light grey, slightly to un-weathered, SILTSTONE, laminated	11	TRIPLE TUBE			20 40 60 80	EW VW W S VS ES		
		Grey, un weathered, weak, SANDSTONE, occasional gravel clasts								
		End of Machine Hole 11.5 m (Target Depth)	12							
			13							
			14							
			15							

Date Started ..... 26 March 2007

Date Finished ..... 26 March 2007

Driller ..... Pro-Drill

Type of Rig ..... Rotary

Shear Vane No. .....

Logged by ..... RMM

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GEOLOGISTS
& ENGINEERING GEOLOGISTS

Prepared for:

Job No:

Project: 17 Ngaio Road

Borehole Location: Refer to site plan

Surface Elevation: Datum:

Surface Conditions: Gentle slope, bush clad

LOG OF BOREHOLE MH2

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery	FIELD TESTS: Strength	FIELD TESTS: Groundwater	FIELD TESTS: SPT
		TOPSOIL, sillt, stiff, mod plastic, dark brown		TRIPLE TUBE						
WAITEMATA GROUP SOILS		SILT, clayey, stiff, moist to wet, highly plastic, brown mottled orange, occasional rootlets						175kpa		
		CLAY, silty, stiff, moist, highly plastic, orange, occasional gravel inclusions	1							
		Becomes light grey						<25kpa		
			2							
		Light grey, highly weathered, extremely weak, SILTSTONE, SANDSTONE, bedded (SILT, sandy, (fine to medium grained, very stiff, wet, non plastic, grey)								
		Becomes slightly weathered, weak, SILTSTONE, SANDSTONE	3							
		Becoming moderatley weathered siltstone								29 50 N=79 for 115mm
			4							
			5							

Date Started ..... 26 March 2007

Date Finished ..... 26 March 2007

Driller ..... Pro-Drill

Type of Rig ..... Rotary

Shear Vane No. .....

Logged by ..... RMM

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& ENGINEERING GEOLOGISTS

Prepared for:

Job No:

Project: 17 Ngaio Road

Borehole Location: Refer to site plan

Surface Elevation: Datum:

Surface Conditions: Gentle slope, bush clad

LOG OF BOREHOLE MH2

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery	FIELD TESTS: Strength	FIELD TESTS: Groundwater	FIELD TESTS: SPT
WAITEMATA GROUP		At 5m becomes coarse grained		TRIPLE TUBE			20 40 60 80	EW VW W S VS ES		
		Light grey, moderately weathered, weak, SILTSTONE, bedded	6							50 N=50 for 95mm
		At 7m loss of water	7							
			8							
			9							50 N=50 for 95mm
		At 9.5m becomes medium to coarse grained SANDSTONE	10							

Date Started 26 March 2007

Date Finished 26 March 2007

Driller Pro-Drill

Type of Rig Rotary

Shear Vane No.

Logged by RMM

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& ENGINEERING GEOLOGISTS

Prepared for:

Job No:

Project: 17 Ngaio Road

Borehole Location:

Surface Elevation: Datum:

Surface Conditions: Gently sloping, bush clad

LOG OF BOREHOLE MH2

Sheet 3 of 3

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery (20, 40, 60, 80)	FIELD TESTS: Strength (EW, VW, W, S, VS, ES)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
WAITEMATA GROUP		Grey, unweathered, weak, SANDSTONE, SILTSTONE	11	TRIPLE TUBE						
		Becomes dark grey, fine grained, fraible, weak	12							50 N = 50 for 95mm
			13							
		Dark grey, unweathered, moderately ,weak, SILTSTONE, SANDSTONE, bedded	14							
		Becomes unweathered, dark grey, weak SANDSTONE	15							

Date Started ..... 26 March 2007

Date Finished ..... 26 March 2007

Driller ..... Pro-Drill

Type of Rig ..... Rotary

Shear Vane No. .....

Logged by ..... RMM

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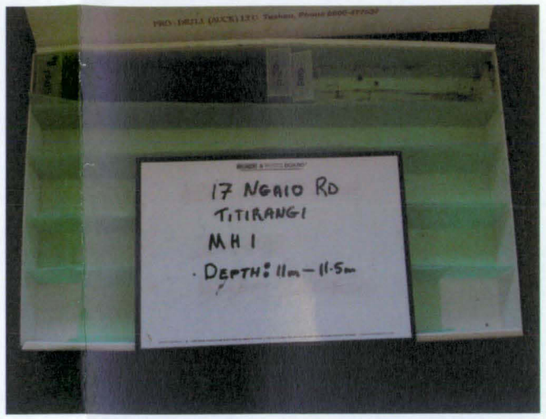
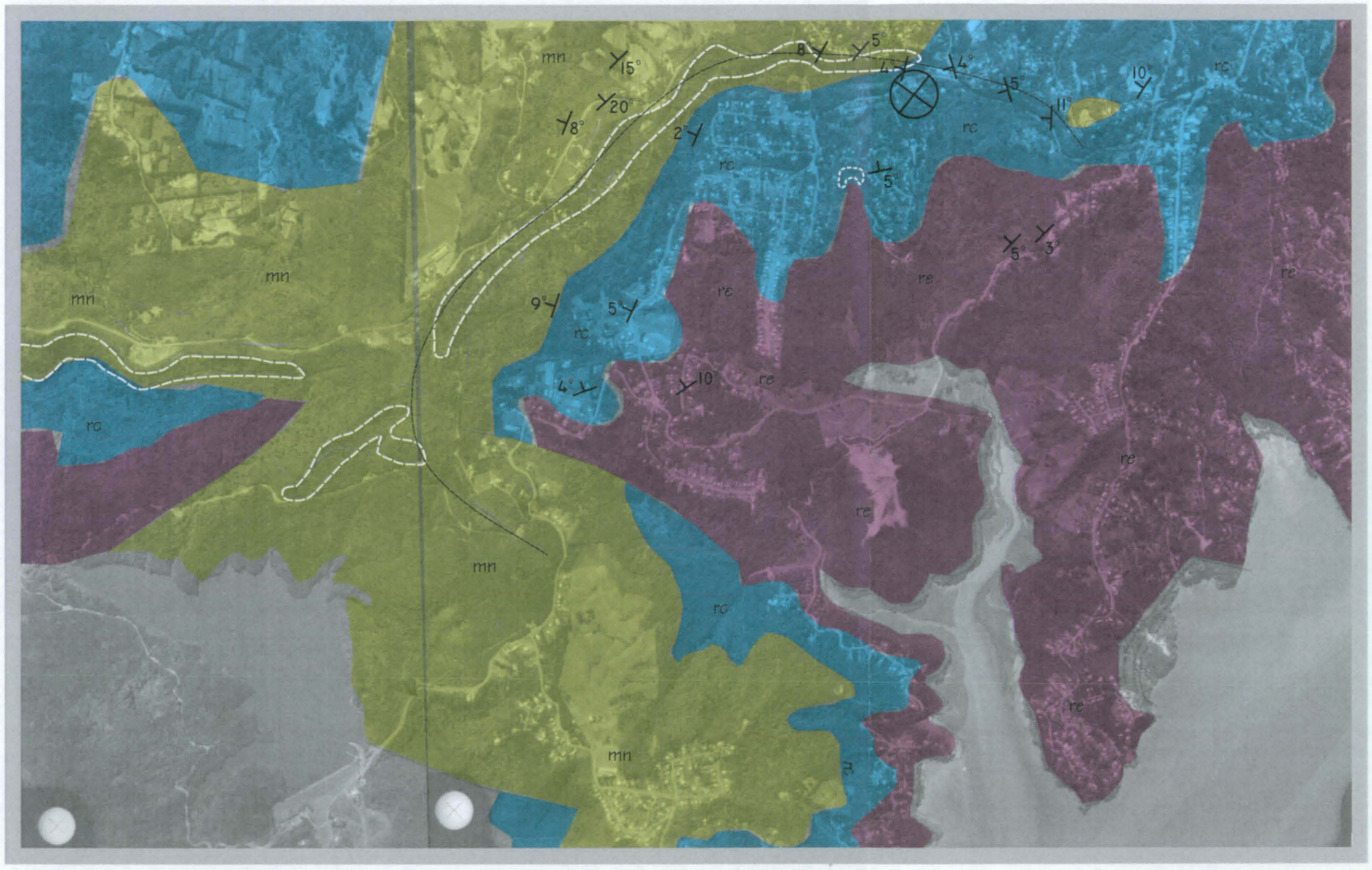
17 Ngaio Road - Core Photos



DRAWINGS



Legend

- mn — Waitakere Formation (Nihotupu Fm) - Alternating Mudstone & Sandstone
- rc — Cornwallis Formation - Volcanic grit and Alternating Siltstones & Sandstones
- re — East Coast Bays Formation - Alternating Siltstones & Sandstones
- 10° — Strike & Dip
- Approximate extent of Major Bluff
- Approximate location of Reservoir No 3
- Approximate extent of arcuate feature

Note: Geologic interpretation is approximate only being based on field observations and Sheet N42/7, Cornwallis, Industrial Map Series

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CONSULTANTS IN GEOTECHNICAL ENGINEERING, GEOLOGY & ENGINEERING GEOLOGY
18 St Martins Lane, Auckland City
P O Box 47-822 Ponsonby, Auckland New Zealand
Ph (00649) 378 1081 Fax (00649) 378 9834

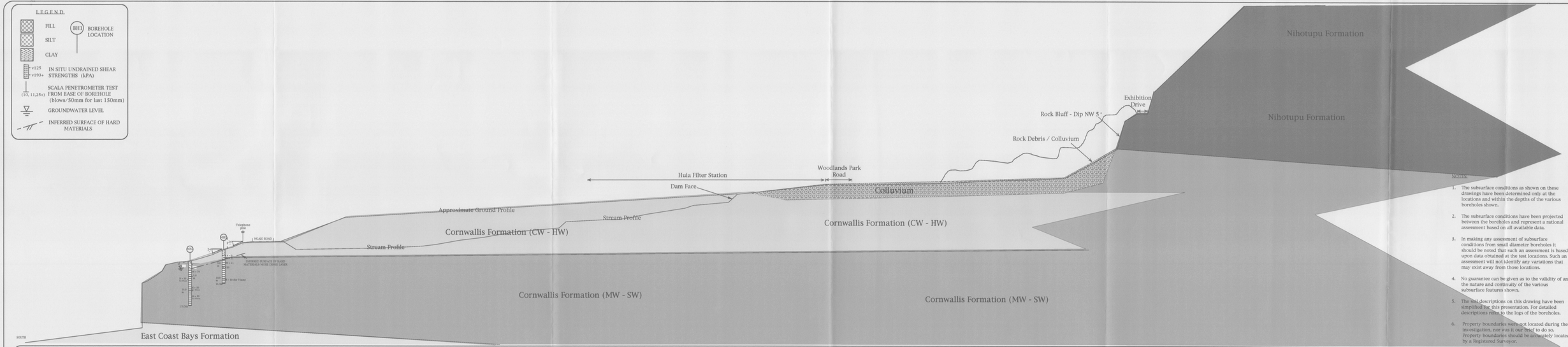
waterCare services limited

TOWER FOUNDATIONS

CLIENT: Watercare Services Ltd
LOCATION: Titirangi No 3 Reservoir
TITLE: Geological Map

SCALE: 1:24000 @ A3
DRAWN: BXH
DATE: 17th Sept 2008
CHECKED: LGD

DRAWING NO
2113/2950-1
SHEET 1 OF 1



NOTES:

1. The subsurface conditions as shown on these drawings have been determined only at the locations and within the depths of the various boreholes shown.
2. The subsurface conditions have been projected between the boreholes and represent a rational assessment based on all available data.
3. In making any assessment of subsurface conditions from small diameter boreholes it should be noted that such an assessment is based upon data obtained at the test locations. Such an assessment will not identify any variations that may exist away from those locations.
4. No guarantee can be given as to the validity of and the nature and continuity of the various subsurface features shown.
5. The soil descriptions on this drawing have been simplified for this presentation. For detailed descriptions refer to the logs of the boreholes.
6. Property boundaries were not located during the investigation, nor was it our brief to do so. Property boundaries should be accurately located by a Registered Surveyor.

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Level 1, 18 St Martins Lane, Auckland City
PO Box 47 822 Ponsonby Auckland New Zealand
Ph (09) 379 1081 & 827 7728 Fax (09) 378 9834

CLIENT : WaterCare Services Ltd
LOCATION : Huia Filter Station, Titirangi
TITLE : Schematic Geologic Cross-section

SCALES	Approx
DRAWN	BXH
DATE	18 Sept 2008
CHECKED	AWO

DRAWING NO
Figure 1
SHEET 1 OF 1

Appendix B

Borehole Logs

Prepared for:	Tower Foundations Ltd.
Job No:	2113/2950
Project:	Manuka Road Water Reservoir
Borehole Location:	
Surface Elevation:	Datum:
Surface Conditions:	

LOG OF BOREHOLE MH1

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
FILL		GRAVEL								
		SILT, clayey, stiff, wet, highly plastic, brownish orange, frequent manganese lenses.								
			1					112 r45		
COLLUVIUM		SILT, clayey, stiff, wet, highly plastic, light grey mottled orange occasional gravels up to 20mm and manganese staining.				PUSH TUBE				2 3 4 N=7
			2	TRIPLE TUBE						
		Orange mottled grey.	3					70 r40		
						PUSH TUBE		75 r25		
		SILT, slightly clayey, very stiff, moist, slightly plastic, greenish grey, occasional clasts (1-5mm), blocky structure.	4							2 2 3 N=5
		Lense of SAND, dark brown, cemented.	5					30 r9		

Date Started ..... 8th September 2008
Date Finished..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... Uncorrected
Logged by ..... BXH/RM

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& ENGINEERING GEOLOGISTS

Prepared for: Tower Foundations Ltd.
Job No: 2113/2950
Project: Manuka Road Water Reservoir
Borehole Location:
Surface Elevation: Datum:
Surface Conditions:

LOG OF BOREHOLE MH1

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery (20 40 60 80)	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
COLLUVIUM		Lense of SAND, dark brown, cemented.		TRIPLE TUBE				68 r24		
		SANDSTONE boulder, completely weathered, brown becoming grey/orange.				PUSH TUBE				
		SILT, clayey, very stiff, wet, highly plastic, brownish orange and grey, freq. sandstone gravels (20-80mm dia.).	6							2 2 3 N=5
			7					102 r10		
CORNWALLIS FORMATION		SILT, very stiff, moist, non plastic, light yellowish orange & brown.						108 r14		
			8			PUSH TUBE				3 6 8 N=14
		Completely weathered siltstone, blocky, orange & brown. Limonite band (10mm).								
		Becomes mottled pink, white, orange, brown & grey.	9					58 r12		
			10					100 r10		

Date Started ..... 8th September 2008
Date Finished..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorrected
Logged by ..... BXH/RM

