A12. Report of Topographic Survey and Soil Investigation

REPORT

Tonkin+Taylor

The Project for Nationwide Early Warning Dissemination and Strengthening Disaster Communications in The Kingdom of Tonga

First Phase of Geotechnical Investigations

Prepared for
Yachiyo Engineering Co., Ltd.

Prepared by
Tonkin & Taylor International Ltd

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Table of contents

1 Introduction

1.1 General

Tonkin and Taylor International (T+TI) was engaged by Yachiyo Engineering Co., Ltd. (YEC) to undertake geotechnical investigations to support the Nationwide Early Warning Dissemination and Strengthening Disaster Communications project in the Kingdom of Tonga. The investigations have been carried out in accordance with the 'Amendment of Contract'[1] provided to T+TI by YEC. The geotechnical assessment was undertaken in accordance with our proposal dated 1 December 2016[2].

Geotechnical investigations were completed at two sites in Nuku'alofa, on the island of Tongatapu, in the Kingdom of Tonga to support the proposed developments comprising:

- A new headquarters building at the current Tonga Broadcasting Commission (TBC) complex (defined herein as 'the TBC HQ site'); and,
- A new medium wave (MW) transmitter mast and transmitter building at a TBC site located in the suburb of Popua (defined herein as 'the TBC MW TX site').

The scope of work for the geotechnical investigations included:

- A review of relevant existing information held in T+TI archives;
- A site walkover by an engineering geologist from T+TI;
- Seven machine boreholes to a maximum depth of 15 m with Standard Penetration Testing (SPT) and shear vane testing at regular intervals;
- Four Scala penetrometer tests;
- Laboratory testing on selected samples;
- Assessment of suitable foundation solutions for the proposed structures;
- Preparation of this report outlining the geology, site subsurface conditions and presenting geotechnical information and recommendations to support the development of the sites.

This report summarises the results of the soils investigations carried out at the sites and laboratory test results.

2 Project and Site Description

The Kingdom of Tonga is an archipelago of 169 islands, stretching over a distance of approximately 800 km in the South Pacific Ocean. The national capital of Tonga is Nuku'alofa, which is located on the island of Tongatapu.

We understand that YEC propose to develop a disaster early warning system throughout the Kingdom of Tonga, with infrastructure comprising a new headquarters building, transmitter mast and building infrastructure on Tongatapu Island, and a series of siren masts across the Tongan islands.

Geotechnical investigations were completed at two sites east of Nuku'alofa; at the TBC HQ site for the proposed new headquarters building, and at the TBC MW TX site for the proposed new MW transmitter mast and transmitter building.

[1] Yachiyo Engineering Co., Ltd. (3 August 2017), Amendment of Contract between Yachiyo Engineering Co., Ltd and Tonkin & Taylor International Ltd regarding Soil Survey Work for the Preparatory Survey on the Project for Nationwide Early Warning System and Strengthening Disaster Communications in the Kingdom of Tonga

[2] Tonkin and Taylor International Ltd. (1 December 2016), The Project for Nationwide Early Warning Dissemination and Strengthening Disaster Communications in the Kingdom of Tonga. Proposal for Topographic and Soil Investigation works.

Both sites are located on the low-lying and relatively flat coastal areas between the Fangakaku Lagoon in the south and the Pacific Ocean in the north (shown in Figure 2.1).

The TBC HQ site is located within a residential area, situated approximately 400 m to the south of the Pacific Ocean foreshore, and 1 km to the east of the Nuku'alofa CBD. The site is generally level with an approximate elevation of RL 1 m. In its current layout, the site contains two single-level office buildings, a storage shed, and a communication satellite which is located in the southern corner of the site.

The TBC MW TX site in the suburb of Popua, is situated approximately 300 m to the south of the Pacific Ocean foreshore and 4 km to the east of the Nuku'alofa CBD. The site is generally level with elevations between RL 0.8 m to RL 1.3 m across the site, grading to RL 2.1 m in the north-west. The site comprises a grassed field with coconut palms scattered around the boundaries. Low lying areas are increasingly vegetated, with swamps extending beyond the site boundaries. We understand the proposed development comprises a new medium wave transmitter in the centre of the site and a new transmitter building on the northern section of the site. In its current layout, the centre of the site contains a large transmitter mast, with remnant concrete pads from previous transmitter masts located throughout. Three single-storey, concrete block utility buildings associated with the transmission masts are situated on the northern section of the site.

Figure 2.1: Aerial photograph of the TBC HQ site and the TBC MW TX site in Nuku'alofa, on Tongatapu.

3 Summary of the Soils investigations

3.1 Geotechnical investigation equipment

The geotechnical investigations were undertaken at the two sites by means of machine boreholes (BH) and Scala penetrometer tests (SC). Scala penetrometer tests were performed by a T+TI engineering geologist at the TBC HQ site.

The machine drilled boreholes were undertaken by Geotech Drilling International Ltd (GDI), under the supervision of T+TI. The machine drilled boreholes were performed using a trailer rig using HQTT (HQ Triple Tube) wireline techniques with Standard Penetration Testing (SPT) performed at regular intervals. A photo of the machine drilling equipment used is shown in Figure 3.1 below.

Figure 3.1: Photo of the GDI drill rig used during the investigations, at the TBC MW TX site.

3.2 General

The soils investigations were carried out in August 2017 and the scope of work was completed in accordance with the "Contract of The Soil Survey Work" – presented in Appendix A. All machine drilled boreholes were terminated in either hard ground following at least 5 m of SPT 'N' counts greater than 30, or at 15 m depth - with permission from a YEC representative.

The following tasks were completed for the soils investigation:

- TBC HQ site:
    - 2 No. machine drilled boreholes (HQ_BH1-BH2) to 13.13 m below existing ground level; with SPTs at regular intervals.
    - 4 No. Scala penetrometer tests (HQ_SC1-SC4) to 2.8 m below existing ground level.
- TBC MW TX site:
    - 5 No. machine drilled boreholes (Pop_BH1-BH5) to 15.45 m below existing ground level; with SPTs at regular intervals.

Geotechnical investigation site plans and geological cross sections are presented in Appendix B, machine borehole and Scala penetrometer logs presented in Appendix C, and laboratory test results presented in Appendix D.

3.3 Machine Borehole Investigations

The machine borehole investigations were undertaken over a period of 9 days (1 August – 9 August 2017) at the TBC HQ site and the TBC MW TX site. The subsurface soils were described in accordance with NZ Geotechnical Society guidelines and shear strengths are recorded on the summary logs presented in Appendix C. Standard Penetration Testing (SPT) was conducted in the boreholes within cohesive material, coral gravels and coral limestone. Core box photographs are presented in Appendix C. A summary of borehole details is presented in Table 3.1.

Table 3.1 – Machine drilled borehole summary

BH ID	Location (Lat/Long)		Depth (m)
	Latitude (deg)	Longitude (deg)	
HQ_BH1	-21.140186	-175.192319	13.00
HQ_BH2	-21.139886	-175.192217	13.13
Pop_BH1	-21.144783	-175.163067	15.03
Pop_BH2	-21.145133	-175.163100	15.12
Pop_BH3	-21.144633	-175.162733	15.13
Pop_BH4	-21.144550	-175.163400	15.29
Pop_BH5	-21.143803	-175.163081	15.45

3.4 Scala Penetrometer Test Investigations

The Scala penetrometer test investigations were undertaken on 5 and 10 August 2017 at the TBC HQ site. The Scala penetrometer tests were applied in accordance with NZS 4402: 1986 Test 6.5.2. The tests were terminated when the penetration had reached refusal (30 blows per 100 mm). Summary logs are presented in Appendix C, and test details are presented in Table 3.2 below.

Table 3.2 – Scala penetrometer Test summary

SC ID	Location (Lat/Long)		Depth (m)
	Latitude (deg)	Longitude (deg)	
HQ_SC1	-21.140153	-175.192322	1.0
HQ_SC2	-21.139906	-175.192211	1.8
HQ_SC3	-21.140017	-175.192492	2.8
HQ_SC4	-21.139817	-175.192417	1.6

4 Subsurface Conditions

4.1 Geological Setting

Tongatapu is part of a chain of islands where lagoonal and reefal limestones have been deposited on relatively deeply submerged volcanic basement rock.

Published geological information[3] suggests that surface geology of Tongatapu, and the location of the two sites, consist of Plio-Pleistocene coral reef limestone. This is generally highly porous, and is described as massive, cream coloured biomicrites and biosparites with many in situ corals, algal-bound masses, vughs, and cavities. The limestones are generally well cemented, however layers of less dense, friable limestones occur within the reef deposits, but are not widespread.

The Holocene deposits are found to overlie the coral reef limestone and is generally a mixture of fine marine sediments and reworked terrestrial volcanic ash. Rare veneers of undisturbed airfall ash deposits overlie the reef limestones in locations where topography has prevented reworking by wave action.

The location of the sites in context of the regional geology is presented in Figure 4.1 below.

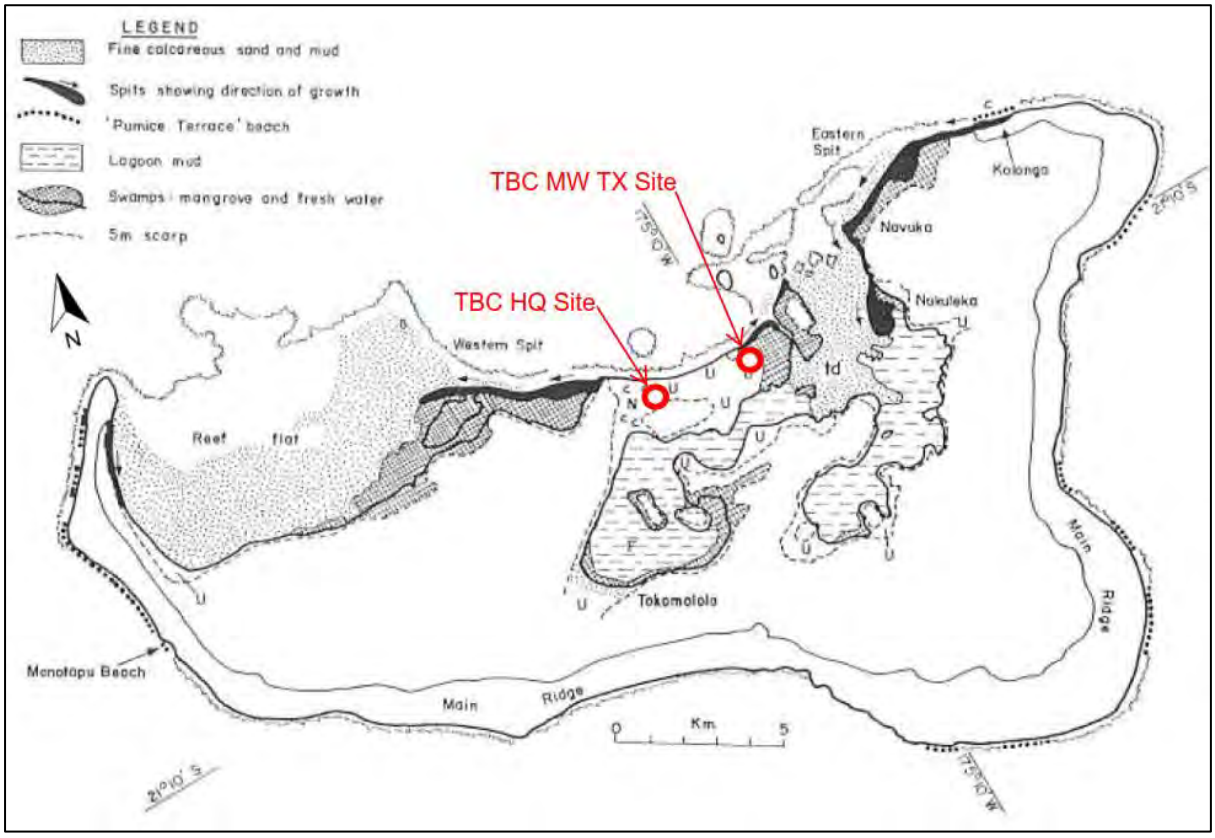


Figure 4.1: Geological map of Tongatapu (Reproduced from Roy P. S., 1990)

[3] Roy P. S., (1990). The morphology and surface geology of the islands of Tongatapu and Vava'u, Kingdom of Tonga. South Pacific Applied Geoscience Commission (SOPAC). Technical Report 62.

4.2 General

The ground conditions at the TBC HQ site and the TBC MW TX site were generally consistent with the geological map. The subsurface conditions encountered can be generalised into the following geological units:

- TBC HQ site:
  - Topsoil;
  - Gravel and Sand (Raised coral reef);
  - Limestone (Raised coral reef).
- TBC MW TX site:
  - Topsoil;
  - Non-engineered fill;
  - Buried Topsoil;
  - Gravel and Sand (Raised coral reef);
  - Limestone (Raised coral reef).

Inferred geological cross sections based on this investigations are presented in Appendix B, with a summary of the geological units provided in Sections 4.3-4.7.

4.3 Topsoil

Topsoil was encountered in all investigations across both the TBC HQ site and the TBC MW TX site, extending to depths of between 0.2 m to 0.6 m bgl. The topsoil material typically comprised organic silt with medium to coarse sand and some fine trace gravel, with decomposing plant material.

4.4 Non-engineered fill

Non-engineered fill was encountered in machine boreholes at the TBC MW TX site only, extending to depths of between 1.7 m to 2.9 m bgl. The fill material typically comprised sandy medium to coarse sand, overlying medium to coarse coral gravel, and cobbles or boulders of coral.

Although the history of the non-engineered fill on this site is unknown, our knowledge of similar sites suggests that the non-engineered fill was placed directly on an in-situ topsoil layer, where it was spread and levelled with minimal compaction. During our investigations, this method of filling was being undertaken on a neighbouring site adjacent to the northern boundary of the TBC MW TX site.

4.5 Buried Topsoil

Buried topsoil was encountered in machine boreholes at the TBC MW TX site only, extending to depths of between 2.6 m and 3.8 m bgl. The buried topsoil material typically comprised soft to stiff, organic silty clay with trace sand and trace to minor fine coral gravel.

The buried topsoil layer is inferred to be in-situ, underlying the non-engineered fill.

4.6 Limestone Gravel and Sand (Raise Coral Reef)

Limestone gravel and sand (Raised Coral Reef) material was encountered in all investigations at the TCB HQ site and the TBC MW TX site. This typically comprised layers of loose to very dense, medium to coarse limestone coral sand, interbedded with fine to coarse limestone coral gravels. These extended to depths of between 7.0 m and 8.0 m bgl at the TCB HQ site and to depths of between 10.0 m to 11.6 m bgl at the TBC MW TX site.

4.7 Limestone (Raised Coral Reef)

The limestone gravel and sand layers transition into weak to moderately strong limestone (coral) rock with layers of increased voids, encountered between 7.0 m to 8.0 m bgl at the TBC HQ site and between 10.0 m to 11.6 m bgl at the TBC MW TX site. All borehole were terminated within the limestone (coral) rock. The SPT N-values in this limestone (coral) rock typically exceed 50 blows, though SPT N-values as low as 12 were encountered in less dense layers.

A shallow layer of limestone (coral) rock was encountered in Pop_BH5 within the limestone sand and gravel layers from 3.8 m bgl. This layer was 2.6 m in thickness with SPT N-values of between 42 and greater than 50. Below this limestone (coral) rock layer, the material transitioned to limestone sand and gravel with SPT N-values of between 12 to 34, where limestone (coral) rock was again encountered at depth of 11.6 m bgl.

4.8 Summary of ground and ground water conditions at Sites 1 and 2

4.8.1 TBC HQ Site

4.8.1.1 HQ_BH1

The subsurface conditions for the southern area of the site (HQ_BH1) are summarised in Table 4.1 below. The investigations extended to 13.0 m below existing ground level. Ground water was encountered at 0.81 m below existing ground level.

Table 4.1: HQ_BH1 – Summary of the ground conditions

Depth (Below ground level)	Geological Unit	Soil Description	Typical SPT 'N' value
0-0.3m	Topsoil	Organic sandy SILT with trace gravel; dark blackish brown. Stiff, moist, non-plastic.	N/A
0.3-1.15m (Core loss 1.0-1.15m)	Limestone gravel and sand (Raised coral reef)	Medium SAND with trace gravel; grades light yellowish brown. Medium dense, moist, uniformly graded.	23
1.15-4.0m (Core loss 2.0-2.2m and 3.45-3.6m)		Fine to coarse GRAVEL; light brownish or yellowish white with dark orange. Medium dense, saturated, uniformly to well graded.	16-22
4.0-5.0m		Fine to coarse GRAVEL; light yellowish brown. Very dense, saturated, well graded.	>50
5.0-6.45m (Core loss 5.0-5.15m and 5.45-5.65m)		Gravelly coarse SAND; light yellowish white. Medium dense, saturated, uniformly graded.	20
6.45-7.0m		Fine to coarse GRAVEL; light yellowish white. Medium dense, saturated, well graded.	N/A
7.0-9.0m (Core loss 7.0-7.2m and 8.27-11.0m)	Limestone (Raised coral reef)	Moderately weathered, light yellowish white with dark orange LIMESTONE (Coral). Weak to moderately strong, voided (Recovered as: Coarse GRAVEL). Iron staining on fracture surfaces.	>50
11.0-13.0m (Core loss 11.0-11.1m)		Slightly weathered, light brownish white with dark orange LIMESTONE (Coral). Weak. (Recovered as: 0.05 m pieces of intact core and medium to coarse GRAVEL).	>50

4.8.1.2 HQ_BH2

The subsurface conditions for the northern area of the site (HQ_BH2) are summarised in Table 4.2 below. The investigations extended 13.13 m below existing ground level. Ground water was encountered at 0.69 m below existing ground level.

Table 4.2: HQ_BH2 – Summary of the ground conditions

Depth (Below ground level)	Geological Unit	Soil Description	Typical SPT 'N' value
0.0-0.5m	Topsoil	Sandy organic SILT; Stiff, moist, non-plastic.	N/A
0.5-1.3m (Core loss 0.5-0.8m)	Limestone gravel and sand (Raised coral reef)	Medium to coarse SAND; light brown. Medium dense, moist, well graded.	13
1.3-3.65m (Core loss 3.25-3.65m)		Silty fine to coarse GRAVEL with trace to minor sand; light yellowish brown and orangey white with dark orange. Medium dense, saturated, well graded.	19-20
3.65-5.0m (Core loss 4.0-4.1m)		Medium to coarse GRAVEL; light yellowish white with dark orange. Medium dense, saturated, well graded.	24
5.0-6.0m		Fine to coarse GRAVEL; light brownish white. Very dense, saturated, well graded.	>50
6.0-8.0m (Core loss 6.0-6.35m and 7.0-7.15m)		Medium to coarse GRAVEL; light yellowish white with dark orange. Medium dense, saturated, well graded.	10-13
8.0-13.13m	Limestone (Raised coral reef)	Slightly weathered, light brownish white stained dark orange LIMESTONE (Coral). Moderately strong, voided.	>50

4.8.2 TBC MW TX Site

4.8.2.1 Pop_BH1

The subsurface conditions for the mast centre location (Pop_BH1) are summarised in Table 4.3 below. The investigations extended 15.03 m below existing ground level. Ground water was encountered at 1.07 m below existing ground level.

Table 4.3: Pop_BH1 - Summary of ground conditions

Depth (Below ground level)	Geological Unit	Soil Description	Typical SPT 'N' value
0-0.4m	Topsoil	Organic SILT with minor sand; dark brown. Stiff, moist, non-plastic.	N/A
0.4-1.0m (Core loss 0.9-1.0m)	Non-engineered Fill	Medium to coarse SAND with trace gravel; light brown. Medium dense, moist, well graded.	N/A
1.0-1.7m (Core loss 1.0-1.7m)		Sandy GRAVEL with minor silt; light brown. Medium dense, wet, well graded.	14
1.7-2.6m (Core loss 1.7-2.25m)	Buried topsoil	Organic silty CLAY with minor gravel; dark brown. Soft to firm, wet, moderate to high plasticity.	0
2.6-4.0m (Core loss 3.45-3.6m)	Limestone gravel and sand (Raised coral reef)	Sandy fine to coarse GRAVEL; light and dark brown. Medium dense, wet, well graded.	21
4.0-5.15m (Core loss 4.0-4.25m and 5.0-5.15m)		Fine to coarse GRAVEL with minor sand; light brown. Loose, wet, well graded.	8
5.15-6.0m		Fine to medium GRAVEL with minor sand; light brown. Medium dense to dense.	42
6.0-7.8m (Core loss 6.0-6.25m)		Fine to coarse GRAVEL with minor sand; light brown. Loose to medium dense, wet, well graded.	8-17
7.8-10.0m		Gravelly medium to coarse SAND with trace silt; white. Medium dense, wet, uniformly graded.	13-23
10.0-11.0m		Sandy fine to medium GRAVEL; white. Dense, wet, well graded	43
11.0-15.03m (Core loss 11.12-11.3m)	Limestone (Raised coral reef)	Unweathered to slightly weathered, white LIMESTONE. Moderately strong, voided.	>50

4.8.2.2 Pop_BH2

The subsurface conditions for the southern support position for the mast (Pop_BH2) are summarised in Table 4.4 below. The investigations extended 15.12 m below existing ground level. Ground water was encountered at 1.22 m below existing ground level.

Table 4.4: Pop_BH2 - Summary of ground conditions

Depth (Below ground level)	Geological Unit	Soil Description	Typical SPT 'N' value
0-0.4m	Topsoil	Sandy organic SILT; dark brown. Stiff, moist, non-plastic.	N/A
0.4-1.3m	Non-engineered Fill	Medium to coarse SAND; light brown. Medium dense, moist, well graded.	25
1.3-1.9m (Core loss 1.3-1.6m)		Medium to coarse GRAVEL; light brown. Medium dense, moist, uniformly graded.	25
1.9-3.0m	Limestone gravel and sand (Raised coral reef)	Gravelly medium to coarse SAND with minor silt; light yellowish brown. Very loose, wet, well N/A graded.	3
3.0-3.45m		Gravelly medium to coarse SAND with minor silt; light yellowish brown. Dense, wet, well graded.	44
3.45-4.8m		Fine to coarse GRAVEL with minor sand; light brown. Medium dense, wet, well graded.	24
4.8-5.7m (Core loss 4.8-5.2m and 5.45-5.7m)		Silty fine to medium SAND with trace gravel; light brown. Very loose, saturated, uniformly graded.	3
5.7-6.2m (Core loss 6.0-6.2m)		Fine to coarse GRAVEL with minor sand; light brownish white. Medium dense, wet, well graded.	15
6.2-7.7m		Sandy fine GRAVEL with minor silt; light brown. Medium dense, wet, uniformly graded.	22
7.7-9.0m		Fine to coarse GRAVEL; light brownish white. Dense, moist, well graded.	46
9.0-10.0m (Core loss 9.0-9.2m)		Fine to coarse GRAVEL; light brownish white. Medium dense, moist, well graded.	18
10.0-10.9m		Fine to coarse GRAVEL; light brownish white. Dense, moist, well graded.	31
10.9-15.117m	Limestone (Raised coral reef)	Unweathered to slightly weathered, light brownish white LIMESTONE (Coral). Moderately strong, voided.	>50

4.8.2.3

4.8.2.4 Pop_BH3

The subsurface conditions for the north-eastern support position for the mast (Pop_BH3) are summarised in Table 4.5 below. The investigations extended 15.13 m below existing ground level. Ground water was encountered at 1.02 m below existing ground level.

Table 4.5: Pop_BH3 - Summary of ground conditions

Depth (Below ground level)	Geological Unit	Soil Description	Typical SPT 'N' value
0.0-0.3m	Topsoil	Organic sandy SILT; dark brown. Stiff, moist, non-plastic.	N/A
0.3-0.8m (Core loss 1.6-1.8m)	Non-engineered Fill	Gravelly medium to coarse SAND; light brown. Tightly packed, moist, well graded.	N/A
0.8-2.0m		COBBLES or BOULDERS; light brownish white. Very dense, moist, coral.	>50
2.0-4.0m	Buried topsoil	Organic silty CLAY with trace sand and minor gravel; dark brown. Soft to firm, saturated, non-plastic to moderately plastic.	2
4.0-5.25m	Limestone gravel and sand (Raised coral reef)	Sandy medium GRAVEL; light brownish white. Very dense, wet, uniformly graded.	>50
5.25-7.45m (Core loss 5.25-5.7m and 6.2-6.9m)		Fine to coarse GRAVEL; light brownish white. Medium dense, saturated, uniformly to well graded.	11-21
7.45-10.0m (Core loss 7.45-7.8m and 8.35-8.6m)		Silty fine to coarse SAND with areas of some gravel; light brownish white. Medium dense, saturated, uniformly to well graded.	19-22
10.0-11.0m	Limestone (Raised coral reef)	Slightly weathered, light brownish white LIMESTONE (Coral). Moderately strong, voided.	>50
11.0-12.0m (Core loss 11.45-11.55m)		Slightly weathered, light brownish white LIMESTONE (Coral). Very to extremely weak.	41
12.0-15.13m		Slightly weathered, light brownish white LIMESTONE (Coral). Moderately strong, voided.	45 - >50

4.8.2.5 Pop_BH4

The subsurface conditions for the north-western support position for the mast (Pop_BH4) are summarised in Table 4.6 below. The investigations extended 15.29 m below existing ground level. Ground water was encountered at 0.92 m below existing ground level.

Table 4.6: Pop_BH4 - Summary of ground conditions

Depth (Below ground level)	Geological Unit	Soil Description	Typical SPT 'N' value
0.0-0.6m (Core loss)	Topsoil	N/A	N/A
0.6-1.1m	Non-engineered Fill	Silty sandy fine to coarse GRAVEL with trace organics; light brown with rare dark brown. Loose, moist, well graded.	0
1.1-3.15m	Buried topsoil	Silty CLAY with trace organics, gravel and sand; dark yellowish brown. Firm to stiff, moist, moderate plasticity.	2
3.15-4.0m	Limestone gravel and sand (Raised coral reef)	Gravelly COBBLES; light brownish white. Medium dense, saturated, uniformly graded.	17
4.0-5.2m (Core loss 5.0-5.2m)		Fine to medium GRAVEL with some sand; light brownish white. Dense, saturated, well graded.	36
5.2-6.7m		Fine to medium GRAVEL with some sand; light brownish white. Very dense, saturated, well graded. Becomes well cemented, voided.	>50
6.7-7.45m		Sandy fine to medium GRAVEL; light whitish brown. Dense, moist, well graded.	26
7.45-8.45m (Core loss 7.45-7.8m)		Silty course SAND with minor gravel; light brownish white. Dense, moist, well graded.	39
8.45-9.45m		Sandy fine to coarse GRAVEL; light brownish white. Medium dense, saturated, well graded.	13
9.45-11.0m (Core loss 9.45-10.0m)		Fine to coarse SAND; white. Medium dense, saturated, uniformly graded.	42
11.0-13.34m (Core loss 13.1-13.34m)	Limestone (Raised coral reef)	Slightly weathered, light brownish white LIMESTONE (Coral). Weak to moderately strong, voided.	>50
13.34-15.29m		Slightly weathered, light brownish white LIMESTONE (Coral). Moderately strong, voided.	>50

4.8.2.6 Pop_BH5

The subsurface conditions for the proposed transmitter building (Pop_BH5) are summarised in Table 4.7 below. The investigations extended 15.45 m below existing ground level. Ground water was encountered at 1.40 m below existing ground level.

Table 4.7: Pop_BH5 - Summary of ground conditions

Depth (Below ground level)	Geological Unit	Soil Description	Typical SPT 'N' value
0.0-0.2m	Topsoil	Sandy organic SILT; dark brown. Stiff, moist, non-plastic.	N/A
0.2-2.9m (Core loss 2.0-2.3m)	Non-engineered Fill	Medium to coarse SAND; light brown. Medium dense, moist, well graded.	14-36
2.9-3.8m	Buried topsoil	Sandy organic clay with lenses of minor sand and gravel; dark brown. Soft to firm, saturated, low to high plasticity.	N/A
3.8-6.4m	Limestone (Raised coral reef)	Moderately to highly weathered, light brownish white LIMESTONE (Coral). Weak.	42 - >50
6.4-7.65m (Core loss 6.4-6.5m)	Limestone gravel and sand (Raised coral reef)	Medium to coarse GRAVEL; light brownish white occasional dark orange. Dense, moist, well graded.	36
7.65-11.6m		Gravelly medium to coarse SAND with trace silt; white. Medium dense, saturated, well graded.	12-34
11.6-14.0m	Limestone (Raised coral reef)	Slightly weathered, white LIMESTONE (Coral). Moderately strong, voided.	>50
14.0-15.45m (14.45-14.7m)		Slightly weathered, light brownish white LIMESTONE (Coral). Very weak.	12-25

5 Geotechnical Laboratory Testing Results

The following laboratory testing has been performed on drill core samples, SPT samples and water samples recovered during the soil investigations. The full set of laboratory testing results are shown in Appendix D.

The results of the:

- Ground water Chloride tests are presented in Table 5.1;
- Unconfined Compressive Strength tests are presented in Table 5.2;
- One-dimension Consolidation test presented in Table 5.3;
- Atterberg Limits and Water Content tests are presented in Table 5.4;
- Solid Density tests are presented in Table 5.5;
- Triaxial test in Table 5.6; and
- Particle Size Distribution tests are presented in Appendix D.

Table 5.1: Laboratory testing summary – Ground water Chloride testing

Machine Borehole No.	Chloride (g/m³)
HQ-BH1	1,930
HQ-BH2	1,760
POP-BH1	520
POP-BH2	1,360
POP-BH3	1,890
POP-BH4	600
POP-BH5	7,200

Table 5.2: Laboratory testing summary – Unconfined Compressive Strength testing

Machine Borehole No.	Sample Depth (m)	Unconfined Compressive Strength (kPA)	Modulus of Elasticity (MPa)	Bulk Density (t/m3)
POP_BH2	11.30-11.52	24,724	3,617	2.24
POP_BH3	11.70-11.90	7,485	1,208	2.28
POP_BH4	12.05-12.35	6,981	816	2.12
POP_BH4	12.43-12.70	14,031	3,284	2.17
POP_BH5	11.60-11.80	11,454	4,538	2.29
POP_BH5	13.48-13.70	7,082	1,514	2.19

Table 5.3: Laboratory testing summary – One-dimensional Consolidation testing

Machine Borehole No.	Sample Depth (m)	Pressure range (kPA)	Coefficient of Consolidation CV (m²/yr) range	Coefficient of Volume Compressibility Mv (m²/MN) range
POP_BH5	3.35-3.40	0.0 - 483	7.1 - 26	0.21 - 0.3

Table 5.4: Laboratory testing summary – Atterberg Limits and Water Content

Machine Borehole No.	Sample Depth (m)	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
HQ_BH1	4.0	16.0	-	-	-
HQ_BH1	7.0	22.0	-	-	-
HQ_BH2	1.0	33.1	-	-	-
HQ_BH2	10.0	18.4	-	-	-
POP_BH1	3.0	23.3	-	-	-
POP_BH1	8.0	39.0	-	-	-
POP_BH2	5.0	41.8	-	-	-
POP_BH2	10.0	31.6	-	-	-
POP_BH3	2.0	60.2	-	-	-
POP_BH3	2.60-2.75	63.3	104	52	52
POP_BH4	1.0	72.8	-	-	-
POP_BH4	2.80-2.95	70.9	106	50	56
POP_BH4	3.0	75.7	106	51	55
POP_BH4	12.0	15.2	-	-	-
POP_BH5	1.0	15.1	-	-	-
POP_BH5	6.0	14.3	-	-	-

Table 5.5: Laboratory testing summary – Density of Soil Particles

Machine Borehole No.	Sample Depth (m)	Density of Soil Particles (t/m^3)
HQ_BH1	2.0	2.49
HQ_BH1	9.0	2.51
HQ_BH2	4.0	2.46
HQ_BH2	7.0	2.48
POP_BH1	5.0	2.53
POP_BH1	12.0	2.53
POP_BH2	2.0	2.65
POP_BH2	13.0	2.56
POP_BH3	4.0	2.47
POP_BH3	9.0	2.54
POP_BH4	8.0	2.47
POP_BH4	10.0	2.47
POP_BH5	4.0	2.55
POP_BH5	11.0	2.60

Table 5.6: Laboratory testing summary – Triaxial test

Machine Borehole No.	Sample Depth (m)	ϕ Angle of frictional resistance (°)		Cohesion (kPa)	
		Total	Effective	Total	Effective
POP_BH3	3.26-3.38	19	34	6	5

6 Discussion and Engineering Properties

Recommendations and opinions in this report are based upon data from the machine boreholes and the Scala penetrometer tests. The nature and continuity of the subsoil away from the test locations is inferred, but it must be appreciated that actual conditions could vary from the assumed model.

From the results of the soils investigation, laboratory testing and published empirical relationships, we have assessed the engineering properties for the underlying soils at the two sites for the designer's consideration in the following subsections.

Actual ground conditions should be confirmed by a geotechnical engineer competent to judge whether the soils exposed in the foundation excavations are comparable with those described within this report.

6.1 Site Seismic Classification

6.1.1 General

The island of Tongatapu, is understood to have been formed by uplift and tilting of the plate over-riding the Tonga subduction zone and in close proximity to the Tonga Trench. As a result, strong earthquakes are to be expected and should be allowed for in the design of the buildings and MW mast.

6.1.2 Site subsoil class

From the geotechnical investigations undertaken we consider that the two sites should be classified as a Class C - (Shallow soil sites), in accordance with New Zealand Standard NZS 1170.5:2004[4]

6.1.3 Importance Level

In accordance with NZS 1170.0:2002[5] which is adopted in Tonga we have completed this assessment on the basis that the proposed developments will be an Importance Level 2 structures. If this is changed during detailed design then updates will be required to this report.

[4] NZS 1170.5: 2004 *Structural design actions – Earthquake Actions (New Zealand).* SANZ.
[5] NZS 1170:0: 2002 *Structural design actions – Part 0: General Principles*

6.2 Soil Parameters

Geotechnical engineering parameters for the TBC HQ site and TBC MW TX site are detailed in Table 6.1-6.2 and Table 6.3-6.7 respectively. Parameters have been assigned based on the results of in situ testing, laboratory test results and our knowledge of ground conditions. The SPT N value based correlation for friction angle of cohesionless soils (Meyerhof, 1956) is presented in Appendix E.

6.2.1 TBC HQ Site

Table 6.1: TBC HQ Site: Geotechnical Engineering Parameters for HQ_BH1

Depth (Below ground level)	Geological Unit	Unit Weight (KN/m³)	Undrained Shear Strength, Cu (kPa)	Effective Cohesion C' (kPa)	Effective Internal Friction Angle ϕ (deg)
0-0.3m	Topsoil	18	N/A	2	25
0.3-7.0m	Limestone gravel and sand (Raised coral reef)	18	-	-	35
7.0-13.0m	Limestone (Raised coral reef)	20		20	40

Chart 6.1: TBC HQ Site: Effective Internal Angle of Friction Values for HQ_BH1

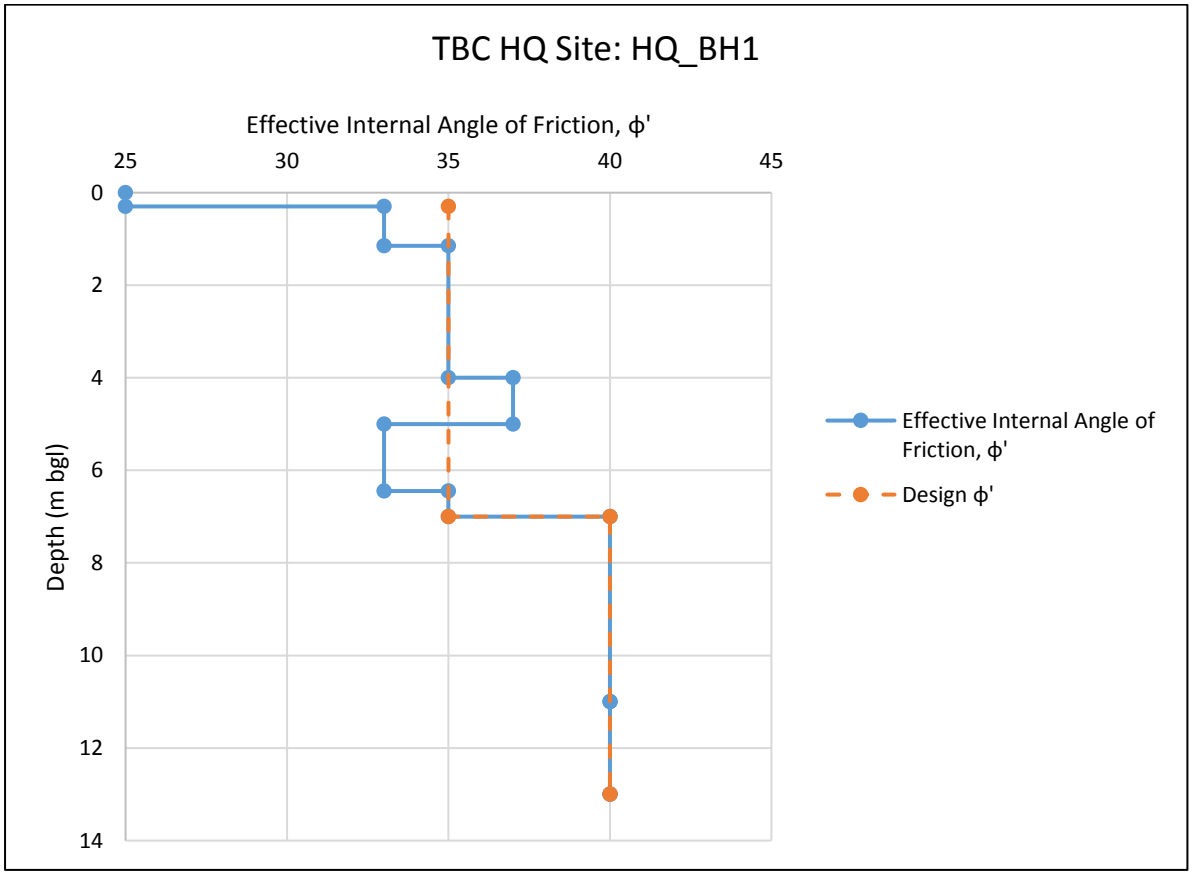
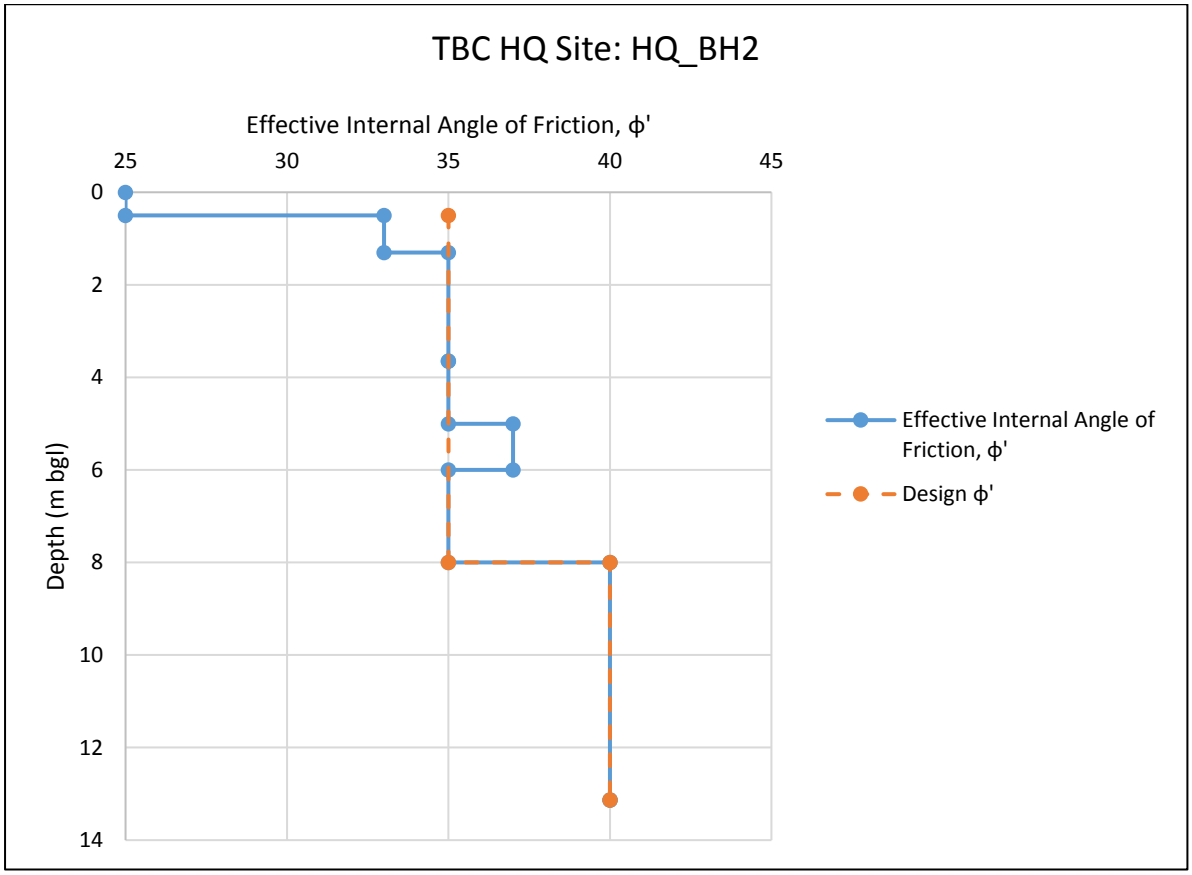


Table 6.2: TBC HQ Site: Geotechnical Engineering Parameters for HQ_BH2

Depth (Below ground level)	Geological Unit	Unit Weight (KN/m³)	Undrained Shear Strength, Cu (kPa)	Effective Cohesion C' (kPa)	Effective Internal Friction Angle ϕ (deg)
0.0-0.3m	Topsoil	18	N/A	2	25
0.5-8.0m	Limestone gravel and sand (Raised coral reef)	18	-	-	35
8.0-13.0m	Limestone (Raised coral reef)	20	-	20	40

Chart 6.2: TBC HQ Site: Effective Internal Angle of Friction Values for HQ_BH2



6.2.2 TBC MW TX Site

Table 6.3: TBC MW TX Site: Geotechnical Engineering Parameters for Pop_BH1

Depth (Below ground level)	Geological Unit	Unit Weight (KN/m³)	Undrained Shear Strength, Cu (kPa)	Effective Cohesion C' (kPa)	Effective Internal Friction Angle ϕ (deg)
0.0-0.4m	Topsoil	18	N/A	2	25
0.4-1.7m	Non-engineered Fill	18	-	-	33
1.7-2.6m	Buried topsoil	18	20	2	28
2.6m-11.0m	Limestone gravel and sand (Raised coral reef)	18	-	-	35
11.0-15.0m	Limestone (Raised coral reef)	20	-	20	40

