A- 8 Soils Investigation Report and Topographic Survey

REPORT

Yachiyo Engineering Co Ltd. and West Japan Engineering Consultants, Inc. JV

Preparation Survey on the Project for Introduction of a Micro-Grid System with Renewable Energy for the Tonga Energy Road Map in the Kingdom of Tonga

Soils Investigation Report

Report prepared for:

Yachiyo Engineering Co Ltd. and West Japan Engineering Consultants, Inc. JV

Report prepared by:

Tonkin & Taylor International Ltd

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1 Introduction

1.1 General

Yachiyo Engineering Co., Ltd (YEC) engaged Tonkin & Taylor International Ltd (T&TI) to carry out the soils investigations for a Power storage devices building at Popua and a Photovoltaic array area at Vaini in the Kingdom of Tonga. The investigations were carried out at Popua Power Sations and in Vaini, Tongatapu, Tonga. A topographical survey of the site at Vaini was undertaken by local surveyors, ITS Pacific Ltd.

The investigations have been carried out in accordance with the "Contract of Soil Explorations" provided to T&TI by YEC (ref: Appendix A). The soils investigation consisted of 8 hand auger boreholes and 12 Scala penetrometer tests at Popua Power Station and 6 hand auger bore holes along with 6 Scala penetrometer tests at Vaini. Laboratory testing of recovered soil samples from the two sites was also undertaken. This work scope was agreed with YEC. This report summarises the results of the soils investigation carried out at these two sites.

1.2 Project Description

The Kingdom of Tonga consists of 176 islands scattered over 700,000 square kilometres of the southern Pacific Ocean. The capital is Nuku'alofa located on the main island of Tongatapu.

The project involves construction at two separate sites on the Island; Power storage devices building for the existing Popua power station and a Photovoltaic array in Vaini. This work is part of a Tonga Energy Road Map for Tongatapu Island.

The construction of the new solar power station in Vaini involves constructing a battery building and a series of solar panels covering approximately 23,791 m^2 of the site.

2 Site Description

The two sites are located on Tongatapu Island, Tonga. The existing Popua power station (Site A) is located 3km east of Nuku'alofa on the edge of the lagoon and the new solar power station (Site B) is located in Vaini 6km south of Nuku'alofa.

The existing Popua power station is a diesel power station, situated on relatively flat land on the edge of the lagoon approximately 1.2m above sea level. Solar panels have recently been erected surrounding the power station as part of a renewable energy scheme.

The proposed new solar power station is situated on the outskirts of Vaini on relatively flat land approximately 13m above sea level. At the time of the investigations the site was vegetated with long grass, coconut palms and some large trees.

A site plan and topographic survey is attached in Appendix B.

3 Summary of Site Survey

The topographic survey of both sites were carried out by local surveying company ITS Pacific Ltd in September and October 2012. Each site investigation location was surveyed and the co-ordinates and reduced levels (RL'S) are presented in Appendix B. The topographic survey plans are also presented in Appendix B.

4 Summary of Soils Investigation

4.1 General

The soils investigations were carried out in September 2012 and the scope of work was completed in accordance with the "Contract Soil Explorations" attached in Appendix A.

The following tasks were completed for the soils investigation:

- Site A - Popua power station
  - 6 No. Hand auger boreholes (BH1A – BH6A) to 1.9m below existing ground level
  - 6 No. Scala penetrometer tests (SC1A – SC6A) to 3m below existing ground level
- Site B - Vaini
  - 8 No. Hand auger boreholes (BH1B – BH6B) to 3m below existing ground level
  - 12 No. Scala penetrometer tests (SC1B – SC6B) to 3m below existing ground level

The subsections below present a summary of the investigation work and laboratory testing results. Site investigation logs are presented in Appendix C and laboratory testing results are presented in Appendix D.

4.2 Handauger and Scala Penetrometer Investigations

The soil investigation testing, including hand augered boreholes and Scala penetrometer tests, was undertaken over three days (26-28 September 2012) at Popua power station and at the new solar power station site in Vaini. In the hand auger boreholes in-situ shear strength testing was carried out in cohesive materials using a calibrated Pilcon shear vane and samples were taken for geotechnical laboratory testing. The subsurface soils were described and shear strengths are recorded on the borehole logs presented in Appendix C. The Scala penetrometer provides continuous soil strength data until hard ground/refusal is achieved (8 to 10 blows per 50mm penetration). The results of the Scala penetrometer tests are included in Appendix C.

4.2.1 Site A - Popua power station

Six hand auger boreholes and six Scala penetrometer tests were completed at this site on 26 September 2012. The hand auger boreholes could only be drilled to a depth of up to 2m below existing ground level due to dense gravely sands that were encountered. Groundwater was encountered at 1m below existing ground surface in each of the hand augers. The Scala penetrometer tests were terminated at depths of up to 3m below ground level.

4.2.2 Site B - Vaini

Eight hand auger boreholes and twelve scala penetrometer tests were completed at t this site on 27 and 28 September 2012. The hand auger boreholes were drilled to a depth of up to 3.6m below exisiting ground level. No ground water was encountered in any of the boreholes. The Scala penetrometer tests were terminated at depths of up to 3m below ground level.

The precise test locations and co-ordinates are presented in the Survey report in Appendix B. The investigations were completed over a period of three days and were undertaken by an Engineering Geologist from T&TI, Mr Conor Morrison.

4.3 Geotechnical Laboratory Schedule

The recovered samples were brought back to Auckland and geotechnical laboratory testing was carried out by Geotechnics Ltd. The laboratory tests have been completed in full accordance with the relevant New Zealand standards, identified in the subsections below, and the laboratory is fully accredited with International Accreditation New Zealand (IANZ) registration.

The soil testing consisted of the following:

- Site A - Popua power station
  - Specific Gravity tests (3 No.)
  - Grain size analysis (3 No.)
  - Moisture content test (3 No.)
- Site B - Vaini
  - Specific Gravity tests (2 No.)
  - Grain size analysis (2 No.)
  - Moisture content test (2 No.)

5 Subsurface Conditions

5.1 Geological Setting

The Island of Tongatapu is composed of emerged and tilted coral limestones of Pliocene and Quarternary age with a volcanic soil mantle. The geology of the Island consists of volcanic soils, coral sand, estuarine deposits and coral limestone (Roy 1990[1]).

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[1] Peter S. Roy 1990: The morphology and surface Geology of the Islands of Tongatapu and Vava'u, Kingdom of Tonga. Department of Mineral Resources New South Wales Government.

5.2 Ground and Groundwater Conditions

5.2.1 Site A - Popua Power Station

The six hand auger boreholes across the building platform encountered very similar ground conditions and these are summarised in Table 1 below:

Table 1 – Summary of ground conditions

Depth (Below ground level)	Geological unit	Soil description
0.0m – 0.2m	Topsoil	SILT with some clay and minor sand, trace gravel, dark brown, stiff, low plasticity
0.2m – 0.6m	Fill	Gravely SAND with some silt, yellowish white, fine to coarse, angular crushed limestone gravel
0.6m – 1.0m	Estuarine Sediments	Silty fine SAND, dark brown, loose to medium dense, some organics
1.0m - >2.0m	Coral Sand	Coarse SAND with some gravel and minor silt, blue/grey, loose to medium dense, saturated

Groundwater was encountered in all the boreholes at a depth of 1.0m below existing ground level.

The six Scala penetrometer tests SC1A – SC6A were terminated at depths of up to 3m below ground level. From this in-situ testing, we can assess the soil strengths at specific depths below the site. The Scala results and inferred soil strength are summarised in Table 2 below:

Table 2 – Summary of Scala penetrometer results

Depth (Below ground level)	Average Scala Blows per 50mm	Soil Type	Inferred Strength
0.5m	10*	Granular	Very dense*
1.0m	1	Granular	Very loose
1.5m	3	Granular	Medium dense
2.0m	4	Granular	Dense
2.5m	6	Granular	Dense
3.0m	8	Granular	Dense

*Compacted hardfill across majority of site to 0.5m below ground

From the table above, it can be noted that the soil strength increases with depth at the site.

5.2.2 Site B - Vaini

The 8 No. hand auger boreholes across the site encountered very similar ground conditions and these are summarised in Table 3 below:

Table 3 – Summary of ground conditions

Depth (Below ground level)	Geological unit	Soil description	Soil shear strength (kPa)
0.0m – 0.5m	Topsoil	Clayey SILT, dark brown, stiff to very stiff, moderate plasticity	71 kPa to 186 kPa
0.5m – 2.5m	Volcanic Tuff	Clayey SILT, orange/red brown, very stiff to hard, moist, highly plastic	101 kPa to 223 kPa
2.3m - 2.5m	Coral Sand	Gravely SAND, yellowish white	N/A
>2.5m	Coral Limestone	No description	N/A

N/A – not applicable

Groundwater was not encountered in any of the boreholes at the site.

The twelve Scala penetrometer tests SC1B – SC12B were terminated at depths of up to 3.1m below ground level. From this in-situ testing, we can assess the soil strengths at specific depths below the site. The Scala results and inferred soil strength are summarised in Table 4 below:

Table 4 – Summary of Scala penetrometer results

Depth (Below ground level)	Average Scala Blows per 50mm	Soil Type	Inferred Strength
0.5m	1	Cohesive	Stiff to Very Stiff
1.0m	2	Cohesive	Very Stiff
1.5m	2	Cohesive	Very Stiff
2.0m	2	Cohesive	Very Stiff
2.5m	20	Cohesive	Very Dense

From the table above, it can be noted that the soil strength increases with depth at the site.

Rather than using the conservative Scala results in the upper 2.5m, it would be beneficial to use the shear strengths recorded in the hand auger boreholes for detailed foundation design. These shear strengths are summarised in Table 4 above.

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6 Geotechnical Laboratory Testing Results

A summary of the geotechnical laboratory testing results is presented in table 5 below. A full set of the geotechnical testing data sheets is presented in Appendix D.

Table 5 – Summary of geotechnical testing

Sample Identification	Specific Gravity	Grain Size Analysis	Moisture Content
HA3A – 1.2m	2.84 t/m^3	SAND with some shell fragments, minor gravel, minor silt and trace clay	34.3%
HA4A – 1.0m	2.81 t/m^3	SAND with some shell fragments, minor gravel, minor silt and trace clay	56.3%
HA5A – 0.5m	2.75 t/m^3	SAND with some shell fragments, minor gravel, minor silt, trace clay and trace organics	41.1%
HA1B – 1.1m	3.00 t/m^3	Silty CLAY with minor sand, stiff, high plasticity	71.4%
HA3B – 0.6m	2.94 t/m^3	Clayey SILT with some sand, stiff, high plasticity	81.5%

7 Discussion and Engineering Properties

Recommendations and opinions contained in this report are based upon data from:

- 6 No. hand auger boreholes and 6 No. Scala penetrometer tests at Popua power station
- 8 No. hand auger boreholes and 12 No. Scala penetrometers tests at Vaini

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, geotechnical laboratory testing and also using 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 person competent to judge whether the soils exposed in the foundation excavations are compatible with those described within this report.

7.1 Solid Density Range

7.1.1 Site A - Popua Power Station

The estuarine sediments (0.6m-1m) can be assumed to have the following solid densities:

Solid Density = 2.75 t/m^3

The coral sand (1m-2m) can be assumed to have the following solid densities:

Solid Density range = 2.81 to 2.84 t/m^3

7.1.2 Site B - Vaini

The volcanic tuff (0.5m-2.5m) can be assumed to have the following solid densities:

Solid Density range = 2.94 to 3.0 t/m^3

7.2 Effective Cohesion (c')

7.2.1 Site A - Popua Power Station

The near surface material are granular and therefore have an effective cohesion of 0 kPa.

c' (Effective Cohesion) = 0 kPa

7.2.2 Site B - Vaini

The near surface material provides some effective cohesion due to the cohesive nature of the soil. A value of 5 kPa should be used for design.

c' (Effective Cohesion) = 5 kPa

7.3 Effective Internal Friction Angle (φ)

7.3.1 Site A - Popua Power Station

The effective internal friction angle for the near surface material (sand) has been estimated using a correlation from the Scala penetrometer results. A value of 30° should be used as the effective internal friction angle for design.

Φ (Effective internal friction angle) = 30°

7.3.2 Site B - Vaini

The effective internal friction angle for the near surface alluvium (clayey silt) has been estimated using a correlation from the Scala penetrometer and shear strength results. A value of 30° should be used as the effective internal friction angle for design.

Φ (Effective internal friction angle) = 30°

7.4 Young's Modulus Range (E)

The soil stiffness or Youngs Modulus, E has been calculated from a correlation with SPT N values (Bowles et al) derived from the available shear strength and Scala penetrometer readings. The table below gives the range of Youngs Modulus values for varying depths.

7.4.1 Site A - Popua Power Station

Table 6 – Summary of Youngs Modulus (E) with depth (granular soils only)

Depth (Below Ground level)	Scala blows/300mm	Corresponding SPT "N" values	Estimated Young's Modulus, E (MPa)
0.5 m	3	2	6
1.0 m	3	2	6
1.5 m	9	6	18
2.0 m	12	7	22
2.5 m	18	13	38
3.0 m	24	17	50

7.4.2 Site B - Vaini

Table 7 – Summary of Youngs Modulus (E) with depth (cohesive soils only)

Depth (Below Ground level)	Shear strength (kPa)	Estimated Young's Modulus, E (MPa)
0.5 m	120	18
1.0 m	150	25
1.5 m	150	25
2.0 m	170	28

7.5 Foundation Design

7.5.1 General

Following discussions with YEC, it is understood that either strip or pad foundations will be constructed for the two proposed buildings at sites A and B and for the solar panels at Vini, providing the ground conditions are suitable.

The site investigation data has indicated that shallow foundations may be utilised at the two sites depending on actual loadings. We have provided bearing pressures at different depths in the upper 3m.

We recommend using a strength reduction factor of 0.5 ($\phi_G = 0.5$) to give an ultimate limit state (ULS) bearing capacity, in accordance with New Zealand Design Standards (ref: NZS 1170). For serviceability limit state design we recommend a strength reduction factor of 0.33 ($\phi_G = 0.3$) to give an allowable bearing capacity.

7.5.2 Site A - Popua Power Station

We recommend that all foundations should be embedded at least 0.5m below finished floor level.

Strip or pad foundations would be constructed in the near surface alluvial material. Bearing capacities for this material based on the in situ testing undertaken are shown in table 8 below.

Table 8 – Bearing pressures within the loose to dense granular sediments

Depth	Bearing Pressures					
	Shallow strip footings up to 1 m wide			Shallow isolated pad footings up to 2.5 m wide		
	Allowable	*ULS*[1]	*Ultimate*	*Allowable*	*ULS*[1]	*Ultimate*
0.5m	50kPa	85kPa	160kPa	70kPa	105kPa	210kPa

[1] ULS = Ultimate Limit State (ref. NZS1170)

We recommend that all foundation excavations are inspected and tested by a competent person to ensure the ground conditions and bearing capacities are similar to those encountered during this investigation.

7.5.3 Site B - Vaini

We recommend that due to the high plasticity exhibited by the near surface soil, all foundations should be embedded a minimum of 600mm below finished ground level to allow for seasonal water content changes (shrink and swell effects).

The strip or pad foundations would be constructed in the near surface volcanic clay material. Bearing capacities for this material based on the in situ testing undertaken are shown in table 9 below.

Table 9 – Bearing pressures within the stiff and very stiff alluvial clay

Depth	Bearing Pressures					
	Shallow strip footings up to 1 m wide			Shallow isolated pad footings up to 2.5 m wide		
	Allowable	*ULS*	*Ultimate*	*Allowable*	*ULS*	*Ultimate*
0.6m	165kPa	248kPa	496kPa	210kPa	310kPa	620kPa

We recommend that all foundation excavations are inspected and tested by a competent person to ensure the ground conditions and bearing capacities are similar to those encountered during this investigation.

7.6 Settlement

T&TI have not been provided with any vertical loads for the proposed structures. It is recommended that settlement analysis is carried out following completion of the detailed design two buildings.

8 Applicability

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

Tonkin & Taylor International Ltd

Environmental and Engineering Consultants

Report prepared by:	Authorised for Tonkin & Taylor International Ltd by:
pp Conor Morrison	Chris Freer
Engineering Geologist	Project Director

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Appendix A: Contract of Soils Explorations

PREPARATION SURVEY
ON
THE PROJECT
FOR
INTRUDUCTION OF A MICRO-GRID SYSTEM WITH RENEWABLE ENERGY FOR THE TONGA ENERGY LOAD MAP
IN
THE KINGDOM OF TONGA

CONTRACT
OF
SOIL EXPLORATIONS

THIS CONTRACT is entered into on this 19th day of September, 2012 by and between **Yachiyo Engineering Co., Ltd.** (hereinafter referred to as "YEC") and **Tonkin & Taylor International**, duly organized and existing under the laws of New Zealand, (hereinafter referred to as "the Contractor").

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

WHEREAS, the quotation for the Work submitted by the Contractor dated 4th of September, 2012 has been accepted by YEC.

WHEREAS, the Contractor has accepted to perform the Work in accordance with the specifications and conditions set forth in this Contract and Annex 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 location is shown in *ATTACHMENT-1*.

Clause 5 : WORK ITEMS

The Work shall cover the followings;

Soil Exploration

- (a) Preparation for field test
- (b) Scala penetrometer test (dynamic cone) and sampling
- (c) Soil laboratory test
- (d) Reporting

Clause 6 : PREPARATION FOR THE WORK

The Contractor shall prepare all the necessary highly-skilled personnel and all of the required materials, facilities and equipment for the performance of the Work at the site and laboratory. 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 after the completion of each item of the Work. If such results are not accepted by YEC, the Contractor shall redeem those works as soon as possible to the satisfaction of YEC, the Contractor shall once more submit the results to YEC for inspection.

Clause 9 : TIME FOR COMPLETION

The Contractor shall complete all the Work by 21st day of October, 2012.

Clause 10 : CONTRACT AMOUNT

The Contract amount shall be **Sixteen Thousand (16,000) US. Dollars.**

Clause 11 : METHOD OF PAYMENT

(a) Advance payment

YEC shall pay an advance payment of thirty (30) percent of the Contract amount to the Contractor upon signing of the Contract.

(b) Final payment

Payment of the remaining balance of the Contract amount shall be remitted to the Contractor's bank account within seven (7) days after the Work has been finished and approved by YEC.

Clause 12 : PENALTY

A penalty of one/one hundred (1/100) of the Contract amount shall be imposed upon the Contractor per day by YEC, with maximum of ten (10) percent of the total Contract amount for a delay in the performance of the Work for which the Contractor is responsible to complete within the period as set forth in Clause 9.

The penalty amount shall be deducted from the final payment amount to be made to the Contractor.

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 the Kingdom of Tonga, strikes and sabotage, natural disasters, declared or undeclared war, blockades, revolutions, and natural calamities 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.

Clause 14 : LIABILITY

YEC shall be exempted from or kept harmless against any damage, loss and/or accident incurred by or arising from a third party in connection with any activity of the Contractor during the period of the Work.

Clause 15 : TERMINATION OF CONTRACT

YEC has the right to terminate the Contract by giving a written prior notice to the Contractor, in case of any of the following cases;

(a) Due to causes attributable to the Contractor, if YEC judges that 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 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

Without prior written consent of YEC, the Contractor shall not assign any or this entire Contract to a third party.

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 change, the time for completion and the Contract amount may be modified by mutual agreement in writing of both parties hereto. However, if extension of Contract period or increase in contract amount is required due to reasons attributable to the improper execution of the Work by the Contractor, such request from the Contractor shall not be approved by YEC. Should the YEC order additional works, an additional fee shall be paid to the Contractor, however, the Contractor shall not refuse to carry out the additional works without satisfactory reasons.

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 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 and/or data 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. In the event of disagreement, YEC shall determine such rates or prices as shall, in his opinion, be reasonable and proper.

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

Mitsuhisa Nishikawa
Chief Consultant
JICA Preparation Survey Team

For and On Behalf of
The Contractor

Chris Freer
Project Director
Tonkin & Taylor International

ANNEX-1

SPECIFICATION

1. Site Locations

Site location shall be shown to *ATTACHMENT-1*.
Work sites for investigation shall locate in Tongatapu.

1) Project site in Vaini (Site B)
2) Project site at Popua Power Station (Site A)

2. Site plan

Site plan for project site in Vaini (Site B) shall be shown to *ATTACHMENT-2*.
Site area is approx. 24,000m2.

Site plan for project site at Popua Power Station (Site A) shall be shown to *ATTACHMENT-3*

3. Soil Explorations

3-1 Application

The soil exploration survey shall be implemented in accordance with the Contract, the instructions of the Representative and the technical specifications described hereafter.

3-2 Scope of works

The scope of works shall be as follows;

- Preparation of work implementation schedule
- Transportation, assembling and disassembling of all the survey equipment
- Installation of scaffold and other safety measures during the execution of the works
- Implementation of miscellaneous works related to penetrating and sampling, field test and laboratory test
- Execution of field test
- Sampling and transportation of sampled soil
- Report on geological aspect based on laboratory test and field test
- Submission of geological samples for inspection
- Presentation of test results and necessary calculations in report form
- Backfilling of sampled hole

3-3 Quantities of the Soil Explorations

The soil explorations shall be executed according to the following quantities. The depth of perforation and quantity of samples mentioned table may be modified according to the conditions of the soil stratum, however, such modifications must be approved by the Representative.

Items	Quantity	Remarks
Scala Penetrometer Test	Max.5 m (if possible)	6 places at Site A 12 places at Site B
Specific Gravity	5 samples	BS1377 or equivalent International Standard
Grain-Size Analysis	5 samples	
Moisture Content Test	5 samples	

3-4 Location of the Scala Penetrometer Tests (Dynamic Cone)

The penetrating shall be executed at the locations of the intersections under study as shown in ***ATTACHMENT-4*** and 4 points in the PV unit area at Vaini Site.

The Contractor shall confirm the location of the penetrometer test on site before commencement in the presence of the Representative.

3-5 Preparation of Implementation Schedule

The implementation schedule to be prepared by the Contractor and submitted to the Representative shall cover the following items;

(1) Study execution program
(2) List of necessary machines and equipment
(3) Work method and measures to maintain security
(4) Relevant remarks
(5) Contractor's staff organized for the Work

3-6 Securing of Geological Samples

The Contractor shall prepare the geological samples and submit them to the Representative with indications of the geological name, position and date of sampling and any other necessary information. The samples and their plastic containers shall be approved by the Representative.

3-7 Sampling Work

(1) Preparation

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

(2) Groundwater level measurement

The Contractor shall measure the groundwater level in the hole.

(3) Completion of sampling

Upon completion of the sampling work, at the instructions of the Representative, 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 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.

3-8 Sampling for Laboratory Testing

(1) Disturbed samples

- Disturbed samples shall be taken from representative soil layers
- The sampling points shall be decided in consultations with the Representative
- Disturbed samples shall be sealed with wax immediately after the sampling
- On the sealed samples shall be clearly indicated depth, soil classification and type of soil test

3-9 Soil Tests in the Laboratory

(1) The soil tests in the laboratory shall be carried out based on the following standards or their equivalent;

Test	Standard
Specific Gravity	BS1377 or equivalent International Standard
Grain-Size Analysis	
Moisture Content Test	

(2) Samples to be tested shall be chosen by the Representative.

(3) The Contractor shall present to the Representative examples of the information sheets and data input used in his laboratory and both sides shall agree on the suitable presentation of the test results.

3-10 Results of the Soil Investigation Study

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

(1) Field test and sampling logs

The field test and sampling log shall contain the following information;

- Depth below ground level
- Graphical symbol of the soil type
- Description of the soil
- Position where soil sample was taken, whether disturbed or undisturbed
- Sample number
- Analysis for result of penetrating
- Groundwater table position
- Other as necessary

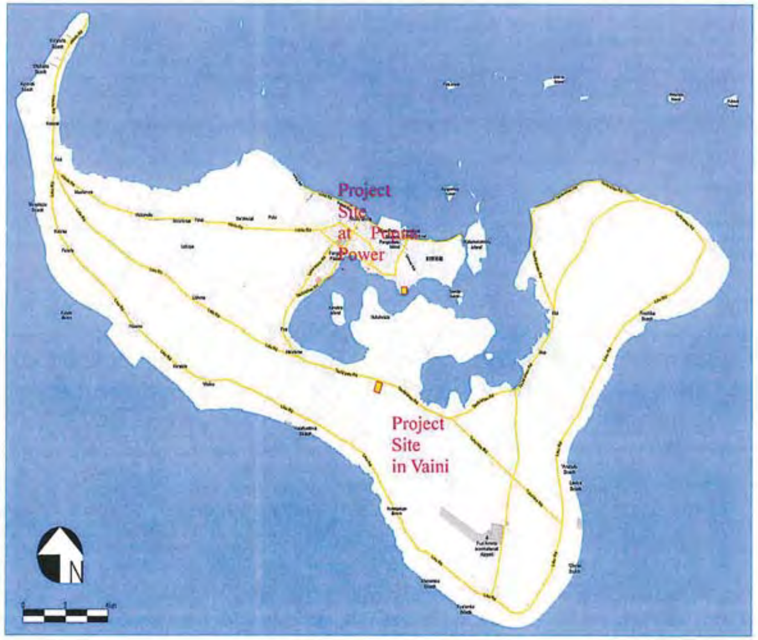
(2) Soil laboratory test results

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

(3) Language

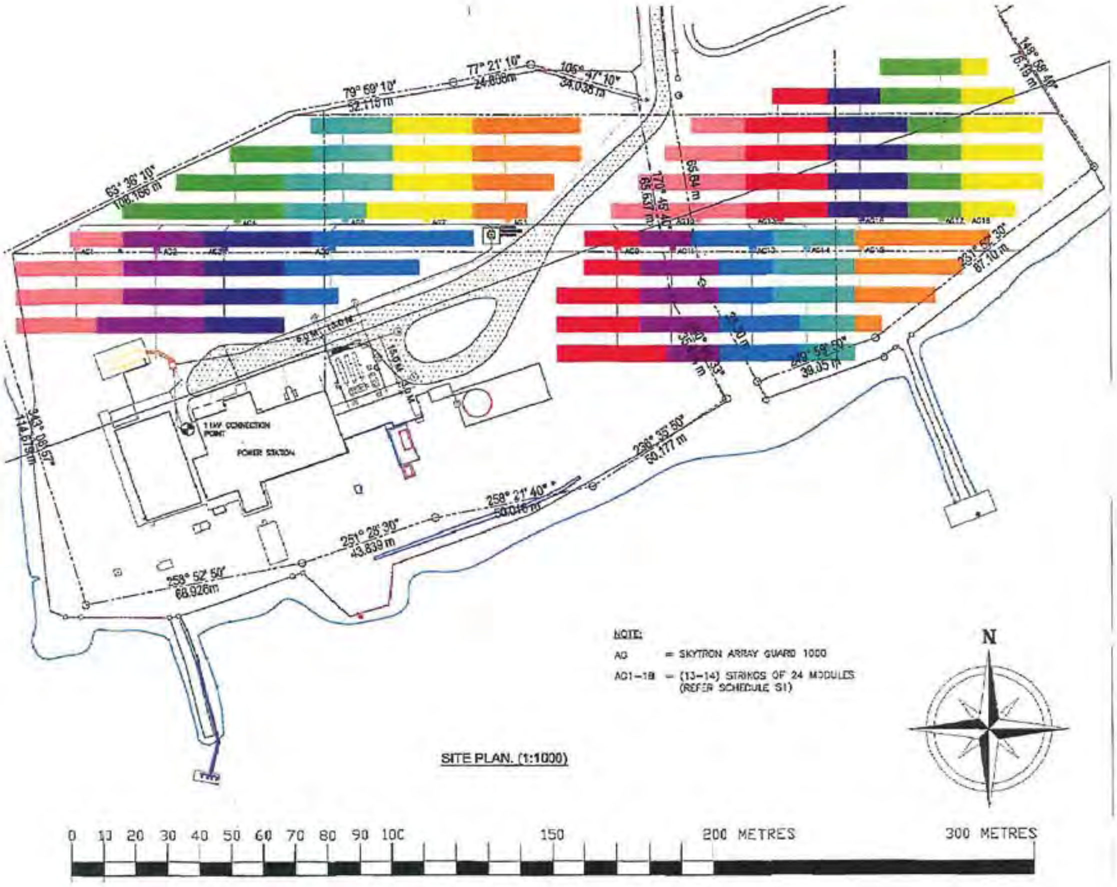
Document and all data shall be written in English.

ATTACHMENT−1
SITE MAP



ATTACHMENT-3
Project Site at Popua Power Station

SITE PLAN

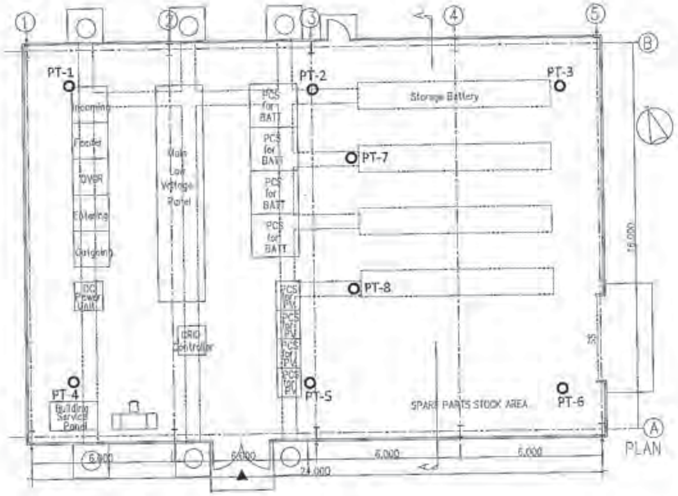


ATTACHMENT-2
Project Site in Vaini

CANDIDATE PHOTOVOLTAIC SITE

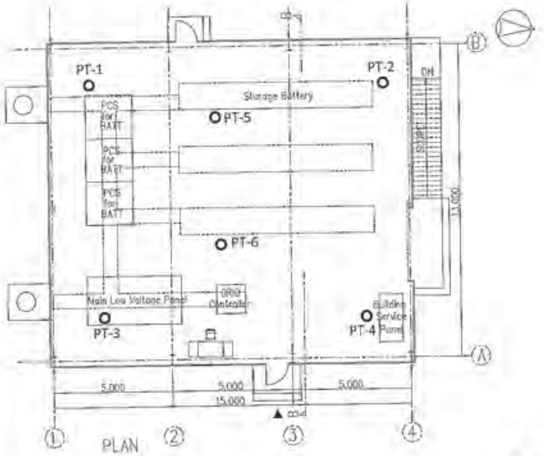
Appendix B: Topographical Survey and Geotechnical Investigation Location Plans

ATTACHMENT-4
SCALE PENETROMETER TEST POINTS



PCS & BATTERIES BUILDING at Project Site in VAINI

PCS & BATTERIES BUILDING IN VAINI



PCS & BATTERIES BUIDING at POPUA Power Station

PCS & BATTERIES BUILDING AT POPUA POWER STATION

○ PT-X: LOCATION OF PENETROMETER TEST

PREPARATION SURVEY
ON
THE PROJECT
FOR
INTRODUCTION OF A MICRO-GRID SYSTEM RENEWABLE ENERGY
FOR THE TONGA ENERGY ROAD MAP

LOCATION MAP
SCALE = NTS

SCHEDULE OF DRAWINGS

SHEET NO.	SHEET TITLE
VAI1	CADATSRAL MAP
VAI2	TOPOGRAPHICAL SURVEY
VAI3	CONTOUR MAP
VAI4	SPOT LEVELS
VAI5	VAINI SPT COORDINATES AND LEVELS
POP1	POPUA SPT COORDINATES

05 OCTOBER 2012

CTS COMPANY LTD.
CIVIL, STRUCTURAL AND WATER
ENGINEERING CONSULTANTS
[illegible]
[illegible]

PREPARATION SURVEY
ON
THE PROJECT
FOR
INTRODUCTION OF A MICRO-GRID SYSTEM WITH RENEWABLE ENERGY
FOR THE TONGA ENERGY ROAD MAP
IN
THE KINGDOM OF TONGA

TOPOGRAPHICAL SURVEY

CLIENT

YACHIYO ENGINEERING CO., LTD. AND
WEST JAPAN ENGINEERING CONSULTANTS, INC. JV

SCHEDULE OF DRAWINGS

SHEET NO.	SHEET TITLE
VAI1	CADATSRAL MAP
VAI2	TOPOGRAPHICAL SURVEY
VAI3	CONTOUR MAP
VAI4	SPOT LEVELS
VAI5	VAINI SPT COORDINATES AND LEVELS
POP1	POPUA SPT COORDINATES

05 OCTOBER 2012

CTS COMPANY LTD.
CIVIL, STRUCTURAL AND WATER
ENGINEERING CONSULTANTS
[illegible]
[illegible]

TOPOGRAPHICAL SURVEY MAP

SCALE = 1:1000M

STATIONS AND COODINATES

STATION	EASTING	NORTHING	REDUCE LEVEL(M)	REFERENCE NAME
STA. 1	1687617.460	2655883.447	13.217	BM1
STA. 2	1687617.460	2655009.393	13.299	BM2
STA. 3	1687559.775	2655920.504	13.293	BM3
STA. 4	1687770.045	2655783.756	12.751	BM4
STA. 5	1687764.359	2655840.927	13.201	BM5
STA. 6	1687857.757	2655881.258	12.331	BM6
STA. 7	1687730.211	2655917.884	13.337	BM7
STA. 8	1687863.072	2655852.849	12.171	BM8
REF. LEVEL	1687857.760	2655869.750	11.682	RL

LEGEND

6 △	STATION POINT
♁	SPT. POINT
●	POWER POLE
⊗	TREE
⊛	BANANA PLANT
◍	COCONUT PALM
—·—	FENCE

HORIZONTAL SCALE = 1:1000
0 10 20 30 40 50 100m

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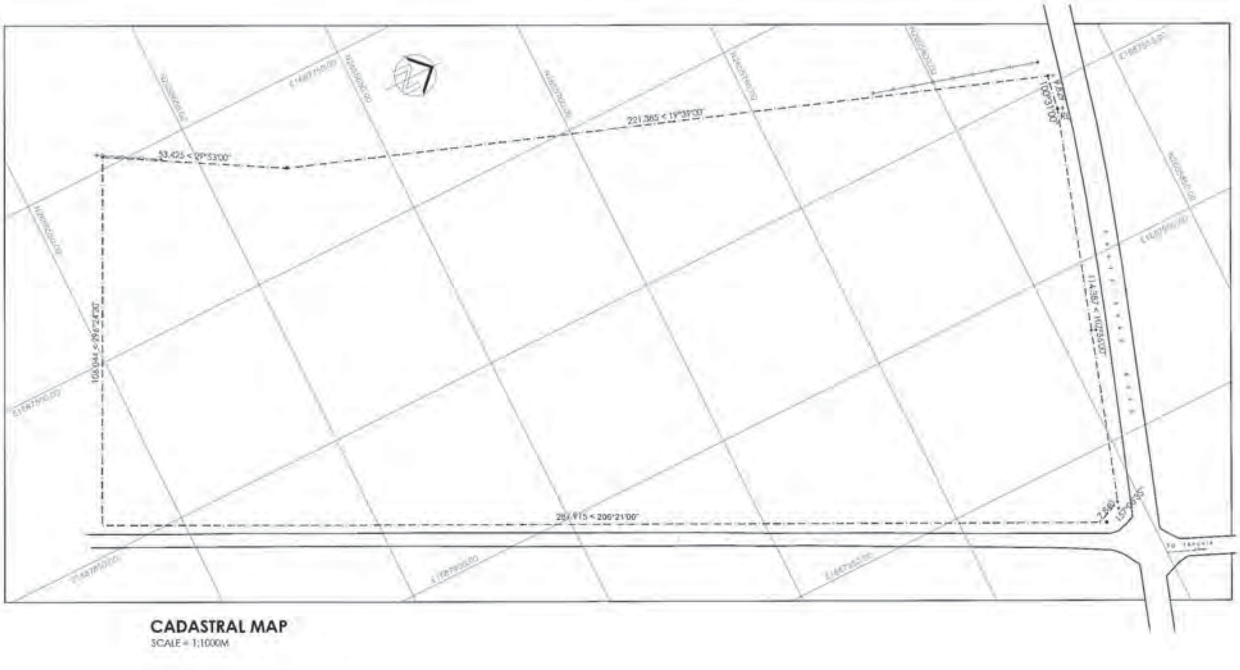
UNIT 1-10 TONGILAVA PLAZA, TAUFA'AHAU ROAD, FANGA
P.O. BOX 194 NUKU'ALOFA. Ph/Fax (676) 25607, 28412. Mob (676) 45478

SURVEYED BY: F.FALEKAONO, E. KAUFUSI, T. FAINGA'ANUKU
DRAWN BY: L. KAUFUSI, T. FAINGA'ANUKU, A. SANCHEZ
CHECKED BY: M. VAKASIUOLA

PROJECT: THE PROJECT FOR INTRODUCTION OF A MICRO-GRID SYSTEM WITH RENEWABLE ENERGY FOR THE TONGA ENERGY ROAD MAP
CLIENT: YACHIYO ENGINEERING CO., LTD. AND WEST JEC JV

