A-８　土質・測量調査報告書

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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Yachiyo Engineering Co Ltd/ West Japan Engineering Consultants, Inc. JV	3 copies
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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]).

[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.

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/m³

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:

Conor Morrison

Engineering Geologist

Authorised for Tonkin & Taylor International Ltd by:

Chris Freer

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.

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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

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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	For and On Behalf of The Contractor
Mitsuhisa Nishikawa Chief Consultant JICA Preparation Survey Team	**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

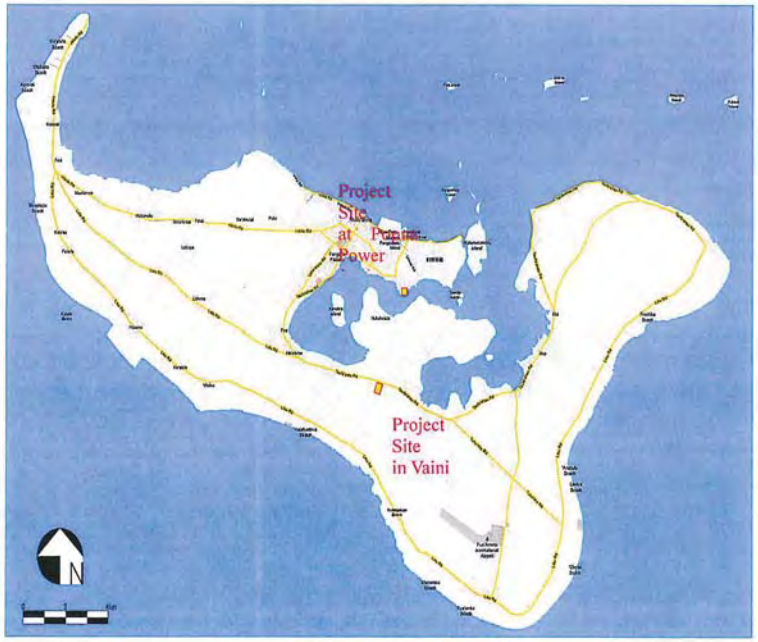
(2) Soil laboratory test results

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

(3) Language

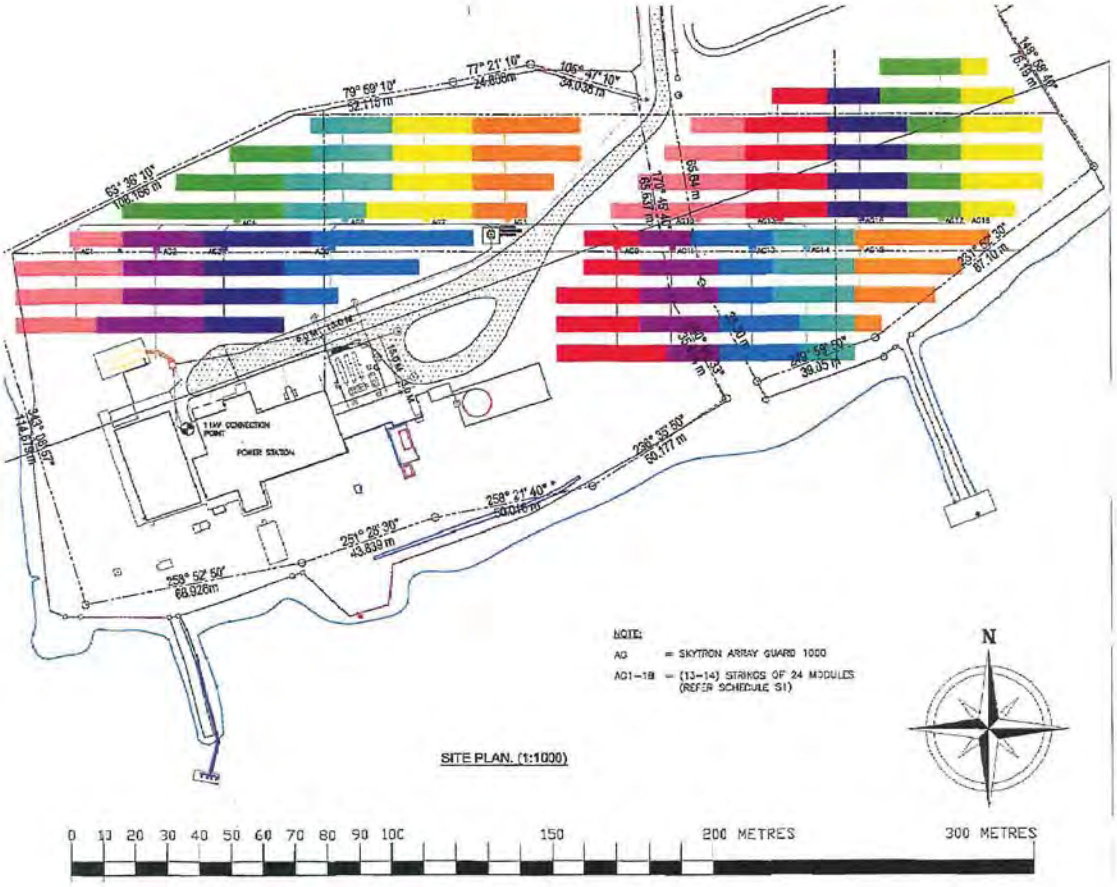
Document and all data shall be written in English.

ATTACHMENT-1
SITE MAP



ATTACHMENT-3
Project Site at Popua Power Station

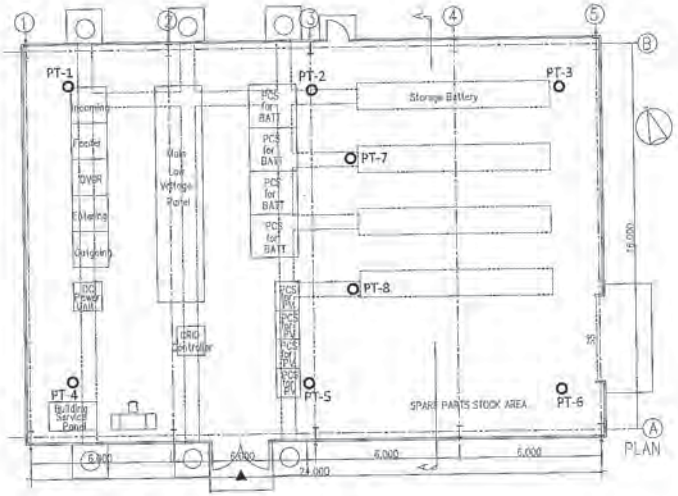
SITE PLAN



ATTACHMENT-2
Project Site in Vaini

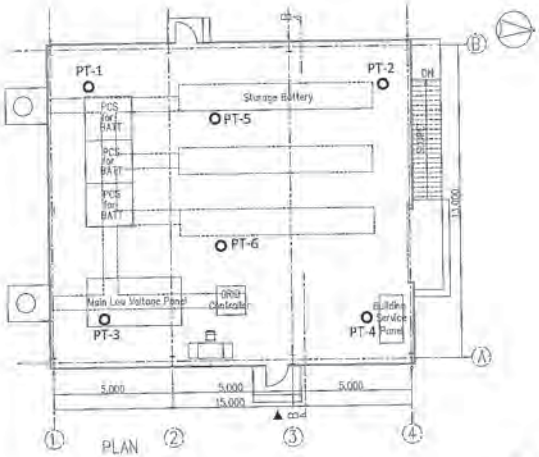
CANDIDATE PHOTOVOLTAIC SITE

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

O PT-X: LOCATION OF PENETROMETER TEST

Appendix B: **Topographical Survey and Geotechnical Investigation Location Plans**