Chart 6.4: TBC HQ Site: Effective Internal Angle of Friction Values for Pop_BH1

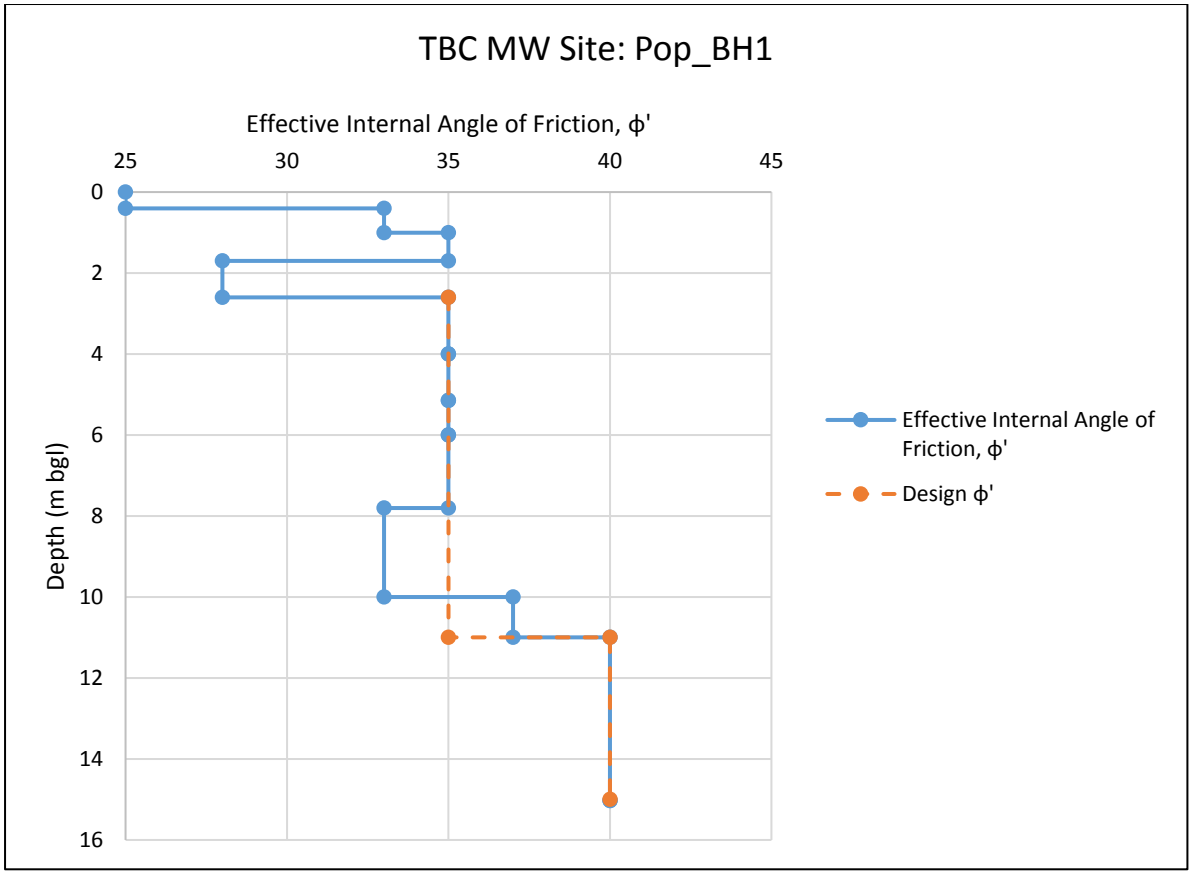


Table 6.4: TBC MW TX Site: Geotechnical Engineering Parameters for Pop_BH2

Depth (Below ground level)	Geological Unit	Unit Weight (KN/m³)	Undrained Shear Strength, Cu (kPa)	Effective Cohesion C' (kPa)	Effective Internal Friction Angle ϕ (deg)
0.0-0.4m	Topsoil	18	N/A	2	25
0.4-1.9m	Non-engineered Fill	18	-	-	33
1.9-6.0m	Limestone gravel and sand (Raised coral reef)	18	-	-	33
6.0-10.9m	Limestone gravel and sand (Raised coral reef)	18	-	-	35
10.9-15.1m	Limestone (Raised coral reef)	20	-	20	40

Chart 6.4: TBC HQ Site: Effective Internal Angle of Friction Values for Pop_BH2

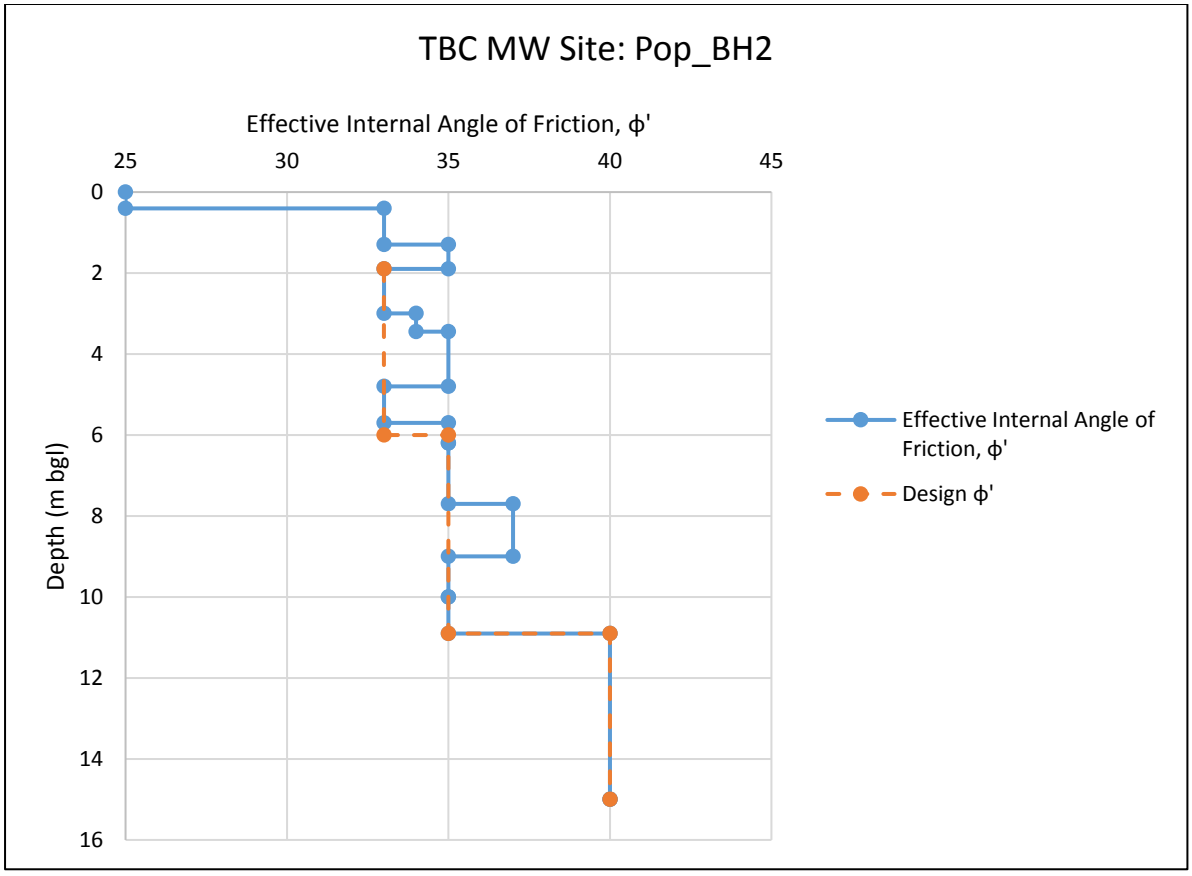


Table 6.5: TBC MW TX Site: Geotechnical Engineering Parameters for Pop_BH3

Depth (Below ground level)	Geological Unit	Unit Weight (KN/m³)	Undrained Shear Strength, Cu (kPa)	Effective Cohesion C' (kPa)	Effective Internal Friction Angle ϕ (deg)
0.0-0.3m	Topsoil	18	N/A	2	25
0.3-2.0m	Non-engineered Fill	18	-	-	33
2.0-4.0m	Buried topsoil	18	40	3	28
4.0-10.0m	Limestone gravel and sand (Raised coral reef)	18	-	-	35
10.0-15.1m	Limestone (Raised coral reef)	20	-	20	40

Chart 6.5: TBC HQ Site: Effective Internal Angle of Friction Values for Pop_BH3

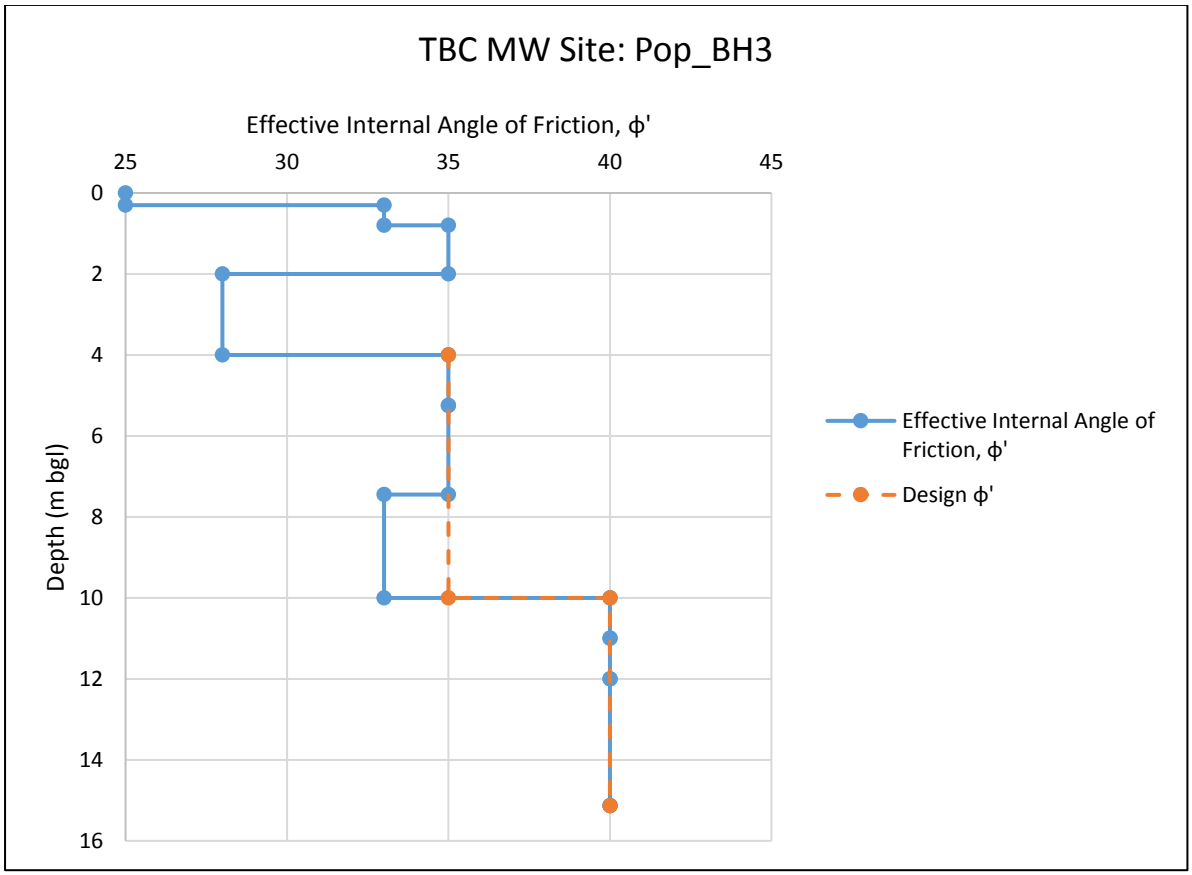


Table 6.6: TBC MW TX Site: Geotechnical Engineering Parameters for Pop_BH4

Depth (Below ground level)	Geological Unit	Unit Weight (KN/m³)	Undrained Shear Strength, Cu (kPa)	Effective Cohesion C' (kPa)	Effective Internal Friction Angle ϕ (deg)
0.0-0.6m	Topsoil	18	N/A	2	25
0.6-1.1m	Non-engineered Fill	18	-	-	33
1.1-3.15m	Buried topsoil	18	50	3	28
3.15-6.7m	Limestone gravel and sand (Raised coral reef)	18	-	-	35
6.7-11.0m	Limestone gravel and sand (Raised coral reef)	18	-	-	33
11.0-15.3m	Limestone (Raised coral reef)	20	-	20	40

Chart 6.6: TBC HQ Site: Effective Internal Angle of Friction Values for Pop_BH4

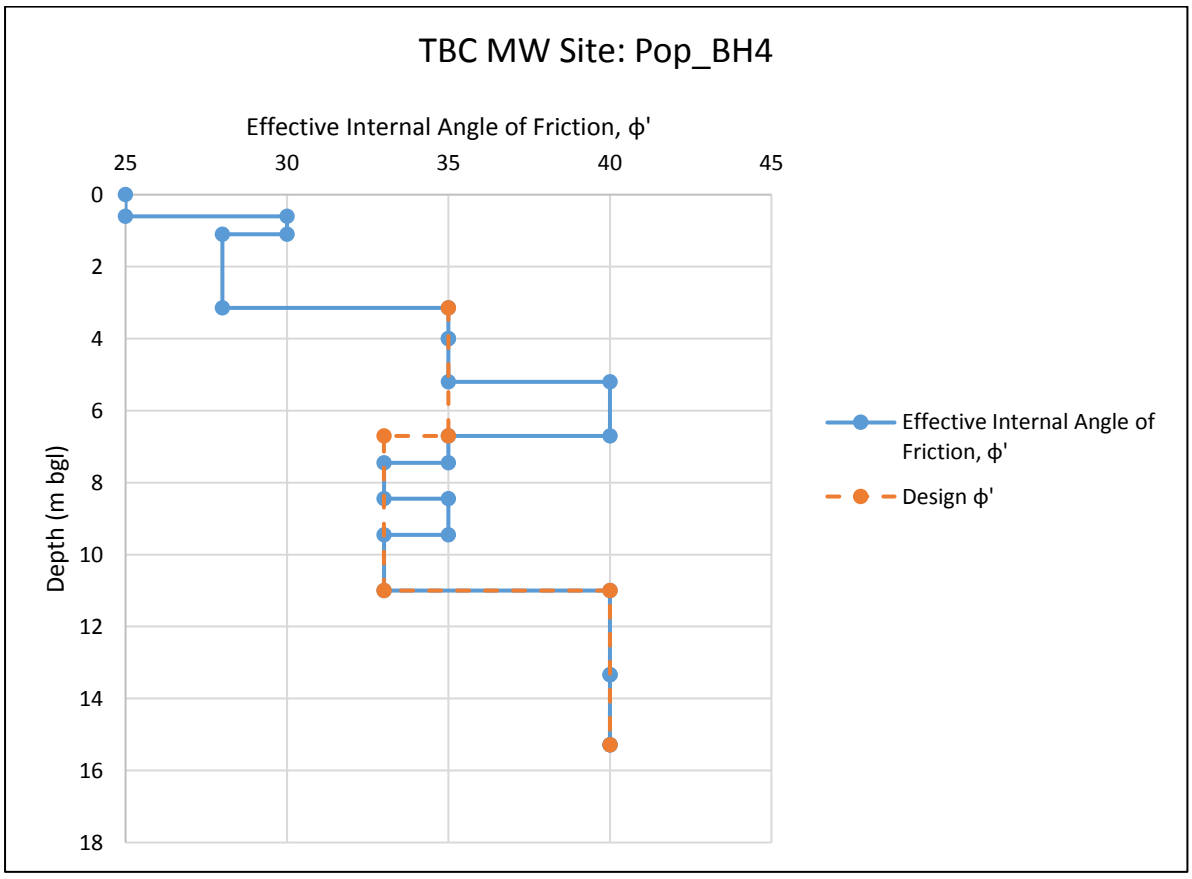
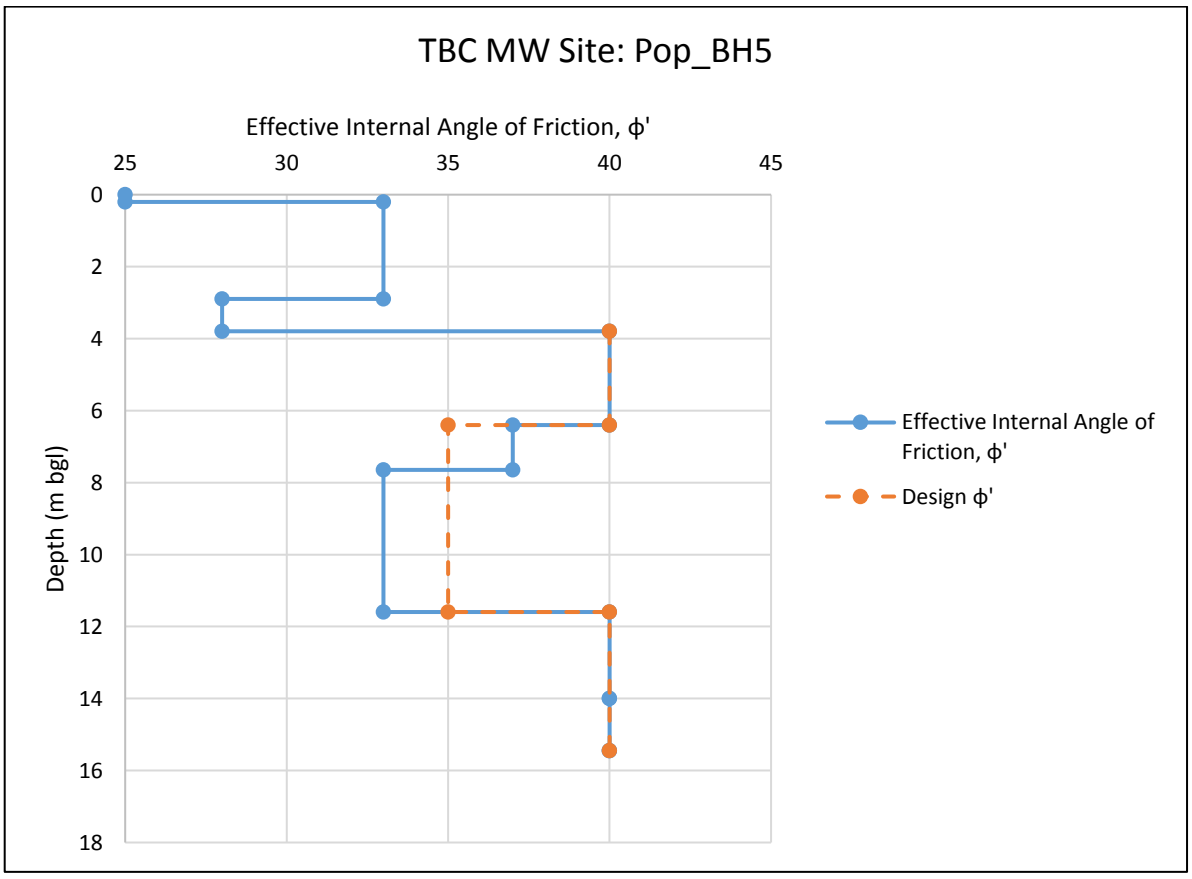


Table 6.7: TBC MW TX Site: Geotechnical Engineering Parameters for Pop_BH5

Depth (Below ground level)	Geological Unit	Unit Weight (KN/m³)	Undrained Shear Strength, Cu (kPa)	Effective Cohesion C' (kPa)	Effective Internal Friction Angle ϕ (deg)
0.0-0.2m	Topsoil	18	N/A	2	25
0.2-2.9m	Non-engineered Fill	18	-	-	33
2.9-3.8m	Buried topsoil	18	25	3	28
3.8-6.4m	Limestone (Raised coral reef)	20	-	20	40
6.4-11.6m	Limestone gravel and sand (Raised coral reef)	18	-	-	35
11.6-15.45m	Limestone (Raised coral reef)	20	-	20	40

Chart 6.7: TBC HQ Site: Effective Internal Angle of Friction Values for Pop_BH5



6.3 Foundation Options

This section outlines the geotechnical analyses undertaken for the proposed foundation options for each structure as part of the Nationwide Early Warning Dissemination and Strengthening Disaster Communications project. Detailed bearing capacity calculations are presented in Appendix E.

The SPT N value based correlation for the allowable bearing capacity for surface loaded footings with settlement limited to 25mm is presented in Appendix E.

The Meyerhof (1963) formula has been used for the calculation of shallow foundation bearing capacities.

Ultimate Bearing Capacity = $q_u = cN_c s_c d_c + qN_q s_q d_q + \frac{1}{2}\gamma B N_\gamma s_\gamma d_\gamma$

Where:

$Cohesion = c = 0$ kPa

Internal angle of friction = $\phi = 35°$ (Section 6.2)

Total unit weight of soil = $\gamma = 18\text{kN}/m^3$

Effective unit weight of soil = $\gamma' = 8\text{kN}/m^3$

D = Depth of foundation

d_w = Depth to groundwater table

Overburden pressure = q

- For foundation subsoils above water table: q = unsaturated overburden

$$q = \gamma D$$

- For foundation subsoils below water table: q = unsaturated overburden + saturated overburden

$$q = (\gamma\, d_w) + (\gamma'\,(D - d_w)$$

$N_q = e^{\pi \tan\phi} tan^2(45 + \frac{\phi}{2})$

$N_c = (N_q - 1)\cot\phi\,, N_q$

$N_\gamma = (N_q - 1)\tan(1.4\phi)$

$s_c = 1 + 0.2K_p\frac{B}{L}$

$s_q = s_\gamma = 1 + 0.1K_p\frac{B}{L}$

$d_c = 1 + 0.2\sqrt{K_p}\frac{D}{B}$

$d_q = d_\gamma = 1 + 0.1\sqrt{K_p}\frac{D}{B}$

$K_p = tan^2(45 + \frac{\phi}{2})$

6.3.1 HQ Building (HQ_BH1 and BH2)

6.3.1.1 Shallow foundations

Based on consultations with YEC, we understand shallow foundations are the preferred foundation option for the proposed HQ Building. Shallow foundations embedded 0.5m depth (minimum), bearing on medium dense sand are considered suitable.

The design bearing capacities presented in Table 6.8 are based upon a footing width of 0.5m. The option of founding at 1.0m depth is also presented. This shallow foundation option requires the sub-excavation of a buried topsoil layer present to 0.5 m depth (HQ_BH2). It should be noted that the ground water table was encountered at 0.7m depth.

Should foundations be subjected to uplift forces, we recommend increasing the mass of foundations or installing grouted anchors for uplift resistance. Grouted anchor recommendations are detailed in Section 6.3.5.

Table 6.8: HQ Building: Shallow Foundation Bearing Capacities

Material Type	Embedment	Geotechnical Ultimate (1)	Ultimate Limit State Design (2)	Working Load Design (3)
Medium dense sand (4)	0.5m	550 kPa	275 kPa	180 kPa
	1.0m	800 kPa	400 kPa	265 kPa

Notes:

1. Geotechnical ultimate (failure) bearing capacity
2. Ultimate limit state bearing capacity pressure (ULS structural loads) using $\phi g = 0.5$, NZ Building Code – B1/VM4
3. Working load (unfactored) bearing pressure using a factor of safety of 3.0
4. Geotechnical parameters:
    a. $c = 0$
    b. $\phi = 35°$
    c. $\gamma = 18 kN/m^3$
    d. $\gamma' = 8 kN/m^3$
    e. $D = 0.5m$ and $1.0m$
    f. $d_w = 0.7m$
    g. $B = 0.5m$
    h. $L = 10m$ (assumed length of strip footing)

6.3.2 Transmitter Building (Pop_BH5)

6.3.2.1 Shallow foundations

Based on consultation with YEC, we understand shallow foundations are the preferred foundation option for the proposed Transmitter Building. The proposed Transmitter Building site is underlain by topsoil, non-engineered fill and buried topsoil to a depth of 3.8m; with the ground water table present at approximately 1.4m depth. We do not consider it practical to excavate the buried topsoil due to the shallow ground water table.

A reinforced gravel raft foundation is considered suitable for the proposed single storey transmitter building, provided the foundation loads do not exceed the design bearing capacities provided in Table 6.9.

YEC may wish to consider the following construction sequence:

- Excavate to 1.0m depth, with excavation batters no steeper than 1(V):2(H);
- Stockpile excavated sand for use as backfill;
- Compact the base of the excavation with a vibrating roller;
- Backfill excavated sand in a 100mm thick layer over the base of the excavation, and compact with vibrating roller;
- Place geogrid over the compacted sand layer;
- Backfill excavated sand in 200mm thick layers to 0.5m depth, and compact with vibrating roller;
- Backfill imported quarry fill in a 100mm thick layer over the compacted sand, and compact with vibrating roller;
- Place geogrid over the compacted imported quarry fill (40mm maximum aggregate size);
- Backfill imported quarry fill in 200mm thick layers to the underside of foundation slabs.

This foundation option is at some risk of long term settlement due to the consolidation of the buried topsoil. We recommend detailed settlement calculations be undertaken using the results of the One Dimensional Consolidation test completed on the push tube sample between 3.0-3.5m depth (Appendix D). The risk of differential settlement is low, assuming the underlying geology is consistent across the building footprint. Should foundations be subjected to uplift forces, we recommend increasing the mass of foundations or installing grouted anchors for uplift resistance. Grouted anchor recommendations are detailed in Section 6.3.5.

Table 6.9: Transmitter Building: Shallow Foundation Bearing Capacities

Material Type	Foundation Type	Depth	Geotechnical Ultimate (1)	Ultimate Limit State Design (2)	Working Load Design (3)
Engineered Fill	Strip/Pad (up to 0.5m wide)	0.3m	300 kPa (4)	150 kPa	100 kPa
	Raft Bearing Pressure	0.3m	N/A	N/A	15 kPa (4)

Notes:

1. Geotechnical ultimate (failure) bearing capacity
2. Ultimate limit state bearing capacity pressure (ULS structural loads) using $\phi g = 0.5$, NZ Building Code – B1/VM4
3. Working load (unfactored) bearing pressure using a factor of safety of 3.0
4. Assessed design values based on T+TI experience.

6.3.2.2 Pile foundations

An alternative foundation type for the Transmitter Building would be to use piles. Pile design parameters are presented in Table 6.10.

Table 6.10: Transmitter Building: Pile Foundation Design Parameters

Material Type	Parameter	Geotechnical Ultimate (1)	Ultimate Limit State Design (2)	Working Load Design (3)
Coral limestone (BH5: 3.8-6.5 depth)	Skin Friction	400 kPa	265 kPa	200 kPa
Coral limestone (BH5: 3.8-6.5 depth)	End Bearing	4 MPa	2 MPa	1.3 MPa

Suitable pile foundation types include:

- Driven steel tube piles;
  - This pile type comprises a steel tube driven to refusal, likely within the underlying coral limestone layer;
  - This pile type is driven using an excavator mounted hydraulic impact hammer;
  - The hydraulic impact hammer would need to be shipped to Tonga for the project;
  - The design would need to consider corrosion of the steel tube piles.
- Screw piles (www.piletech.co.nz);
  - This pile type comprises a steel shaft with a steel helix welded at the base of the shaft;
  - Screw piles would be screwed into the coral limestone layer;
  - This pile type is installed using an excavator mounted torque head;
  - Screw pile foundations are generally contractor designed;
  - Screw piles can be prefabricated and shipped to site, along with the torque head to install the piles;
  - Screw piles can be designed to resist lateral foundation loads, yet have less lateral capacity than bored cast in-situ piles;
  - The design would need to consider corrosion of the screw piles.
- Bored cast in-situ concrete piles;
  - Bored piles would be socketed into the underlying coral limestone layer;
  - This pile type is installed with a specialist bored piling rig;
  - The bored piling rig would likely be shipped from New Zealand;
  - Holes would need to be cased to remove the risk of shaft wall collapse, due to the sites shallow ground water table and non-engineered fill;
  - Bored cast in-situ piles can be designed to resist lateral foundation loads.

6.3.3 MW Mast Foundations (Pop_BH1)

6.3.3.1 Mass concrete foundations

We consider mass concrete foundations would be suitable for the proposed MW Mast, with foundations bearing on medium dense gravel present at 2.6m depth. This foundation option would require the excavation of topsoil, non-engineered fill and buried topsoil present to 2.6m depth. The ground water table was encountered at approximately 1m depth.

Dewatering of the foundation excavation is not considered practical or economical; instead we recommend mass concrete foundations be poured below the water table using a tremie pipe. The tremie pipe will allow for concrete to displace ground water without washing out the cement content of the concrete. Bearing capacities for mass concrete foundations are presented in Table 6.11.

Temporary foundation excavations walls should be no steeper than 1(V):2(H). Alternatively, the foundation excavation may be shored with driven sheet piles founded into the underlying medium dense gravel.

It will be essential to check and confirm settlement with appropriate geotechnical calculations.

Should foundations be subjected to uplift forces, we recommend increasing the mass of foundations or installing grouted anchors for uplift resistance. Grouted anchor recommendations are detailed in Section 6.3.5.

Table 6.11: MW Mast: Shallow Foundation Bearing Capacities

Material Type	Assessment Method	Geotechnical Ultimate (1)	Ultimate Limit State Design (2)	Working Load Design (3)
Gravel (BH1: >2.6m depth)	Meyerhof 1963 (4)	2280 kPa	1140 kPa	760 kPa
	Bowles – Fig 4-7 Settlement limited to 25mm (5)	1000 kPa	500 kPa	330 kPa

Notes:

1. Geotechnical ultimate (failure) bearing capacity
2. Ultimate limit state bearing capacity pressure (ULS structural loads) using $\phi g = 0.5$, NZ Building Code – B1/VM4
3. Working load (unfactored) bearing pressure using a factor of safety of 3.0
4. Geotechnical parameters:
    - $c = 0$
    - $\phi = 35°$
    - $\gamma = 18 kN/m^3$
    - $\gamma' = 8 kN/m^3$
    - $D = 2.6m$
    - $d_w = 1.0m$
    - $B = 1.5m$
    - $L = 1.5m$
    - Vertical settlement not limited
5. Joseph E. Bowles, Foundation Analysis and Design, 4th Edition – Figure 4-7 (Appendix E)
    a. SPT Value $N = 21$ at $3m$ depth
    b. Vertical settlement limited to $25mm$

6.3.3.2 Piled Foundation

An alternative foundation type would be to use piles. Pile design parameters are presented in Table 6.12. MW Mast foundation loads were not provided at the time of writing this report.

Table 6.12: MW Mast: Deep Foundation Design Parameters

Material Type	Parameter	Geotechnical Ultimate	Ultimate Limit State Design	Working Load Design
Limestone gravel and sand (BH1: 2.6-11m depth)	End-bearing	2 MPa	1.3 MPa	1 MPa
	Skin friction	50 kPa	33 kPa	25 kPa
Coral Limestone (BH1: >11m depth)	End-bearing	7 MPa	3.5 MPa	2.3 MPa
	Skin friction	400 kPa	265 kPa`	200 kPa

6.3.4 MW Mast Guy Wires (Pop_BH2-BH4)

6.3.4.1 Shallow Foundations

We do not consider shallow foundations would be appropriate for the guy wires supporting the proposed MW Mast due to the presence of non-engineered fill and buried topsoil to a maximum depth of 3.7m, and the ground water table present between 0.9m and 1.2m depth.

We recommend guy wires tension loads be resisted grouted anchors (detailed in Section 6.3.5) or screw piles.

6.3.4.2 Screw Piles

Screw piles are suitable for resisting uplift loads. We recommend screw piles be founded below 4.0m depth within medium dense to dense gravel. Uplift helix plate bearing capacities for screw piles are presented in Table 6.13. The design of screw piles is generally completed by the screw pile contractor.

Table 6.13: Grouted Anchor Design Parameters

Material Type	Parameter	Geotechnical Ultimate	Ultimate Limit State Design	Working Load Design
Limestone gravel and sand (BH2-BH4: >4m depth)	Uplift helix plate bearing capacity	2 MPa	1.3 MPa	1 MPa

6.3.5 Grouted anchors

Should grouted anchors be required to resist uplift loads, we recommend the anchors be embedded into the underlying coral limestone, rather than relying on coral gravel for anchor capacity. Skin friction design capacities for grouted anchors at each borehole location are presented in Table 6.14.

We expect a single bar type anchor (i.e. http://www.reids.co.nz/reidbar-threaded-reinforcing-system/) would be a suitable option. There is a high risk of excessive grout loss where anchors intersect voids within the coral limestone layers. We recommend the use of grout socks (Grout Grippa or similar) to reduce the volume of grout loss.

Table 6.14: Grouted Anchor Design Parameters

Material Type	Depth to Founding Layer	Skin Friction Capacity		
		Geotechnical Ultimate	Ultimate Limit State Design	Working Load Design
Coral limestone	HQ BH1: >7.2m HQ BH2: >8m Pop BH1: >11m Pop BH2: >10.9m Pop BH3: >10m Pop BH4: >11m Pop BH5: 3.8-6.5m Pop BH5: >11.6m	400 kPa	265 kPa	200 kPa

7 Construction Considerations

Driven Steel Tube Piles

We are not aware of any local contractor in the Kingdom of Tonga who have an excavator mounted impact hammer for pile driving. A New Zealand piling contractor would likely be required to supply the impact hammer. The impact hammer may be transported via air-freight to the Kingdom of Tonga. A local excavator may be used for the installation of piles.

Screw Piles

There are no screw piling contractors operating in the Kingdom of Tonga. This foundation option would require a New Zealand piling contractor to pre-fabricate screw piles in New Zealand, likely Piletech. The torque head used to install piles and the pre-fabricated screw piles would be shipped to the Kingdom of Tonga. A local excavator may be used for the installation of screw piles.

Bored Piles

There are no bored piling contractors available in the Kingdom of Tonga. Should bored piles be chosen, a New Zealand piling contractor would likely need to ship a bored piling rig to the Kingdom of Tonga. This option would likely be more expensive than driven steel tube piles and screw piles.

Grouted Anchors

There are also no grouted anchor contractors available in the Kingdom of Tonga. Should grouted anchors be chosen, a New Zealand contractor would likely be able to air-freight a grouted anchor rig to the Kingdom of Tonga. We consider this option to be of greater practicality than shipping a bored piling rig from New Zealand to the Kingdom of Tonga.

8 Geotechnical Risks

Geotechnical risks associated with the proposed structures are outlined in Table 8.1.

Table 8.1: Geotechnical Risks

Risk	Likelihood of risk	Consequence	Recommendations
Shallow ground water requiring foundations to be constructed beneath the ground water table.	Very high	• The walls of shallow foundation excavations may collapse below water table. • Concrete foundations will be additional consideration when pouring concrete below the water table.	• Shallow foundation excavations can be battered back to a stable angle. • The pouring of concrete foundations may be completed using a tremie pipe.
Consolidation of the buried topsoil layer beneath the transmitter building.	Moderate	• Potential settlement damage to the transmitter building.	• Shallow foundations should be lightly loaded; or • The Transmitter building may be supported on a piled foundation if loads exceed the bearing capacities for shallow foundations.
Buried historical foundations within building footprint.	Low to Moderate	• Buried foundations may cause differential displacement of new foundations.	• Excavate and replace buried foundations with engineered fill.

9 Applicability

This report has been prepared for the exclusive use of our client Yachiyo Engineering Co., Ltd., with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor International Ltd

Report prepared by:	Authorised for Tonkin & Taylor International Ltd by:
.....	.....
Richard Bond + John Martin	Chris Freer
Eng Geologist + Geotech Engineer	Project Director

JOMA
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Appendix A: Contract of Soils Explorations

- **Contract of Soils Survey Work**
- **Amendment of Contract**

AMENDMENT OF CONTRACT

BETWEEN

YACHIYO ENGINEERING CO., LTD

AND

Tonkin and Tylor International Limited

REGARDING

SOIL SURVEY WORK

FOR

PREPARATORY SURVEY

ON

THE PROJECT FOR NATIONWIDE EARLY WARNING DISSEMINATION AND STRENGTHENING DISASTER COMMUNICATIONS IN THE KINGDOM OF TONGA

August 2017

THIS AMENDMENT OF CONTRACT (hereinafter referred to as "the Amendment of Contract"), made and entered into on this 3rd day of August 2017 by and between **Yachiyo Engineering Co., Ltd.** (hereinafter referred to as "YEC") and **Tonkin and Taylor International Limited** (hereinafter referred to as "the Contractor") as the amendment of the original contract regarding Soil Survey Work for the Project for Nationwide Early Warning Dissemination and Strengthening Disaster Communications in the Kingdom of Tonga, made on the 13th day of July 2017 (hereinafter referred to as "the Original Contract"),

WITNESSETH

WHEREAS, this amendment is made in accordance with "Clause 18: CHANGES IN WORKING PROGRAM" of the original Contract between YEC and the Contractor, on the 15th day of March regarding the Topographic Survey for the Project for Nationwide Early Warning Dissemination and Strengthening Disaster Communications in the Kingdom of Tonga;
NOW THEREFORE, the parties hereto hereby agree as follows:

1. "Clause 9 : TIME FOR COMMENCEMENT AND COMPLETION" in the original Contract shall be amended as follows;

The words "The Contractor shall complete the Work and submit a Draft copy of the report by the 25th day of August 2017." and "The Contractor shall complete and submit the final report to YEC by the 7th day of September 2017" shall be deleted and "The Contractor shall complete the Work and submit a Draft copy of the report by the 31st day of August 2017." And "The Contractor shall complete and submit the final report to YEC by the 30th day of September 2017" shall be substituted in lieu thereof.

2. "Clause 10 : CONTRACT AMOUNT" in the original Contract shall be amended as follows;

The words "The Contract amount shall be **US$ 79,750**" shall be deleted and "The Contract amount shall be US**$ 132,150**" shall be substituted in lieu thereof.

3. "Clause 11 : METHOD OF PAYMENT (a)Advance payment" in the original Contract shall be amended as follows;

The words "YEC shall pay an advance payment of thirty (30 %) percent of the Contract amount to the Contractor upon signing of the Contract." shall be deleted and "YEC shall pay an advance payment of thirty (30 %) percent of the Original Contract amount to the Contractor upon signing of the Contract." shall be substituted in lieu thereof.

4. "Annex 1 TECHNICAL SPECIFICATIONS FOR SURVEY WORK" in the original

Contract shall be amended as follows;

The table

"**TBC HQ Bldg site and TBC MW TX site**

Item	Description	Unit	Q'ty
1-1	Transportation included airfares and mobilization of equipment, arrangement for accommodation, deputation of technical personnel and demobilization after completion of the work.	Lot.	1
1-2	Execution of boring down to a depth of 15 m from the existing ground level, recording of soil stratification and ground water level. 2 boreholes at TBC HQ Bldg site and 1 boreholes at TBC MW TX site (Totally 3 boreholes)	m	45
1-3	Execution of Standard Penetration Test at a regular interval of 1.0 m and collection of disturbed soil samples and their preservation in airtight state. 3 samples per borehole	Lot	45
1-4	Collection of undisturbed soil samples by Denison core sampler from cohesive soil layer & their preservation by sealing with wax. 3 samples at 3 boring sites.	Lot	3
1-5	Pressuremeter test in boreholes	Lot	3
1-6	Execution of Dynamic Cone Penetration Test or Scala Penetrometer Test to the depth of 3 m from the existing ground level, recording blows of penetration.	Lot	12
1-7	Laboratory Test (2 samplings for each boring survey)		
	a) Natural moisture content	test	6
	b) Specific gravity	test	6
	c) Atterberg limit	test	6
	d) Wet & dry density	test	6
	e) Complete grain size analysis	test	6
	f) Unconfined compressive test	test	3
	g) Consolidation test	test	6
	h) Triaxial compressive strength	test	6
	i) Chloride concentration contained in groundwater	test	6
1-8	Submission of final report in three (3) copies with relevant charts and diagrams.	L.S.	1

"

shown in "6. Bill of Quantity" shall be deleted and following table shall be substituted in lieu thereof.

"

TBC HQ Bldg site and TBC MW TX site

Item	Description	Unit	Q'ty
1-1	Transportation included airfares and mobilization of equipment, arrangement for accommodation, deputation of technical personnel and demobilization after completion of the work.	Lot.	1
1-2	Execution of boring survey for building and antenna constructions down to a depth of 15 m from the existing ground level, recording of soil stratification and ground water level for building constructions. 2 boreholes at TBC HQ Bldg site and 1 boreholes for a building and 4 boreholes for antenna construction at TBC MW TX site (Totally 7 boreholes)	m	105
1-3	Execution of Standard Penetration Test at a regular interval of 1.0 m and collection of disturbed soil samples and their preservation in airtight state. 3 samples per borehole	Lot	105
1-4	Collection of undisturbed soil samples by Denison core sampler from cohesive soil layer & their preservation by sealing with wax. 3 samples at 3 boring sites.	Lot	3
1-5	Execution of Dynamic Cone Penetration Test or Scala Penetrometer Test to the depth of 3 m from the existing ground level, recording blows of penetration.	Lot	12
1-6	Laboratory Test (2 samplings for each boring survey)		
	a) Natural moisture content	test	14
	b) Specific gravity	test	14
	c) Atterberg limit	test	14
	d) Wet & dry density	test	14
	e) Complete grain size analysis	test	14
	f) Unconfined compressive test	test	7
	g) Consolidation test	test	14
	h) Triaxial compressive strength	test	14
	i) Chloride concentration contained in groundwater	test	14
1-7	Submission of final report in three (3) copies with relevant charts and diagrams.	L.S.	1

"

IN WITNESS WHEREOF, the parties hereto have caused this Amendment of Contract by the duly authorized representatives in the Kingdom of Tonga as of the dated first above written.

For and On Behalf of
The YEC

Tatsuya Kobayashi
Chief Consultant
Yachiyo Engineering Co., Ltd.
(JICA Project Team)

For and On Behalf of
The Contractor

P.P. R. Boord

Chris Freer
Director – Pacific Business
Development Manager
Tonkin + Taylor International

SOIL SURVEY WORK
ON
THE PROJECT FOR NATIONWIDE EARLY WARNING DISSEMINATION AND STRENGTHENING DISASTER COMMUNICATIONS IN THE KINGDOM OF TONGA

CONTRACT OF SOIL SURVEY

THIS CONTRACT is entered into on the **13th day of July 2017** by the **30th of September 2017** and between **Yachiyo Engineering Co., Ltd.** (hereinafter referred to as "YEC") and **Tonkin and Taylor International Limited** (hereinafter referred to as "the Contractor") duly organized and existing under the laws of Tonga and New Zealand. This Agreement shall be deemed to be entered into and governed under the substantive laws of New Zealand and Japan.

WHEREAS, YEC requested the Contractor to perform the Soil Survey Work (hereinafter referred to as "the Work") which is outlined in Annex 1.

WHEREAS, the Contractor has accepted to perform the Work in accordance with the specifications and conditions set forth in this Contract and Annex 1 hereto.

THEREFORE, based on and in consideration of the foregoing premises and of the terms and conditions hereinafter provided, both parties hereto agree as follows:

Clause 1 : WORK

The Contractor shall implement the Work as hereinafter defined under the terms and conditions of this Contract.

Clause 2 : YEC's REPRESENTATIVE

YEC shall assign a representative (hereinafter referred to as "the Representative") at the site. The Representative shall have the right to supervise, inspect and give approval for the Work.

Clause 3 : SPECIFICATIONS

The Work shall be performed in accordance with specifications in Annex 1.

Clause 4 : SITE LOCATION

The site locations are shown in Annex 2.

Clause 5 : WORK ITEMS

The Work shall cover the followings;

1) Soil survey

(a) Mobilization and Demobilization
(b) Borehole Drilling Survey
(c) Standard Penetration Test
(d) Collection of Undisturbed Soil Samples
(e) Pressuremeter Test in Boreholes
(f) Dynamic Cone Penetration Test (or Scala Penetrometer Test)
(g) Collection of Undisturbed Soil Samples
(h) Laboratory Soil Test
    1) Natural moisture content
    2) Specific gravity
    3) Atterberg limit
    4) Wet & dry density
    5) Complete grain size analysis
    6) Unconfined compressive test
    7) Consolidation test
    8) Triaxial compressive strength
    9) Chloride concentration contained in groundwater

The contents and quantities of the work is specified in the attached TECHNICAL SPECIFICATION.

Clause 6: PREPARATION FOR THE WORK

The Contractor shall prepare all necessary highly-skilled personnel and all required materials, facilities and equipment for the performance of the Work at the site and an office. The Representative shall have the right to check and review such materials, facilities and equipment at any time during the execution of the Work.

Clause 7: REPORTING

The Contractor shall submit a written daily report of the Work in English to YEC.

Clause 8: INSPECTIONS OF RESULTS

The Contractor shall request YEC for an inspection of results immediately at the completion of each item of the Work. If the results of the Work are not accepted by YEC, the Contractor shall redeem those works as soon as possible for the satisfaction of YEC and once more submit the results to YEC for inspection.

Clause 9 : TIME FOR COMMENCEMENT AND COMPLETION

The Contractor shall commence the Work at the site between the **25th day of July, 2017 to** the **31st day of July, 2017.** . The Contractor shall complete the Work and submit a Draft copy of the report by the **25th day of August 2017**. The Contractor shall submit the Draft of the final report for the approval by YEC. If the submitted the draft of the report is not accepted by YEC, the Contractor shall redeem the draft as soon as possible for the satisfaction of YEC. The Contractor shall complete and submit the final report to YEC by the **7th day of September 2017**.

Clause 10 : CONTRACT AMOUNT

The Contract amount shall be **US $ 79,750**

Clause 11 : METHOD OF PAYMENT

(a) Advance payment
YEC shall pay 30 % of the above Contract Amount as an advance payment to the Contractor upon signing the Contract.

(b) Final payment
Payments of the remaining balance of the contract amount shall be made by YEC within ten (10) days after the Contractor's invoice is received by YEC, which is submitted by the Contractors based on the agreements of the both sides. The payment for services provided under this Contract shall be subject to the approval of YEC. If YEC finds any disputed items in the final report, YEC shall notify the items to the Contractor in writing within five (5) working days from the date that the final report is received by YEC. Accordingly, the Contractor shall redeem the Work for the satisfaction of YEC.