SHEET CONTENTS: TOPOGRAPHICAL SURVEY
SHEET NUMBER: VAI2
DATE: 05 OCT 2012



CADASTRAL MAP

SCALE = 1:1000M

HORIZONTAL SCALE = 1:1000
0 10 20 30 40 50 100m

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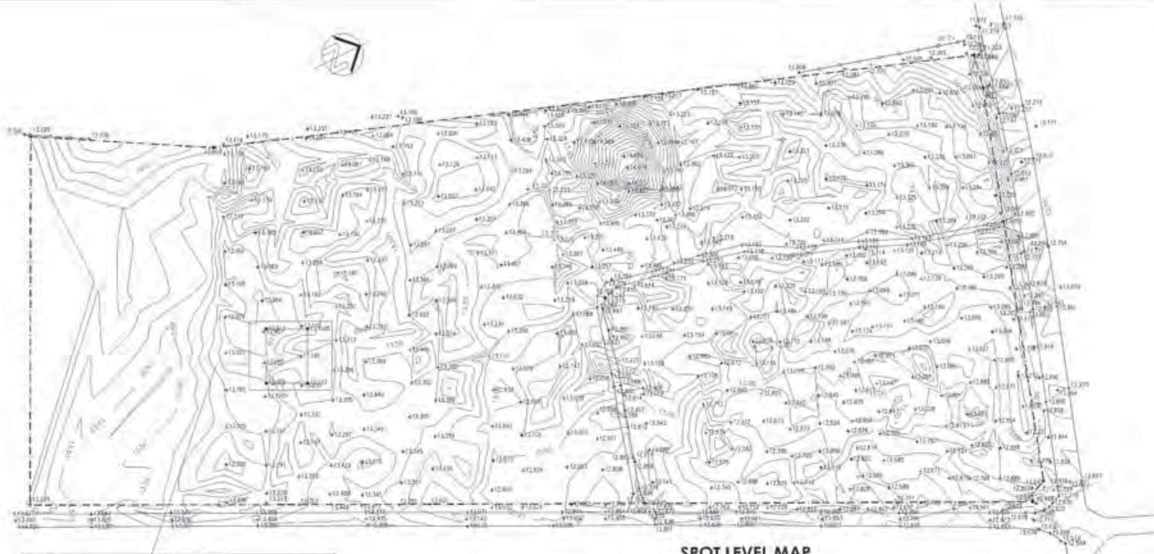
DRAWN BY: L. KAUFUSI, T. FAINGA'ANUKU, A. SANCHEZ
CHECKED BY: M. VAKASIUOLA

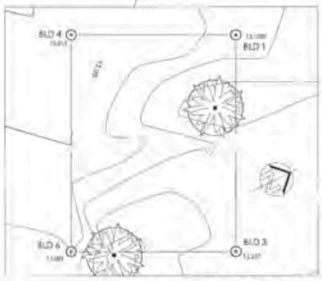
PROJECT: THE PROJECT FOR INTRODUCTION OF A MICRO-GRID SYSTEM WITH RENEWABLE ENERGY FOR THE TONGA ENERGY ROAD MAP
CLIENT: YACHIYO ENGINEERING CO., LTD. AND WEST JEC JV

SHEET CONTENTS: CADASTRAL MAP
SHEET NUMBER: VAI1
DATE: 05 OCT 2012



SPOT LEVEL MAP

SCALE = 1:1000M



BUILDING STAKEOUT MAP

SCALE = 1:250M

BUILDING STAKEOUT LEVEL AND COORDINATES

BUILDING SPOT	EASTING	NORTHING	REDUCE LEVEL(M)	REFERENCE NAME
SPOT 1	1687654.709	2655918.877	13.110	BLD 1
SPOT 3	1687646.209	2655905.797	13.237	BLD 3
SPOT 4	1687644.687	2655925.384	12.913	BLD 4
SPOT 6	1687636.187	2655912.303	13.099	BLD 6

LEGEND

- 6 STATION POINT
- SPT POINT
- POWER POLE
- TREE
- BANANA PLANT
- COCONUT PALM
- FENCE

HORIZONTAL SCALE = 1:1000

0 10 20 30 40 50 100m

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P.O. BOX 194 NUKU'ALOFA. Ph/Fax (676) 28807, 28412. Mob (676) 45679

SURVEYED BY: T.FALEKAOHO L. KAUFUSI T. FANGA'ANUKU

DRAWN BY: L. KAUFUSI, T. FANGA'ANUKU, A. SANCHEZ

CHECKED BY: M. VAKASIUOLA

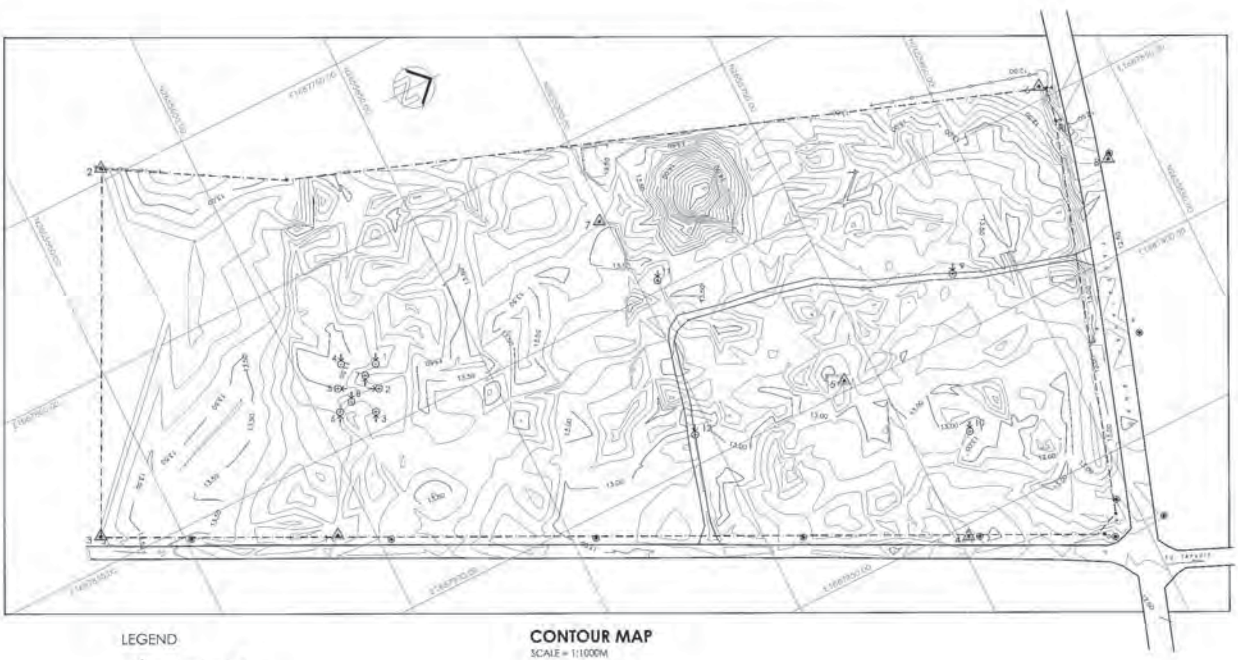
PROJECT: THE PROJECT FOR INTRODUCTION OF A MICRO-GRID SYSTEM WITH RENEWABLE ENERGY FOR THE TONGA ENERGY ROAD MAP

CLIENT: YACHIYO ENGINEERING CO., LTD. AND WEST JEC JV

SHEET CONTENTS: SPOT LEVELS

SHEET NUMBER: VAI4

DATE: 05 OCT 2012



CONTOUR MAP

SCALE = 1:1000M

LEGEND

- 6 STATION POINT
- SPT POINT
- POWER POLE
- TREE
- BANANA PLANT
- COCONUT PALM
- FENCE

HORIZONTAL SCALE = 1:1000

0 10 20 30 40 50 100m

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P.O. BOX 194 NUKU'ALOFA. Ph/Fax (676) 28807, 28412. Mob (676) 45679

SURVEYED BY: T.FALEKAOHO L. KAUFUSI T. FANGA'ANUKU

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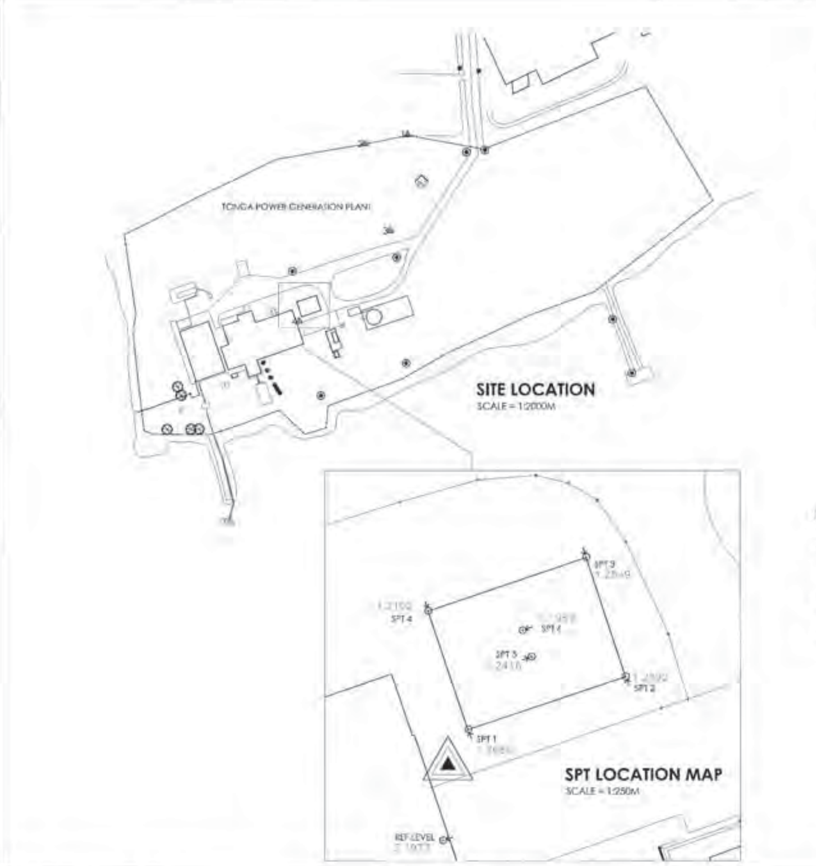
CLIENT: YACHIYO ENGINEERING CO., LTD. AND WEST JEC JV

SHEET CONTENTS: CONTOUR MAP

SHEET NUMBER: VAI3

DATE: 05 OCT 2012



STATIONS AND COORDINATES

STATION	EASTING	NORTHING	REDUCE LEVEL(M)	REFERENCE NAME
STA. 1	1691335.667	2659433.475	0.749	BM1
STA. 2	1691335.667	2659458.354	0.918	BM2
STA. 3	1691283.730	2659454.929	1.083	BM3
STA. 4	1691243.754	2659517.222	1.229	BM4

SPT LEVELS AND COORDINATES

SPT	EASTING	NORTHING	REDUCE LEVEL(M)	REFERENCE NAME
SPOT 1	1691245.981	2659515.279	1.269	SPT 1
SPOT 2	1691247.292	2659503.365	1.259	SPT 2
SPOT 3	1691256.269	2659504.315	1.255	SPT 3
SPOT 4	1691254.906	2659516.312	1.210	SPT 4
SPOT 5	1691230.125	2659509.674	1.242	SPT 5
SPOT 6	1691252.122	2659509.907	1.199	SPT 6

LEGEND

- STATION POINT
- SPT POINT
- POWER POLE
- TREE
- BANANA PLANT
- COCONUT PALM
- FENCE

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P.O. BOX 1949 NUKU'ALOFA, Phone (676) 28607, 28612, Mob (676) 45679

SURVEYED BY: T.FALEKAONO, L. KAUFUSI, T. FANGA'ANIUHI
DRAWN BY: L. KAUFUSI, T. FANGA'ANIUHI, A. SANCHEZ
CHECKED BY: M. VAKASIUOLA

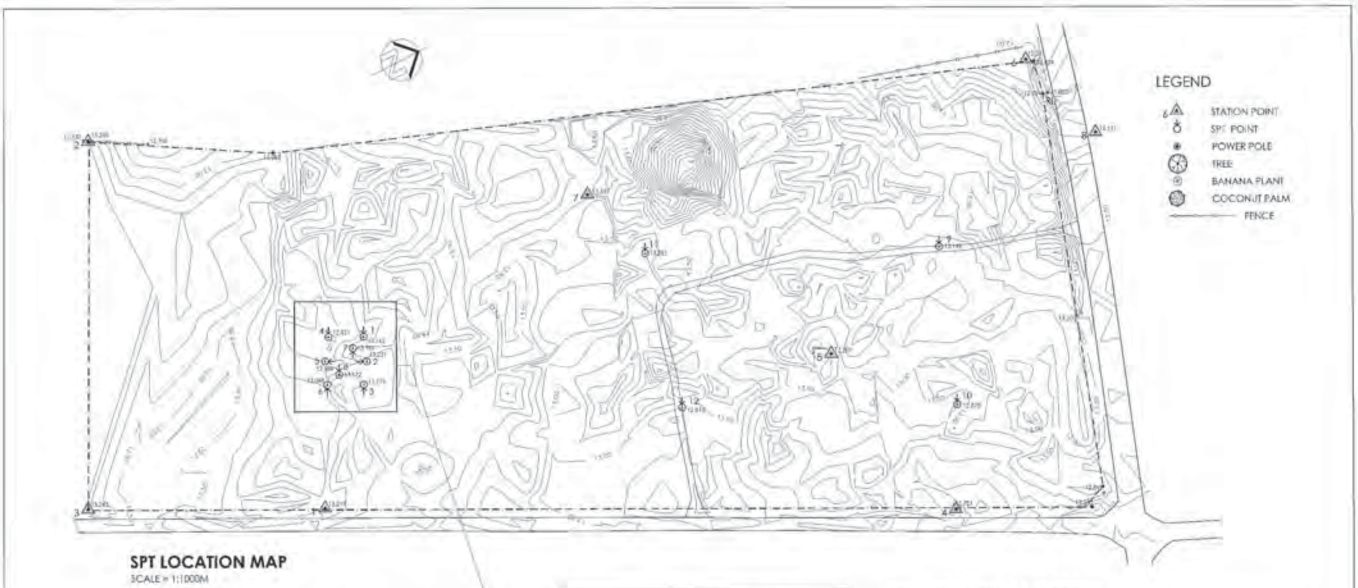
PROJECT: THE PROJECT FOR INTRODUCTION OF A MICRO-GRID SYSTEM WITH RENEWABLE ENERGY FOR THE TONGA ENERGY ROAD MAP

CLIENT: YACHIYO ENGINEERING CO., LTD. AND WEST JEC JV

SHEET CONTENTS: SPT COORDINATES AND LEVELS

SHEET NUMBER: POP1

DATE: 05 OCT 2012



SPT LEVELS AND COORDINATES

SPT	EASTING	NORTHING	REDUCE LEVEL(M)	REFERENCE NAME
SPT. 1	1687653.545	2655918.830	13.142	SPT. 1
SPT. 2	1687650.455	2655912.323	13.231	SPT. 2
SPT. 3	1687646.121	2655907.215	13.279	SPT. 3
SPT. 4	1687645.037	2655924.215	12.921	SPT. 4
SPT. 5	1687640.424	2655918.848	12.999	SPT. 5
SPT. 6	1687637.292	2655912.821	13.068	SPT. 6
SPT. 7	1687649.187	2655917.711	13.166	SPT. 7
SPT. 8	1687641.709	2655913.470	13.172	SPT. 8
SPT. 9	1687807.297	2655849.639	13.149	SPT. 9
SPT. 10	1687786.810	2655806.863	12.875	SPT. 10
SPT. 11	1687734.922	2655894.510	13.282	SPT. 11
SPT. 12	1687719.828	2655851.402	12.920	SPT. 12

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PROJECT: THE PROJECT FOR INTRODUCTION OF A MICRO-GRID SYSTEM WITH RENEWABLE ENERGY FOR THE TONGA ENERGY ROAD MAP

CLIENT: YACHIYO ENGINEERING CO., LTD. AND WEST JEC JV

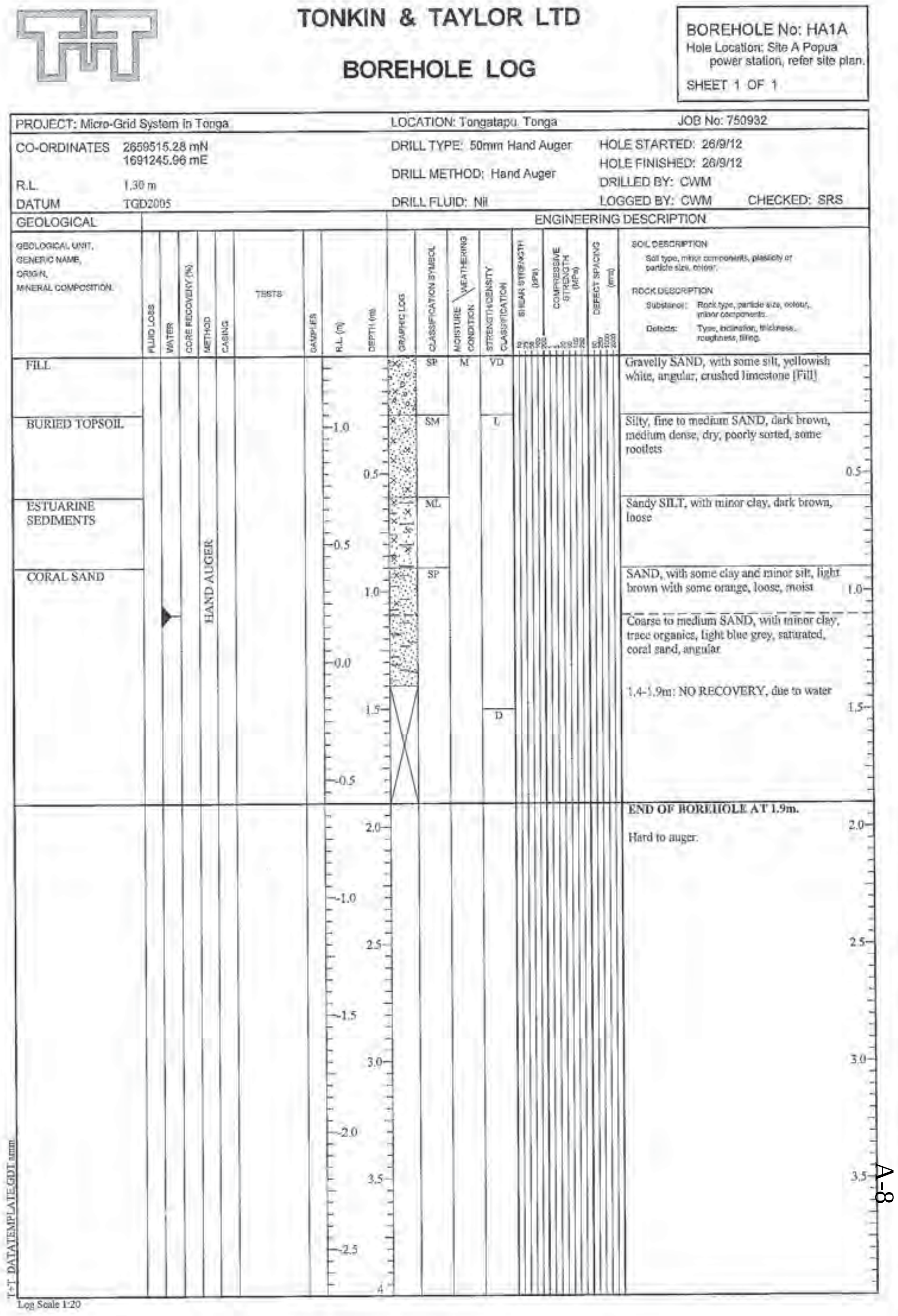
SHEET CONTENTS: SPT COORDINATES AND LEVELS

SHEET NUMBER: VAI5

DATE: 05 OCT 2012

Appendix C: Site A - Investigation Logs and Geotechnical Laboratory Testing

- **Hand auger borehole logs**
- **Scala Penetrometer results**
- **Geotechnical Laboratory Testing**



TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: HA1A
Hole Location: Site A Popua power station, refer site plan.
SHEET 1 OF 1

PROJECT: Micro-Grid System in Tonga
LOCATION: Tongatapu, Tonga
JOB No: 750932

CO-ORDINATES 2659515.28 mN 1691245.96 mE
R.L. 1.30 m
DATUM TGD2005
DRILL TYPE: 50mm Hand Auger
DRILL METHOD: Hand Auger
DRILL FLUID: Nil
HOLE STARTED: 26/9/12
HOLE FINISHED: 26/9/12
DRILLED BY: CWM
LOGGED BY: CWM
CHECKED: SRS

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	METHOD	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
FILL	HAND AUGER	SP	M	VD	Gravelly SAND, with some silt, yellowish white, angular, crushed limestone [Fill]
BURIED TOPSOIL		SM		L	Silty, fine to medium SAND, dark brown, medium dense, dry, poorly sorted, some rootlets
ESTUARINE SEDIMENTS		ML			Sandy SILT, with minor clay, dark brown, loose
CORAL SAND		SP			SAND, with some clay and minor silt, light brown with some orange, loose, moist
					Coarse to medium SAND, with minor clay, trace organics, light blue grey, saturated, coral sand, angular
					1.4-1.9m: NO RECOVERY, due to water
				D	
					END OF BOREHOLE AT 1.9m.
					Hard to auger.

T+T DATATEMPLATE.GDT mm

Log Scale 1:20

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: HA2A
Hole Location: Site A Popua power station, refer site plan.
SHEET 1 OF 1

PROJECT: Micro-Grid System in Tonga	LOCATION: Tongatapu, Tonga	JOB No: 750932	
CO-ORDINATES 2659503.37 mN 1691247.29 mE	DRILL TYPE: 50mm Hand Auger	HOLE STARTED: 26/9/12	
R.L. 1.30 m	DRILL METHOD: Hand Auger	HOLE FINISHED: 26/9/12	
		DRILLED BY: CWM	
DATUM TGD2005	DRILL FLUID: Nil	LOGGED BY: CWM	CHECKED: SRS

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	METHOD	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
TOPSOIL	HAND AUGER	ML	M	L	SILT, with some clay and minor sand, trace gravel, dark brown with light brown sand and gravel, firm, low plasticity, moist, many rootlets
CORAL SAND		SP		VD	Gravelly, coarse to medium SAND, with some silt, dark brown with some light ~~brown gravel, dense to very dense, dry,~~ angular coral sand and gravel
					END OF BOREHOLE AT 0.55m. Hard to auger (gravel).

Log Scale 1:20

T+T DATATEMPLATE.GDT mm

TONKIN & TAYLOR LTD

BOREHOLE LOG

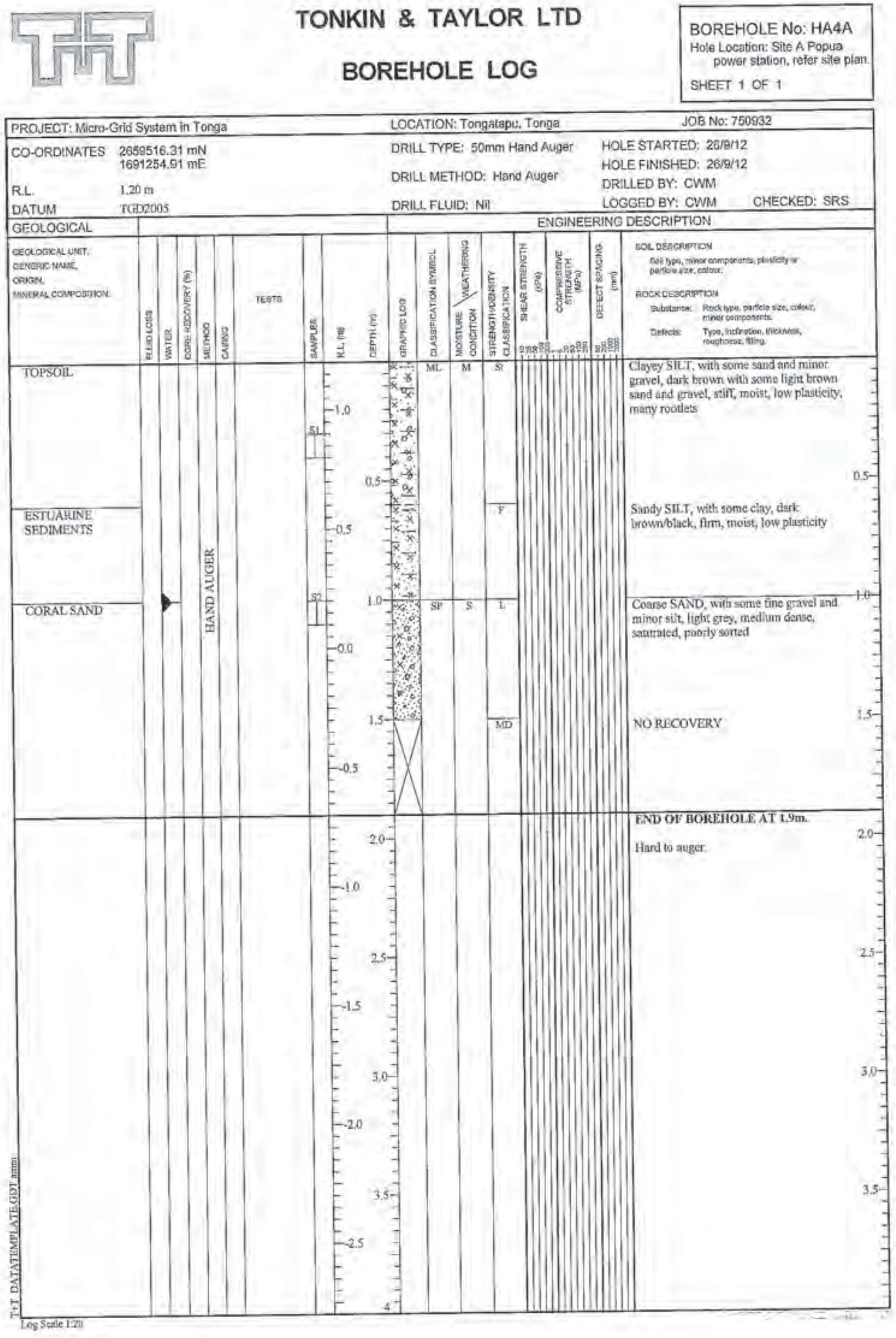
BOREHOLE No: HA3A
Hole Location: Site A Popua power station, refer site plan.
SHEET 1 OF 1

PROJECT: Micro-Grid System in Tonga	LOCATION: Tongatapu, Tonga	JOB No: 750932	
CO-ORDINATES 2659504.32 mN 1691253.27 mE	DRILL TYPE: 50mm Hand Auger	HOLE STARTED: 26/9/12	
R.L. 1.30 m	DRILL METHOD: Hand Auger	HOLE FINISHED: 26/9/12	
		DRILLED BY: CWM	
DATUM TGD2005	DRILL FLUID: Nil	LOGGED BY: CWM	CHECKED: SRS

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	WATER	METHOD	SAMPLES	CLASSIFICATION SYMBOL	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
TOPSOIL		HAND AUGER		SM	M	L	Silty SAND, with some clay, dark brown, loose, many rootlets
FILL			S1	SP		VD	Coarse SAND, with some gravel, light yellow brown, very dense, angular coral limestone sand [Fill]
BURIED TOPSOIL						L	Silty, fine SAND, dark brown, medium dense, moist, massive
ESTUARINE SEDIMENTS	▶						
CORAL SAND			S2		S	D	Coarse SAND, with some gravel and minor silt, light blue grey, loose to medium dense, saturated, angular coral sand NO RECOVERY
							END OF BOREHOLE AT 1.9m. Hard to auger.

Log Scale 1:20

T+T DATATEMPLATE.GDT mm



TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: HA4A
Hole Location: Site A Popua power station, refer site plan.
SHEET 1 OF 1

PROJECT: Micro-Grid System in Tonga
LOCATION: Tongatapu, Tonga
JOB No: 750932
CO-ORDINATES 2659516.31 mN 1691254.91 mE
R.L. 1.20 m
DATUM TGD2005
DRILL TYPE: 50mm Hand Auger
DRILL METHOD: Hand Auger
DRILL FLUID: Nil
HOLE STARTED: 26/9/12
HOLE FINISHED: 26/9/12
DRILLED BY: CWM
LOGGED BY: CWM
CHECKED: SRS

SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour.
ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.

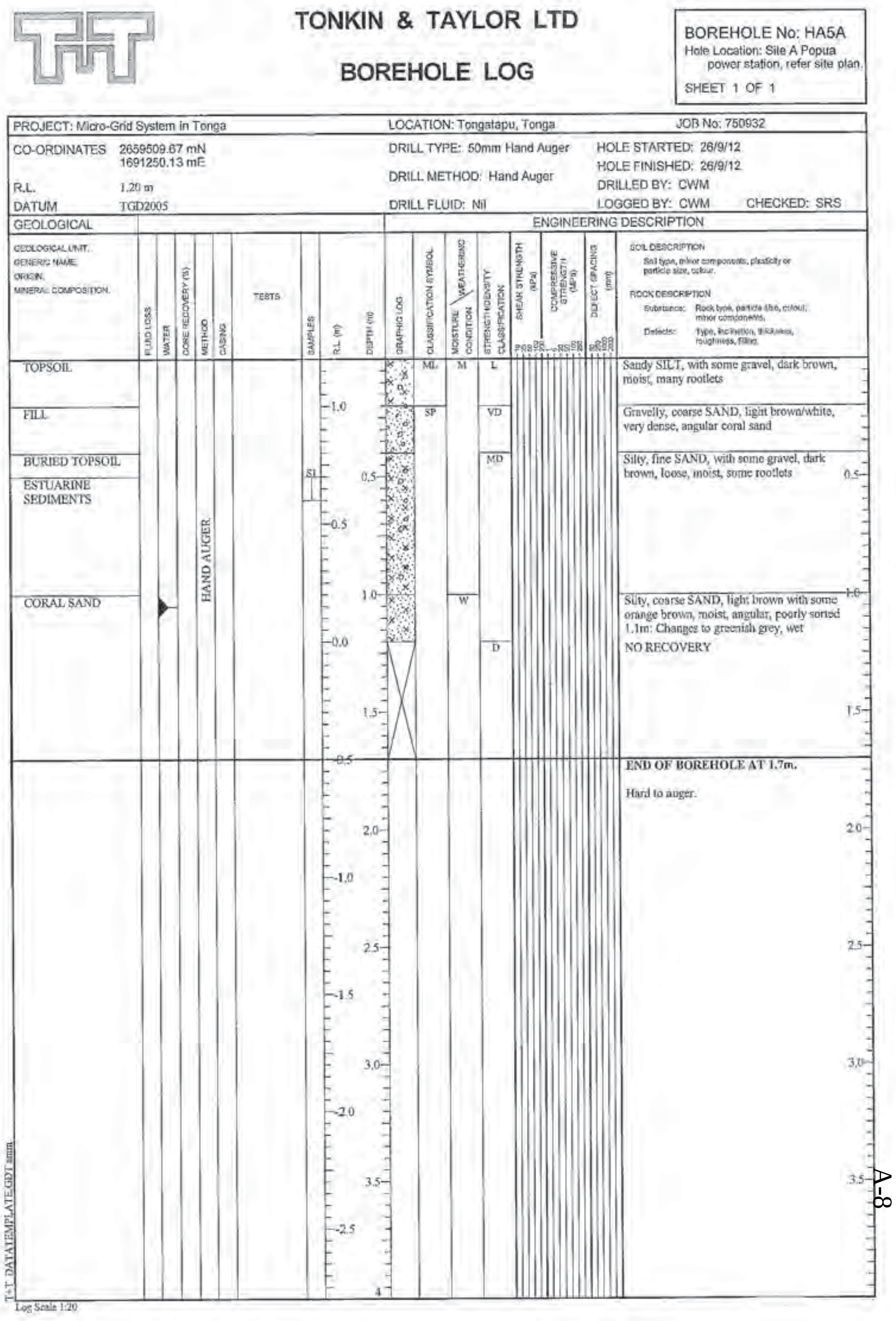
Method: HAND AUGER

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	SAMPLES	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION
TOPSOIL	S1	ML	M	St	Clayey SILT, with some sand and minor gravel, dark brown with some light brown sand and gravel, stiff, moist, low plasticity, many rootlets
ESTUARINE SEDIMENTS				F	Sandy SILT, with some clay, dark brown/black, firm, moist, low plasticity
CORAL SAND	S2	SP	S	L	Coarse SAND, with some fine gravel and minor silt, light grey, medium dense, saturated, poorly sorted
				MD	NO RECOVERY

END OF BOREHOLE AT 1.9m.

Hard to auger.

T+T DATATEMPLATE.GDT mmm
Log Scale 1:20



TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: HA5A
Hole Location: Site A Popua power station, refer site plan.
SHEET 1 OF 1

PROJECT: Micro-Grid System in Tonga
LOCATION: Tongatapu, Tonga
JOB No: 750932
CO-ORDINATES 2659509.67 mN 1691250.13 mE
R.L. 1.20 m
DATUM TGD2005
DRILL TYPE: 50mm Hand Auger
DRILL METHOD: Hand Auger
DRILL FLUID: Nil
HOLE STARTED: 26/9/12
HOLE FINISHED: 26/9/12
DRILLED BY: CWM
LOGGED BY: CWM
CHECKED: SRS

SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour.
ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.

Method: HAND AUGER

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	SAMPLES	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION
TOPSOIL		ML	M	L	Sandy SILT, with some gravel, dark brown, moist, many rootlets
FILL		SP		VD	Gravelly, coarse SAND, light brown/white, very dense, angular coral sand
BURIED TOPSOIL ESTUARINE SEDIMENTS	S1			MD	Silty, fine SAND, with some gravel, dark brown, loose, moist, some rootlets
CORAL SAND			W		Silty, coarse SAND, light brown with some orange brown, moist, angular, poorly sorted 1.1m: Changes to greenish grey, wet
				D	NO RECOVERY

END OF BOREHOLE AT 1.7m.

Hard to auger.

T+T DATATEMPLATE.GDT mmm
Log Scale 1:20

TONKIN & TAYLOR LTD

BOREHOLE LOG

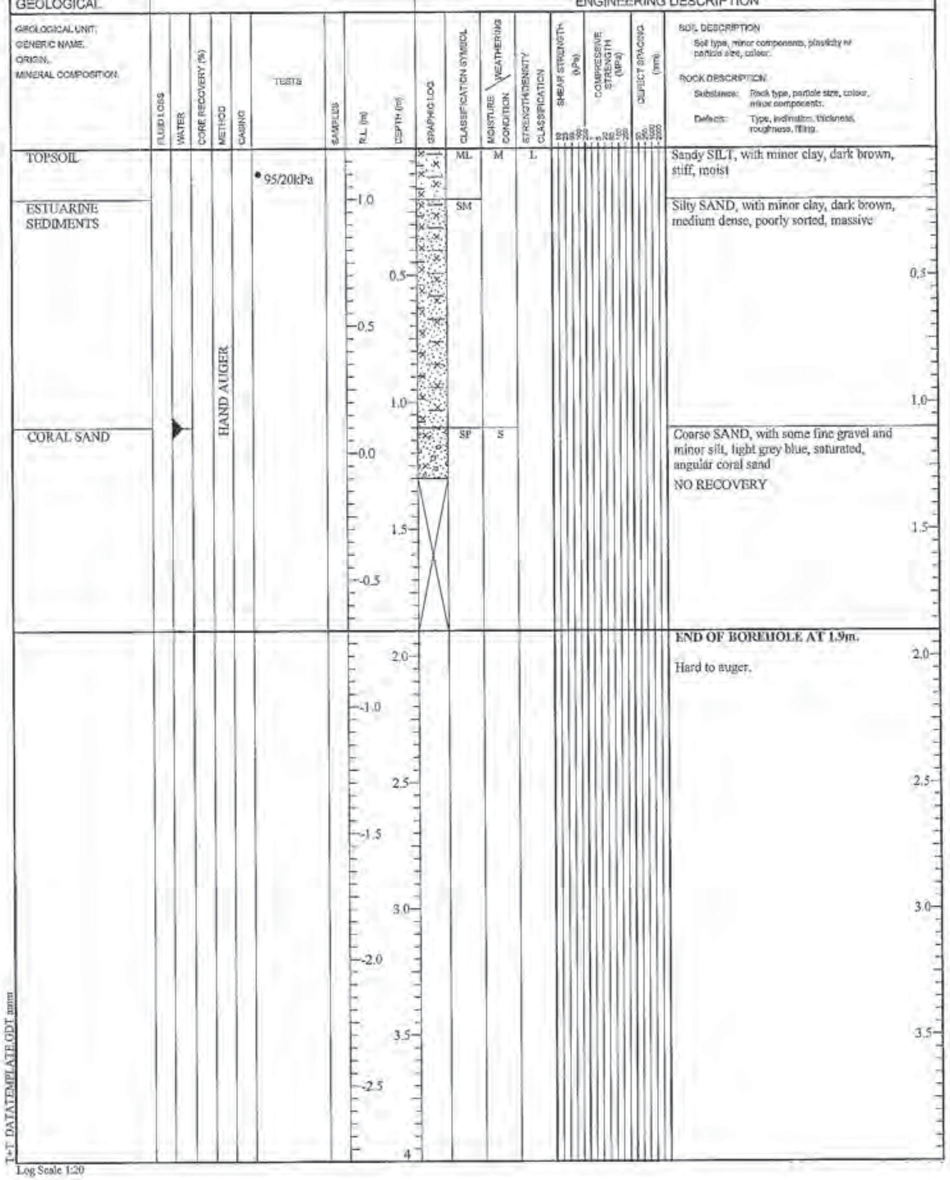
BOREHOLE No: HA6A
Hole Location: Site A Popua power station, refer site plan.
SHEET 1 OF 1

PROJECT: Micro-Grid System in Tonga
LOCATION: Tongatapu, Tonga
JOB No: 750932

CO-ORDINATES 2659509.91 mN
1691252.12 mE
R.L. 1.20 m
DATUM TGD2005

DRILL TYPE: 50mm Hand Auger
DRILL METHOD: Hand Auger
DRILL FLUID: Nil

HOLE STARTED: 26/9/12
HOLE FINISHED: 26/9/12
DRILLED BY: CWM
LOGGED BY: CWM CHECKED: SRS



Geological unit	Tests	Classification symbol	Moisture condition	Strength/density classification	Engineering description
TOPSOIL	● 95/20kPa	ML	M	L	Sandy SILT, with minor clay, dark brown, stiff, moist
ESTUARINE SEDIMENTS		SM			Silty SAND, with minor clay, dark brown, medium dense, poorly sorted, massive
CORAL SAND		SP	S		Coarse SAND, with some fine gravel and minor silt, light grey blue, saturated, angular coral sand NO RECOVERY
					END OF BOREHOLE AT 1.9m. Hard to auger.