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

TS COMPANY LTD. CIVIL, STRUCTURAL AND WATER ENGINEERING CONSULTANTS

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

TS COMPANY LTD. CIVIL, STRUCTURAL AND WATER ENGINEERING CONSULTANTS

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

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

HORIZONTAL SCALE = 1:1000

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REVISION / ISSUE

TS COMPANY LTD.
CIVIL, STRUCTURAL AND WATER ENGINEERING CONSULTANTS
UNIT 1-15 TONGILAVA PLAZA, TAUFA'AHAU ROAD, FANGA
P.O. BOX 194 NUKU'ALOFA. Ph/Fax (676) 28807, 28412. Mob (676) 43478

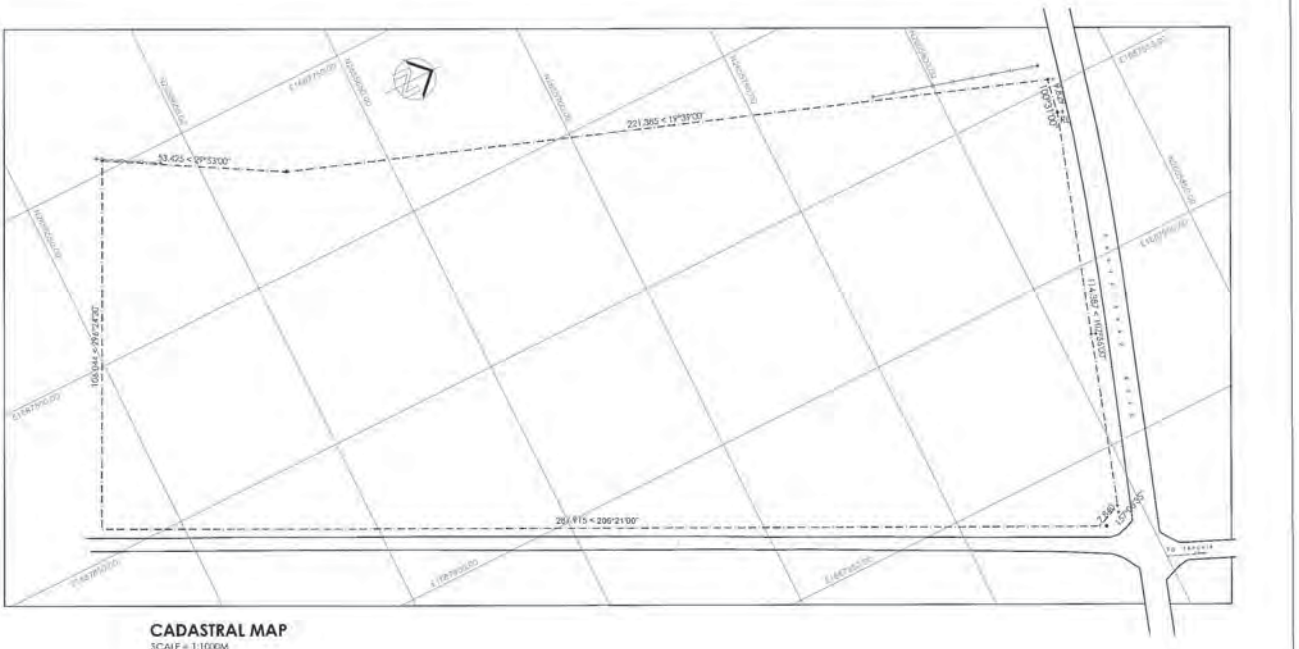
SURVEYED BY: F.FAUMAONO, S. SAMUELA, T. FANGA'ANUKU
DRAWN BY: L. KAUFUSI, T. FANGA'ANUKU, A. SANCHEZ
CHECKED BY: M. VAKAMOLA

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

SHEET CONTENTS: TOPOGRAPHICAL SURVEY

SHEET NUMBER: VAI2

DATE: 15 OCT 2012



CADASTRAL MAP
SCALE = 1:1000M

HORIZONTAL SCALE = 1:1000

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REVISION / ISSUE

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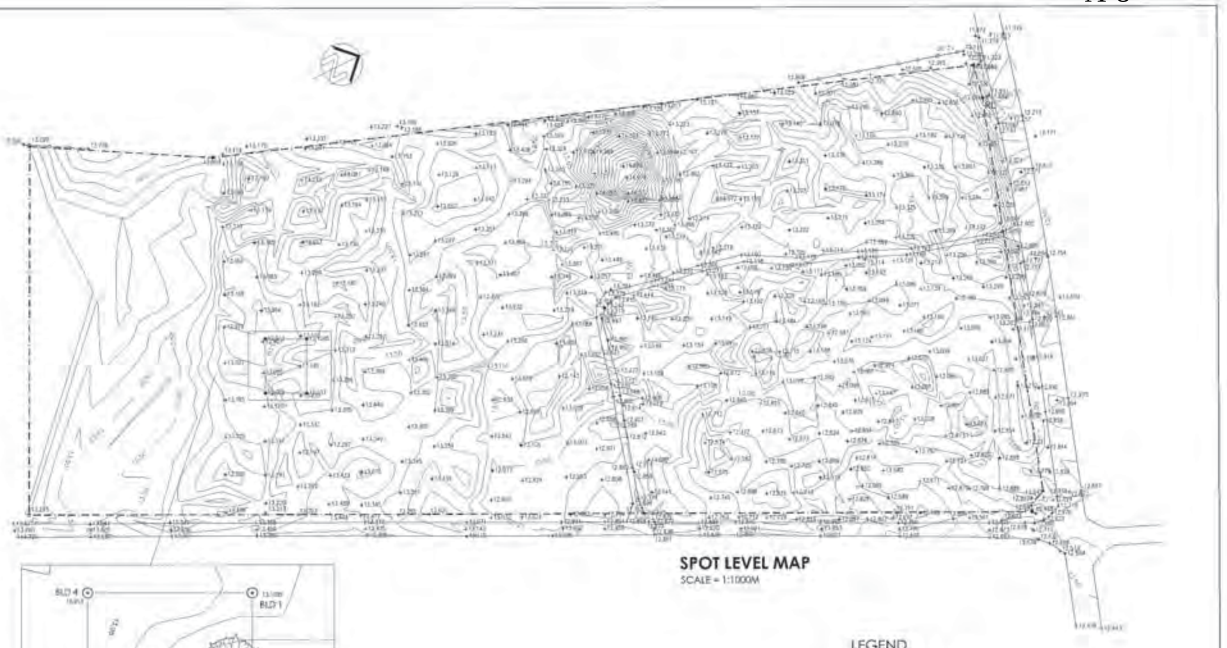
CHECKED BY: M. VAKAMOLA