Clause 12 : PENALTY

In the case of the delayed completion of the Work, the Contractor is obliged to pay to YEC a contractual penalty of 1 % of the overall Contract payment for each day of the delay from the period as set forth in Clause 9; however, at most 10 % of the payment. The penalty amount shall be deducted from the final payment to be made to the Contractor.

In the case of the delayed payment, YEC is obliged to pay to the Contractor a contractual penalty of 1 % of the overall Contract payment for each day of the delay from the period as set forth in Clause 9; however, at most 10 % of the payment.

This penalty amount shall be added to the final payment.

Clause 13 : FORCE MAJEURE

The Contractor shall not be responsible for any delay caused by Force Majeure such as change in laws and regulations of Tonga, strikes and sabotage, natural disasters, declared or undeclared war, blockades, revolutions, and natural calamities and severe weather conditions (e.g. cyclone) beyond the control of the Contractor. If it appears that such Force Majeure continues to the end of the Contract period mentioned in Clause 9, YEC shall have the right to terminate this contract (at any time) by giving the Contractor one (1) week written notice.

Clause 14: LIABILITY

YEC shall be exempted from or kept harmless against any reasonably foreseeable damage, loss and/or accident incurred by or arising from any negligent act or omission of the Contractor during the period of the Work.

Notwithstanding anything else contained in the Agreement, the Contractor's liability under or arising from the Agreement or in tort (including negligence) or under statute arising from acts or omissions by the Contractor shall be five times of the Contract Amount with a maximum limit of $500,000 US. Dollars.

The Contractor shall not be liable to YEC under this Agreement for YEC's indirect, consequential or special loss, or loss of profit, however arising, whether under contract, in tort or otherwise.

Clause 15 : TERMINATION OF CONTRACT

YEC has the right to terminate the Contract by giving one (1) week, written notice to the Contractor, in any following cases;

(a) Due to causes attributable to the Contractor, if YEC judges that the completion of the Work cannot be expected within the time set forth in Clause 9, and in accordance with the detailed time schedule submitted by the Contractor and approved by YEC.

(b) If the Work is not fully performed by the Contractor in accordance with the Contract and the specifications without (at YEC's discretion) justified reasons.

(c) If the Contractor does not commence the Work or if the Contractor suspends the Work for a certain period without (at YEC's discretion) justified reasons after the effective date of this Contract.

(d) If the Contractor violates any provision of this Contract and does not rectify it within ten (10) days after the Contractor has received notice of breach of contract from YEC.

Clause 16 : ASSIGNMENT AND/OR SUBCONTRACT

1. The Contractor shall perform the Services hereunder as an independent contractor and not as an agent or employee of YEC.

2. Is understood and agreed that the Contractor may engage as parts of its professional team, the services of a third party/company to carryout parts of this contract. YEC shall not be liable to pay any sub-contractor or third party/company utilized by the Contractor to carry out any work under this contract.

Clause 17 : EFFECTIVE DATE OF THIS CONTRACT

This Contract shall become effective on the date first above written.

Clause 18 : CHANGES IN WORKING PROGRAM

YEC has the right to change the contents of the Work, if modifications are necessary. In case of such changes, the completion time of the Work and the amount of the Contract payment shall be modified by mutual agreement in writing from both parties hereto. However, if an extension of the Contract period or an increase in the Contract payment is required due to reasons attributable to the improper execution of the work by the Contractor, request of the payment by the Contractor shall not be approved by YEC.

If the YEC orders additional works to the Contractors, the Contractor shall not refuse to carry out the additional work without satisfactory reasons and an additional fee shall be paid to the Contractor by YEC.

Clause 19 : DOUBTS OR UNSPECIFIED ITEMS

Any doubts in connection with this Contract or anything not specified in this Contract shall be determined amicably by mutual agreement between the both parties.

Clause 20 : MAINTENANCE OF SECRECY

Without obtaining YEC's prior written approval, the Contractor shall not disclose, not only during the effective period of this Contract but also after the termination or completion of the Contract, any information, data, drawings, maps and/or etc., which has been made known to the Contractor in executing the Work.

Clause 21 : EVALUATION OF ADDITIONAL AND OMITTED WORK

All work added or omitted under the instructions of YEC shall be evaluated at rates and prices set out in this Contract. If no applicable rates or prices are set out in this Contract, then suitable rates or prices shall be agreed upon between YEC and the Contractor.

Clause 22: DISPUTE AND RESOLUTION

Any disputes arising under this contract between YEC and the Contractor shall be settled by mediation.

IN WITNESS WHEREOF; the parties hereto have executed this Contract by there duly authorized representatives as of the date first above written.

For and On Behalf of
The YEC

Date: 13th July 2017

Tatsuya Kobayashi
Chief Consultant
Yachiyo Engineering Co., Ltd.
(JICA Project Team)

For and On Behalf of
The Contractor

Date 9/8/17

P.P R. Boord

Chris Freer
Director – Pacific Business
Development Manager
Tonkin + Taylor International

Soil Survey

1. **2 sites for construction of new building at the Tongatapu island**

TBC HQ Building site and TBC MW TX site

Item	Description	Unit	Qty	Rate	Costs ($USD)
1.1	Transportation included airfares and mobilisation of equipment, arrangement for accommodation, deputation of technical personnel and demobilisation after completion of the work.	Lot	1	$25,000	$25,000
1.2	Execution of boring down to a depth of 15 m from the existing ground level, recording of soil stratification and ground water level. 2 boreholes at TBC HQ Building site and 1 borehole at TBC MW TX site.	m	45	$400	$18,000
1.3	Execution of Standard Penetration Test at a regular interval of 1.0 m and collection of disturbed soil samples and their preservation in airtight state. 15 samples per borehole.	No.	45	$100	$4,500
1.4	Collection of undisturbed soil samples by Denison core sampler	No.	3	$300	$900
1.5	Pressuremeter test in boreholes	No.	1	$3,500	$3,500
1.6	Execution of Scala penetrometer test and Handauger borehole	No.	12	$500	$6,000
1.7	Laboratory Test:				
	a) Natural moisture content	Test	6	$25	$150
	b) Specific gravity	Test	6	$210	$1,260
	c) Atterberg limit	Test	6	$235	$1,410
	d) Wet and dry density	Test	6	$185	$1,110
	e) Complete grain size analysis	Test	6	$560	$3,360
	f) Unconfined compressive test	Test	3	$150	$450
	g) Consolidation test	Test	6	$650	$3,900
	h) Triaxial compressive strength	Test	6	$325	$1,950
	i) Chloride concentration contained in groundwater	Test	6	$60	$360
1.8	Submission of final report in three (3) copies with relevant charts and diagrams.	LS	1	$7,900	$7,900
				Total	**$79,750**

TBC HQ Building site and TBC MW TX site

Item	Description	Unit	Qty	Rate	Costs
1.1	Transportation included airfares and mobilisation of equipment, arrangement for accommodation, deputation of technical personnel and demobilisation after completion of the work (NZ to Tongatapu).	Lot	1	$25,000	$25,000
1.2	Execution of boring down to a depth of 15 m from the existing ground level, recording of soil stratification and ground water level. 2 boreholes at TBC HQ Building site and 1 borehole at TBC MW TX site.	m	105	$400	$42,000
1.3	Execution of Standard Penetration Test at a regular interval of 1.0 m and collection of disturbed soil samples and their preservation in airtight state.	No.	105	$100	$10,500
1.4	Collection of undisturbed soil layer and their preservation by sealing with wax.	No.	3	$300	$4,200
1.5	Execution of Scala penetrometer test and Handauger borehole	Lot	12	$500	$10,000
1.6	**Laboratory Testing**				
	a) Moisture Content	Test	14	$25	$350
	b) Specific gravity	Test	14	$210	$2,940
	c) Atterberg limit	Test	14	$235	$3,290
	d) Wet and dry density	Test	14	$185	$2,590
	e) Complete grain size analysis	Test	14	$560	$7,840
	f) Unconfined compressive test	Test	7	$150	$1,050
	g) Consolidation test	Test	14	$650	$9,100
	h) Triaxial compressive strength (UU)	Test	14	$325	$4,550
	i) Chloride concentration contained in groundwater	Test	14	$60	$840
1.7	Submission of final report in three (3) copies with relevant charts and diagrams – Combined report for Buildings and siren masts	LS	1	$7,900	$7,900
				Total (US $$$)	**$132,150**

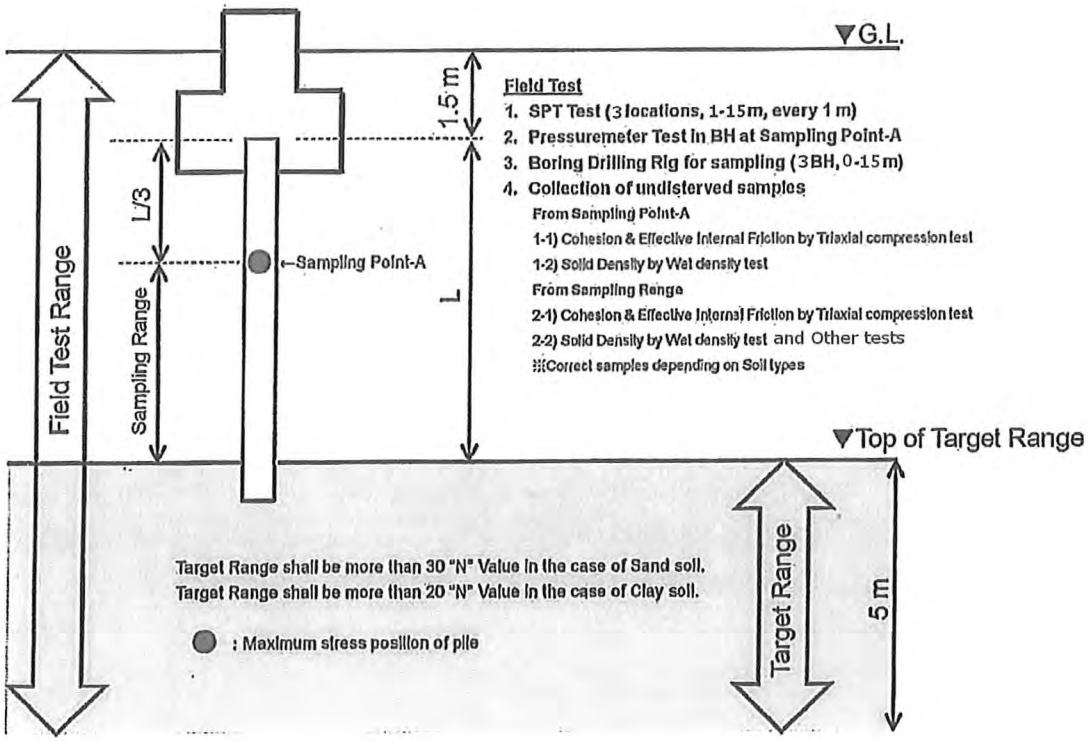
Annex A
TECHNICAL SPECIFICATION
FOR
SOIL INVESTIGATION AT BUILDING SITES
The Project for Nationwide Early Warning Dissemination and Strengthening Disaster Communications in the Kingdom of Tonga

1-1 Purpose of Survey

Boring, in-situ test (Standard Penetration Test), sampling, soil test and Dynamic Cone Penetration Test are carried out with the purpose of identifying of the strata, bearing strength and soil characteristics at the proposed construction sites in the Kingdom of Tonga which will be used as basic data for designs of building foundations.

1-2 Survey Areas

Field survey shall be carried out at the site, which is shown in the attached map (Annex-B). Field tests to be conducted are shown in the bellow drawing:



1-3 Borehole Drilling operation

(1) Preparation

Prior to the execution of drilling, the Contractor shall survey the boring drilling points and their heights above mean sea level.

(2) Groundwater level measurement

The Contractor shall measure the groundwater level in the each borehole.

(3) Completion of drilling

Upon completion of the boring work, the Contractor shall measure the exact perforation depth.

(4) Daily progress report

The Contractor shall provide daily progress reports containing the results of the standard penetration tests, conditions of samples, penetration speed, and any problems or observations encountered.

(5) Transport of machinery and samples

The Contractor shall be responsible for the safe transport of his drilling equipment to and from the soil investigation site. The Contractor shall also be careful in the transport of soil samples to avoid excessive vibrations or changes in volume and composition.

(6) Scaffold

The Contractor shall maintain a scaffold and other safety measures to ensure sufficient working space and safety of his personnel.

1-4 Standard Penetration Test

Standard Penetration Test shall be done at TBC HQ Bldg site and TBC MW TX site during borehole drilling operation. Detail methods for Standard Penetration Test are followings.

(1) The works shall be applied BS-5930:1999 "The Code of Practice for Site Investigations" or equivalent international standard.

(2) The works shall be carried out at the planned boring locations and the specification prepared by the Representative of YEC.

(3) Rotary Boring with circulation of water shall be performed with diameter not less than 66 mm.

(4) The drilling depth shall be 15 m, however in case sufficient bearing stratum is not found up to there, the drilling shall be continued to encounter the sufficient bearing stratum (by 5m continuous length). The cohesive soil layer which has more than 20 and the sand layer which has more than 30 in N-value are assumed the sufficient bearing stratum.

When drilling length does not amount to 15 m, and when the length exceeding a depth of 15m, payment is balanced at the time of the final payment based on actual drilling length,

(5) The diameter for the borehole drilling shall be set with 66mm or larger, and the diameter for undisturbed soil samples shall be set by 116mm or larger.

1-5 Pressuremeter Test

Pressure meter test shall be conducted during the drilling operation by loading effective vertical loading pressures to the borehole wall surface. The deformation coefficient, yield stress and ultimate stress of the ground are obtained from the series of the loaded pressures.

1-6 Dynamic Cone Penetration Test

Dynamic Cone Penetration Test (DCPT) or Scala Penetrometer Test shall be carried out as a supplemental soil investigation at the building sites. Detailed methods for DCPT are followings:

(1) The test shall be applied NZS 4402: 1986 Test 6.5.2 or other equivalent international standard.

(2) The test shall be carried out at the planned test locations indicated by the Representative of YEC.

(3) For the measurement, the penetrometer shall be placed with the cone tip pressed into the soil. A small circular bubble level placed on the end of the penetrometer enabled the operator to keep the shaft vertical.

(4) The slide hammer (weight 8 kg) shall be raised to a predetermined height and then released. This operation defined one 'blow' of the dynamic penetrometer and this was repeated until a penetration is reached a predetermined depth (50/100/150 mm) and the blow shall be recorded in a field note.

(5) The measurement shall be stopped when it reaches the target depth of 3 m, refusal is encountered (30 blows per 100/150 mm) or the rod of the penetrometer goes on an angle preventing the weight from falling freely (normally because of gravel).

1-7 Laboratory Test

(1) Undisturbed sample from boring shall be submitted to physical and mechanical tests;

1) Natural moisture content

2) Specific gravity

3) Plastic limit & Liquid limit
4) Wet & dry density
5) Complete grain size analysis
6) Unconfined compressive strength test
7) Triaxial compressive strength (UU) test
8) Consolidation test
9) Chloride concentration contained in groundwater

Laboratory test shall be applied BS-1377, British Standard "Methods of Test for Soils for Civil Engineering Purposes" or equivalent international standard.

1-8 Results

The Contractor shall submit to the Representative of YEC the results of the soil investigation study, in one (1) original and three (3) copies as follows;

(1) Boring logs

The boring log shall contain the following information;

- Daily drilling report
- Depth below ground level
- Elevation of soil layers and ground water table
- Graphical symbol of the soil type
- Description of the soil
- Position where soil sample was taken, whether disturbed or undisturbed
- Sample number
- Moisture content
- Number of blows
- Other as necessary

(2) Soil laboratory test results

Results of the tests shall include the numerical values and graphs derived, standards applied and formula used.

(3) Recommendation of foundation system

In accordance with results of the soil investigation study, the Contractor shall recommend in detail the type of foundation(s), which are planned to construct at the Project Site. It shall be included proposed soil parameters(c, φ, γ, C_c, c_v and P_c).

(4) Language

Document and all data shall be written in English.

1-9 Termination of the Works

(1) Field work July and August, 2017

(2) Report within 45 days after the Contract has been signed

1-10 Products

(1) One(1) Original Report

(2) Two(2) Photo copies file

(3) One(1) set of digital data(CD or USB Memory)

1-11 Required Quantities

The Contractor shall finish the works with the quantity of the next table securely within a predetermined schedule.

(1) 2 Sites for construction of new building at the Tongatapu Island

TBC HQ Bldg site and TBC MW TX site

Item	Description	Unit	Q'ty
1-1	Transportation included airfares and mobilization of equipment, arrangement for accommodation, deputation of technical personnel and demobilization after completion of the work.	Lot.	1
1-2	Execution of boring down to a depth of 15 m from the existing ground level, recording of soil stratification and ground water level. 2 boreholes at TBC HQ Bldg site and 1 boreholes at TBC MW TX site (Totally 43 boreholes)	m	45
1-3	Execution of Standard Penetration Test at a regular interval of 1.0 m and collection of disturbed soil samples and their preservation in airtight state. 3 samples per borehole	Lot	45
1-4	Collection of undisturbed soil samples by Denison core sampler from cohesive soil layer & their preservation by sealing with wax. 3 samples at 3 boring sites.	Lot	3
1-5	Pressuremeter test in boreholes	Lot	3
1-6	Execution of Dynamic Cone Penetration Test or Scala Penetrometer Test to the depth of 3 m from the existing ground level, recording blows of penetration.	Lot	12
1-7	Laboratory Test (2 samplings for each boring survey)		
	a) Natural moisture content	test	6
	b) Specific gravity	test	6
	c) Atterberg limit	test	6
	d) Wet & dry density	test	6
	e) Complete grain size analysis	test	6
	f) Unconfined compressive test	test	3
	g) Consolidation test	test	6
	h) Triaxial compressive strength	test	6
	i) Chloride concentration contained in groundwater	test	6
1-8	Submission of final report in three (3) copies with relevant charts and diagrams.	L.S.	1

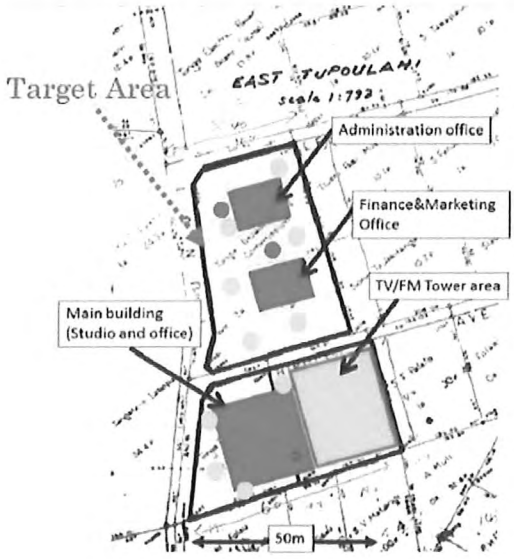
ANNEX-B
Building sites in TBC HQ and TBC MW TX,

TBC HQ Bldg site
21° 8'24.15"S
175°11'32.75"W

TBC MW TX site
21° 8'37.21"S
175° 9'47.59"W

Taget area

Existing transmitter huts



TBC HQ Bldg site

Existing MW mast

Dynamic cone penetration Test	12
Plate load test	3

Appendix B: Site Plans and Cross Sections

- **Site plans**
    - **TBC HQ site**
    - **TBC MW TX site**
- **Cross sections**
    - **TBC HQ site**
    - **TBC MW TX site**

NOTES :
1. All dimensions are in millimetres unless noted otherwise.
2. Baseplan supplied by Yachiyo Engineering Co Ltd, reference file name "A.01.1 Site Services Layout.dwg" dated Aug 2017.
3. Existing contour supplied by Yachiyo Engineering Co Ltd, reference file name "TBC TOPO_01.dwg" dated Aug 2017.

LEGEND

- Existing contour (0.25m interval)
- Existing contour (0.05m interval)
- Main Electricity Line (Overhead)
- Main Water Line
- HQ_BH1 — Tonkin + Taylor International Borehole Location (Aug 2017)
- HQ_SC1 — Tonkin + Taylor International Scala Location (Aug 2017)

A3 SCALE 1:500
0 5 10 15 20 25 (m)
ORIGINAL IN COLOUR

DRAWN	JC	Aug.17
DRAFTING CHECKED		
APPROVED		
CADFILE	\\1001314–HQ–F1.dwg	

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GEOTECHNICAL INVESTIGATIONS

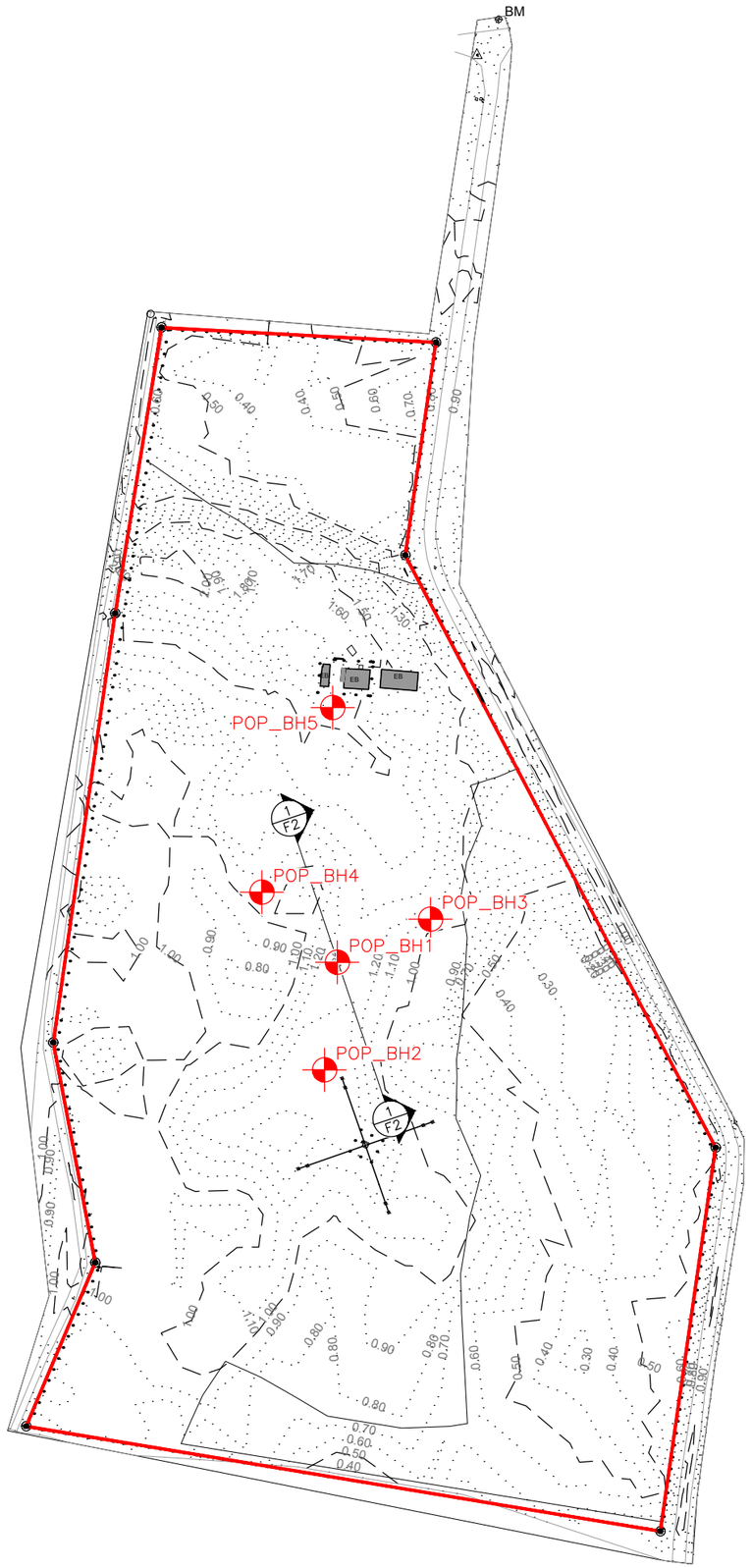
TBC HQ BUILDING SITE TUNGI ROAD

Site Plan

SCALES (AT A3 SIZE) 1:500
PROJECT No. 1001314
FIG. No. Figure 1
REV. 0

A-12-60

A-12-61



N

NOTES :
1. All dimensions are in millimetres unless noted otherwise.
2. Basepla and existing contour supplied by Yachiyo Engineering Co Ltd, reference file name "A.04 Site Contour Layout.dwg" dated Aug 2017.

LEGEND

- Site Extent
- 1.00 Existing contour (0.25m interval)
- Existing contour (0.05m interval)
- POP_BH1 Tonkin + Taylor International Borehole Location (Aug 2017)

A3 SCALE 1:2500
0 50 100 150 (m)
ORIGINAL IN COLOUR

DRAWN	JC	Aug.17
DRAFTING CHECKED		
APPROVED		
CADFILE	\\1001314-POP-F2.dwg	

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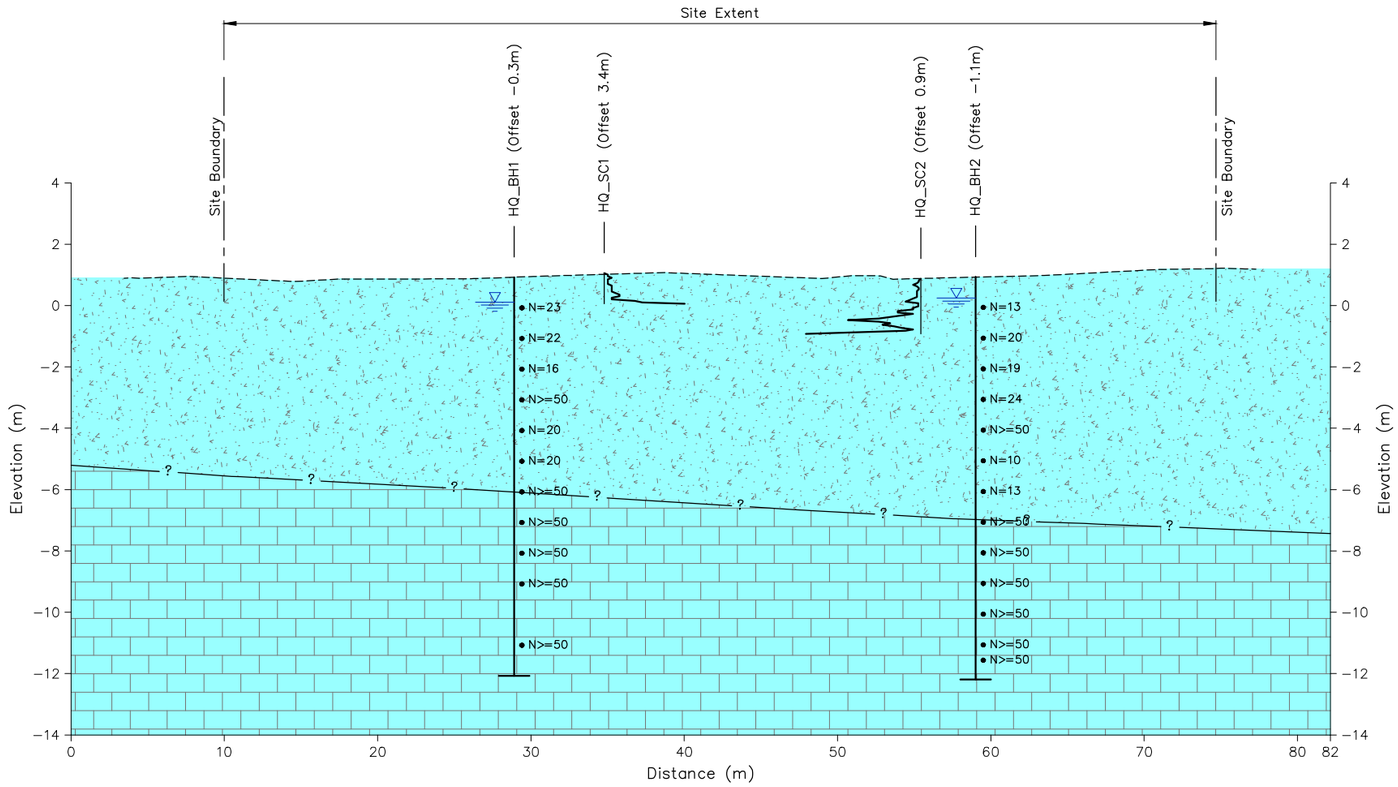
TBC MW TX SITE
POPUA, NUKU'ALOFA, TONGA

Site Plan

SCALES (AT A3 SIZE)	1:2500
PROJECT No.	1001314
FIG. No.	Figure 2
REV.	0

A-12-62



SECTION 1 / F2
SCALE 1:400(H)
1:200(V)

LEGEND

- Existing Ground Profile
- ? Inferred Geological Boundary
- Gravel and Sand – Raised Coral Reef (Pliestocene/Pliocene)
- Limestone – Raised Coral Reef (Pliestocene/Pliocene) SPT N–Value >50
- N>=50 Borehole Location with SPT N–Values
- Static water level
- Scala Penetration Test Location with trace

A3 SCALE 1:400 (H)
0 4 8 12 16 20 (m)

A3 SCALE 1:200 (V)
0 2 4 6 8 10 (m)

ORIGINAL IN COLOUR

NOTES :
1. All dimensions are in metres unless noted otherwise.
2. Existing contour profile based on darwing supplied by Yachiyo Engineering Co Ltd, reference file name "TBC TOPO_01.dwg" dated Aug 2017.
3. Variability in actual geological boundaries between investigation locations may exist.

DRAWN	JC	Aug.17
DRAFTING CHECKED		
APPROVED		
CADFILE	\\1001314–HQ–F3.dwg	

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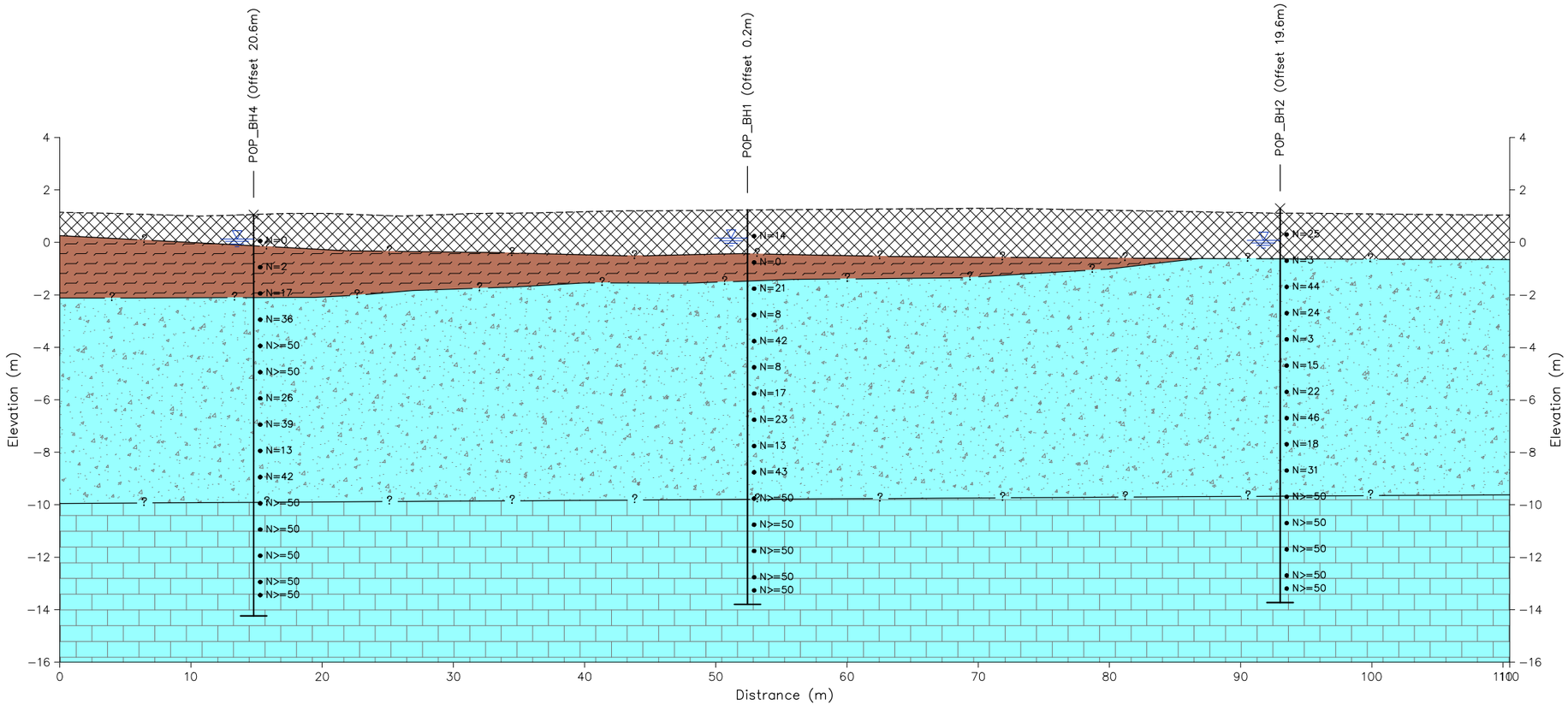
GEOTECHNICAL INVESTIGATIONS

TBC HQ BUILDING STE TUNGI ROAD

Geological Cross Section 1

SCALES (AT A3 SIZE): AS SHOWN
PROJECT No.: 1001314
FIG. No.: Figure 3
REV.: 0

A-12-63



SECTION 1/F2
SCALE 1:400(H)
1:200(V)

LEGEND

- Existing Ground Profile
- Inferred Geological Boundary
- Non-engineered fill
- Buried Topsoil
- Gravel and Sand – Raised Coral Reef (Pliestocene/Pliocene)
- Limestone – Raised Coral Reef (Pliestocene/Pliocene) SPT N-Value >50
- N>=50 Borehole Location with SPT N-Values
- Static water level

A3 SCALE 1:400 (H)
0 4 8 12 16 20 (m)

A3 SCALE 1:200 (V)
0 2 4 6 8 10 (m)

ORIGINAL IN COLOUR

NOTES :
1. All dimensions are in metres unless noted otherwise.
2. Existing contour profile based on darwing supplied by Yachiyo Engineering Co Ltd, reference file name "TA.04 Site Contour Layout.dwg" dated Aug 2017.
3. Variability in actual geological boundaries between investigation locations may exist.

DRAWN	JC	Aug.17
DRAFTING CHECKED		
APPROVED		
CADFILE	\\1001314-POP-F4.dwg	

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GEOTECHNICAL INVESTIGATIONS

TBC MW TX SITE
POPUA, NUKU'ALOFA, TONGA

Geological Cross Section 1

SCALES (AT A3 SIZE)
AS SHOWN

PROJECT No.
1001314

FIG. No.
Figure 4

REV.
0

Appendix C: Soils Exploration Logs

- **Machine drilled boreholes**
    - **HQ_BH1-BH2**
    - **Pop_BH1-BH5**
- **Core photographs**
    - **HQ_BH1-BH2**
    - **Pop_BH1-BH5**
- **Scala penetrometer tests**
    - **HQ_SC1-SC4**

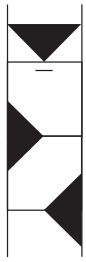
Tonkin+Taylor

Engineering log terminology

General

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

Water



Core recovery

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

Drilling method/casing

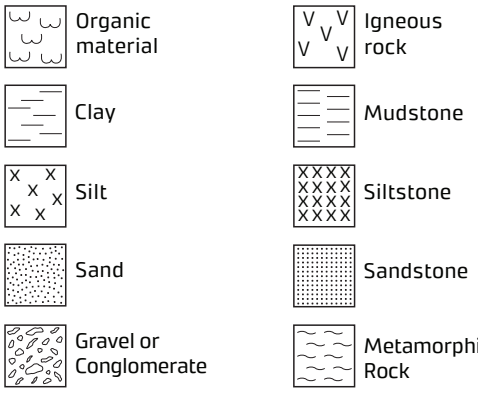
Common types:

OB	Open barrel
W	Wash
HQ3	HQ triple tube
PQ3	PQ triple tube
HSA	Hollow Stem Auger
WS	Window Sampler
HA	Hand Auger
HFS	High Frequency Sonic Drilling
LFS	Low Frequency Sonic Drilling

Graphic logs

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

Typical material symbols:



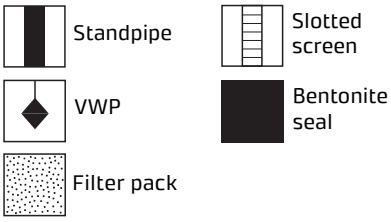
Tests

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

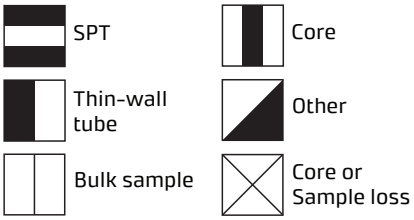
Laboratory test(s) carried out:

PMT	Pressuremeter test
LT	Lugeon test
LV	Laboratory vane
AL	Atterburg limits
UU	Undrained triaxial
PSD	Particle size distribution
c' Ø'	Effective stress
CONS	Consolidation
DS	Direct shear
COMP	Compaction
UCS	Unconfined compression
IS_{50}	Point load

Installation type



Sample type



Soil description

Moisture content

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

Consistency/undrained shear strength

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

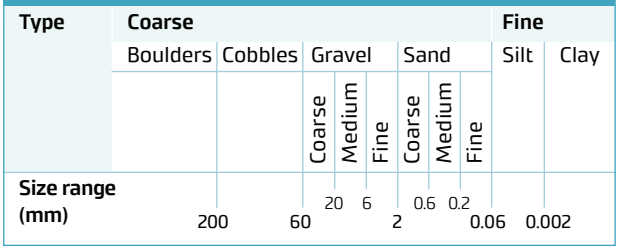
Density index

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

Proportional terms definition (Coarse soils)

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

Grain size criteria



BOREHOLE LOG

Tonkin+Taylor

BOREHOLE No.: HQ_BH1

SHEET: 1 OF 2

PROJECT: Tonga Comms Masts
JOB No.: 1001314.00
LOCATION: TBC HQ, Nuku'alofa, Tonga

CO-ORDINATES: -175.192319 -21.140186 (WGS84)
DIRECTION:
ANGLE FROM HORIZ.: -90°

R.L. GROUND: 1.00m
R.L. COLLAR:
DATUM:
SURVEY: Handheld GPS

DRILLED BY: Mark and Slade
LOGGED BY: RLXB
CHECKED: CWM
START DATE: 01/08/2017
FINISH DATE: 02/08/2017
CONTRACTOR: Geotech Drilling

GEOLOGICAL UNIT	DESCRIPTION OF CORE (SOIL: Classification, colour, consistency / density, moisture, plasticity; ROCK: Weathering, colour, fabric, name, strength, cementation)	Rock Weathering	Rock Strength	Sampling Method	Core Recovery (%)	Testing	RL (m) / Depth (m)	Graphic Log	ROCK DEFECTS: Defect Log	Fracture Spacing (mm)	RQD (%)	Description & Additional Observations	Fluid Loss (%)	Water Level	Casing	Installation	Core Box No
Topsoil	0.0 m - Organic sandy SILT with trace gravel; dark blackish brown. Stiff, moist, non plastic. Organics: decomposing plant material. Sand: medium to coarse coral. Gravel: medium coral.			HQTT	100			TS									
Limestone gravel and sand (Raised Coral Reef)	0.3 m - Medium SAND with trace gravel; grades light yellowish brown. Medium dense, moist, uniformly graded. Sand: subangular coral. Gravel: fine to medium, subangular coral.			SPT	77	4/6 4/6 6/7 **N=23**	1							10/08/2017			
	No recovery.																
	1.15 m - Fine to coarse GRAVEL; light brownish white. Medium dense, moist, well graded. Gravel: subangular coral.			HQTT	100												
	No recovery.			SPT	55	6/7 8/6 5/3 **N=22**	2										
	2.0 m - Medium to coarse GRAVEL; light brownish white with dark orange. Medium dense, saturated, uniformly graded. Gravel: subangular coral. Dark orange Fe staining.			HQTT	100												
				SPT	100	5/9 6/4 4/2 **N=16**	3										Box 1, 0.0-3.8m
	No recovery.			HQTT	72												
	3.6 m - Fine GRAVEL; light yellowish white. Medium dense, saturated, uniformly graded.																
	4.0 m - Fine to coarse GRAVEL; light yellowish brown. Very dense, saturated, well graded.			SPT	100	8/6 33/17 for 75mm **N>=50**	4										
				HQTT	78												
	No recovery.			SPT	55	8/9 9/5 3/3 **N=20**	5										
	5.15 m - Gravelly coarse SAND; light yellowish white. Medium dense, saturated, uniformly graded. Sand: sub-angular coral. Gravel: medium subangular coral.			HQTT	63												
	No recovery.																
	5.65 m - Gravelly coarse SAND; light yellowish white. Medium dense, saturated, uniformly graded. Sand: sub-angular coral. Gravel: medium subangular coral.			SPT	100	2/3 1/3 8/8 **N=20**	6										
	6.45 m - Fine to coarse GRAVEL; light yellowish white. Medium dense, saturated, well graded. Gravel: subangular coral.			HQTT	100												
	No recovery.			SPT	37	3/4 21/15 15 for 20mm **N>=50**	7										
Limestone (Raised Coral Reef)	7.2 m - Moderately weathered, light yellowish white with dark orange LIMESTONE (Coral). Weak to moderately strong (Recovered as: Coarse GRAVEL). Dark orange Fe staining on fracture surfaces. *8.00m:* Increasingly intact core.	MW	MS	HQTT	100						0	7.20 - 8.27m: BZ, recovered as angular medium to coarse gravel. Fe staining within voids or solution cavities and fractures.					
						50 for 72mm **N>=50**	8										
	No recovery.			HQTT	37						0						
	9.0 m - Slightly weathered, light yellowish white with dark orange LIMESTONE (Coral). Weak to moderately strong (recovered as: Coarse GRAVEL). Dark orange Fe staining on fracture surfaces. *9.60m:* Increasingly intact core.	MW	MS	SPT	100	4/5 4/4 20/22 for 55mm **N>=50**	9									Box 2, 3.0-7.8m	
				HQTT	100						0	9.00 - 10.60m: BZ, recovered					

COMMENTS: Target depth reached. Co-ordinates were recorded using a handheld GPS and corrected by tape measuring to reference objects. PVC pipe (32 mm diameter) installed to 13 m bgl.

Hole Depth 13m

Scale 1:50

Rev.: A

BOREHOLE LOG

BOREHOLE No.: HQ_BH1

SHEET: 2 OF 2

Tonkin+Taylor

PROJECT: Tonga Comms Masts
JOB No.: 1001314.00
LOCATION: TBC HQ, Nuku'alofa, Tonga

CO-ORDINATES: -175.192319 (WGS84) -21.140186
DIRECTION:
ANGLE FROM HORIZ.: -90°

R.L. GROUND: 1.00m
R.L. COLLAR:
DATUM:
SURVEY: Handheld GPS

DRILLED BY: Mark and Slade
LOGGED BY: RLXB
CHECKED: CWM
START DATE: 01/08/2017
FINISH DATE: 02/08/2017
CONTRACTOR: Geotech Drilling

GEOLOGICAL UNIT	DESCRIPTION OF CORE SOIL: Classification, colour, consistency / density, moisture, plasticity ROCK: Weathering, colour, fabric, name, strength, cementation	Rock Weathering	Rock Strength	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)	Graphic Log	ROCK DEFECTS: Defect Log	ROCK DEFECTS: Fracture Spacing (mm)	ROCK DEFECTS: RQD (%)	ROCK DEFECTS: Description & Additional Observations	Fluid Loss (%)	Water Level	Casing	Installation	Core Box No
Limestone (Raised Coral Reef)	10.0 m - Slightly weathered, light yellowish white with dark orange LIMESTONE (Coral). Weak to moderately strong (recovered as: Coarse GRAVEL). Dark orange Fe staining on fracture surfaces.	UW SW MW HW CW	EW VW W MS S ES	HQTT	100	30/20 for 15mm **N>=50**		10				0	as angular medium to coarse gravel. Fe staining within voids and fractures. 9.60 - 11.00m: J, 5°, St, R, Regularly fractured at 0.05 m intervals.	25 50 75				Box 3, 7.8-10.8m
	10.6 m - Slightly weathered, light brownish white with dark orange LIMESTONE (Coral). Weak to moderately strong, voided (20%, 4 mm average diameter). Dark orange Fe staining.			HQTT	90			11				0						
	No recovery.																	
	11.1 m - Slightly weathered, light brownish white with dark orange LIMESTONE (Coral). Weak (Recovered as: 0.05 m pieces of intact core and medium to coarse GRAVEL).			SPT	100	7/8 4/17 25/4 for 25mm **N>=50**		12				0	11.00 - 13.00m: J, Regularly fractured and broken into gravels.					Box 4, 10.8-13.0m
				HQTT	100			13				0						
	13m: END OF BOREHOLE							14										
								15										
								16										
								17										
								18										
								19										

COMMENTS: Target depth reached. Co-ordinates were recorded using a handheld GPS and corrected by tape measuring to reference objects. PVC pipe (32 mm diameter) installed to 13 m bgl.