T+T DATATEMPLATE.GDT mm

Log Scale 1:20

SC1.xlsx

TONKIN & TAYLOR

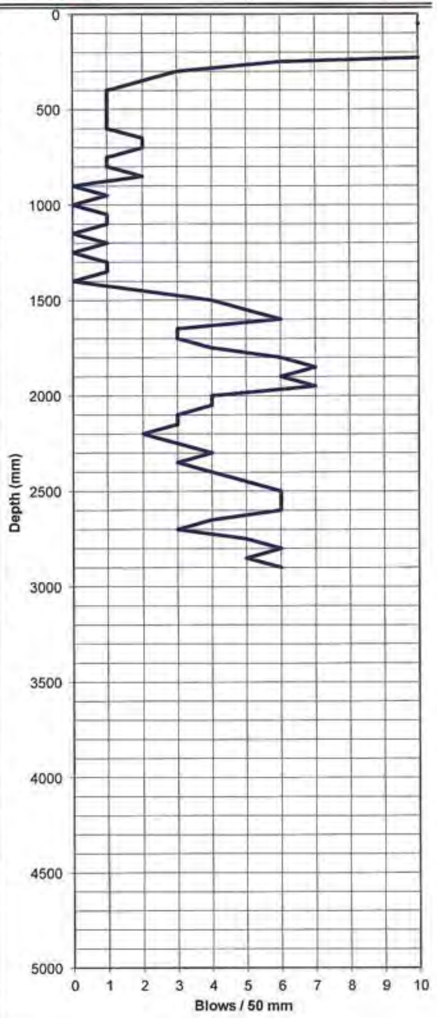
SCALA PENETROMETER LOG

Job No: 750932
Project: Micro-Grid System in Tonga
Location: Site A
RL: 1.27m

Date: 27/09/2012
Operated by: CWM
Logged by: CWM
Checked by: ADP

Test No. SC1A
Sheet 1
of 1

mm Driven	No. of Blows	mm Driven	No. of Blows
50	10	2550	6
100	15	2600	6
150	12	2650	4
200	16	2700	3
250	6	2750	5
300	3	2800	6
350	2	2850	5
400	1	2900	6
450	1	2950	
500	1	3000	
550	1	3050	
600	1	3100	
650	2	3150	
700	2	3200	
750	1	3250	
800	1	3300	
850	2	3350	
900	0	3400	
950	1	3450	
1000	0	3500	
1050	1	3550	
1100	1	3600	
1150	0	3650	
1200	1	3700	
1250	0	3750	
1300	1	3800	
1350	1	3850	
1400	0	3900	
1450	2	3950	
1500	4	4000	
1550	5	4050	
1600	6	4100	
1650	3	4150	
1700	3	4200	
1750	4	4250	
1800	6	4300	
1850	7	4350	
1900	6	4400	
1950	7	4450	
2000	4	4500	
2050	4	4550	
2100	3	4600	
2150	3	4650	
2200	2	4700	
2250	3	4750	
2300	4	4800	
2350	3	4850	
2400	4	4900	
2450	5	4950	
2500	6	5000	



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

CLIENT Yachiyo Engineering
TITLE Scala Penetrometer Test
REFERENCE No. 750932

September 2012

SC2.xlsx

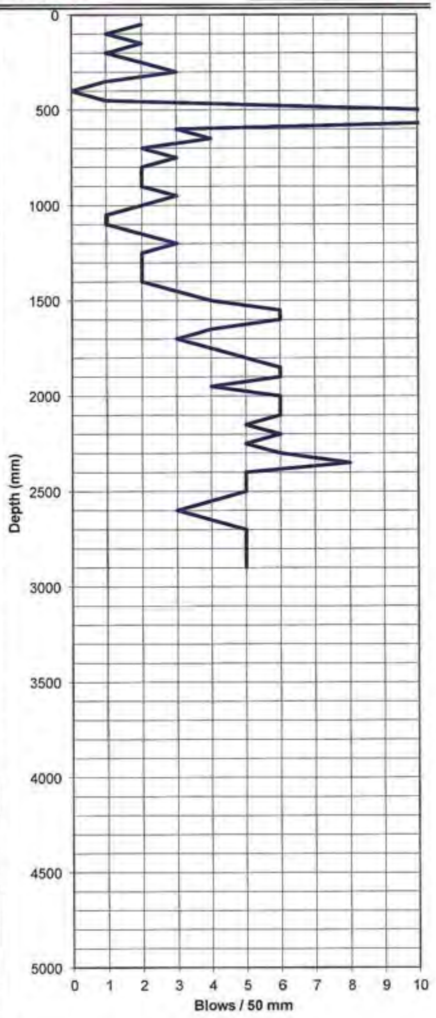
TONKIN & TAYLOR
SCALA PENETROMETER LOG

Job No: 750932
Project: Micro-Grid System in Tonga
Location: Site A
RL: 1.26m

Date: 27/09/2012
Operated by: CWM
Logged by: CWM
Checked by: ADP

Test No. SC2A
Sheet 1
of 1

mm Driven	No. of Blows	mm Driven	No. of Blows
50	2	2550	4
100	1	2600	3
150	2	2650	4
200	1	2700	5
250	2	2750	5
300	3	2800	5
350	1	2850	5
400	0	2900	5
450	1	2950	
500	10	3000	
550	15	3050	
600	3	3100	
650	4	3150	
700	2	3200	
750	3	3250	
800	2	3300	
850	2	3350	
900	2	3400	
950	3	3450	
1000	2	3500	
1050	1	3550	
1100	1	3600	
1150	2	3650	
1200	3	3700	
1250	2	3750	
1300	2	3800	
1350	2	3850	
1400	2	3900	
1450	3	3950	
1500	4	4000	
1550	6	4050	
1600	6	4100	
1650	4	4150	
1700	3	4200	
1750	4	4250	
1800	5	4300	
1850	6	4350	
1900	6	4400	
1950	4	4450	
2000	6	4500	
2050	6	4550	
2100	6	4600	
2150	5	4650	
2200	6	4700	
2250	5	4750	
2300	6	4800	
2350	8	4850	
2400	5	4900	
2450	5	4950	
2500	5	5000	



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

CLIENT Yachiyo Engineering
TITLE Scala Penetrometer Test
REFERENCE No. 750932

September 2012

[1]

SC3.xlsx

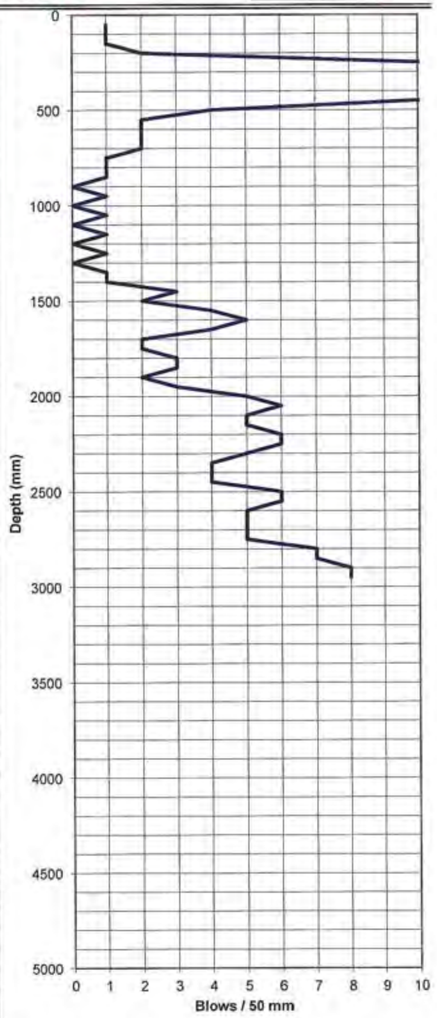
TONKIN & TAYLOR
SCALA PENETROMETER LOG

Job No: 750932
Project: Micro-Grid System in Tonga
Location: Site A
RL: 1.26m

Date: 27/09/2012
Operated by: CWM
Logged by: CWM
Checked by: ADP

Test No. SC3A
Sheet 1
of 1

mm Driven	No. of Blows	mm Driven	No. of Blows
50	1	2550	6
100	1	2600	5
150	1	2650	5
200	2	2700	5
250	10	2750	5
300	20	2800	7
350	20	2850	7
400	17	2900	8
450	10	2950	8
500	4	3000	
550	2	3050	
600	2	3100	
650	2	3150	
700	2	3200	
750	1	3250	
800	1	3300	
850	1	3350	
900	0	3400	
950	1	3450	
1000	0	3500	
1050	1	3550	
1100	0	3600	
1150	1	3650	
1200	0	3700	
1250	1	3750	
1300	0	3800	
1350	1	3850	
1400	1	3900	
1450	3	3950	
1500	2	4000	
1550	4	4050	
1600	5	4100	
1650	4	4150	
1700	2	4200	
1750	2	4250	
1800	3	4300	
1850	3	4350	
1900	2	4400	
1950	3	4450	
2000	5	4500	
2050	6	4550	
2100	5	4600	
2150	5	4650	
2200	6	4700	
2250	6	4750	
2300	5	4800	
2350	4	4850	
2400	4	4900	
2450	4	4950	
2500	6	5000	



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

CLIENT Yachiyo Engineering
TITLE Scala Penetrometer Test
REFERENCE No. 750932

September 2012

[1]

SC4.xlsx

TONKIN & TAYLOR

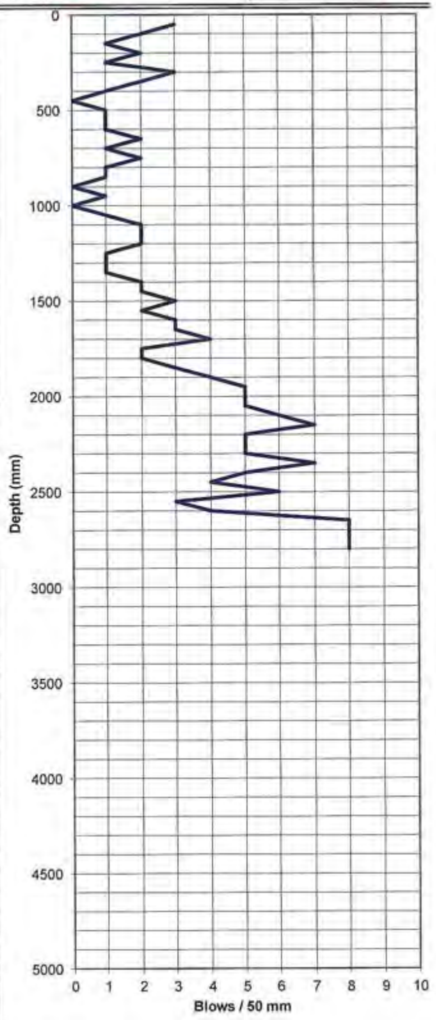
SCALA PENETROMETER LOG

Job No: 750932
Project: Micro-Grid System in Tonga
Location: Site A
RL: 1.25m

Date: 27/09/2012
Operated by: CWM
Logged by: CWM
Checked by: ADP

Test No. SC4A
Sheet 1
of 1

mm Driven	No. of Blows	mm Driven	No. of Blows
50	3	2550	3
100	2	2600	4
150	1	2650	8
200	2	2700	8
250	1	2750	8
300	3	2800	8
350	2	2850	
400	1	2900	
450	0	2950	
500	1	3000	
550	1	3050	
600	1	3100	
650	2	3150	
700	1	3200	
750	2	3250	
800	1	3300	
850	1	3350	
900	0	3400	
950	1	3450	
1000	0	3500	
1050	1	3550	
1100	2	3600	
1150	2	3650	
1200	2	3700	
1250	1	3750	
1300	1	3800	
1350	1	3850	
1400	2	3900	
1450	2	3950	
1500	3	4000	
1550	2	4050	
1600	3	4100	
1650	3	4150	
1700	4	4200	
1750	2	4250	
1800	2	4300	
1850	3	4350	
1900	4	4400	
1950	5	4450	
2000	5	4500	
2050	5	4550	
2100	6	4600	
2150	7	4650	
2200	5	4700	
2250	5	4750	
2300	5	4800	
2350	7	4850	
2400	5	4900	
2450	4	4950	
2500	6	5000	



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

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SC5.xlsx

TONKIN & TAYLOR

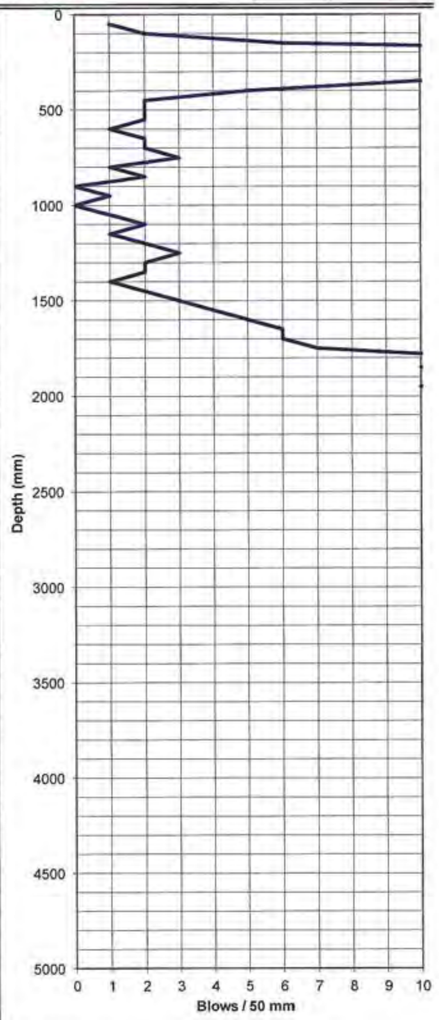
SCALA PENETROMETER LOG

Job No: 750932
Project: Micro-Grid System in Tonga
Location: Site A
RL: 1.20m

Date: 27/09/2012
Operated by: CWM
Logged by: CWM
Checked by: ADP

Test No. SC5A
Sheet 1
of 1

mm Driven	No. of Blows	mm Driven	No. of Blows
50	1	2550	
100	2	2600	
150	6	2650	
200	20	2700	
250	14	2750	
300	13	2800	
350	10	2850	
400	5	2900	
450	2	2950	
500	2	3000	
550	2	3050	
600	1	3100	
650	2	3150	
700	2	3200	
750	3	3250	
800	1	3300	
850	2	3350	
900	0	3400	
950	1	3450	
1000	0	3500	
1050	1	3550	
1100	2	3600	
1150	1	3650	
1200	2	3700	
1250	3	3750	
1300	2	3800	
1350	2	3850	
1400	1	3900	
1450	2	3950	
1500	3	4000	
1550	4	4050	
1600	5	4100	
1650	6	4150	
1700	6	4200	
1750	7	4250	
1800	12	4300	
1850	10	4350	
1900	15	4400	
1950	10	4450	
2000	12	4500	
2050		4550	
2100		4600	
2150		4650	
2200		4700	
2250		4750	
2300		4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



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

SC6.xlsx

TONKIN & TAYLOR

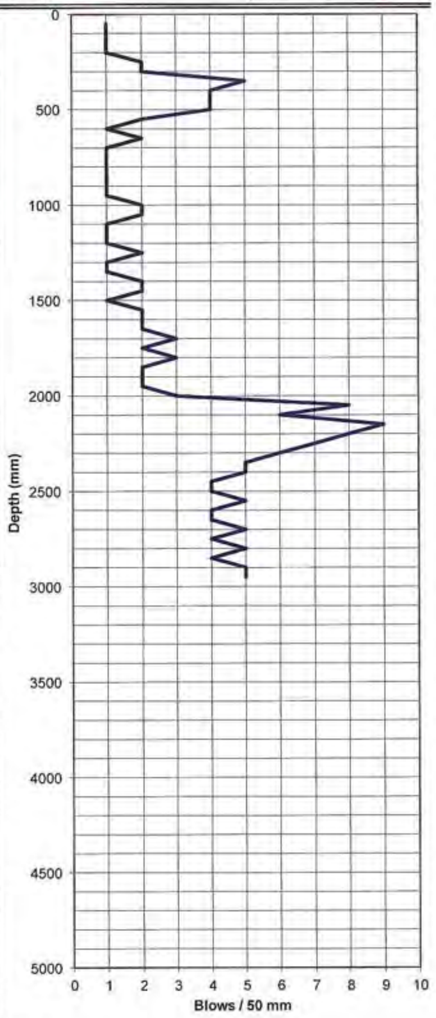
SCALA PENETROMETER LOG

Job No: *750932*
Project: *Micro-Grid System in Tonga*
Location: *Site A*
RL: *1.24m*

Date: *27/09/2012*
Operated by: *CWM*
Logged by: *CWM*
Checked by: *ADP*

Test No. *SC6A*
Sheet *1*
of *1*

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



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

CLIENT Yachiyo Engineering
TITLE Scala Penetrometer Test
REFERENCE No. 750932

September 2012

[1]

GEOTECHNICS

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Auckland 1023, New Zealand
p. +64 9 356 3510
w. www.geotechnics.co.nz

Form No.: 84
Form Date: January 2004

Page of

Your Job No.: 750932

Site : Popua, Tongatapu, Tonga - Site A

Our Job No.: 615931.000

Test Method Used:NZS 4402:1986 Test 2.1 Determination of the water content

WATER CONTENT TEST RESULTS

Table 1: Water Content

HA No.:	3	4	5
Depth (m)	1.2	1.0	0.5
Water Content (%)	34.3	56.3	41.1

Tested by: ST
Date: 10/10/12
Checked by: ASFG
Date: 10/10/12

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Form No.: 58
Form Date: January 2004
[illegible]

Page of

Your Job No.: 750932

Site : Popua, Tongatapu, Tonga - Site A

Our Job No.: 615931.000

Test Method Used:NZS 4402:1986 Test 2.7.2 Determination of Solid Density of Soil Particles - Vacuum Method

SOLID DENSITY TEST RESULTS

Table 1: Solid Density

	*Single Specimen tested	*Single Specimen tested	*Single Specimen tested
HA No.:	3	4	5
Depth (m)	1.2	1.0	0.5
Solid Density (t/m^3)	2.84	2.81	2.75

Remarks :

Solid density was performed on whole material.

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

Tested by: ST Date: 10/10/12 Checked by: ASFC Date: 10/10/12

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Form No.: 55
Form Date: JANUARY 2004
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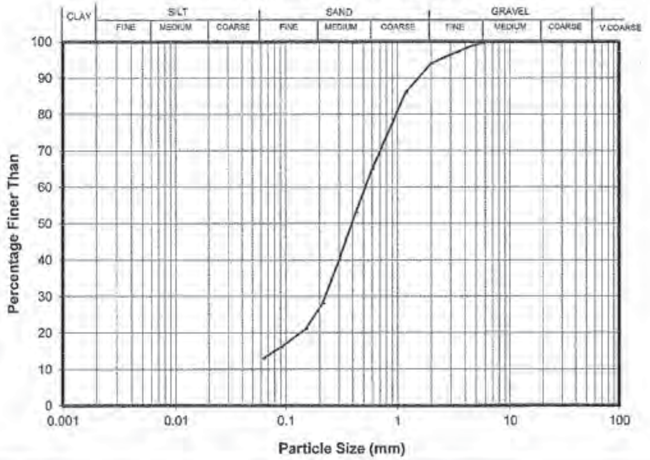
Plate No.: Page of
Site : **Popua, Tongatapu, Tonga - Site A**
HA No.: **3** Sample No.: ---
Test Method Used : NZS 4402 : 1986 Test 2.8.1 Wet Sieve

Your Job No.: **750932**
Our Job No.: **615931.000**
Depth (m) **1.2**

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing
63.0	---
53.0	---
37.5	---
26.5	---
19.0	---
13.2	---
9.50	---
6.70	100
4.75	99
3.35	97

Sieve (mm)	Total % Passing
2.00	94
1.18	86
0.600	65
0.425	53
0.300	40
0.212	28
0.150	21
0.090	16
0.063	13

Sample history : As received.

Description : Coral SAND mixed with shell fragments, minor gravel, minor silt and trace of clay, loose/soft lumps, light brownish grey with white.

Remarks: The minimum mass of sample required for sieving is 0.2 kg, but due to insufficient sample mass the sieving was carried out on ~ 0.10 kg.
The classification of sand and gravel was described on the basis of particle size analysis.
Percentage passing the finest sieve was obtained by difference.
Sample description and test results are not IANZ endorsed.

Entered by : ST Date : 10/10/12 Checked by : ASFC Date : 10/10/12

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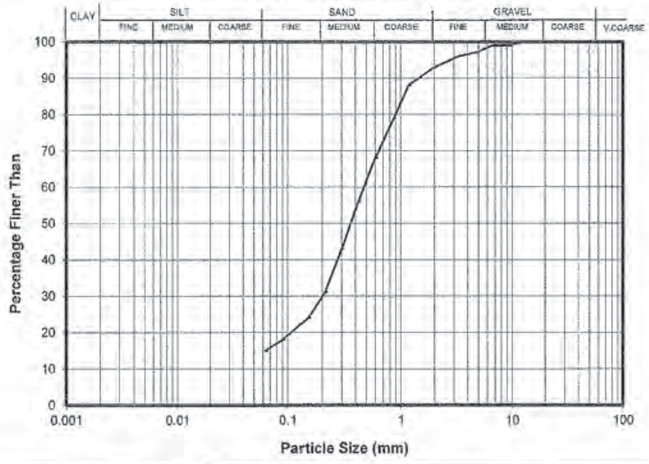
Form No: S5
Form Date: JANUARY 2004

Plate No.: Page of
Site : **Popua, Tongatapu, Tonga - Site A**
HA No.: **4** Sample No.: ---
Test Method Used : NZS 4402 : 1986 Test 2.8.1 Wet Sieve

Your Job No.: **750932**
Our Job No.: **615931.000**
Depth (m) **1.0**

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing
63.0	---
53.0	---
37.5	---
26.5	---
19.0	---
13.2	100
9.50	99
6.70	99
4.75	97
3.35	96

Sieve (mm)	Total % Passing
2.00	93
1.18	88
0.600	68
0.425	56
0.300	43
0.212	31
0.150	24
0.090	18
0.063	15

Sample history : As received.

Description : Coral SAND mixed with shell fragments, minor gravel, some silt and trace of clay, loose/soft lumps, light brown-dark grey with white.

Remarks: The minimum mass of sample required for sieving is 1.0 kg, but due to insufficient sample mass the sieving was carried out on ~ 0.17 kg.
The classification of sand and gravel was described on the basis of particle size analysis.
Percentage passing the finest sieve was obtained by difference.
Sample description and test results are not IANZ endorsed.

Entered by : ST Date : 10/10/12 Checked by : ASFL Date : 10/10/12

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Auckland 1023, New Zealand
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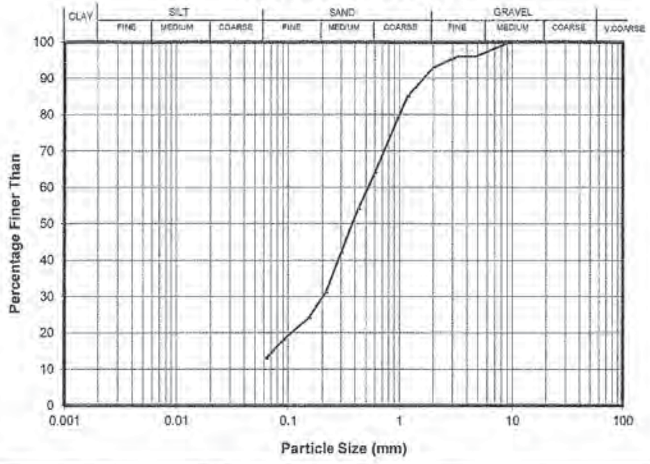
Form No: S5
Form Date: JANUARY 2004

Plate No.: Page of
Site : **Popua, Tongatapu, Tonga - Site A**
HA No.: **5** Sample No.: ---
Test Method Used : NZS 4402 : 1986 Test 2.8.1 Wet Sieve

Your Job No.: **750932**
Our Job No.: **615931.000**
Depth (m) **0.5**

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing
63.0	---
53.0	---
37.5	---
26.5	---
19.0	---
13.2	100
9.50	100
6.70	98
4.75	96
3.35	96

Sieve (mm)	Total % Passing
2.00	93
1.18	85
0.600	64
0.425	54
0.300	42
0.212	31
0.150	24
0.090	18
0.063	13

Sample history : As received.

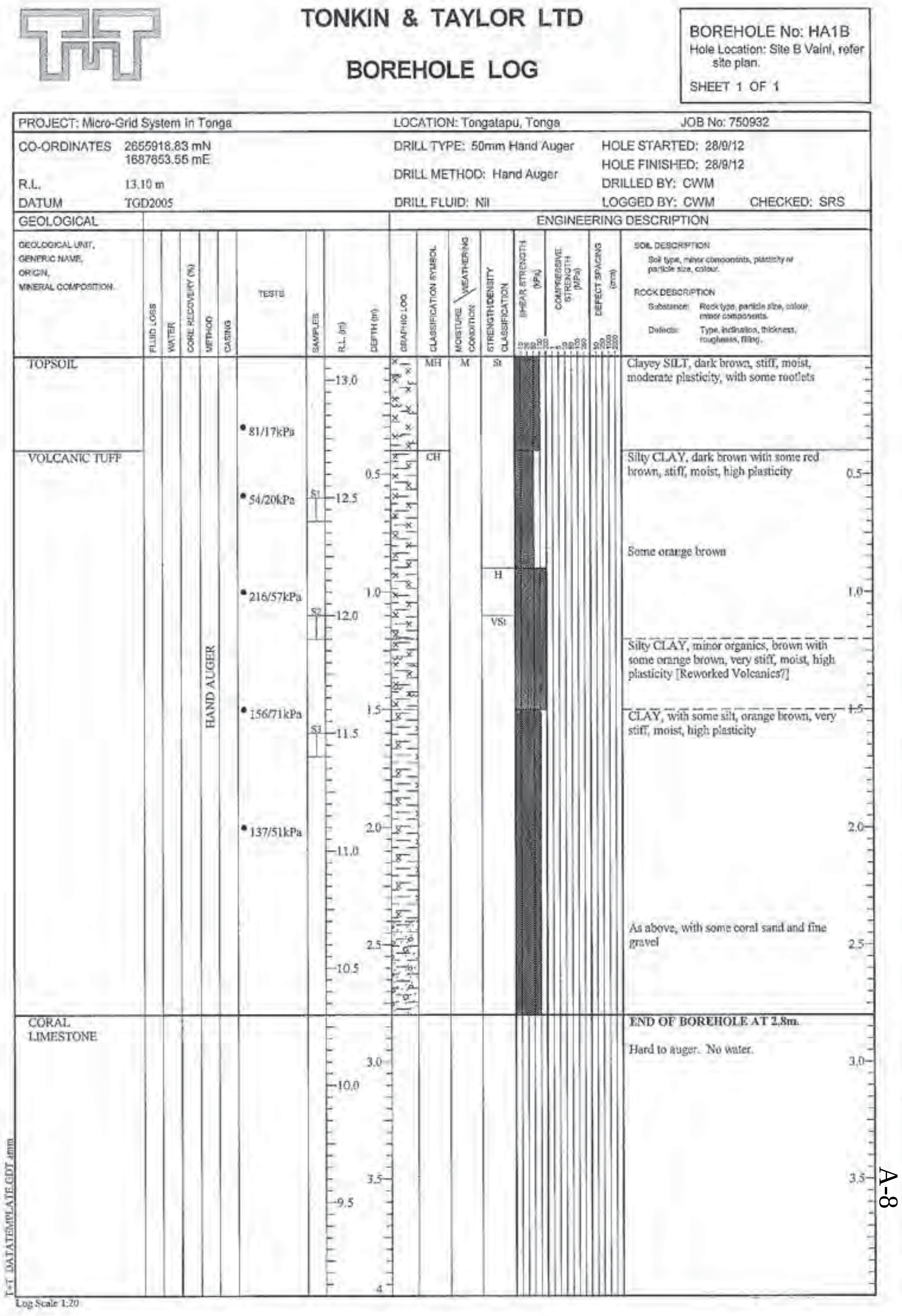
Description : Coral SAND mixed with shell fragments, minor gravel, minor silt and trace of clay, trace of organics, loose/soft lumps, dark brown with grey and white.

Remarks: The minimum mass of sample required for sieving is 1.0 kg, but due to insufficient sample mass the sieving was carried out on ~ 0.17 kg.
The classification of sand and gravel was described on the basis of particle size analysis.
Percentage passing the finest sieve was obtained by difference.
Sample description and test results are not IANZ endorsed.

Entered by : ST Date : 10/10/12 Checked by : ASFL Date : 10/10/12

Appendix D: Site B - Investigation Logs and Geotechnical Laboratory Testing

- Hand auger borehole logs
- Scala Penetrometer results
- Geotechnical Laboratory Testing



TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: HA1B
Hole Location: Site B Vaini, refer site plan.
SHEET 1 OF 1

PROJECT: Micro-Grid System in Tonga
LOCATION: Tongatapu, Tonga
JOB No: 750932
CO-ORDINATES 2655918.83 mN 1687653.55 mE
R.L. 13.10 m
DATUM TGD2005
DRILL TYPE: 50mm Hand Auger
DRILL METHOD: Hand Auger
DRILL FLUID: Nil
HOLE STARTED: 28/9/12
HOLE FINISHED: 28/9/12
DRILLED BY: CWM
LOGGED BY: CWM
CHECKED: SRS

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	METHOD	TESTS	SAMPLES	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION / ROCK DESCRIPTION
TOPSOIL	HAND AUGER	81/17kPa		MH	M	St	Clayey SILT, dark brown, stiff, moist, moderate plasticity, with some rootlets
VOLCANIC TUFF		54/20kPa	S1	CH			Silty CLAY, dark brown with some red brown, stiff, moist, high plasticity
							Some orange brown
		216/57kPa	S2			H	
						VSt	Silty CLAY, minor organics, brown with some orange brown, very stiff, moist, high plasticity [Reworked Volcanics?]
		156/71kPa	S3				CLAY, with some silt, orange brown, very stiff, moist, high plasticity
		137/51kPa					
							As above, with some coral sand and fine gravel
CORAL LIMESTONE							**END OF BOREHOLE AT 2.8m.** Hard to auger. No water.

T+T DATATEMPLATE.GDT 4mm

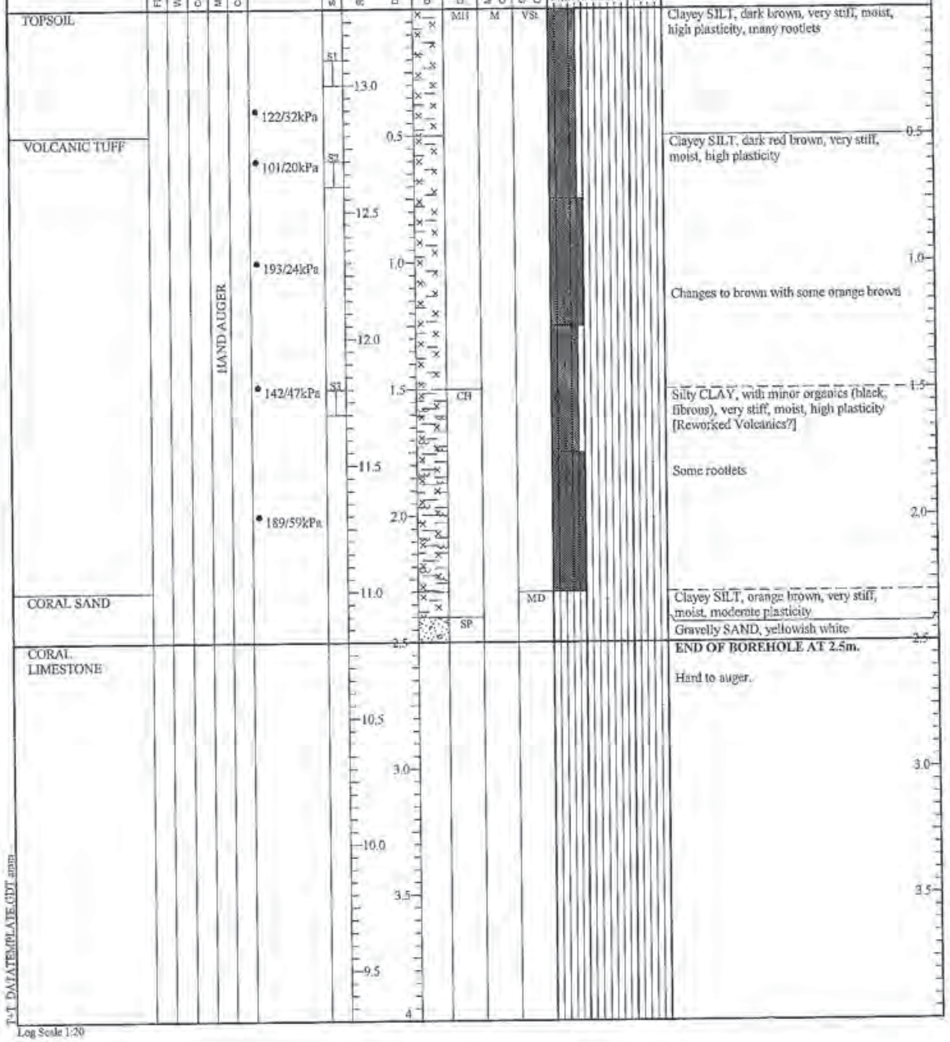
Log Scale 1:20

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: HA3B
Hole Location: Site B Vaini, refer site plan.
SHEET 1 OF 1

PROJECT: Micro-Grid System in Tonga
LOCATION: Tongatapu, Tonga
JOB No: 750932
CO-ORDINATES 2655907.22 mN 1687646.12 mE
R.L. 13.30 m
DATUM TGD2005
DRILL TYPE: 50mm Hand Auger
DRILL METHOD: Hand Auger
DRILL FLUID: Nil
HOLE STARTED: 28/9/12
HOLE FINISHED: 28/9/12
DRILLED BY: CWM
LOGGED BY: CWM
CHECKED: SRS



GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	METHOD	TESTS	SAMPLES	DEPTH (m)	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION
TOPSOIL	HAND AUGER	122/32kPa	S1	0.0	MH	M	VSt	Clayey SILT, dark brown, very stiff, moist, high plasticity, many rootlets
VOLCANIC TUFF		101/20kPa 193/24kPa	S2	0.5				Clayey SILT, dark red brown, very stiff, moist, high plasticity Changes to brown with some orange brown
		142/47kPa 189/59kPa	S3	1.5	CH			Silty CLAY, with minor organics (black, fibrous), very stiff, moist, high plasticity [Reworked Volcanics?] Some rootlets
CORAL SAND							MD	Clayey SILT, orange brown, very stiff, moist, moderate plasticity
					SP			Gravelly SAND, yellowish white
CORAL LIMESTONE				2.5				END OF BOREHOLE AT 2.5m. Hard to auger.