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

SHEET CONTENTS: CADASTRAL MAP

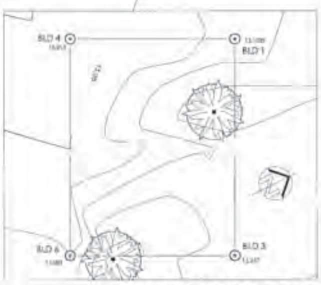
SHEET NUMBER: VAI1

DATE: 15 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

- 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

SURVEYED BY: F.FALEKAONO, L. KAUHUE, T. FAINGA'ANUKU

DRAWN BY: L. KAUHUE, T. FAINGA'ANUKU, A. SANCHEZ

CHECKED BY: M. VAKASIUOLA

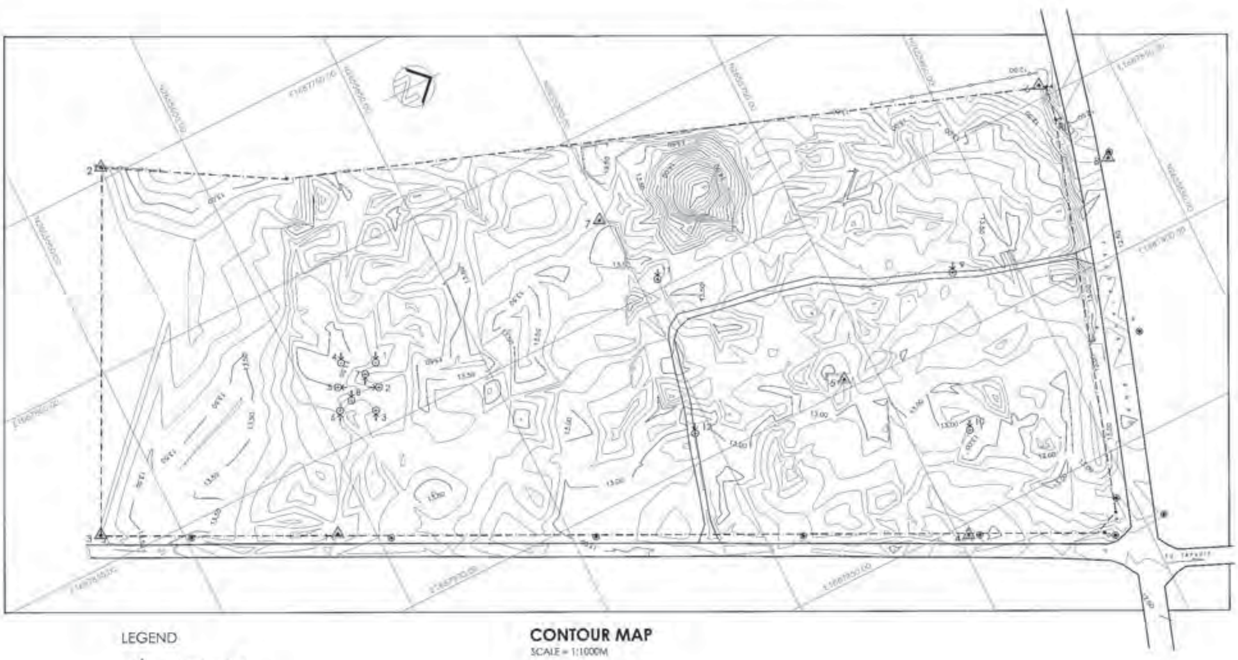
PROJECT: THE PROJECT FOR INTRODUCTION OF A MICRO-GRID SYSTEM WITH RENEWABLE ENERGY FOR THE TONGA ENERGY ROAD MAP

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

SHEET CONTENTS: SPOT LEVELS

SHEET NUMBER: VAI4

DATE: 30 OCT 2012



CONTOUR MAP

SCALE = 1:1000M

LEGEND

- 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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CIVIL, STRUCTURAL AND WATER ENGINEERING CONSULTANTS