Hole Depth 13m

Scale 1:50

Rev.: A

BOREHOLE LOG

Tonkin+Taylor

BOREHOLE No.: HQ_BH2

SHEET: 1 OF 2

PROJECT: Tonga Comms Masts
JOB No.: 1001314.00
LOCATION: TBC HQ, Nuku'alofa, Tonga

CO-ORDINATES: -175.192217 (WGS84) -21.139886
DIRECTION:
ANGLE FROM HORIZ.: -90°

R.L. GROUND: 0.80m
R.L. COLLAR:
DATUM:
SURVEY: Handheld GPS

DRILLED BY: Mark and Slade
LOGGED BY: RLXB
CHECKED: CWM
START DATE: 02/08/2017
FINISH DATE: 03/08/2017
CONTRACTOR: Geotech Drilling

GEOLOGICAL UNIT	DESCRIPTION OF CORE SOIL: Classification, colour, consistency / density, moisture, plasticity ROCK: Weathering, colour, fabric, name, strength, cementation	Rock Weathering	Rock Strength	Sampling Method	Core Recovery (%)	Testing	RL (m) / Depth (m)	Graphic Log	ROCK DEFECTS: Defect Log	Fracture Spacing (mm)	RQD (%)	Description & Additional Observations	Fluid Loss (%)	Water Level	Casing	Installation	Core Box No
Limestone gravel and sand (Raised Coral Reef)	0.0 m - Sandy organic SILT; dark brown. Stiff, moist, non plastic. Organics: decomposing plant material. Sand: coarse coral.			HQTT	70		0	TS						10/08/2017			
	No recovery.																
	0.8 m - Medium to coarse SAND; light brown. Medium dense, moist, well graded. Sand: subangular coral.			SPT	100	3/2 4/3 3/3 **N=13**	1										
	1.3 m - Silty fine to medium GRAVEL with minor sand; light yellowish brown. Medium dense, moist, well graded. Gravel: subangular coral. Sand: medium to coarse, subangular coral.			HQTT	100												
	No recovery.			SPT	77	6/5 5/6 5/4 **N=20**	2										
	2.1 m - Fine to coarse GRAVEL with trace sand; light orangy white with dark orange. Medium dense, saturated, well graded. Gravel: subangular coral with dark orange Fe staining on surfaces. Sand: coarse, subangular coral.			HQTT	100												
	No recovery.			SPT	55	5/4 6/5 3/5 **N=19**	3										Box 1, 0.0-3.5m
	3.65 m - Medium to coarse GRAVEL; light yellowish white with dark orange. Medium dense, saturated, well graded. Gravel: subangular coral with dark orange Fe staining on surfaces.			HQTT	63												
	No recovery.			SPT	77	6/4 6/6 7/5 **N=24**	4										
	4.1 m - Medium to coarse GRAVEL; light yellowish white with dark orange. Medium dense, saturated, well graded. Gravel: subangular coral with dark orange Fe staining on surfaces.			HQTT	100												
	5.0 m - Fine to coarse GRAVEL; light brownish white. Very dense, saturated, well graded. Gravel: subangular coral.			SPT	100	11/13 18/32 for 5mm **N>=50**	5										
				HQTT	100												
	No recovery.			SPT	22	2/1 1/1 4/4 **N=10**	6										
	6.35 m - Medium to coarse GRAVEL; light yellowish white with dark orange. Medium dense, saturated, well graded. Gravel: subangular coral with dark orange Fe staining on surfaces.			HQTT	100												Box 2, 3.5-7.0m
	No recovery.			SPT	66	3/3 3/4 3/3 **N=13**	7										
	7.15 m - Medium to coarse GRAVEL; light yellowish white with dark orange. Medium dense, saturated, well graded. Gravel: subangular coral with dark Fe staining on surfaces.			HQTT	100												
Limestone (Raised Coral Reef)	8.0 m - Slightly weathered, light brownish white stained dark orange LIMESTONE (Coral). Moderately strong, voided (20%, 3 mm average diameter). Dark orange Fe staining within voids.			SPT	100	9/36 15 for 25mm **N>=50**	8				0						
				HQTT	100												
				HQTT	98	for 25mm **N>=50** Bouncing	9				13	8.00 - 10.00m: J, 5° dip, St, R, jointed at 0.05 m intervals.					Box 3, 7.0-9.6m

COMMENTS: Target depth reached. Co-ordinates were recorded using a handheld GPS and corrected by tape measuring to reference objects. PVC pipe (32 mm diameter) installed to 13 m bgl with water pumped out of borehole for 10 minutes on 3/08/2017.

Hole Depth 13.13m

Scale 1:50

Rev.: A

BOREHOLE LOG

BOREHOLE No.: HQ_BH2

SHEET: 2 OF 2

PROJECT: Tonga Comms Masts
JOB No.: 1001314.00
LOCATION: TBC HQ, Nuku'alofa, Tonga

CO-ORDINATES: -175.192217 (WGS84) -21.139886
DIRECTION:
ANGLE FROM HORIZ.: -90°

R.L. GROUND: 0.80m
R.L. COLLAR:
DATUM:
SURVEY: Handheld GPS

DRILLED BY: Mark and Slade
LOGGED BY: RLXB
CHECKED: CWM
START DATE: 02/08/2017
FINISH DATE: 03/08/2017
CONTRACTOR: Geotech Drilling

GEOLOGICAL UNIT	DESCRIPTION OF CORE SOIL: Classification, colour, consistency / density, moisture, plasticity ROCK: Weathering, colour, fabric, name, strength, cementation	Rock Weathering	Rock Strength	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)	Graphic Log	ROCK DEFECTS: Defect Log	ROCK DEFECTS: Fracture Spacing (mm)	ROCK DEFECTS: RQD (%)	ROCK DEFECTS: Description & Additional Observations	Fluid Loss (%)	Water Level	Casing	Installation	Core Box No
Limestone (Raised Coral Reef)	8.0 m - Slightly weathered, light brownish white stained dark orange LIMESTONE (Coral). Moderately strong, voided (20%, 3 mm average diameter). (Recovered as: medium to coarse GRAVEL with cobbles of intact core). Dark orange Fe staining within voids. *11.70m:* Fe staining on vesicule and joint surfaces.	UW SW MW HW CW	ES VS S MS HS VW EW	HQTT	100	50 for 75mm **N>=50**		11				0						
				HQTT	104	25 for 45mm **N>=50** Bouncing		12				0	10.00 - 13.00m: J, Broken at regular intervals with gently dipping joints in intact core, or broken into gravel.					Box 4, 9.6-12.0m
				SPT	100	15/30 50 for 50mm **N>=50**												
				HQTT	100	25/25 for 50mm **N>=50**		13				0						Box 5, 12.0-13.1m
	13.13m: END OF BOREHOLE							14										
								15										
								16										
								17										
								18										
								19										

COMMENTS: Target depth reached. Co-ordinates were recorded using a handheld GPS and corrected by tape measuring to reference objects. PVC pipe (32 mm diameter) installed to 13 m bgl with water pumped out of borehole for 10 minutes on 3/08/2017.

Hole Depth 13.13m

Scale 1:50

Rev.: A

BOREHOLE LOG

Tonkin+Taylor

BOREHOLE No.: Pop_BH1

SHEET: 1 OF 2

PROJECT: Tonga Comms Masts
JOB No.: 1001314.00
LOCATION: Popua TBC, Nuku'alofa, Tonga

CO-ORDINATES: -175.163067 (WGS84) -21.144783
DIRECTION:
ANGLE FROM HORIZ.: -90°

R.L. GROUND: 1.20m
R.L. COLLAR:
DATUM:
SURVEY: Handheld GPS

DRILLED BY: Mark and Slade
LOGGED BY: RLXB
CHECKED: CWM
START DATE: 03/08/2017
FINISH DATE: 04/08/2017
CONTRACTOR: Geotech Drilling

GEOLOGICAL UNIT	DESCRIPTION OF CORE (SOIL: Classification, colour, consistency / density, moisture, plasticity; ROCK: Weathering, colour, fabric, name, strength, cementation)	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)
Topsoil	0.0 m - Organic SILT with minor sand; dark brown. Stiff, moist, non plastic. Organics: decomposing plant material. Sand: medium to coarse coral.	HQTT	90		1	
Fill	0.4 m - Medium to coarse SAND with trace gravel; light brown. Medium dense, moist, well graded. Sand: subangular coral. Gravel: medium, subangular coral.					
	No recovery.	SPT	100	5/3 3/4 4/3 N=14	0	1
	1.0 m - Sandy GRAVEL with minor silt; light brown. Medium dense, wet, well graded. Gravel: subangular coral. Sand: medium to coarse coral.	HQTT	45			
Buried TSoil	No recovery.	SPT	44	0/0 0/0 0/0 N=0	-1	2
	2.25 m - Organic silty CLAY with minor gravel; dark brown. Soft to firm, wet, moderate to high plasticity. Gravel: medium, subangular coral.	HQTT	100			
Limestone gravel and sand (Raised Coral Reef)	2.6 m - Sandy fine to medium GRAVEL; dark brown. Medium dense, wet, well graded. Sand: medium to coarse, subangular coral. Gravel: subangular coral.	SPT	100	5/5 5/6 5/5 N=21	-2	3
	No recovery.	HQTT	72			
	3.6 m - Fine to coarse GRAVEL with minor sand; light brown. Medium dense, wet, well graded. Gravel: subangular coral. Sand: coarse coral.	SPT	44	2/1 2/2 2/2 N=8	-3	4
	No recovery.	HQTT	100			
	4.25 m - Fine to coarse GRAVEL with minor sand; light brown. Loose, wet, well graded. Gravel: subangular coral. Sand: coarse coral.	SPT	55	2/5 13/13 9/7 N=42	-4	5
	No recovery.	HQTT	100			
	5.15 m - Fine to medium GRAVEL with minor sand; light brown. Medium dense to dense, wet, well graded. Gravel: subangular coral. Sand: coarse coral.	SPT	55	1/1 1/1 1/5 N=8	-5	6
	No recovery.	HQTT	100			
	6.25 m - Fine to coarse GRAVEL with minor sand; light brown. Loose to medium dense, wet, well graded. Gravel: subangular coral. Sand: coarse coral.	SPT	100	7/7 /5 4/8 N=17	-6	7
	7.00m: Grades; fine to medium gravel.	HQTT	100			
	7.8 m - Gravelly medium to coarse SAND with trace silt; white. Medium dense, wet, uniformly graded. Sand: coral. Gravel: fine, subangular coral.	SPT	100	5/5 5/5 7/6 N=23	-7	8
		HQTT	100			
		SPT	100	3/4 1/4 4/4 N=13	-8	9
		HQTT	100			

ROCK DEFECTS: Defect Log; Fracture Spacing (mm); RQD (%); Description & Additional Observations

1.80m: Core bound.

Fluid Loss (%); Water Level: 10/08/2017; Casing; Installation; Core Box No: Box 1, 0.0-4.0m; Box 2, 4.0-7.5m; Box 3, 7.5-9.0m

COMMENTS: Target depth reached. PVC pipe (32 mm diameter) installed to 15 m bgl.

Hole Depth 15.03m

Scale 1:50

Rev.: A

BOREHOLE LOG

BOREHOLE No.: Pop_BH1

SHEET: 2 OF 2

Tonkin+Taylor

PROJECT: Tonga Comms Masts
JOB No.: 1001314.00
LOCATION: Popua TBC, Nuku'alofa, Tonga

CO-ORDINATES: -175.163067 (WGS84) -21.144783
DIRECTION:
ANGLE FROM HORIZ.: -90°

R.L. GROUND: 1.20m
R.L. COLLAR:
DATUM:
SURVEY: Handheld GPS

DRILLED BY: Mark and Slade
LOGGED BY: RLXB
CHECKED: CWM
START DATE: 03/08/2017
FINISH DATE: 04/08/2017
CONTRACTOR: Geotech Drilling

GEOLOGICAL UNIT	DESCRIPTION OF CORE SOIL: Classification, colour, consistency / density, moisture, plasticity ROCK: Weathering, colour, fabric, name, strength, cementation	Rock Weathering	Rock Strength	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)	Graphic Log	ROCK DEFECTS: Defect Log	ROCK DEFECTS: Fracture Spacing (mm)	ROCK DEFECTS: RQD (%)	ROCK DEFECTS: Description & Additional Observations	Fluid Loss (%)	Water Level	Casing	Installation	Core Box No
Limestone gravel and sand (Raised Coral Reef)	10.0 m - Sandy fine to medium GRAVEL; white. Dense, wet, well graded. Gravel: subangular coral. Sand: medium to coarse coral.			SPT	100	5/6 5/6 8/24 **N=43**	-9	11										
				HQTT	100							0						
Limestone (Raised Coral Reef)	11.0 m - Unweathered to slightly weathered, white LIMESTONE (Coral). Moderately strong. (Recovered as: Fine to medium GRAVEL).			SPT	100	37/13 for 40mm **N>=50**	-10											
	No recovery.			HQTT	77							0						
	11.3 m - Unweathered to slightly weathered, white LIMESTONE (Coral). Moderately strong. (Recovered as: Medium to coarse GRAVEL).			SPT	100	8/17 15/35 for 40mm **N>=50**	-11	12										
				HQTT	100							0	11.00 - 13.50m: BZ, Core broken and recovered as medium to coarse gravel.					Box 4, 9.0-12.7m
				SPT	100	17/26 10 for 10mm **N>=50**	-12	13										
	13.5 m - Unweathered to slightly weathered, white LIMESTONE (Coral). Moderately strong, voided (20% voids, 3 mm average diameter).			HQTT	100							0						
				HQTT	100	50 for 75mm **N>=50** 25 for 30mm **N>=50** Bouncing	-13	14				0	13.50 - 15.50m: J, 5° dip, St, R, Regular joints in intact core at approx. 0.05 m intervals.					Box 5, 12.7-15.0m
	15.03m: END OF BOREHOLE						-14	15										
							-15	16										
							-16	17										
							-17	18										
							-18	19										

COMMENTS: Target depth reached. PVC pipe (32 mm diameter) installed to 15 m bgl.

Hole Depth 15.03m

Scale 1:50

Rev.: A

BOREHOLE LOG

Tonkin+Taylor

BOREHOLE No.: Pop_BH2

SHEET: 1 OF 2

PROJECT: Tonga Comms Masts
JOB No.: 1001314.00
LOCATION: Popua TBC, Nuku'alofa, Tonga, Tonga

CO-ORDINATES: -175.163100 (WGS84) -21.145133
DIRECTION:
ANGLE FROM HORIZ.: -90°

R.L. GROUND: 1.30m
R.L. COLLAR:
DATUM:
SURVEY: Handheld GPS

DRILLED BY: Mark and Slade
LOGGED BY: RLXB
CHECKED: CWM
START DATE: 04/08/2017
FINISH DATE: 05/08/2017
CONTRACTOR: Geotech Drilling

GEOLOGICAL UNIT	DESCRIPTION OF CORE (SOIL: Classification, colour, consistency / density, moisture, plasticity; ROCK: Weathering, colour, fabric, name, strength, cementation)	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)
Topsoil	0.0 m - Sandy organic SILT; dark brown. Stiff, moist, non plastic. Sand: coarse subrounded coral. Organics: rootlets and decomposing plant material.	HQTT	100		1	0
Fill	0.4 m - Medium to coarse SAND; light brown. Medium dense, moist, well graded. Sand: subrounded to subangular coral.	HQTT	100			
	No recovery.	SPT	100	14/13 8/7 5/5 N=25	0	1
	1.6 m - Medium to coarse GRAVEL; light brown. Medium dense, moist, uniformly graded. Gravel: subangular coral.	HQTT	72			
	1.9 m - Gravelly medium to coarse SAND with minor silt; light yellowish brown. Very loose, wet, well graded. Sand: subangular coral. Gravel: fine to medium subangular coral.	SPT	100	2/1 2/1 0/0 N=3	-1	2
	3.00m: Grades; dense.	HQTT	100			
		SPT	100	2/13 10/9 11/14 N=44	-2	3
Limestone gravel and sand (Raised Coral Reef)	3.45 m - Fine to coarse GRAVEL with minor sand; light brown. Medium dense, wet, well graded. Gravel: angular coral. Sand: coarse subangular coral.	HQTT	100			
	No recovery.	SPT	55	8/11 11/4 5/4 N=24	-3	4
	4.2 m - Fine to coarse GRAVEL with minor sand; light brown. Medium dense, wet, well graded. Gravel: angular coral. Sand: coarse subangular coral.	HQTT	63			
	No recovery.	SPT	44	0/2 0/0 1/2 N=3	-4	5
	5.2 m - Silty fine to medium SAND with trace gravel; light brown. Very loose, saturated, uniformly graded. Gravel: subangular, medium coral.	HQTT	54			
	No recovery.	SPT	55	3/3 3/3 4/5 N=15	-5	6
	5.7 m - Fine to coarse GRAVEL with minor sand; light brownish white. Medium dense, wet, well graded. Gravel: subangular coral. Sand: subangular coarse coral.	HQTT	100			
	No recovery.	SPT	100	3/3 4/5 6/7 N=22	-6	7
	6.2 m - Sandy fine GRAVEL with minor silt; light brown. Medium dense, wet, uniformly graded. Gravel: angular coral. Sand: coarse, angular coral.	HQTT	100			
	7.7 m - Fine to coarse GRAVEL; light brownish white. Dense, moist, well graded. Gravel: subangular coral.	SPT	100	2/5 9/17 7/13 N=46	-7	8
		HQTT	100			
	No recovery.	SPT	55	4/4 4/5 5/4 N=18	-8	9
	9.2 m - Fine to coarse GRAVEL; light brownish white. Medium dense, moist, well graded. Gravel: subangular coral.	HQTT	100			

ROCK DEFECTS: Defect Log; Fracture Spacing (mm); RQD (%); Description & Additional Observations

Fluid Loss (%); Water Level (16/08/2017); Casing; Installation; Core Box No (Box 1, 0.0-3.8m; Box 2, 3.8-7.5m)

COMMENTS: Target depth reached.

Hole Depth 15.12m

Scale 1:50

Rev.: A

BOREHOLE LOG

Tonkin+Taylor

BOREHOLE No.: Pop_BH2

SHEET: 2 OF 2

PROJECT: Tonga Comms Masts
JOB No.: 1001314.00
LOCATION: Popua TBC, Nuku'alofa, Tonga, Tonga

CO-ORDINATES: -175.163100 (WGS84) -21.145133
DIRECTION:
ANGLE FROM HORIZ.: -90°

R.L. GROUND: 1.30m
R.L. COLLAR:
DATUM:
SURVEY: Handheld GPS

DRILLED BY: Mark and Slade
LOGGED BY: RLXB
CHECKED: CWM
START DATE: 04/08/2017
FINISH DATE: 05/08/2017
CONTRACTOR: Geotech Drilling

GEOLOGICAL UNIT	DESCRIPTION OF CORE SOIL: Classification, colour, consistency / density, moisture, plasticity ROCK: Weathering, colour, fabric, name, strength, cementation	Rock Weathering	Rock Strength	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)	Graphic Log	ROCK DEFECTS: Defect Log	ROCK DEFECTS: Fracture Spacing (mm)	ROCK DEFECTS: RQD (%)	ROCK DEFECTS: Description & Additional Observations	Fluid Loss (%)	Water Level	Casing	Installation	Core Box No
	10.0 m - Fine to coarse GRAVEL; light brownish white. Dense, moist, well graded. Gravel: subangular coral.			SPT	100	2/3 5/7 11/8 **N=31**	-9											Box 3, 7.5-10.5m
Limestone (Raised Coral Reef)	10.9 m - Unweathered to slightly weathered, light brownish white LIMESTONE (Coral). Moderately strong, voids (10% voids, 2 - 4 mm diameter).			HQTT	100			11										
	No recovery.					27/23 for 7mm **N>=50**	-10											
	11.28 m - Unweathered to slightly weathered, light brownish white LIMESTONE (Coral). Moderately strong, voids (10% voids, 2 - 4 mm diameter). *12.00m:* Recovered as; medium to coarse GRAVEL. Dark orange Fe staining on gravel surfaces.			HQTT	76							50	11.70m: J, Pl, R					
				SPT	100	18/10 23/25 2 for 15mm **N>=50**	-11	12										
				HQTT	100							0						
	No recovery.			SPT	0	15/35 for 50mm **N>=50**	-12	13										Box 4, 10.5-14.0m
	13.63 m - Unweathered to slightly weathered, light brownish white LIMESTONE (Coral). Moderately strong, voids (10% voids, 2 - 4 mm diameter).			HQTT	42							0	12.32 - 15.00m: BZ, Core recovered as medium to coarse gravel.					
	14.0 - 14.37 m - Sample not recovered - Solid cone SPT.			SPT	0	7/10 7/16 27 for 70mm **N>=50** Solid	-13	14										
	No recovery.			HQTT	52							0						Box 5, 14.0-15.1m
	14.67 m - Unweathered to slightly weathered, light brownish white LIMESTONE (Coral). Moderately strong, voids (10% voids, 2 - 4 mm diameter). Occasional dark orange Fe staining.					19/31 for 42mm **N>=50** Solid		15										
	15.0 - 15.117 m - Sample not recovered - Solid cone SPT.						-14											
							-15	16										
							-16	17										
							-17	18										
								19										
							-18											

COMMENTS: Target depth reached.

Hole Depth 15.12m

Scale 1:50

Rev.: A

BOREHOLE LOG

Tonkin+Taylor

BOREHOLE No.: Pop_BH3

SHEET: 1 OF 2

PROJECT: Tonga Comms Masts

JOB No.: 1001314.00

LOCATION: Popua TBC, Nuku'alofa, Tonga, Tonga

CO-ORDINATES: -175.162733 (WGS84) -21.144633

DIRECTION:

ANGLE FROM HORIZ.: -90°

R.L. GROUND: 1.00m

R.L. COLLAR:

DATUM:

SURVEY: Handheld GPS

DRILLED BY: Mark and Slade

LOGGED BY: RLXB

CHECKED: CWM

START DATE: 07/08/2017

FINISH DATE: 07/08/2017

CONTRACTOR: Geotech Drilling

GEOLOGICAL UNIT	DESCRIPTION OF CORE (SOIL: Classification, colour, consistency / density, moisture, plasticity; ROCK: Weathering, colour, fabric, name, strength, cementation)	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)
Topsoil	0.0 m - Organic sandy SILT; dark brown. Stiff, moist, non plastic. Organics: decomposing plant material. Sand: coarse coral.	HQTT	80		0	1
Fill	0.3 m - Gravelly medium to coarse SAND; light brown. Tightly packed, moist, well graded. Sand: subangular coral. Gravel: fine, subangular coral.					
	No recovery.	SPT	100	15/7 5/5 20/20 for 23mm **N>=50**		
	0.8 m - COBBLES or BOULDERS; light brownish white. Very dense, moist. Coral.	HQTT	100			
Buried Topsoil	2.0 m - Organic silty CLAY with trace sand and gravel; dark brown. Firm, saturated, low to moderate plasticity. Organics: clay and decomposing plant material. Sand: coarse, light grey, subangular. Gravel: fine, subangular coral.	SPT	100	2/1 1/0 1/0 **N=2**	-1	2
		HQTT	100	● 41/6 kPa barrel 1 @ 3.0m		
	3.0 - 3.5 m - PUSH TUBE. Medium to coarse light yellowish brown SAND at top, and, Soft dark brown organic CLAY at base.	PT	100		-2	3
	3.5 m - Organic silty CLAY; dark brown. Soft, saturated, moderate plasticity. Organics: clay and decomposing plant material.	HQTT	100			
Limestone gravel and sand (Raised Coral Reef)	3.7 m - Sandy gravelly SILT with minor organics; dark brown with light yellowish brown. Soft, saturated, non plastic. Sand: medium to coarse, subangular coral. Gravel: fine subangular coral. Organics: clay and decomposing plant material.	SPT	100	3/6 10/20 18/2 for 12mm **N>=50**	-3	4
	4.0 m - Sandy medium GRAVEL; light brownish white. Very dense, wet, uniformly graded. Weakly cemented. Gravel: subangular coral. Gravel: coarse, subangular coral. *4.70m:* Grades; medium dense, non-cemented.	HQTT	100			
	No recovery.	SPT	55	7/6 5/5 5/6 **N=21**	-4	5
	5.7 m - Medium to coarse GRAVEL; light brownish white. Medium dense, saturated, uniformly graded. Gravel: subangular to angular coral.	HQTT	54			
	No recovery.	SPT	44	0/0 2/2 3/4 **N=11**	-5	6
		HQTT	18			
	6.9 m - Fine to medium GRAVEL; light brownish white. Medium dense, moist, well graded. Gravel: angular to subangular coral.	SPT	100	4/4 4/4 5/6 **N=19**	-6	7
	No recovery.	HQTT	45			
	7.8 m - Silty fine to coarse SAND; light brownish white. Medium dense, wet, well graded. Very weakly cemented.	SPT	77	4/3 4/4 5/6 **N=19**	-7	8
	No recovery.	HQTT	72			
	8.6 m - Gravelly medium to coarse SAND with trace silt; light brownish white. Medium dense, saturated, well graded. Sand: angular coral. Gravel: subangular, fine to medium coral.	SPT	100	4/6 6/6 5/5 **N=22**	-8	9
	9.45 m - Silty fine SAND; light brownish white. Medium dense, saturated, uniformly graded. Slow dilatency.	HQTT	100			

ROCK DEFECTS: Defect Log; Fracture Spacing (mm) (2000, 600, 200, 60, 20); RQD (%); Description & Additional Observations

Graphic Log: TS

Fluid Loss (%) (25, 50, 75)

Water Level: ▼ 10/08/2017

Casing

Installation

Core Box No: Box 1, 0.0-3.0m; Box 2, 3.0-7.5m

COMMENTS: Target depth reached.

Hole Depth 15.13m

Scale 1:50

Rev.: A

BOREHOLE LOG

Tonkin+Taylor

BOREHOLE No.: Pop_BH3

SHEET: 2 OF 2

PROJECT: Tonga Comms Masts
JOB No.: 1001314.00
LOCATION: Popua TBC, Nuku'alofa, Tonga, Tonga

CO-ORDINATES: -175.162733 (WGS84) -21.144633
DIRECTION:
ANGLE FROM HORIZ.: -90°

R.L. GROUND: 1.00m
R.L. COLLAR:
DATUM:
SURVEY: Handheld GPS

DRILLED BY: Mark and Slade
LOGGED BY: RLXB
CHECKED: CWM
START DATE: 07/08/2017
FINISH DATE: 07/08/2017
CONTRACTOR: Geotech Drilling

GEOLOGICAL UNIT	DESCRIPTION OF CORE (SOIL: Classification, colour, consistency / density, moisture, plasticity; ROCK: Weathering, colour, fabric, name, strength, cementation)	Rock Weathering	Rock Strength	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)	Graphic Log	ROCK DEFECTS: Defect Log	ROCK DEFECTS: Fracture Spacing (mm)	ROCK DEFECTS: RQD (%)	ROCK DEFECTS: Description & Additional Observations	Fluid Loss (%)	Water Level	Casing	Installation	Core Box No
Limestone (Raised Coral Reef)	10. 0 m - Slightly weathered, light brownish white LIMESTONE. Moderately strong, voids (2%, 2 mm average diameter). *11.00m:* Grades; very weak to extremely weak.	UW SW MW HW CW	ES VS S MS W VW EW	SPT HQTT	100 100	5/25 20 for 8mm **N>=50**	-10	11			2000 600 200 60 20	23	10.60m: J, 5° dip, St, R	25 50 75				Box 3, 7.5-11.0m
	No recovery.			SPT HQTT	55 81	5/9 12/7 12/10 **N=41**	-11	12				0						
	11.55 m - Slightly weathered, light brownish white LIMESTONE (Coral). Extremely weak (Recovered as: Medium to coarse GRAVEL).			SPT HQTT	100 100	18/16 50 for 70mm **N>=50**	-12	13				0	10.75 - 13.50m: BZ, Broken to gravel. 10.90m: J, 5° dip, St, R 11.55 - 13.50m: , Broken to gravel with occasional intact core.					
	12.0 m - Slightly weathered, light brownish white LIMESTONE (Coral). Moderately strong, voids (10% voids, up to 30 mm diameter). Dark orange Fe staining in voids.																	
	13.0 - 13.28 m - Sample not recovered - Solid cone SPT.			SPT	0	5/42 25/15 for 50mm **N>=50** Solid	-13	14				0						Box 4, 11.0-14.5m
	13.28 m - Unweathered to slightly weathered, light brownish white LIMESTONE (Coral). Moderately strong, voids (20% voids, 3 mm average diameter, up to 30 mm).			HQTT	76													
	14.0 - 14.45 m - Sample not recovered - Solid cone SPT.			SPT	0	10/9 11/17 8/9 **N=45** Solid	-14	15				0						
	14.45 m - Slightly weathered, light brownish white LIMESTONE (Coral). Moderately strong, voids (20% voids, 3 mm diameter average, up to 30 mm diameter).			HQTT	100							36	13.50 - 15.30m: , Jointed at regular 0.05 - 0.08 m intervals. Voided.					Box 5, 14.5-15.1m
	15.0 - 15.13 m - Sample not recovered - Solid cone SPT.			SPT	0	25/25 for 55mm **N>=50** Solid	-15	16										
	15.13m: END OF BOREHOLE						-16	17										
							-17	18										
							-18	19										

COMMENTS: Target depth reached.

Hole Depth 15.13m

Scale 1:50

Rev.: A

BOREHOLE LOG

Tonkin+Taylor

BOREHOLE No.: Pop_BH4

SHEET: 1 OF 2

PROJECT: Tonga Comms Masts
JOB No.: 1001314.00
LOCATION: Popua TBC, Nuku'alofa, Tonga

CO-ORDINATES: -175.163400 (WGS84) -21.144550
DIRECTION:
ANGLE FROM HORIZ.: -90°

R.L. GROUND: 1.00m
R.L. COLLAR:
DATUM:
SURVEY: Handheld GPS

DRILLED BY: Mark and Slade
LOGGED BY: RLXB
CHECKED: CWM
START DATE: 08/08/2017
FINISH DATE: 08/08/2017
CONTRACTOR: Geotech Drilling

GEOLOGICAL UNIT	DESCRIPTION OF CORE (SOIL: Classification, colour, consistency / density, moisture, plasticity; ROCK: Weathering, colour, fabric, name, strength, cementation)	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)
Topsoil	No recovery.	HQTT	40			
Fill	0.6 m - Silty sandy fine to coarse GRAVEL with trace organics; light brown with rare dark brown. Loose, moist, well graded. Gravel: subangular coral. Sands: coarse subangular coral. Organics: decomposing plant material and rootlets.	SPT	100	1/1 0/0 0/0 **N=0**	0	1
Buried Topsoil	1.1 m - Silty CLAY with trace organics, gravel and sand; dark yellowish brown. Firm to stiff, moist, moderate plasticity. Organics: decomposing plant material. Gravel: fine to medium coral. Sand: coarse coral. *2.40m:* Grades; dark brown organic silty clay.	HQTT	100			
		SPT	100	50/6 kPa 0/0 1/0 1/0 **N=2**	-1	2
		HQTT	100			
Limestone gravel and sand (Raised Coral Reef)	3.15 m - Gravelly COBBLES; light brownish white. Medium dense, saturated, uniformly graded. Cobbles or boulders: weak to moderately strong coral. Gravel: coarse, subangular coral.	SPT	100	5/6 2/2 3/10 **N=17**	-2	3
		HQTT	100			
	4.0 m - Fine to medium GRAVEL with some sand; light brownish white. Dense, saturated, well graded. Gravel: subangular coral. Sand: coarse subangular coral. *4.60m:* Grades; medium to coarse gravel with minor white silt.	SPT	100	12/10 13/12 7/4 **N=36**	-3	4
		HQTT	100			
	No recovery.	SPT	55	11/14 17/12 12/9 **N>=50**	-4	5
	5.2 m - Fine to medium GRAVEL with some sand; light brownish white. Very dense, saturated, well graded. Gravel: subangular coral. Sand: coarse subangular coral. *5.60m:* Grades; well cemented. Voids (10%, 4 mm average diameter). dark orange Fe staining on joint and void surfaces.	HQTT	100			
		SPT	100	20/18 19/14 12/5 for 20mm **N>=50**	-5	6
		HQTT	100			
	6.7 m - Sandy fine to medium GRAVEL; light whitish brown. Medium dense, moist, well graded. Gravel: subangular coral. Sand: coarse subangular coral.	SPT	100	4/6 7/5 7/7 **N=26**	-6	7
	No recovery.	HQTT	36			
	7.8 m - Silty coarse SAND with minor gravel; light brownish white. Dense, moist, well graded. Sand: subangular coral. Gravel: fine subangular coral.	SPT	100	6/6 11/10 8/10 **N=39**	-7	8
	8.45 m - Sandy fine to coarse GRAVEL; light brownish white. Medium dense, saturated, well graded. Gravel: subangular coral. Sand: medium to coarse, subangular coral.	HQTT	100			
		SPT	100	3/4 3/4 3/3 **N=13**	-8	9
	No recovery.	HQTT	1			

ROCK DEFECTS: Rock Weathering (UW, SW, MW, HW, CW); Rock Strength (ES, VS, S, MS, W, VW, EW); Defect Log; Fracture Spacing (mm) (2000, 600, 200, 60, 20); RQD (%); Description & Additional Observations

Graphic Log

Fluid Loss (%) (25, 50, 75)

Water Level: ▼ 10/08/2017

Casing

Installation

Core Box No: Box 1, 0.0-3.9m; Box 2, 3.9-7.0m

COMMENTS: Target depth reached.

Hole Depth 15.29m

Scale 1:50

Rev.: A

BOREHOLE LOG

BOREHOLE No.: Pop_BH4

SHEET: 2 OF 2

PROJECT: Tonga Comms Masts
JOB No.: 1001314.00
LOCATION: Popua TBC, Nuku'alofa, Tonga

CO-ORDINATES: -175.163400 (WGS84) -21.144550
DIRECTION:
ANGLE FROM HORIZ.: -90°

R.L. GROUND: 1.00m
R.L. COLLAR:
DATUM:
SURVEY: Handheld GPS

DRILLED BY: Mark and Slade
LOGGED BY: RLXB
CHECKED: CWM
START DATE: 08/08/2017
FINISH DATE: 08/08/2017
CONTRACTOR: Geotech Drilling

GEOLOGICAL UNIT	DESCRIPTION OF CORE SOIL: Classification, colour, consistency / density, moisture, plasticity ROCK: Weathering, colour, fabric, name, strength, cementation	Rock Weathering	Rock Strength	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)	Graphic Log	ROCK DEFECTS: Defect Log	Fracture Spacing (mm)	RQD (%)	Description & Additional Observations	Fluid Loss (%)	Water Level	Casing	Installation	Core Box No
Limestone gravel and sand (Raised Coral Reef)	9.9 m - Fine to medium SAND; white. Medium dense, saturated, uniformly graded. *10.20m:* Grades; coarse sand with some fine to medium gravel. *10.60m:* Grades; intact core of weakly cemented sand and gravel.			SPT HQTT	100 100	22/22 9/12 11/10 **N=42**	-10	11				0						
Limestone (Raised Coral Reef)	11.0 m - Slightly weathered, light brownish white LIMESTONE (Coral). Weak to moderately strong, voided (20%, 3 mm average diameter).			HQTT	100	5/45 for 45mm **N>=50**	-11	12				22	11.00 - 12.00m: , Fractured at 0.2 m intervals along weakened areas from increased voids.					Box 3, 7.0-11.1m
				HQTT	100	50 for 46mm **N>=50**	-12	13				42	12.40m: J, 5° dip, St, R					
	13.12 - 13.34 m - CORE LOSS.					25/25 for 40mm **N>=50**												
	13.14 m - Unweathered to slightly weathered, white LIMESTONE (Coral). Moderately strong, voids (10% , 3 mm average diameter). (Recovered as: Coarse GRAVEL.) *14.14m:* Grades; intact through fractured core with no gravel. Voids (avg. 30 mm diameter).			HQTT	65		-13	14				0	12.70 - 14.00m: , Broken to gravel.					Box 4, 11.1-14.1m
				HQTT	68	50 for 50mm **N>=50** Solid 18/8 10/40 for 65mm **N>=50** Solid	-14	15				0	14.20 - 15.00m: , Jointed to cobbles.					Box 5, 14.1-15.3m
	15.29m: END OF BOREHOLE			SPT	0		-15 -16 -17 -18	16 17 18 19										

COMMENTS: Target depth reached.

Hole Depth 15.29m

Scale 1:50

Rev.: A

BOREHOLE LOG

Tonkin+Taylor

BOREHOLE No.: Pop_BH5

SHEET: 1 OF 2

PROJECT: Tonga Comms Masts
JOB No.: 1001314.00
LOCATION: Popua TBC, Nuku'alofa, Tonga

CO-ORDINATES: -175.163081 (WGS84) -21.143803°
DIRECTION:
ANGLE FROM HORIZ.: -90°

R.L. GROUND: 1.60m
R.L. COLLAR:
DATUM:
SURVEY: Handheld GPS

DRILLED BY: Mark and Slade
LOGGED BY: RLXB
CHECKED: CWM
START DATE: 09/08/2017
FINISH DATE: 09/08/2017
CONTRACTOR: Geotech Drilling

GEOLOGICAL UNIT	DESCRIPTION OF CORE (SOIL: Classification, colour, consistency / density, moisture, plasticity; ROCK: Weathering, colour, fabric, name, strength, cementation)	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)
Topsoil	0.0 m - Sandy organic SILT; dark brown. Stiff, moist, non plastic. Sand: medium to coarse, subangular coral. Organics: silt and decomposing plant material.	HQTT	100		1	0
Fill	0.2 m - Medium to coarse SAND; light brown. Medium dense, moist, well graded. Sand: subangular coral.	SPT	100	3/5 10/10 8/8 **N=36**		
		HQTT	100		0	1
	No recovery.	SPT	33	5/7 5/4 2/3 **N=14**		
	2.3 m - Medium to coarse SAND; light brown. Medium dense, moist, well graded. Sand: subangular coral.	HQTT	100		-1	2
Buried TSoil	2.9 m - Sandy organic CLAY; dark brown. Soft to firm, saturated, low plasticity. Organics: clay and decomposing plant material. Sand: medium to coarse, subangular coral.	PT	90	2 @ 3.0m		
	3.0 - 3.5 m - PUSH TUBE. Top of tube: Coarse SAND. Base of tube: organic clay and coarse SAND.	HQTT	110		-2	3
Limestone (Raised Coral Reef)	3.5 m - Gravelly medium to coarse SAND; light brown. Medium dense, saturated, well graded. Sand: subangular coral. Gravel: fine to medium subangular gravel.	SPT	100	6/10 11/18 15/6 for 20mm **N>=50**		
	3.7 m - Organic CLAY with trace sand; dark brown. Firm, saturated, moderate to high plasticity. Sand: medium to coarse, subangular coral.	HQTT	110		-3	4
	3.8 m - Moderately to highly weathered, light brownish white LIMESTONE (Coral). Weak. (Recovered as: Medium to coarse GRAVEL).	SPT	100	8/13 8/12 10/12 **N=42**		
		HQTT	100		-4	5
		SPT	100	5/5 9/15 20/6 for 35mm **N>=50**		
Limestone gravel and sand (Raised Coral Reef)	No recovery.	HQTT	83		-5	6
	6.51 m - Medium to coarse GRAVEL; light brownish white with occasional dark orange. Dense, moist, well graded. Gravel: angular coral.	SPT	100	6/6 9/9 6/12 **N=36**		
	7.65 m - Sandy fine to medium GRAVEL; light yellowish white. Medium dense, moist, well graded. Gravel: angular coral.	HQTT	100		-6	7
	8.0 m - Gravelly medium to coarse SAND with trace silt; white. Medium dense, saturated, well graded. Sand: angular coral. Gravel: fine, angular coral.	SPT	100	3/5 5/2 3/2 **N=12**		
		HQTT	100		-7	8
		SPT	100	3/3 5/4 4/4 **N=17**		
		HQTT	100		-8	9

ROCK DEFECTS: Defect Log; Fracture Spacing (mm); RQD (%); Description & Additional Observations

RQD (%): 0 (3.5 - 3.8 m); 0 (3.8 - 4.0 m)

Description & Additional Observations: 3.80 - 6.41m: , Broken to gravel. Intact though some fractures between 5.8 - 6.0 m.

Fluid Loss (%); Water Level: 10/08/2017; Casing; Installation

Core Box No: Box 1, 0.0-3.0m; Box 2, 3.0-6.4m; Box 3, 6.4-9.5m

COMMENTS: Target depth reached.

Hole Depth 15.45m

Scale 1:50

Rev.: A

BOREHOLE LOG

BOREHOLE No.: Pop_BH5

SHEET: 2 OF 2

Tonkin+Taylor

PROJECT: Tonga Comms Masts
JOB No.: 1001314.00
LOCATION: Popua TBC, Nuku'alofa, Tonga

CO-ORDINATES: -175.163081 (WGS84) -21.143803°
DIRECTION:
ANGLE FROM HORIZ.: -90°

R.L. GROUND: 1.60m
R.L. COLLAR:
DATUM:
SURVEY: Handheld GPS

DRILLED BY: Mark and Slade
LOGGED BY: RLXB
CHECKED: CWM
START DATE: 09/08/2017
FINISH DATE: 09/08/2017
CONTRACTOR: Geotech Drilling

GEOLOGICAL UNIT	DESCRIPTION OF CORE SOIL: Classification, colour, consistency / density, moisture, plasticity ROCK: Weathering, colour, fabric, name, strength, cementation	Rock Weathering	Rock Strength	Sampling Method	Core Recovery (%)	Testing	RL (m)	Depth (m)	Graphic Log	ROCK DEFECTS: Defect Log	Fracture Spacing (mm)	RQD (%)	Description & Additional Observations	Fluid Loss (%)	Water Level	Casing	Installation	Core Box No
Limestone gravel and sand (Raised Coral Reef)	10.0 m - Gravelly medium to coarse SAND with trace silt; white. Medium dense, saturated, well graded. Sand: angular coral. Gravel: fine, angular coral.			SPT	100	5/5 7/6 6/4 **N=23**		-9 10 11										
				HQTT	100													
				SPT	100	5/4 7/4 9/14 **N=34**												
Limestone (Raised Coral Reef)	11.6 m - Slightly weathered, white LIMESTONE (Coral). Moderately strong, voided (10%, 2 mm average diameter).			HQTT	34		-10	12				27						Box 4, 9.5-12.2m
				SPT	100	9/27 25 for 15mm **N>=50** Bouncing												
				HQTT	100		-11	13				30	12.30m: J, 5° dip, St, R 12.50m: J, 5° dip, St , R					
				SPT	100	8/7 18/18 14 for 19mm **N>=50**							12.70 - 13.00m: , Broken to gravel.					
	14.00m: Grades to moderately weathered LIMESTONE, extremely weak (recovered as: medium to coarse GRAVEL).			HQTT	100		-12	14				70	13.40m: J, 5° dip, St, R					
				SPT	100	8/8 6/5 8/6 **N=25**												
	No recovery.			HQTT	54		-13	15				0						Box 5, 12.2-15.5m
	14.7 m - Slightly weathered, light brownish white LIMESTONE (Coral). Weak. (Recovered as: medium GRAVEL).			SPT	100	2/2 2/3 4/3 **N=12**							14.70 - 15.00m: , Broken to gravel.					
	15.45m: END OF BOREHOLE						-14 -15 -16 -17 -18	16 17 18 19										

COMMENTS: Target depth reached.