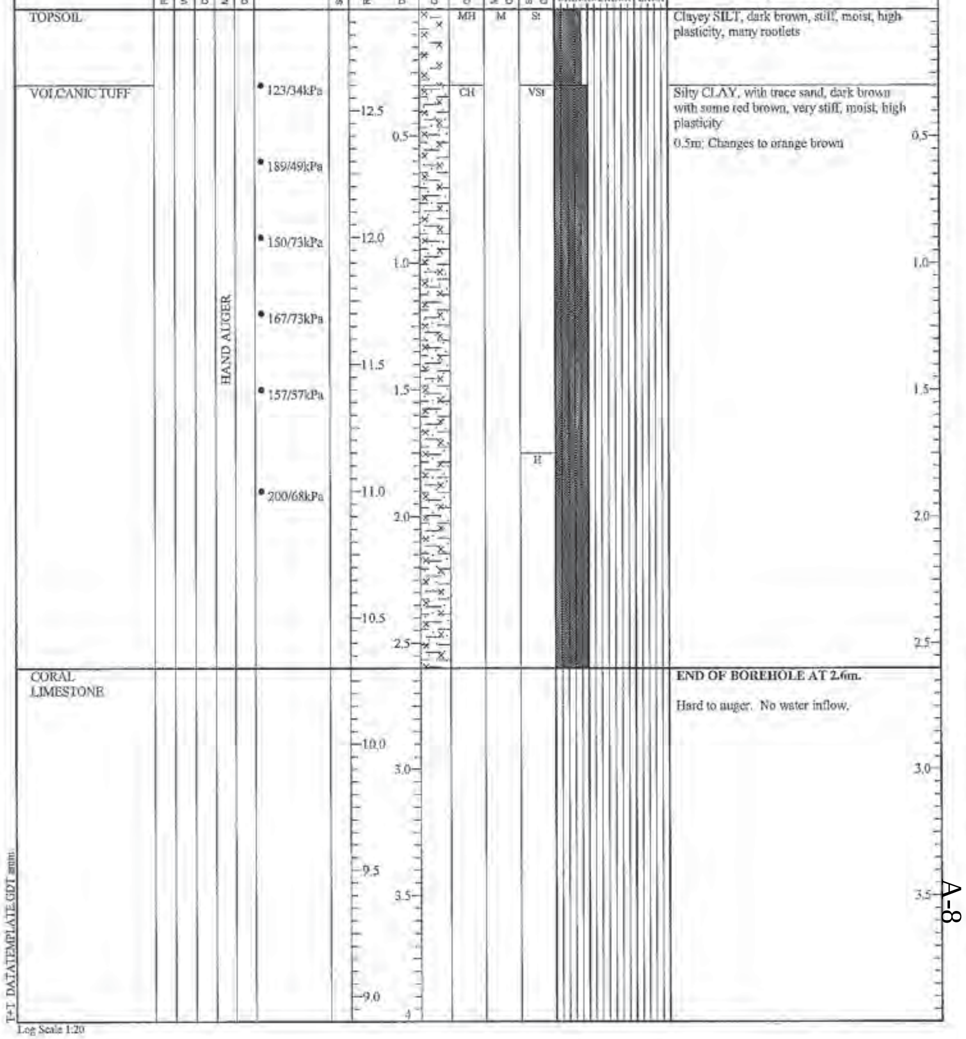
T+T DATATEMPLATE.GDT
Log Scale 1:20

TONKIN & TAYLOR LTD

BOREHOLE LOG

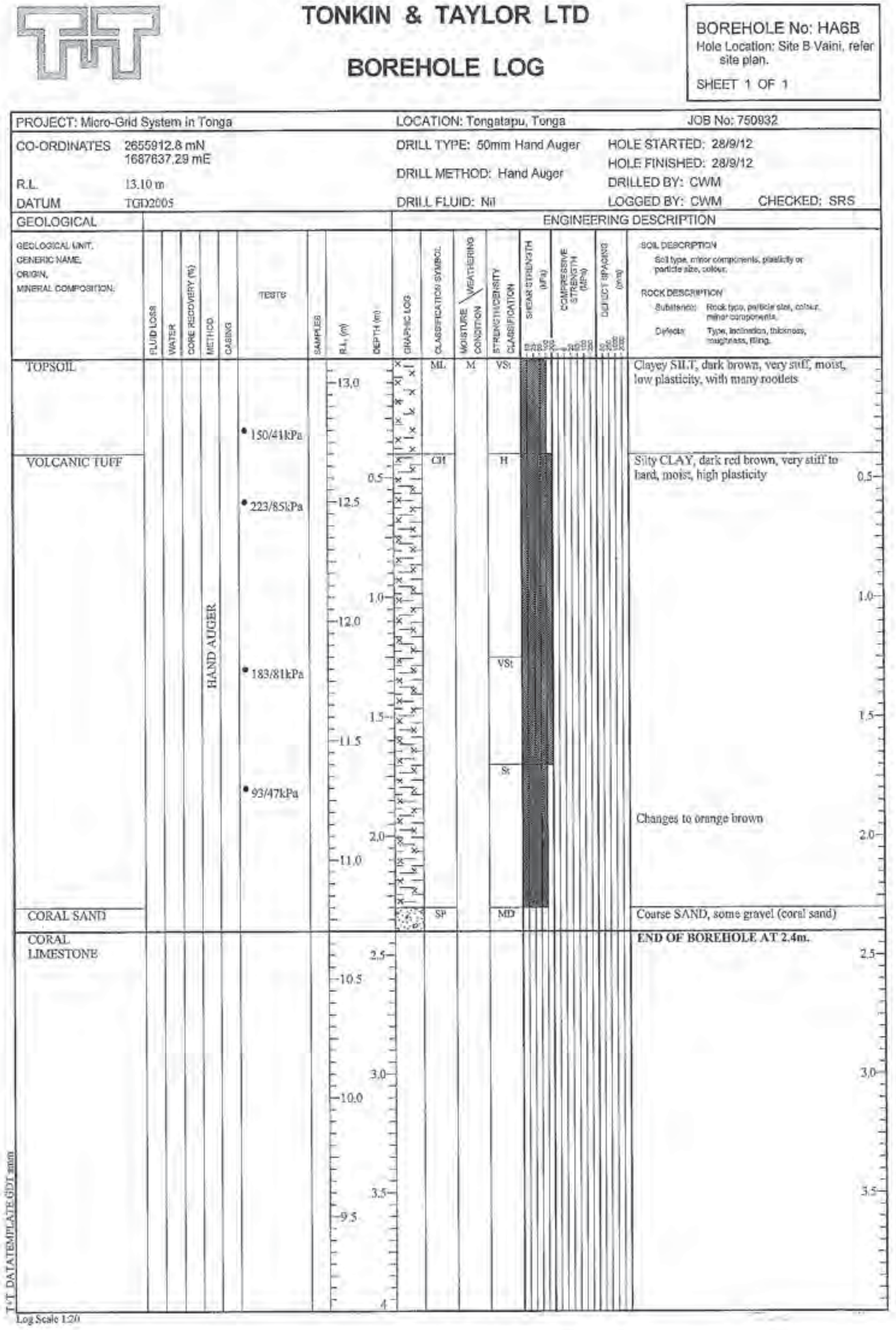
BOREHOLE No: HA4B
Hole Location: Site B Vaini, refer site plan.
SHEET 1 OF 1

PROJECT: Micro-Grid System in Tonga
LOCATION: Tongatapu, Tonga
JOB No: 750932
CO-ORDINATES 2655924.22 mN 1687645.04 mE
R.L. 12.90 m
DATUM TGD2005
DRILL TYPE: 50mm Hand Auger
DRILL METHOD: Hand Auger
DRILL FLUID: Nil
HOLE STARTED: 28/9/12
HOLE FINISHED: 28/9/12
DRILLED BY: CWM
LOGGED BY: CWM
CHECKED: SRS



GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	METHOD	TESTS	DEPTH (m)	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION
TOPSOIL	HAND AUGER		0.0	MH	M	St	Clayey SILT, dark brown, stiff, moist, high plasticity, many rootlets
VOLCANIC TUFF		123/34kPa 189/49kPa 150/73kPa 167/73kPa 157/57kPa 200/68kPa		CH		VSt H	Silty CLAY, with trace sand, dark brown with some red brown, very stiff, moist, high plasticity 0.5m: Changes to orange brown
CORAL LIMESTONE			2.6				END OF BOREHOLE AT 2.6m. Hard to auger. No water inflow.

T+T DATATEMPLATE.GDT
Log Scale 1:20



TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: HA6B
Hole Location: Site B Vaini, refer site plan.
SHEET 1 OF 1

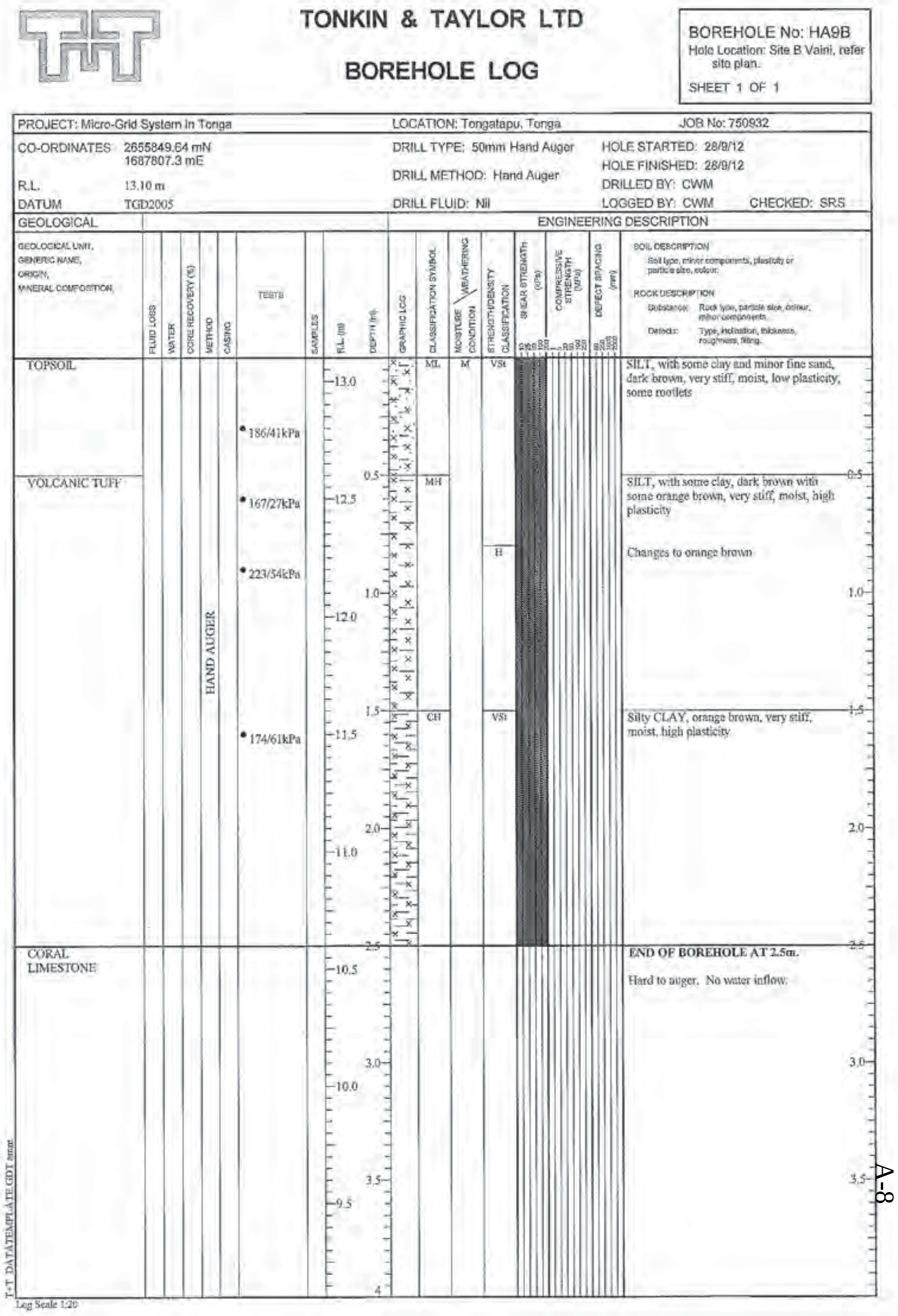
PROJECT: Micro-Grid System in Tonga
LOCATION: Tongatapu, Tonga
JOB No: 750932
CO-ORDINATES 2655912.8 mN 1687637.29 mE
R.L. 13.10 m
DATUM TGD2005
DRILL TYPE: 50mm Hand Auger
DRILL METHOD: Hand Auger
DRILL FLUID: Nil
HOLE STARTED: 28/9/12
HOLE FINISHED: 28/9/12
DRILLED BY: CWM
LOGGED BY: CWM
CHECKED: SRS

METHOD: HAND AUGER

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	TESTS	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION
TOPSOIL	150/41kPa	ML	M	VSt	Clayey SILT, dark brown, very stiff, moist, low plasticity, with many rootlets
VOLCANIC TUFF	223/85kPa	CH		H	Silty CLAY, dark red brown, very stiff to hard, moist, high plasticity
	183/81kPa			VSt	
	93/47kPa			St	Changes to orange brown
CORAL SAND		SP		MD	Course SAND, some gravel (coral sand)
CORAL LIMESTONE					**END OF BOREHOLE AT 2.4m.**

R.L. (m): 13.0, 12.5, 12.0, 11.5, 11.0, 10.5, 10.0, 9.5
DEPTH (m): 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4

T+T DATATEMPLATE.GDT mm
Log Scale 1:20



TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: HA9B
Hole Location: Site B Vaini, refer site plan.
SHEET 1 OF 1

PROJECT: Micro-Grid System in Tonga
LOCATION: Tongatapu, Tonga
JOB No: 750932
CO-ORDINATES 2655849.64 mN 1687807.3 mE
R.L. 13.10 m
DATUM TGD2005
DRILL TYPE: 50mm Hand Auger
DRILL METHOD: Hand Auger
DRILL FLUID: Nil
HOLE STARTED: 28/9/12
HOLE FINISHED: 28/9/12
DRILLED BY: CWM
LOGGED BY: CWM
CHECKED: SRS

METHOD: HAND AUGER

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.	TESTS	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION
TOPSOIL	186/41kPa	ML	M	VSt	SILT, with some clay and minor fine sand, dark brown, very stiff, moist, low plasticity, some rootlets
VOLCANIC TUFF	167/27kPa	MH			SILT, with some clay, dark brown with some orange brown, very stiff, moist, high plasticity
	223/54kPa			H	Changes to orange brown
	174/61kPa	CH		VSt	Silty CLAY, orange brown, very stiff, moist, high plasticity
CORAL LIMESTONE					**END OF BOREHOLE AT 2.5m.** Hard to auger. No water inflow.

R.L. (m): 13.0, 12.5, 12.0, 11.5, 11.0, 10.5, 10.0, 9.5
DEPTH (m): 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4

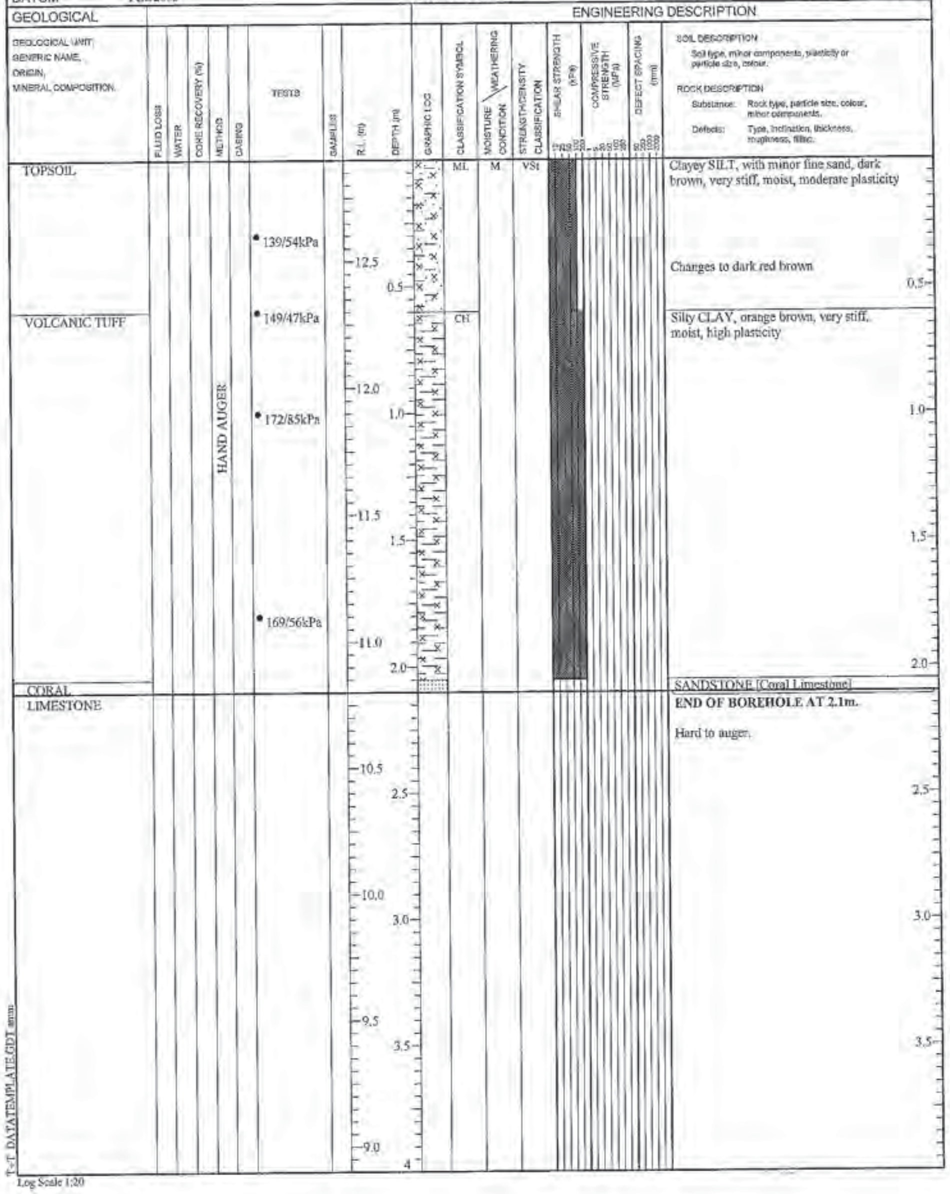
T+T DATATEMPLATE.GDT mm
Log Scale 1:20

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: HA10B
Hole Location: Site B Vaini, refer site plan.
SHEET 1 OF 1

PROJECT: Micro-Grid System in Tonga
LOCATION: Tongatapu, Tonga
JOB No: 750932
CO-ORDINATES 2655808.86 mN 1687786.81 mE
R.L. 12.90 m
DATUM TGD2005
DRILL TYPE: 50mm Hand Auger
DRILL METHOD: Hand Auger
DRILL FLUID: Nil
HOLE STARTED: 28/9/12
HOLE FINISHED: 28/9/12
DRILLED BY: CWM
LOGGED BY: CWM
CHECKED: SRS



TOPSOIL — ML, M, VSt — Clayey SILT, with minor fine sand, dark brown, very stiff, moist, moderate plasticity

Changes to dark red brown

VOLCANIC TUFF — CH — Silty CLAY, orange brown, very stiff, moist, high plasticity

CORAL LIMESTONE — SANDSTONE [Coral Limestone]

END OF BOREHOLE AT 2.1m.

Hard to auger.

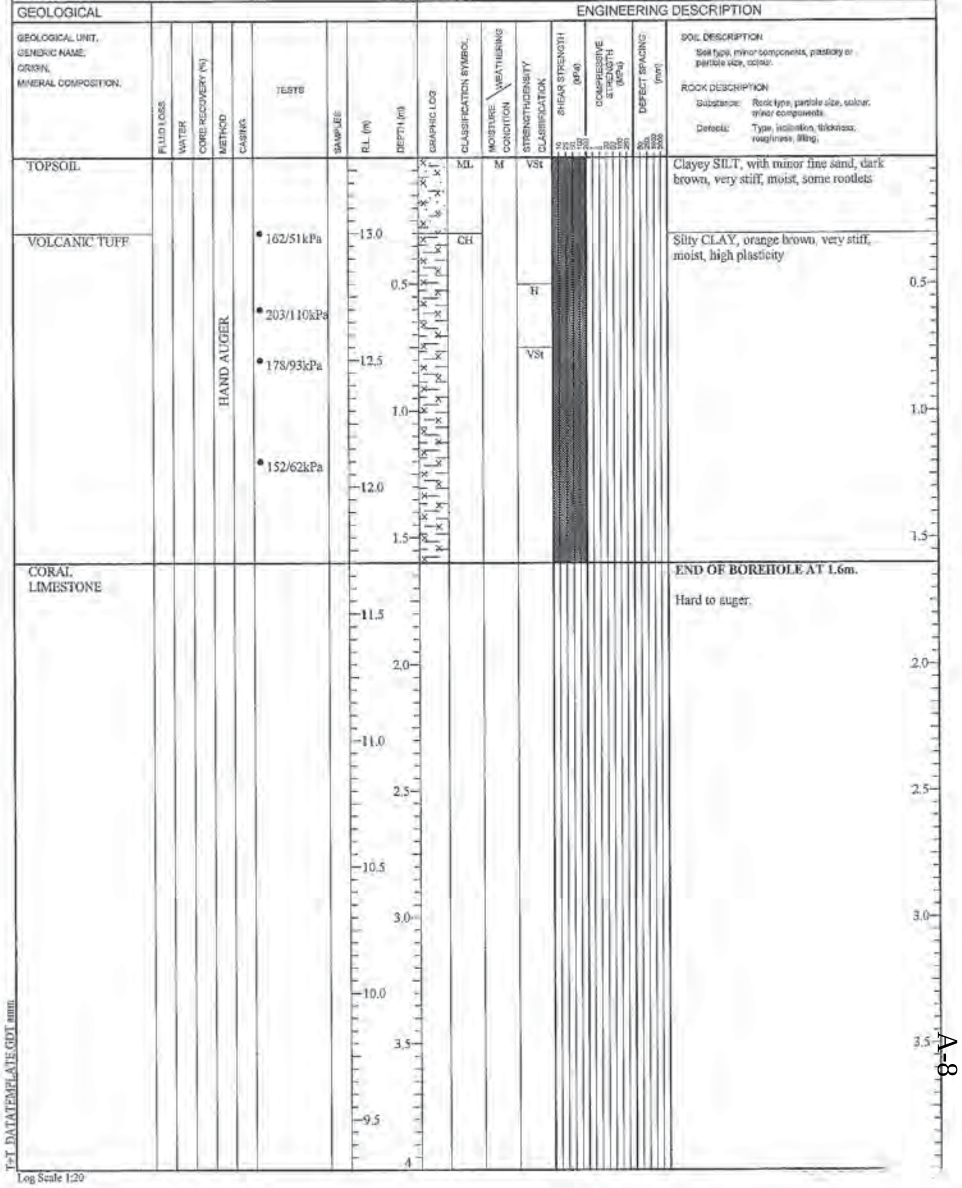
Log Scale 1:20

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: HA11B
Hole Location: Site B Vaini, refer site plan.
SHEET 1 OF 1

PROJECT: Micro-Grid System in Tonga
LOCATION: Tongatapu, Tonga
JOB No: 750932
CO-ORDINATES 2655894.51 mN 1687734.92 mE
R.L. 13.30 m
DATUM TGD2005
DRILL TYPE: 50mm Hand Auger
DRILL METHOD: Hand Auger
DRILL FLUID: Nil
HOLE STARTED: 28/9/12
HOLE FINISHED: 28/9/12
DRILLED BY: CWM
LOGGED BY: CWM
CHECKED: SRS



TOPSOIL — ML, M, VSt — Clayey SILT, with minor fine sand, dark brown, very stiff, moist, some rootlets

VOLCANIC TUFF — CH — Silty CLAY, orange brown, very stiff, moist, high plasticity

CORAL LIMESTONE

END OF BOREHOLE AT 1.6m.

Hard to auger.

Log Scale 1:20

TONKIN & TAYLOR LTD

BOREHOLE LOG

BOREHOLE No: HA12B
Hole Location: Site B Vaini, refer site plan.
SHEET 1 OF 1

PROJECT: Micro-Grid System in Tonga
LOCATION: Tongatapu, Tonga
JOB No: 750932

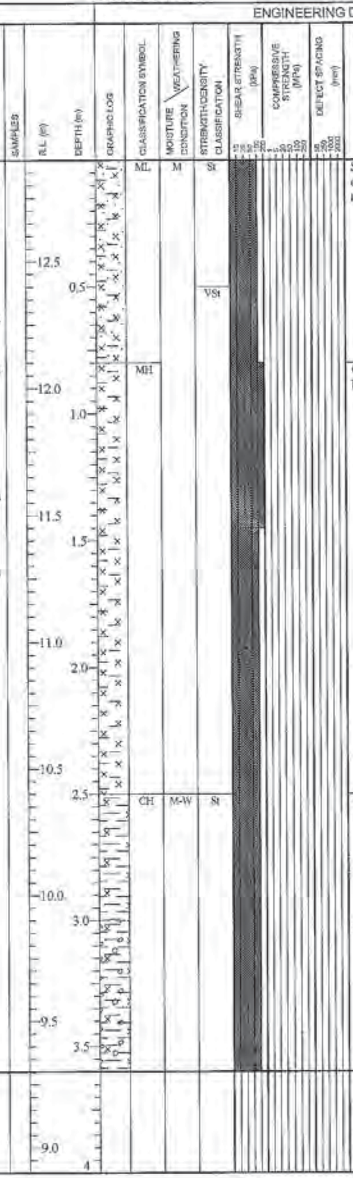
CO-ORDINATES 2655851.4 mN
1687719.83 mE
R.L. 12.90 m
DATUM TGD2005

DRILL TYPE: 50mm Hand Auger
DRILL METHOD: Hand Auger
DRILL FLUID: Nil

HOLE STARTED: 28/9/12
HOLE FINISHED: 28/9/12
DRILLED BY: CWM
LOGGED BY: CWM
CHECKED: SRS

GEOLOGICAL: GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION.

ENGINEERING DESCRIPTION: SOIL DESCRIPTION Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.



GEOLOGICAL	METHOD	TESTS	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	ENGINEERING DESCRIPTION
TOPSOIL	HAND AUGER	71/17kPa 118/25kPa	ML	M	St VSt	SILT, with some clay and minor fine sand, dark brown, stiff, moist, low plasticity, many rootlets
VOLCANIC TUFF		189/51kPa 178/42kPa 139/25kPa	MH			Clayey SILT, orange brown with some black, very stiff, moist, moderate plasticity
			CH	M-W	St	CLAY, with some silt, orange brown, stiff, moist to wet, high plasticity Minor limestone gravel
CORAL LIMESTONE						END OF BOREHOLE AT 3.6m. Hard to auger (scala hit rock at 2.45m, 100mm from hand auger. Infilled void/cavity?).

T+T DATATEMPLATE.GDT [illegible]

Log Scale 1:20

SC1.xlsx

TONKIN & TAYLOR

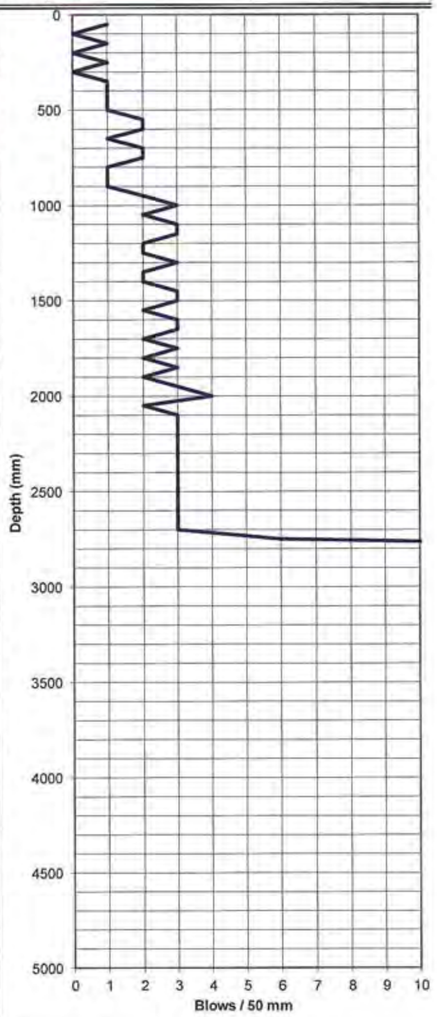
SCALA PENETROMETER LOG

Job No: 750932
Project: Micro-Grid System in Tonga
Location: Site B
RL: 12.91m

Date: 27/09/2012
Operated by: CWM
Logged by: CWM
Checked by: ADP

Test No. SC1B
Sheet 1
of 1

mm Driven	No. of Blows
50	1
100	0
150	1
200	0
250	1
300	0
350	1
400	1
450	1
500	1
550	2
600	2
650	1
700	2
750	2
800	1
850	1
900	1
950	2
1000	3
1050	2
1100	3
1150	3
1200	2
1250	2
1300	3
1350	2
1400	2
1450	3
1500	3
1550	2
1600	3
1650	3
1700	2
1750	3
1800	2
1850	3
1900	2
1950	3
2000	4
2050	2
2100	3
2150	3
2200	3
2250	3
2300	3
2350	3
2400	3
2450	3
2500	3
2550	3
2600	3
2650	3
2700	3
2750	6
2800	20
2850	
2900	
2950	
3000	
3050	
3100	
3150	
3200	
3250	
3300	
3350	
3400	
3450	
3500	
3550	
3600	
3650	
3700	
3750	
3800	
3850	
3900	
3950	
4000	
4050	
4100	
4150	
4200	
4250	
4300	
4350	
4400	
4450	
4500	
4550	
4600	
4650	
4700	
4750	
4800	
4850	
4900	
4950	
5000	



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

CLIENT Yachiyo Engineering
TITLE Scala Penetrometer Test
REFERENCE No. 750932

September 2012

(1)

SC2.xlsx

TONKIN & TAYLOR

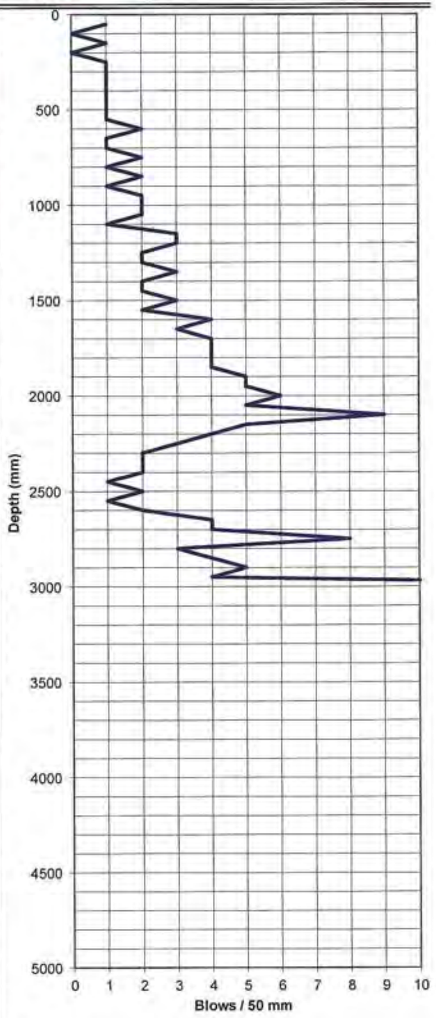
SCALA PENETROMETER LOG

Job No: *750932*
Project: *Micro-Grid System in Tonga*
Location: *Site B*
RL: *13.23m*

Date: *27/09/2012*
Operated by: *CWM*
Logged by: *CWM*
Checked by: *ADP*

Test No. *SC2B*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50	1	2550	1
100	0	2600	2
150	1	2650	4
200	0	2700	4
250	1	2750	8
300	1	2800	3
350	1	2850	4
400	1	2900	5
450	1	2950	4
500	1	3000	20
550	1	3050	
600	2	3100	
650	1	3150	
700	1	3200	
750	2	3250	
800	1	3300	
850	2	3350	
900	1	3400	
950	2	3450	
1000	2	3500	
1050	2	3550	
1100	1	3600	
1150	3	3650	
1200	3	3700	
1250	2	3750	
1300	2	3800	
1350	3	3850	
1400	2	3900	
1450	2	3950	
1500	3	4000	
1550	2	4050	
1600	4	4100	
1650	3	4150	
1700	4	4200	
1750	4	4250	
1800	4	4300	
1850	4	4350	
1900	5	4400	
1950	5	4450	
2000	6	4500	
2050	5	4550	
2100	9	4600	
2150	5	4650	
2200	4	4700	
2250	3	4750	
2300	2	4800	
2350	2	4850	
2400	2	4900	
2450	1	4950	
2500	2	5000	



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

CLIENT Yachiyo Engineering
TITLE Scala Penetrometer Test
REFERENCE No. 750932

September 2012

[1]

SC3.xlsx

TONKIN & TAYLOR

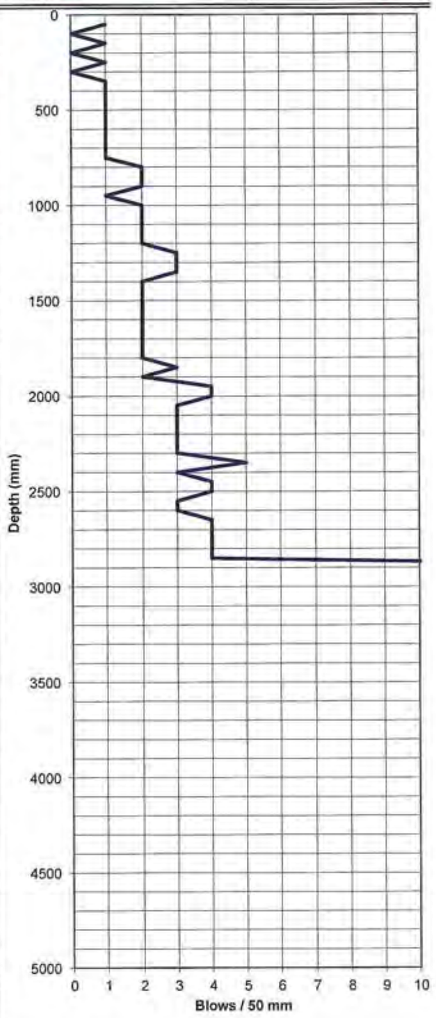
SCALA PENETROMETER LOG

Job No: *750932*
Project: *Micro-Grid System in Tonga*
Location: *Site B*
RL: *13.28m*

Date: *27/09/2012*
Operated by: *CWM*
Logged by: *CWM*
Checked by: *ADP*

Test No. *SC3B*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50	1	2550	3
100	0	2600	3
150	1	2650	4
200	0	2700	4
250	1	2750	4
300	0	2800	4
350	1	2850	4
400	1	2900	20
450	1	2950	
500	1	3000	
550	1	3050	
600	1	3100	
650	1	3150	
700	1	3200	
750	1	3250	
800	2	3300	
850	2	3350	
900	2	3400	
950	1	3450	
1000	2	3500	
1050	2	3550	
1100	2	3600	
1150	2	3650	
1200	2	3700	
1250	3	3750	
1300	3	3800	
1350	3	3850	
1400	2	3900	
1450	2	3950	
1500	2	4000	
1550	2	4050	
1600	2	4100	
1650	2	4150	
1700	2	4200	
1750	2	4250	
1800	2	4300	
1850	3	4350	
1900	2	4400	
1950	4	4450	
2000	4	4500	
2050	3	4550	
2100	3	4600	
2150	3	4650	
2200	3	4700	
2250	3	4750	
2300	3	4800	
2350	5	4850	
2400	3	4900	
2450	4	4950	
2500	4	5000	



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

CLIENT Yachiyo Engineering
TITLE Scala Penetrometer Test
REFERENCE No. 750932

September 2012

[1]

SC4.xlsx

TONKIN & TAYLOR

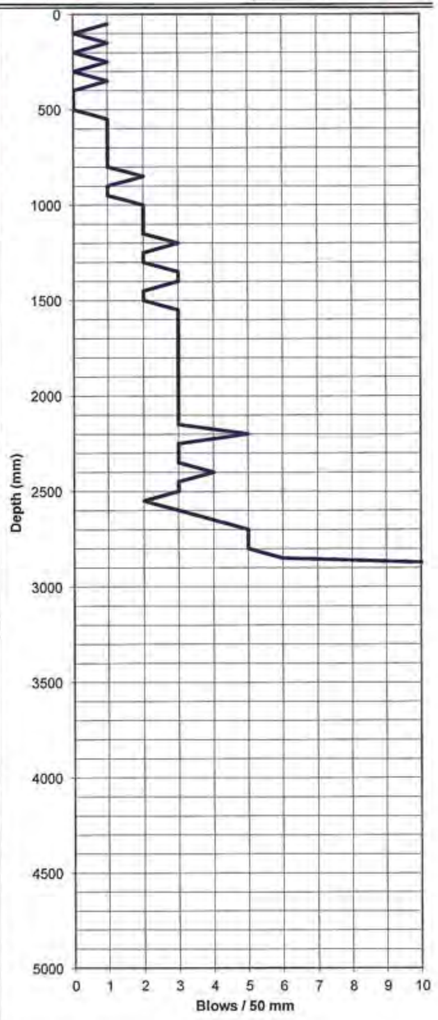
SCALA PENETROMETER LOG

Job No: *750932*
Project: *Micro-Grid System in Tonga*
Location: *Site B*
RL: *12.92m*

Date: *27/09/2012*
Operated by: *CWM*
Logged by: *CWM*
Checked by: *ADP*

Test No. *SC4B*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50	1	2550	2
100	0	2600	3
150	1	2650	4
200	0	2700	5
250	1	2750	5
300	0	2800	5
350	1	2850	6
400	0	2900	15
450	0	2950	
500	0	3000	
550	1	3050	
600	1	3100	
650	1	3150	
700	1	3200	
750	1	3250	
800	1	3300	
850	2	3350	
900	1	3400	
950	1	3450	
1000	2	3500	
1050	2	3550	
1100	2	3600	
1150	2	3650	
1200	3	3700	
1250	2	3750	
1300	2	3800	
1350	3	3850	
1400	3	3900	
1450	2	3950	
1500	2	4000	
1550	3	4050	
1600	3	4100	
1650	3	4150	
1700	3	4200	
1750	3	4250	
1800	3	4300	
1850	3	4350	
1900	3	4400	
1950	3	4450	
2000	3	4500	
2050	3	4550	
2100	3	4600	
2150	3	4650	
2200	5	4700	
2250	3	4750	
2300	3	4800	
2350	3	4850	
2400	4	4900	
2450	3	4950	
2500	3	5000	



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

CLIENT Yachiyo Engineering
TITLE Scala Penetrometer Test
REFERENCE No. 750932

September 2012

(1)