UNIT 1-10 TONGILAVA PLAZA, TAUFA'AHAU ROAD, FANGA

SURVEYED BY: F.FALEKAONO, L. KAUHUE, T. FAINGA'ANUKU

DRAWN BY: L. KAUHUE, T. FAINGA'ANUKU, A. SANCHEZ

CHECKED BY: M. VAKASIUOLA

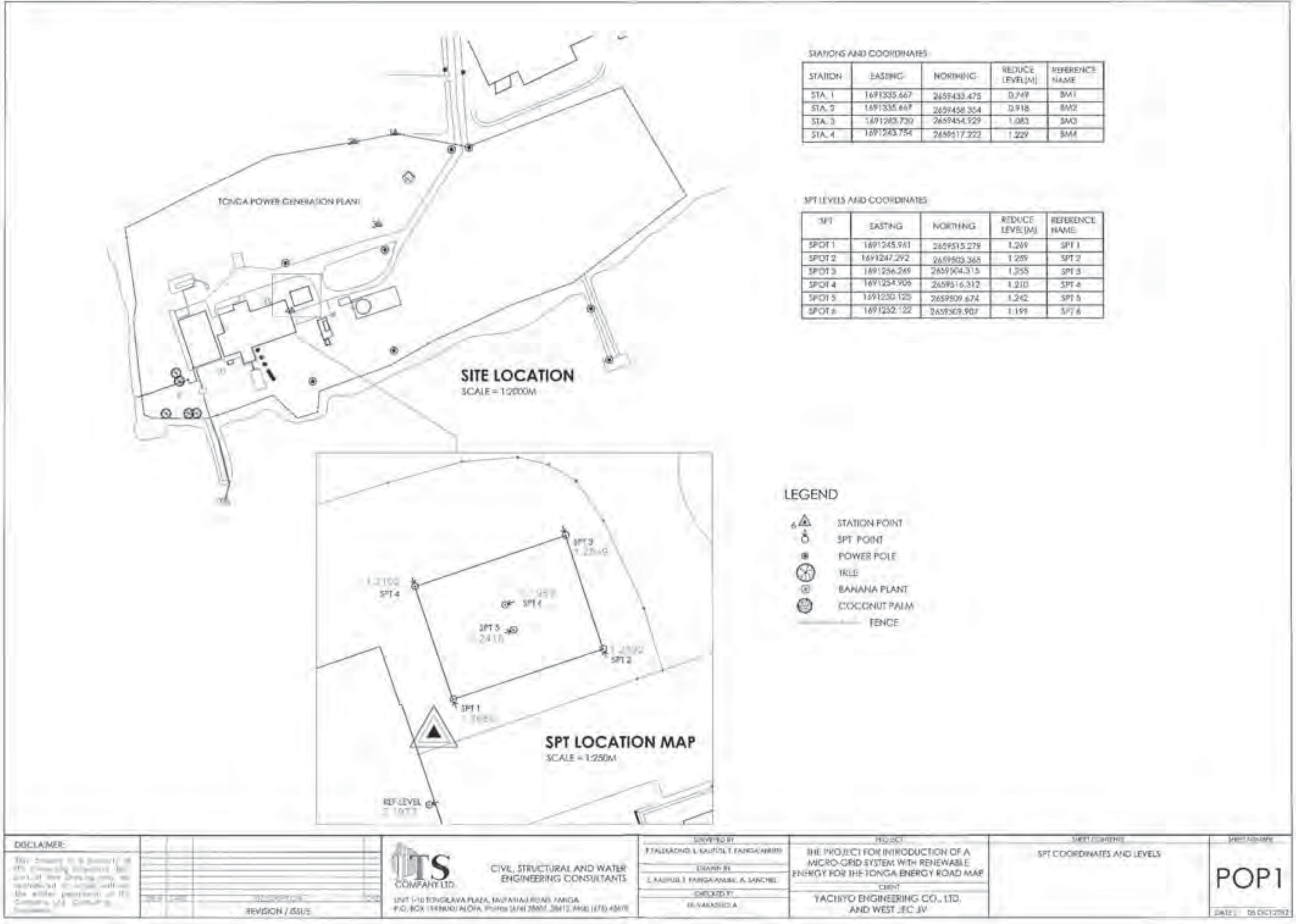
PROJECT: THE PROJECT FOR INTRODUCTION OF A MICRO-GRID SYSTEM WITH RENEWABLE ENERGY FOR THE TONGA ENERGY ROAD MAP

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

SHEET CONTENTS: CONTOUR MAP

SHEET NUMBER: VAI3

DATE: 30 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	1691280.730	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	1691245.961	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	1691232.122	2659509.907	1.199	SPT 6

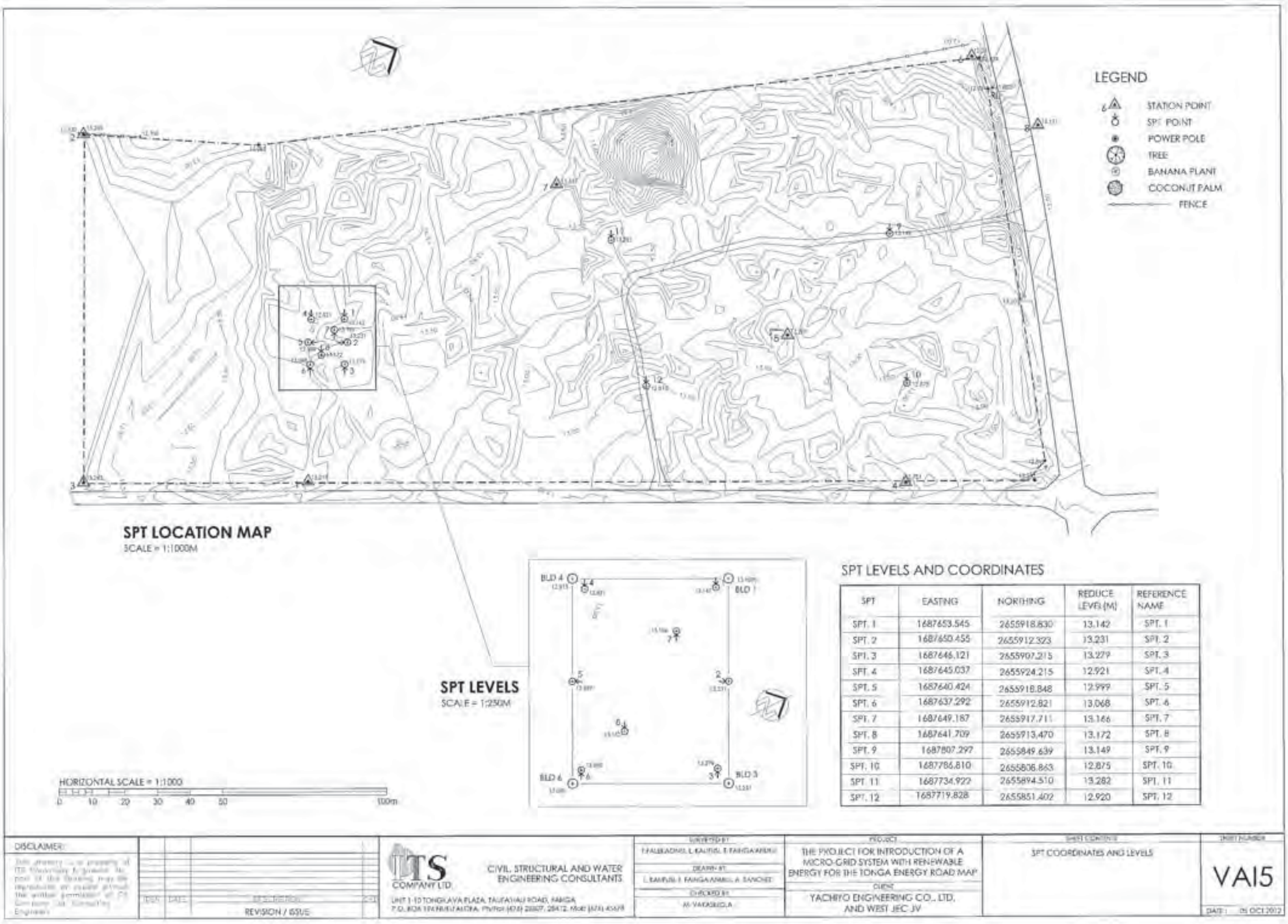
CIVIL, STRUCTURAL AND WATER ENGINEERING CONSULTANTS

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

YACHIYO ENGINEERING CO., LTD. AND WEST JEC JV

SPT COORDINATES AND LEVELS

POP1



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

CIVIL, STRUCTURAL AND WATER ENGINEERING CONSULTANTS

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

YACHIYO ENGINEERING CO., LTD. AND WEST JEC JV

SPT COORDINATES AND LEVELS

VAI5

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 | DRILL TYPE: 50mm Hand Auger | HOLE STARTED: 26/9/12