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& ENGINEERING GEOLOGISTS

Prepared for:	Tower Foundations Ltd.
Job No:	2113/2950
Project:	Manuka Road Water Reservoir
Borehole Location:	Refer Site Plan
Surface Elevation:	Datum:
Surface Conditions:	

LOG OF BOREHOLE MH1

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery (20 40 60 80)	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
CORNWALLIS FORMATION		Completely weathered siltstone, blocky, mottled pink, white, orange, brown & grey. Occasional gravels.	11	TRIPLE TUBE		PUSH TUBE		UTP		3, 4, 7, N=11
		SILT, very stiff, moist, non plastic, orange & brown, freq. completely weathered lithic fragments up to 20mm dia., freq. brown clay lenses (1-2mm).	12							6, 12, 15, N=27
		SANDSTONE(CW), SAND (fine), dense, moist, non plastic, brown. Occasional well cemented lithic fragments up to 50mm.	13							
		SAND (med-coarse), dense, moist, brown, freq. fine gravels.	14							5, 13, 10, N=23
			15							

Date Started ..... 8th September 2008
Date Finished ..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorrected
Logged by ..... BXH/RM

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& ENGINEERING GEOLOGISTS

Prepared for:	Tower Foundations Ltd.
Job No:	2113/2950
Project:	Manuka Road Water Reservoir
Borehole Location:	Refer Site Plan.
Surface Elevation:	Datum:
Surface Conditions:	

LOG OF BOREHOLE MH1

Geol. Unit	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery (20 40 60 80)	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
CORNWALLIS FORMATION	SAND (med-coarse), dense, moist, brown, freq. fine gravels.	16	TRIPLE TUBE				UTP		12 13 21 N=34
		17					UTP		50 (for 150 N=50)
	Slightly to mod. weathered, very weak, massive, Sandstone, brown. Defect 60° to core axis, rough, tight. (drilling induced). Defect 45° to core axis, rough, tight. (drilling induced).	18							8 16 21 N=37
	Rock fabric destroyed by drilling from 19.5m - 21.0m.	19							8 16 16 N=32
		20							

Date Started ..... 8th September 2008
Date Finished ..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorrected
Logged by ..... BXH/RM

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Prepared for:	Tower Foundations Ltd.
Job No:	2113/2950
Project:	Manuka Road Water Reservoir
Borehole Location:	Refer Site Plan
Surface Elevation:	Datum:
Surface Conditions:	

LOG OF BOREHOLE MH1

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
CORNWALLIS FORMATION		Slightly to mod. weathered, very weak, massive, Sandstone, brown.		TRIPLE TUBE						
		Becomes highly fractured from 21.0 - 22.5m	21							6 18 25 N=43
		SANDSTONE (band), very fine grained (Boulder). Defect 70° to core axis, limonite coated, tight.	22							15 20 28 N=48
		Defect 90° to core axis, rough, tight. (drilling induced).								
		Defect parallel to core axis (300mm length), rough, calcite coated.	23							
		Slightly weathered, greenish grey, massive, SANDSTONE (fine grained), very weak to extremely weak.								
		Fine grained grading to coarse grained, becomes very weak from 24.0 - 25.7m (highly fractured).	24							50 (for 110) N=50+
		Angular gravels in a clay matrix.								
		Slightly weathered, greenish grey, massive, SANDSTONE (coarsely grained), very weak, highly fractured.	25							

Date Started ..... 8th September 2008
Date Finished ..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorrected
Logged by ..... BXH/RM

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Prepared for:	Tower Foundations Ltd.
Job No:	2113/2950
Project:	Manuka Road Water Reservoir
Borehole Location:	Refer Site Plan
Surface Elevation:	Datum:
Surface Conditions:	

LOG OF BOREHOLE MH1

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
CORNWALLIS FORMATION		Slightly weathered, greenish grey, massive, SANDSTONE (coarsely grained), very weak, highly fractured.	26	TRIPLE TUBE			20 40 60 80 100			50 (for 120 N=50+)
		Becomes slightly fractured. Defects 90° to core axis. (drill induced). From 27.3-28.5m becomes slightly fractured. Defect 90° to core axis. (drill induced).	27							50 (for 100 N=50+)
		End of Borehole 28.5m (Target Depth)	28							50 (for 140 N=50+)
			29							
			30							

Date Started ..... 8th September 2008
Date Finished ..... 8th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorrected
Logged by ..... BXH/RM

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& ENGINEERING GEOLOGISTS

Prepared for:	Tower Foundations Ltd.
Job No:	2113/2950
Project:	Manuka Road Water Reservoir
Borehole Location:	
Surface Elevation:	Datum:
Surface Conditions:	

LOG OF BOREHOLE MH2

Sheet 1 of 4

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery (20 40 60 80)	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
COLLUVIUM		TOPSOIL, moist, firm, dark brown.		TRIPLE TUBE				73 r32		2 4 4 N=8
		SILT, clayey, very stiff, wet, highly plastic, orange mottled grey, frequent topsoil inclusions.	1			PUSH TUBE		82 r32		
		SILT, very stiff, moist to wet, non plastic, orange mottled grey, relict rock fabric visible.	2							
		SILT, clayey, very stiff, wet, highly plastic, light greyish brown mottled orange.	3					25 r8		
						PUSH TUBE		44 r15		
ALLUVIAL DEPOSITS		CLAY, very soft, wet, highly plastic, light grey.	4							1 2 2 N=4
		Frequent partly decomposed rootlets (8-10mm dia.)	5					40 r16		

Date Started ..... 8th September 2008
Date Finished..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... Uncorrected
Logged by ..... BXH/RM

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Prepared for:	Tower Foundations Ltd.
Job No:	2113/2950
Project:	Manuka Road Water Reservoir
Borehole Location:	
Surface Elevation:	Datum:
Surface Conditions:	

LOG OF BOREHOLE MH2

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery (20 40 60 80)	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
ALLUVIAL DEPOSITS		CLAY, very soft, wet, highly plastic, light grey.								
		Becomes slightly sandy (fine).				PUSH TUBE		53 r26		
			6							1 3 3 N=6
CORNWALLIS FORMATION		SILT, very stiff, moist to wet, non to slightly plastic, greenish grey, trace clay in lenses.		TRIPLE TUBE						
			7					UTP		
		Occasional angular gravels up to 5mm dia.				PUSH TUBE		50 r10		
		Occasional lithic fragments up to 80mm dia.	8							3 5 6 N=11
			9					UTP		
								90 r29		
			10							

Date Started ..... 8th September 2008
Date Finished ..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorrected
Logged by ..... BXH/RM

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Prepared for:	Tower Foundations Ltd.
Job No:	2113/2950
Project:	Manuka Road Water Reservoir
Borehole Location:	Refer Site Plan
Surface Elevation:	Datum:
Surface Conditions:	

LOG OF BOREHOLE MH2

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery (20 40 60 80)	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
CORNWALLIS FORMATION		SILT, very stiff, moist to wet, non to slightly plastic, greenish grey, frequent lithic fragments oup to 80mm dia.				PUSH TUBE		UTP		8 12 14 N=26
		Frequent limonite inclusions.								
		Relic rock fabric (completely weathered), brown & grey. Frequent bands of sandstone (50mm), very weak, grey. (Boulder).	11							
		SILT, stiff, moist to wet, non plastic, brownish grey, frequent lithic fragments of sandstone & siltstone.	12	TRIPLE TUBE						14 25 25 (for 110mm) N=50+
		Weathered, brown, SANDSTONE (fine to medium grained), very weak to extremely weak.	13							17 26 24 (for 100mm) N=50+
		Fractures at 45° and 90° to core axis.	14							
		Defect at 45° to core axis, rought, tight.	15							

Date Started ..... 8th September 2008
Date Finished ..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorrected
Logged by ..... BXH/RM

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Prepared for:	Tower Foundations Ltd.
Job No:	2113/2950
Project:	Manuka Road Water Reservoir
Borehole Location:	Refer Site Plan.
Surface Elevation:	Datum:
Surface Conditions:	

LOG OF BOREHOLE MH2

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
CORNWALLIS FORMATION		End of Borehole 15.0m (Target Depth)	15	TRIPLE TUBE						20 / 50 (for 130mm) N=50+

Date Started ..... 8th September 2008
Date Finished ..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorreted
Logged by ..... BXH/RM

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& ENGINEERING GEOLOGISTS

Prepared for:	Tower Foundations Ltd.
Job No:	2113/2950
Project:	Manuka Road Water Reservoir
Borehole Location:	
Surface Elevation:	Datum:
Surface Conditions:	

LOG OF BOREHOLE MH3

Sheet 1 of 3

Geol. Unit	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
COLLUVIUM	TOPSOIL, moist, firm, dark brown.		TRIPLE TUBE		PUSH TUBE		80 r40		2 2 3 N=5
	SILT, slightly clayey, very stiff, moist, moderately plastic, orange mottled light grey.	1							
	SILT, stiff, wet, non plastic, brown mottled orange & grey, frequent limonite staining. Occasional cream mottles. Interbedded layers of cream clay. (100mm).	2							
		3			PUSH TUBE				
ALLUVIAL DEPOSITS	CLAY, silty, soft, wet, highly plastic, frequent minor organics.	4							2 3 4 N=7
	100mm layer of sand (fine to medium), manganese staining, brown. Occasional lenses of sand.	5					50 r16		

Date Started ..... 8th September 2008
Date Finished ..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... Uncorrected
Logged by ..... BXH/RM

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Prepared for:	Tower Foundations Ltd.
Job No:	2113/2950
Project:	Manuka Road Water Reservoir
Borehole Location:	
Surface Elevation:	Datum:
Surface Conditions:	

LOG OF BOREHOLE MH3

Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
ALLUVIAL DEPOSITS		CLAY, silty, soft, wet, highly plastic, frequent minor organics & occasional lenses of sand.	6	TRIPLE TUBE		PUSH TUBE		85 r10		3 3 4 N=7
								42 r4		
CORNWALLIS FORMATION		SAND (fine to medium), dense, brown. (completely weathered sandstone). Vertical clay filled joint (50mm).	7			PUSH TUBE		85 r28		11 6 24 N=30
		Extremely weak (CW Sandstone).	8					UTP		
			9					UTP		20 23 27 N=50
		Moderately to highly weathered, brown, massive, SANDSTONE, very weak. Defect at 70° to core axis, clay filled. (3mm).	10							

Date Started ..... 8th September 2008
Date Finished ..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorrected
Logged by ..... BXH/RM

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Prepared for: Tower Foundations Ltd.
Job No: 2113/2950
Project: Manuka Road Water Reservoir
Borehole Location: Refer Site Plan
Surface Elevation: Datum:
Surface Conditions:

LOG OF BOREHOLE MH3

Sheet 3 of 3

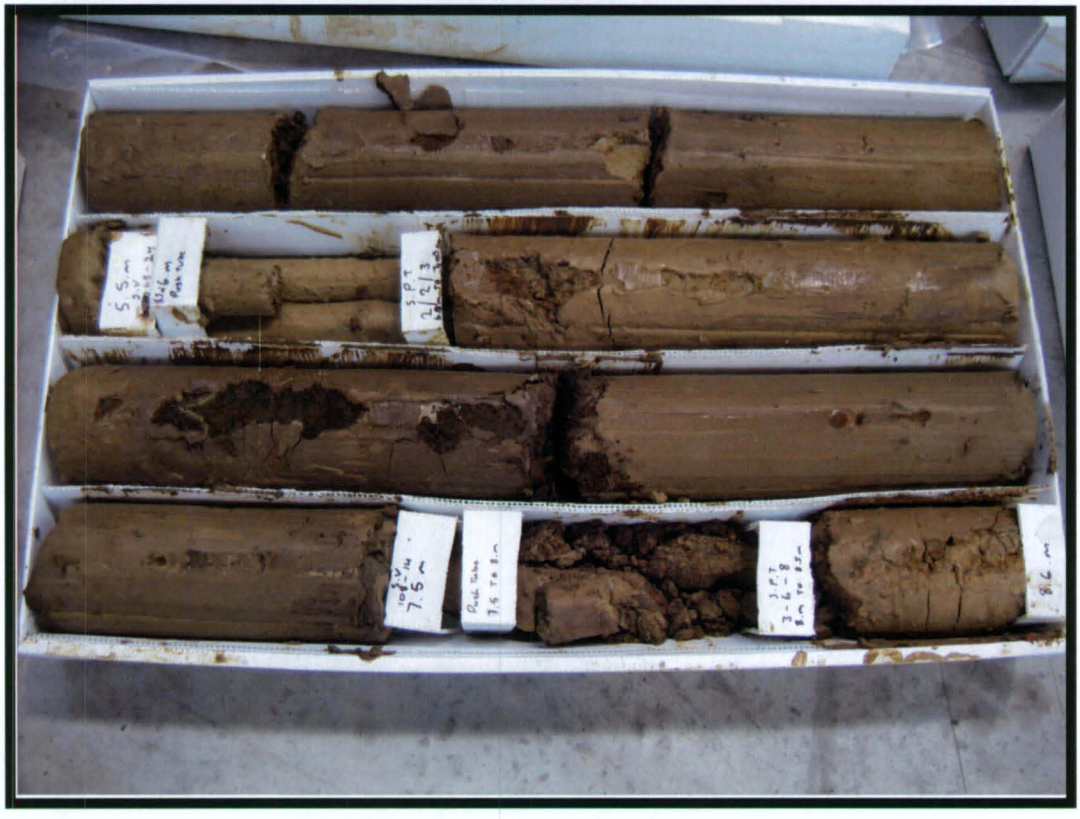
Geol. Unit	Graphic Log	Soil / Rock Description	Depth (m)	Drilling Method	SAMPLE DATA: Condition	SAMPLE DATA: Type	SAMPLE DATA: Sample Recovery (20 40 60 80)	FIELD TESTS: Shear Strength (kPa)	FIELD TESTS: Groundwater	FIELD TESTS: SPT
CORNWALLIS FORMATION		Moderately to highly weathered, brown, massive, SANDSTONE, very weak.		TRIPLE TUBE						21
		Very weak, grey, SANDSTONE.								50 (For 145mm)
		Defect 90° to core axis, rough, tight, limonite coated surfaces.	11							N=50+
		Slightly weathered, blue grey, massive, SANDSTONE (fine to medium grained), weak. (Boulder).								
		Highly fractured from 12.0m - 12.3m.	12							50/80
		Highly fractured, slightly weathered, fractures limonite stained from 12.3-3.0m.								N=50+
		End of Borehole 13.0m (Target Depth)	13							
			14							
			15							

Date Started ..... 8th September 2008
Date Finished ..... 9th September 2008
Driller ..... Pro Drill
Type of Rig ..... Rotary
Shear Vane No. ..... UnCorrected
Logged by ..... BXH/RM