SC5.xlsx

TONKIN & TAYLOR

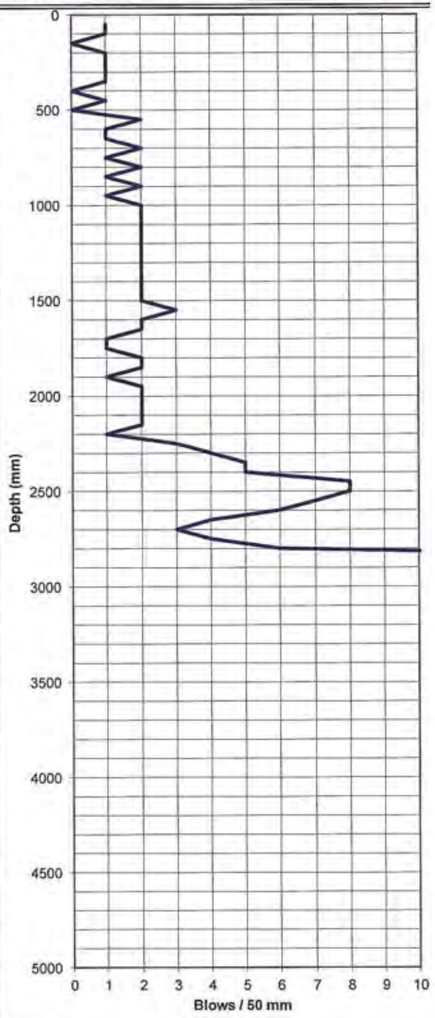
SCALA PENETROMETER LOG

Job No: *750932*
Project: *Micro-Grid System in Tonga*
Location: *Site B*
RL: *13.00m*

Date: *27/09/2012*
Operated by: *CWM*
Logged by: *CWM*
Checked by: *ADP*

Test No. *SC5B*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50	1	2550	7
100	1	2600	6
150	0	2650	4
200	1	2700	3
250	1	2750	4
300	1	2800	6
350	1	2850	20
400	0	2900	
450	1	2950	
500	0	3000	
550	2	3050	
600	1	3100	
650	1	3150	
700	2	3200	
750	1	3250	
800	2	3300	
850	1	3350	
900	2	3400	
950	1	3450	
1000	2	3500	
1050	2	3550	
1100	2	3600	
1150	2	3650	
1200	2	3700	
1250	2	3750	
1300	2	3800	
1350	2	3850	
1400	2	3900	
1450	2	3950	
1500	2	4000	
1550	3	4050	
1600	2	4100	
1650	2	4150	
1700	1	4200	
1750	1	4250	
1800	2	4300	
1850	2	4350	
1900	1	4400	
1950	2	4450	
2000	2	4500	
2050	2	4550	
2100	2	4600	
2150	2	4650	
2200	1	4700	
2250	3	4750	
2300	4	4800	
2350	5	4850	
2400	5	4900	
2450	8	4950	
2500	8	5000	



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

CLIENT Yachiyo Engineering
TITLE Scala Penetrometer Test
REFERENCE No. 750932

September 2012

(1)

SC6.xlsx

TONKIN & TAYLOR

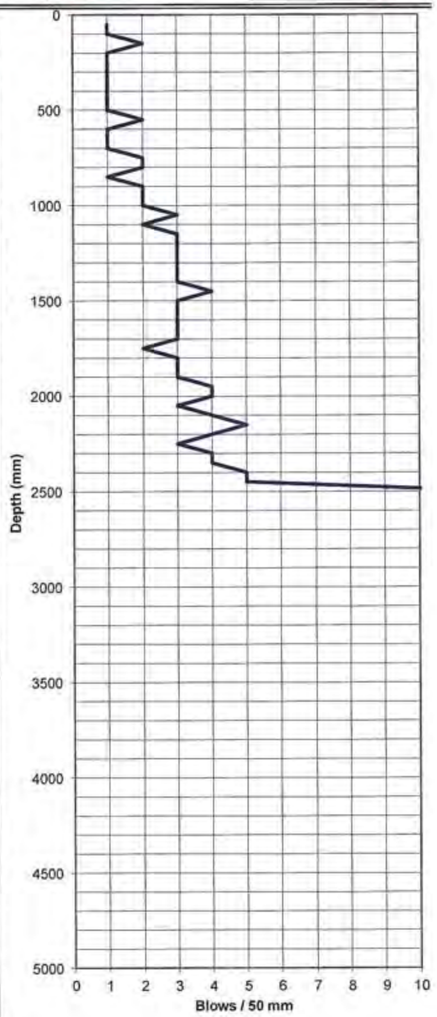
SCALA PENETROMETER LOG

Job No: *750932*
Project: *Tonga Solar*
Location: *Site B*
RL: *13.07m*

Date: *27/09/2012*
Operated by: *CWM*
Logged by: *CWM*
Checked by: *ADP*

Test No. *SC6B*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50	1	2550	19
100	1	2600	
150	2	2650	
200	1	2700	
250	1	2750	
300	1	2800	
350	1	2850	
400	1	2900	
450	1	2950	
500	1	3000	
550	2	3050	
600	1	3100	
650	1	3150	
700	1	3200	
750	2	3250	
800	2	3300	
850	1	3350	
900	2	3400	
950	2	3450	
1000	2	3500	
1050	3	3550	
1100	2	3600	
1150	3	3650	
1200	3	3700	
1250	3	3750	
1300	3	3800	
1350	3	3850	
1400	3	3900	
1450	4	3950	
1500	3	4000	
1550	3	4050	
1600	3	4100	
1650	3	4150	
1700	3	4200	
1750	2	4250	
1800	3	4300	
1850	3	4350	
1900	3	4400	
1950	4	4450	
2000	4	4500	
2050	3	4550	
2100	4	4600	
2150	5	4650	
2200	4	4700	
2250	3	4750	
2300	4	4800	
2350	4	4850	
2400	5	4900	
2450	5	4950	
2500	12	5000	



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

CLIENT Yachiyo Engineering
TITLE Scala Penetrometer Test
REFERENCE No. 750932

September 2012

(1)

SC7.xlsx

TONKIN & TAYLOR

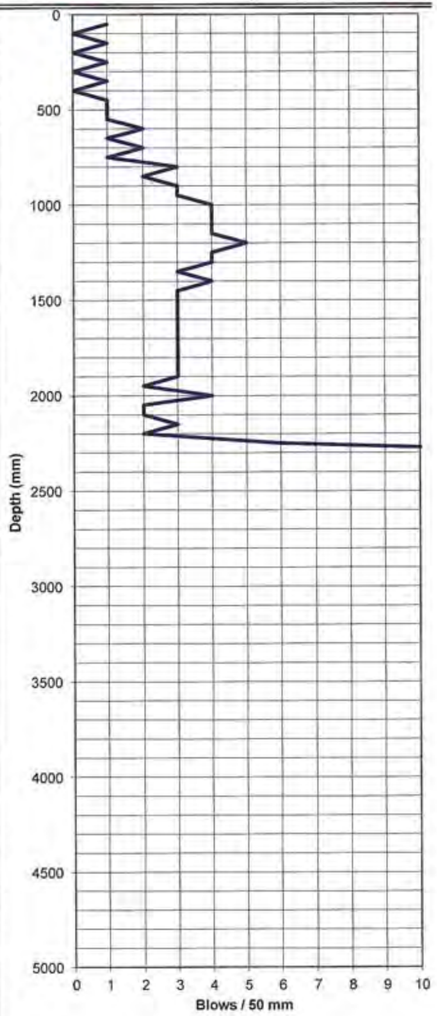
SCALA PENETROMETER LOG

Job No: *750932*
Project: *Micro-Grid System in Tonga*
Location: *Site B*
RL: *13.14m*

Date: *27/09/2012*
Operated by: *CWM*
Logged by: *CWM*
Checked by: *ADP*

Test No. *SC7B*
Sheet *1*
of *1*

mm Driven	No. of Blows	mm Driven	No. of Blows
50	1	2550	
100	0	2600	
150	1	2650	
200	0	2700	
250	1	2750	
300	0	2800	
350	1	2850	
400	0	2900	
450	1	2950	
500	1	3000	
550	1	3050	
600	2	3100	
650	1	3150	
700	2	3200	
750	1	3250	
800	3	3300	
850	2	3350	
900	3	3400	
950	3	3450	
1000	4	3500	
1050	4	3550	
1100	4	3600	
1150	4	3650	
1200	5	3700	
1250	4	3750	
1300	4	3800	
1350	3	3850	
1400	4	3900	
1450	3	3950	
1500	3	4000	
1550	3	4050	
1600	3	4100	
1650	3	4150	
1700	3	4200	
1750	3	4250	
1800	3	4300	
1850	3	4350	
1900	3	4400	
1950	2	4450	
2000	4	4500	
2050	2	4550	
2100	2	4600	
2150	3	4650	
2200	2	4700	
2250	6	4750	
2300	15	4800	
2350		4850	
2400		4900	
2450		4950	
2500		5000	



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

CLIENT Yachiyo Engineering
TITLE Scala Penetrometer Test
REFERENCE No. 750932

September 2012

(1)

SC8.xlsx

TONKIN & TAYLOR

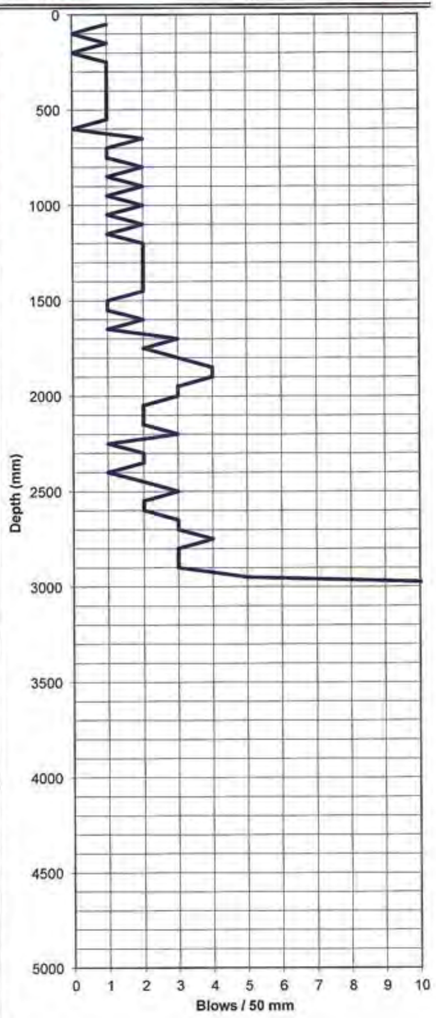
SCALA PENETROMETER LOG

Job No: 750932
Project: Micro-Grid System in Tonga
Location: Site B
RL: 13.07m

Date: 27/09/2012
Operated by: CWM
Logged by: CWM
Checked by: ADP

Test No. SC8B
Sheet 1
of 1

mm Driven	No. of Blows	mm Driven	No. of Blows
50	1	2550	2
100	0	2600	2
150	1	2650	3
200	0	2700	3
250	1	2750	4
300	1	2800	3
350	1	2850	3
400	1	2900	3
450	1	2950	5
500	1	3000	15
550	1	3050	
600	0	3100	
650	2	3150	
700	1	3200	
750	1	3250	
800	2	3300	
850	1	3350	
900	2	3400	
950	1	3450	
1000	2	3500	
1050	1	3550	
1100	2	3600	
1150	1	3650	
1200	2	3700	
1250	2	3750	
1300	2	3800	
1350	2	3850	
1400	2	3900	
1450	2	3950	
1500	1	4000	
1550	1	4050	
1600	2	4100	
1650	1	4150	
1700	3	4200	
1750	2	4250	
1800	3	4300	
1850	4	4350	
1900	4	4400	
1950	3	4450	
2000	3	4500	
2050	2	4550	
2100	2	4600	
2150	2	4650	
2200	3	4700	
2250	1	4750	
2300	2	4800	
2350	2	4850	
2400	1	4900	
2450	2	4950	
2500	3	5000	



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

CLIENT Yachiyo Engineering
TITLE Scala Penetrometer Test
REFERENCE No. 750932

September 2012

(1)

SC9.xlsx

TONKIN & TAYLOR

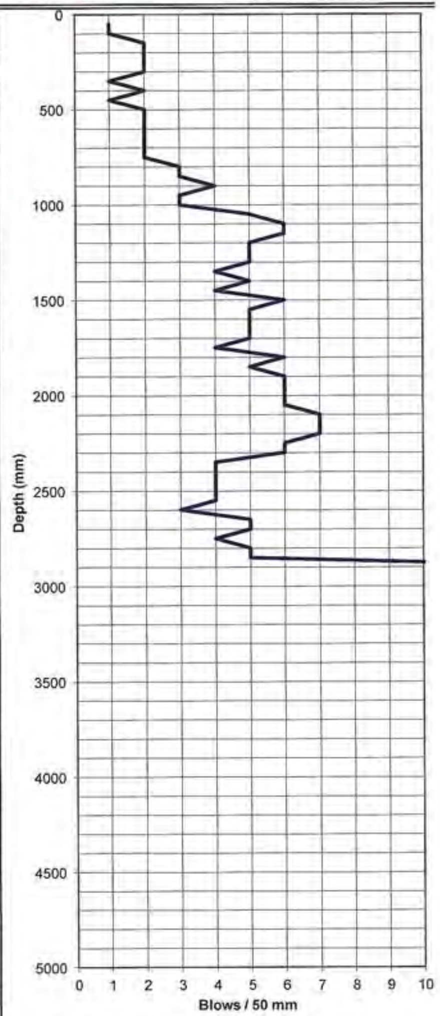
SCALA PENETROMETER LOG

Job No: 750932
Project: Micro-Grid System in Tonga
Location: Site B
RL: 13.15m

Date: 27/09/2012
Operated by: CWM
Logged by: CWM
Checked by: ADP

Test No. SC9B
Sheet 1
of 1

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



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

CLIENT Yachiyo Engineering
TITLE Scala Penetrometer Test
REFERENCE No. 750932

September 2012

(1)

SC10.xlsx

TONKIN & TAYLOR

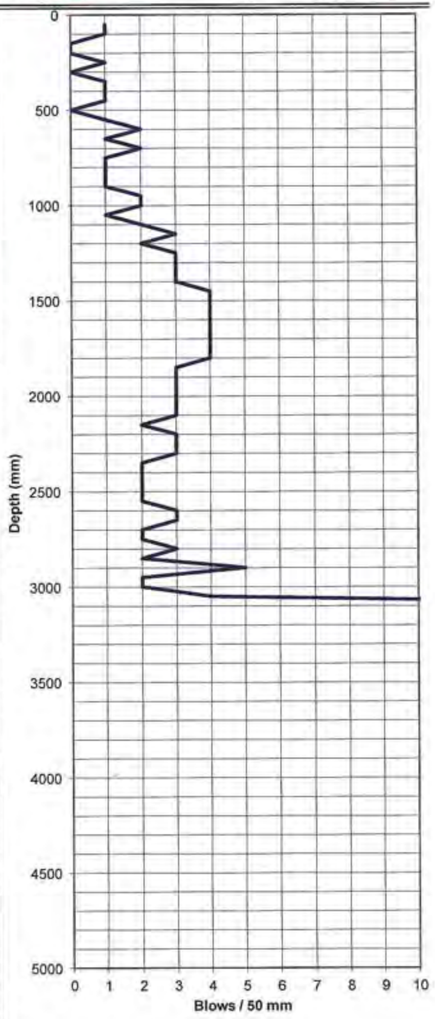
SCALA PENETROMETER LOG

Job No: 750932
Project: Micro-Grid System in Tonga
Location: Site B
RL: 12.87m

Date: 27/09/2012
Operated by: CWM
Logged by: CWM
Checked by: ADP

Test No. SC10B
Sheet 1
of 1

mm Driven	No. of Blows	mm Driven	No. of Blows
50	1	2550	2
100	1	2600	3
150	0	2650	3
200	0	2700	2
250	1	2750	2
300	0	2800	3
350	1	2850	2
400	1	2900	5
450	1	2950	2
500	0	3000	2
550	1	3050	4
600	2	3100	20
650	1	3150	
700	2	3200	
750	1	3250	
800	1	3300	
850	1	3350	
900	1	3400	
950	2	3450	
1000	2	3500	
1050	1	3550	
1100	2	3600	
1150	3	3650	
1200	2	3700	
1250	3	3750	
1300	3	3800	
1350	3	3850	
1400	3	3900	
1450	4	3950	
1500	4	4000	
1550	4	4050	
1600	4	4100	
1650	4	4150	
1700	4	4200	
1750	4	4250	
1800	4	4300	
1850	3	4350	
1900	3	4400	
1950	3	4450	
2000	3	4500	
2050	3	4550	
2100	3	4600	
2150	2	4650	
2200	3	4700	
2250	3	4750	
2300	3	4800	
2350	2	4850	
2400	2	4900	
2450	2	4950	
2500	2	5000	



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

CLIENT Yachiyo Engineering
TITLE Scala Penetrometer Test
REFERENCE No. 750932

September 2012

[1]

SC11.xlsx

TONKIN & TAYLOR

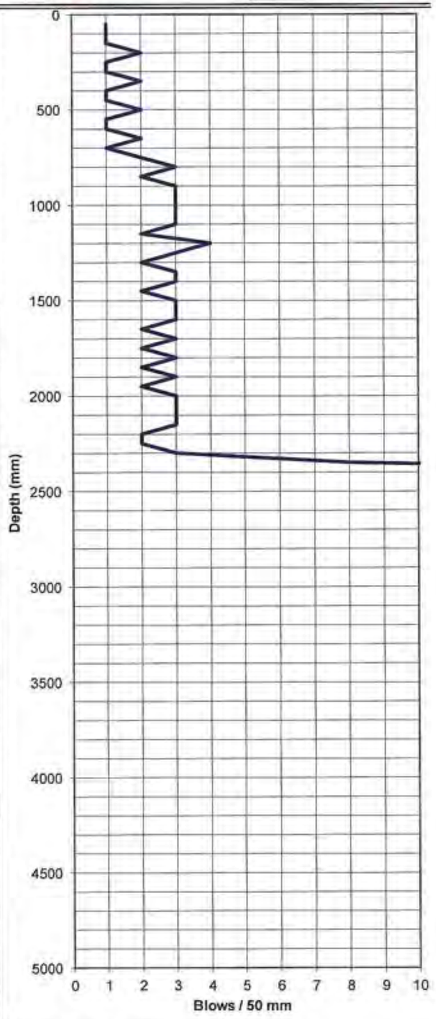
SCALA PENETROMETER LOG

Job No: 750932
Project: Micro-Grid System in Tonga
Location: Site B
RL: 13.28m

Date: 27/09/2012
Operated by: CWM
Logged by: CWM
Checked by: ADP

Test No. SC11B
Sheet 1
of 1

mm Driven	No. of Blows	mm Driven	No. of Blows
50	1	2550	
100	1	2600	
150	1	2650	
200	2	2700	
250	1	2750	
300	1	2800	
350	2	2850	
400	1	2900	
450	1	2950	
500	2	3000	
550	1	3050	
600	1	3100	
650	2	3150	
700	1	3200	
750	2	3250	
800	3	3300	
850	2	3350	
900	3	3400	
950	3	3450	
1000	3	3500	
1050	3	3550	
1100	3	3600	
1150	2	3650	
1200	4	3700	
1250	3	3750	
1300	2	3800	
1350	3	3850	
1400	3	3900	
1450	2	3950	
1500	3	4000	
1550	3	4050	
1600	3	4100	
1650	2	4150	
1700	3	4200	
1750	2	4250	
1800	3	4300	
1850	2	4350	
1900	3	4400	
1950	2	4450	
2000	3	4500	
2050	3	4550	
2100	3	4600	
2150	3	4650	
2200	2	4700	
2250	2	4750	
2300	3	4800	
2350	8	4850	
2400	20	4900	
2450		4950	
2500		5000	



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

CLIENT Yachiyo Engineering
TITLE Scala Penetrometer Test
REFERENCE No. 750932

September 2012

[1]

SC12.xlsx

TONKIN & TAYLOR

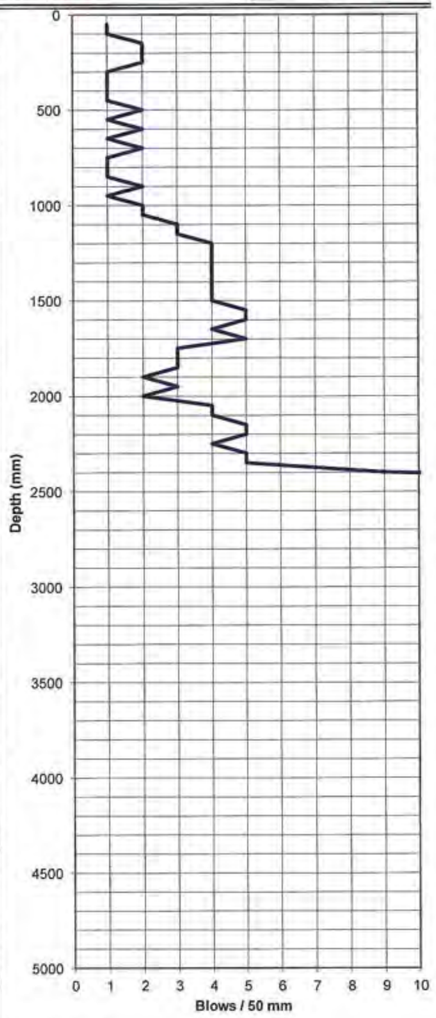
SCALA PENETROMETER LOG

Job No: 750932
Project: Micro-Grid System in Tonga
Location: Site B
RL: 12.92m

Date: 27/09/2012
Operated by: CWM
Logged by: CWM
Checked by: ADP

Test No. SC12B
Sheet 1 of 1

mm Driven	No. of Blows	mm Driven	No. of Blows
50	1	2550	
100	1	2600	
150	2	2650	
200	2	2700	
250	2	2750	
300	1	2800	
350	1	2850	
400	1	2900	
450	1	2950	
500	2	3000	
550	1	3050	
600	2	3100	
650	1	3150	
700	2	3200	
750	1	3250	
800	1	3300	
850	1	3350	
900	2	3400	
950	1	3450	
1000	2	3500	
1050	2	3550	
1100	3	3600	
1150	3	3650	
1200	4	3700	
1250	4	3750	
1300	4	3800	
1350	4	3850	
1400	4	3900	
1450	4	3950	
1500	4	4000	
1550	5	4050	
1600	5	4100	
1650	4	4150	
1700	5	4200	
1750	3	4250	
1800	3	4300	
1850	3	4350	
1900	2	4400	
1950	3	4450	
2000	2	4500	
2050	4	4550	
2100	4	4600	
2150	5	4650	
2200	5	4700	
2250	4	4750	
2300	5	4800	
2350	5	4850	
2400	9	4900	
2450	20	4950	
2500		5000	



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

CLIENT Yachiyo Engineering
TITLE Scala Penetrometer Test
REFERENCE No. 750932

September 2012

(1)

GEOTECHNICS

23 Morgan Street, Newmarket
Auckland 1023, New Zealand
p. +64 9 356 3510
w. www.geotechnics.co.nz

Page of

Your Job No.: 750932

Site : Vaini, Tongatapu, Tonga - Site B

Our Job No.: 615931.000

Test Method Used:NZS 4402:1986 Test 2.1 Determination of the water content

WATER CONTENT TEST RESULTS

Table 1: Water Content

HA No.:	1	3
Depth (m)	1.1	0.6
Water Content (%)	71.4	81.5

Tested by: ST Date: 10/10/12 Checked by: AJFC Date: 10/10/12

GEOTECHNICS
23 Morgan Street, Newmarket
Auckland 1023, New Zealand
p. +64 9 356 3510
w. www.geotechnics.co.nz

Form No: 54
Form Date: January 2004
[illegible]

Page of
Your Job No.: 750932

Site : Vaini, Tongatapu, Tonga - Site B
Our Job No.: 615931.000

Test Method Used:NZS 4402:1986 Test 2.7.2 Determination of Solid Density of Soil Particles - Vacuum Method

SOLID DENSITY TEST RESULTS

Table 1: Solid Density

	*Single Specimen tested	*Single Specimen tested
HA No.:	1	3
Depth (m)	1.1	0.6
Solid Density (t/m^3)	3.00	2.94

Remarks :

Solid density was performed on whole material.

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

Tested by: ST Date: 10/10/12 Checked by: ASTC Date: 10/10/12

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23 Morgan Street, Newmarket
Auckland 1023, New Zealand
p. +64 9 356 3510
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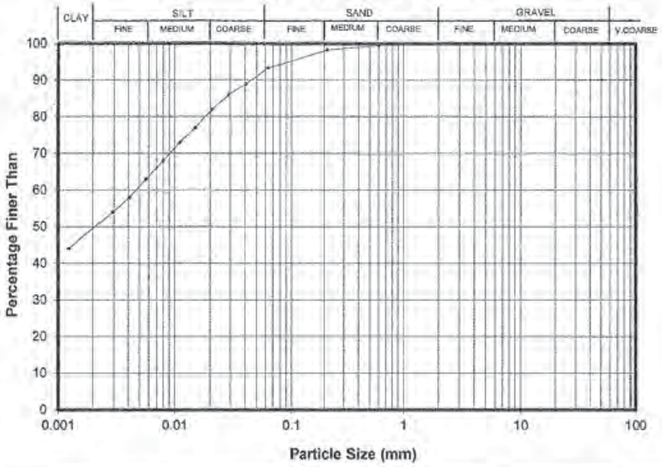
Form No.: P6
Form Date: January 2004
File: P:\615931.000\Working material\HA1_1.1m.xlsx

Plate No.: Page of Your Job No.: **750932**
Site : **Vaini, Tongatapu, Tonga - Site B** Our Job No.: **615931.000**
HA No.: **1** Sample No.: -- Depth: **1.1 (m)**
Test Method Used : NZS 4402:1986 Test 2.8.4 Hydrometer

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing	Sieve (mm)	Total % Passing	Equivalent Particle Diameter D (mm)	% of Particles Finer than D
2.00	100			0.0408	89
0.600	99			0.0291	86
0.212	98			0.0209	82
0.063	93			0.0150	77
				0.0111	73
				0.0080	68
				0.0057	63
				0.0041	58
				0.0029	54
				0.0012	44

Sample history : As received.

Description: silty CLAY with minor sand, stiff, dark red with dark brown, mottled orange, high plasticity.

Solid Density (Measured) : 3.00 t/m^3

Remarks : A sub sample was split from the original sample for hydrometer analysis. This sample was soaked with a dispersing agent (~3 hours), then the mechanical shaker was used, until the material was brought into suspension, before proceeding with the test.

Suspension pH 8.0

The classification of sand-silt-clay components are described on the basis of particle size analysis.

Sample description is not IANZ endorsed.

Entered by : ST Date : 10/10/12 Checked by : ASTC Date : 10/10/12

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23 Morgan Street, Newmarket
Auckland 1023, New Zealand
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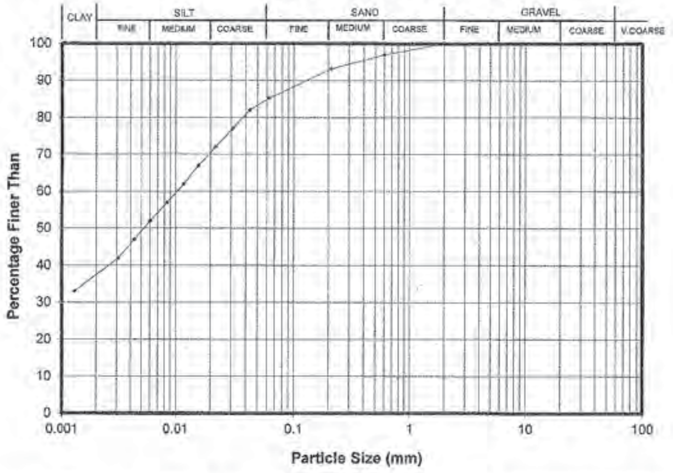
Form No.: P8
Form Date: January 2004
File: P:\615931.000\Working material\HA3_0.6m.xlsx

Plate No.: Page of
Site : **Vaini, Tongatapu, Tonga - Site B**
HA No.: **3** Sample No.: **---**
Test Method Used : NZS 4402:1986 Test 2.8.4 Hydrometer

Your Job No.: **750932**
Our Job No.: **615931.000**
Depth: **0.6 (m)**

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing	Sieve (mm)	Total % Passing
2.00	100		
0.600	97		
0.212	93		
0.063	85		

Equivalent Particle Diameter D (mm)	% of Particles Finer than D
0.0431	82
0.0309	77
0.0222	72
0.0159	67
0.0118	62
0.0084	57
0.0060	52
0.0043	47
0.0031	42
0.0013	33

Sample history : As received.

Description: clayey SILT with some sand, stiff, dark red with dark brown, mottled orange, high plasticity.

Solid Density (Measured) : 2.94 t/m^3

Remarks : A sub sample was split from the original sample for hydrometer analysis. This sample was soaked with a dispersing agent (~3 hours), then the mechanical shaker was used, until the material was brought into suspension, before proceeding with the test.

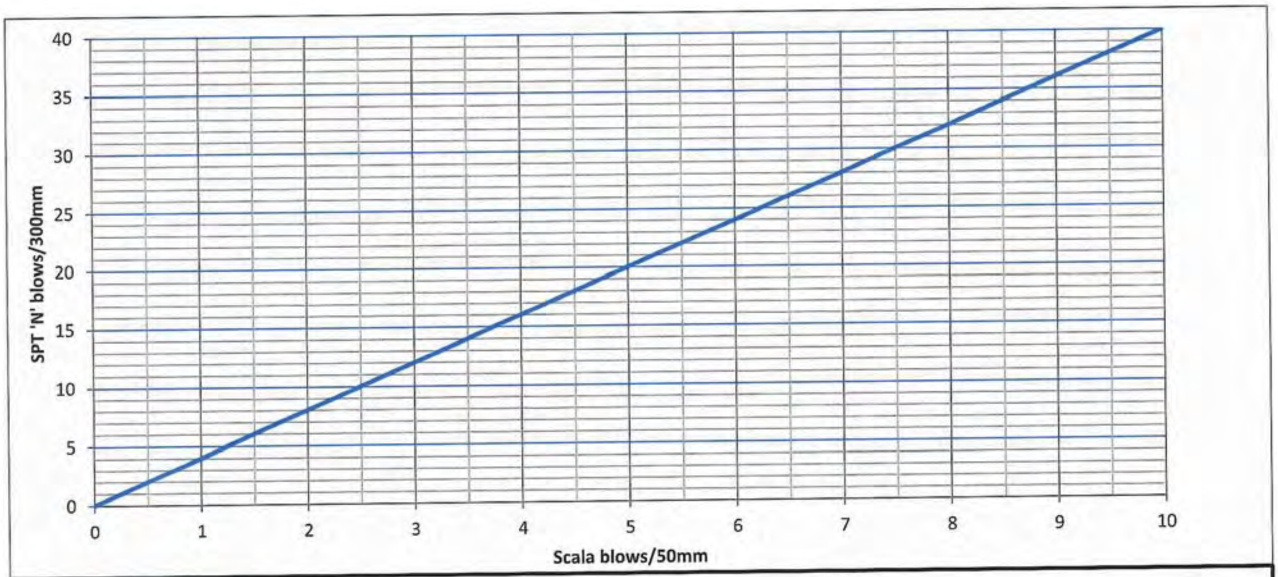
Suspension pH 8.0

The classification of sand-silt-clay components are described on the basis of particle size analysis.

Sample description is not IANZ endorsed.

Entered by : ST Date : 10|10|12 Checked by : ASFC Date : 10/10/12

Appendix E: Scala Penetrometer /SPT 'N' Value Conversion Chart



Tonkin & Taylor

Scala Penetrometer / SPT 'N' Value conversion Chart

A-9 Data Analysis for Wind Turbine Generation

Report of data Analysis for wind conditions in the Kingdom of Tonga

December 2012

West JEC, INC.

CONTENTS

This is a report summarized a feasibility evaluation for introduction of wind power by organizing and analyzing based on existing data of wind condition and determining the energy characteristics in mind the wind turbine scale that can be introduced in the Kingdom of Tonga.

1. Preconditions

1.1. Existing wind condition data

The specification of the existing wind condition data is shown in Table 1-1.

Table 1-1 Specification of the existing wind condition data and the observation site

Observation site of the existing data	Lapaha site (near Ha'malo Beach on the eastern coast of Tnogatapu Island) Latitude of 21°11' 22" degrees south, Longitude of 175° 05' 35" degrees east, Altitude of 28 m
Observation period of wind condition data	from July 2010 to October 2011
Applicable period for analysis of wind condition data	form 1st August 2010 to 31st July 2011
Implementation agency	MLECCNR
Specification of measuring instruments	6 anemometers 30 m above the ground, installed sensors at 22.5 and 202.5 degrees to magnetic north. 40 m above the ground, installed sensors at 22.5 and 202.5 degrees to magnetic north. 50 m above the ground, installed sensors at 22.5 and 202.5 degrees to magnetic north.
	2 wind vanes 37 m above the ground, installed sensor at 22.5 degrees to magnetic north 48 m above the ground, installed sensor at 22.5 degrees to magnetic north

1.2. Observation site of the existing data and candidate site for wind turbine

As noted above, the existing wind condition data has been observed by MLECCNR, the other place determined as candidate site for wind turbine is going to be developed.

Candidate site for wind turbine is approximately 6.5 km away from the observation site of the existing data in the straight-line distance. (Figure 1-1)

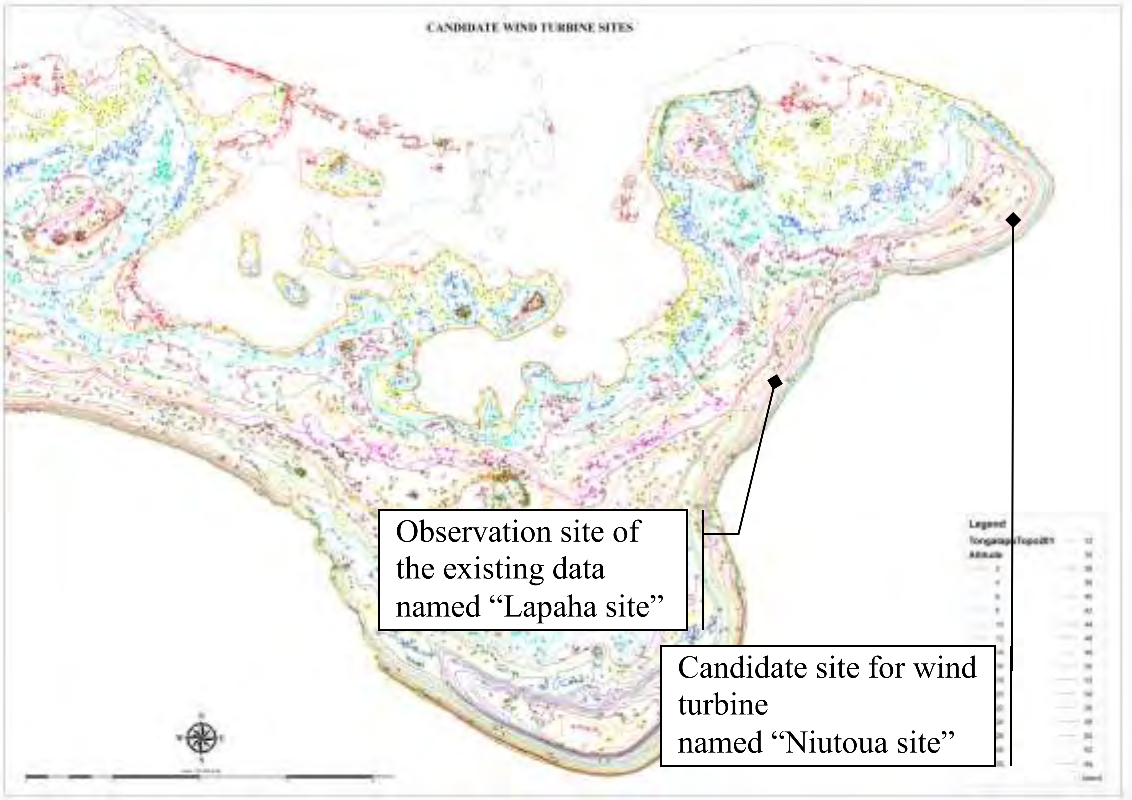
However, on the grounds that both sites are about the same with respect to topography and altitude conditions, this evaluation can be assumed to adapt to the candidate site for wind turbine.

The information of candidate site for wind turbine is shown in Table 1-2.

Also, the wind condition data is expected to be observed in the candidate site for wind turbine.

Table 1-2 The candidate site for wind turbine

Candidate site for wind turbine	Niutoua site (near Finehika Beach on the north eastern coast of Tongatapu Island) Latitude of 21° 09' 23" degrees south, Longitude 175° 02' 24" degrees east, Altitude of 26 m
Planning agency	TPL



Observation site of the existing data named “Lapaha site”

Candidate site for wind turbine named “Niutoua site”

Figure 1-1 The observation site and the candidate site

1.3. A wind turbine model

Considering the current situation of Tonga as an isolated island, the introduction of a medium-sized wind turbine is realistic in terms of construction.

A typical specification and a figure for 300 kW class wind turbine are shown in Table 1-3 and Figure 1-2.

Since a hub height is approximately 40 m in general, the wind condition data with a height of 40 m are used for analysis.