DRILL METHOD: Hand Auger | HOLE FINISHED: 26/9/12

R.L. 1.30 m | DRILLED BY: CWM

DATUM TGD2005 | DRILL FLUID: Nil | LOGGED BY: CWM | CHECKED: SRS

GEOLOGICAL								ENGINEERING DESCRIPTION							
GEOLOGICAL UNIT, GENETIC NAME, ORIGIN, MINERAL COMPOSITION	FLUID LOSS	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	R.L. (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE / WEATHERING CONDITION	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (mm)	SOIL DESCRIPTION: Soil type, minor components, plasticity or particle size, colour. ROCK DESCRIPTION: Substance: Rock type, particle size, colour, minor components. Defects: Type, inclination, thickness, roughness, filling.
FILL				HAND AUGER				1.0	0.5		SP	M	VD				Gravelly SAND, with some silt, yellowish white, angular, crushed limestone (Fill)
BURIED TOPSOIL								0.5	1.0		SM		L				Silty, fine to medium SAND, dark brown, medium dense, dry, poorly sorted, some rootlets 0.5
ESTUARINE SEDIMENTS								0.0	1.5		ML						Sandy SILT, with minor clay, dark brown, loose
CORAL SAND								-0.5	2.0		SP						SAND, with some clay and minor silt, light brown with some orange, loose, moist 1.0
								-1.0	2.5				D				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 1.5
								-1.5	3.0								END OF BOREHOLE AT 1.9m. Hard to auger. 2.0
								-2.0	3.5								2.5 3.0 3.5
								-2.5	4								

T+T DATATEMPLATE.GDT 4mm

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
		DRILL METHOD: Hand Auger	HOLE FINISHED: 26/9/12
R.L.	1.30 m		DRILLED BY: CWM
DATUM	TGD2005	DRILL FLUID: Nil	LOGGED BY: CWM CHECKED: SRS

GEOLOGICAL / ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION / ROCK DESCRIPTION
TOPSOIL	0.5		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	0.5		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).

FLUID LOSS: — WATER: — CORE RECOVERY (%): — METHOD: HAND AUGER — CASING: — TESTS: — SAMPLES: — R.L. (m): —

T+T DATATEMPLATE.ODT mm

Log Scale 1:20

A-8-20

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
		DRILL METHOD: Hand Auger	HOLE FINISHED: 26/9/12
R.L.	1.30 m		DRILLED BY: CWM
DATUM	TGD2005	DRILL FLUID: Nil	LOGGED BY: CWM CHECKED: SRS

GEOLOGICAL / ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION / ROCK DESCRIPTION
TOPSOIL	0.5		SM	M	L	Silty SAND, with some clay, dark brown, loose, many rootlets
FILL	0.5		SP		VD	Coarse SAND, with some gravel, light yellow brown, very dense, angular coral limestone sand [Fill]
BURIED TOPSOIL	1.0				L	Silty, fine SAND, dark brown, medium dense, moist, massive
ESTUARINE SEDIMENTS	1.0					
CORAL SAND	1.5			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.

FLUID LOSS: — WATER: — CORE RECOVERY (%): — METHOD: HAND AUGER — CASING: — TESTS: — SAMPLES: S1, S2 — R.L. (m): —

T+T DATATEMPLATE.ODT mm

Log Scale 1:20

A-8

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 | DRILL TYPE: 50mm Hand Auger | HOLE STARTED: 26/9/12

DRILL METHOD: Hand Auger | HOLE FINISHED: 26/9/12

R.L. 1.20 m | DRILLED BY: CWM

DATUM TGD2005 | DRILL FLUID: Nil | LOGGED BY: CWM | CHECKED: SRS

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION / ROCK DESCRIPTION
TOPSOIL	0.0		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	0.5				F	Sandy SILT, with some clay, dark brown/black, firm, moist, low plasticity
CORAL SAND	1.0		SP	S	L	Coarse SAND, with some fine gravel and minor silt, light grey, medium dense, saturated, poorly sorted
	1.5				MD	NO RECOVERY
	1.9					**END OF BOREHOLE AT 1.9m.** Hard to auger.

TESTS: HAND AUGER; SAMPLES: S1, S2

T+T DATATEMPLATE.GDT 4mm

Log Scale 1:20

A-8-21

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 2659509.87 mN, 1691250.13 mE | DRILL TYPE: 50mm Hand Auger | HOLE STARTED: 26/9/12

DRILL METHOD: Hand Auger | HOLE FINISHED: 26/9/12

R.L. 1.20 m | DRILLED BY: CWM

DATUM TGD2005 | DRILL FLUID: Nil | LOGGED BY: CWM | CHECKED: SRS

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION / ROCK DESCRIPTION
TOPSOIL	0.0		ML	M	L	Sandy SILT, with some gravel, dark brown, moist, many rootlets
FILL	0.3		SP		VD	Gravelly, coarse SAND, light brown/white, very dense, angular coral sand
BURIED TOPSOIL	0.5				MD	Silty, fine SAND, with some gravel, dark brown, loose, moist, some rootlets
ESTUARINE SEDIMENTS	1.0			W		Silty, coarse SAND, light brown with some orange brown, moist, angular, poorly sorted 1.1m: Changes to greenish grey, wet
CORAL SAND	1.5				D	NO RECOVERY
	1.7					**END OF BOREHOLE AT 1.7m.** Hard to auger.

TESTS: HAND AUGER; SAMPLES: S1

T+T DATATEMPLATE.GDT 4mm

Log Scale 1:20

A-8

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 (Geological unit, generic name, origin, mineral composition)	Method	Tests	R.L. (m)	Depth (m)	Classification symbol	Moisture condition	Strength/density classification	Engineering description
TOPSOIL	HAND AUGER	95/20kPa	1.0	0.0–0.1	ML	M	L	Sandy SILT, with minor clay, dark brown, stiff, moist
ESTUARINE SEDIMENTS			0.5	0.1–1.1	SM			Silty SAND, with minor clay, dark brown, medium dense, poorly sorted, massive
CORAL SAND			0.0 / -0.5	1.1–1.9	SP	S		Coarse SAND, with some fine gravel and minor silt, light grey blue, saturated, angular coral sand NO RECOVERY
				1.9				END OF BOREHOLE AT 1.9m. Hard to auger.

Water level ▼ at approx. 1.1 m.

Column headings: FLUID LOSS, WATER, CORE RECOVERY (%), METHOD, CASING, TESTS, SAMPLES, R.L. (m), DEPTH (m), GRAPHIC LOG, CLASSIFICATION SYMBOL, MOISTURE CONDITION / WEATHERING, STRENGTH/DENSITY CLASSIFICATION, SHEAR STRENGTH (kPa), COMPRESSIVE STRENGTH (MPa), DEFECT SPACING (mm), 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.)