Hole Depth 15.45m

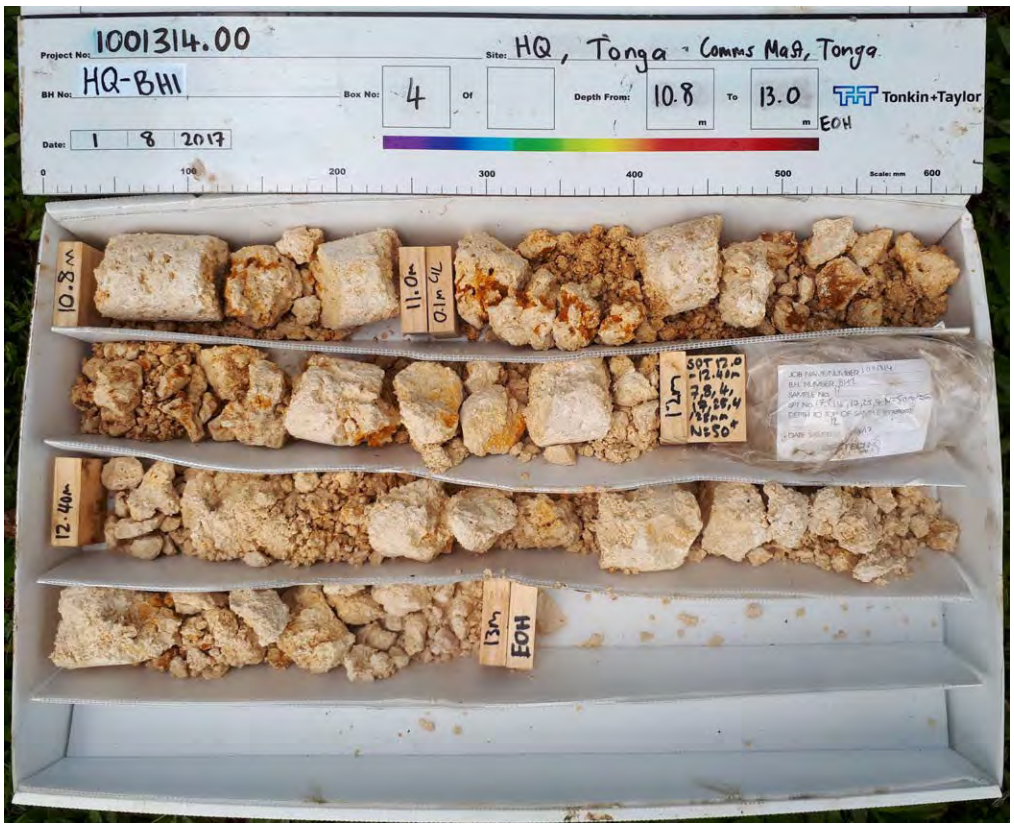
Scale 1:50

Rev.: A

HQ-BH1_Box 1_0.0 - 3.8m.jpg

HQ-BH1_Box 2_3.8 - 7.8m.jpg

HQ-BH1_Box 3_7.8 - 10.8m.jpg



HQ-BH1_Box 4_10.8 - 13.0m.jpg

HQ-BH2_Box 1_0.0 - 3.45m.jpg

HQ-BH2_Box 2_3.45 - 7.0m.jpg

HQ-BH2_Box 3_7.0 - 9.55m.jpg

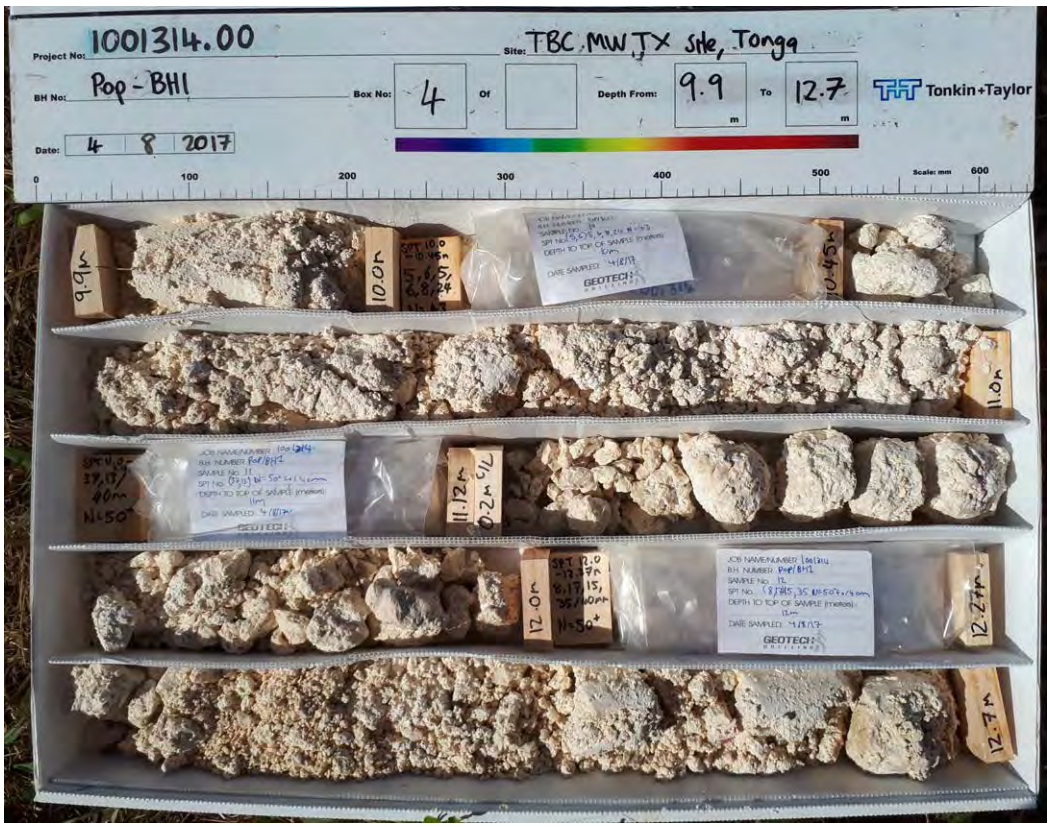
HQ-BH2_Box 4_9.55 - 12.0m.jpg

HQ-BH2_Box 5_12.0 - 13.13m.jpg

Pop-BH1_Box 1_0.0 - 4.0m.jpg

Pop-BH1_Box 2_4.0 - 7.45m.jpg

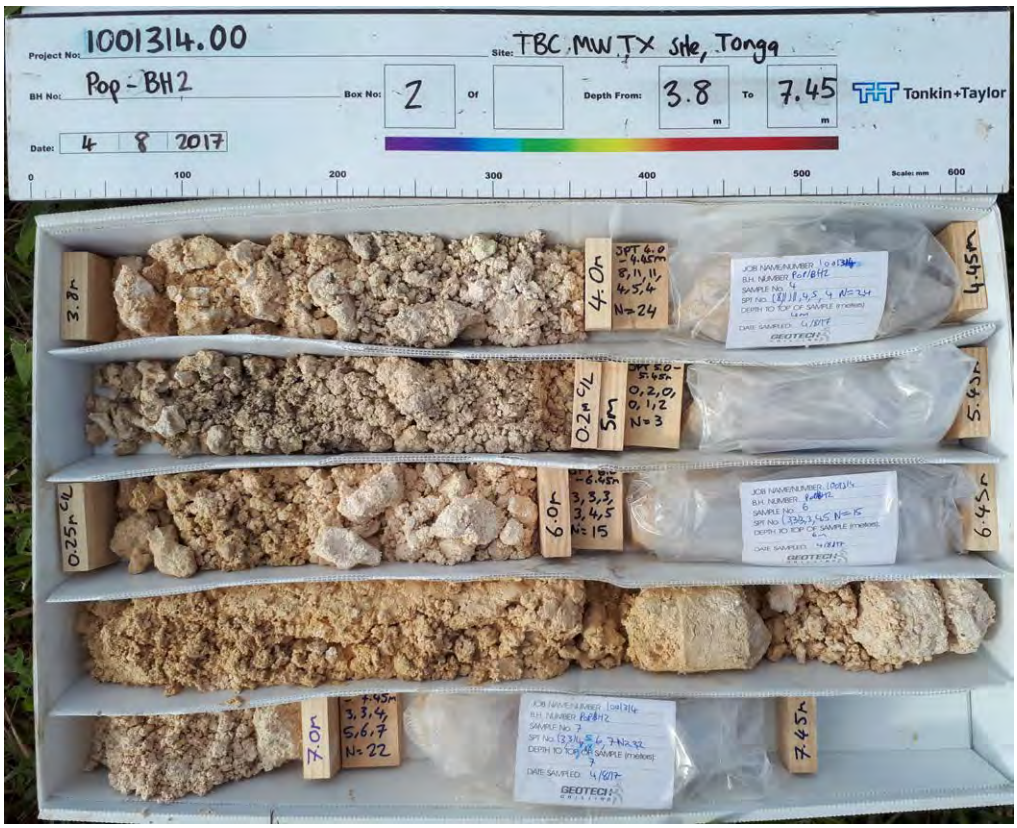
Pop-BH1_Box 3_7.45 - 9.9m.jpg



Pop-BH1_Box 4_9.9 - 12.7m.jpg

Pop-BH1_Box 5_12.7 - 15.03m.jpg

Pop-BH2_Box 1_0.0 - 4.0m.jpg



Pop-BH2_Box 2_3.8 - 7.45m.jpg

Pop-BH2_Box 3_7.45 - 10.45m.jpg

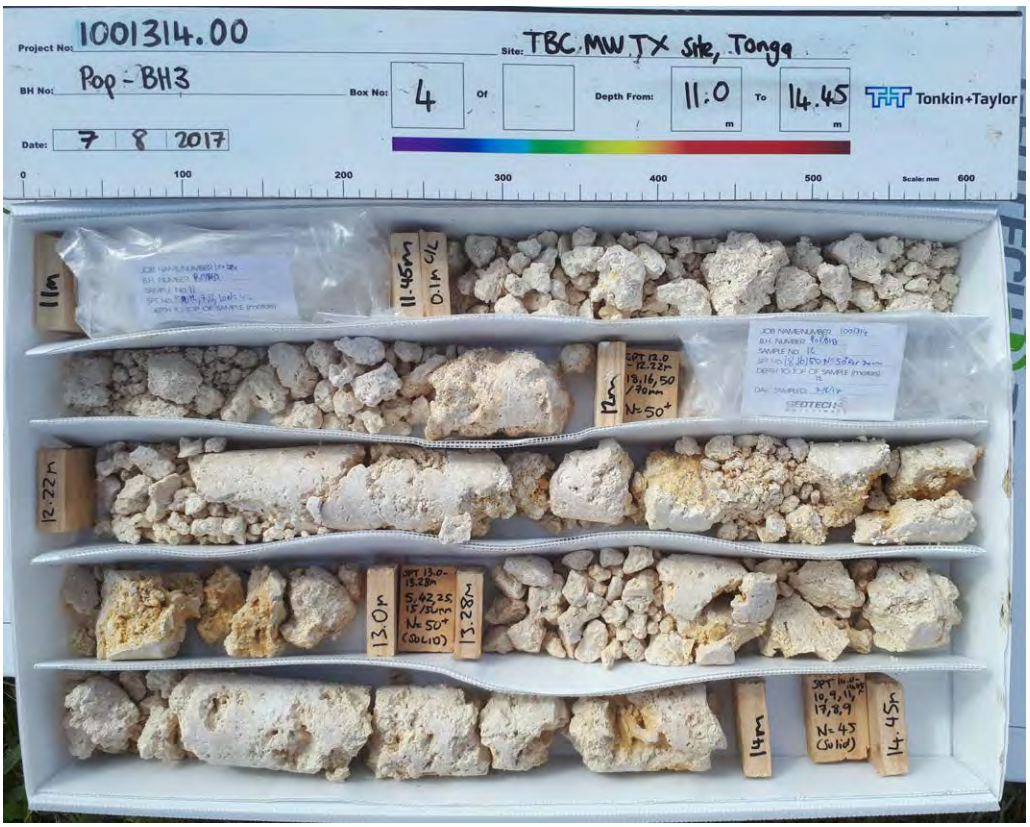
Pop-BH2_Box 4_10.45 - 14.0m.jpg

Pop-BH2_Box 5_14.0 - 15.117m.jpg

Pop-BH3_Box 1_0.0 - 3.0m.jpg

Pop-BH3_Box 2_3.0 - 7.45m.jpg

Pop-BH3_Box 3_7.45 - 11.0m.jpg



Pop-BH3_Box 4_11.0 - 14.45m.jpg

Pop-BH3_Box 5_14.45 - 15.13m.jpg

Pop-BH4_Box 1_0.0 - 3.9m.jpg

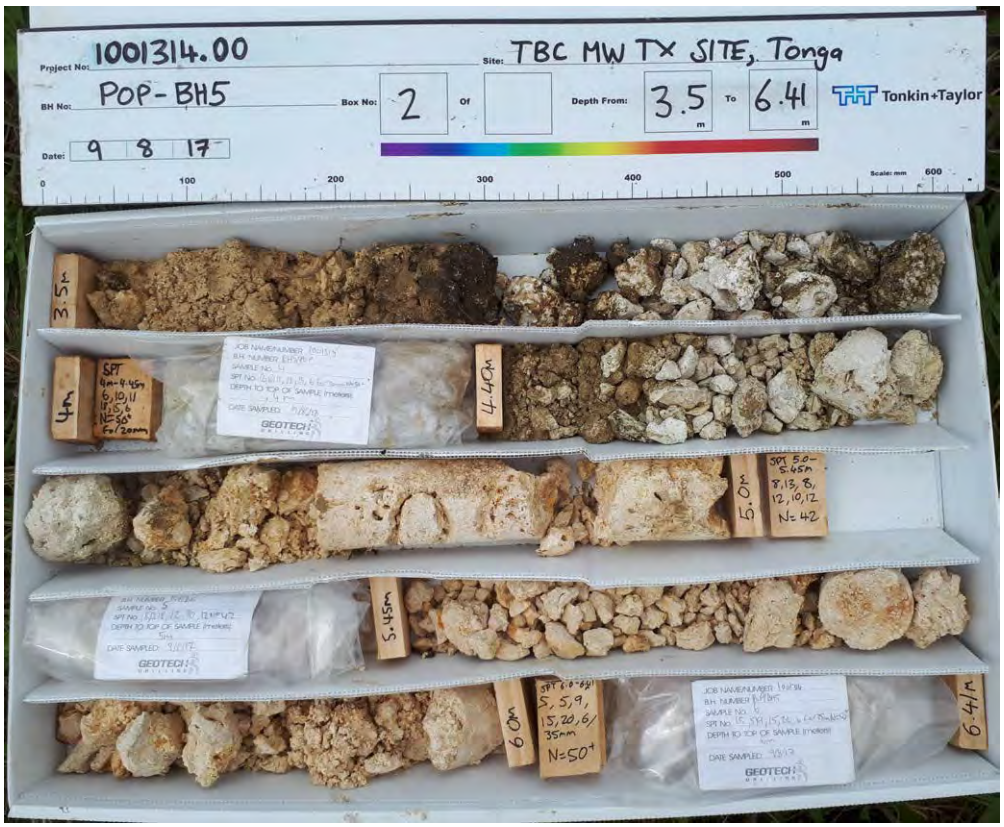
Pop-BH4_Box 2_3.9 - 7.0m.jpg

Pop-BH4_Box 3_7.0 - 11.12m.jpg

Pop-BH4_Box 4_11.12 - 14.05m.jpg

Pop-BH4_Box 5_14.05 - 15.29m.jpg

Pop-BH5_Box 1_0.0 - 3.5m.jpg



Pop-BH5_Box 2_3.5 - 6.41m.jpg

Pop-BH5_Box 3_6.41 - 9.45m.jpg

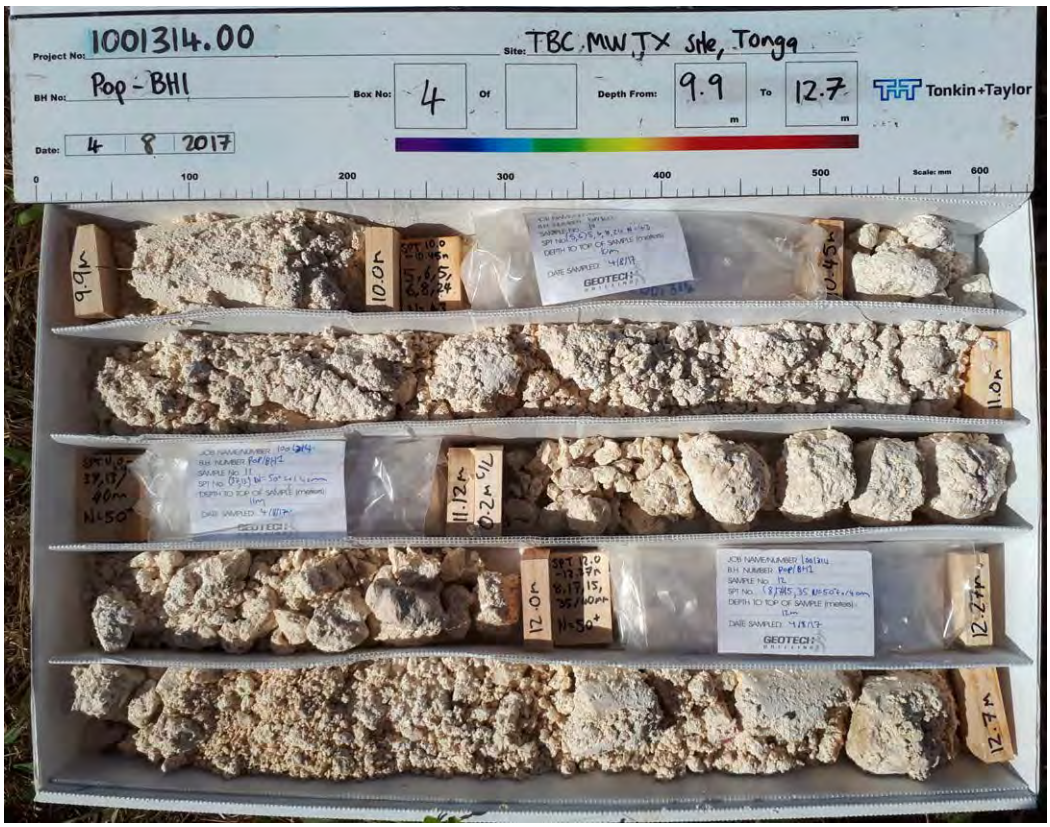
Pop-BH5_Box 4_9.45 - 12.17m.jpg

Pop-BH5_Box 5_12.17 - 15.45m.jpg

Pop-BH1_Box 1_0.0 - 4.0m.jpg

Pop-BH1_Box 2_4.0 - 7.45m.jpg

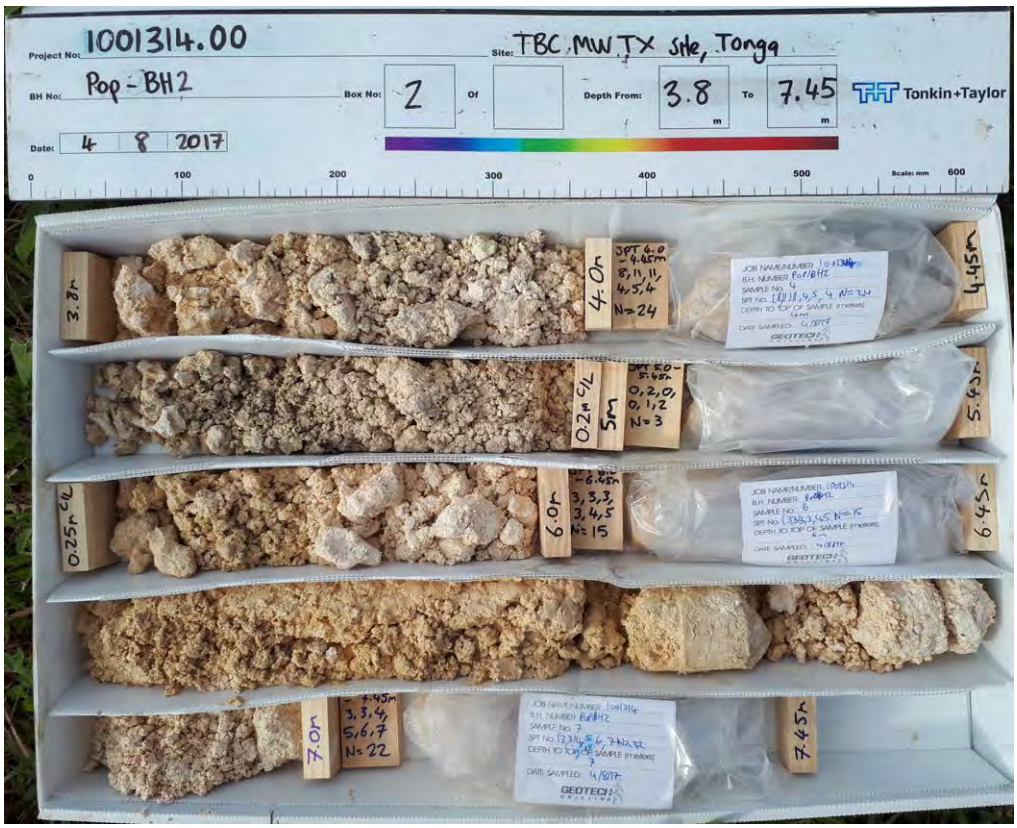
Pop-BH1_Box 3_7.45 - 9.9m.jpg



Pop-BH1_Box 4_9.9 - 12.7m.jpg

Pop-BH1_Box 5_12.7 - 15.03m.jpg

Pop-BH2_Box 1_0.0 - 4.0m.jpg



Pop-BH2_Box 2_3.8 - 7.45m.jpg

Pop-BH2_Box 3_7.45 - 10.45m.jpg

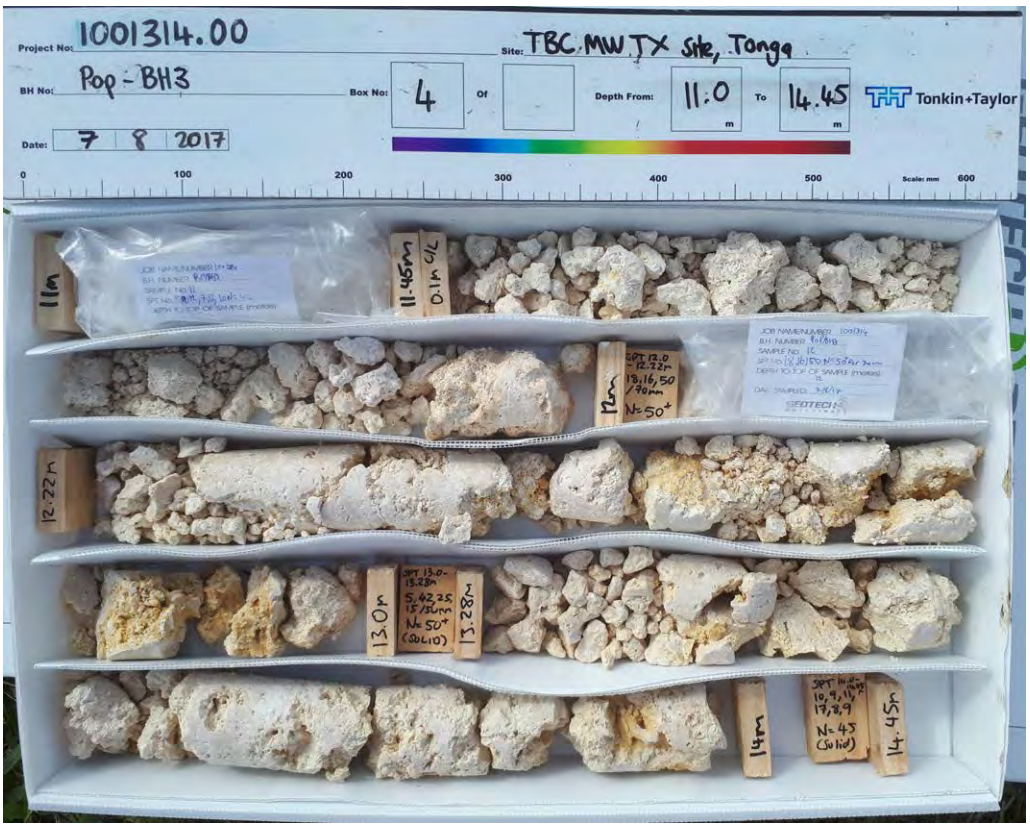
Pop-BH2_Box 4_10.45 - 14.0m.jpg

Pop-BH2_Box 5_14.0 - 15.117m.jpg

Pop-BH3_Box 1_0.0 - 3.0m.jpg

Pop-BH3_Box 2_3.0 - 7.45m.jpg

Pop-BH3_Box 3_7.45 - 11.0m.jpg



Pop-BH3_Box 4_11.0 - 14.45m.jpg

Pop-BH3_Box 5_14.45 - 15.13m.jpg

Pop-BH4_Box 1_0.0 - 3.9m.jpg

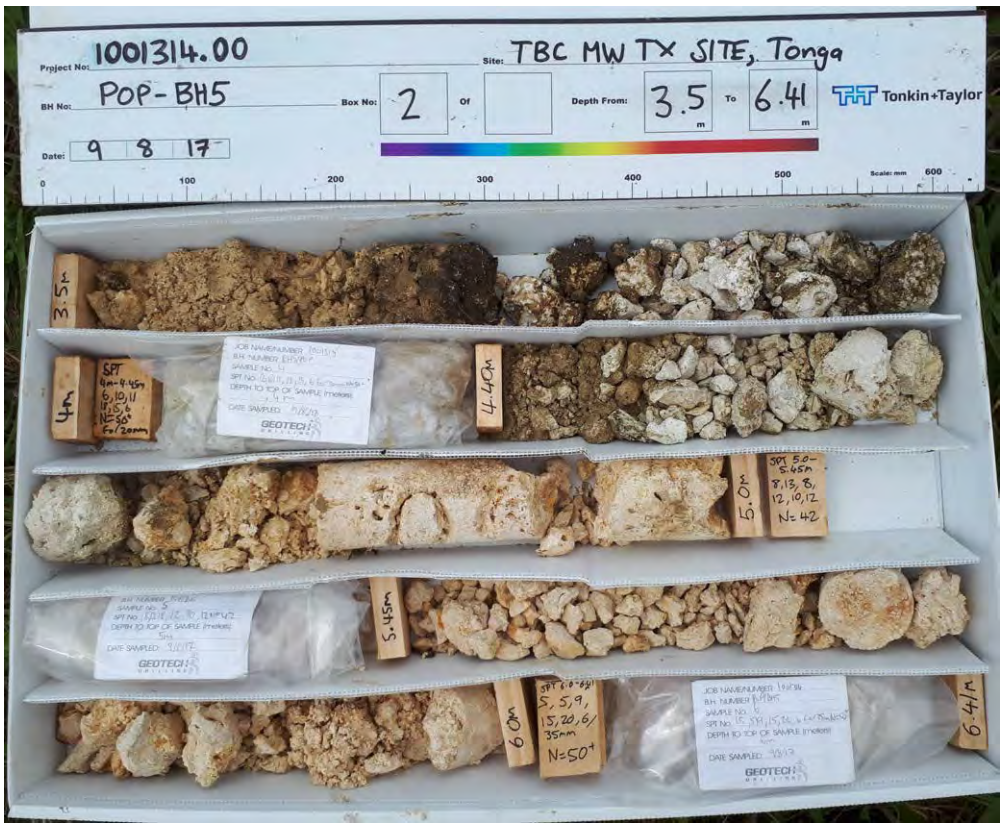
Pop-BH4_Box 2_3.9 - 7.0m.jpg

Pop-BH4_Box 3_7.0 - 11.12m.jpg

Pop-BH4_Box 4_11.12 - 14.05m.jpg

Pop-BH4_Box 5_14.05 - 15.29m.jpg

Pop-BH5_Box 1_0.0 - 3.5m.jpg



Pop-BH5_Box 2_3.5 - 6.41m.jpg

Pop-BH5_Box 3_6.41 - 9.45m.jpg

Pop-BH5_Box 4_9.45 - 12.17m.jpg

Pop-BH5_Box 5_12.17 - 15.45m.jpg

TONKIN & TAYLOR

SCALA PENETROMETER LOG

Job No: *1001314.0000*
Project: *Tonga Comms Masts*
Location: *HQ, TBC*
RL:

Date: *5/08/2017*
Operated by: *RLXB*
Logged by: *RLXB*
Checked by: *CWM*

Test No. ***HQ_SC1***

Sheet **1 of 1**

mm Driven	No. of Blows
50	1
100	1
150	2
200	1
250	1
300	1
350	1
400	2
450	2
500	2
550	2
600	2
650	3
700	4
750	4
800	2
850	2
900	8
950	10
1000	21
1050	
1100	
1150	
1200	
1250	
1300	
1350	
1400	
1450	
1500	
1550	
1600	
1650	
1700	
1750	
1800	
1850	
1900	
1950	
2000	
2050	
2100	
2150	
2200	
2250	
2300	
2350	
2400	
2450	
2500	

mm Driven	No. of Blows
2550	
2600	
2650	
2700	
2750	
2800	
2850	
2900	
2950	
3000	
3050	
3100	
3150	
3200	
3250	
3300	
3350	
3400	
3450	
3500	
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4000	
4050	
4100	
4150	
4200	
4250	
4300	
4350	
4400	
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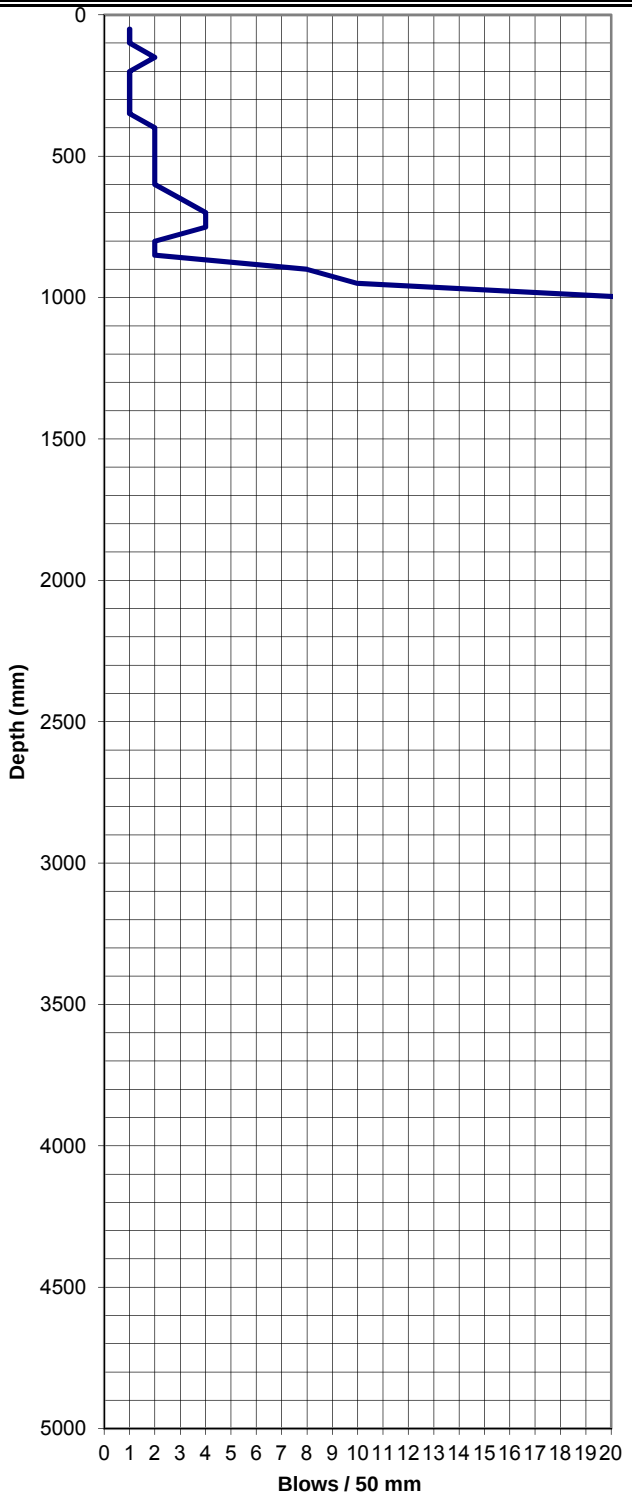

Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

TONKIN & TAYLOR

SCALA PENETROMETER LOG

Job No: *1001314.0000*
Project: *Tonga Comms Masts*
Location: *HQ, TBC*
RL:

Date: *5/08/2017*
Operated by: *RLXB*
Logged by: *RLXB*
Checked by: *CWM*

Test No. ***HQ_SC2***

Sheet **1 of 1**

mm Driven	No. of Blows
50	0.5
100	0.5
150	1
200	2
250	1
300	0.5
350	0.5
400	1
450	1
500	1
550	1
600	1
650	2
700	3
750	4
800	0.66
850	0.66
900	0.66
950	2
1000	2
1050	6
1100	6
1150	2
1200	5
1250	8
1300	11
1350	19
1400	11
1450	8
1500	10
1550	7
1600	5
1650	2
1700	4
1750	17
1800	30
1850	
1900	
1950	
2000	
2050	
2100	
2150	
2200	
2250	
2300	
2350	
2400	
2450	
2500	

mm Driven	No. of Blows
2550	
2600	
2650	
2700	
2750	
2800	
2850	
2900	
2950	
3000	
3050	
3100	
3150	
3200	
3250	
3300	
3350	
3400	
3450	
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4350	
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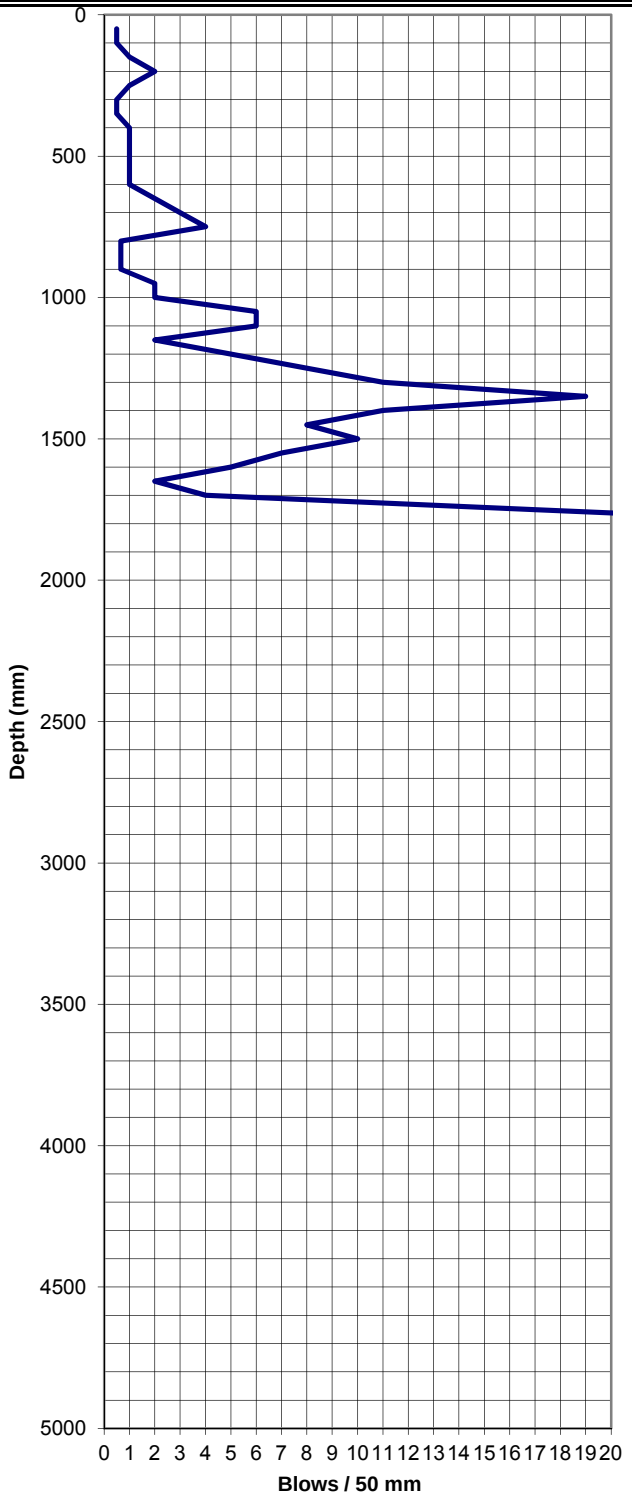
5000	



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

TONKIN & TAYLOR

SCALA PENETROMETER LOG

Job No: *1001314.0000*
Project: *Tonga Comms Masts*
Location: *HQ, TBC*
RL:

Date: *5/08/2017*
Operated by: *RLXB*
Logged by: *RLXB*
Checked by: *CWM*

Test No. *HQ_SC3*

Sheet 1 of *1*

mm Driven	No. of Blows
50	3
100	2
150	2
200	2
250	2
300	1
350	0.3
400	0.3
450	0.3
500	2
550	2
600	1
650	1
700	1
750	1
800	0.5
850	1.5
900	1
950	1
1000	1
1050	2
1100	2
1150	1
1200	2
1250	1
1300	3
1350	6
1400	5
1450	8
1500	10
1550	5
1600	2
1650	2
1700	2
1750	2
1800	1
1850	1
1900	2
1950	1
2000	1
2050	1
2100	1
2150	1
2200	1
2250	2
2300	2
2350	2
2400	1
2450	2
2500	2

mm Driven	No. of Blows
2550	6
2600	19
2650	6
2700	5
2750	8
2800	30
2850	
2900	
2950	
3000	
3050	
3100	
3150	
3200	
3250	
3300	
3350	
3400	
3450	
3500	
3550	
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3700	
3750	
3800	
3850	
3900	
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4050	
4100	
4150	
4200	
4250	
4300	
4350	
4400	
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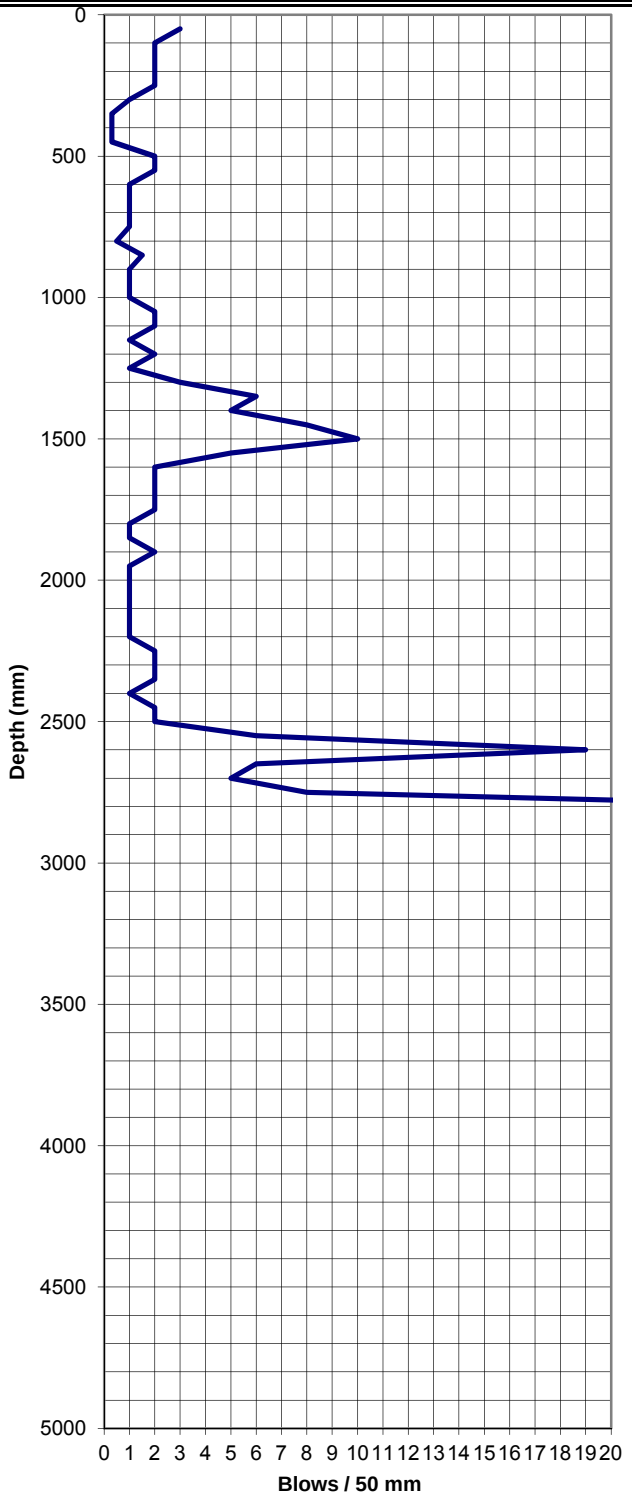

Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

TONKIN & TAYLOR

SCALA PENETROMETER LOG

Job No: *1001314.0000*
Project: *Tonga Comms Masts*
Location: *HQ, TBC*
RL:

Date: *5/08/2017*
Operated by: *RLXB*
Logged by: *RLXB*
Checked by: *CWM*

Test No. ***HQ_SC4***

Sheet **1 of 1**

mm Driven	No. of Blows
50	3
100	2
150	7
200	2
250	2
300	1
350	1
400	1
450	2
500	2
550	1
600	1
650	1
700	1
750	2
800	2
850	0.5
900	0.5
950	2
1000	1
1050	1
1100	3
1150	8
1200	13
1250	8
1300	6
1350	7
1400	4
1450	4
1500	5
1550	20
1600	30
1650	
1700	
1750	
1800	
1850	
1900	
1950	
2000	
2050	
2100	
2150	
2200	
2250	
2300	
2350	
2400	
2450	
2500	

mm Driven	No. of Blows
2550	
2600	
2650	
2700	
2750	
2800	
2850	
2900	
2950	
3000	
3050	
3100	
3150	
3200	
3250	
3300	
3350	
3400	
3450	
3500	
3550	
3600	
3650	
3700	
3750	
3800	
3850	
3900	
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4000	
4050	
4100	
4150	
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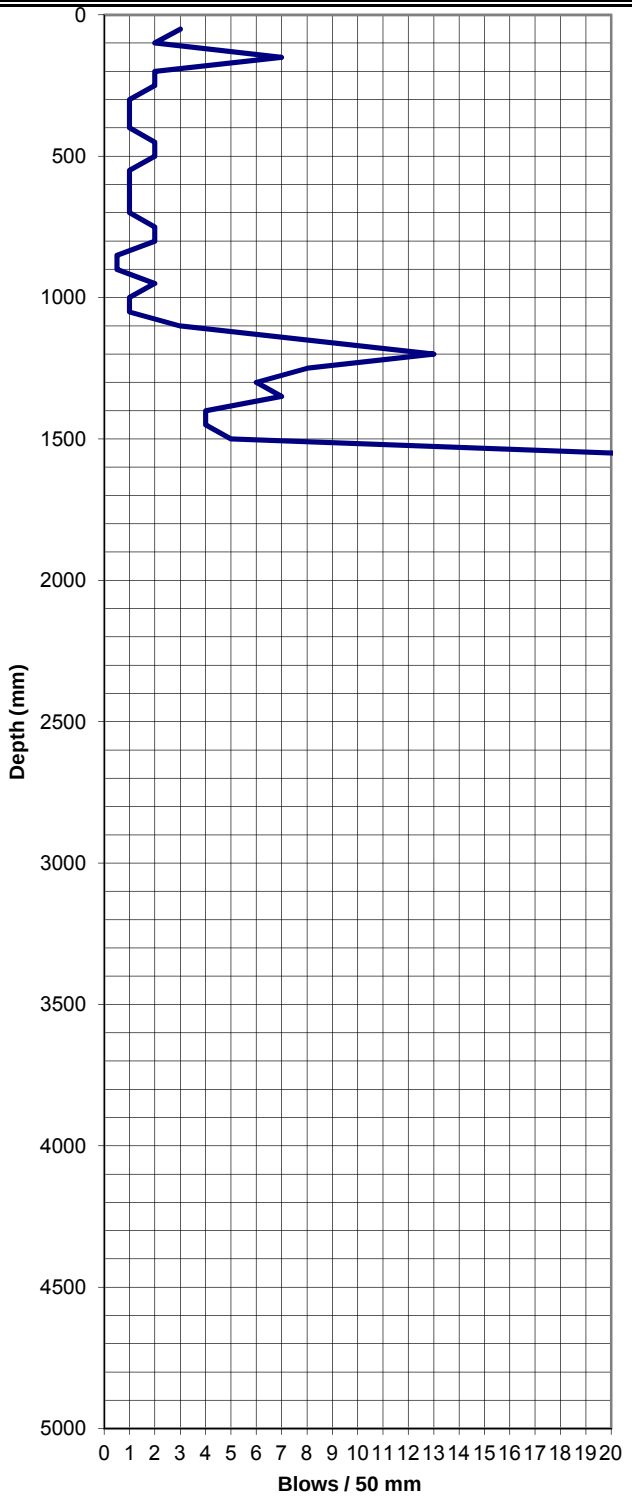

Test Method Used: NZS 4402:1988 Test 6.5.2 Dynamic Cone Penetrometer

Appendix D: Laboratory Test Results

- **Ground water Chloride Test Results:**
  - **HQ_BH1-BH2 (2 tests)**
  - **Pop_BH1-BH5 (5 tests)**
- **Water Content Test Results:**
  - **HQ_BH1-BH2 (4 tests)**
  - **Pop_BH1-BH5 (10 tests)**
- **Atterberg Limits Test Results:**
  - **Pop_BH3-BH4 (3 tests)**
- **Solid Density Test Results:**
  - **HQ_BH1-BH2 (4 tests)**
  - **Pop_BH1-BH5 (10 tests)**
- **One-Dimensional Consolidation Test Results:**
  - **Pop_BH5 (1 test)**
- **Triaxial Test Results:**
  - **Pop_BH3 (1 test)**
- **Unconfined Compressive Strength Test Results:**
  - **Pop_BH2-BH5 (6 tests)**
- **Particle Size Distribution Test Results:**
  - **HQ_BH1-BH2 (4 tests)**
  - **Pop_BH1-BH5 (10 tests)**

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ANALYSIS REPORT

Client:	Tonkin & Taylor	**Lab No:**	1840594	SPv1
Contact:	Richard Bond	**Date Received:**	09-Sep-2017	
	C/- Tonkin & Taylor	**Date Reported:**	18-Sep-2017	
	PO Box 5271	**Quote No:**	80842	
	Auckland 1141	**Order No:**	1001314.0000	
		Client Reference:	1001314.0000	
		Submitted By:	Richard Bond	

Sample Type: Aqueous

Sample Name:		HQ-BH1 10-Aug-2017	HQ-BH2 10-Aug-2017	POP-BH1 09-Aug-2017	POP-BH2 10-Aug-2017	POP-BH3 10-Aug-2017
Lab Number:		1840594.1	1840594.2	1840594.3	1840594.4	1840594.5
Chloride	g/m³	1,930	1,760	520	1,360	1,890

Sample Name:		POP-BH4 10-Aug-2017	POP-BH5 10-Aug-2017			
Lab Number:		1840594.6	1840594.7			
Chloride	g/m³	600	7,200	-	-	-

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-7
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m³	1-7

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

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ANALYSIS REPORT

Client:	Tonkin & Taylor	**Lab No:**	1840594	SUPv1
Contact:	Richard Bond	**Date Received:**	09-Sep-2017	
	C/- Tonkin & Taylor	**Date Reported:**	18-Sep-2017	
	PO Box 5271	**Quote No:**	80842	
	Auckland 1141	**Order No:**	1001314.0000	
		Client Reference:	1001314.0000	
		Submitted By:	Richard Bond	

Sample Type: Aqueous

Sample Name:		HQ-BH1 10-Aug-2017	HQ-BH2 10-Aug-2017	POP-BH1 09-Aug-2017	POP-BH2 10-Aug-2017
Lab Number:		1840594.1	1840594.2	1840594.3	1840594.4
Chloride	g/m³	1,930 ± 120	1,760 ± 110	524 ± 32	1,355 ± 82

Sample Name:		POP-BH3 10-Aug-2017	POP-BH4 10-Aug-2017	POP-BH5 10-Aug-2017	
Lab Number:		1840594.5	1840594.6	1840594.7	
Chloride	g/m³	1,890 ± 120	602 ± 37	7,170 ± 440	-

The reported uncertainty is an expanded uncertainty with a level of confidence of approximately 95 percent (i.e. two standard deviations, calculated using a coverage factor of 2). Reported uncertainties are calculated from the performance of typical matrices, and do not include variation due to sampling.