ORMISTON ASSOCIATES LTD
CONSULTING GEOTECHNICAL ENGINEERS,
GEOLOGISTS
& ENGINEERING GEOLOGISTS

Appendix C

Borelog Photos



Titirangi No 3 Reservoir

Borehole MH1

Box 1 - 0.0m to 5.0m

Box 2 - 5.0m to 8.6m

waterCare services limited

TOWER FOUNDATIONS

ORMISTON ASSOCIATES LTD

CONSULTANTS IN GEOTECHNICAL ENGINEERING, GEOLOGY & ENGINEERING GEOLOGY

Titirangi No 3 Reservoir

Borehole MH1

Box 3 - 8.6m to 11.5m

Box 4 - 11.5m to 14.9m

waterCare services limited

TOWER FOUNDATIONS

ORMISTON ASSOCIATES LTD

CONSULTANTS IN GEOTECHNICAL ENGINEERING, GEOLOGY & ENGINEERING GEOLOGY

Titirangi No 3 Reservoir

Borehole MH1

Box 5 - 14.9m to 18.5m

Box 6 - 18.5m to 24.0m

waterCare services limited

TOWER FOUNDATIONS

ORMISTON ASSOCIATES LTD

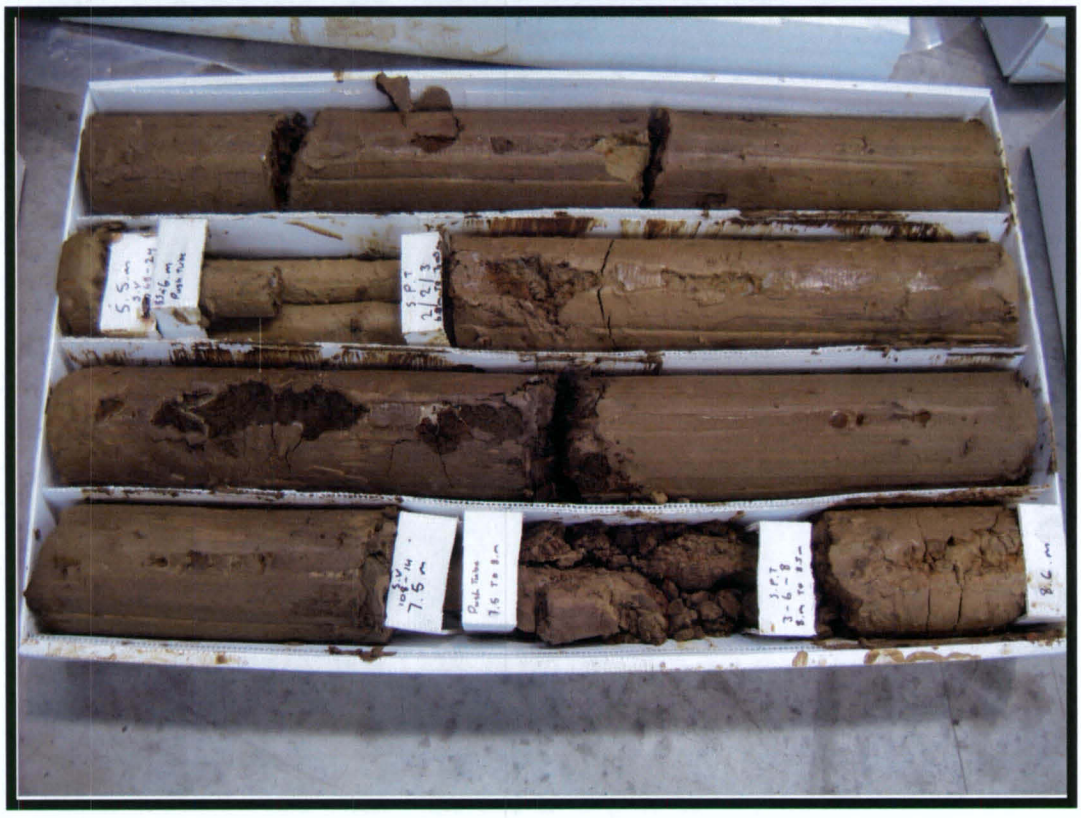
CONSULTANTS IN GEOTECHNICAL ENGINEERING, GEOLOGY & ENGINEERING GEOLOGY

Titirangi No 3 Reservoir

Borehole MH1

Box 7 - 24.0m to 28.5m

End Of Bore



Titirangi No 3 Reservoir

Borehole MH1

Box 1 - 0.0m to 5.0m

Box 2 - 5.0m to 8.6m

waterCare services limited

TOWER FOUNDATIONS

ORMISTON ASSOCIATES LTD

CONSULTANTS IN GEOTECHNICAL ENGINEERING, GEOLOGY & ENGINEERING GEOLOGY

Titirangi No 3 Reservoir

Borehole MH1

Box 3 - 8.6m to 11.5m

Box 4 - 11.5m to 14.9m

waterCare services limited

TOWER FOUNDATIONS

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Titirangi No 3 Reservoir

Borehole MH1

Box 5 - 14.9m to 18.5m

Box 6 - 18.5m to 24.0m

waterCare services limited

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Titirangi No 3 Reservoir

Borehole MH1

Box 7 - 24.0m to 28.5m

End Of Bore

waterCare services limited

TOWER FOUNDATIONS

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Titirangi No 3 Reservoir

Borehole MH1

Box 1 - 0.0m to 5.0m

Box 2 - 5.0m to 8.6m

waterCare services limited

TOWER FOUNDATIONS

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Borehole MH1

Box 3 - 8.6m to 11.5m

Box 4 - 11.5m to 14.9m

waterCare services limited

TOWER FOUNDATIONS

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waterCare services limited

TOWER FOUNDATIONS

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Titirangi No 3 Reservoir

Borehole MH1

Box 7 - 24.0m to 28.5m

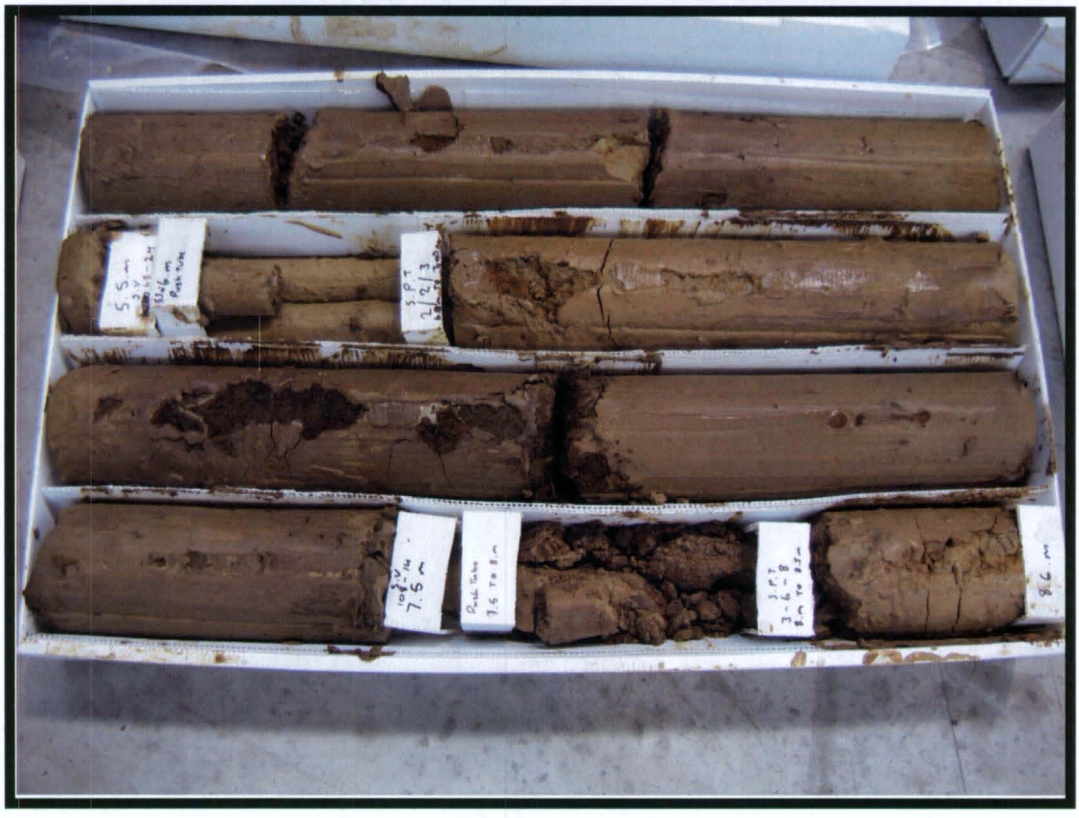
End Of Bore

waterCare services limited

TOWER FOUNDATIONS

ORMISTON ASSOCIATES LTD

CONSULTANTS IN GEOTECHNICAL ENGINEERING, GEOLOGY & ENGINEERING GEOLOGY



Titirangi No 3 Reservoir

Borehole MH1

Box 1 - 0.0m to 5.0m

Box 2 - 5.0m to 8.6m

waterCare services limited

TOWER FOUNDATIONS

ORMISTON ASSOCIATES LTD

CONSULTANTS IN GEOTECHNICAL ENGINEERING, GEOLOGY & ENGINEERING GEOLOGY

Titirangi No 3 Reservoir

Borehole MH1

Box 3 - 8.6m to 11.5m

Box 4 - 11.5m to 14.9m

waterCare services limited

TOWER FOUNDATIONS

ORMISTON ASSOCIATES LTD

CONSULTANTS IN GEOTECHNICAL ENGINEERING, GEOLOGY & ENGINEERING GEOLOGY

Titirangi No 3 Reservoir

Borehole MH1

Box 5 - 14.9m to 18.5m

Box 6 - 18.5m to 24.0m

waterCare services limited

TOWER FOUNDATIONS

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CONSULTANTS IN GEOTECHNICAL ENGINEERING, GEOLOGY & ENGINEERING GEOLOGY

Titirangi No 3 Reservoir

Borehole MH1

Box 7 - 24.0m to 28.5m

End Of Bore

waterCare services limited

TOWER FOUNDATIONS

ORMISTON ASSOCIATES LTD

CONSULTANTS IN GEOTECHNICAL ENGINEERING, GEOLOGY & ENGINEERING GEOLOGY

Appendix D

Laboratory Test Results

B G L
BABBAGE GEOTECHNICAL LABORATORY

Babbage Geotechnical Laboratory
Level 1
68 Beach Road
Auckland 1010
Telephone
Fax
E-mail

P O Box 2027
New Zealand
64-9-367 4954
64-9-377 0554
wec@babbage.co.nz

Please reply to: W.E. Campton

Watercare Services Ltd
2 Nuffield Street
Newmarket
Auckland

Job Number: 43710

Checked by:
WEC

2nd October 2008

Attention: **NEIL JACKA**

Dear Sir,

Re: ***Titirangi No.3 Reservoir***
Plasticity Index Test Results
Report Number 43710/AL

We have completed testing of the samples delivered to our laboratory on the 10th of September 2008 from the site investigation for Titirangi No.3 Reservoir. Our instructions were to determine the natural moisture content and plasticity indices of these samples. Test results are tabulated below, with the following page showing where the samples plot on the Casagrande Chart. Test standards used were:

Moisture Content:	NZS4402:1986:Test 2.1
Liquid Limit:	NZS4402:1986:Test 2.2
Plastic Limit:	NZS4402:1986:Test 2.3
Plasticity Index:	NZS4402:1986:Test 2.4

Sample No	Moisture Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
BH1 1.0 - 1.5m	41.8	98	34	**64**
BH1 3.5 - 4.0m	47.3	84	32	**52**
BH1 5.5 - 6.0m	41.6	76	24	**52**
BH2 3.5 - 4.0m	55.3	91	27	**64**
BH2 5.5 - 6.0m	44.7	64	29	**35**
BH3 5.0 - 5.5m	39.6	57	23	**34**
BH1 7.5 - 8.0m	52.0	Atterburg Limits testing not carried out		

Note: The whole soil was used in this test (except for BH2 5.5 – 6.0m where the fraction passing the 425μm sieve was used), and was wet up & dried back where necessary.

Please note that test results relate only to the samples under test.

Thank you for the opportunity to carry out this testing. If you have any queries regarding the content of this report, please contact the undersigned at your convenience.

Yours faithfully,

Wayne Campton
Signatory (Laboratory Manager)
Babbage Geotechnical Laboratory

BGL

BABBAGE GEOTECHNICAL LABORATORY

Job Number:	43710	Sheet 1 of 1	Page 2 of 2
Reg. Number:	1674	Revision No:	0
Report No:	43710/AL	Issue Date:	February 2006
Project:	TITIRANGI NO.3 RESERVOIR		

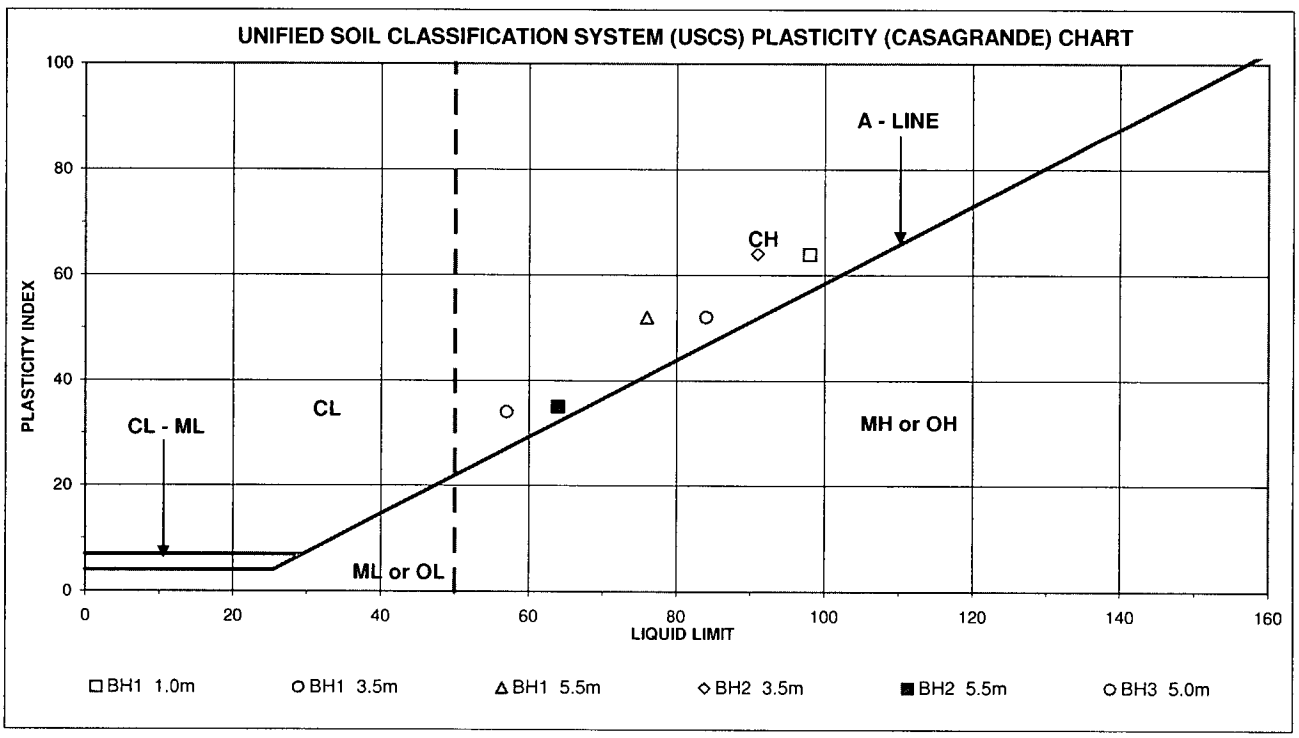
Determination of the Liquid Limit, Plastic Limit & the Plasticity Index

Test Method: NZS4402: 1986: Test 2.2, Test 2.3 and Test 2.4

Tested By:	WEC	29-Sep-08
Compiled By:	JF	2-Oct-08
Checked By:	JF	2-Oct-08

SUMMARY OF TESTING

SAMPLE NUMBER	Liquid Limit	Plastic Limit	Plasticity Index	Soil Classification
BH1 1.0m	98	34	**64**	**CH**
BH1 3.5m	84	32	**52**	**CH**
BH1 5.5m	76	24	**52**	**CH**
BH2 3.5m	91	27	**64**	**CH**
BH2 5.5m	64	29	**35**	**CH**
BH3 5.0m	57	23	**34**	**CH**



LEGEND

CL	Clay - low plasticity	**CH**	Clay - high plasticity
ML	Silt - low liquid limit	**MH**	Silt - high liquid limit
OL	Organic Soil - low liquid limit	**OH**	Organic Soil - high liquid limit

NOTE: soil type descriptions are based on recommendations in the NZGS "Field Description of Soils & Rocks" (Draft for comment Feb 2003).