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

TONKIN & TAYLOR

SCALA PENETROMETER LOG

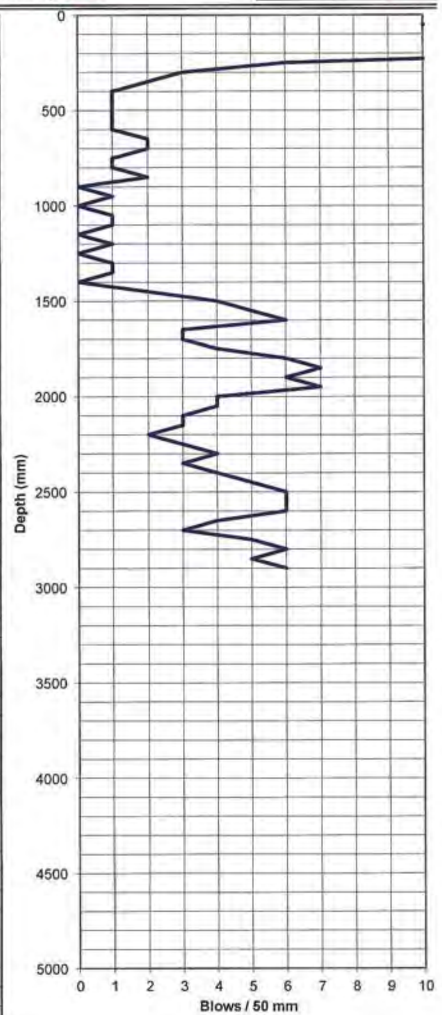
SC1.xlsx

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

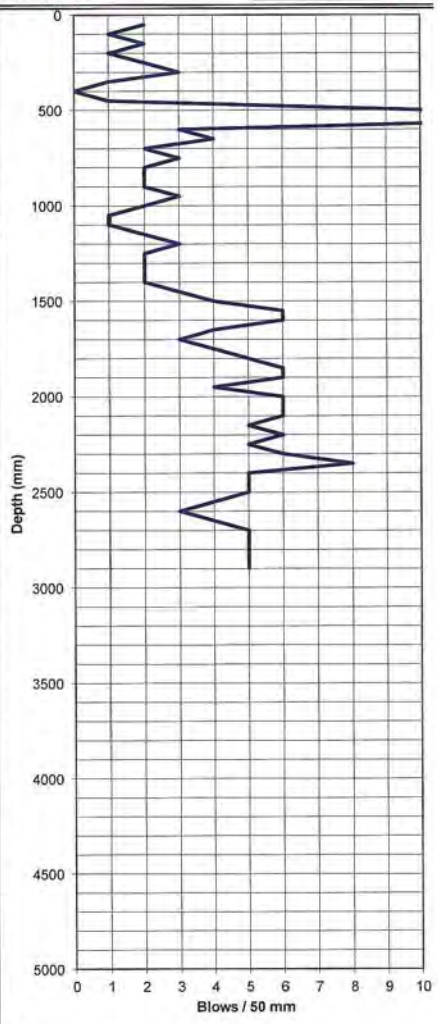
SCALA PENETROMETER LOG

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

SC3.xlsx

TONKIN & TAYLOR

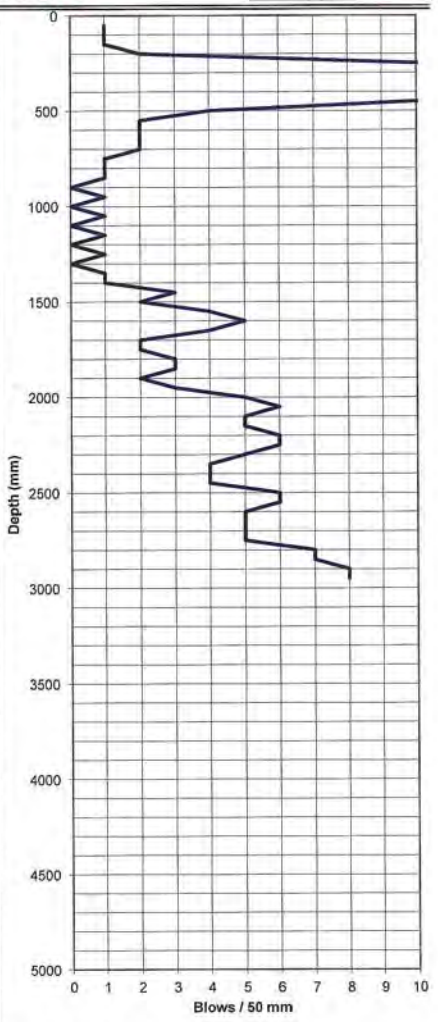
SCALA PENETROMETER LOG

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

SC4.xlsx

TONKIN & TAYLOR

SCALA PENETROMETER LOG

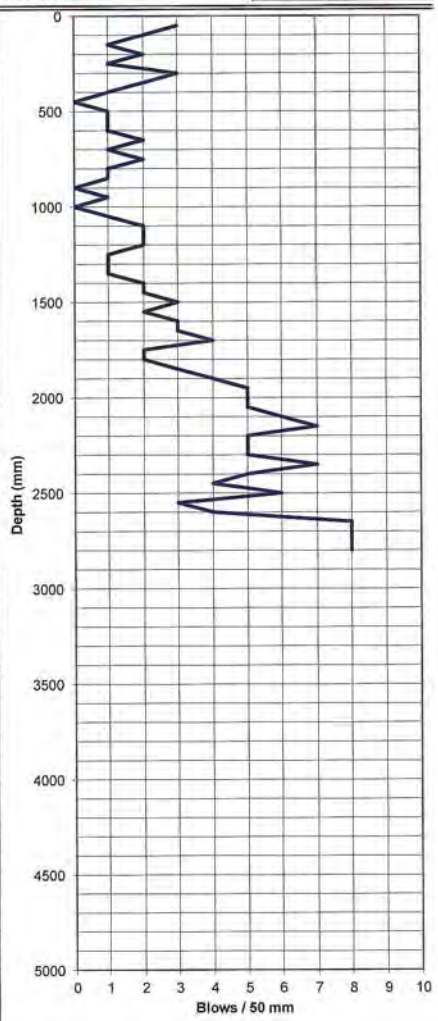
Job No: 750932
Project: Micro-Grid System in Tonga
Location: Site A
RL: 1.25m