Table 1-3 Typical specification of 300 kW class wind turbine

Rating capacity	300 kW
Type	Horizontal axis
System	Upwind turbine
Rotor diameter	33 m
Hub height	41.5 m (approx. 40 m)
Rated wind speed	11.5 m/s
Rated rotating speed	40.5 rpm
Cut-in wind speed	3.0 m/s
Cut-out wind speed	25 m/s (average per 10 minutes)
Optimum tip speed ratio	7.5
Survival wind speed	70 m/s
Design life	20 years

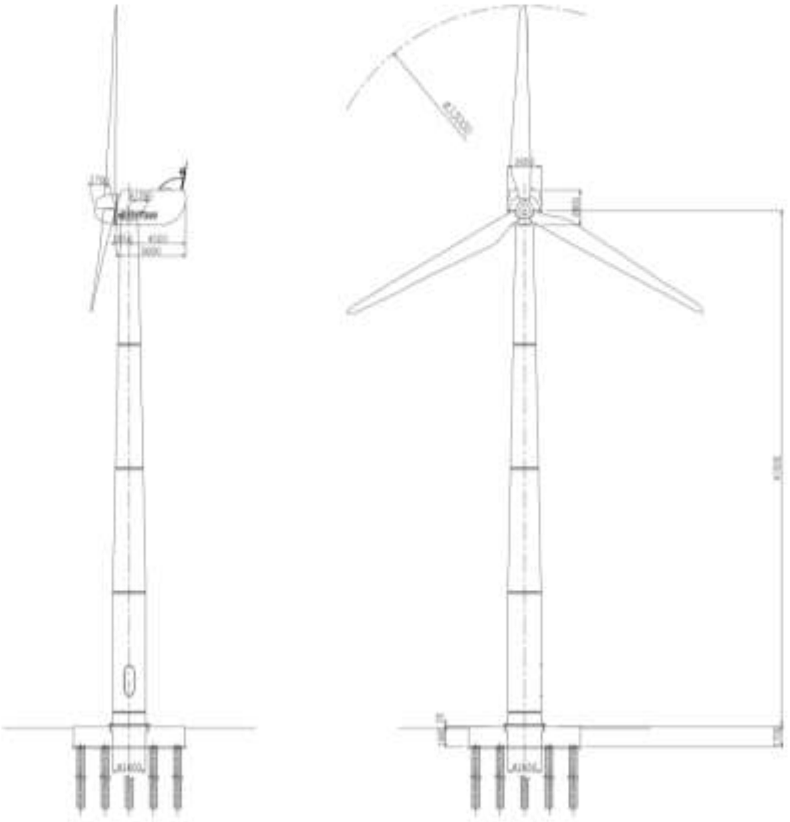


Figure 1-2 Typical figure of 300 kW wind turbine

Target of installed capacity for wind turbine is 500 kW in Tonga.
Therefore, it is assumed that two units of wind turbine the rated power of which is 250 kW are introduced (total installed capacity is 500 kW).
Here, it is assumed that 300 kW class wind turbine is adopted as rated power of 250 kW.
The assumed component of wind turbine is shown in Table 1-4.

Table 1-4 Assumed components of wind turbine

Installed capacity	Components
500 kW	250 kW (rated power) x 2 units

1.4. The objective of the evaluation in the report

Environmental impact assessment in accordance with the development of wind power has not been carried out, this project is not in the situation which immediately steps to the implementation phase.

Therefore, potential evaluation including expected energy production is carried out only in this report.

The items analyzed in this report are shown in Table 1-5.

Table 1-5 Analysis items

Attribution	Analysis items	Object
Wind conditions characteristics	Mean wind speed	To determine whether the development of wind power should be carried out.
	Frequency distribution of wind direction	To determine annual prevailing wind direction
	Hourly frequency distribution of wind direction	To determine hourly fluctuation characteristics of wind direction
	Frequency distribution of wind direction for each wind force scale, and correlation between wind speed and wind direction	To determine correlation between the wind speed and the wind direction
	Wind profile	To determine the wind shear for each wind direction
	Turbulence intensity	To determine the magnitude of the turbulence
	Maximum instantaneous wind speed	To determine the maximum instantaneous wind speed
	Wind speed distribution	To determine the wind speed distribution
Energy characteristics	Density of wind energy	To determine whether the development of wind power should be carried out.
	Availability	
	Annual energy production, Capacity factor	

2. Mean wind speed

2.1. Monthly average wind speed

Monthly average wind speed with a height of 40 m is shown in Table 2-1 and Figure 2-1.
The datas in March to April and July are 5.1 ~ 5.5 m/s, other months are more than 6.0 m/s in general. In particular the dates in September to December are greater than or equal to 7.0 m/s.
The annual average wind speed is 6.2 m/s.

Table 2-1 Monthly average wind speed and annual average by ground height

(unit: m/s)

Ground height	2011							2010					
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave.
30 m	5.0	4.9	4.4	4.4	5.2	5.3	4.8	5.5	6.1	6.3	6.4	6.1	5.4
40 m	5.8	5.7	5.1	5.2	6.0	6.2	5.5	6.2	6.9	7.1	7.2	7.0	6.2
50 m	6.2	6.1	5.4	5.5	6.4	6.6	5.9	6.6	7.3	7.4	7.6	7.4	6.5

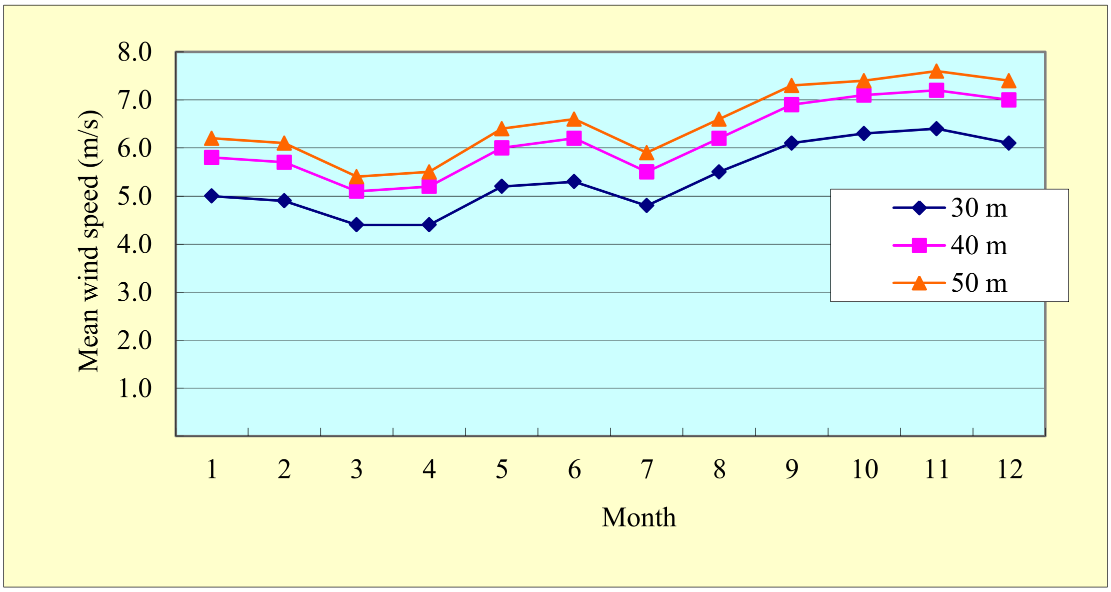


Figure 2-1 Monthly average wind speed by ground height

2.2. Hourly average wind speed

Diurnal variation of hourly average wind speed with a height of 40 m per year is small (5.8 to 6.4 m/s), tended to be somewhat weaker at midnight to morning than during the day as shown in Table 2-2 and Figure 2-2.

With respect to the hourly variation of each month, the data in January indicates a similar tendency as the data in a year. In contrast, wind speed in August tends to be slightly stronger in early morning.

Table 2-2 Hourly average wind speed and standard deviation [ground height: 40 m]

(unit: m/s)

year/month	item	Hour																								Ave.
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Jan. 2011	WS	5.7	5.5	5.5	5.4	5.6	5.6	5.7	5.4	5.4	5.5	5.9	6.1	6.3	6.3	6.2	6.1	5.9	5.9	5.7	5.7	6.0	6.3	6.4	6.0	5.8
	SD	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.0	1.0	1.1	1.1	1.0	1.0	0.9	0.8	0.8	0.9	0.9	0.9	0.9
Feb. 2011	WS	5.6	5.4	5.1	5.0	5.1	5.2	5.3	5.4	5.6	5.7	6.0	6.1	6.1	6.0	5.8	5.8	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.5	5.7
	SD	0.7	0.7	0.7	0.6	0.6	0.6	0.7	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.8	0.7	0.7	0.7	0.7	0.8
Mar. 2011	WS	4.9	4.9	4.8	4.7	4.8	4.8	4.7	5.0	5.1	5.4	5.5	5.6	5.8	5.6	5.5	5.3	5.0	5.0	5.0	5.0	5.2	5.0	5.1	5.0	5.1
	SD	0.7	0.7	0.7	0.6	0.7	0.7	0.7	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.8
Apr. 2011	WS	4.8	4.9	4.8	4.7	4.8	4.8	5.0	5.2	5.2	5.5	5.6	6.0	6.0	5.8	5.5	5.5	5.6	5.1	5.0	4.9	5.0	4.9	4.8	4.7	5.2
	SD	0.6	0.7	0.6	0.6	0.6	0.6	0.6	0.7	0.8	0.9	0.9	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.8
May. 2011	WS	6.2	6.0	5.9	6.0	6.0	6.1	6.2	6.0	5.9	5.9	6.0	6.0	6.1	5.8	5.9	5.7	5.7	5.8	6.0	6.1	6.3	6.3	6.1	5.8	6.0
	SD	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.7	0.8	0.8	0.8	0.8	0.8
Jun. 2011	WS	6.4	6.2	5.8	5.6	5.8	5.9	5.9	5.9	5.9	6.1	6.2	6.2	6.2	6.0	6.1	6.3	6.5	6.5	6.4	6.5	6.4	6.4	6.6	6.8	6.2
	SD	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.8
Jul. 2011	WS	5.0	5.2	5.2	5.3	5.3	5.5	5.4	5.3	5.4	5.4	5.7	5.6	5.5	5.7	5.8	6.1	5.8	5.8	5.7	5.7	5.6	5.6	5.4	5.2	5.5
	SD	0.7	0.7	0.6	0.7	0.7	0.7	0.7	0.7	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.8
Aug. 2010	WS	6.6	6.5	6.3	6.3	6.4	6.3	6.1	5.8	5.8	5.7	5.7	6.0	6.3	6.0	6.4	6.4	6.6	6.4	6.5	6.5	6.4	6.1	6.2	6.2	6.2
	SD	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.8
Sep. 2010	WS	6.6	6.7	6.5	6.4	6.5	6.2	6.4	6.6	6.7	6.7	6.9	7.1	7.1	7.1	7.0	6.9	7.1	7.0	7.2	7.3	7.4	7.4	7.3	7.1	6.9
	SD	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.8
Oct. 2010	WS	7.1	6.9	6.7	7.1	7.1	7.0	7.1	7.2	7.2	7.1	7.2	7.2	7.1	7.2	7.1	6.9	7.0	6.9	7.1	7.1	7.1	7.2	7.2	7.0	7.1
	SD	0.8	0.7	0.8	0.8	0.8	0.7	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Nov. 2010	WS	7.0	6.7	6.7	6.8	6.9	7.1	6.9	7.3	7.4	7.5	7.4	7.5	7.5	7.5	7.5	7.4	7.5	7.2	7.1	7.2	7.1	7.1	7.0	7.1	7.2
	SD	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.9
Dec. 2010	WS	6.9	6.8	6.6	6.6	6.4	6.8	6.7	6.7	6.9	7.3	7.3	7.1	7.1	7.1	7.0	7.0	7.0	7.0	7.1	7.3	7.4	7.3	7.2	7.0	7.0
	SD	0.8	0.8	0.8	0.8	0.7	0.7	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.8
Ave.	WS	6.1	6.0	5.8	5.8	5.9	5.9	5.9	6.0	6.0	6.2	6.3	6.4	6.4	6.4	6.3	6.3	6.3	6.2	6.2	6.3	6.3	6.3	6.3	6.1	6.2
	SD	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.8	0.9	0.9	0.9	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8

WP: Wind speed, SD: Standard deviation

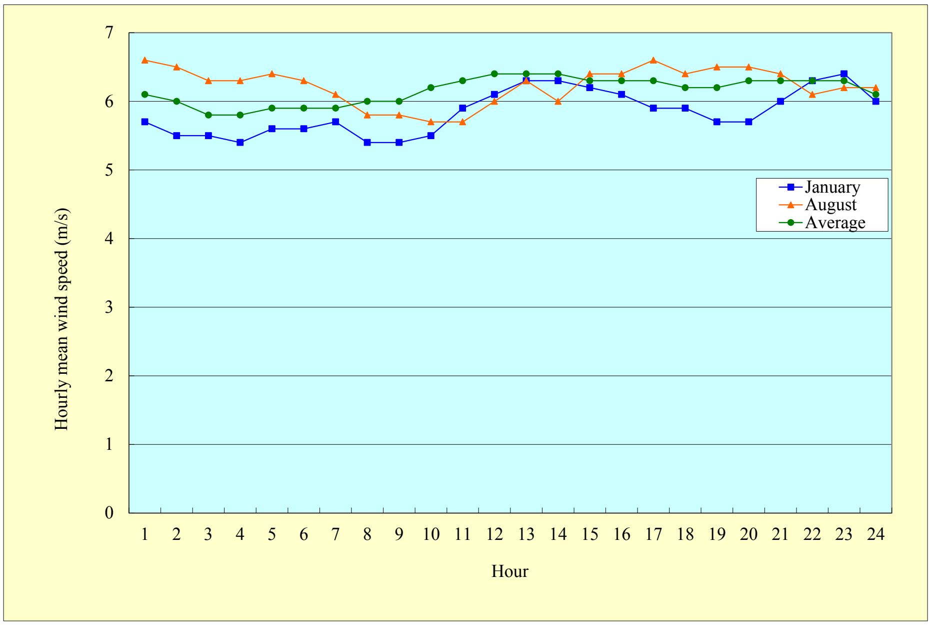


Figure 2-2 Hourly average wind speed

3. Frequency distribution of wind direction

3.1. Annual and monthly frequency distribution of wind direction

Frequency distribution of wind direction with a height of 40 m is shown in Table 3-1, Figure 3-1a and 3-1b.
The observation point is located in the trade wind belt, a prevailing wind (approximately 53% per year) blow from east (east to southeast) throughout the year. As regarding other wind directions, the north-northeast to northeast wind (approximately 10-14%) is superior to annual average in winter and spring season (January to May), and the east-southeast to southeast east wind (approximately 15-28%) is superior to annual average in summer and autumn season (June to November).
Angular difference between the magnetic north and the arm mounted wind vane was 22.5 (east side) degrees. Assumed that the raw data of wind direction have not been corrected for angular difference, the raw data of all was added 22.5 degrees before evaluations.
The magnetic declination in Tonga is 13.0 (east side) degrees. Assumed that the raw data of wind direction have already been corrected for the magnetic declination, the raw data of all have not made the correction before evaluation.

Table 3-1 Monthly and annual frequency distribution of wind direction
[ground height: 40 m]

(unit: %)

month/year	Calm	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Quantity ofdata
Jan. 2011	0.0	10.9	13.8	12.0	14.4	18.1	19.1	5.1	0.4	1.2	0.3	0.1	0.0	0.4	0.1	0.5	3.5	744
Feb. 2011	0.0	6.5	3.1	11.0	10.9	11.0	20.4	8.0	3.9	1.9	0.0	0.6	1.5	4.2	5.8	5.7	5.5	672
Mar. 2011	0.0	5.1	14.4	10.3	8.5	11.7	18.0	11.7	4.3	1.9	1.1	0.9	0.3	0.0	1.1	3.9	6.9	744
Apr. 2011	0.0	5.3	4.9	14.0	8.8	9.4	11.3	15.8	4.9	2.1	1.8	0.8	1.8	1.4	2.1	7.5	8.2	720
May. 2011	0.0	1.3	2.0	11.7	12.4	21.2	14.5	21.2	3.6	1.5	1.5	0.4	0.8	0.8	3.2	1.9	1.9	744
Jun. 2011	0.0	1.9	4.2	6.0	13.1	17.9	21.1	14.9	11.4	5.7	3.1	0.6	0.1	0.0	0.0	0.0	0.1	720
Jul. 2011	0.0	3.2	2.7	7.0	4.6	5.8	15.5	16.3	9.8	4.8	4.2	2.6	4.2	5.4	5.1	5.6	3.4	744
Aug. 2010	0.0	0.9	2.0	7.1	9.8	19.1	21.0	20.3	10.8	2.6	1.3	0.7	0.7	0.8	1.1	0.9	0.9	744
Sep. 2010	0.0	0.6	1.1	1.0	9.2	17.6	34.4	17.9	8.9	4.2	3.1	0.8	0.1	0.4	0.3	0.4	0.0	720
Oct. 2010	0.0	1.6	2.7	1.3	3.9	9.3	21.4	28.1	15.2	9.0	0.9	0.5	0.7	0.9	1.5	1.7	1.2	744
Nov. 2010	0.0	5.1	3.9	2.9	3.8	5.6	15.3	35.0	12.8	9.3	0.6	0.3	0.4	0.3	1.3	0.4	3.2	720
Dec. 2010	0.0	3.9	1.2	1.5	3.4	26.9	44.1	11.3	1.1	0.9	0.0	0.8	0.4	0.8	0.5	1.3	1.9	744
Ave.	0.0	3.9	4.7	7.1	8.5	14.5	21.3	17.2	7.2	3.8	1.5	0.8	0.9	1.3	1.8	2.5	3.0	8760

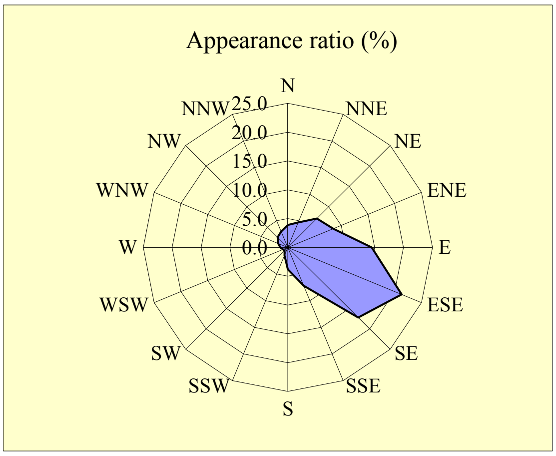


Figure 3-1a Annual wind rose

Note) The trade winds (also called trades) are the prevailing pattern of easterly surface winds found in the tropics, within the lower portion of the Earth's atmosphere, in the lower section of the troposphere near the Earth's equator.

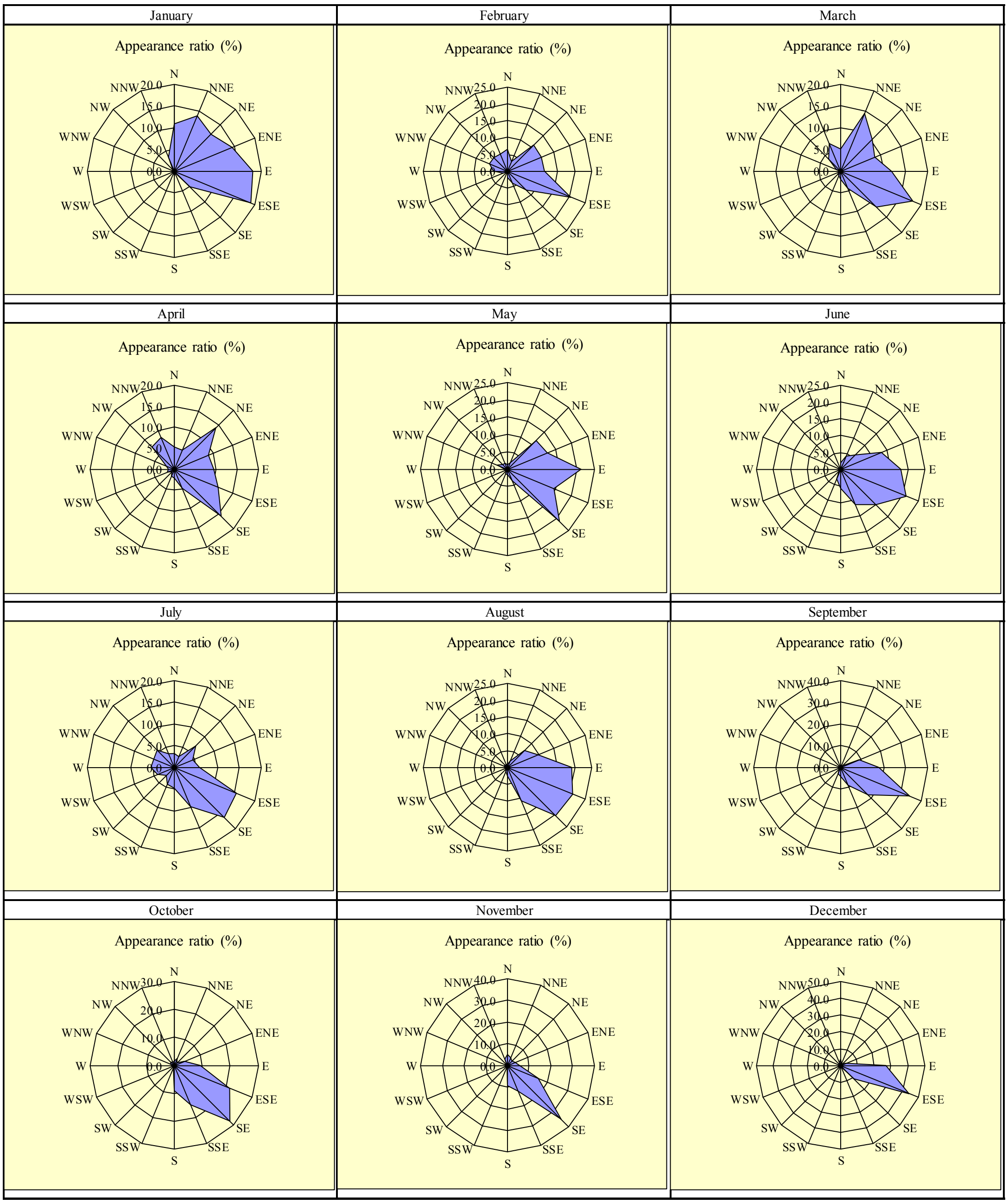

January February March April May June July August September October November December

Figure 3-1b Monthly wind rose

3.2. Hourly frequency distribution of wind direction

On hourly frequency distribution of wind direction per year with a height of 40 m, the wind directions of east to southeast prevail throughout the day. In particular, the wind directions of east-northeast and northeast appear continually from afternoon to evening (at 12:00 am to 19:00 pm). In addition, the wind direction of southeast is reduced and east-southeast and east are increased from morning to night (at 10:00 am to18:00 pm).

Table3-2 Hourly frequency distribution of wind direction in year [ground height: 40 m]

(unit: %)

Hour	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	sum
1	0.2	0.2	0.3	0.4	0.6	0.9	0.7	0.3	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.1	0.0	4.2
2	0.2	0.2	0.4	0.4	0.6	0.8	0.8	0.3	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0	4.2
3	0.2	0.2	0.5	0.3	0.6	0.7	0.8	0.3	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.0	4.2
4	0.2	0.2	0.4	0.3	0.5	0.7	0.8	0.3	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	4.2
5	0.2	0.2	0.4	0.4	0.5	0.8	0.8	0.3	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.0	4.2
6	0.2	0.2	0.4	0.4	0.4	0.8	0.8	0.3	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0	4.2
7	0.2	0.2	0.4	0.4	0.5	0.7	0.9	0.3	0.2	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.0	4.2
8	0.2	0.3	0.3	0.4	0.6	0.8	0.7	0.3	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.0	4.2
9	0.2	0.2	0.2	0.5	0.5	0.8	0.7	0.3	0.1	0.0	0.1	0.0	0.0	0.1	0.1	0.1	0.0	4.2
10	0.2	0.2	0.2	0.5	0.6	0.8	0.7	0.4	0.2	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	4.2
11	0.1	0.2	0.2	0.4	0.8	0.9	0.6	0.4	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	4.2
12	0.1	0.3	0.2	0.4	0.7	1.0	0.7	0.3	0.1	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	4.2
13	0.1	0.3	0.1	0.4	0.7	1.1	0.5	0.4	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	4.2
14	0.1	0.2	0.2	0.3	0.7	1.1	0.6	0.4	0.2	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.0	4.2
15	0.1	0.2	0.2	0.3	0.7	1.0	0.6	0.3	0.2	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.0	4.2
16	0.2	0.2	0.2	0.3	0.6	1.1	0.6	0.3	0.3	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.0	4.2
17	0.1	0.2	0.2	0.3	0.6	1.1	0.6	0.3	0.3	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	4.2
18	0.1	0.1	0.2	0.4	0.5	1.1	0.6	0.3	0.2	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0	4.2
19	0.2	0.1	0.3	0.3	0.6	1.0	0.7	0.3	0.2	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0	4.2
20	0.1	0.2	0.4	0.2	0.7	0.9	0.7	0.3	0.2	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0	4.2
21	0.1	0.1	0.4	0.3	0.7	0.8	0.8	0.3	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	4.2
22	0.2	0.2	0.3	0.3	0.7	0.8	0.8	0.3	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.0	4.2
23	0.1	0.2	0.3	0.4	0.6	0.8	0.9	0.2	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.0	4.2
24	0.2	0.2	0.4	0.3	0.7	0.9	0.7	0.2	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.0	4.2
Ave.	3.9	4.7	7.1	8.5	14.5	21.3	17.2	7.2	3.8	1.5	0.8	0.9	1.3	1.8	2.5	3.0	0.0	100.0

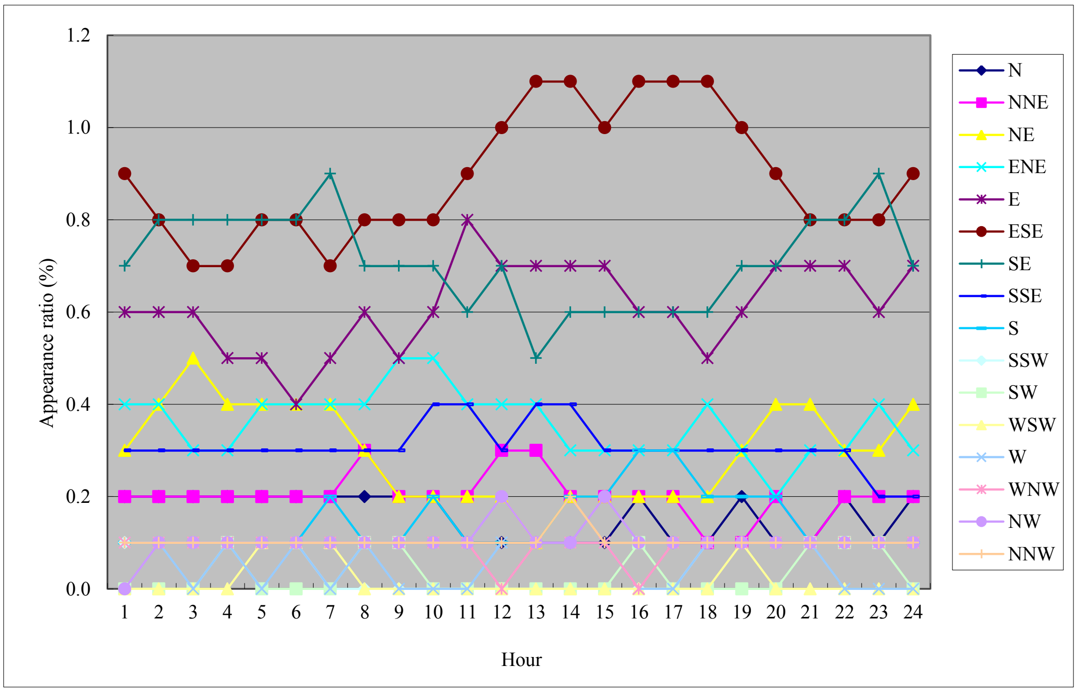


Figure 3-2 Hourly frequency direction of wind direction in year [ground height: 40 m]

4. Frequency distribution of wind direction for each wind force scale, and correlation between mean wind speed and frequency distribution of wind direction

The wind direction of east-southeast is dominant with appearance ratio of 21.3%, the appearance of wind direction of east to southeast centered on the east-southeast is occupied 53% of the total. It should be noted that the frequency distribution of wind direction correlate significantly with mean wind speed.

Table 4-1 Frequency distribution of wind direction for each wind force scale, and correlation between mean wind speed and appearance ratio [ground height: 40 m]

(unit: %)

Wind speed	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0<V< 1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
1≦V< 2	0.3	0.2	0.2	0.2	0.1	0.1	0.3	0.3	0.3	0.2	0.2	0.2	0.3	0.2	0.2	0.2
2≦V< 3	0.5	0.5	0.7	0.6	0.4	0.5	0.6	0.5	0.4	0.3	0.1	0.1	0.2	0.4	0.3	0.3
3≦V< 4	1.0	1.1	2.8	1.5	1.4	1.0	1.0	0.7	0.3	0.4	0.3	0.3	0.3	0.6	0.5	0.6
4≦V< 5	0.7	1.1	1.7	1.3	2.2	1.8	1.7	0.9	0.5	0.3	0.1	0.2	0.2	0.4	0.5	0.8
5≦V< 6	0.5	0.6	0.5	1.5	2.5	2.2	1.8	1.3	0.6	0.1		0.1	0.1	0.1	0.5	0.5
6≦V< 7	0.4	0.3	0.5	1.3	2.1	2.1	2.2	1.1	0.6	0.1			0.0	0.1	0.2	0.3
7≦V< 8	0.3	0.3	0.4	0.9	1.9	2.6	2.0	0.9	0.3	0.0	0.0		0.1	0.0	0.0	0.2
8≦V< 9	0.2	0.1	0.2	0.5	1.3	3.1	2.0	0.5	0.2	0.0		0.0		0.0	0.0	0.1
9≦V<10	0.0	0.3	0.0	0.3	0.8	2.6	1.6	0.4	0.1	0.0					0.0	0.0
10≦V<11		0.1		0.2	0.7	2.2	1.5	0.4	0.0							
11≦V<12			0.0	0.1	0.5	1.8	1.4	0.2	0.0							
12≦V<13			0.0	0.0	0.1	0.8	0.6	0.0	0.0							
13≦V<14				0.0	0.2	0.2	0.3	0.0	0.0							
14≦V<15				0.0	0.1	0.1	0.1	0.0	0.1							
Mean wind speed (m/s)	4.4	4.7	4.3	5.6	6.5	7.9	7.4	6.1	5.4	3.6	2.8	3.2	3.2	3.4	4.1	4.5
Appearance ratio (%)	3.9	4.7	7.1	8.5	14.5	21.3	17.2	7.2	3.8	1.5	0.8	0.9	1.3	1.8	2.5	3.0

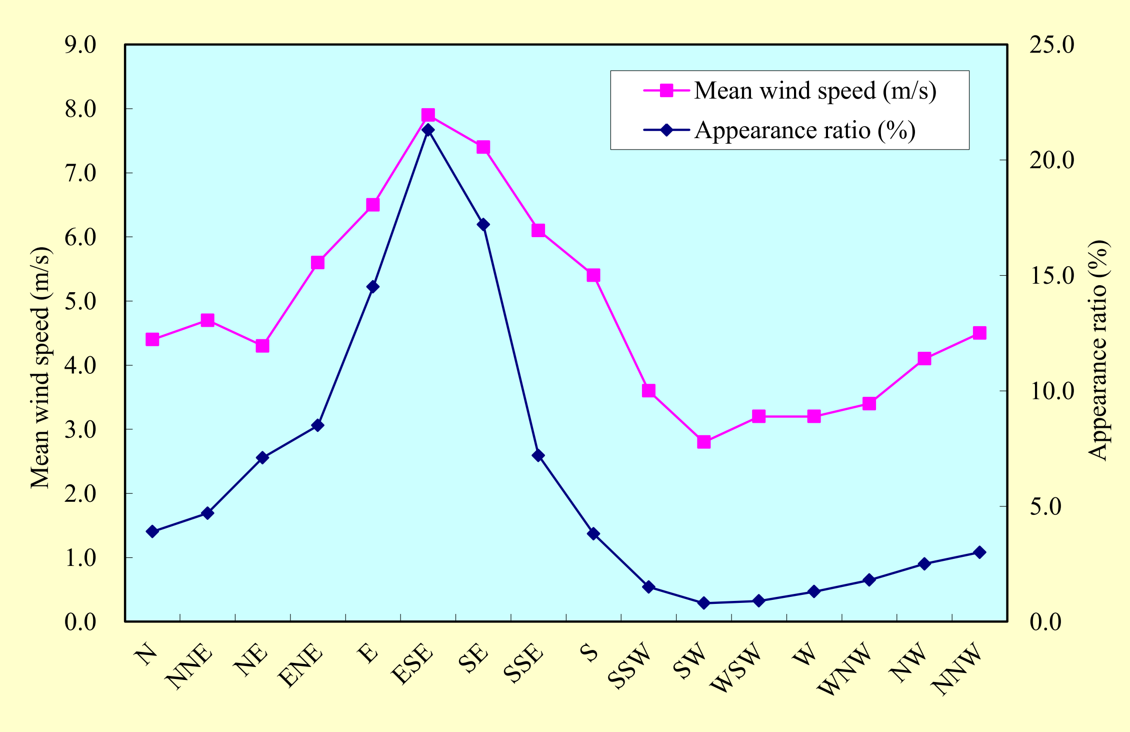


Figure 4-1 Correlation between mean wind speed and frequency distribution of wind direction

5. Wind profile

In general, the wind speed increases with increasing altitude. It is said that the power low is applicable to the wind speed from near the ground up to height of 300 m. Therefore to clarify the wind profile, the power index is calculated.
Power law is defined by the following equation.

$$U/U_1 = \left(Z/Z_1\right)^{1/n}$$

U : The wind speed at ground height of z m/s

U_1: The wind speed at ground height of z_1 m/s

$1/n$: Power index

Power index, which varies depending on the atmospheric stability and roughness condition of the ground surface, the power index is shown in the table below in the case of the neutral atmospheric stability.

The value of the power index n of the power law

Ground condition	"n" value
Flat ground (grassland, coast)	7~10
Rural area	4~6
Urban area	2~4

Calculation result of power index ("n" value) is shown in Table 5-1 using the data for height of 40 m and 50m.
The "n" value is 3.5 in all directional average, indicates as same as the grand condition of urban area.
By direction, "n" value in east-southeast is 5.2, equivalent to the ground condition of rural area. Other direction's "n" values are 4.0 or less, it is assumed that wind profile is reflected by around timber (palm tree).

Table 5-1 Power index of wind direction

Wind direction	Mean wind speed (m/s)		Power index (n)	Appearance frequency
	40 m	50 m		40 m
N	4.4	4.8	2.3	332
NNE	4.7	4.7	—	360
NE	4.4	4.6	2.9	485
ENE	5.1	5.6	2.4	743
E	6.4	6.9	3.2	1461
ESE	7.8	8.2	5.2	1899
SE	7.4	7.8	3.9	1505
SSE	6.1	6.5	3.5	635
S	5.4	5.9	2.9	330
SSW	3.6	3.6	—	130
SW	2.8	2.9	5.0	67
WSW	3.2	3.4	2.7	82
W	3.3	3.6	2.4	104
WNW	3.2	3.5	1.9	160
NW	4.1	4.5	2.0	210
NNW	4.6	5.1	2.1	257
All directions	6.2	6.5	3.5	8760

Note) "-" means a negative value or a value greater than or equal to 10.

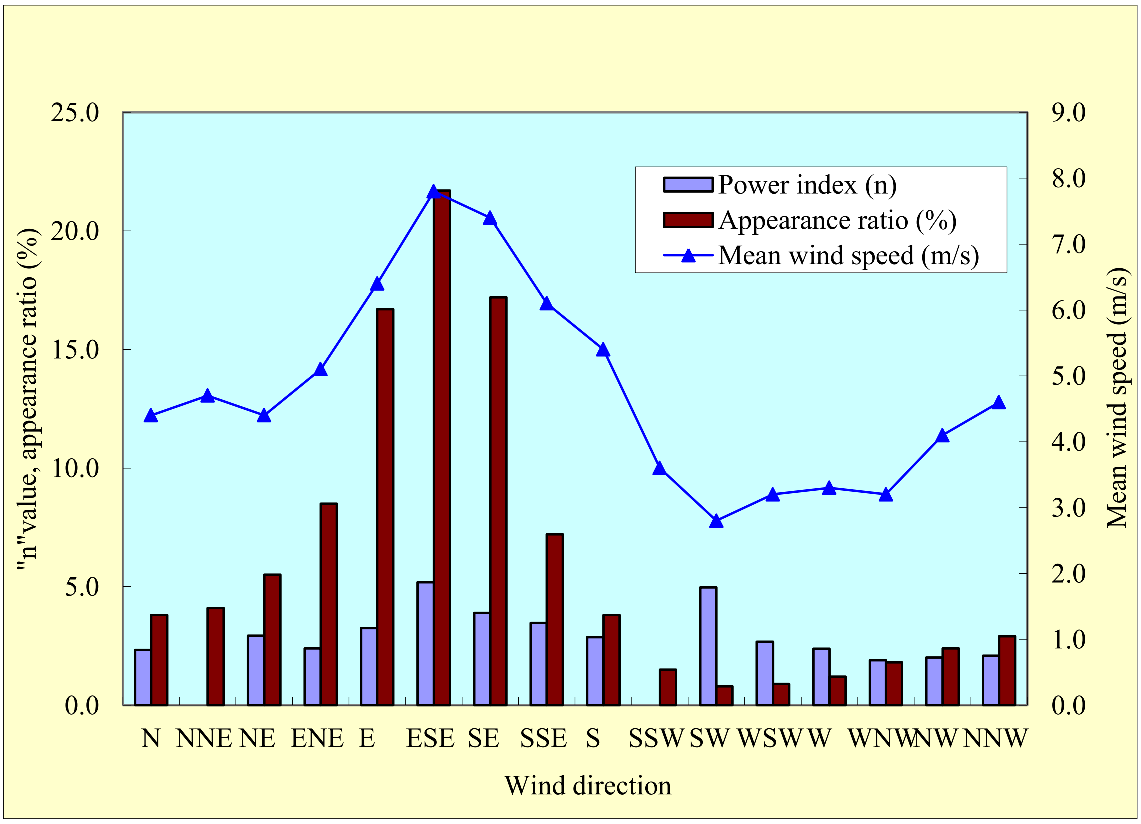


Figure 5-1 Correlation between frequency distribution of wind direction and power index

6. Turbulence intensity

Turbulence intensity with a height of 40 m is 0.15 in all directional average, which is equivalent to the type of the plain field with reference to the following table named "Correlation between terrain types and disturbance intensity". In addition, the turbulence intensity at around wind speed of 15 m/s is 0.11, which fully satisfy the evaluation criteria of 0.18 or less.