Babbage Geotechnical Laboratory
Level 4
68 Beach Road
Auckland 1010
P O Box 2027
New Zealand
Telephone 64-9-367 4954
Fax 64-9-377 0554
Email wec@babbage.co.nz

Please reply to: W.E. Campton

Watercare Services Ltd
2 Nuffield Street
Newmarket
Auckland, New Zealand

Job Number: 43710

Checked by:
WEC
30th September 2008

Attention: Neil Jacka

Dear Sir,

Re: Titirangi No3 Reservoir
Single Point Triaxial Test Results
Report Number 43710/UTC Sept 08

Client Request:

To measure the consolidated undrained compression of a sample in a triaxial apparatus under known conditions of effective stress, with measurement of pore water pressure.

Test Standards:

NZS4402:1986 Methods of Testing Soils for Civil Engineering Purposes
Test 2.1 Determination of Water Content

BS1377:1990 Part 8 Section 7 Consolidated Undrained Triaxial Compression Test with Pore Pressure Measurement

The following six pages presents the results of testing three 60mm diameter push-tube samples delivered to our laboratory on 10th September 2008. We were instructed to test each sample at a single effective pressure as set by yourself at time of sample delivery (based on depth of sample). Each sample was extruded from the tube and trimmed to length. Each sample was then saturated using a final cell pressure of 400kPa and a backpressure of 390kPa, and then tested to confirm saturation by increasing cell pressure to obtain the target effective pressures. Excess pore water pressure was then dissipated during a consolidation cycle at the specified confining pressures and compression was then taken beyond the maximum deviator stress.

Test Summary	Stain at Failure (mm)	Max. Deviator Stress (kPa)	Major Stress (kPa)	Minor Stress (kPa)	S'	T'
BH1, 3.5 – 4.0m @ 80kPa	4.036	99	137	38	87	49
BH2, 5.5 – 6.0m @ 120kPa	5.837	154	222	68	145	77
BH3, 5.0 – 5.5m @ 90kPa	6.015	147	202	55	128	73

Each test result is data obtained at a specific test location. The nature and continuity of subsoil conditions away from the test area could vary from the data recovered during this testing.

Thank you for the opportunity to carry out this testing. If you have any queries regarding the content of this report please contact the undersigned at your convenience.

Yours faithfully,

Wayne Campton
Signatory (Laboratory Manager)
Babbage Geotechnical Laboratory

new zealand accredited laboratory

All tests reported herein have been performed in accordance with the laboratory's scope of accreditation. This report may not be reproduced except in full & with written approval from BGL.

BGL
BABBAGE GEOTECHNICAL LABORATORY

TRIAXIAL COMPRESSION TEST

In House Method based on BS 1377:1990 Test 8 Consolidated Undrained with Pore Pressure Measurement

PROJECT	Titirangi No 3 Reservoir			**Bore No**	BH1	**Sheet** 2a of 4	**Issue Date** Nov-99
				Sample No	T2		**Rev. No** 0
				Depth	3.5 - 4.0m		**Auth. By** WEC
				Strain Rate	0.011 mm/min		Initials / Date
				Failure Type	Planar	Tested By:	wec Sep-08
JOB No	43710		With/~~without~~ side drains			Plotted By:	comp Sep-08
REG No	1674		Sample Type: Tube			Checked By:	wec 2/10/2008

Mohr Circle Plot:

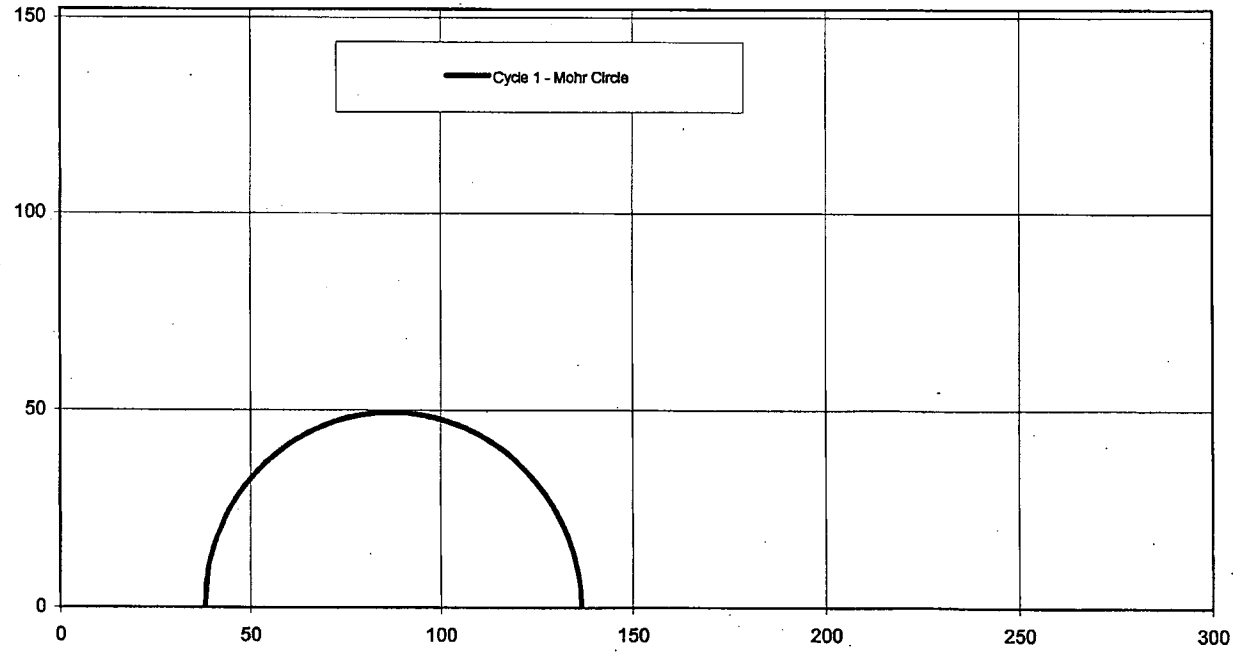
From Test Sheets

	(σ1') kPa	(σ3') kPa	(σ1' + σ3')/2 kPa	(σ1' - σ3')/2 kPa
1	137	38	87	49
2				
3				

From Graph Below:

Angle of Shear Resistance	ϕ'= deg
Cohesion	c'= kPa

Cycle 1 - Mohr Circle



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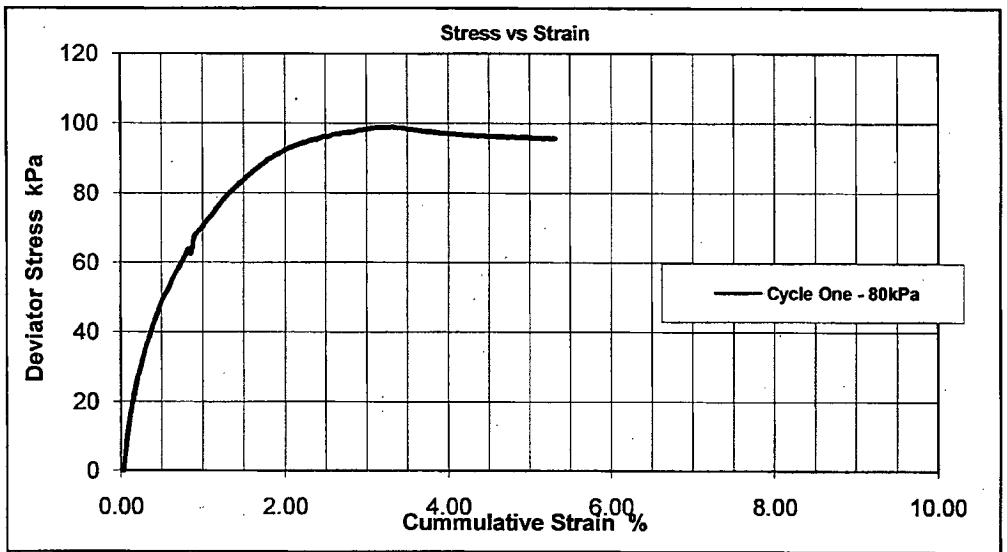
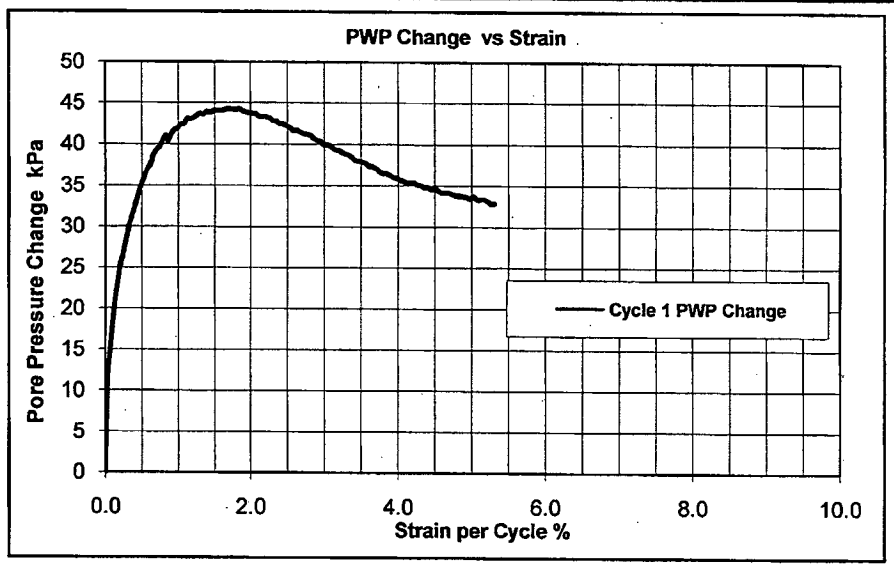
BABBAGE GEOTECHNICAL LABORATORY

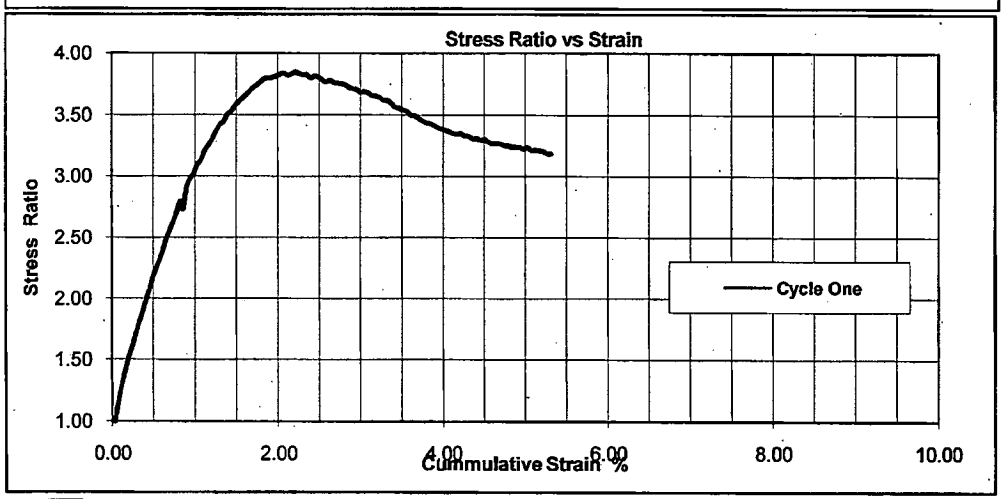
TRIAXIAL COMPRESSION TEST

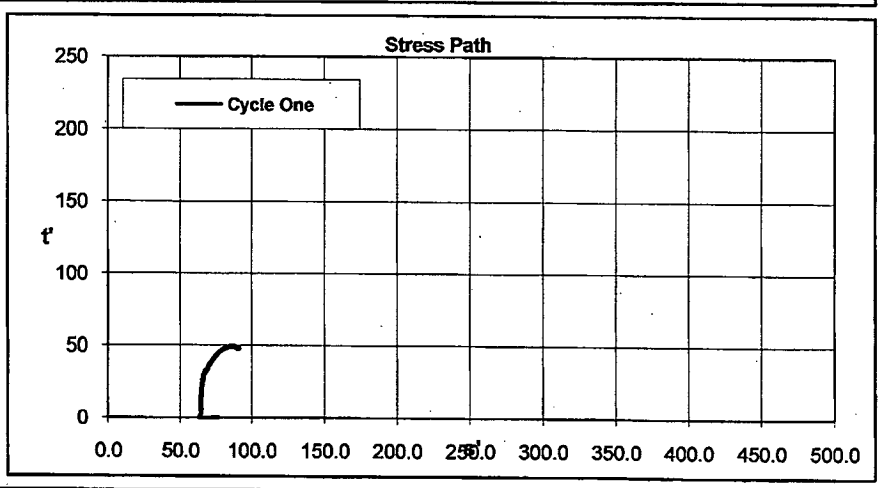
In House Method based on BS 1377:1990 Test 8 Consolidated Undrained with Pore Pressure Measurement