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
50	3
100	2
150	1
200	2
250	1
300	3
350	2
400	1
450	0
500	1
550	1
600	1
650	2
700	1
750	2
800	1
850	1
900	0
950	1
1000	0
1050	1
1100	2
1150	2
1200	2
1250	1
1300	1
1350	1
1400	2
1450	2
1500	3
1550	2
1600	3
1650	3
1700	4
1750	2
1800	2
1850	3
1900	4
1950	5
2000	5
2050	5
2100	6
2150	7
2200	5
2250	5
2300	5
2350	7
2400	5
2450	4
2500	6

mm Driven	No. of Blows
2550	3
2600	4
2650	8
2700	8
2750	8
2800	8
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

SC5.xlsx

TONKIN & TAYLOR

SCALA PENETROMETER LOG

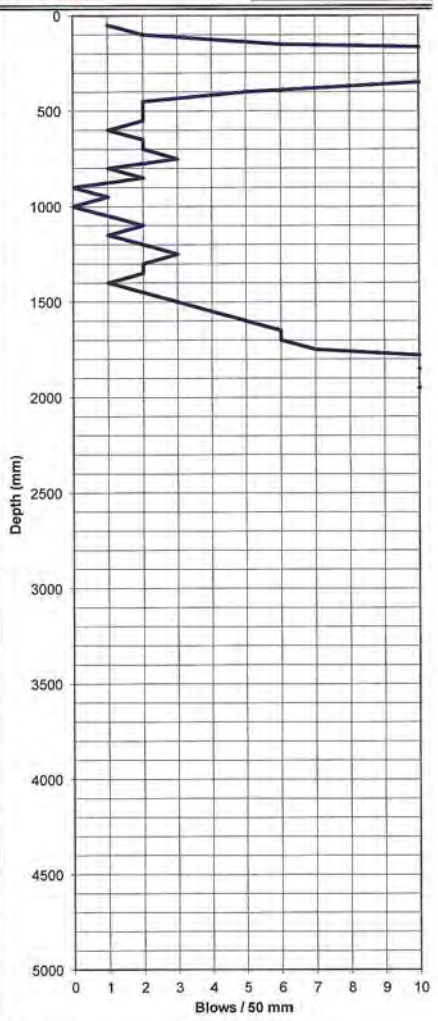
Job No: 750932
Project: Micro-Grid System in Tonga
Location: Site A
RL: 1.20m

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
50	1
100	2
150	6
200	20
250	14
300	13
350	10
400	5
450	2
500	2
550	2
600	1
650	2
700	2
750	3
800	1
850	2
900	0
950	1
1000	0
1050	1
1100	2
1150	1
1200	2
1250	3
1300	2
1350	2
1400	1
1450	2
1500	3
1550	4
1600	5
1650	6
1700	6
1750	7
1800	12
1850	10
1900	15
1950	10
2000	12
2050	
2100	
2150	
2200	
2250	
2300	
2350	
2400	
2450	
2500	

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

SC6.xlsx

TONKIN & TAYLOR

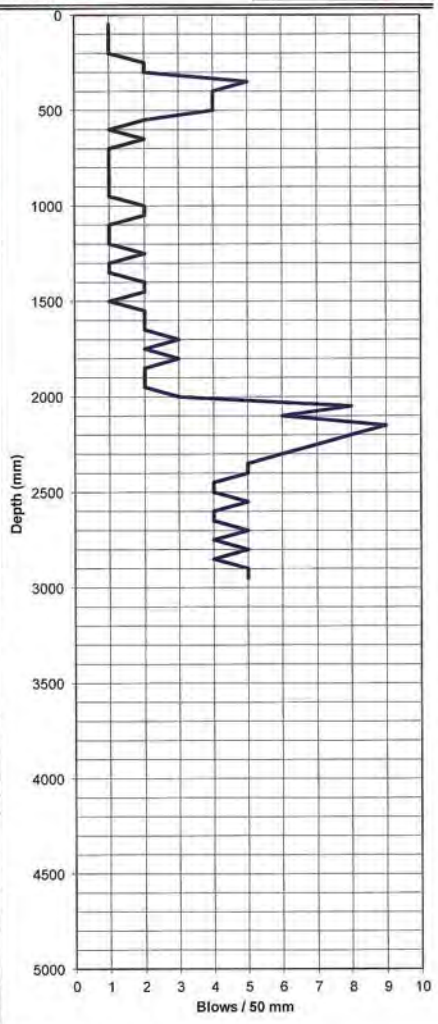
SCALA PENETROMETER LOG

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|1

A-8-25

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

Form No.: B4
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: ASFa Date: 10/10/12

A-8

GEOTECHNICS
23 Morgan Street, Newmarket
Auckland 1023, New Zealand
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w. www.geotechnics.co.nz

Form No.: S6
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 2.7.2 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: AJFC Date: 10/10/12

GEOTECHNICS
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Form No.: S5
Form Date: JANUARY 2004

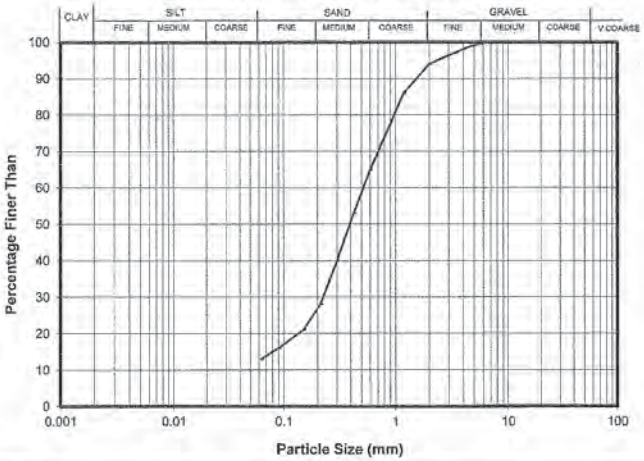
Plate No.: Page of Your Job No.: 750932

Site : Popua, Tongatapu, Tonga - Site A Our Job No.: 615931.000

HA No.: 3 Sample No.: --- Depth (m) 1.2

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

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 : AJFC Date : 10/10/12

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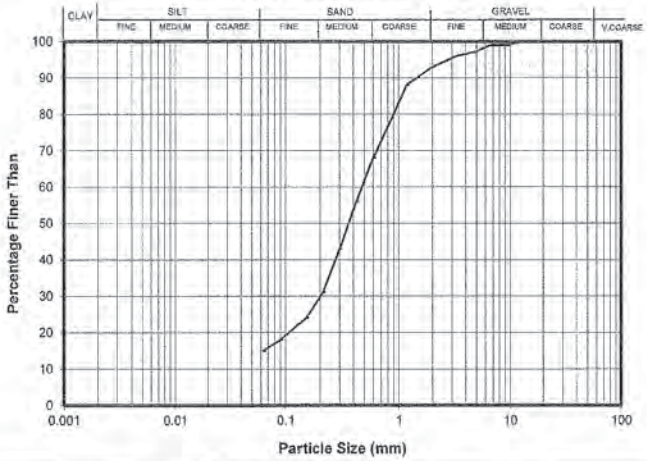
Form No.: S5
Form Date: JANUARY 2004