For further information on uncertainty of measurement at Hill Laboratories, refer to the technical note on our website: www.hill-laboratories.com/files/Intro_To_UOM.pdf, or contact the laboratory.

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-7
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m³	1-7

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

Our Ref: 1004231.0000.0.0/Rep 1
Customer Ref: 1001314.0000
11 October 2017

Tonkin & Taylor
PO Box 5271, Wellesley Street, Auckland 1141

Attention: Mr Andy Pomfret

Dear Andy

TBC HQ, Nuku'alofa, Tonga

TBC MW TX, Popua, Nuku'alofa, Tonga

Laboratory Test Report

Samples from the above mentioned site have been tested as received and according to your instructions. Test results are included in this report.

Samples were destroyed during testing.

Descriptions are enclosed for your information, but are not covered under the IANZ endorsement of this report.

Please reproduce this report in full when transmitting to others or including in internal reports.

If we can be of any further assistance, feel free to get in touch. Contact details are provided at the bottom of this page.

GEOTECHNICS LTD

Report prepared by:

Sim Tirunahari
I am the author of this document
2017.10.11 11:56:46 +13'00'

.....
Sim Tirunahari
Soils Laboratory Manager

Authorised for Geotechnics by:

Vic O'Connor
I am approving this document
2017.10.11 12:26:56 +13'00'

.....
Vic O'Connor
Project Director
Approved Signatory

Report checked by:

Vic O'Connor
I have reviewed this document
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.....
Vic O'Connor
Managing Director
Approved Signatory

This document consists of 27 pages

11-Oct-17

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File: T:Geotechnics Group\Projects\1004231\Working Material\HQ_Water Content Summary.xlsx

Site : TBC HQ, Nuku'alofa, Tonga

Your Job No.: **1001314**

Our Job No.: **1004231.0000.0.0**

Test Method Used: NZS 4402:1986 **Test 2.1 Determination of the Water Content**

TEST RESULTS

Water Content Test Results Summary:

BH No.:		HQ - BH1	HQ - BH1	HQ - BH2	HQ - BH2
Depth	(m)	**4.0**	**7.0**	**1.0**	**10.0**
Water Content	%	**16.0**	**22.0**	**33.1**	**18.4**

Remarks :

The material used for testing was natural.

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File: T:Geotechnics Group\Projects\1004231\Working Material\POP_Water Content Summary.xlsx

Site : TBC MW TX, Popua, Nuku'alofa, Tonga

Your Job No.: **1001314**

Our Job No.: **1004231.0000.0.0**

Test Method Used: NZS 4402:1986 **Test 2.1 Determination of the Water Content**

TEST RESULTS

Water Content Test Results Summary

Table 1:

BH No.:		POP - BH1	POP - BH1	POP - BH2	POP - BH2	POP - BH3	POP - BH3
Depth	(m)	3.0	8.0	5.0	10.0	2.0	10.0
Water Content	%	23.3	39.0	41.8	31.6	60.2	14.8

Table 2:

BH No.:		POP - BH4	POP - BH4	POP - BH5	POP - BH5
Depth	(m)	1.0	12.0	1.0	6.0
Water Content	%	72.8	15.2	15.1	14.3

Remarks :

The material used for testing was natural.

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File: T:Geotechnics Group\Projects\1004231.0000\Working Material\Atterberg Limits Summary.xlsx

Your Job No.: **1001314**

Site : TBC MW TX, Popua, Nuku'alofa, Tonga

Our Job No.: **1004231.0000.0.0**

Test Method Used: NZS 4402:1986

Test 2.2 Determination of the Liquid Limit

Test 2.3 Determination of the Plastic Limit

Test 2.4 Determination of the Plasticity Index

TEST RESULTS

Atterberg Limits Test Results Summary

Table 1:

BH No.:		**POP BH3**	**POP BH4**	**POP BH4**
Depth	(m)	**2.60-2.75**	**2.80-2.95**	**3.0**
Liquid Limit		**104**	**106**	**106**
Plastic Limit		**52**	**50**	**51**
Plasticity Index		**52**	**56**	**55**

Remarks : The material used for testing was natural, fraction passing a 0.425mm test sieve.

The test results are IANZ accredited.

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File: T:Geotechnics Group\Projects\1004231\Working Material\HQ_Solid density summary.xlsx

Site : TBC HQ, Nuku'alofa, Tonga

Your Ref No.: 1001314

Our Job No.: 1004231.0000.0.0

Test Method Used:NZS 4402:1986 Test 2.7.1 Determination of Solid Density of Soil Particles - Pycnometer Method

SOLID DENSITY TEST RESULTS

Table 1: Solid Density

Borehole No.:		HQ-BH1	HQ-BH1	HQ-BH2	HQ-BH2
Sample ID.:		SPT	SPT	SPT	SPT
Depth	(m)	2.0	9.0	4.0	7.0
*Solid Density	(t/m^3)	2.49	2.51	2.46	2.48

Remarks : The material used for testing was natural, whole soil.

*As per the standard, two specimens are required to perform a solid density, but due to insufficient SPT sample mass obtained, it was performed on a single specimen as directed by the engineer. Therefore the test results are not IANZ accredited.

Entered by: JK Date: 11/10/2017 Checked by: ST Date: 11/10/2017

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File: T:Geotechnics Group\Projects\1004231\Working Material\POP_Solid density summary.xlsx

Site : TBC MW TX, Popua, Nuku'alofa, Tonga

Your Ref No.: 1001314

Our Job No.: 1004231.0000.0.0

Test Method Used:NZS 4402:1986 Test 2.7.1 Determination of Solid Density of Soil Particles - Pycnometer Method

SOLID DENSITY TEST RESULTS

Table 1: Solid Density

Borehole No.:		POP-BH1	POP-BH1	POP-BH2	POP-BH2	POP-BH3	POP-BH3
Sample ID.:		SPT	SPT	SPT	SPT	SPT	SPT
Depth	(m)	5.0	12.0	2.0	13.0	4.0	9.0
*Solid Density	(t/m^3)	2.53	2.53	2.65	2.56	2.47	2.54

Table 2: Solid Density

Borehole No.:		POP-BH4	POP-BH4	POP-BH5	POP-BH5
Sample ID.:		SPT	SPT	SPT	SPT
Depth	(m)	8.0	10.0	4.0	11.0
*Solid Density	(t/m^3)	2.47	2.47	2.55	2.60

Remarks : The material used for testing was natural, whole soil.

*As per the standard, two specimens are required to perform a solid density, but due to insufficient SPT sample mass obtained, it was performed on a single specimen as directed by the engineer. Therefore the test results are not IANZ accredited.

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File:T:\Geotechnics\Geogit\1004231\Working Material\HQ_BH1_3.0m_Wet Sieve Summary.xlsx

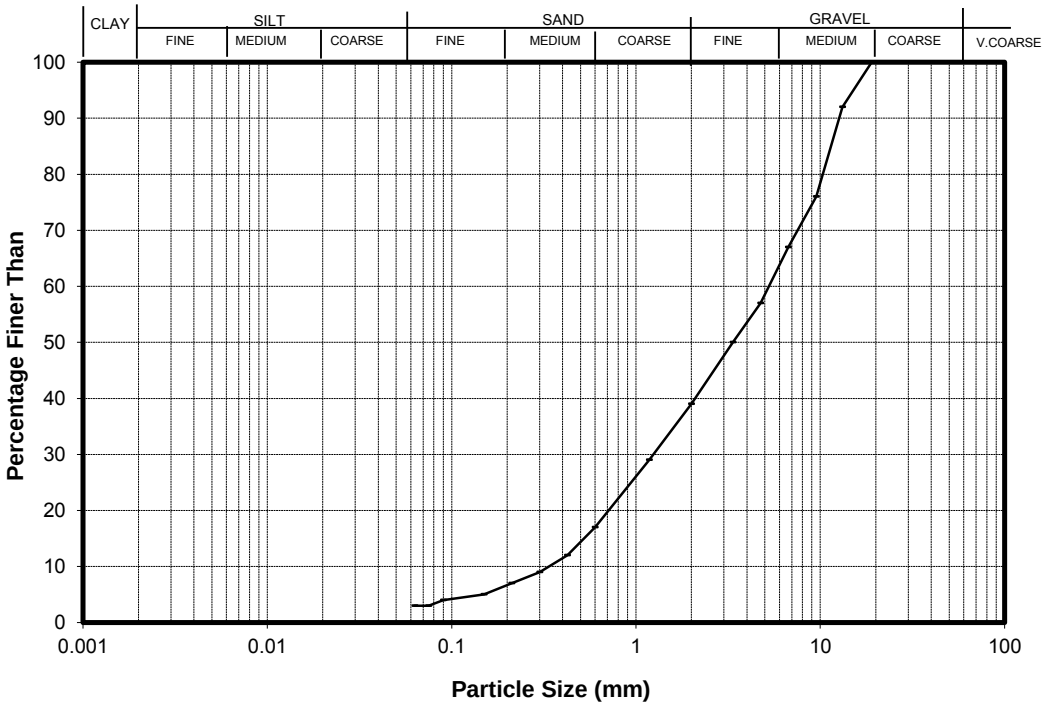
Your Job No.: **1001314**

Site : **TBC HQ, Nuku'alofa, Tonga**
Our Job No.: **1004231.0000.0.0**

BH No.: **HQ-BH1** Sample ID.: **SPT** Depth (m): **3.0**

Test Method Used : NZS 4402:1986 Test 2.8.1 Wet Sieve

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing	Sieve (mm)	Total % Passing
26.5	---	0.425	12
19.0	100	0.300	9
13.2	92	0.212	7
9.50	76	0.150	5
6.70	67	0.090	4
4.75	57	0.075	3
3.35	50	0.063	3
2.00	39		
1.18	29		
0.600	17		

Sample history : As received

Description : CORAL - sandy GRAVEL with trace of silt, loose, white-light yellow, mottled orange.

Remarks : The wet sieve sample was washed over 0.063mm test sieve, until the individual particles were clean. The material retained on 0.063mm test sieve was oven dried and dry sieved.

The minimum mass of sample required for sieving is 2.0 kg, but due to insufficient SPT sample mass the sieving was carried out on ~ 0.35 kg.

The sample description and test results are not IANZ accredited.

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File:T:\Geotechnics\Geogit\1004231\Working Material\HQ_BH1_12.0m_Wet Sieve Summary.xlsx

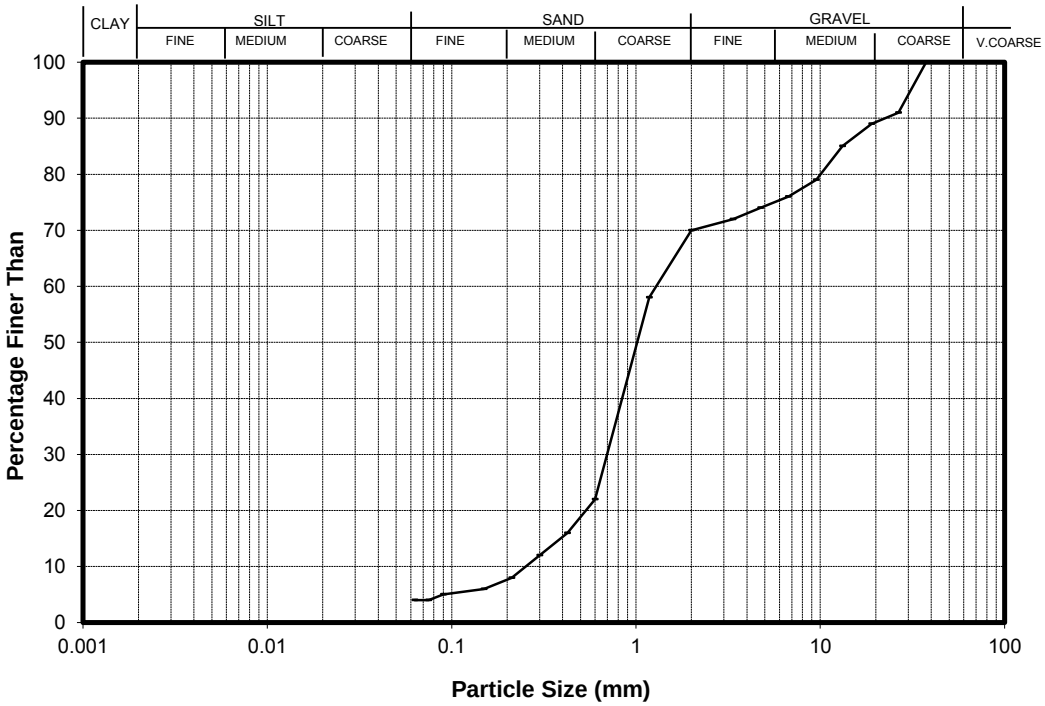
Your Job No.: **1001314**

Site : **TBC HQ, Nuku'alofa, Tonga**
Our Job No.: **1004231.0000.0.0**

BH No.: **HQ-BH1** Sample ID.: **SPT** Depth (m): **12.0**

Test Method Used : NZS 4402:1986 Test 2.8.1 Wet Sieve

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing	Sieve (mm)	Total % Passing
37.5	100	0.600	22
26.5	91	0.425	16
19.0	89	0.300	12
13.2	85	0.212	8
9.50	79	0.150	6
6.70	76	0.090	5
4.75	74	0.075	4
3.35	72	0.063	4
2.00	70		
1.18	58		

Sample history : As received

Description : CORAL - gravelly SAND with trace of silt, loose, white-light yellow, mottled orange.

Remarks : The wet sieve sample was washed over 0.063mm test sieve, until the individual particles were clean. The material retained on 0.063mm test sieve was oven dried and dry sieved.

The minimum mass of sample required for sieving is 15.0 kg, but due to insufficient SPT sample mass the sieving was carried out on ~ 0.37 kg.

The sample description and test results are not IANZ accredited.

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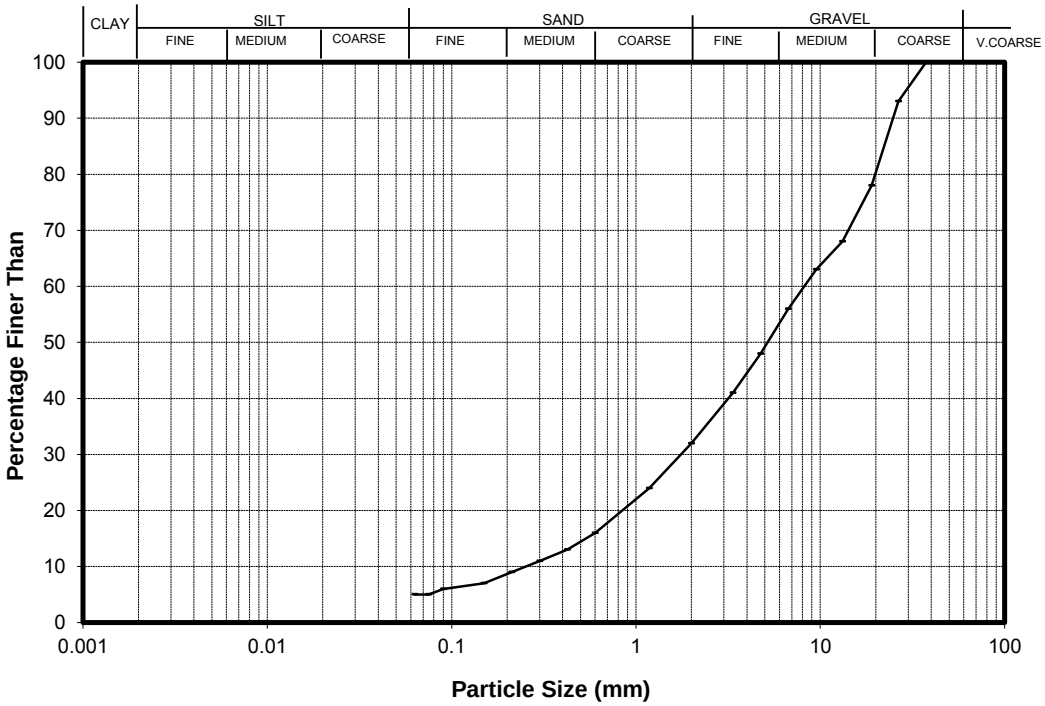
Your Job No.: **1001314**

Site : **TBC HQ, Nuku'alofa, Tonga**
Our Job No.: **1004231.0000.0.0**

BH No.: **HQ-BH2** Sample ID.: **SPT** Depth (m): **5.0**

Test Method Used : NZS 4402:1986 Test 2.8.1 Wet Sieve

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing	Sieve (mm)	Total % Passing
37.5	100	0.600	16
26.5	93	0.425	13
19.0	78	0.300	11
13.2	68	0.212	9
9.50	63	0.150	7
6.70	56	0.090	6
4.75	48	0.075	5
3.35	41	0.063	5
2.00	32		
1.18	24		

Sample history : As received

Description : CORAL - sandy GRAVEL with trace of silt, loose, white-light yellow, mottled orange.

Remarks : The wet sieve sample was washed over 0.063mm test sieve, until the individual particles were clean. The material retained on 0.063mm test sieve was oven dried and dry sieved.

The minimum mass of sample required for sieving is 15.0 kg, but due to insufficient SPT sample mass the sieving was carried out on ~ 0.46 kg.

The sample description and test results are not IANZ accredited.

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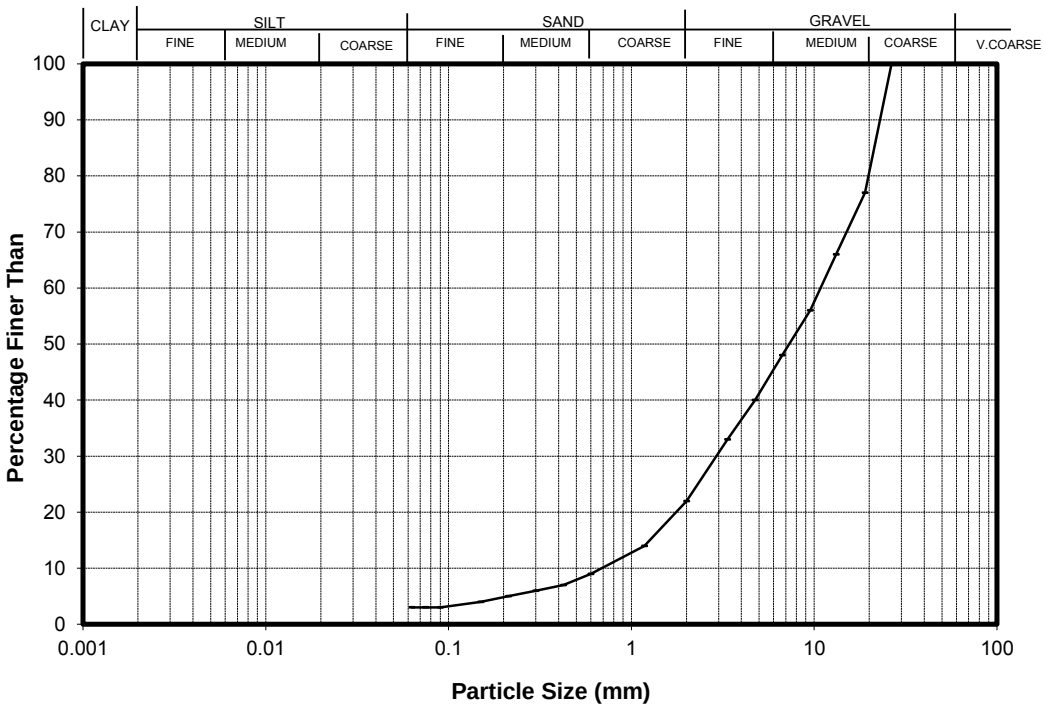
File:T:\Geotechnics\Geogit\1004231\Working Material\HQ_BH2_8.0m_Wet Sieve Summary.xlsx

Your Job No.: **1001314**
Our Job No.: **1004231.0000.0.0**

Site : **TBC HQ, Nuku'alofa, Tonga**
BH No.: **HQ-BH 2** Sample ID.: **SPT** Depth (m): **8.0**
Test Method Used : NZS 4402:1986 Test 2.8.1 Wet Sieve

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing	Sieve (mm)	Total % Passing
26.5	100	0.425	7
19.0	77	0.300	6
13.2	66	0.212	5
9.50	56	0.150	4
6.70	48	0.090	3
4.75	40	0.075	3
3.35	33	0.063	3
2.00	22		
1.18	14		
0.600	9		

Sample history : As received

Description : CORAL - GRAVEL with some sand and trace of silt, loose, white, mottled orange.

Remarks : The wet sieve sample was washed over 0.063mm test sieve, until the individual particles were clean. The material retained on 0.063mm test sieve was oven dried and dry sieved.

The minimum mass of sample required for sieving is 5.0 kg, but due to insufficient SPT sample mass the sieving was carried out on ~ 0.2 kg.

The sample description and test results are not IANZ accredited.

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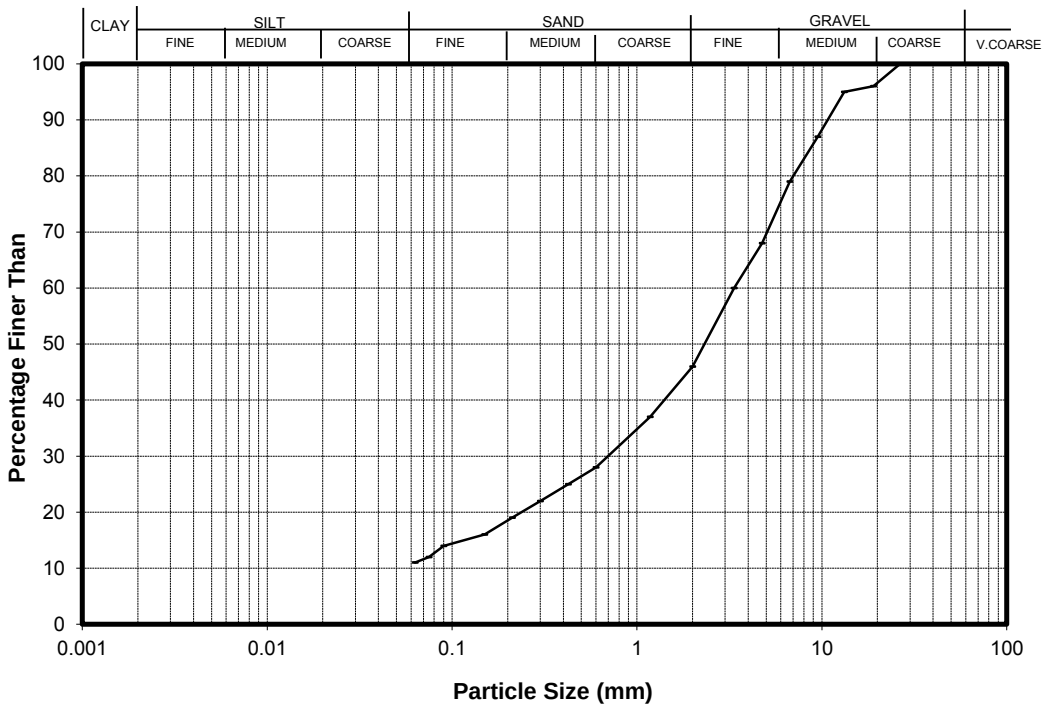
File:T:\Geotechnics\Geogit\1004231\Working Material\POP_BH1_6.0m_Wet Sieve Summary.xlsx

Your Job No.: **1001314**

Site : **TBC MW TX, Popua, Nuku'alofa, Tonga**
Our Job No.: **1004231.0000.0.0**
BH No.: **POP-BH 1** Sample ID.: **SPT**
Depth (m): **6.0**
Test Method Used : NZS 4402:1986 Test 2.8.1 Wet Sieve

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing	Sieve (mm)	Total % Passing
26.5	100	0.425	25
19.0	96	0.300	22
13.2	95	0.212	19
9.50	87	0.150	16
6.70	79	0.090	14
4.75	68	0.075	12
3.35	60	0.063	11
2.00	46		
1.18	37		
0.600	28		

Sample history : As received

Description : CORAL - sandy GRAVEL with minor silt, loose, white-light yellow, mottled orange.

Remarks : The wet sieve sample was washed over 0.063mm test sieve, until the individual particles were clean. The material retained on 0.063mm test sieve was oven dried and dry sieved.

The minimum mass of sample required for sieving is 5.0 kg, but due to insufficient SPT sample mass the sieving was carried out on ~ 0.41 kg.

The sample description and test results are not IANZ accredited.

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File:T:\Geotechnics\Geogit\1004231\Working Material\POP_BH1_13.0m_Wet Sieve Summary.xlsx

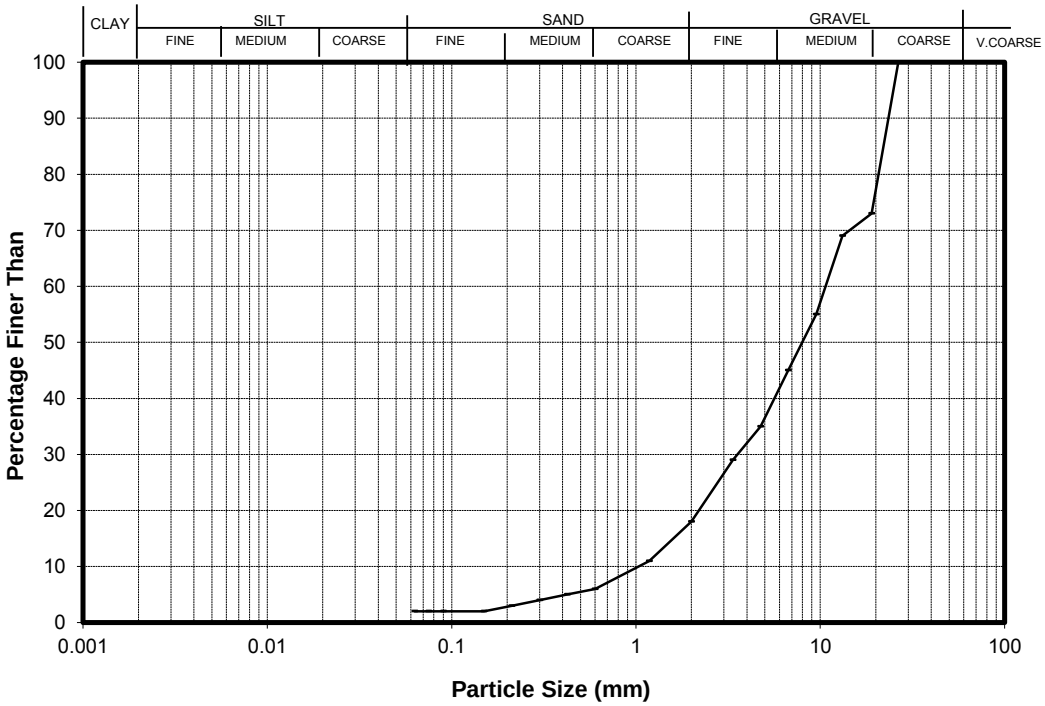
Your Job No.: **1001314**

Site : **TBC MW TX, Popua, Nuku'alofa, Tonga** Our Job No.: **1004231.0000.0.0**

BH No.: **POP-BH 1** Sample ID: **SPT** Depth (m): **13.0**

Test Method Used : NZS 4402:1986 Test 2.8.1 Wet Sieve

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing	Sieve (mm)	Total % Passing
26.5	100	0.425	5
19.0	73	0.300	4
13.2	69	0.212	3
9.50	55	0.150	2
6.70	45	0.090	2
4.75	35	0.075	2
3.35	29	0.063	2
2.00	18		
1.18	11		
0.600	6		

Sample history : As received

Description : CORAL - GRAVEL with some sand and trace of silt, loose, white, mottled orange.

Remarks : The wet sieve sample was washed over 0.063mm test sieve, until the individual particles were clean. The material retained on 0.063mm test sieve was oven dried and dry sieved.

The minimum mass of sample required for sieving is 5.0 kg, but due to insufficient SPT sample mass the sieving was carried out on ~ 0.18 kg.

The sample description and test results are not IANZ accredited.

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File:T:\Geotechnics\Geogit\1004231\Working Material\POP_BH2_3.0m_Wet Sieve Summary.xlsx

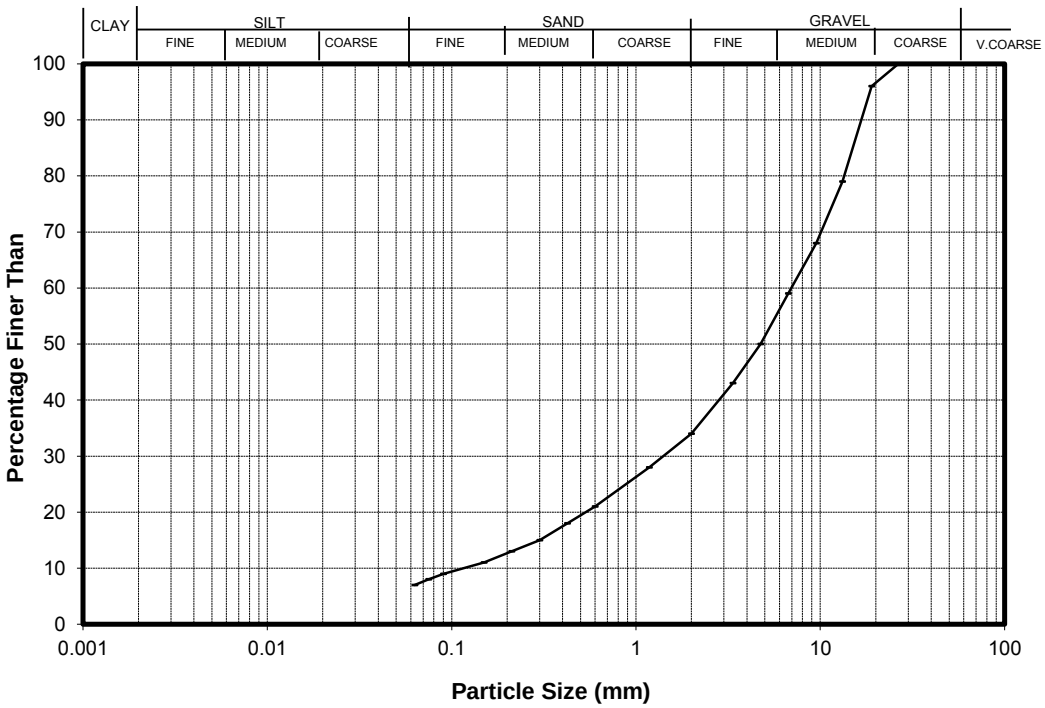
Your Job No.: **1001314**

Site : **TBC MW TX, Popua, Nuku'alofa, Tonga**
Our Job No.: **1004231.0000.0.0**

BH No.: **POP-BH 2** Sample ID.: **SPT**
Depth (m): **3.0**

Test Method Used : NZS 4402:1986 Test 2.8.1 Wet Sieve

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing	Sieve (mm)	Total % Passing
26.5	100	0.425	18
19.0	96	0.300	15
13.2	79	0.212	13
9.50	68	0.150	11
6.70	59	0.090	9
4.75	50	0.075	8
3.35	43	0.063	7
2.00	34		
1.18	28		
0.600	21		

Sample history : As received

Description : CORAL - sandy GRAVEL with minor silt, loose, white-light yellow, mottled orange.

Remarks : The wet sieve sample was washed over 0.063mm test sieve, until the individual particles were clean. The material retained on 0.063mm test sieve was oven dried and dry sieved.

The minimum mass of sample required for sieving is 5.0 kg, but due to insufficient SPT sample mass the sieving was carried out on ~ 0.52 kg.

The sample description and test results are not IANZ accredited.

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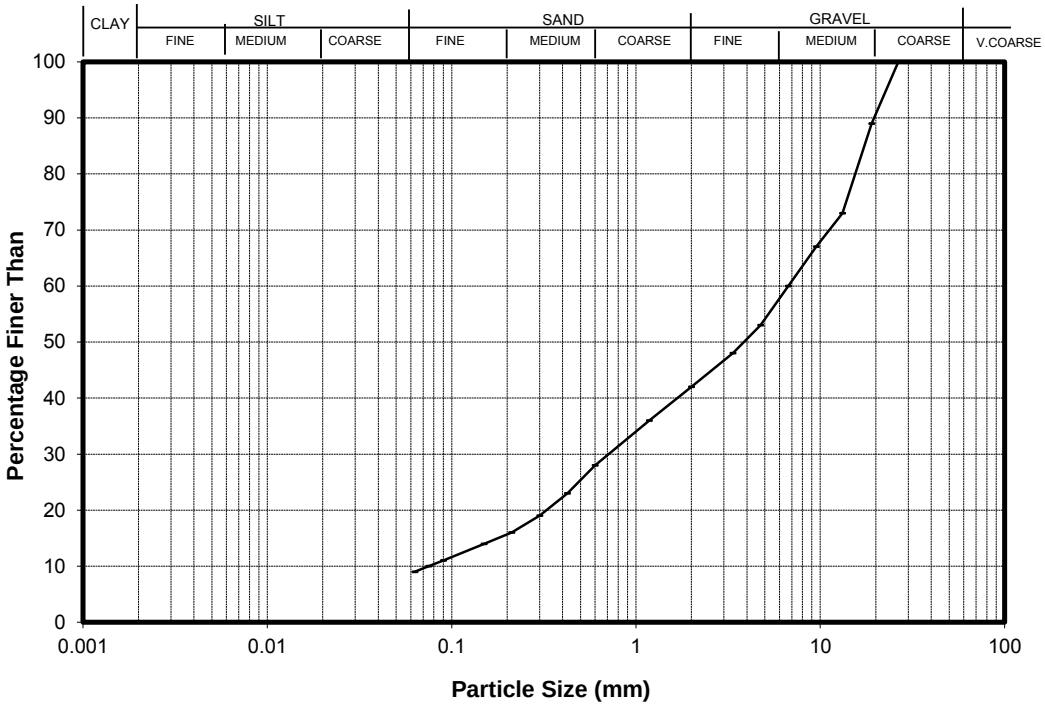
File:T:\Geotechnics\Geogit\1004231\Working Material\POP_BH2_9.0m_Wet Sieve Summary.xlsx

Your Job No.: **1001314**
Our Job No.: **1004231.0000.0.0**

Site : **TBC MW TX, Popua, Nuku'alofa, Tonga**
BH No.: **POP-BH 2** Sample ID.: **SPT**
Depth (m): **9.0**
Test Method Used : NZS 4402:1986 Test 2.8.1 Wet Sieve

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing	Sieve (mm)	Total % Passing
26.5	100	0.425	23
19.0	89	0.300	19
13.2	73	0.212	16
9.50	67	0.150	14
6.70	60	0.090	11
4.75	53	0.075	10
3.35	48	0.063	9
2.00	42		
1.18	36		
0.600	28		

Sample history : As received

Description : CORAL - sandy GRAVEL with minor silt, loose, white-light yellow, mottled orange.

Remarks : The wet sieve sample was washed over 0.063mm test sieve, until the individual particles were clean. The material retained on 0.063mm test sieve was oven dried and dry sieved.

The minimum mass of sample required for sieving is 5.0 kg, but due to insufficient SPT sample mass the sieving was carried out on ~ 0.42 kg.

The sample description and test results are not IANZ accredited.

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File:T:\Geotechnics\Geop\1004231\Working Material\POP_BH3_6.0m_Wet Sieve Summary.xlsx

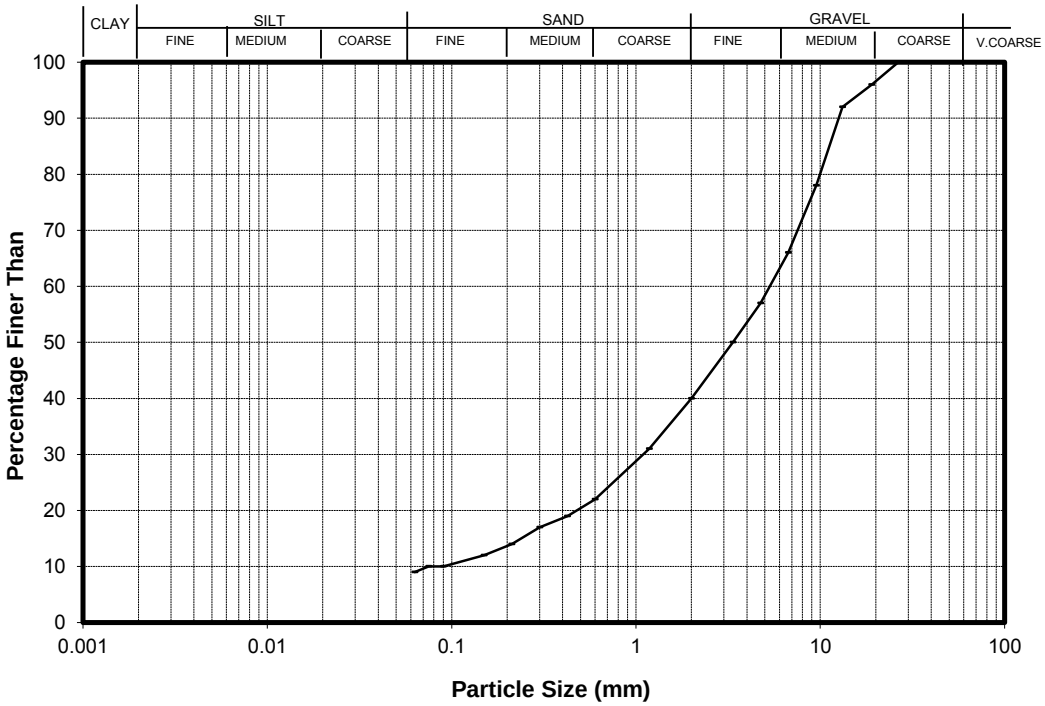
Your Job No.: **1001314**

Site : **TBC MW TX, Popua, Nuku'alofa, Tonga** Our Job No.: **1004231.0000.0.0**

BH No.: **POP-BH 3** Sample ID.: **SPT** Depth (m): **6.0**

Test Method Used : NZS 4402:1986 Test 2.8.1 Wet Sieve

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing	Sieve (mm)	Total % Passing
26.5	100	0.425	19
19.0	96	0.300	17
13.2	92	0.212	14
9.50	78	0.150	12
6.70	66	0.090	10
4.75	57	0.075	10
3.35	50	0.063	9
2.00	40		
1.18	31		
0.600	22		

Sample history : As received

Description : CORAL - sandy GRAVEL with minor silt, loose, white-light yellow, mottled orange.

Remarks : The wet sieve sample was washed over 0.063mm test sieve, until the individual particles were clean. The material retained on 0.063mm test sieve was oven dried and dry sieved.

The minimum mass of sample required for sieving is 5.0 kg, but due to insufficient SPT sample mass the sieving was carried out on ~ 0.31 kg.

The sample description and test results are not IANZ accredited.

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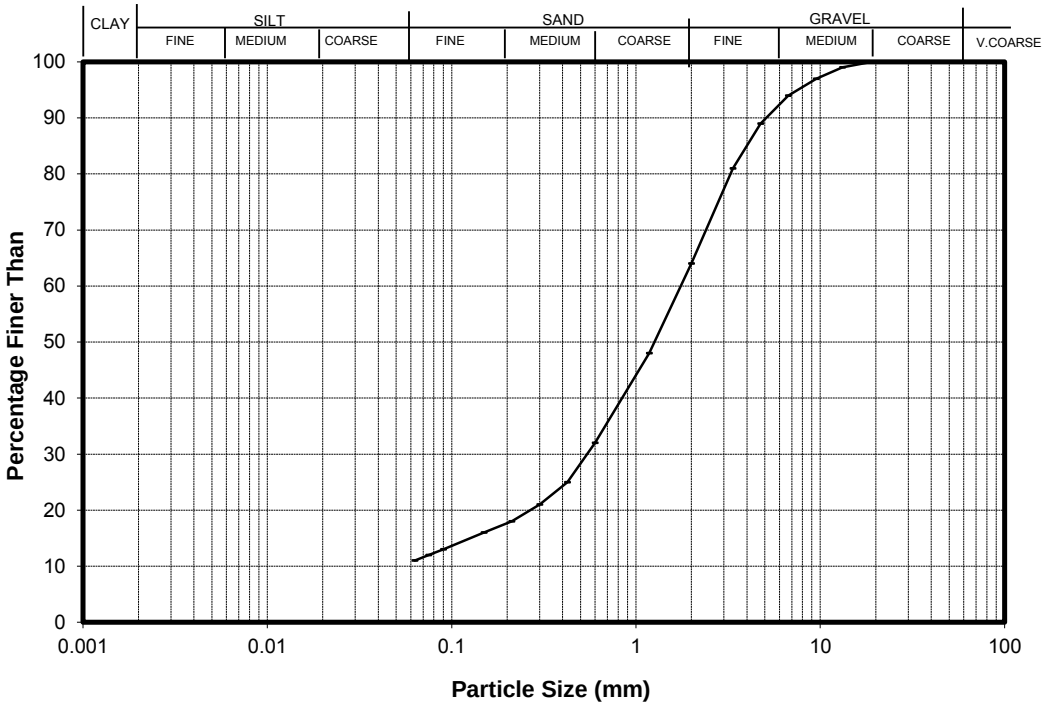
Your Job No.: **1001314**
Our Job No.: **1004231.0000.0.0**

Site : **TBC MW TX, Popua, Nuku'alofa, Tonga**
BH No.: **POP-BH 3** Sample ID.: **SPT** Depth (m): **8.0**
Test Method Used : NZS 4402:1986 Test 2.8.1 Wet Sieve

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing	Sieve (mm)	Total % Passing
26.5	---	0.425	25
19.0	100	0.300	21
13.2	99	0.212	18
9.50	97	0.150	16
6.70	94	0.090	13
4.75	89	0.075	12
3.35	81	0.063	11
2.00	64		
1.18	48		
0.600	32		

Sample history : As received

Description : CORAL - gravelly SAND with minor silt, loose, white, mottled orange.