PROJECT	Titirangi No 3 Reservoir		**Bore No**	BH1	**Sheet**	2b of 4	**Issue Date**	Nov-99
			Sample No	T2			**Rev. No**	0
			Depth	3.5 - 4.0m			**Auth. By**	WEC
			Strain Rate	0.011 mm/min			Initials	Date
JOB No	43710	With/~~without~~ side drains	**Failure Type**	Planar		Tested By:	wec	Sep-08
REG No	1674	Sample Type: Tube				Plotted By:	comp	Sep-08
						Checked By:	wec	2/10/2008









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BABBAGE GEOTECHNICAL LABORATORY

TRIAXIAL COMPRESSION TEST

In House Method based on BS 1377:1990 Test 8 Consolidated Undrained with Pore Pressure Measurement

PROJECT	Titirangi No 3 Reservoir			**Bore No**	BH2	**Sheet**	3a of 4	**Issue Date**	Nov-99
				Sample No	Tube			**Rev. No**	0
				Depth	5.5 - 6.0m			**Auth. By**	WEC
				Strain Rate	0.01 mm/min			Initials	Date
				Failure Type	Planar		Tested By:	wec	Sep-08
JOB No	43710		With/~~without~~ side drains				Plotted By:	comp	Sep-08
REG No	1674		Sample Type:Tube				Checked By:	wec	2/10/2008

Mohr Circle Plot:

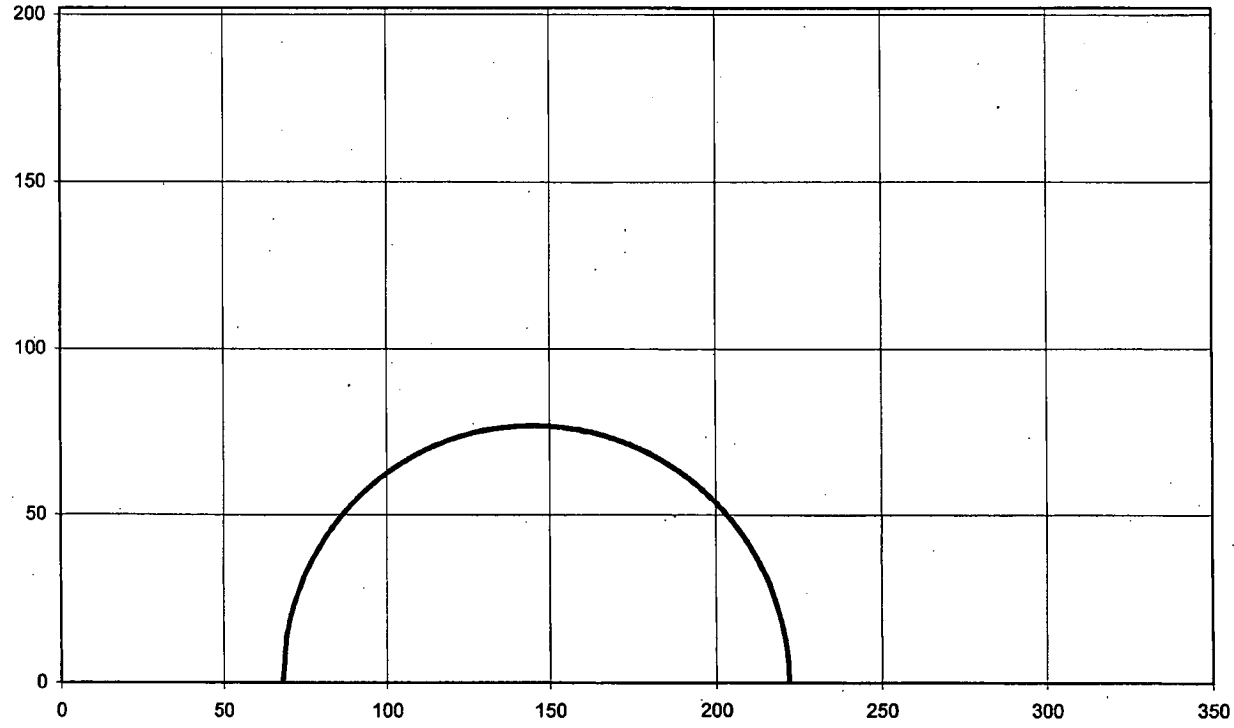
From Test Sheets

	(σ1') kPa	(σ3') kPa	(σ1' + σ3')/2 kPa	(σ1' - σ3')/2 kPa
1	222	68	145	77
2				
3				

From Graph Below:

Angle of Shear Resistance	ϕ'= deg
Cohesion	c'= kPa

Cycle 1 - Mohr Circle

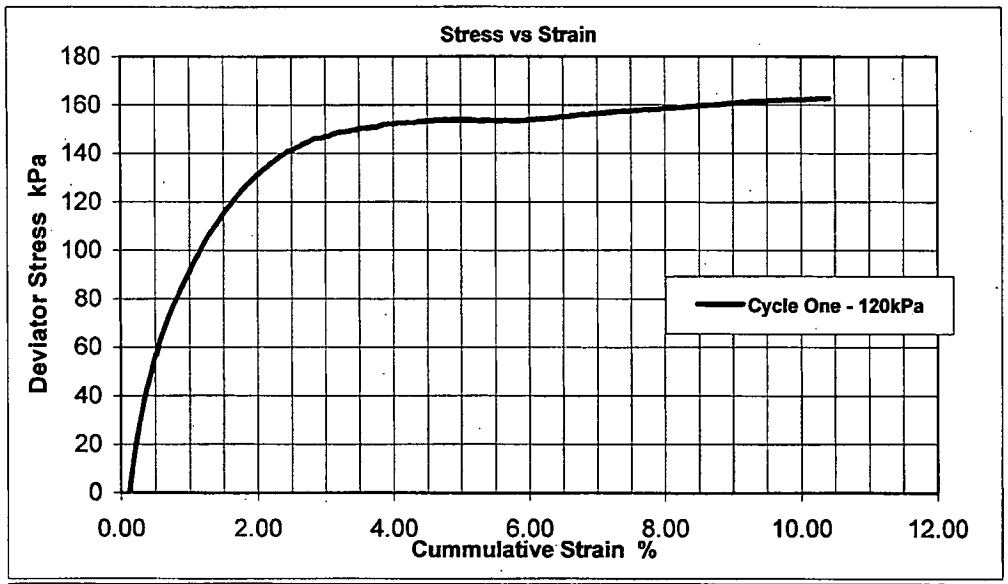


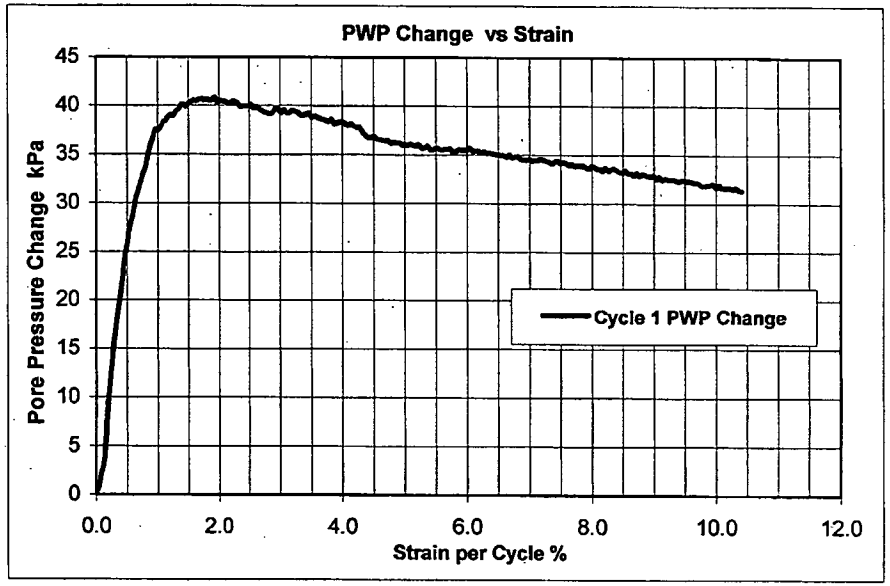
BGL
BARBAGE GEOTECHNICAL LABORATORY

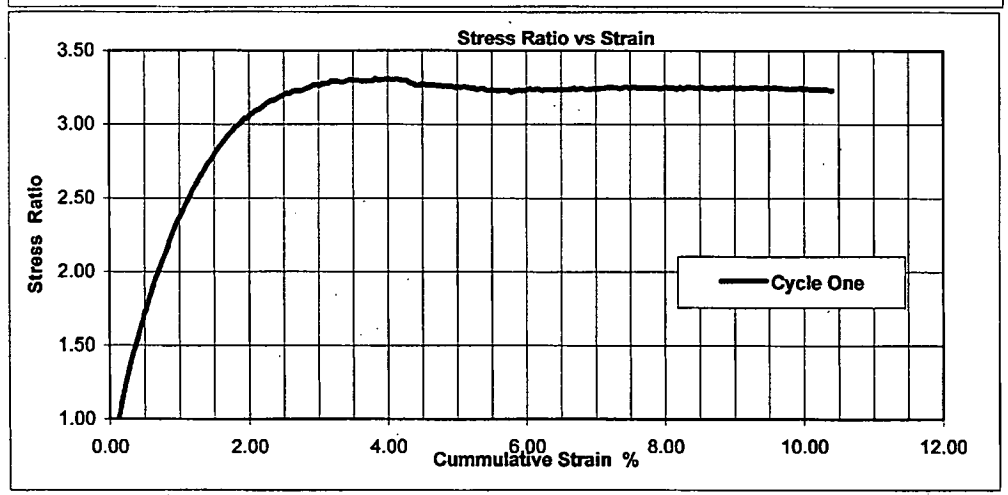
TRIAXIAL COMPRESSION TEST

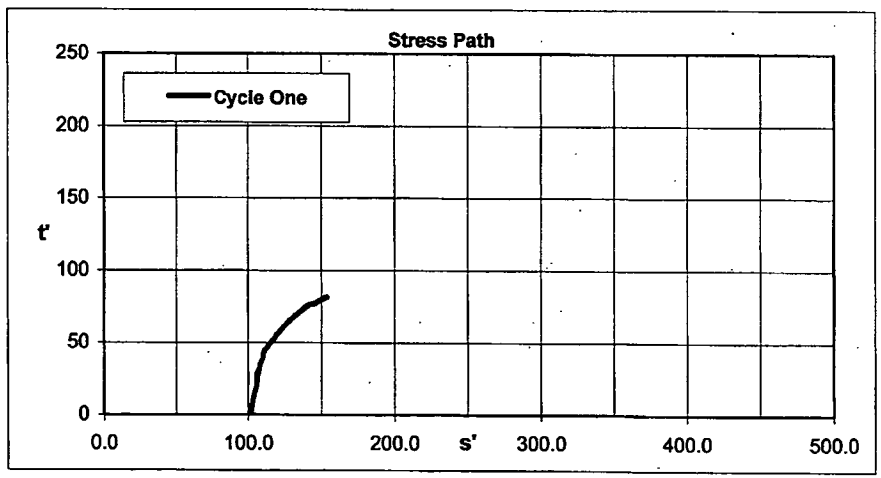
In House Method based on BS 1377:1990 Test 8 Consolidated Undrained with Pore Pressure Measurement

PROJECT	Titirangi No 3 Reservoir			Bore No	BH2	Sheet 3b of 4	Issue Date: Nov-99
				Sample No	Tube		Rev. No: 0
				Depth	5.5 - 6.0m		Auth. By: WEC
				Strain Rate	0.01 mm/min		Initials / Date
				Failure Type	Planar	Tested By:	wec / Sep-08
JOB No	43710		With/~~without~~ side drains			Plotted By:	comp / Sep-08
REG No	1674		Sample Type:Tube			Checked By:	wec / 2/10/2008









BGL
BABBAGE GEOTECHNICAL LABORATORY

TRIAXIAL COMPRESSION TEST

In House Method based on BS 1377:1990 Test 8 Consolidated Undrained with Pore Pressure Measurement

PROJECT	Titirangi No 3 Reservoir		
JOB No	43710		With/~~without~~ side drains
REG No	1674		Sample Type:

Bore No	BH3	**Sheet**	4a of 4	**Issue Date**	Nov-99
Sample No	T2			**Rev. No**	0
Depth	5.0 - 5.5m			**Auth. By**	WEC
Strain Rate	0.008 mm/min			Initials	Date
Failure Type	Planar		Tested By:	wec	Sep-08
			Plotted By:	comp	Sep-08
			Checked By:	wec	2/10/2008

Mohr Circle Plot:

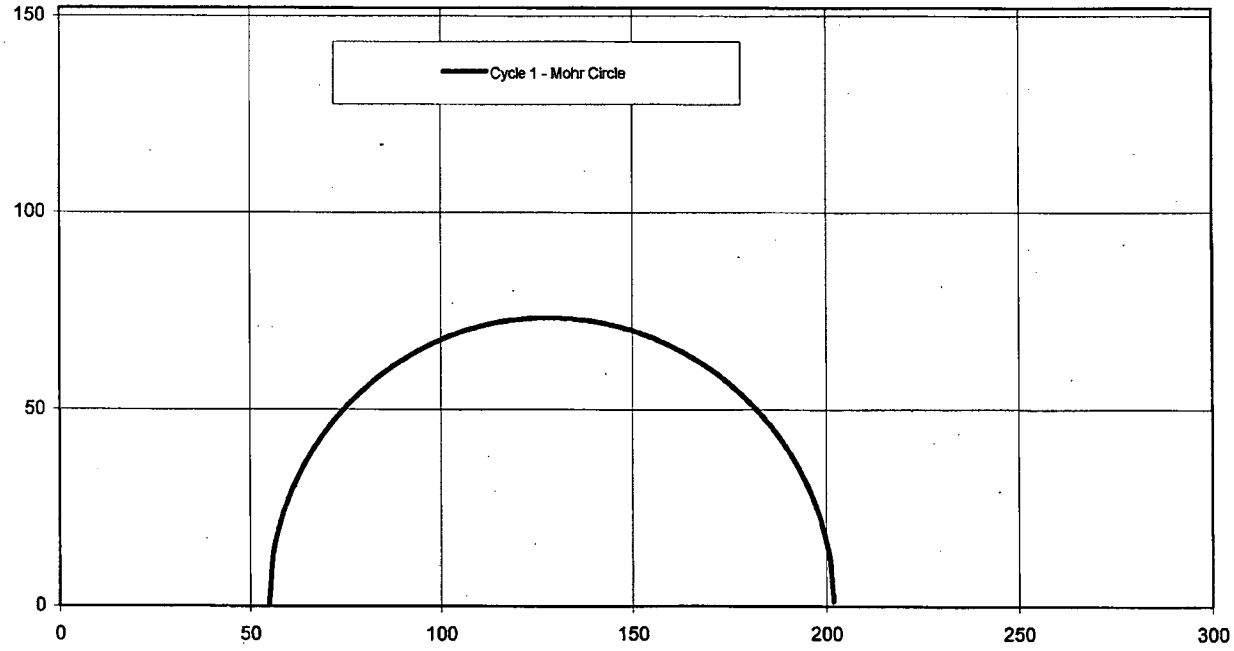
From Test Sheets

	(σ1') kPa	(σ3') kPa	(σ1' + σ3')/2 kPa	(σ1' - σ3')/2 kPa
1	202	55	128	73
2				
3				

From Graph Below:

Angle of Shear Resistance	ϕ'= deg
Cohesion	c'= kPa

Cycle 1 - Mohr Circle



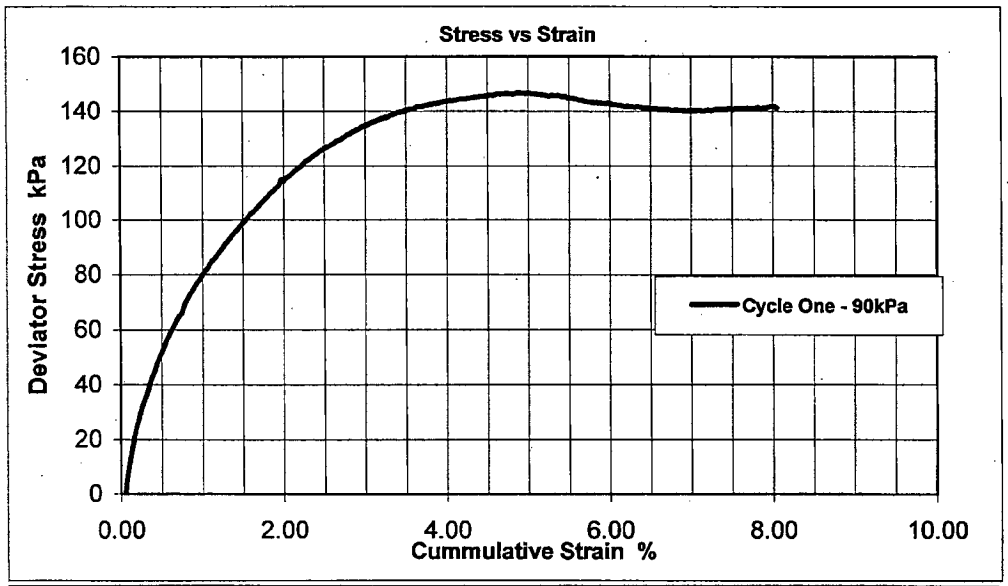
BGL
BARRAGE GEOTECHNICAL LABORATORY

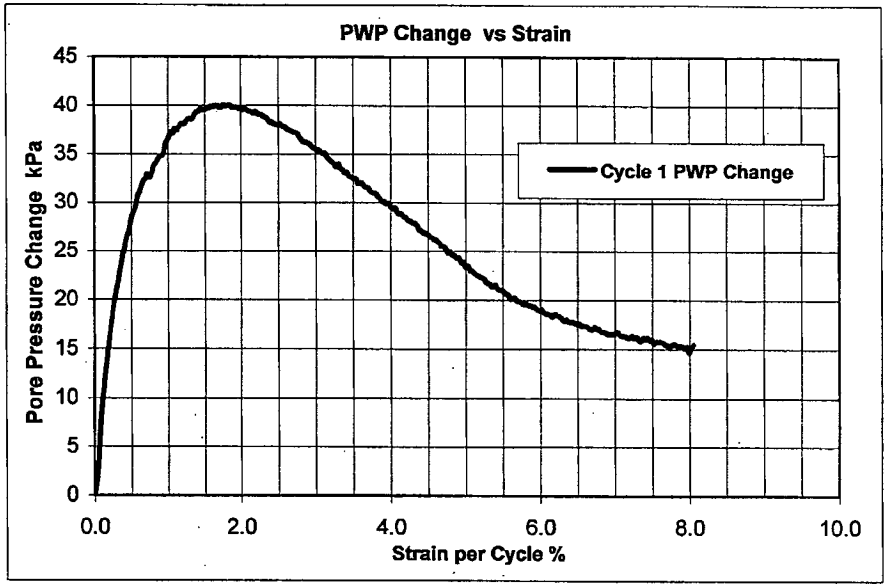
TRIAXIAL COMPRESSION TEST

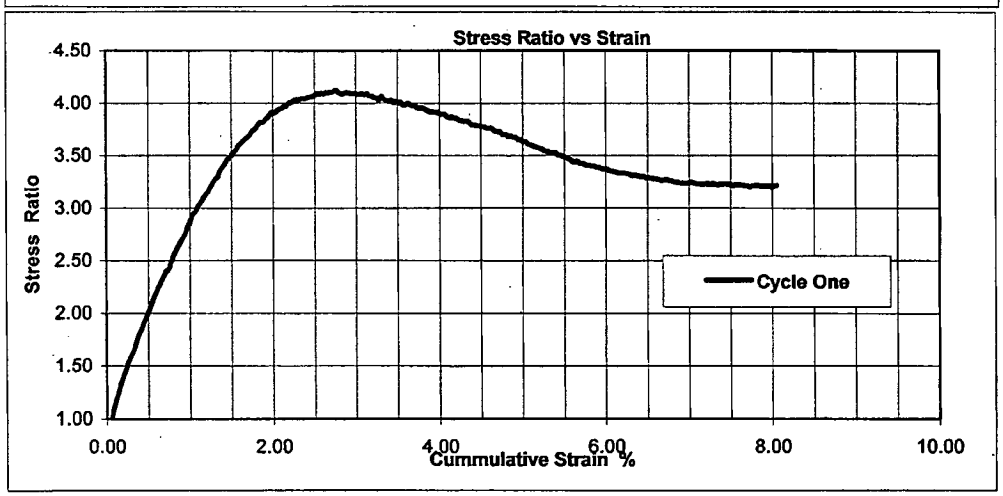
In House Method based on BS 1377:1990 Test 8 Consolidated Undrained with Pore Pressure Measurement

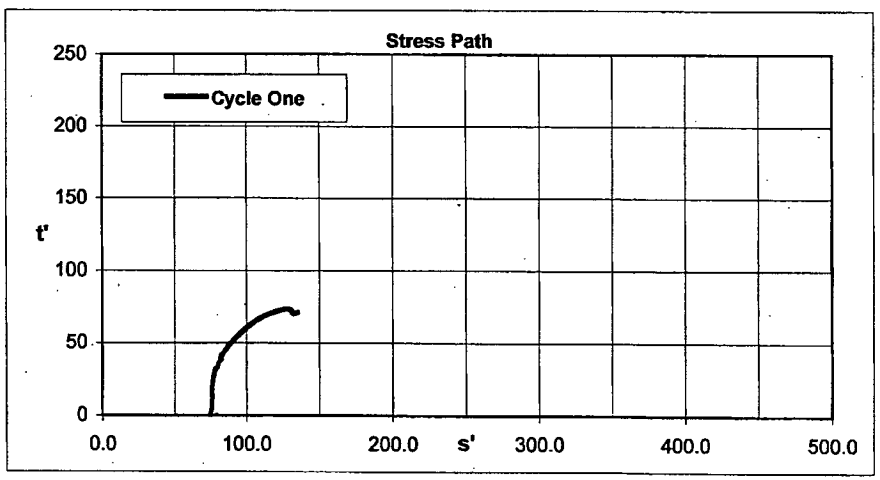
PROJECT	Titirangi No 3 Reservoir		
JOB No	43710	With/without side drains	
REG No	1674	Sample Type:	

Bore No	BH3	Sheet	4b of 4	Issue Date	Nov-99
Sample No	T2			Rev. No	0
Depth	5.0 - 5.5m			Auth. By	WEC
Strain Rate	0.008 mm/min			Initials	Date
Failure Type			Tested By:	wec	Sep-08
			Plotted By:	comp	Sep-08
			Checked By:	wec	2/10/2008









Babbage Geotechnical Laboratory
Level 4
68 Beach Road
Auckland 1010
Telephone
Fax
Email

P O Box 2027
New Zealand
64-9-367 4954
64-9-377 0554
wec@babbage.co.nz

Please reply to: W.E. Campton

Watercare Services Ltd
2 Nuffield Street
Newmarket
Auckland, New Zealand

Job Number: 43710

Checked by:
WEC
30th September 2008

Attention: Neil Jacka

Dear Sir,

Re: Titirangi No.3 Reservoir
One Dimensional Consolidation Results
Report Number 43710/ODC Sept 08

The following nine pages presents a summary of the results of one dimensional consolidation testing on the samples delivered to this laboratory on the 10th September 2008 from the site investigation for the No3 Reservoir. The 60 mm Ø tube samples were tested in accordance with the following standard:

One Dimensional Consolidation: **NZS4402:1986:Test 7.1**

The samples were extruded from tubes after other test samples were prepared so that any compressible materials were not disturbed during the extruding process. A 60mm Ø ring was then pushed over the trimmed soil until the sample protruded from both ends of the ring. A wire was then used to cut the sample from the remaining tube and a flat edge used to trim the soil in the ring.

Sample Descriptions: **BH1**, 3.5-4.0m: CLAY: silty, some coarse sand inclusions, stiff, moderately plastic, mid brown light grey with dark orange speckles.
BH2, 5.5-6.0m: SAND: (fine grained), clayey, (firm to stiff), slightly to moderately plastic, light greyish blue.
BH3, 5-5.5m: CLAY: slightly silty, firm to stiff, moderately to highly plastic, light to mid grey brown with orange veins, numerous small organics.

These test results relate to the samples tested only. The values of Mv shown on the respective tables have been calculated for each pressure increment, using void ratio difference for that increment.

Each test result is data obtained at a specific test location. The nature and continuity of subsoil conditions away from the test area could vary from the data recovered during this testing.

Thank you for the opportunity to carry out this testing. If you have any queries regarding the content of this report please contact the undersigned at your convenience.

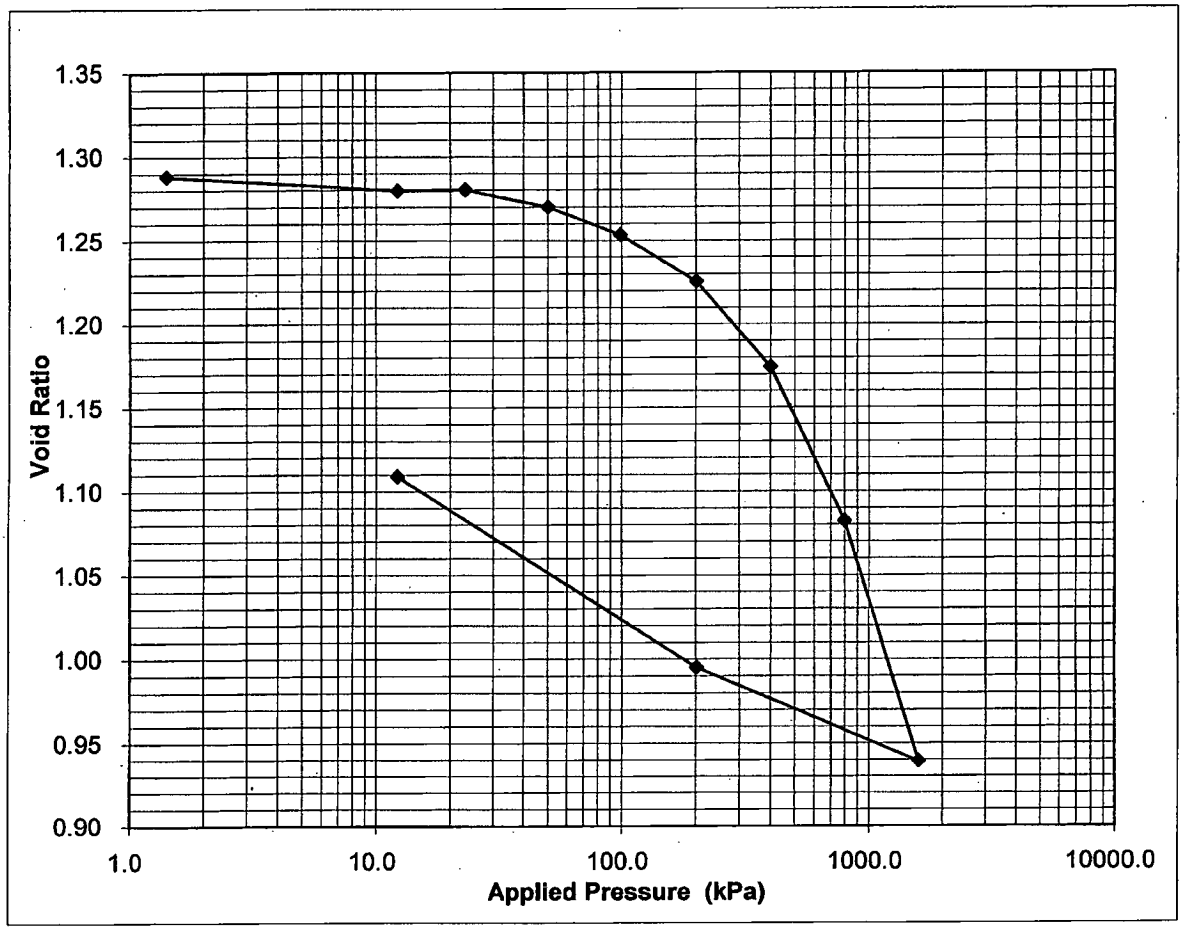
Yours faithfully,

Wayne Campton
Signatory (Laboratory Manager)
Babbage Geotechnical Laboratory

new zealand accredited laboratory

BGL Barrage Geotechnical Laboratory	Job No: 43710	Reg. No: 1674	Sheet 2 of 10	Issue Date:	Aug-99
	PROJECT Titirangi Reservoir No 3			Rev. No:	4
				Auth. By:	WEC
				Initials	Date
ONE DIMENSIONAL CONSOLIDATION Test Method: NZS4402:1986:Test 7.1			Tested By:	wec	Sep-08
			Compiled By:	comp	Sep-08
			Checked By:	wec	29/09/08

Bore No: BH1 **Sample Number:** T **Depth:** 3.5-4.0m



Applied Pressure kPa	Void Ratio e	Mv m^2/MN	Consolidation Coefficient Cv (log t) m^2/year	Cv (sqrt t) m^2/year
1.4	1.288			
12.2	1.280	0.346		
23.1	1.280	-0.020	17.9	35.1
50.2	1.270	0.165	7.0	30.6
99.0	1.253	0.151	3.2	4.5
200.8	1.226	0.121	4.8	6.2
400.3	1.175	0.115	2.6	3.7
799.1	1.082	0.106	1.8	2.2
1602.3	0.939	0.086	1.0	1.4
200.8	0.995	0.021		
12.2	1.109	0.302		

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	PROJECT Titirangi Reservoir No 3			Rev. No:	4
				Auth. By:	WEC
				Initials	Date
ONE DIMENSIONAL CONSOLIDATION Test Method: NZS4402:1986:Test 7.1			Tested By:	wec	Sep-08
			Compiled By:	comp	Sep-08
			Checked By:	wec	29/09/08

RESULT SUMMARY:

Bore Number: BH1 **Sample Number:** T **Depth:** 3.5-4.0m

Sample History: Undisturbed ~~/ remoulded / compacted / other~~
Specimen from 60mm diameter tube
~~Compacted with ..... compactive effort / other~~

Sample preparation: Extruded from 60mm dia. tube in increments and trimmed around ring. 60.mm diameter ring then pushed over sample.