Correlation between terrain types and turbulence intensity

Terrain types	Turbulence intensity
Sea, lake	0.10
Plain field	0.15
Hilly terrain	0.20
Low mountain terrain	0.25
High mountain terrain	0.30

Table 6-1 Turbulence intensity of wind direction for each wind force scale (ground height: 40m)

wind speed	Wind direction																
（m/s）	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
0＜V＜ 1	0.47	0.49	0.44	0.48	0.45	0.46	0.47	0.42	0.50	0.45	0.47	0.53	0.42	0.41	0.43	0.41	0.45
1≦V＜ 2	0.29	0.29	0.27	0.30	0.27	0.28	0.31	0.28	0.28	0.24	0.32	0.25	0.25	0.23	0.25	0.26	0.27
2≦V＜ 3	0.19	0.19	0.18	0.19	0.18	0.19	0.19	0.20	0.19	0.15	0.18	0.19	0.19	0.18	0.18	0.18	0.19
3≦V＜ 4	0.15	0.16	0.14	0.16	0.17	0.15	0.15	0.15	0.17	0.15	0.18	0.18	0.17	0.13	0.16	0.15	0.16
4≦V＜ 5	0.18	0.18	0.16	0.17	0.16	0.14	0.13	0.14	0.18	0.17	0.16	0.17	0.18	0.14	0.18	0.16	0.16
5≦V＜ 6	0.21	0.20	0.19	0.17	0.15	0.12	0.12	0.13	0.17	0.18	0.22	0.21	0.20	0.18	0.19	0.20	0.15
6≦V＜ 7	0.20	0.20	0.19	0.16	0.14	0.11	0.12	0.12	0.15	0.19	0.21	0.21	0.22	0.17	0.19	0.20	0.14
7≦V＜ 8	0.20	0.20	0.19	0.15	0.14	0.11	0.11	0.12	0.15	0.19	0.23	0.32	0.19	0.19	0.19	0.20	0.13
8≦V＜ 9	0.21	0.20	0.18	0.16	0.13	0.10	0.11	0.11	0.15	0.19	0.17	0.23	0.19	0.19	0.19	0.20	0.12
9≦V＜10	0.21	0.20	0.19	0.15	0.13	0.10	0.10	0.11	0.14	0.20		0.21	0.22	0.15	0.18	0.19	0.12
10≦V＜11	0.18	0.19	0.20	0.15	0.13	0.10	0.10	0.11	0.14	0.19	0.21		0.28		0.20	0.20	0.11
11≦V＜12		0.19	0.18	0.15	0.13	0.10	0.10	0.10	0.14	0.51					0.17		0.11
12≦V＜13			0.19	0.14	0.13	0.09	0.10	0.11	0.15						0.18		0.10
13≦V＜14			0.19	0.14	0.13	0.09	0.09	0.09	0.15	0.15							0.10
14≦V＜15	0.21		0.19	0.14	0.12	0.10	0.09	0.11	0.14								0.11
15≦V＜16			0.17	0.14	0.12	0.11	0.09	0.10	0.13								0.12
16≦V＜17			0.18	0.14	0.08	0.09	0.11	0.08	0.10								0.11
17≦V＜18			0.17	0.15	0.12												0.15
18≦V＜19				0.16		0.11	0.09										0.12
19≦V＜20				0.15		0.08											0.13
20≦V＜21				0.15	0.13	0.10	0.12										0.13
21≦V＜22				0.15	0.13	0.08											0.13
22≦V＜23				0.14	0.13	0.11											0.12
23≦V＜24					0.12	0.12											0.12
24≦V＜25																	
Sum	0.20	0.19	0.17	0.17	0.15	0.12	0.12	0.14	0.18	0.18	0.22	0.21	0.20	0.17	0.19	0.18	0.15

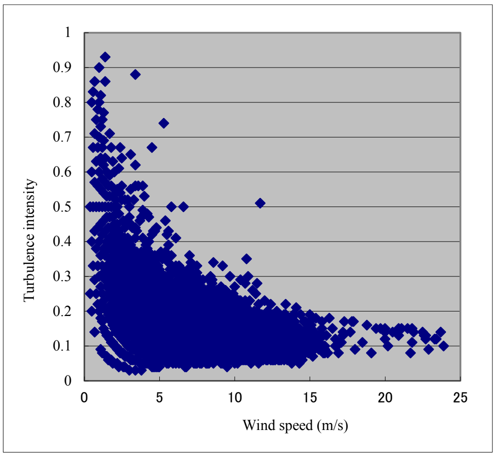


Figure 6-1 Correlation between turbulence intensity and 10 minutes average wind speed [in all wind directions, ground height: 40 m]

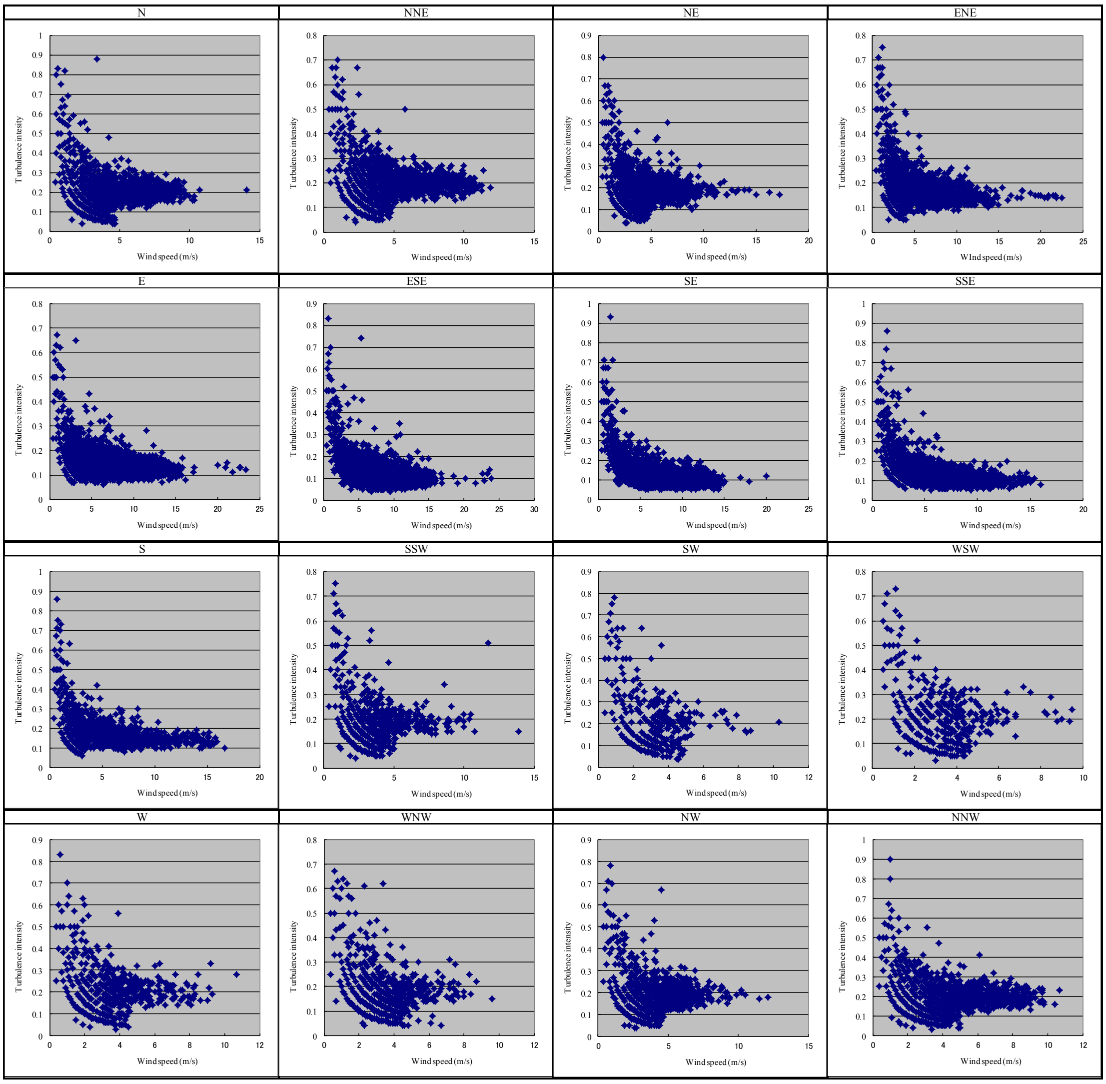


Figure 6-2 Correlation between turbulence intensity and 10 minutes average wind speed [each wind directions, ground height: 40 m]

7. Maximum instantaneous wind speed

Maximum instantaneous wind speed during the observation period is 32.9 m/s (1:00 am, January 25th, 2011).
In general, Survival wind speed for wind turbine of class 300kW is designed to 70 m/s, instantaneous wind speed exceeds survival wind speed is not observed in same period.

Table 7-1 Maximum wind speed and maximum instantaneous wind speed
[ground height : 40 m]

(unit: m/s)

Monty	2011							2010					Muximum value
	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Max. wind speed	23.9	13.2	14.1	11.3	17.1	21.9	15.5	14.6	15.6	15.1	13.4	13.9	23.9
Max. instantaneous wind speed	32.9	18.9	22.3	15.5	21.2	28.7	20.8	22.7	19.3	18.9	18.1	21.2	32.9

Maximum instantaneous wind speed: AM1:00 25th January

8. Wind speed distribution

On distribution ratio for each wind force, the distribution ratio of class not less than 4 m/s but less than 5 m/s is most commonly (14.2%), the distribution ratio of more than 6 m/s is occupied approximately 48% of the total.
Incidentally, the distribution ratio of more than 12 m/s and less than 25 m/s which is generated rated output of 250 kW is 3 % of the total.
It is noted that wind speed distribution can be approximated by the Weibull distribution. Also in this evaluation, the Weibull parameters which are scale parameter represented by “c” and shape parameter represented by “k” are calculated by the method of least squares.
The Weibull function is defined as following equation.
Consequently, wind speed distribution is shown in Table 8-1, the scale parameter of the Weibull function is c = 7.18, the shape parameter of the Weiblull function is k = 2.21.

$$f(V) = \frac{k}{c}\left(\frac{V}{c}\right)^{k-1} \cdot \exp\left\{-\left(\frac{V}{c}\right)^{k}\right\}$$

Where

$f(V)$: appearance ratio of wind speed of “V” (%)
c : the scale parameter of the Weibull function
k : the shape parameter of the Weibull function

Table 8-1 Monthly and annual wind speed distribution [ground height: 40 m]

(unit: %)

Wind speed (m/s)	2011							2010					In a year
	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
0<V< 1	0.7	0.6	3.6	2.1	1.5	0.4	4.8	0.7	0.7	1.5	0.3	0.9	1.5
1≦V< 2	3.8	1.6	3.2	2.4	6.0	1.7	7.9	1.5	1.7	2.7	2.5	4.2	3.3
2≦V< 3	8.7	4.0	7.3	4.7	8.9	7.4	10.5	5.9	4.6	5.9	3.5	6.6	6.5
3≦V< 4	17.9	15.3	17.6	21.8	14.5	14.0	12.9	20.8	8.9	7.7	6.1	6.2	13.6
4≦V< 5	12.1	18.8	24.2	18.1	11.0	18.2	13.4	15.5	11.5	15.2	6.4	7.1	14.3
5≦V< 6	11.4	19.0	14.2	15.0	10.1	17.2	9.9	10.9	17.2	13.0	10.4	7.8	13.0
6≦V< 7	10.9	13.8	9.0	16.4	9.8	12.9	8.1	8.2	12.1	9.5	15.3	9.7	11.3
7≦V< 8	12.6	11.9	7.9	9.9	9.0	7.2	7.3	7.7	12.5	5.6	13.3	16.5	10.1
8≦V< 9	10.8	7.7	4.2	6.7	10.8	4.7	9.0	6.2	6.0	4.7	15.1	14.1	8.3
9≦V<10	5.1	4.0	4.7	2.9	6.7	3.6	6.2	5.9	3.9	6.5	13.1	10.8	6.1
10≦V<11	1.9	1.6	2.4	0.1	6.3	1.8	5.1	6.2	7.9	8.7	8.8	9.8	5.1
11≦V<12	1.5	1.3	1.5		4.2	3.1	3.0	6.9	7.4	9.7	4.0	5.5	4.0
12≦V<13	0.4	0.1	0.1		0.8	1.5	0.8	3.2	4.4	5.4	1.3	0.8	1.6
13≦V<14	1.1				0.3	2.1	0.8	0.4	1.0	3.6			0.8
14≦V<15	0.4					2.8	0.3	0.1	0.3	0.3			0.3
15≦V<16	0.3				0.1	1.0							0.1
16≦V<17						0.1							
17≦V<18													
18≦V<19	0.1												
19≦V<20	0.1					0.1							
20≦V<21						0.1							
21≦V<22													
22≦V<23	0.3												
23≦V<24													
24≦V<25													
Sum	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 8-2 Monthly and annual Weibull parameter

(unit: %)

Parameter	2011							2010					In a year
	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
k	2.01	3.14	2.46	3.05	2.34	2.32	1.89	2.77	2.85	2.30	2.81	2.65	2.21
c	7.10	6.57	5.92	5.83	6.49	7.65	6.13	7.08	7.56	7.95	8.01	7.27	7.17

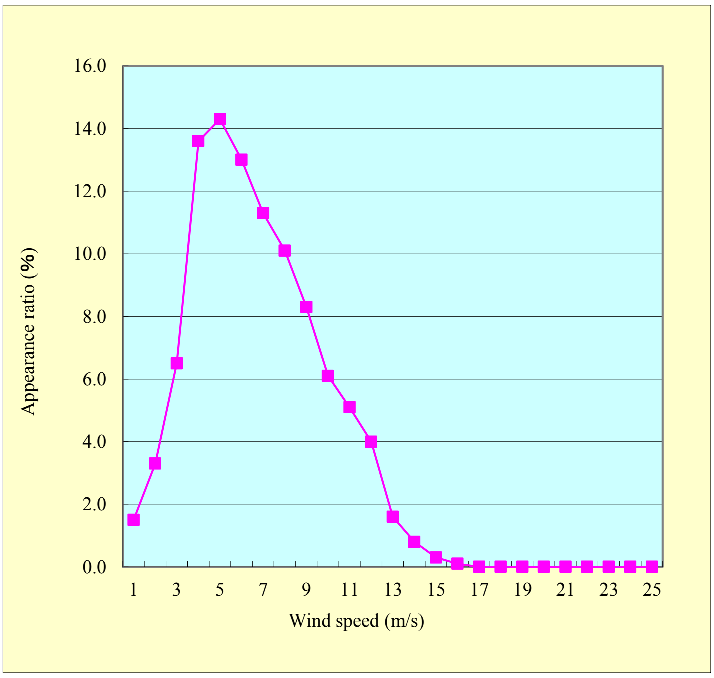


Figure 8-1 Annual wind speed distribution

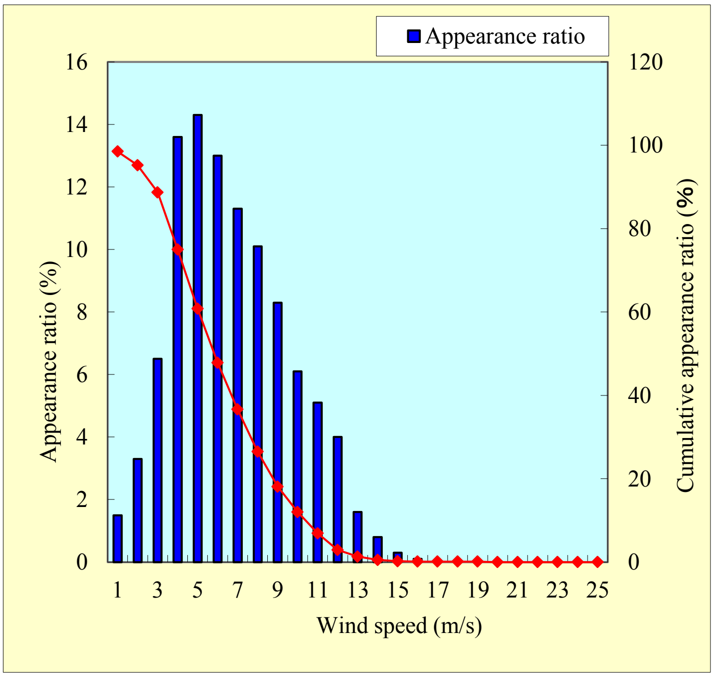


Figure 8-2 Annual cumulative wind speed distribution

9. Density of wind energy

Density of wind energy is calculated Annual average spot the of (air field) and by using standard atmospheric conditions (temperature: 15^{o}C, atmospheric pressure: 1013 hPa, vapor pressure: 17.05 hPa) and annual average of local atmospheric conditions (temperature: 24.2^{o}C, atmospheric pressure: 1012.7 hPa, vapor pressure: 29.8 hPa) in order to evaluate the amount of potential for wind development.
The density of wind energy is calculated by the following equation.

$$P_0 = \sum \left(0.5 \cdot \rho \cdot V^3\right) / n$$

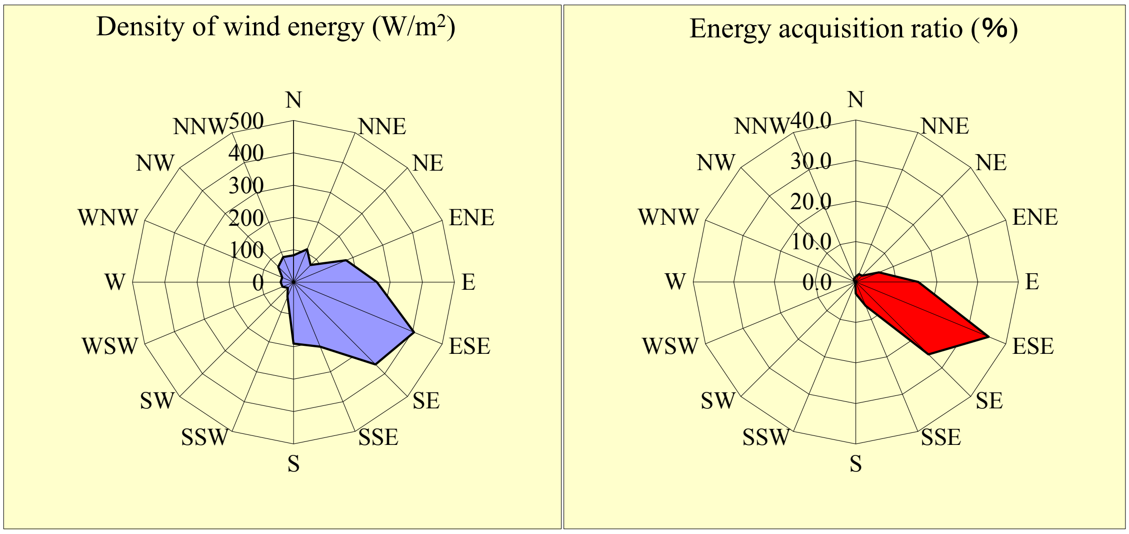
P_0 : annual density of wind energy (w/m^2)
ρ : air density (kg/m^3)
V : hourly average wind speed (m/s)
n : number of hours in the applicable period

The energy density with height of 40 m is 244 W/m^2 at the standard atmospheric conditions and 236 W/m^2 at local atmospheric conditions which is approximately 3% less than the value at standard atmospheric conditions.
By direction, the energy density of east-northeast is the largest (390 W/m^2: standard atmospheric conditions, 405 W/m^2: local atmospheric conditions), and east is second largest (360 W m^2: standard atmospheric conditions, 347 W/m^2: local atmospheric conditions).
As well as the energy density, the energy acquisition ratio of east-southeast is the largest (35.4%), and southeast is second largest (25.3%).
In addition, energy acquisition ratio in just three directions (northeast to east) is occupied approximately 76% of the total. (with regard to energy acquisition ratio, there is no significant distinction between the ratio under standard atmospheric conditions and local atmospheric conditions)

Table 9-1 Density of wind energy and energy acquisition ratio

Wind direction	Density of wind energy (W/m^2)		Energy acquisition ratio (%)	
	SAC	LAC	SAC	LAC
N	83	80	1.3	1.3
NNE	110	106	2.1	2.1
NE	75	73	2.2	2.2
ENE	177	171	6.2	6.2
E	259	250	15.4	15.4
ESE	405	390	35.4	35.4
SE	360	347	25.3	25.3
SSE	216	208	6.4	6.4
S	190	183	2.9	2.9
SSW	49	48	0.3	0.3
SW	25	24	0.1	0.1
WSW	37	35	0.1	0.1
W	40	39	0.2	0.2
WNW	38	37	0.3	0.3
NW	67	65	0.7	0.7
NNW	84	81	1.0	1.0
All directions	244	235	100.0	100.0

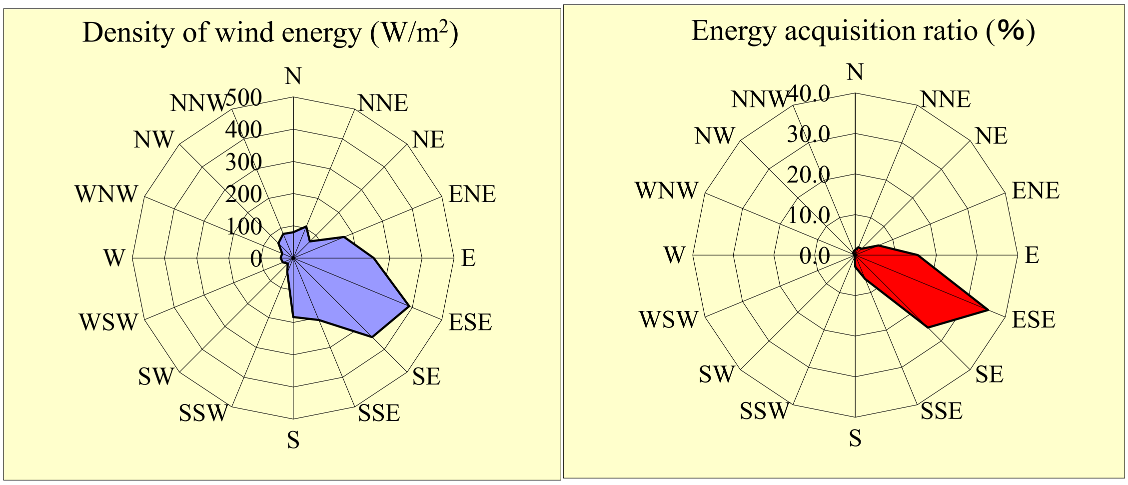
SAC: Standard atmospheric conditions
LAC: Local atmospheric conditions



Density of wind energy (W/m²)

Energy acquisition ratio (%)

Figure 9-1 Density of wind energy and energy acquisition ratio
(standard atmospheric conditions)



Density of wind energy (W/m²)

Energy acquisition ratio (%)

Figure 9-2 Density of wind energy and energy acquisition ratio
(local atmospheric conditions)

10. Availability (generation available time ratio)

The availability of the wind turbine is calculated by using the data of wind condition with height of 40 m. As a result of the calculation is shown in Table 10-1 and Figure 10-1.
The availability of the wind turbine is 88.7% in the year.
Looking at monthly availability, the highest is 93.8% in February, meanwhile the lowest is 76.7% in July.

The term "Availability" here, means the ratio of the amount of time that the operable wind speed is obtained to all calendar time during the same period.

Table 10-1 Generation available time ratio

(unit: %)

year/month	Wind turbine 250 kW
Jan. 2011	86.8
Feb. 2011	93.8
Mar. 2011	85.9
Apr. 2011	90.8
May. 2011	83.6
Jun. 2011	90.6
Jul. 2011	76.7
Aug. 2010	91.9
Sep. 2010	93.1
Oct. 2010	89.9
Nov. 2010	93.8
Dec. 2010	88.3
In a year	88.7

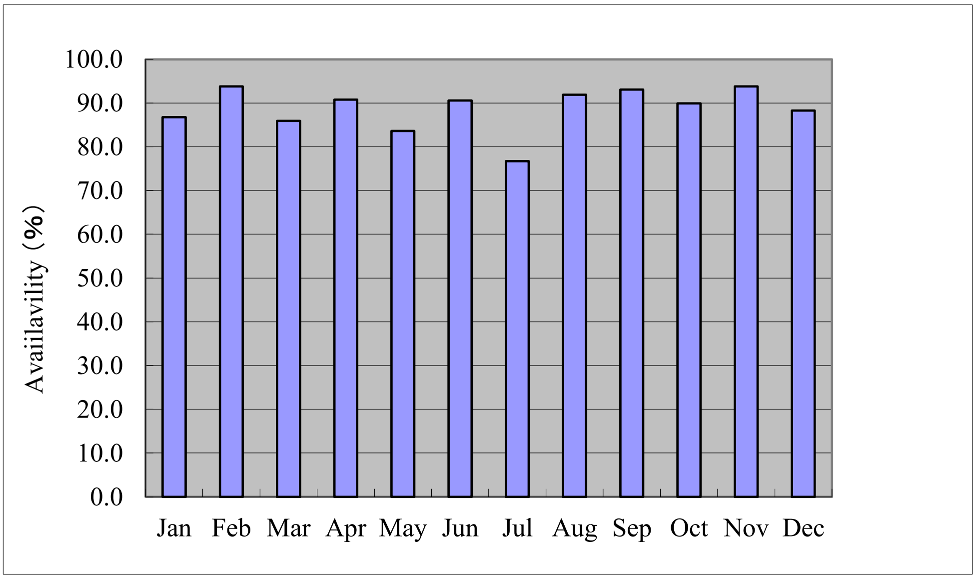


Figure 10-1 Generation available time ratio

11. Wind energy production and capacity factor

11.1. Wind energy production

The wind energy production is calculated by accumulating the hourly value corresponding to the performance curve a wind turbine of 250 kW based on hourly average wind speed with height of 40 m.

The performance curve of 300 kW class wind turbine to calculate wind energy production is used to limit to 250 kW rated output.

As a result, the wind energy production per year is estimated to 565 MWh. The largest monthly wind energy production is approximately 69 MWh in October, and the lowest is approximately 24 MWh in April.

In addition, since wind energy density at local atmospheric conditions is approximately 3% less than the wind energy density at standard atmospheric conditions, the wind energy production is assumed to decline by approximately 3% compared with the results calculated by the standard atmospheric conditions.

Table 11-1 Monthly production of wind energy

風車№	Item	2010					2011							Sum
		Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	
トンガ	Energy production (kWh)	51,165	59,148	68,864	65,160	66,916	40,248	29,648	27,435	24,022	47,995	42,576	41,658	564,835
	Mean wind speed (m/s)	6.2	6.9	7.1	7.2	7.0	5.8	5.7	5.1	5.2	6.0	6.2	5.5	6.2
	Genenration available time ratio（%）	91.9	93.1	89.9	93.8	88.3	86.8	93.8	85.9	90.8	83.6	90.6	76.7	88.7
	Capacity factor （%）	27.5	32.9	37.0	36.2	36.0	21.6	17.6	14.8	13.3	25.8	23.7	22.4	25.8

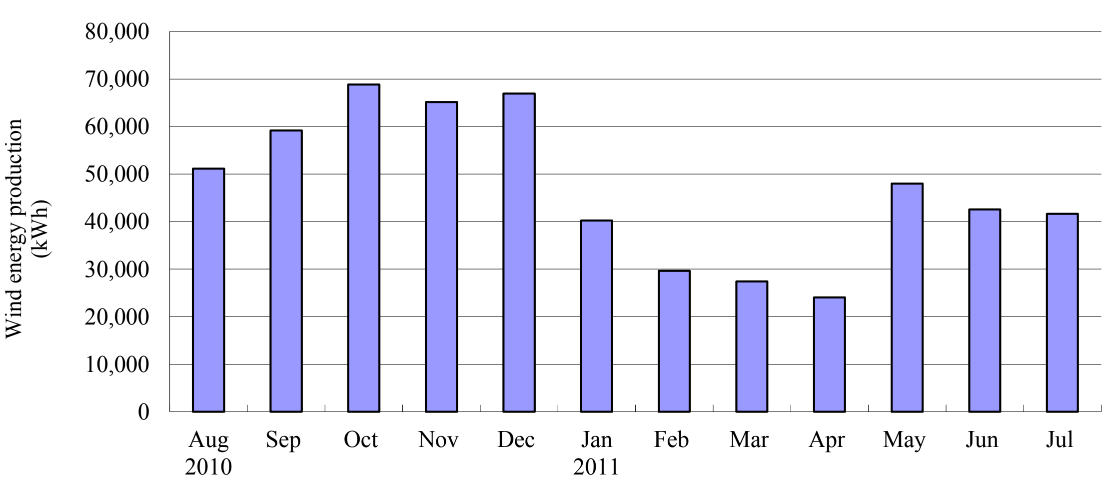


Figure 11-1 Monthly production of wind energy

Table 11-2 Wind energy production by wind direction

Item	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
Energy production (kWh)	7,096	11,866	10,161	32,547	85,456	204,471	147,584	37,892	15,193	1,263	215	484	906	989	3,274	5,437	564,835

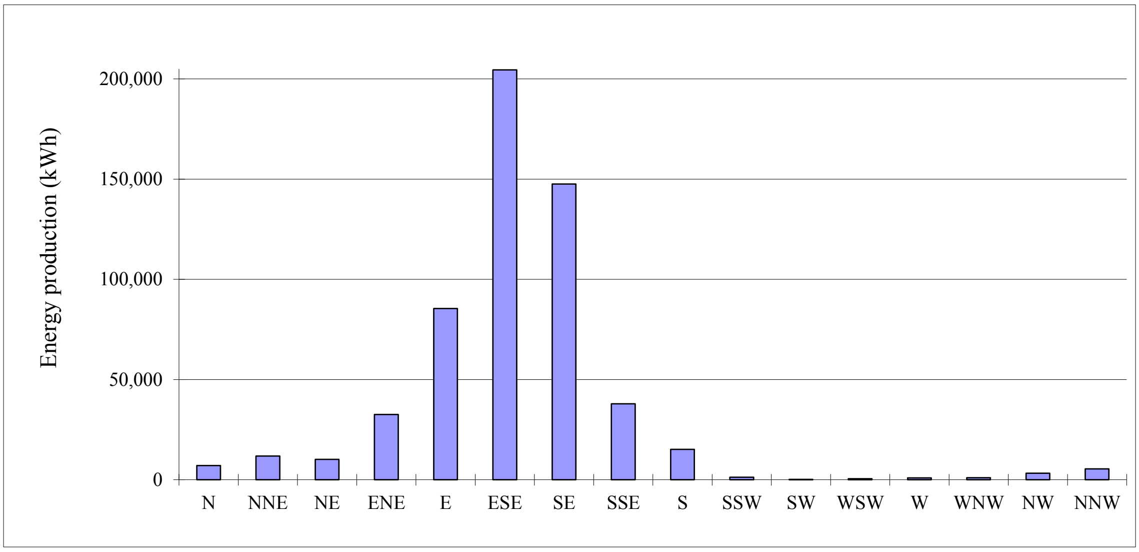


Figure 11-2 Wind energy production by wind direction

Wind speed （m/s）	Output (kW)
	250 kW
0.0	-
1.0	-
2.0	-
3.0	0.0
4.0	1.8
5.0	11.2
6.0	35.0
7.0	66.7
8.0	103.9
9.0	143.9
10.0	184.0
11.0	221.7
12.0	250.0
13.0	250.0
14.0	250.0
15.0	250.0
16.0	250.0
17.0	250.0
18.0	250.0
19.0	250.0
20.0	250.0
21.0	250.0
22.0	250.0
23.0	250.0
24.0	250.0
25.0	250.0
Cut-in wind speed （m/s）	3.0
Rated wind speed（m/s）	11.5
Cut-out wind speed （m/s）	25.0

Note: Standard power curve at air density of 1.225kg/m^2

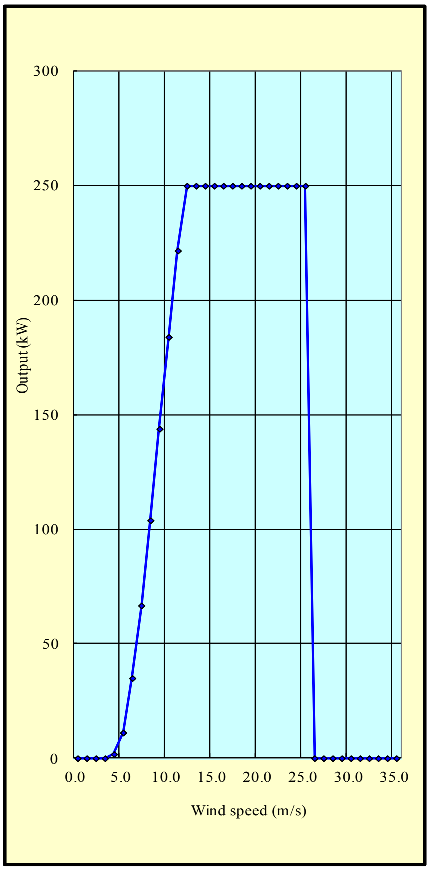


Figure 11-3 Performance curve of a 250 kW wind turbine

11.2. Capacity factor

The capacity factor is calculated based on the wind energy production at standard atmospheric conditions is shown in Table 11-3 and Figure 11-4. The annual capacity factor is 25.8%, the highest monthly capacity factor is 37.0% in October and the lowest is 13.3% in April.

In addition, when local atmospheric conditions is considered, the capacity factor is assumed to decline by about 3% compared with the results calculated by the standard atmospheric conditions.

Table 11-3 Monthly utilization of wind turbine equipment

(unit: %)

year/month	wind turbine 250 kW
Jan. 2011	21.6
Feb. 2011	17.6
Mar. 2011	14.8
Apr. 2011	13.3
May. 2011	25.8
Jun. 2011	23.7
Jul. 2011	22.4
Aug. 2010	27.5
Sep. 2010	32.9
Oct. 2010	37.0
Nov. 2010	36.2
Dec. 2010	36.0
In a year	25.8

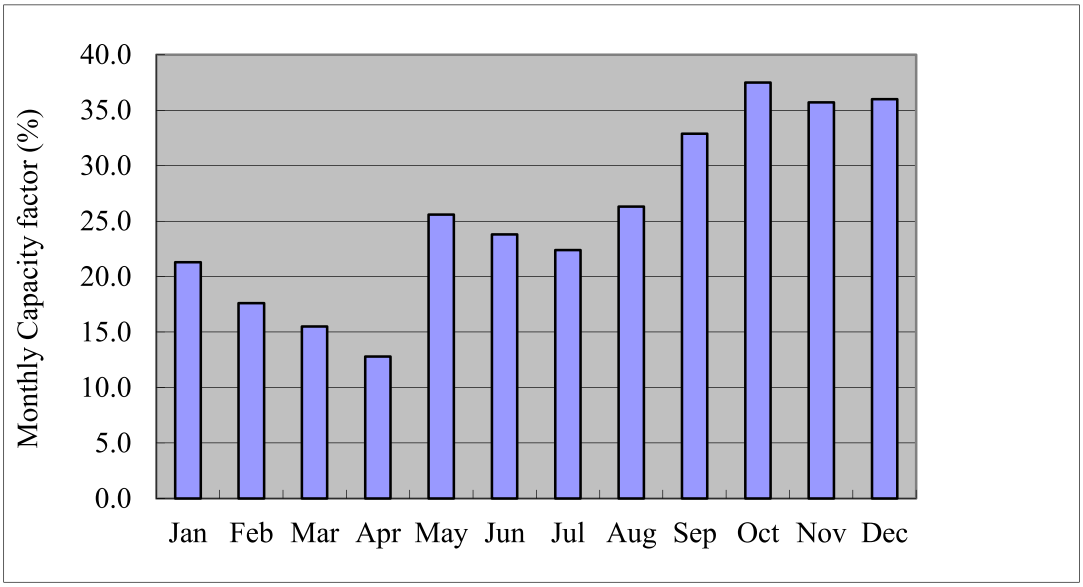


Figure 11-4 Monthly capacity factor

12. Conclusion

12.1. Wind conditions

- Annual average wind speed (40m height above ground) is calculated to be 6.2m/s.
Monthly average wind speed has tendency to be the highest (7.2 m/s) in October to November and to be somewhat lower (5.1 to 5.5 m/s) in March to April and July.

- With regard to wind distribution, three wind directions which are east (14.5%), east-southeast (21.3%) and southeast (17.2%) are dominant.
Therefore, the wind axis is considered to be a line from east-southeast to west-northwest (58.6%).