Remarks : The wet sieve sample was washed over 0.063mm test sieve, until the individual particles were clean. The material retained on 0.063mm test sieve was oven dried and dry sieved.

The minimum mass of sample required for sieving is 2.0 kg, but due to insufficient SPT sample mass the sieving was carried out on ~ 0.44 kg.

The sample description and test results are not IANZ accredited.

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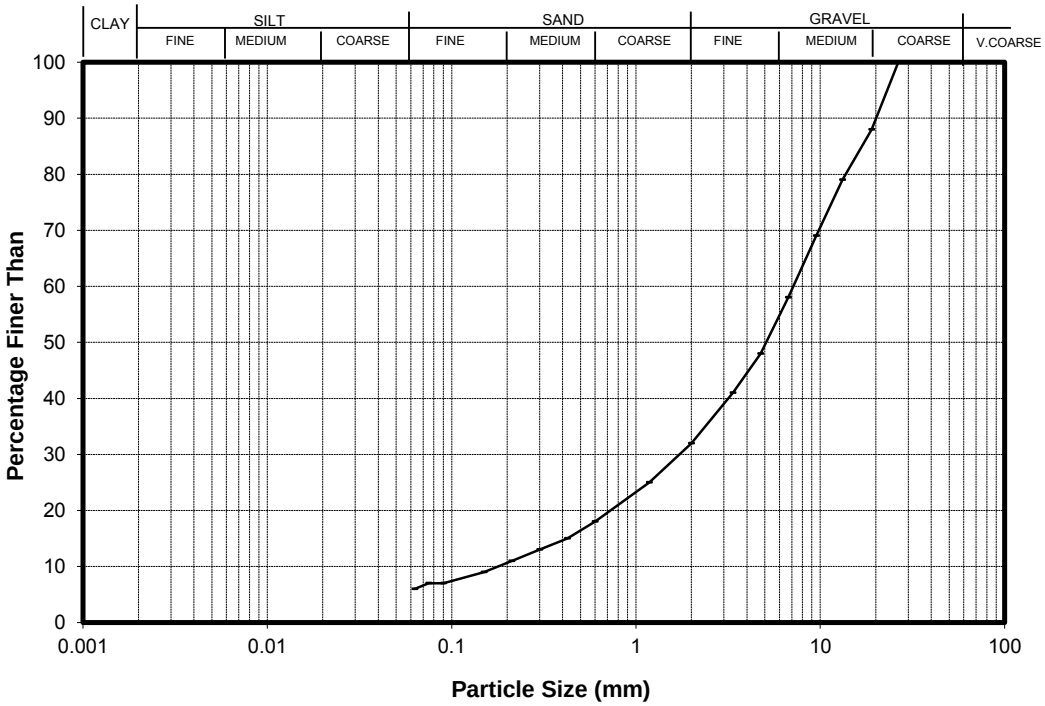
Your Job No.: **1001314**

Site : **TBC MW TX, Popua, Nuku'alofa, Tonga** Our Job No.: **1004231.0000.0.0**

BH No.: **POP-BH 4** Sample ID.: **SPT** Depth (m): **6.0**

Test Method Used : NZS 4402:1986 Test 2.8.1 Wet Sieve

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing	Sieve (mm)	Total % Passing
26.5	100	0.425	15
19.0	88	0.300	13
13.2	79	0.212	11
9.50	69	0.150	9
6.70	58	0.090	7
4.75	48	0.075	7
3.35	41	0.063	6
2.00	32		
1.18	25		
0.600	18		

Sample history : As received

Description : CORAL - sandy GRAVEL with minor silt, loose, white-light yellow, mottled orange.

Remarks : The wet sieve sample was washed over 0.063mm test sieve, until the individual particles were clean. The material retained on 0.063mm test sieve was oven dried and dry sieved.

The minimum mass of sample required for sieving is 5.0 kg, but due to insufficient SPT sample mass the sieving was carried out on ~ 0.46 kg.

The sample description and test results are not IANZ accredited.

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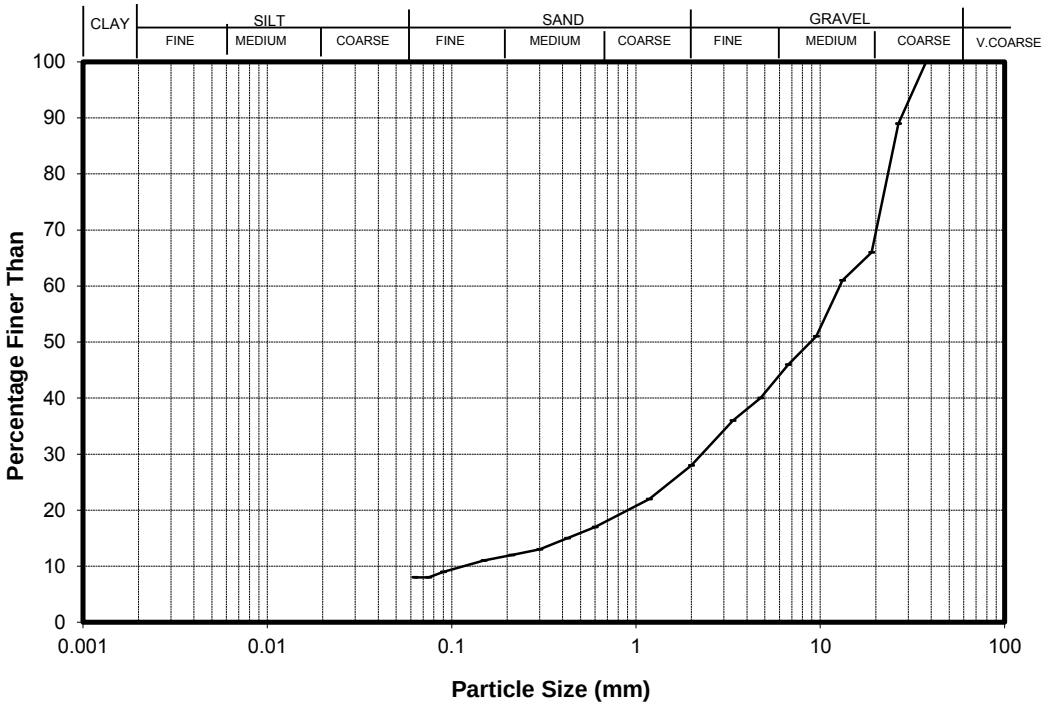
Your Job No.: **1001314**
Our Job No.: **1004231.0000.0.0**

Site : **TBC MW TX, Popua, Nuku'alofa, Tonga**
BH No.: **POP-BH 4** Sample ID.: **SPT** Depth (m): **11.0**
Test Method Used : NZS 4402:1986 Test 2.8.1 Wet Sieve

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing	Sieve (mm)	Total % Passing
37.5	100	0.600	17
26.5	89	0.425	15
19.0	66	0.300	13
13.2	61	0.212	12
9.50	51	0.150	11
6.70	46	0.090	9
4.75	40	0.075	8
3.35	36	0.063	8
2.00	28		
1.18	22		

Sample history : As received

Description : CORAL - sandy GRAVEL with minor silt, loose, white-light yellow, mottled orange.

Remarks : The wet sieve sample was washed over 0.063mm test sieve, until the individual particles were clean. The material retained on 0.063mm test sieve was oven dried and dry sieved.

The minimum mass of sample required for sieving is 15.0 kg, but due to insufficient SPT sample mass the sieving was carried out on ~ 0.26 kg.

The sample description and test results are not IANZ accredited.

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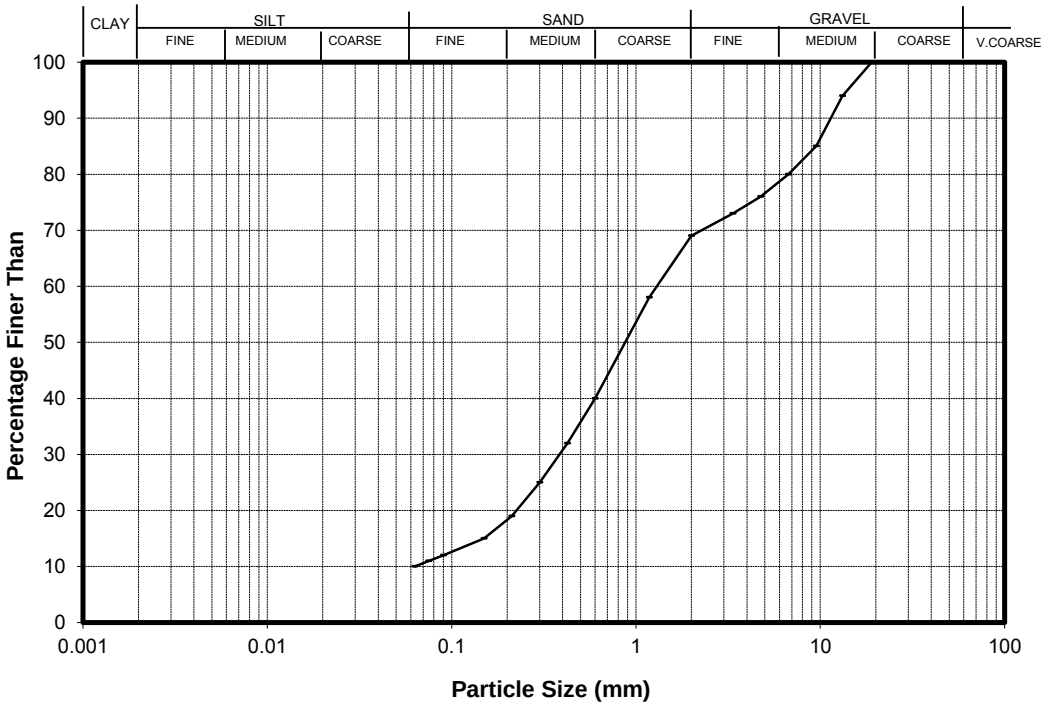
Your Job No.: **1001314**

Site : **TBC MW TX, Popua, Nuku'alofa, Tonga** Our Job No.: **1004231.0000.0.0**

BH No.: **POP-BH 5** Sample ID.: **SPT** Depth (m): **1.0**

Test Method Used : NZS 4402:1986 Test 2.8.1 Wet Sieve

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing	Sieve (mm)	Total % Passing
26.5	---	0.425	32
19.0	100	0.300	25
13.2	94	0.212	19
9.50	85	0.150	15
6.70	80	0.090	12
4.75	76	0.075	11
3.35	73	0.063	10
2.00	69		
1.18	58		
0.600	40		

Sample history : As received

Description : CORAL - gravelly SAND with minor silt, loose, white-light yellowish brown, mottled orange.

Remarks : The wet sieve sample was washed over 0.063mm test sieve, until the individual particles were clean. The material retained on 0.063mm test sieve was oven dried and dry sieved.

The minimum mass of sample required for sieving is 2.0 kg, but due to insufficient SPT sample mass the sieving was carried out on ~ 0.4 kg.

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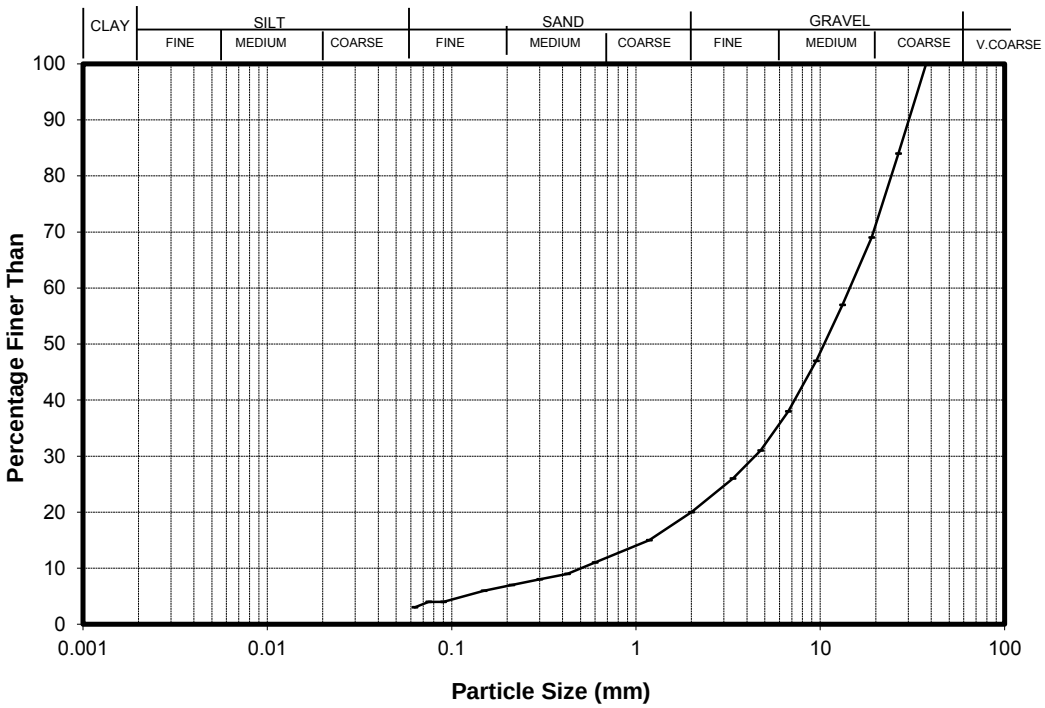
Your Job No.: **1001314**

Site : **TBC MW TX, Popua, Nuku'alofa, Tonga**
Our Job No.: **1004231.0000.0.0**
BH No.: **POP BH 5** Sample ID.: **SPT**
Depth (m): **5.0**
Test Method Used : NZS 4402:1986 Test 2.8.1 Wet Sieve

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing	Sieve (mm)	Total % Passing
37.5	100	0.600	11
26.5	84	0.425	9
19.0	69	0.300	8
13.2	57	0.212	7
9.50	47	0.150	6
6.70	38	0.090	4
4.75	31	0.075	4
3.35	26	0.063	3
2.00	20		
1.18	15		

Sample history : As received

Description : CORAL - GRAVEL with some sand and trace of silt, loose, white-light yellow, mottled orange.

Remarks : The wet sieve sample was washed over 0.063mm test sieve, until the individual particles were clean. The material retained on 0.063mm test sieve was oven dried and dry sieved.

The minimum mass of sample required for sieving is 15.0 kg, but due to insufficient SPT sample mass the sieving was carried out on ~ 0.48 kg.

The sample description and test results are not IANZ accredited.

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Geotechnics Project ID	1004231.0000.0.0
Customer Project ID	1001314.0000

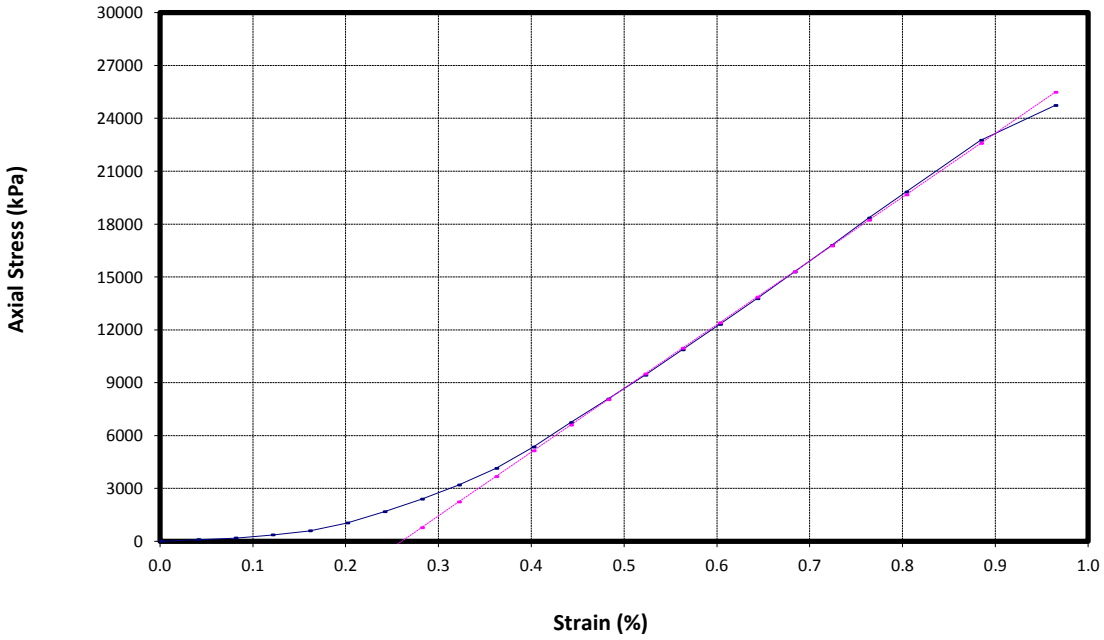
Determination of the unconfined compressive strength of cohesive soil - NZS 4402:1986 Test 6.3.1

Sample Details

Geotechnics Sample ID	--				
Site	TBC MW TX, Popua, Nuku'alofa, Tonga				
BH No	POP BH2	Sample ID	--	Depth (m)	11.30-11.52m
Sample Description	White, mottled light yellow, moderately strong, CORAL				

Test Result

Unconfined Compressive Strength Test
Axial Stress vs Strain



Sample Parameters

Sample Height	(mm)	124.48	Bulk Density	(t/m³)	2.24
Sample Diameter	(mm)	60.00	Dry Density	(t/m³)	2.09
Test Height	(mm)	124.48	Water Content	(%)	6.8
Test H/D Ratio		2.07			

Failure Value

Axial Strain (%)	Unconfined Compressive Strength qu (kPa)	Rate of Compression (mm/min)	Modulus of Elasticity (MPa)
0.96	24724	0.15	3617

Mode of Failure Shear

Sample History Undisturbed core trimmed at natural water content.

Test Remarks

Unconfined Compressive Strength reported to the nearest 1 kPa and provided as indicative only.
Modulus of Elasticity value reported based on the straight line portion of the curve and provided as indicative only.
Sample description and modulus of elasticity value reported are not IANZ accredited.

Entered by JK Date 11/10/2017 Checked by ST Date 11/10/2017

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Geotechnics Project ID: 1004231.0000.0.0
Customer Project ID: 1001314.0000

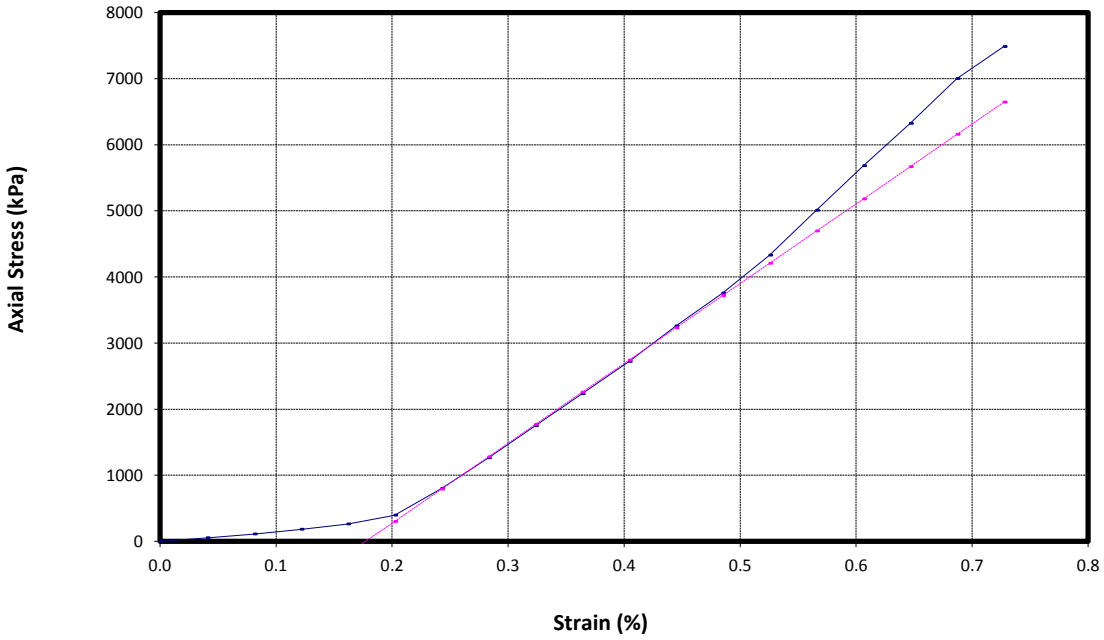
Determination of the unconfined compressive strength of cohesive soil - NZS 4402:1986 Test 6.3.1

Sample Details

Geotechnics Sample ID	--				
Site	TBC MW TX, Popua, Nuku'alofa, Tonga				
BH No	POP BH3	Sample ID	--	Depth (m)	11.7-11.9
Sample Description	White, mottled light yellowish brown, weak, CORAL				

Test Result

Unconfined Compressive Strength Test
Axial Stress vs Strain



Sample Parameters

Sample Height	(mm)	123.76	Bulk Density	(t/m³)	2.28
Sample Diameter	(mm)	60.77	Dry Density	(t/m³)	2.12
Test Height	(mm)	123.76	Water Content	(%)	7.6
Test H/D Ratio		2.04			

Failure Value

Axial Strain (%)	Unconfined Compressive Strength qu (kPa)	Rate of Compression (mm/min)	Modulus of Elasticity (MPa)
0.73	7485	0.11	1208

Mode of Failure Shear

Sample History Undisturbed core trimmed at natural water content.

Test Remarks

Unconfined Compressive Strength reported to the nearest 1 kPa and provided as indicative only.
Modulus of Elasticity value reported based on the straight line portion of the curve and provided as indicative only.
Sample description and modulus of elasticity value reported are not IANZ accredited.

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Geotechnics Project ID	1004231.0000.0.0
Customer Project ID	1001314.0000

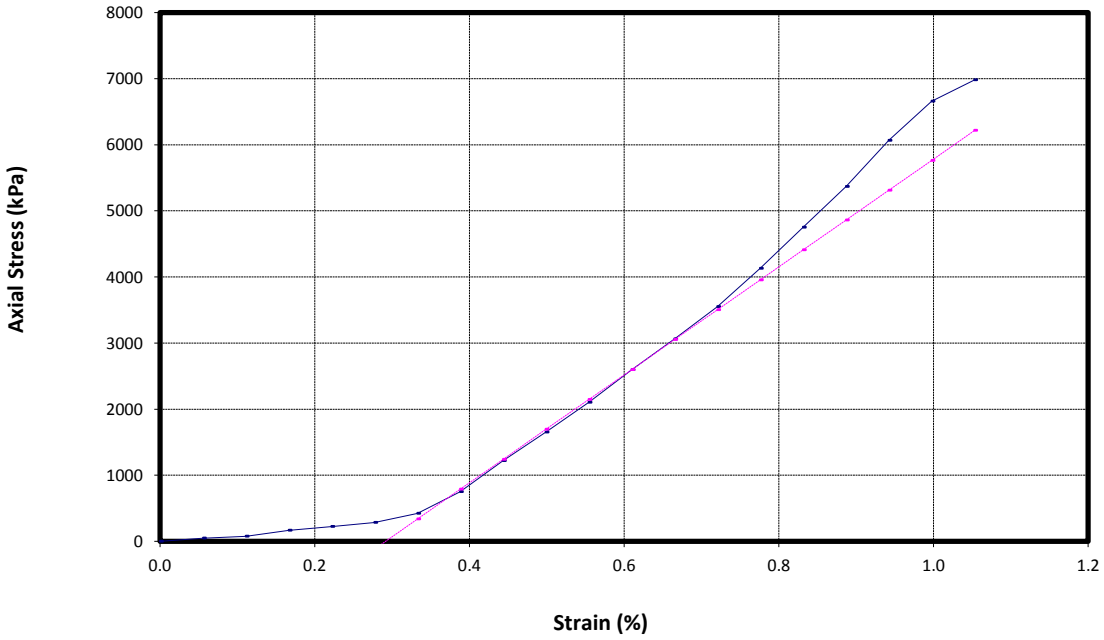
Determination of the unconfined compressive strength of cohesive soil - NZS 4402:1986 Test 6.3.1

Sample Details

Geotechnics Sample ID	--				
Site	TBC MW TX, Popua, Nuku'alofa, Tonga				
BH No	POP BH4	Sample ID	--	Depth (m)	12.05-12.35m
Sample Description	White, mottled light yellowish brown, weak, CORAL				

Test Result

Unconfined Compressive Strength Test
Axial Stress vs Strain



Sample Parameters

Sample Height	(mm)	90.22	Bulk Density	(t/m³)	2.12
Sample Diameter	(mm)	60.64	Dry Density	(t/m³)	2.03
Test Height	(mm)	90.22	Water Content	(%)	4.4
Test H/D Ratio		1.49			

Failure Value

Axial Strain (%)	Unconfined Compressive Strength qu (kPa)	Rate of Compression (mm/min)	Modulus of Elasticity (MPa)
1.05	6981	0.13	816

Mode of Failure Shear

Sample History Undisturbed core trimmed at natural water content.

Test Remarks

The sample height to diameter ratio is less than the required 2. The strength may be lower, due to the height to diameter ratio.

Unconfined Compressive Strength reported to the nearest 1 kPa and provided as indicative only.

Modulus of Elasticity value reported based on the straight line portion of the curve and provided as indicative only.

Sample description, UCS and modulus of elasticity value reported are not IANZ accredited.

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Geotechnics Project ID	1004231.0000.0.0
Customer Project ID	1001314.0000

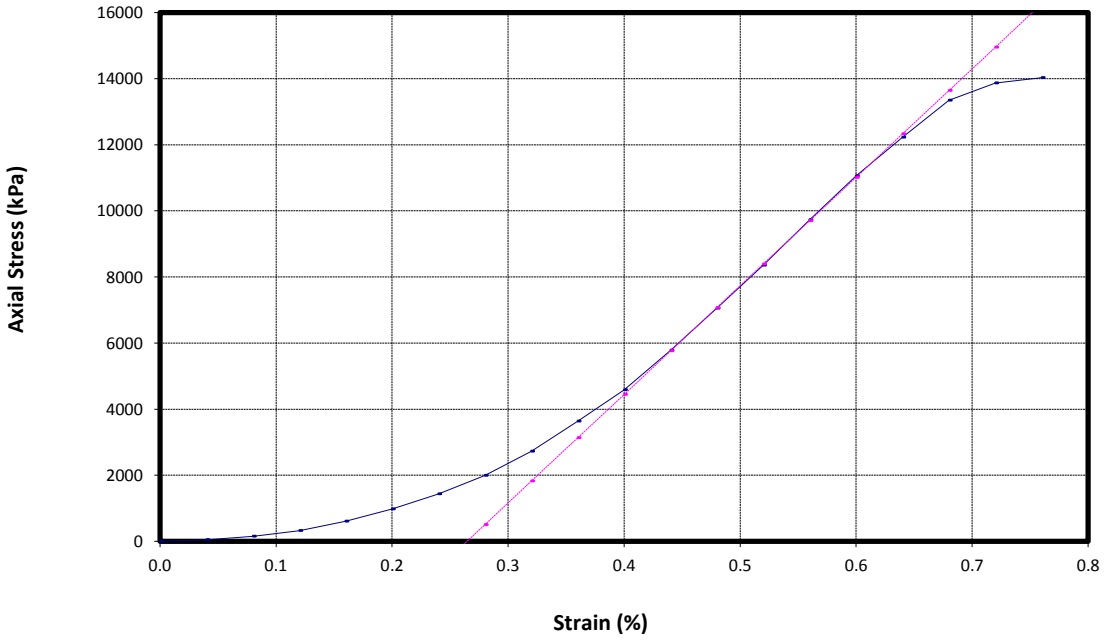
Determination of the unconfined compressive strength of cohesive soil - NZS 4402:1986 Test 6.3.1

Sample Details

Geotechnics Sample ID	-				
Site	TBC MW TX, Popua, Nuku'alofa, Tonga				
BH No	POP BH4	Sample ID	--	Depth (m)	12.43-12.70m
Sample Description	White, mottled light yellowish brown, weak, CORAL				

Test Result

Unconfined Compressive Strength Test
Axial Stress vs Strain



Sample Parameters

Sample Height	(mm)	125.01	Bulk Density	(t/m³)	2.17
Sample Diameter	(mm)	60.54	Dry Density	(t/m³)	2.07
Test Height	(mm)	125.01	Water Content	(%)	5.1
Test H/D Ratio		2.07			

Failure Value

Axial Strain (%)	Unconfined Compressive Strength qu (kPa)	Rate of Compression (mm/min)	Modulus of Elasticity (MPa)
0.76	14031	0.10	3284

Mode of Failure Shear

Sample History Undisturbed core trimmed at natural water content.

Test Remarks

Unconfined Compressive Strength reported to the nearest 1 kPa and provided as indicative only.
Modulus of Elasticity value reported based on the straight line portion of the curve and provided as indicative only.
Sample description and modulus of elasticity value reported are not IANZ accredited.

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Geotechnics Project ID	1004231.0000.0.0
Customer Project ID	1001314.0000

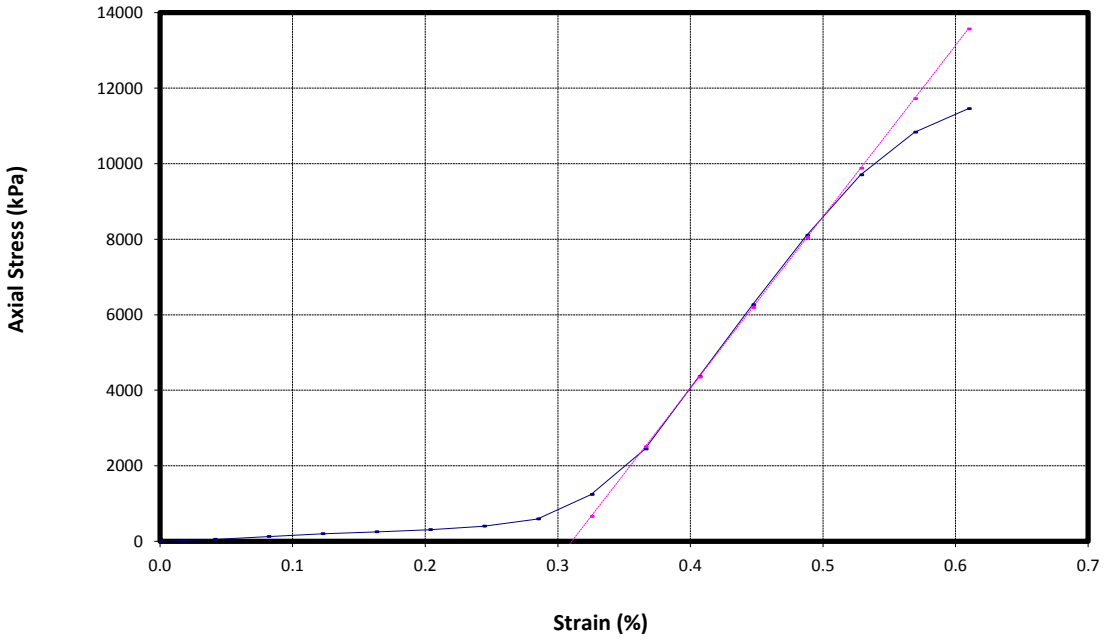
Determination of the unconfined compressive strength of cohesive soil - NZS 4402:1986 Test 6.3.1

Sample Details

Geotechnics Sample ID	-				
Site	TBC MW TX, Popua, Nuku'alofa, Tonga				
BH No	POP BH5	Sample ID	--	Depth (m)	11.6-11.8m
Sample Description	White, mottled light yellowish brown, weak, CORAL				

Test Result

Unconfined Compressive Strength Test
Axial Stress vs Strain



Sample Parameters

Sample Height	(mm)	123.06	Bulk Density	(t/m³)	2.29
Sample Diameter	(mm)	59.57	Dry Density	(t/m³)	2.12
Test Height	(mm)	123.06	Water Content	(%)	7.9
Test H/D Ratio		2.07			

Failure Value

Axial Strain (%)	Unconfined Compressive Strength qu (kPa)	Rate of Compression (mm/min)	Modulus of Elasticity (MPa)
0.61	11454	0.11	4538

Mode of Failure Shear

Sample History Undisturbed core trimmed at natural water content.

Test Remarks

Unconfined Compressive Strength reported to the nearest 1 kPa and provided as indicative only.
Modulus of Elasticity value reported based on the straight line portion of the curve and provided as indicative only.
Sample description and modulus of elasticity value reported are not IANZ accredited.

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Geotechnics Project ID	1004231.0000.0.0
Customer Project ID	1001314.0000

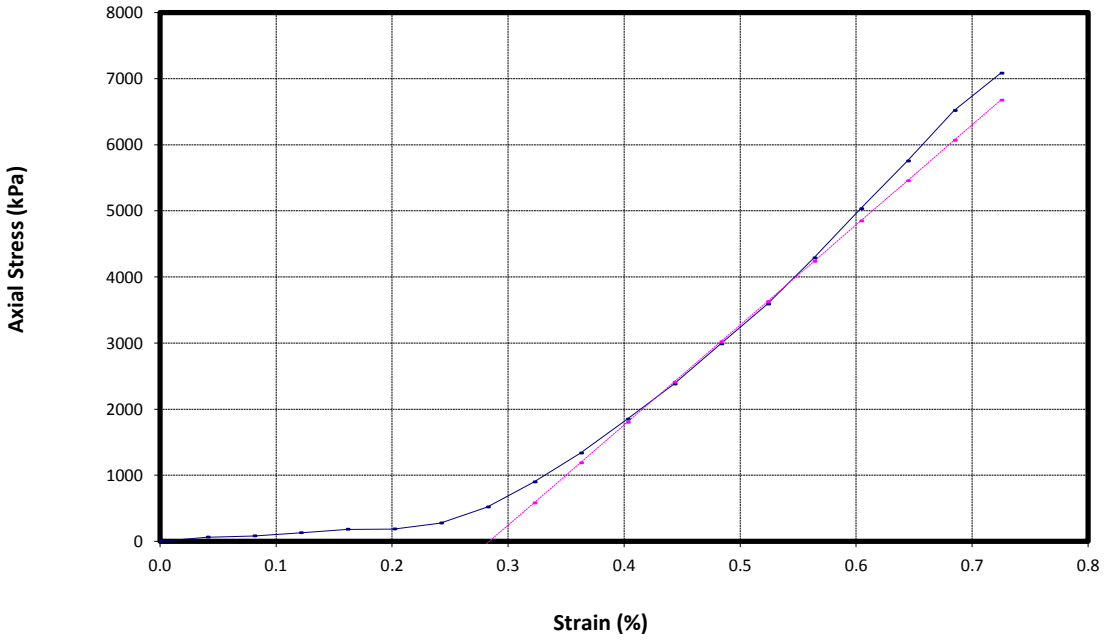
Determination of the unconfined compressive strength of cohesive soil - NZS 4402:1986 Test 6.3.1

Sample Details

Geotechnics Sample ID	-				
Site	TBC MW TX, Popua, Nuku'alofa, Tonga				
BH No	POP BH5	Sample ID	--	Depth (m)	13.48-13.70m
Sample Description	White, mottled light yellowish brown, weak, CORAL				

Test Result

Unconfined Compressive Strength Test
Axial Stress vs Strain



Sample Parameters

Sample Height	(mm)	124.22	Bulk Density	(t/m³)	2.19
Sample Diameter	(mm)	59.78	Dry Density	(t/m³)	2.03
Test Height	(mm)	124.22	Water Content	(%)	8.2
Test H/D Ratio		2.08			

Failure Value

Axial Strain (%)	Unconfined Compressive Strength qu (kPa)	Rate of Compression (mm/min)	Modulus of Elasticity (MPa)
0.72	7082	0.12	1514

Mode of Failure Shear

Sample History Undisturbed core trimmed at natural water content.

Test Remarks

Unconfined Compressive Strength reported to the nearest 1 kPa and provided as indicative only.
Modulus of Elasticity value reported based on the straight line portion of the curve and provided as indicative only.
Sample description and modulus of elasticity value reported are not IANZ accredited.

Entered by JK Date 11/10/2017 Checked by ST Date 11/10/2017

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File: T:\Geotechnics\groups\1004231\Working Material\POP BH5_3.35-3.40m_1D Consolidation.xlsx

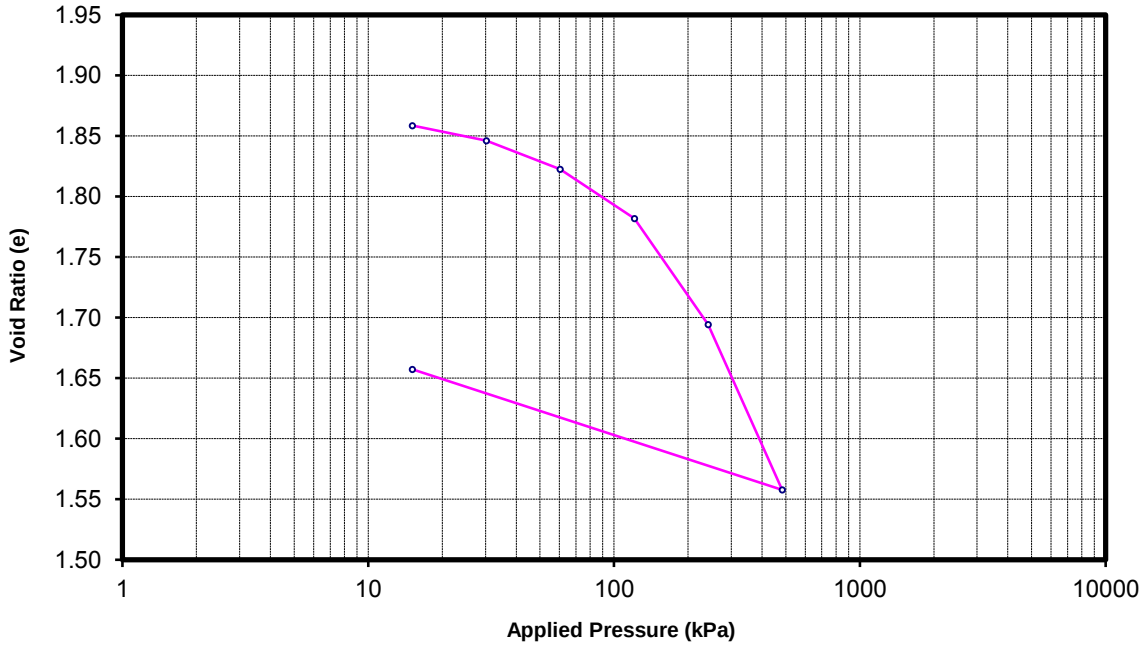
Page of Your Job No.: **1001314**

Site: **TBC MW TX, Popua, Nuku'alofa, Tonga** Our Job No.: **1004231.0000.0.0**

BH No.: **POP BH5** Sample ID.: **---** Depth: **3.35-3.40 (m)**

Test Method Used: NZS 4402:1986 Test 7.1 One-Dimensional Consolidation

ONE-DIMENSIONAL CONSOLIDATION TEST



Pressure (kPa)		Void Ratio (e)	Pressure Increment (kPa)	Coefficient of Consolidation Cv (m^2/yr)	Coefficient of Volume Compressibility Mv (m^2/MN)
As received	0	1.865			
Preload	15.1	1.859	0 to 15.1	NA	0.30
	30.2	1.846	15.1 to 30.2	26	0.29
	60.3	1.823	30.2 to 60.3	20	0.28
	121	1.782	60.3 to 121	18	0.24
	241	1.694	121 to 241	15	0.26
	483	1.558	241 to 483	7.1	0.21
Unload	15.1	1.657	483 to 15.1	NA	NA

Sample History: Undisturbed core trimmed at NWC. SQR of time fitting method used.

Description: Organic SILT with some clay and some sand, soft to firm, dark brown.

Initial Dry Density (t/m³): 0.87 Initial Water Content: 71.9%

Solid Density (t/m³): 2.50 (Assumed) Initial Saturation: 96%

Temperature During Testing: Max = 18 ^{0}C Min = 16 ^{0}C

Remarks: The calculations of void ratio are affected by the solid density value. We have assumed a value of 2.50 t/m³.

The test results are IANZ accredited but the sample description is not IANZ accredited.

Entered by: JK Date: 11/10/2017 Checked by: ST Date: 11/10/2017

Our Ref: 1004435.0000
Customer Ref: 1001314.0000
15 September 2017

Tonkin & Taylor Ltd
105 Carlton Gore Road
Newmarket
Auckland 1023

Attention: Andy Pomfret

Dear Mr. Pomfret

TBC MW TX, Popua, Nukúalofa, Tonga

Laboratory Test Report

Samples from the above mentioned site have been tested as received according to your instructions. Test results are included in this report.

Samples not destroyed during testing will be retained for one month from the date of this report before being discarded.

Descriptions are enclosed for your information, but are not covered under the IANZ endorsement of this report.

Please reproduce this report in full when transmitting to others or including in internal reports.

If we can be of any further assistance, feel free to get in touch. Contact details are provided at the bottom of this page.