Test details: Consolidation machine number : 1 Ring number : Silver
Area of ring : 2827mm^2
Solid density of soil particles, Ps = 2.65 t/m^3 : ~~measured~~/assumed

		INITIAL		FINAL	
Mass of dry specimen	Ms (g)		81.85		81.85
Thickness of specimen	H (mm)	Hi	25.000	Hf	21.184
Water content	w (%)	w_i	49.6	w_f	44.6
Dry density $Pd = \frac{Ms}{H \times A}$	t/m^3	Pd_i	1.16	Pd_f	1.37
Height of Soil Particles $Hs = \frac{Ms \times 1000}{Ps \times A}$	mm	Hs	10.924	Hs	10.924
Void Ratio $e = \frac{H - Hs}{Hs}$		e_i	1.288	e_f	0.939
Degree of Saturation $S = \frac{Ps \times w}{e}$	%	Si	101.9	Sf	126

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				Initials	Date
ONE DIMENSIONAL CONSOLIDATION Test Method: NZS4402:1986:Test 7.1			Tested By:	wec	Sep-08
			Compiled By:	comp	Sep-08
			Checked By:	wec	29/09/08

Bore No: BH1 **Sample Number:** T **Depth:** 3.5-4.0m

Applied Pressure kPa	Incremental Deflection mm	Thickness of Specimen mm	Comp. Ratio	Height of Voids mm	Void Ratio e	Coefficient of Consolidation (log t) m^2/year	Coefficient of Consolidation (sqrt t) m^2/year
1.4	0.000	25.000	1.000	14.076	1.288		
12.2	0.094	24.906	0.996	13.982	1.280		
23.1	-0.005	24.912	0.996	13.987	1.280	17.92	35.13
50.2	0.112	24.800	0.992	13.875	1.270	7.02	30.62
99.0	0.182	24.618	0.985	13.693	1.253	3.20	4.49
200.8	0.304	24.314	0.973	13.389	1.226	4.77	6.18
400.3	0.558	23.755	0.950	12.831	1.175	2.56	3.72
799.1	1.007	22.748	0.910	11.824	1.082	1.83	2.23
1602.3	1.564	21.184	0.847	10.260	0.939	1.03	1.36
200.8	-0.613	21.797	0.872	10.873	0.995		
12.2	-1.243	23.041	0.922	12.116	1.109		

Overburden Pressure	P_o	kpa
Pressure P_i	$P_o + 100$	kPa
Thickness at P_o	H_o	mm
Thickness at P_i	H_i	mm
Voids Ratio at P_o	e_o	
Voids Ratio at P_i	e_i	

Coefficient of Compressibility M_v m^2/MN

$$\frac{(e_o - e_i)}{(1+e_o)(P_i - P_o)} * 1000$$

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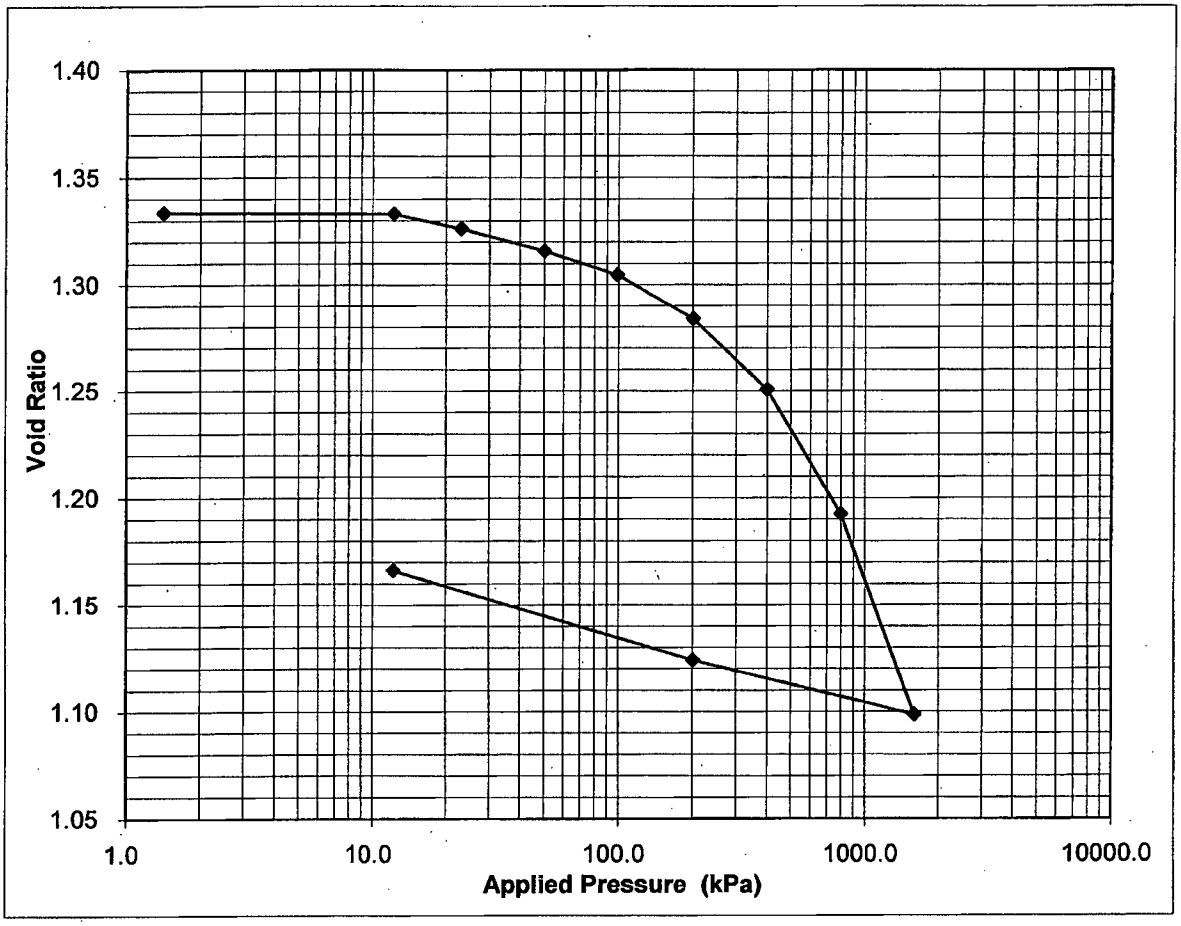
	PROJECT Titirangi No3 Reservoir			Auth. By:	WEC
				Initials	Date
ONE DIMENSIONAL CONSOLIDATION Test Method: NZS4402:1986:Test 7.1			Tested By:	wec	Sep-08
			Compiled By:	comp	Sep-08
			Checked By:	wec	30/09/08

Bore No: BH2 **Sample Number:** Tube **Depth:** 5.5m - 6.0m



Applied Pressure kPa	Void Ratio e	Mv m^2/MN	Consolidation Coefficient Cv (log t) m^2/year	Cv (sqrt t) m^2/year
1.4	1.334			
12.2	1.333	0.020		
23.1	1.326	0.270	10.8	25.5
50.2	1.316	0.166	14.7	22.5
99.0	1.305	0.098	10.0	26.7
200.8	1.284	0.089	10.6	23.4
400.3	1.251	0.073	10.4	16.6
799.1	1.193	0.065	10.1	16.1
1602.3	1.099	0.053	9.6	12.7
200.8	1.124	0.009		
12.2	1.166	0.105		

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				Initials	Date
ONE DIMENSIONAL CONSOLIDATION Test Method: NZS4402:1986:Test 7.1			Tested By:	wec	Sep-08
			Compiled By:	comp	Sep-08
			Checked By:	wec	30/09/08

RESULT SUMMARY:

Bore Number: BH2 **Sample Number:** Tube **Depth:** 5.5m - 6.0m

Sample History: Undisturbed ~~/ remoulded / compacted / other~~
Specimen from 60mm diameter tube
~~Compacted with ..... compactive effort / other~~

Sample preparation: Extruded from 60mm dia. tube in increments and trimmed around ring. 60mm diameter ring then pushed over sample.

Test details: Consolidation machine number : 1 Ring number : Silver
Area of ring : 2827mm^2
Solid density of soil particles, Ps = 2.65 t/m^3 : ~~measured~~/assumed

		INITIAL		FINAL	
Mass of dry specimen	Ms (g)		80.26		80.26
Thickness of specimen	H (mm)	Hi	25.000	Hf	22.483
Water content	w (%)	w_i	44.7	w_f	41.5
Dry density $Pd = \frac{Ms}{H \times A}$	t/m^3	Pd_i	1.14	Pd_f	1.26
Height of Soil Particles $Hs = \frac{Ms \times 1000}{Ps \times A}$	mm	Hs	10.712	Hs	10.712
Void Ratio $e = \frac{H - Hs}{Hs}$		e_i	1.334	e_f	1.099
Degree of Saturation $S = \frac{Ps \times w}{e}$	%	Si	88.9	Sf	100

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				Initials	Date
ONE DIMENSIONAL CONSOLIDATION Test Method: NZS4402:1986:Test 7.1			Tested By:	wec	Sep-08
			Compiled By:	comp	Sep-08
			Checked By:	wec	30/09/08

Bore No: BH2 **Sample Number:** Tube **Depth:** 5.5m - 6.0m

Applied Pressure kPa	Incremental Deflection mm	Thickness of Specimen mm	Comp. Ratio	Height of Voids mm	Void Ratio e	Coefficient of Consolidation (log t) m^2/year	Coefficient of Consolidation (sqrt t) m^2/year
1.4	0.000	25.000	1.000	14.288	1.334		
12.2	0.005	24.995	1.000	14.282	1.333		
23.1	0.073	24.921	0.997	14.209	1.326	10.83	25.47
50.2	0.113	24.809	0.992	14.096	1.316	14.68	22.51
99.0	0.118	24.690	0.988	13.978	1.305	10.00	26.69
200.8	0.225	24.466	0.979	13.753	1.284	10.57	23.41
400.3	0.355	24.111	0.964	13.398	1.251	10.38	16.61
799.1	0.623	23.488	0.940	12.776	1.193	10.08	16.13
1602.3	1.005	22.483	0.899	11.771	1.099	9.56	12.65
200.8	-0.272	22.755	0.910	12.043	1.124		
12.2	-0.451	23.206	0.928	12.494	1.166		

Overburden Pressure	P_o	kpa
Pressure P_i	$P_o + 100$	kPa
Thickness at P_o	H_o	mm
Thickness at P_i	H_i	mm
Voids Ratio at P_o	e_o	
Voids Ratio at P_i	e_i	

Coefficient of Compressibility M_v m^2/MN

$$\frac{(e_o - e_i)}{(1+e_o)(P_i - P_o)} * 1000$$

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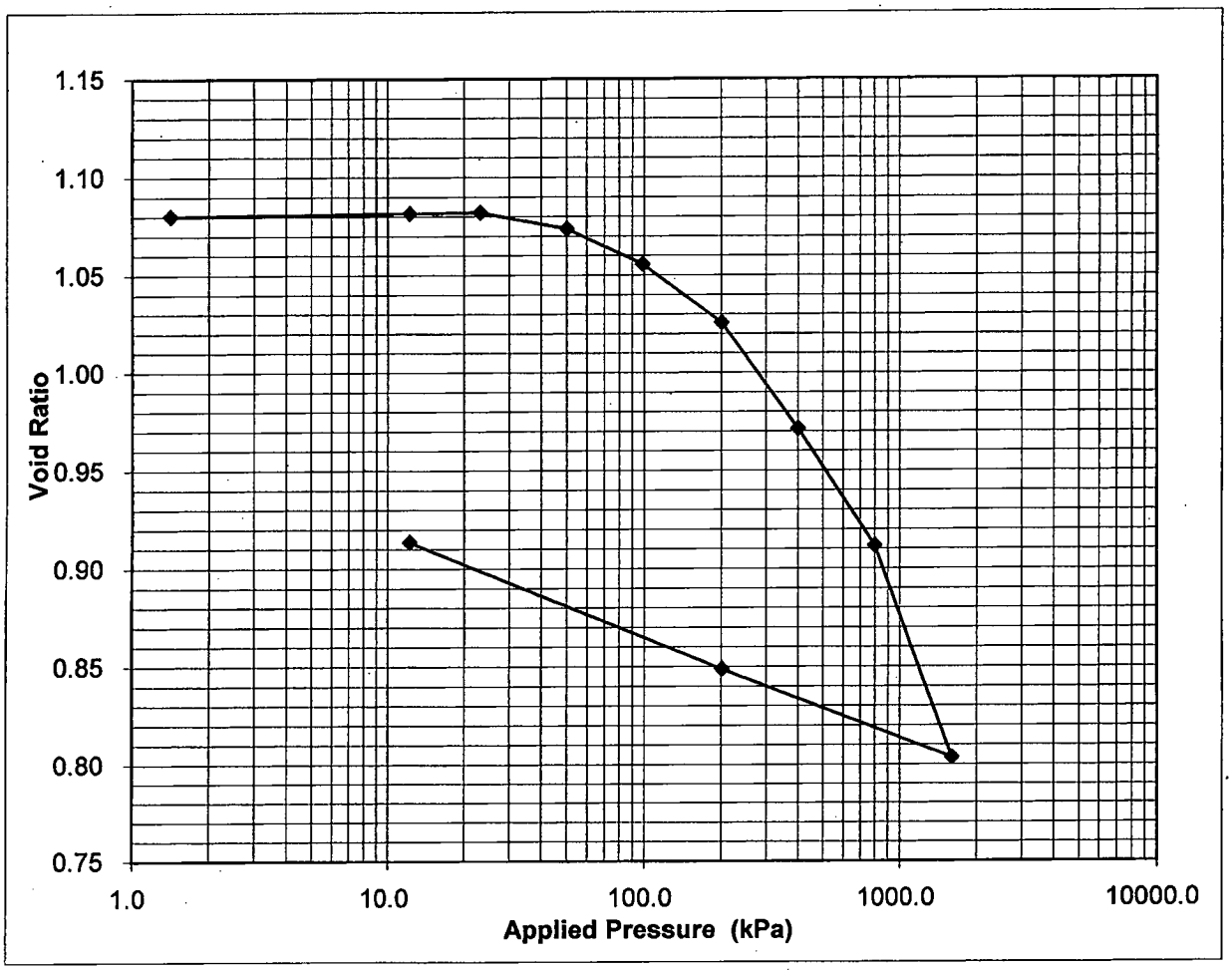
				Initials	Date
ONE DIMENSIONAL CONSOLIDATION Test Method: NZS4402:1986:Test 7.1			Tested By:	wec	Sep-08
			Compiled By:	comp	Sep-08
			Checked By:	wec	30/09/08

Bore No: BH3 **Sample Number:** Tube **Depth:** 5.0 - 5.5m



Applied Pressure kPa	Void Ratio e	Mv m^2/MN	Consolidation Coefficient Cv (log t) m^2/year	Cv (sqrt t) m^2/year
1.4	1.080			
12.2	1.082	-0.054		
23.1	1.082	-0.022		30.9
50.2	1.074	0.146	10.9	44.5
99.0	1.056	0.179	2.0	4.8
200.8	1.026	0.144	2.6	4.7
400.3	0.971	0.134	2.5	3.4
799.1	0.912	0.076	2.1	2.5
1602.3	0.804	0.070	1.4	2.2
200.8	0.849	0.018		
12.2	0.914	0.185		

	Job No:	Reg. No:	Sheet of		Issue Date:	Aug-99
BGL Barrage Geotechnical Laboratory	43710	1674	9	10	Rev. No:	4
	PROJECT				Auth. By:	WEC
	Titirangi No3 Reservoir					
					Initials	Date
ONE DIMENSIONAL CONSOLIDATION			Tested By:		wec	Sep-08
Test Method: NZS4402:1986:Test 7.1			Compiled By:		comp	Sep-08
			Checked By:		wec	30/09/08

RESULT SUMMARY:

Bore Number: BH3 **Sample Number:** Tube **Depth:** 5.0 - 5.5m

Sample History: Undisturbed ~~/ remoulded / compacted / other~~
Specimen from 60mm diameter tube
~~Compacted with ..... compactive effort / other~~

Sample preparation: Extruded from 60mm dia. tube in increments and trimmed around ring. 60mm diameter ring then pushed over sample.