- The power index ("n" value) in all directions is n=3.5 equivalent of urban area.
And the power index in prevailing wind direction (east-southeast) is n=45 to 5.0 equivalent of rural area.

- Turbulence intensity is 0.15 in omni-directional average, which is equivalent to the type of the plain field. In addition, the turbulence intensity at around wind speed of 15 m/s is 0.11, which fully satisfy the evaluation criteria of 0.18 or less.

- Maximum instantaneous wind speed during the observation period is 32.9 m/s (1:00 am January 25th, 2011).
In general, Survival wind speed for wind turbine of class 300kW is designed to 70 m/s, there is little possibility of appearance over survival wind speed in the region.

- With regard to distribution ratio for each wind force, the distribution ratio of class more than 4 m/s and less than 5 m/s is most commonly (14.2%).
Incidentally, the distribution ratio of more than 12 m/s and less than 25 m/s which can be generated rated output of 250 kW is 3 % of the total.

- The scale parameter of the Weibull function is c = 7.18, and the shape parameter of the Weiblull function is k = 2.21.

12.2. Wind energy

The energy density with height of 40 m is 244 W/m² at the standard atmospheric conditions and 235 W/m² at local atmospheric conditions which is approximately 3% less than the value at standard atmospheric conditions.
Energy density required for the development of wind power is equal to or greater than 240 W/m² (30 m height above ground), the above results slightly below the criteria.
However, in these days the criterion of mean wind speed for wind power in Japan is more than 6 m/s at hub height of wind turbine.
Because the annual average wind speed is 6.2 m/s at 40m height above ground, the value can be expected towards the development of wind power.

12.3. Capacity factor and generation available time ratio

The capacity factor of the wind turbine is 25.7% and the availability is 88.7%.
Those values are fully satisfied the criteria (capacity factor should be 20% or more, availability should be 45% or more).

12.4. Comprehensive evaluation

According to the analysis of wind conditions, wind speed condition such as mean wind speed and density of wind energy generally meet the criteria. Furthermore, capacity factor of the wind turbine and availability are also fully satisfied the criteria, it is deemed to be feasible to develop wind power generation at the site.
The results of the analysis of the wind profile, since the “n” value indicate urban area, examination of wind turbine layout should be consider the effects of ground roughness (such as felling of trees around)
In the case of the arrangement of the wind turbine plurality, it is necessary to be separated by 3D (D: rotor diameter) or more in the direction perpendicular to the wind axis (east-northeast)
The results of the analysis of wind conditions are shown in Table 12-1.

The amount of wind energy production by the assumed components of wind turbine is estimated as follows.

Components	Amount of wind energy production	Conditions
Installed capacity:500kW（250kW x 2 units）	1,130 MWh/year	Standard atmospheric conditions
	1,096 MWh/year (approx. 1.1 GWh/year)	Local atmospheric conditions

The wind energy production noted above is gross output.
To assume net output, it is necessary to consider the loss as shown below. The total loss is roughly estimated to be about 20% of the gross output.
Therefore, net output is able to be estimated at 80% of gross output.

Type of loss	Contents
Outage	Scheduled maintenance
Mechanical loss	Loss on speed-up gear, loss on lag of wind direction following, etc.
Electrical loss	Transformer loss, Transmission loss to the point of interconnection, etc.

Table 12-1 Analysis result for wind condition

Analysis item		Result of analysis	Judgment	Remarks
Mean wind speed	Annual average	6.2 m/s	Good (Criteria #1）	
	Maximum	7.2 m/s		November
	Minimum	5.1 m/s		March
Wind direction	Prevailing wind direction	ESE 21.3%		
	Wind axis	ESE - WNW (E-W) (SE-NW) 58.6%	Basically good (Criteria #2）	Wind axis means 6 wind directions (the prevailing wind direction and the both sides, and their opposing wind directions
Correlation between wind direction and wind speed		Roughly fit		
Maximum instantaneous wind speed		32.9 m/s	Good (Criteria #3）	25th January 2011 AM 1:00
Turbulence intensity	360-degree	0.15	Good （Criteria #4）	
	In wind speed of 15m/s	0.11		
Wind profile （power index: n)		3.5	Poor （Criteria #5）	5.2 (at prevailing wind direction): Basically good
Weibull function	Shape parameter (k)	7.17		
	Scale parameter (C)	2.21		
Density of wind energy (in all directions)		244 W/m^2 (235 W/m^2)	Basically good (Criteria #6）	The value as calculated under local atmospheric conditions is shown in parentheses
Availability (Generation available time ratio)		88.7%	Good (Criteria #7）	
Annual energy production		565 MWh		In case of 250 kW wind turbine
Capacity factor		25.8%	Good (Criteria #8)	

Criteria #1: Annual average should be 6m/s or more

Criteria #2: Annual frequency distribution of wind direction on wind axis should be 60% or more

Criteria #3: Maximum instantaneous wind speed should be 70 m/s (typical survival wind speed) or less

Criteria #4: Turbulence intensity should be 1.8 (in around wind speed of 15 m/s) or less

Criteria #5: high power index of wind profile, and low wind shear

Criteria #6: Density of wind energy should be 240 W/m^2 or more

Criteria #7: Annual availability (generation available time ratio) should be 45% or more

Criteria #8: Capacity factor should be 20% or more

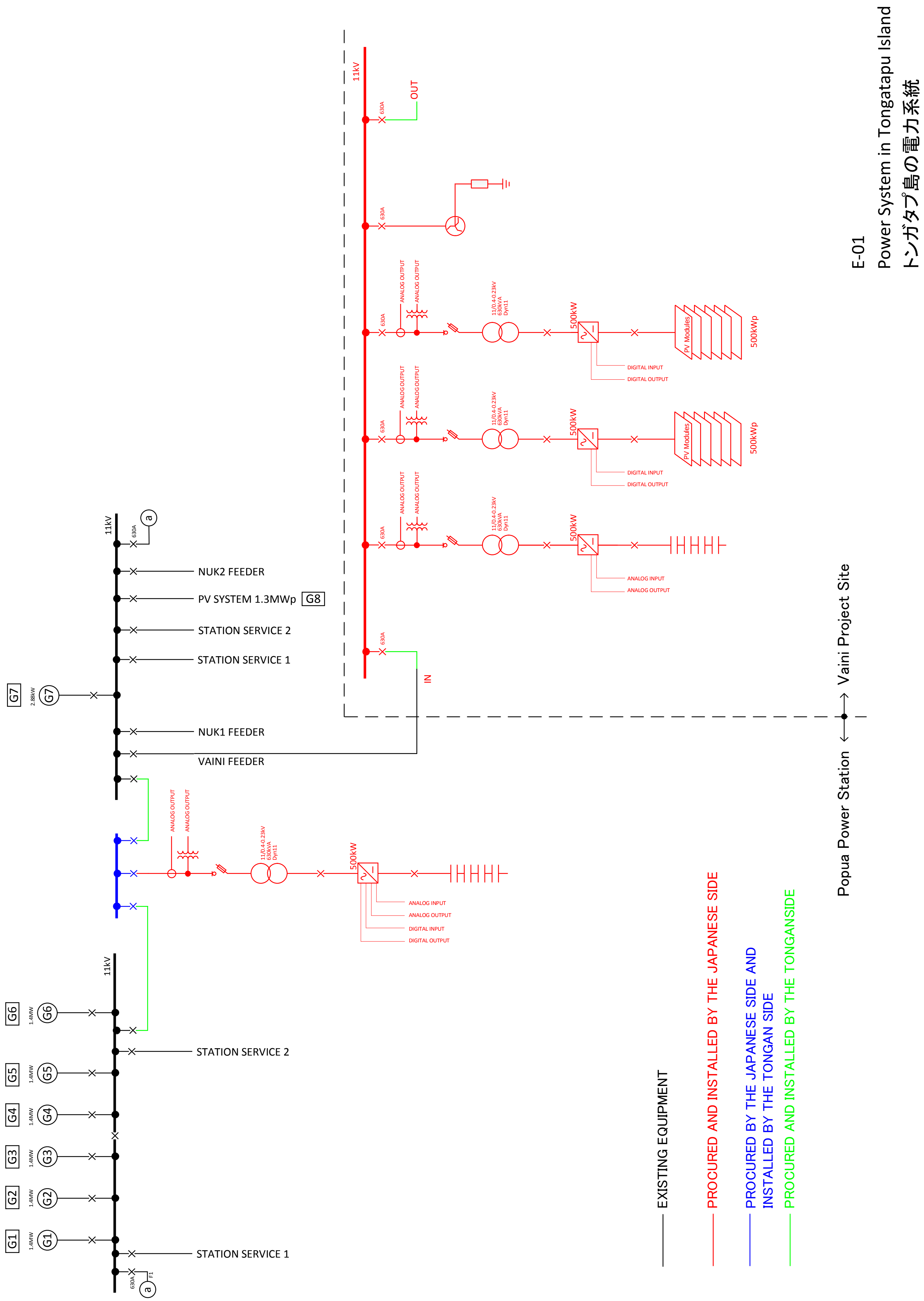
Note) The above criteria are given by the following manuals and guidelines which has been established by NEDO (New Energy and Industrial Technology Development Organization, an independent government agency in Japan).

- Evaluation manual for wind conditions (Dec. 1997, digest version)
- Evaluation manual for high-altitude wind conditions (Feb. 2006)
- Introduction guidebook for wind power generation (Feb. 2008 the revised ninth version)

A-10 Outline Design Drawings

Drawing List
図面リスト

Dwg. No.	Title
E-01	Power System in Tongatapu Island トンガタプ島の電力系統
E-02	Control System of Generation Facilities 発電設備システムの制御システム
E-03	Single Line Diagram of the Equipment at Vaini Project Site バイニ計画地側の対象設備の単線結線図
E-04	Single Line Diagram of the Equipment at Popua Power Station ポプア発電所側の対象設備の単線結線図
E-05	Layout of the Equipment at Vaini Project Site バイニ計画地側の対象設備の機材配置
E-06	Layout of the Equipment at Popua Power Station ポプア発電所側の対象設備の機材配置
E-07	Layout of PV Arrays at Vaini Project Site バイニ計画地におけるPVアレイ配置
E-08	Control System of Number of CAT Diesel Engine Generators in Operation CAT製ディーゼル発電機の運転台数制御システム



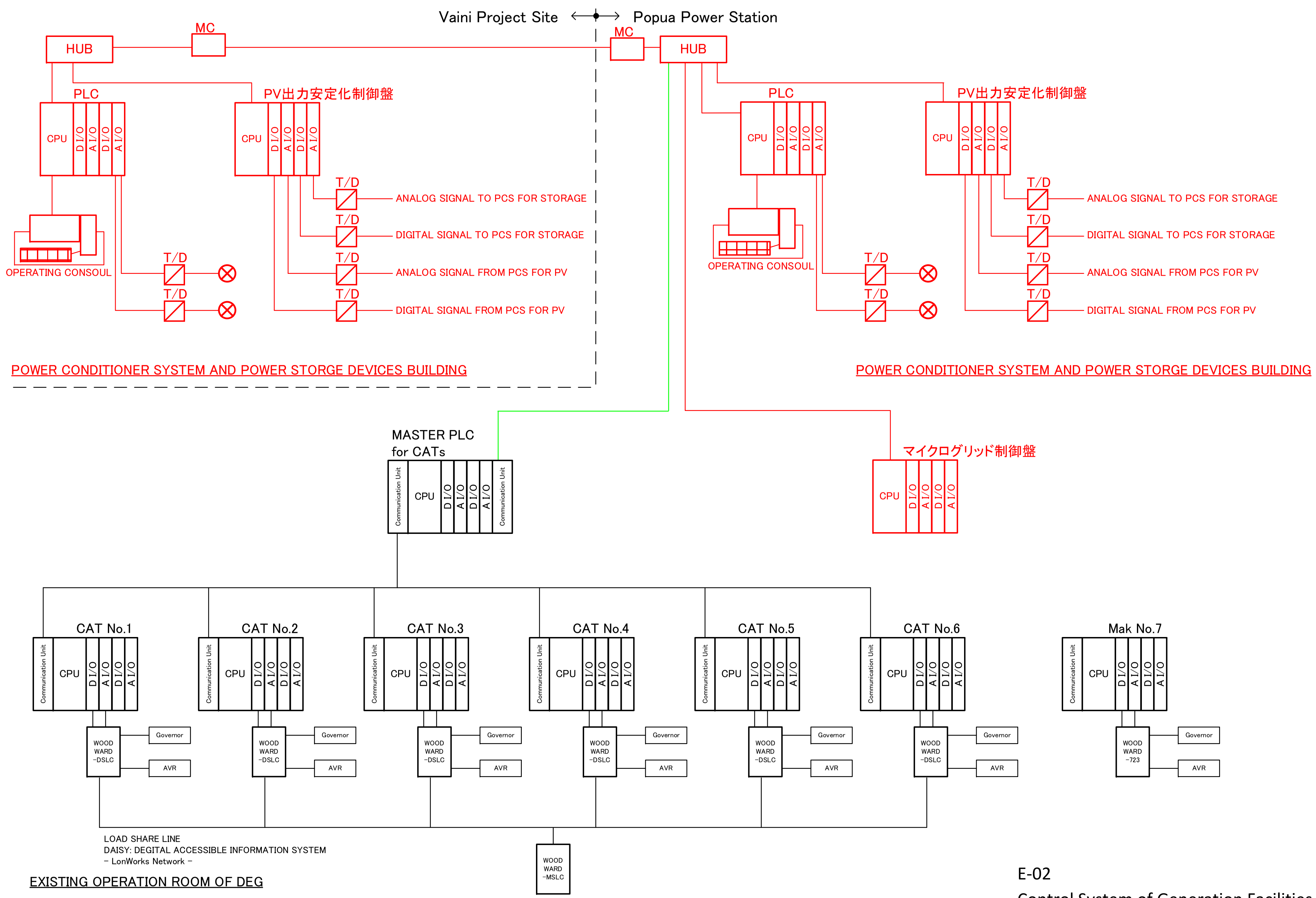
E-01
Power System in Tongatapu Island
トンガタプ島の電力系統

— EXISTING EQUIPMENT

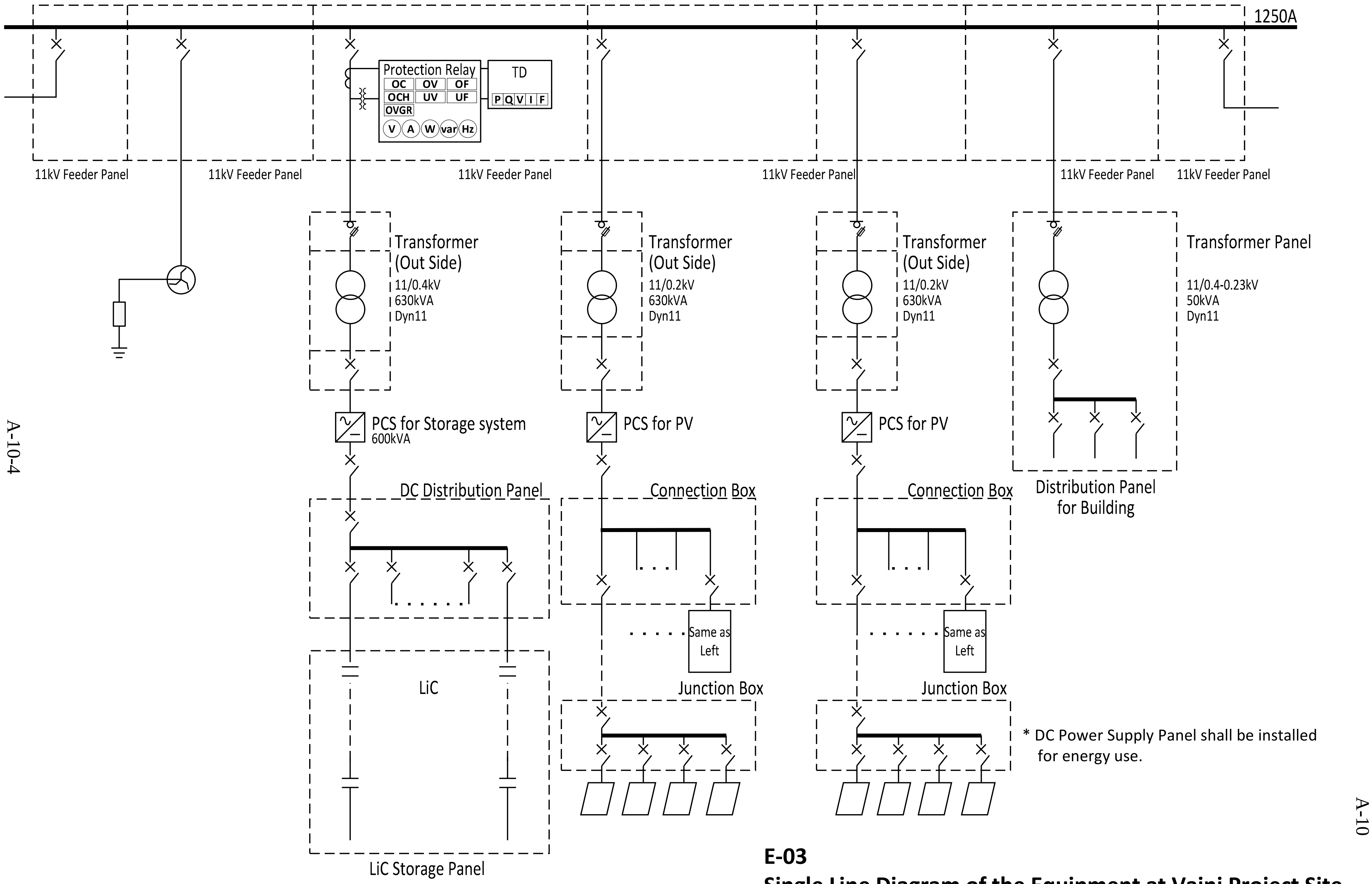
— PROCURED AND INSTALLED BY THE JAPANESE SIDE

— PROCURED BY THE JAPANESE SIDE AND INSTALLED BY THE TONGAN SIDE

— PROCURED AND INSTALLED BY THE TONGANSIDE

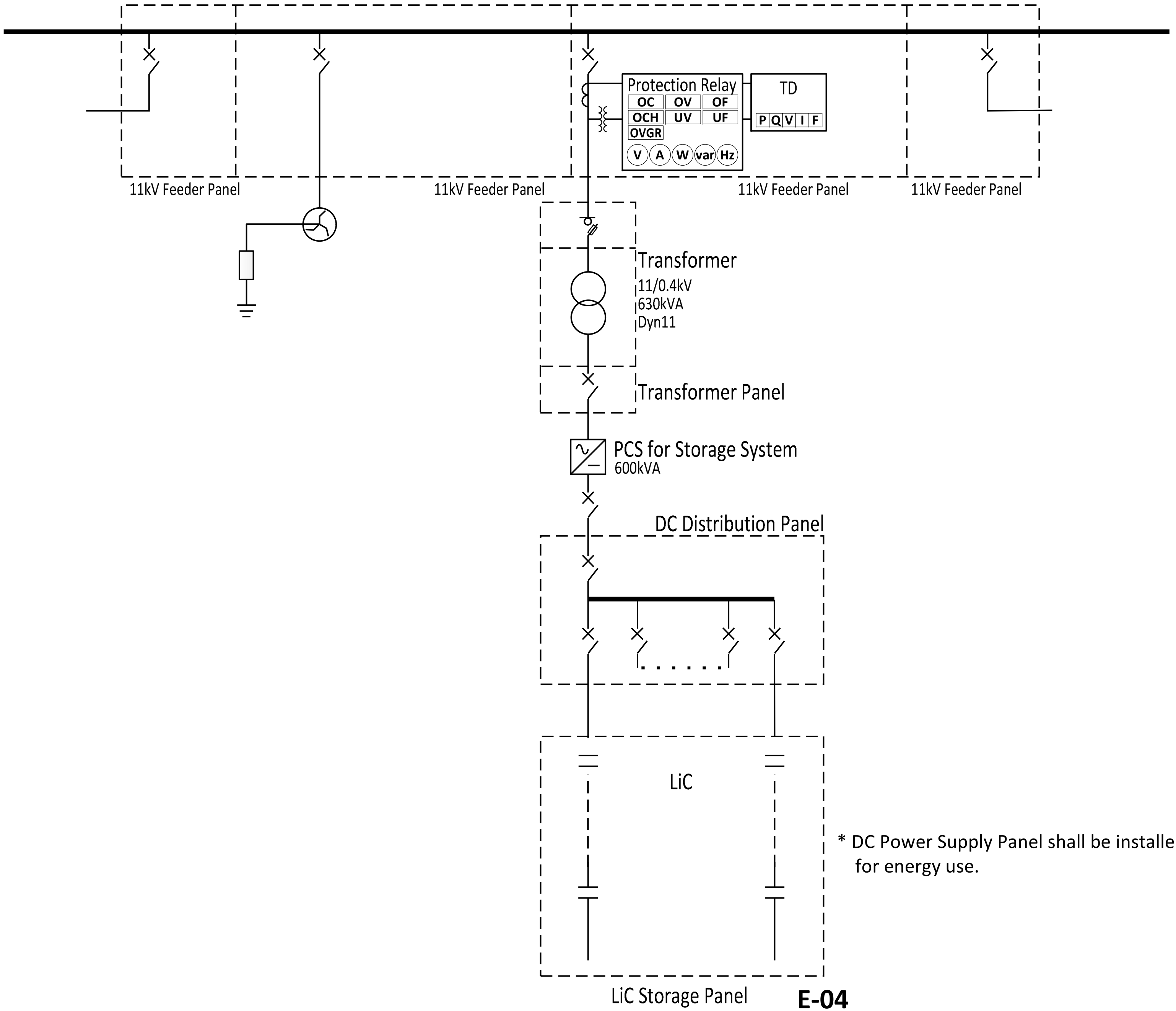


E-02
Control System of Generation Facilities
発電設備システムの制御システム



* DC Power Supply Panel shall be installed
for energy use.

E-03
Single Line Diagram of the Equipment at Vaini Project Site
バイニ計画地側の対象設備の単線結線図

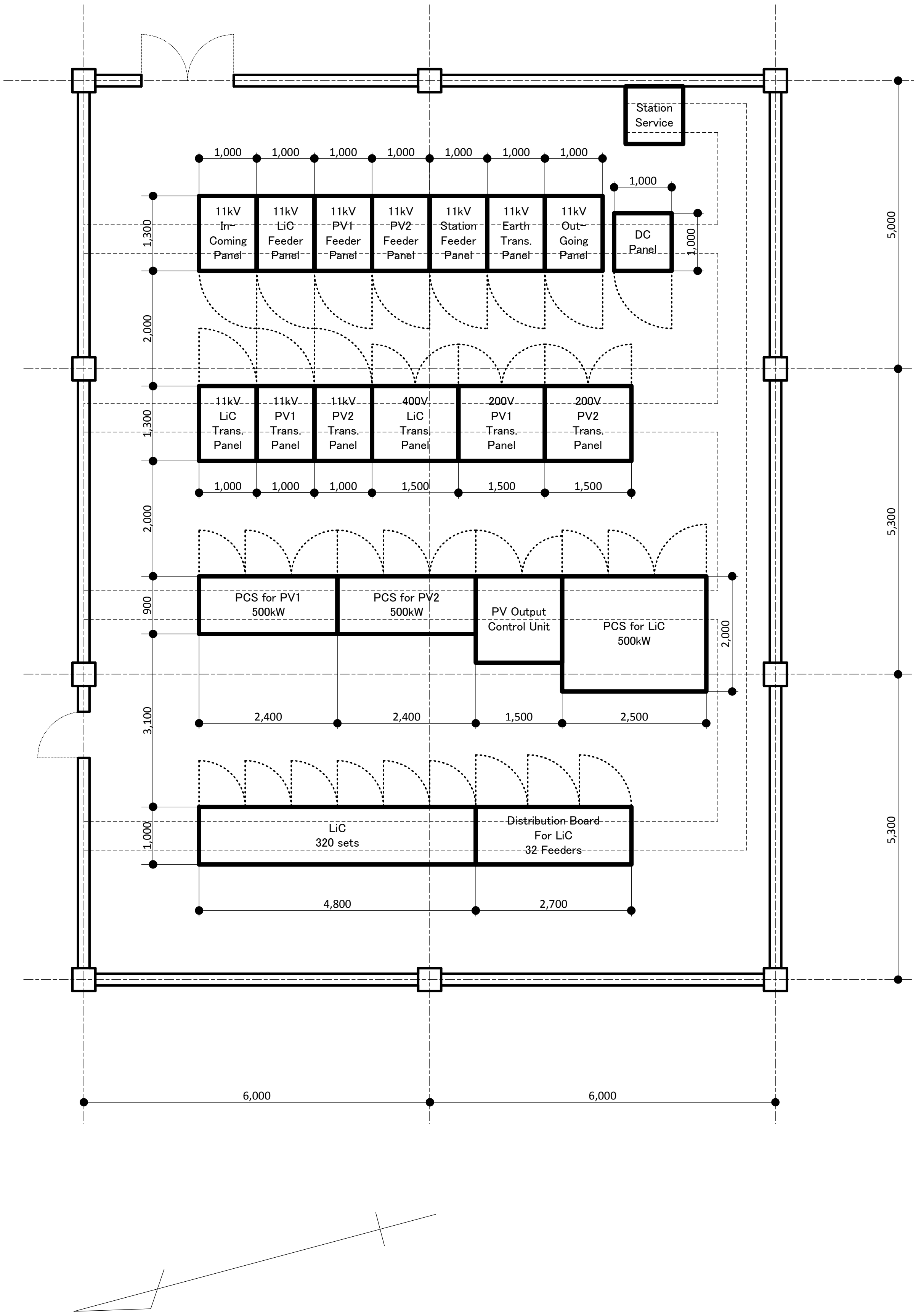


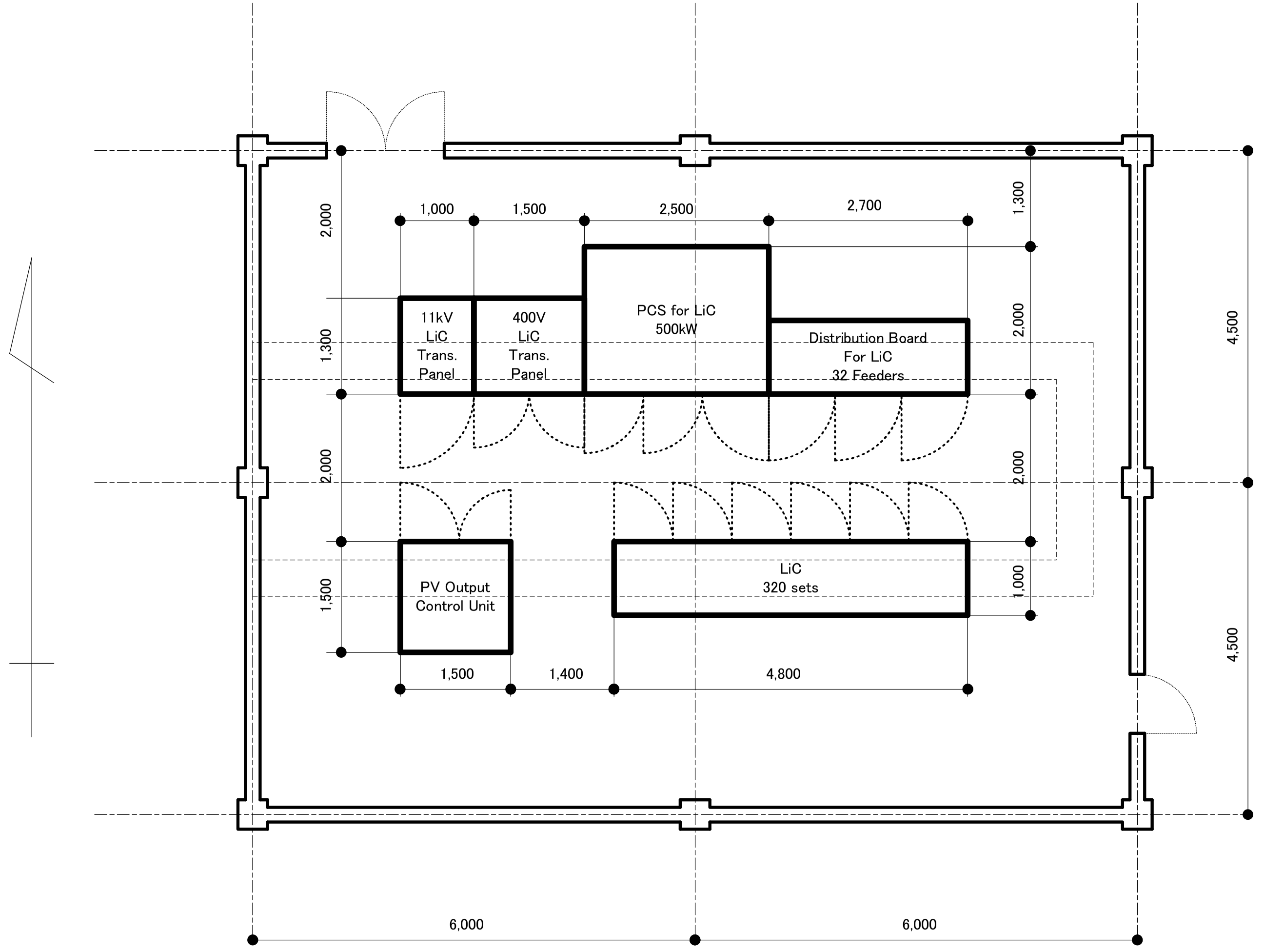
* DC Power Supply Panel shall be installed
for energy use.

E-04

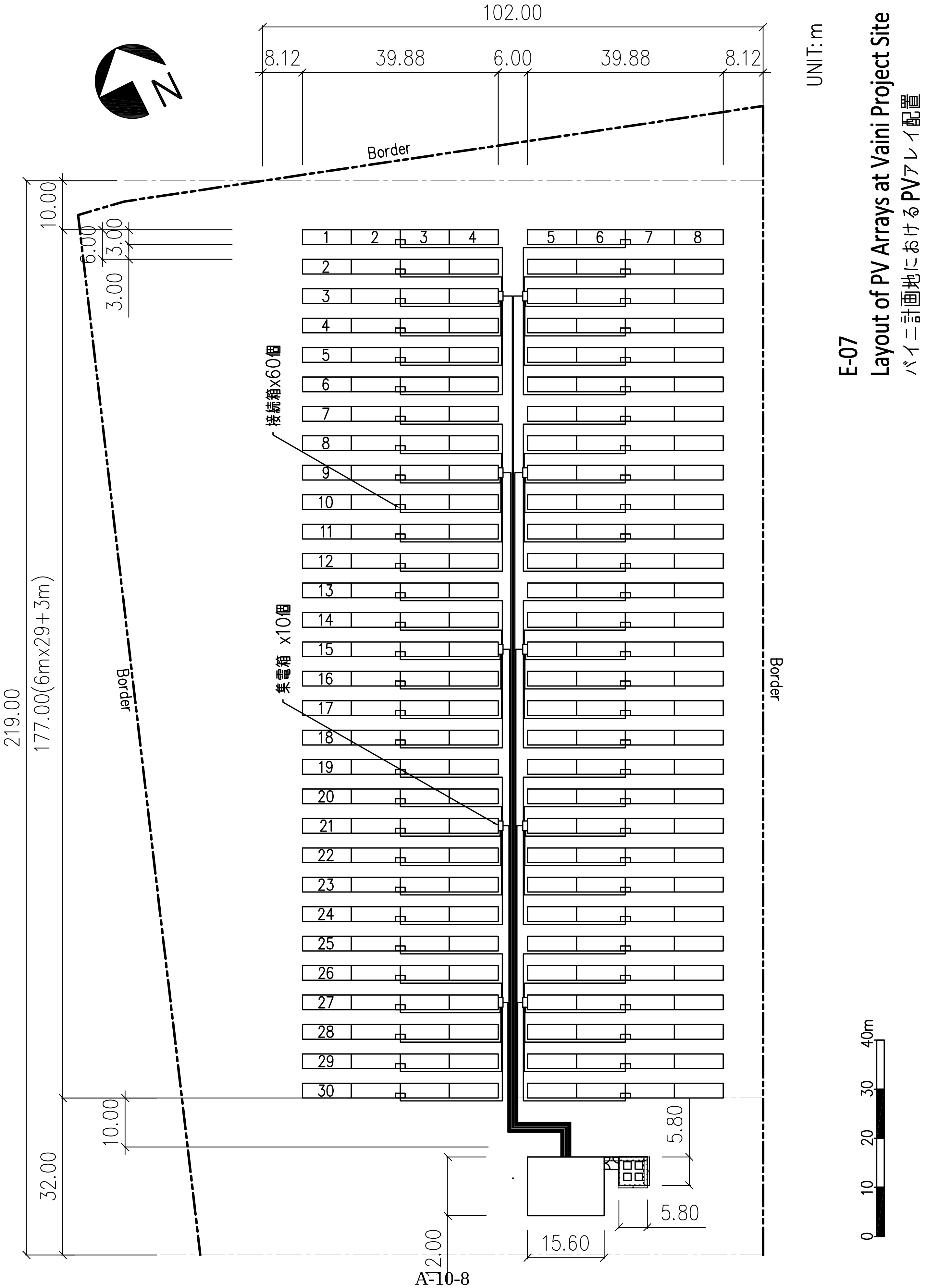
Single Line Diagram of the Equipment at Popua Power Station
ポプア発電所側の対象設備の単線結線図

E-05
Layout of the Equipment at Vaini Project Site
バイニ計画地側の対象設備の機材配置





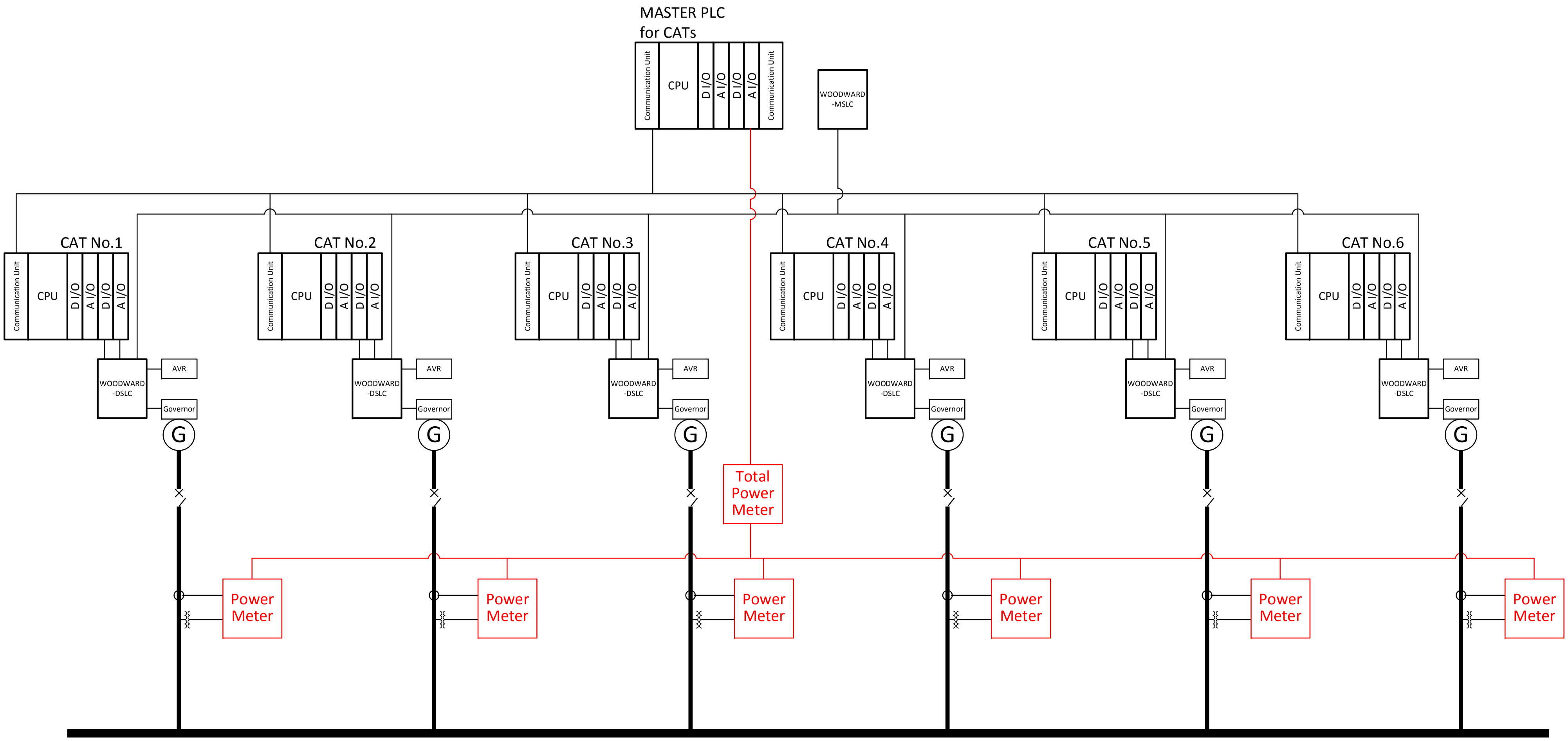
E-06
Layout of the Equipment at Popua Power Station
ポプア発電所側の対象設備の機材配置



E-07

Layout of PV Arrays at Vaini Project Site

バイニ計画地における**PV**アレイ配置



E-08

Control System of Number of CAT Diesel Engine Generators in Operation

CAT製ディーゼル発電機の運転台数制御システム