GEOTECHNICS LTD

Report prepared by:

.....
Thomas Rishworth
Triaxial Laboratory Technician

Authorised for Geotechnics by:

Steven Anderson
I am approving this document
2017.09.18 13:04:27 +12'00'

.....
Steven Anderson
Project Director
Approved Signatory

Report checked by:

.....
Helen Wang
Triaxial Laboratory Manager

IANZ ACCREDITED LABORATORY
All tests reported herein have been performed in accordance with the laboratory's scope of accreditation

15-Sep-17
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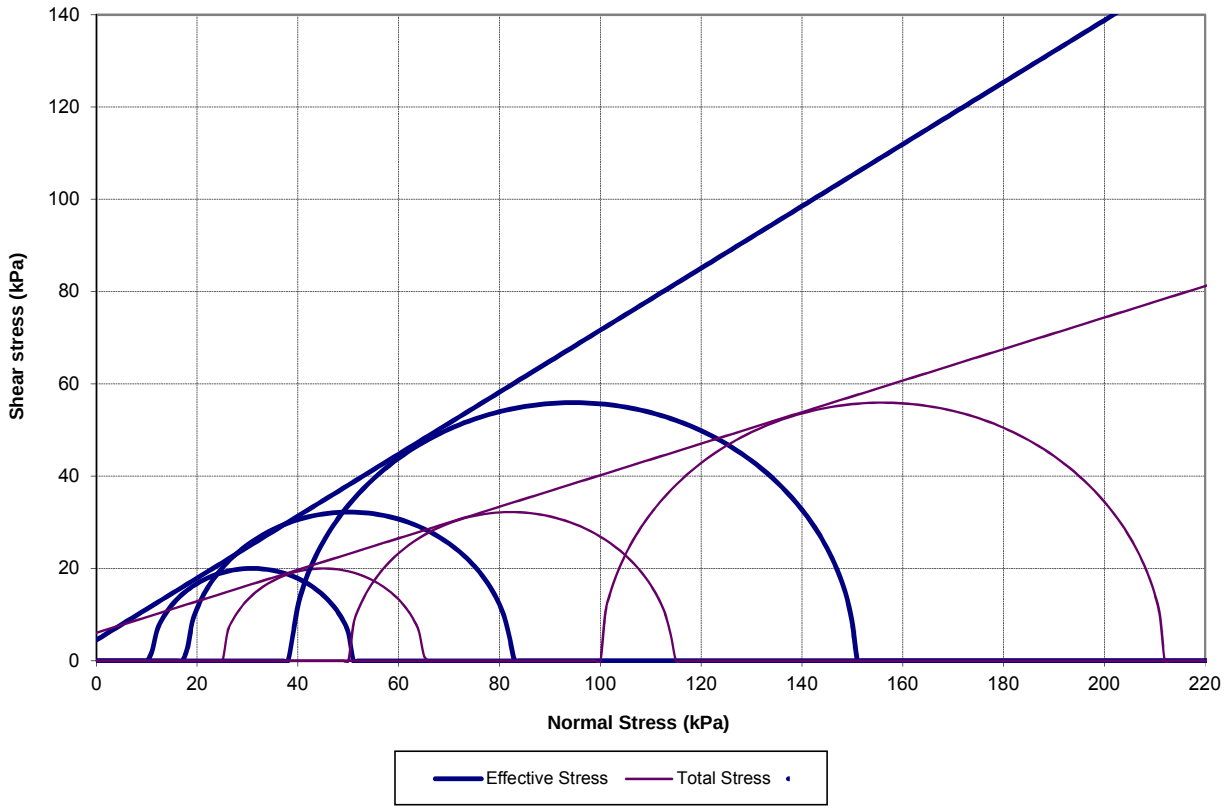
Site: TBC MW TX, Popua, Nukúalofa, Tonga | Your Project ID: 1001314 | Project ID: 1004435.0000
Location ID: POP BH3 | Sample Ref.: -- | Depth: 3.26 -- 3.38 (m)
Test method used: BS1377:Part 8:1990:Clause 5 Saturation | BS1377:Part 8:1990:Clause 6 Consolidation
BS1377:Part 8:1990:Clause 7 Consolidated-undrained triaxial compression test with pore pressure measurement

CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST (3 STAGES)
MOHR CIRCLES OF TOTAL AND EFFECTIVE STRESSES



Initial Sample Height:	124.96	mm	Initial Water Content:	79.5	%
Initial Sample Diameter:	61.98	mm	Initial Bulk Density:	1.48	t/m³
Initial B Value:	98	%	Initial Dry Density:	0.82	t/m³
B Value before Consolidation:	98	%	Final Water Content:	60.8	%

	Consolidation Stage			Failure Values				
	Cell Pressure (kPa)	Back Pressure (kPa)	Eff. Consol. Stress (kPa)	Deviator Stress (kPa)	Pore Pressure Change During Shearing δμ (kPa)	Effective Principal Stress (kPa) Major σ1'	Minor σ3'	Vertical Strain (%)
STAGE 1	325	300	25	40.03	14.1	50.93	10.90	4.49
STAGE 2	350	300	50	64.47	32.1	82.37	17.90	2.02
STAGE 3	400	300	100	111.88	61.3	150.58	38.70	6.69

		Total			Effective	
Angle of Frictional Resistance:	ϕ =	19	°	ϕ′ =	34	°
Cohesion:	c =	6	kPa	c' =	5	kPa
Linear Regression Coefficient:	r =	1.000		r =	0.999	

Sample History: Undisturbed core trimmed at natural water content.

Soil description: SILT, with some sand and gravel, minor clay, soft, dark brown with light brown and white.

Failure Mode: Planar / Plastic **Test Speed:** 0.025 (mm/min)

Test Remarks: The sample was saturated by increments of cell pressure and back pressure.
Failure for each stage was determined by either the maximum effective stress ratio or the maximum deviator stress. Strength parameters have been derived by using a linear regression fitting method.

Entered by: Date: 14/08/17 Checked by: Date: 15/09/17

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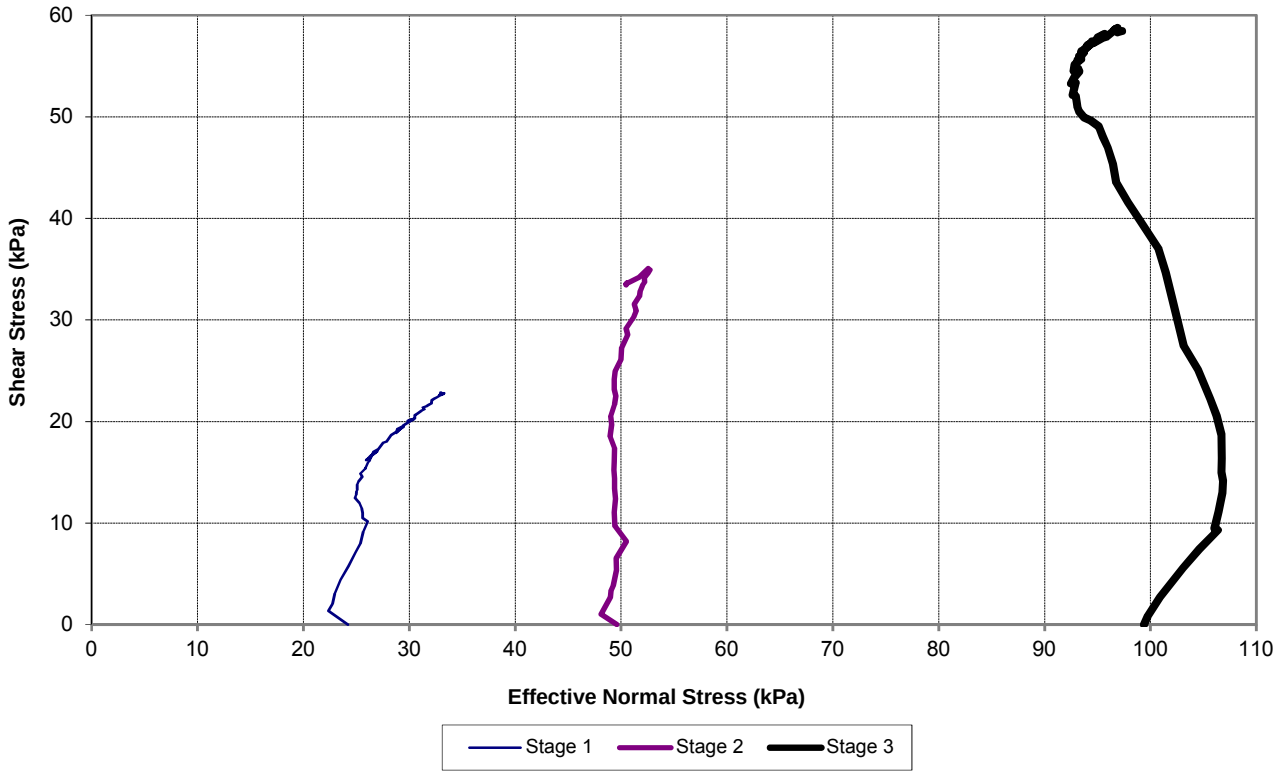
Site: TBC MW TX, Popua, Nukúalofa, Tonga Your Project ID: 1001314 Project ID: 1004435.0000

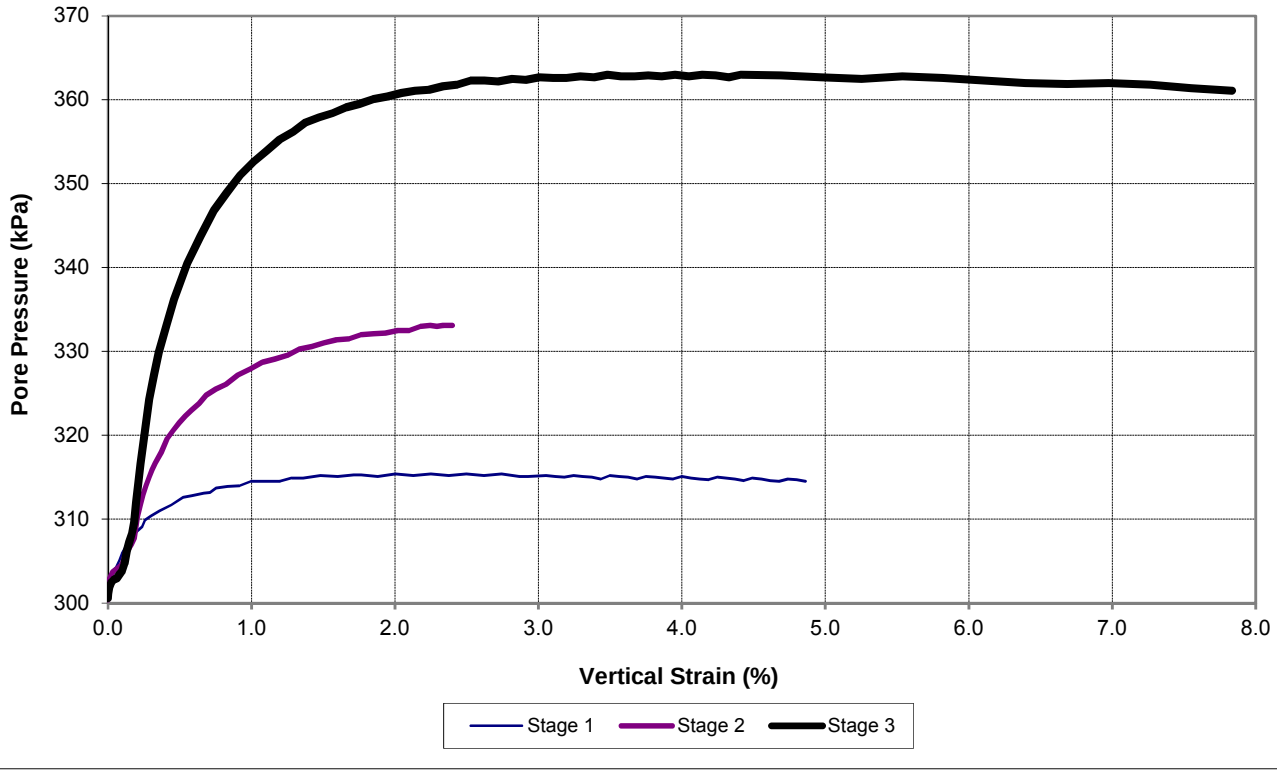
Location ID: POP BH3 Sample Ref.: -- Depth: 3.26 -- 3.38 (m)

GRAPHS

STRESS PATH



PORE PRESSURE Vs VERTICAL STRAIN



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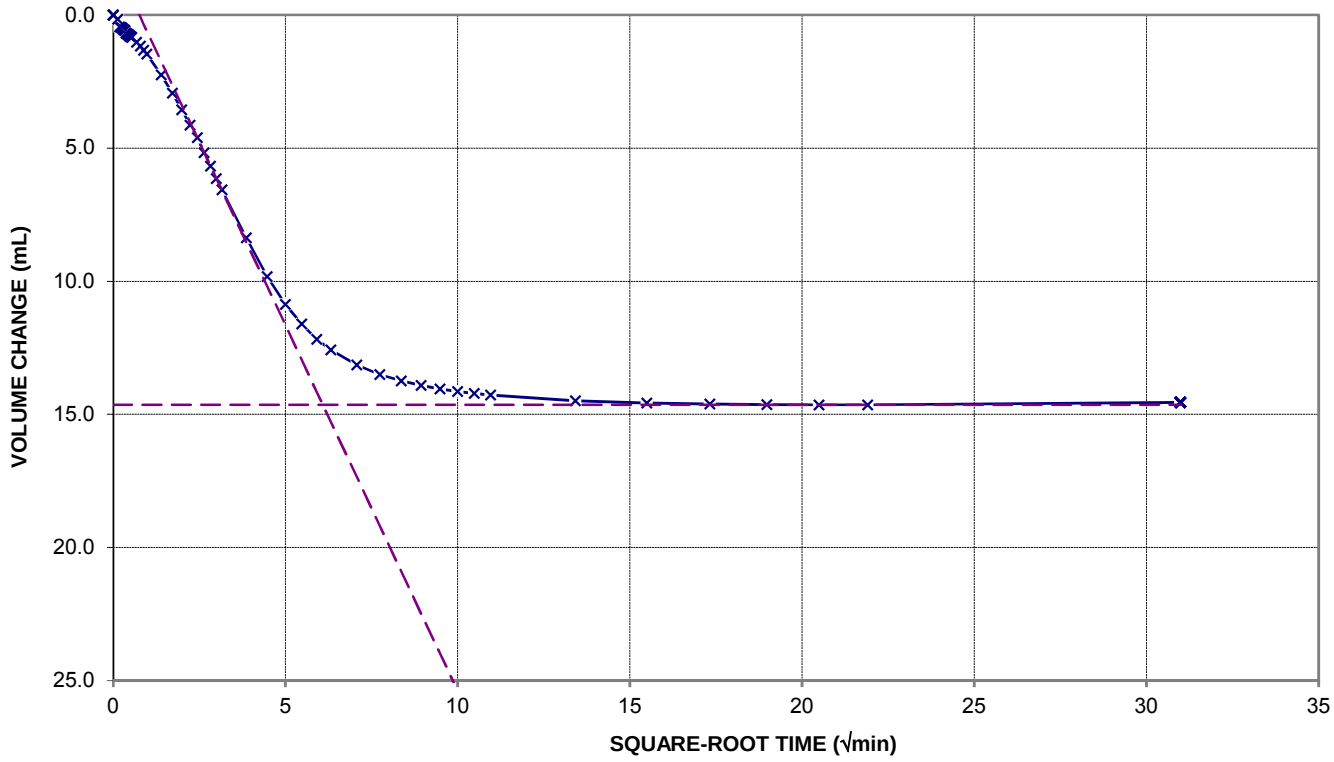
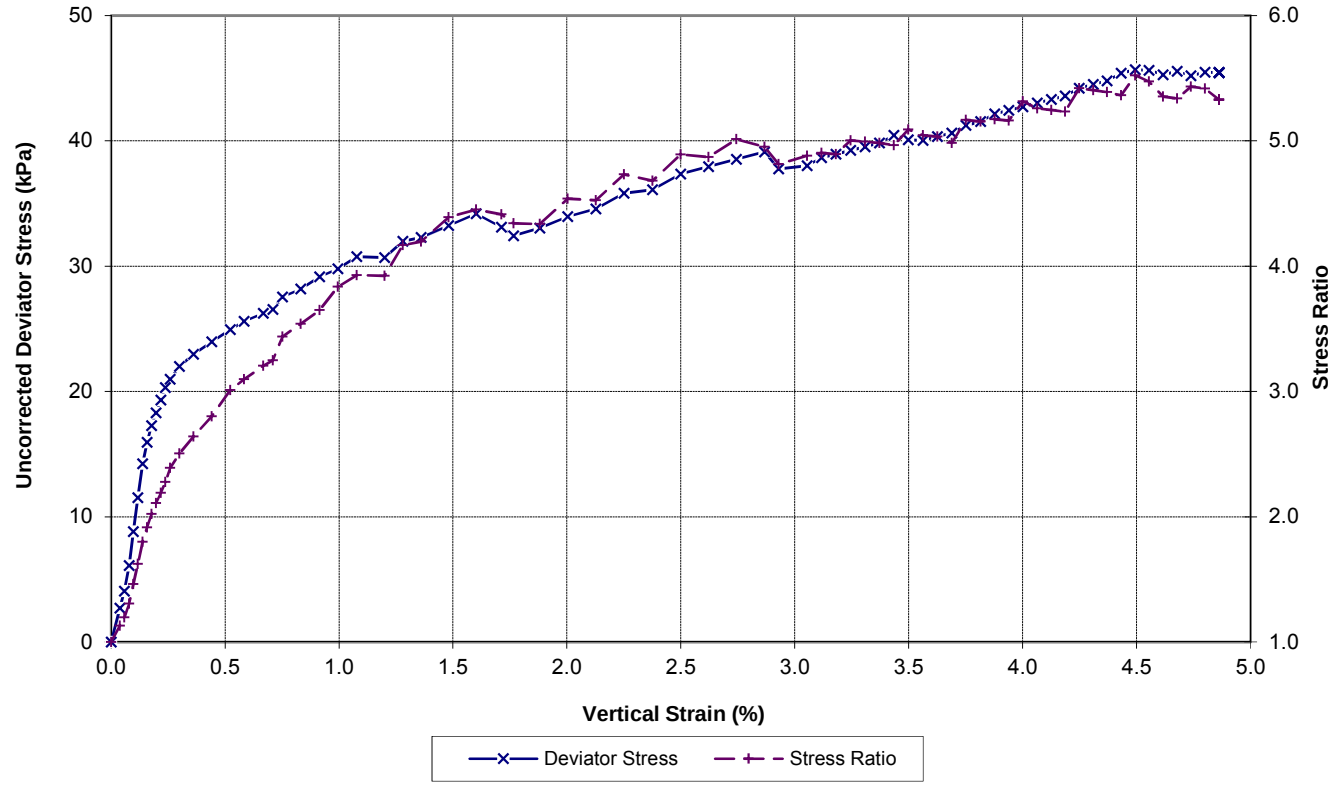
Location ID: POP BH3 Sample Ref.: -- Depth: 3.26 -- 3.38 (m)

STAGE 1 GRAPHS

CONSOLIDATION



STRESS-STRAIN CURVE



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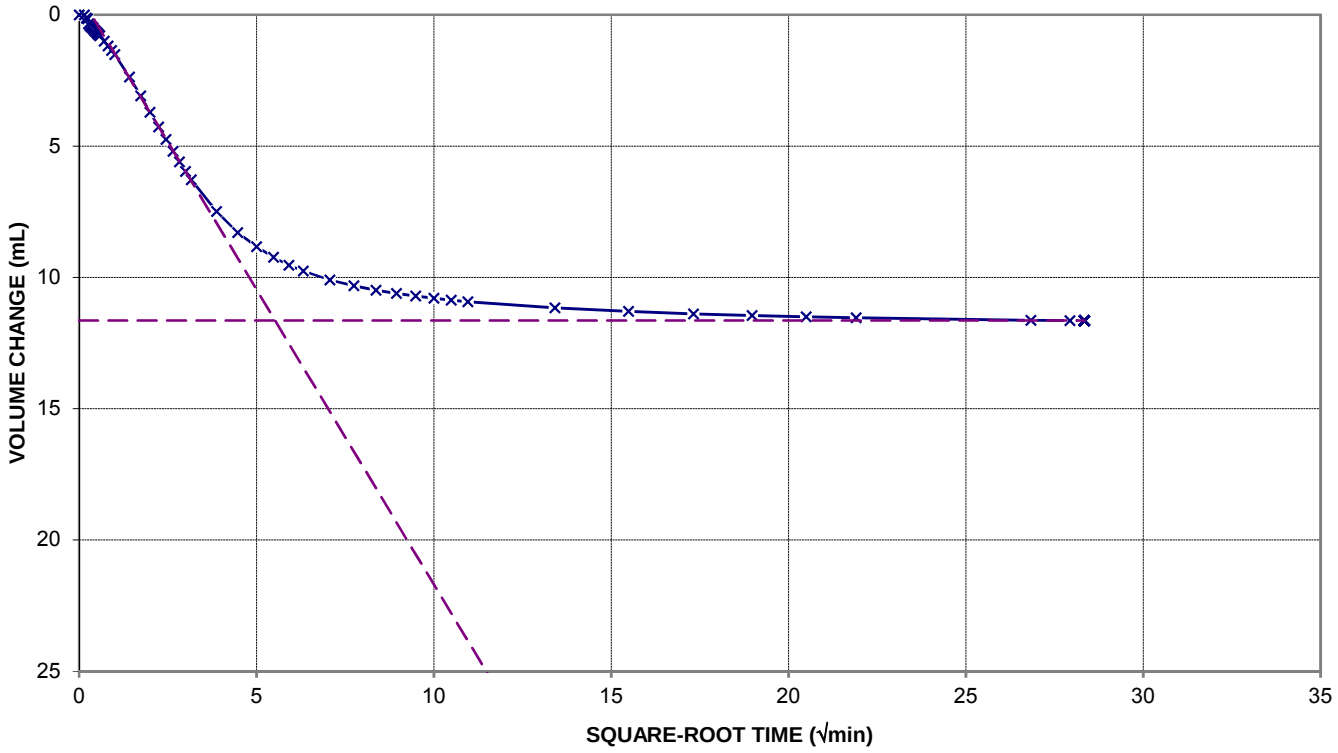
Site: TBC MW TX, Popua, Nukúalofa, Tonga Your Project ID: 1001314 Project ID: 1004435.0000

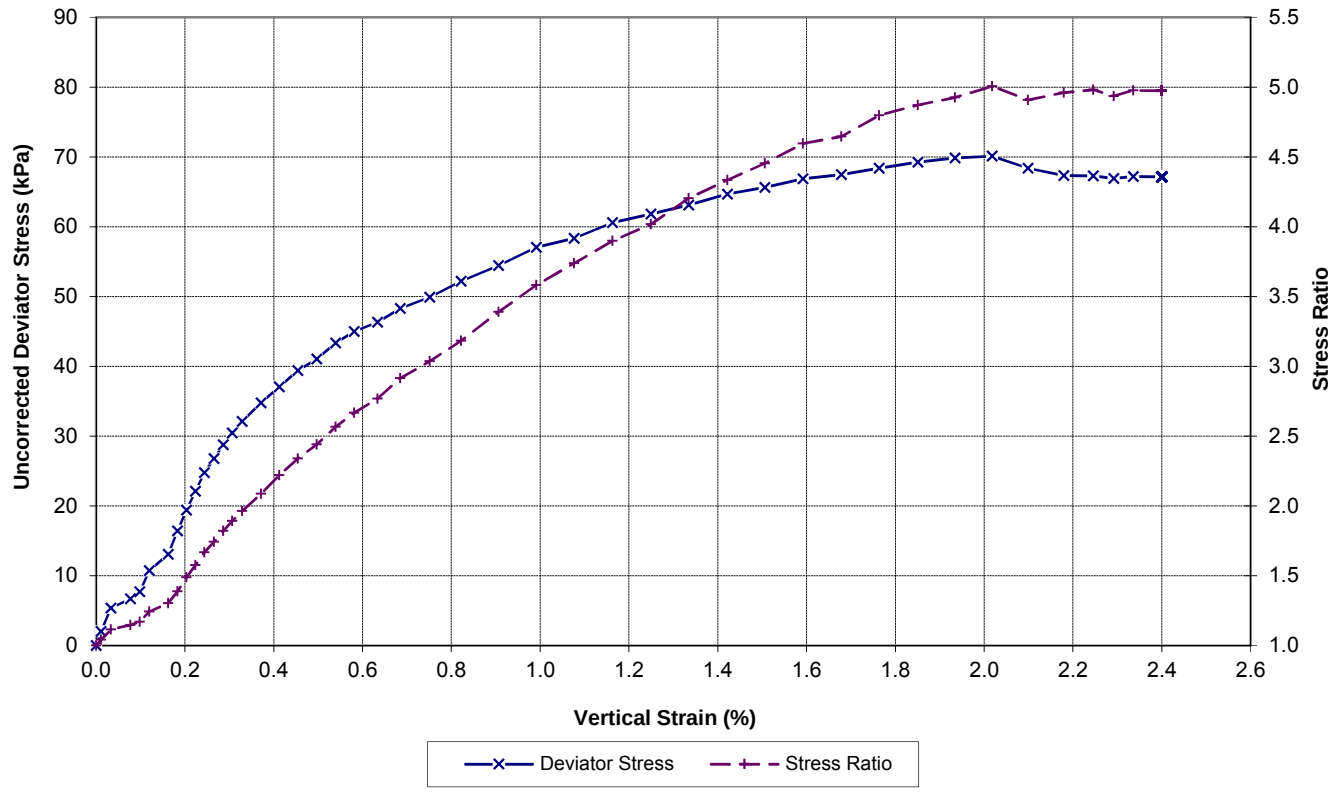
Location ID: POP BH3 Sample Ref.: -- Depth: 3.26 -- 3.38 (m)

STAGE 2 GRAPHS

CONSOLIDATION



STRESS-STRAIN CURVE



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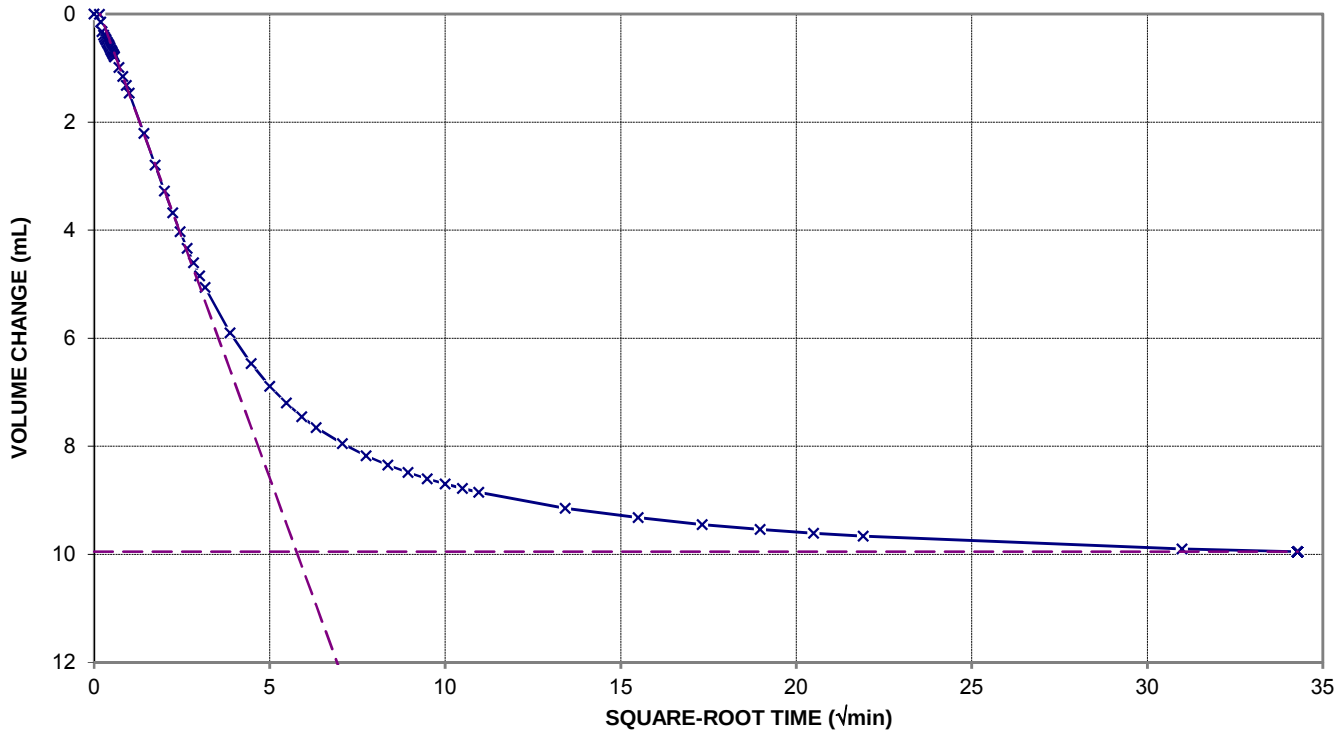
Site: TBC MW TX, Popua, Nukúalofa, Tonga Your Project ID: 1001314 Project ID: 1004435.0000

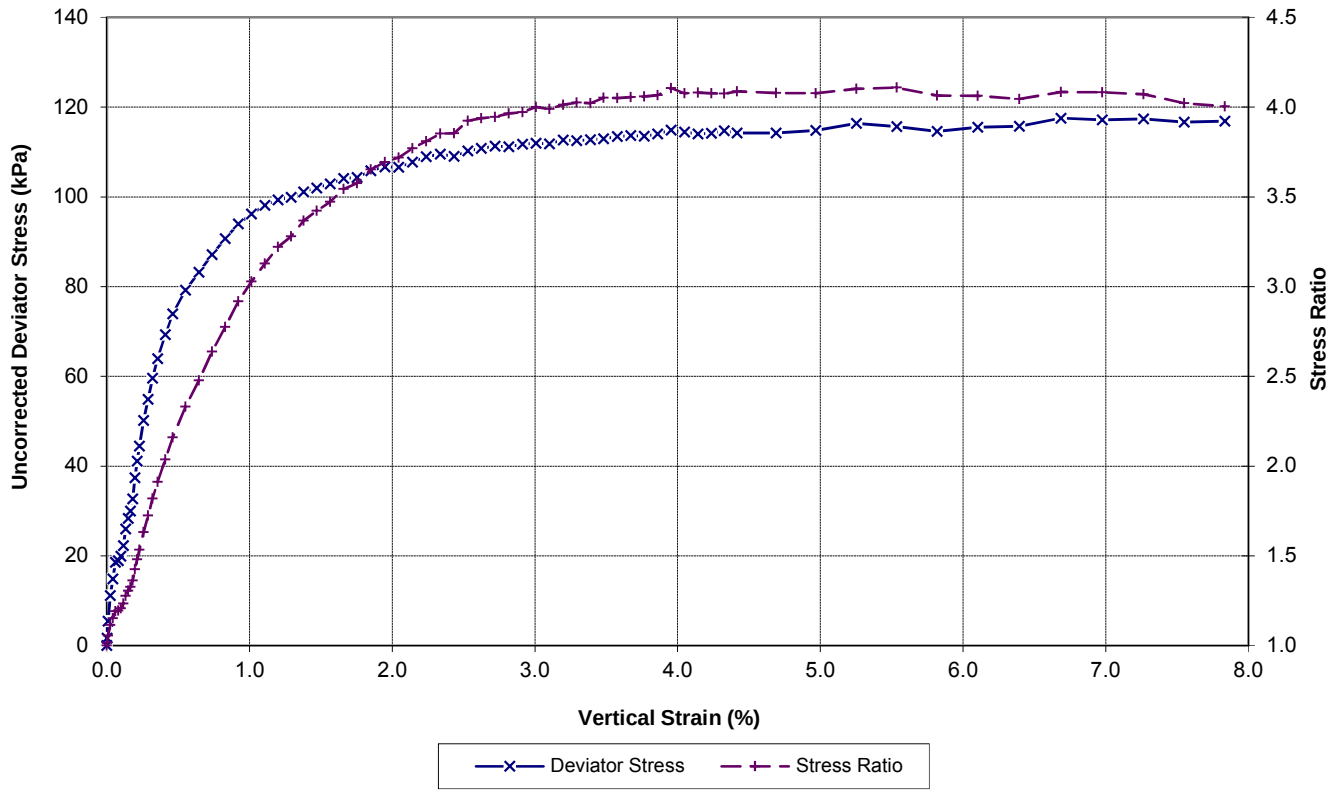
Location ID: POP BH3 Sample Ref.: -- Depth: 3.26 -- 3.38 (m)

STAGE 3 GRAPHS

CONSOLIDATION



STRESS-STRAIN CURVE



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Appendix E: Supporting Calculations

- **Correlation between SPT N value and friction angle**
- **Bearing capacity calculations for shallow foundations using Meyerhof (1963) formula**
- **The SPT N value based correlation for the allowable bearing capacity for surface loaded footings with settlement limited to 25mm**

Correlation between SPT-N value, friction angle, and relative density

Correlation between SPT-N value and friction angle and Relative density (Meyerhoff 1956)			
SPT N3 [Blows/0.3 m - 1 ft]	Soil packing	Relative Density [%]	Friction angle [°]
< 4	Very loose	< 20	< 30
4 -10	Loose	20 - 40	30 - 35
10 - 30	Compact	40 - 60	35 - 40
30 - 50	Dense	60 - 80	40 - 45
> 50	Very Dense	> 80	> 45

Meyerhof, G. (1956). Penetration tests and bearing capacity of cohesionless soils. J Soils Mechanics and Foundation Division ASCE, 82(SM1).

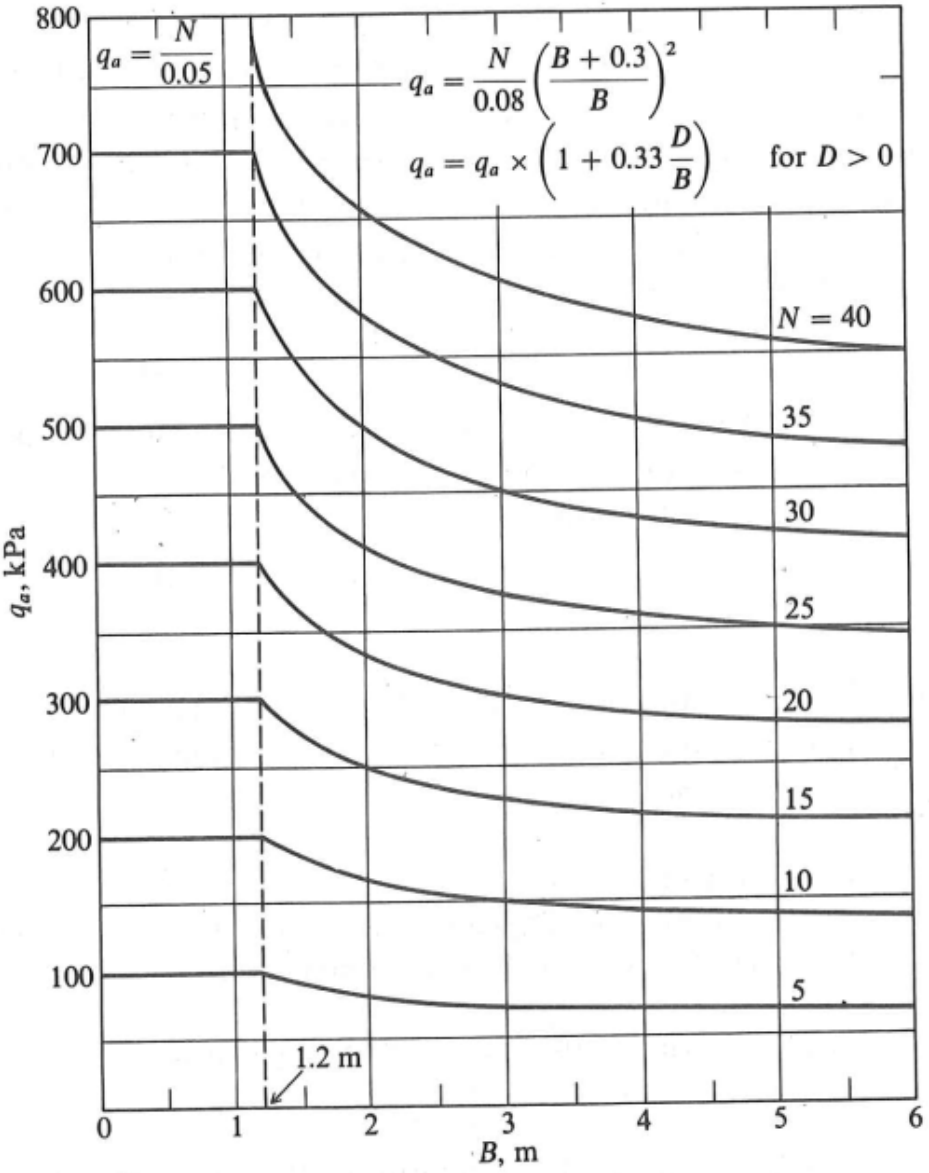


FIGURE 4-7 Allowable bearing capacity for surface loaded footings with settlement limited to approximately 25 mm. Equations used are shown on figure. Depth-factor adjustment also shown. N shown in approximately N_{55}.

Meyerhof Bearing Capacity

HQ Building
Strip footing @ 0.5m

Input Parameters			
Reduction Factor	SRF	0.5	
Corrected SPT	N	0	
Friction Angle	ϕ	35	degrees
Cohesion	c	0	kPa
Unit Weight	γ	18	kN/m^3
Width	B	0.5	m
Length	L	10	m
Depth	D	0.5	m
Load Inclination	θ	0	degrees

Rankine Passive Pressure Coefficient

	K_p	3.69

Bearing Capacity Factors

	N_q	33.3
	N_c	46.1
	N_γ	37.2

Shape Factors

	s_c	1.04
	s_q	1.02
	s_γ	1.02

Depth Factors

	d_c	1.38
	d_q	1.19
	d_γ	1.19

Inclination Factors

	i_c	1.00
	i_q	1.00
	i_γ	1.00

Bearing Capacity

from cohesion	0
from overburden	364
from depth	203

Geotech ultimate capacity (kPa)	567
Allowable bearing capacity (kPa)	189
ULS bearing capacity (kPa)	283

HQ Building
Strip footing @ 1.0m

Meyerhof Bearing Capacity

Input Parameters			
Reduction Factor	SRF	0.5	
Corrected SPT	N	0	
Friction Angle	ϕ	35	degrees
Cohesion	c	0	kPa
Unit Weight	γ	18	kN/m^3
Effective Unit Weight	γ'	8	kN/m^3
Groundwater depth	dw	0.7	m
Width	B	0.5	m
Length	L	10	m
Depth	D	1	m
Load Inclination	θ	0	degrees

Rankine Passive Pressure Coefficient

	K_p	3.69

Bearing Capacity Factors

	N_q	33.3
	N_c	46.1
	N_γ	37.2

Shape Factors

	s_c	1.04
	s_q	1.02
	s_γ	1.02

Depth Factors

	d_c	1.77
	d_q	1.38
	d_γ	1.38

Inclination Factors

	i_c	1.00
	i_q	1.00
	i_γ	1.00

Bearing Capacity

from cohesion	0
from overburden	704
from depth	105

Geotech ultimate capacity (kPa)	809
Allowable bearing capacity (kPa)	270
ULS bearing capacity (kPa)	404

POP_BH1
Mass Concrete footing
@ 2.6m

Meyerhof Bearing Capacity

Input Parameters			
Reduction Factor	SRF	0.5	
Corrected SPT	N	0	
Friction Angle	ϕ	35	degrees
Cohesion	c	0	kPa
Unit Weight	γ	18	kN/m^3
Effective Unit Weight	γ'	8	kN/m^3
Groundwater depth	dw	1	m
Width	B	1.5	m
Length	L	1.5	m
Depth	D	2.6	m
Load Inclination	θ	0	degrees

Rankine Passive Pressure Coefficient		
	K_p	3.69

Bearing Capacity Factors		
	N_q	33.3
	N_c	46.1
	N_γ	37.2

Shape Factors		
	s_c	1.74
	s_q	1.37
	s_γ	1.37

Depth Factors		
	d_c	1.67
	d_q	1.33
	d_γ	1.33

Inclination Factors		
	i_c	1.00
	i_q	1.00
	i_γ	1.00

Bearing Capacity	
from cohesion	0
from overburden	1871
from depth	407

Geotech ultimate capacity (kPa)	2278
Allowable bearing capacity (kPa)	759
ULS bearing capacity (kPa)	1139

Tonkin+Taylor

Description:

Project: First phase geotech. kingdom of Tonga

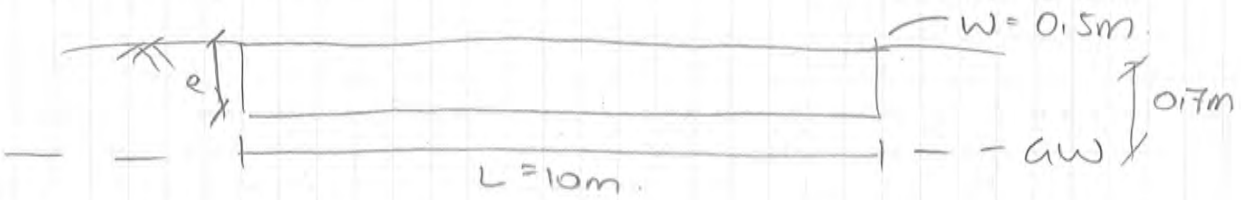
Computed: AWM 15/11/2017 | Checked: 20 | Revised: 20 | Checked: 20

Office: Akl | Job No: 1001314 | File: | Sheet No. 1

Aim: complete bearing capacity check.

References: T+T Report: The project for Nation-wide early warning dissemination and strengthening disaster communications in The kingdom of Tonga- first phase of geotechnical investigations. (October 2017) T+T ref: 1001314.V1

Analysis model:



e = 0.5m or 1m.

Soil properties: $c = 0$, $\gamma = 18 kN/m^3$, $\phi = 35°$, $k_p = \left(\frac{1+\sin 35}{1-\sin 35}\right) = 3.7$

Using Meyerhof formula: $q_u = cN_c s_c d_c + q N_q s_q d_q + \frac{1}{2}\gamma B N_\gamma s_\gamma d_\gamma$

$N_q = e^{\pi \tan\phi} \tan^2(45 + \phi/2) = e^{\pi \tan 35} \tan^2(45 + 35/2)$
$= 33.3$

$N_\gamma = (N_q - 1)\tan(1.4\phi) = (33.1 - 1)\tan(1.4 \times 35)$
$= 36.9$

$s_\gamma = s_q = 1 + 0.1 k_p \frac{B}{L} = 1 + 0.1 \times 3.7 \times \frac{0.5}{10}$
$= 1.0185$

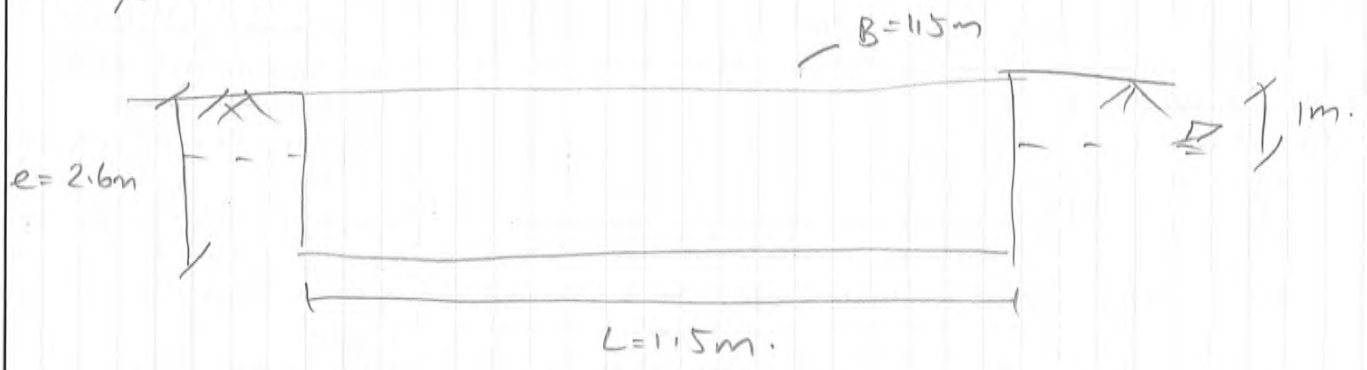
$d_q = d_\gamma = 1 + 0.1\sqrt{k_p}\, D/B = 1 + 0.1\sqrt{3.7}\,\frac{0.5}{0.5}$ (e = 0.5)
$= 1.19$

For e = 1m
$= 1 + 0.1\sqrt{3.7}\,\frac{1}{0.5}$
$= 1.38$

$q_u (e=0.5) = (18 \times 0.5) \times 33.3 \times 1.0185 \times 1.19 + \frac{1}{2} \times 18 \times 0.5 \times 36.9 \times 1.0185 \times 1.19$
$= 557 kPa.$

$q_u (e=1m) = (18 \times 0.7 + (18 - 9.81) \times 0.3) \times 33.3 \times 1.0185 \times 1.38 + 0.5 \times 18 \times 0.5 \times 36.9 \times 1.0185 \times 1.38$
$= 809 kPa$

Analysis model:



Soil properties: $c=0$, $\phi=35°$, $\gamma=18\ kN/m^3$, $\gamma'=8\ kN/m^3$

$$k_p = \frac{1+\sin 35}{1-\sin 35} = 3.7$$

$$q_u = q N_q s_q d_q + \tfrac{1}{2}\gamma B N_\gamma s_\gamma d_\gamma$$

$N_q = e^{\pi \tan\phi} \tan^2(45+\phi/2) = 33.3$ (from page 1)

$N_\gamma = (N_q - 1)\tan(1.4\phi) = 36.9$ (from page 1)

$s_\gamma = s_q = 1 + 0.1 k_p \frac{B}{L} = 1 + 0.1 \times 3.7 \times \frac{1.5}{1.5}$

$= 1.37$

$d_q = d_\gamma = 1 + 0.1\sqrt{k_p} \times \frac{D}{B} = 1 + 0.1\sqrt{3.7} \times \frac{2.6}{1.5}$

$= 1.33$

$q_u = \frac{((1\times 18)+(1.6\times 8))\times 33.3\times 1.37\times 1.33}{1.33} + \underbrace{0.5\times 8\times 1.5\times 36.9\times 1.37\times}_{406\ kPa}$

$= 2255\ kPa$ (*1)

if $q = 8\times 2.6$ (γ')

$q_u = 1665\ kPa$.