Test details: Consolidation machine number : 1 Ring number : Silver
Area of ring : 2827mm^2
Solid density of soil particles, Ps = 2.65 t/m^3 : ~~measured~~/assumed

			INITIAL		FINAL
Mass of dry specimen	Ms (g)		90.04		90.04
Thickness of specimen	H (mm)	Hi	25.000	Hf	21.676
Water content	w (%)	w_i	29.0	w_f	35.4
Dry density $Pd = \frac{Ms}{H \times A}$	t/m^3	Pd_i	1.27	Pd_f	1.47
Height of Soil Particles $Hs = \frac{Ms \times 1000}{Ps \times A}$	mm	Hs	12.017	Hs	12.017
Void Ratio $e = \frac{H - Hs}{Hs}$		e_i	1.080	e_f	0.804
Degree of Saturation $S = \frac{Ps \times w}{e}$	%	Si	71.2	Sf	117

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				Initials	Date
ONE DIMENSIONAL CONSOLIDATION Test Method: NZS4402:1986:Test 7.1			Tested By:	wec	Sep-08
			Compiled By:	comp	Sep-08
			Checked By:	wec	30/09/08

Bore No: BH3 **Sample Number:** Tube **Depth:** 5.0 - 5.5m

Applied Pressure kPa	Incremental Deflection mm	Thickness of Specimen mm	Comp. Ratio	Height of Voids mm	Void Ratio e	Coefficient of Consolidation (log t) m^2/year	Coefficient of Consolidation (sqrt t) m^2/year
1.4	0.000	25.000	1.000	12.983	1.080		
12.2	-0.015	25.015	1.001	12.998	1.082		
23.1	-0.006	25.021	1.001	13.004	1.082		30.87
50.2	0.100	24.921	0.997	12.904	1.074	10.85	44.47
99.0	0.218	24.703	0.988	12.686	1.056	2.02	4.77
200.8	0.361	24.342	0.974	12.325	1.026	2.64	4.69
400.3	0.651	23.691	0.948	11.674	0.971	2.46	3.40
799.1	0.718	22.973	0.919	10.956	0.912	2.08	2.49
1602.3	1.297	21.676	0.867	9.659	0.804	1.44	2.17
200.8	-0.542	22.218	0.889	10.201	0.849		
12.2	-0.777	22.995	0.920	10.978	0.914		

Overburden Pressure	P_o	kpa
Pressure P_i	P_o + 100	kPa
Thickness at P_o	H_o	mm
Thickness at P_i	H_i	mm
Voids Ratio at P_o	e_o	
Voids Ratio at P_i	e_i	

Coefficient of Compressibility M_v m^2/MN

$$\frac{(e_o - e_i)}{(1+e_o)(P_i - P_o)} * 1000$$

Appendix E

Westergard's Stress Influence Factors

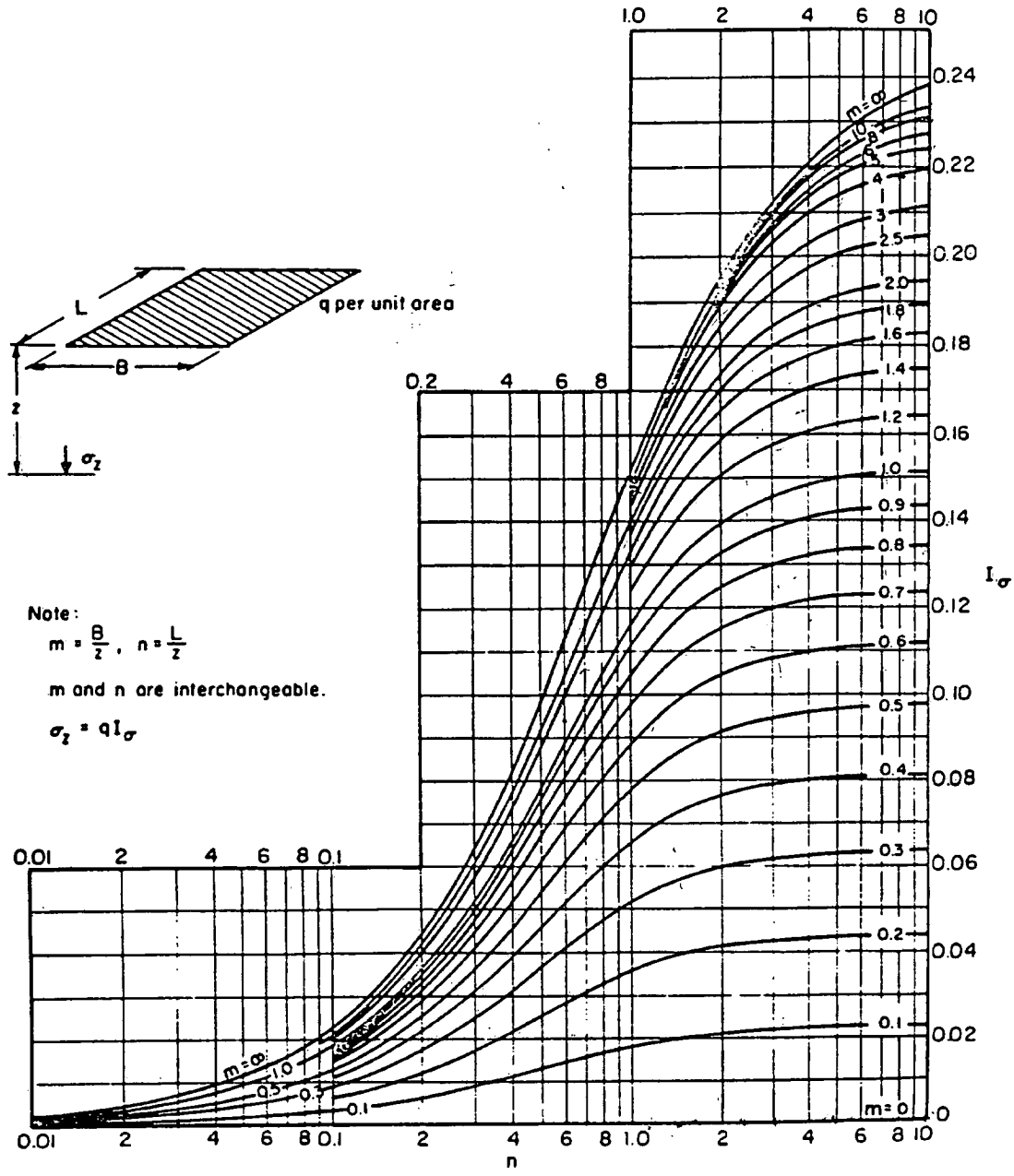

Figure C-3. Influence Factor I_σ for the increase in vertical stress beneath a corner of a uniformly loaded rectangular area for the Westergaard stress distribution (from NAVFAC DM 7.1)

Appendix F

Settlement Calculation Tabulation

One- Dimensional Consolidation

Fill Location	Profile Number	Uniform Raft Pressure (kPa)	Reservoir Floor Level (mRL)	Primary Consolidation "ΔH_p"	Rotational Distortion
Titirangi No.3 Reservoir	1	90.0	5.5	0.066	
					605
	2	90.0	5.5	0.143	
					932
	3	90.0	5.5	0.093	

One- Dimensional Consolidation

Location: **Settlement Profile 1**

Depth to Groundwater (m) 0.0

Layer No.	Bulk Unit Weight "γ" (kN/m^3)	Depth (m)	Total Vertical stress σ_{vo} (kPa)	Layer Thickness H (m)	Depth to Centre of Layer (m)	Initial Total Vertical stress at Centre of Layer σ'_{vo} (kPa)	Initial pore pressure at Centre of Layer "u" (kPa)	Initial Effective Vertical stress at Centre of	Primary Compression Index "C_c" of Clays	Initial Void Ratio e_o	Stress influence factor	Increase in Effective Vertical Stress $\Delta\sigma$	Incremental Primary Consolidation Settlement "ΔH_c" (m)
		0.00	0										
1	18.0	2.00	36	2	1.0	18	9.8	8.2	0.06	1.24	0.24	21.6	0.03
2	18.0	4.00	72	2	3.0	54	29.4	24.6	0.06	1.24	0.24	21.6	0.01
3	18.0	6.00	108	2	5.0	90	49.1	41.0	0.06	1.24	0.235	21.15	0.01
4	18.0	8.00	144	2	7.0	126	68.7	57.3	0.03	1.25	0.23	20.7	0.00
5	18.0	10.00	180	2	9.0	162	88.3	73.7	0.03	1.25	0.22	19.8	0.00
6	18.0	15.00	270	5	12.5	225	122.6	102.4	0.03	1.26	0.21	18.9	0.00
7	18.0	20.00	360	5	17.5	315	171.7	143.3	0	1.27	0.2	18	0.00
8	18.0	25.00	450	5	22.5	405	220.7	184.3	0	1.28	0.18	16.2	0.00
9	18.0	30.00	540	5	27.5	495	269.8	225.2	0	1.29	0.17	15.3	0.00
10	18.0	35.00	630	5	32.5	585	318.8	266.2	0	1.30	0.16	14.4	0.00
												TOTAL	**0.066**

One- Dimensional Consolidation

Location: **Settelment Profile 2**

Depth to Groundwater (m) 0.0

Layer No.	Bulk Unit Weight "γ" (kN/m^3)	Depth (m)	Total Vertical stress σ_{vo} (kPa)	Layer Thickness H (m)	Depth to Centre of Layer (m)	Initial Total Vertical stress at Centre of Layer σ'_{vo} (kPa)	Initial pore pressure at Centre of Layer "u" (kPa)	Initial Effective Vertical stress at Centre of Layer σ'_{vo} (kPa)	Primary Compression Index "C_c" of Clays	Initial Void Ratio e_o	Stress influence factor	Increase in Effective Vertical Stress $\Delta\sigma$	Incremental Primary Consolidation Settlement "ΔH_c" (m)
		0.00	0										
1	18.0	2.00	36	2	1.0	18	9.8	8.2	0.06	1.24	0.96	86.4	0.06
2	18.0	4.00	72	2	3.0	54	29.4	24.6	0.06	1.24	0.92	82.8	0.03
3	18.0	6.00	108	2	5.0	90	49.1	41.0	0.06	1.24	0.872	78.48	0.02
4	18.0	8.00	144	2	7.0	126	68.7	57.3	0.06	1.25	0.832	74.88	0.02
5	18.0	10.00	180	2	9.0	162	88.3	73.7	0.03	1.25	0.78	70.2	0.01
6	18.0	15.00	270	5	12.5	225	122.6	102.4	0	1.26	0.7	63	0.00
7	18.0	20.00	360	5	17.5	315	171.7	143.3	0	1.27	0.592	53.28	0.00
8	18.0	25.00	450	5	22.5	405	220.7	184.3	0	1.28	0.52	46.8	0.00
9	18.0	30.00	540	5	27.5	495	269.8	225.2	0	1.29	0.42	37.8	0.00
10	18.0	35.00	630	5	32.5	585	318.8	266.2	0	1.30	0.38	34.2	0.00
												TOTAL	**0.143**

One- Dimensional Consolidation

Location: **Settelment Profile 3**

Depth to Groundwater (m) 0.0

Layer No.	Bulk Unit Weight "γ" (kN/m^3)	Depth (m)	Total Vertical stress σ_{vo} (kPa)	Layer Thickness H (m)	Depth to Centre of Layer (m)	Initial Total Vertical stress at Centre of Layer σ'_{vo} (kPa)	Initial pore pressure at Centre of Layer "u" (kPa)	Initial Effective Vertical stress at Centre of Layer σ'_{vo} (kPa)	Primary Compression Index "C_c" of Clays	Initial Void Ratio e_o	Stress influence factor	Increase in Effective Vertical Stress $\Delta\sigma$	Incremental Primary Consolidation Settlement "ΔH_c" (m)
		0.00	0										
1	18.0	2.00	36	2	1.0	18	9.8	8.2	0.09	1.24	0.24	21.6	0.05
2	18.0	4.00	72	2	3.0	54	29.4	24.6	0.09	1.24	0.24	21.6	0.02
3	18.0	6.00	108	2	5.0	90	49.1	41.0	0.09	1.24	0.235	21.15	0.01
4	18.0	8.00	144	2	7.0	126	68.7	57.3	0.03	1.25	0.23	20.7	0.00
5	18.0	10.00	180	2	9.0	162	88.3	73.7	0.03	1.25	0.22	19.8	0.00
6	18.0	15.00	270	5	12.5	225	122.6	102.4	0.03	1.26	0.21	18.9	0.00
7	18.0	20.00	360	5	17.5	315	171.7	143.3	0	1.27	0.2	18	0.00
8	18.0	25.00	450	5	22.5	405	220.7	184.3	0	1.28	0.18	16.2	0.00
9	18.0	30.00	540	5	27.5	495	269.8	225.2	0	1.29	0.17	15.3	0.00
10	18.0	35.00	630	5	32.5	585	318.8	266.2	0	1.30	0.16	14.4	0.00
												TOTAL	**0.093**