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 : AJFL Date : 10/10/12

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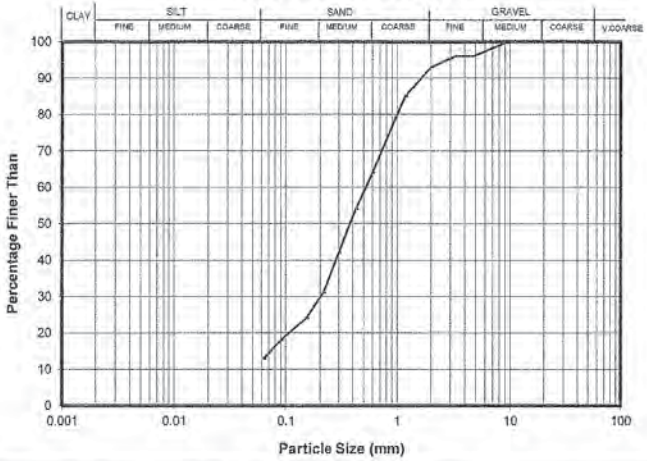
Form No.: S5
Form Date: JANUARY 2004

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 : AJFL Date : 10/10/12

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

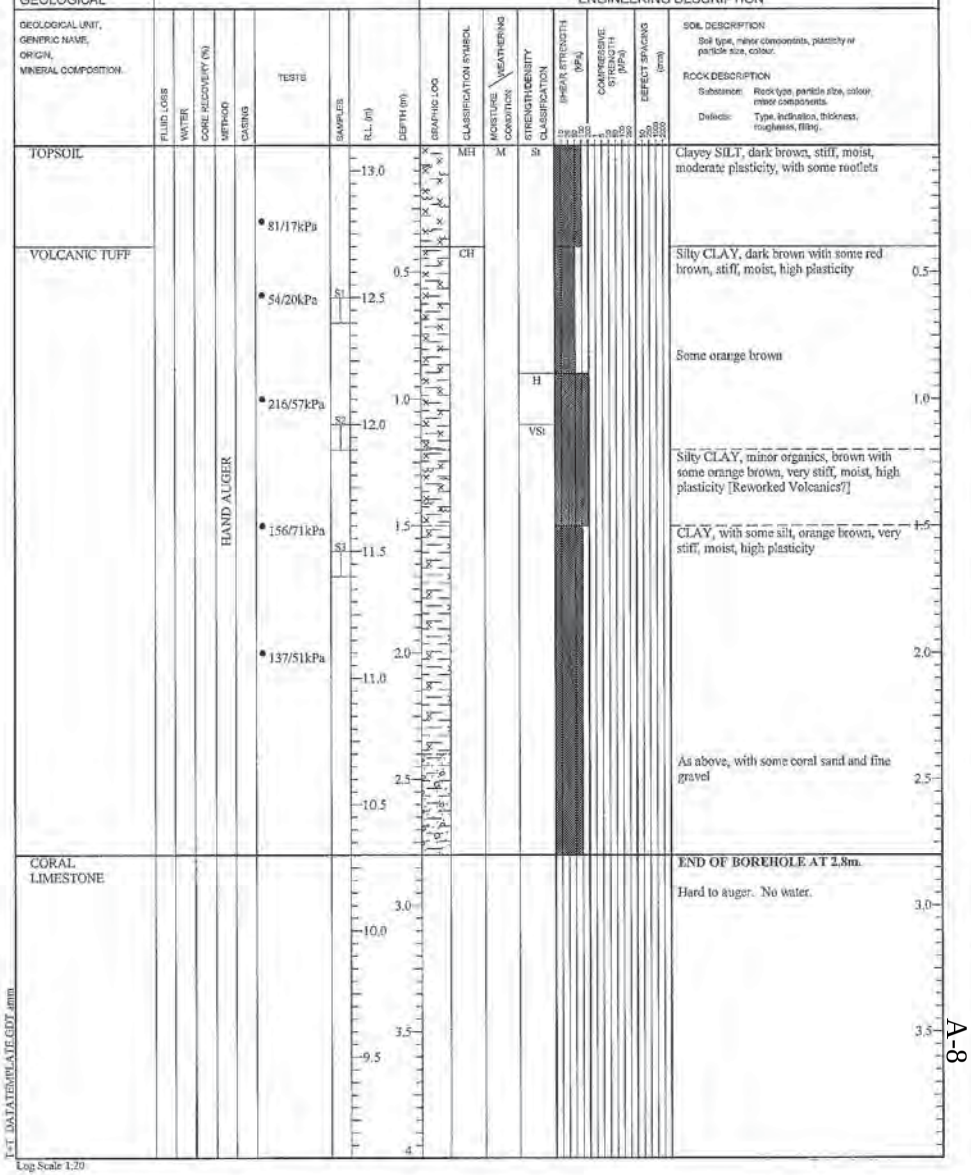
- Hand auger borehole logs
- Scala Penetrometer results
- Geotechnical Laboratory Testing

TONKIN & TAYLOR LTD

BOREHOLE LOG

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

PROJECT: Micro-Grid System in Tonga		LOCATION: Tongatapu, Tonga	JOB No: 750932
CO-ORDINATES	2655918.83 mN 1687653.56 mE	DRILL TYPE: 50mm Hand Auger	HOLE STARTED: 28/9/12
		DRILL METHOD: Hand Auger	HOLE FINISHED: 28/9/12
R.L.	13.10 m		DRILLED BY: CWM
DATUM	TGD2005	DRILL FLUID: Nil	LOGGED BY: CWM CHECKED: SRS



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 | DRILL TYPE: 50mm Hand Auger | HOLE STARTED: 28/9/12

DRILL METHOD: Hand Auger | HOLE FINISHED: 28/9/12

R.L. 13.30 m | DRILLED BY: CWM

DATUM TGD2005 | DRILL FLUID: Nil | LOGGED BY: CWM | CHECKED: SRS

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION	DEPTH (m)	R.L. (m)	TESTS	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION / ROCK DESCRIPTION
TOPSOIL	0.5	13.0	• 122/32kPa	MH	M	VSt	Clayey SILT, dark brown, very stiff, moist, high plasticity, many rootlets
VOLCANIC TUFF	1.0	12.5	• 101/20kPa				Clayey SILT, dark red brown, very stiff, moist, high plasticity
	1.5	12.0	• 193/24kPa				Changes to brown with some orange brown
	2.0	11.5	• 142/47kPa	CH			Silty CLAY, with minor organics (black, fibrous), very stiff, moist, high plasticity [Reworked Volcanics?]
			• 189/59kPa				Some rootlets
CORAL SAND	2.5	11.0		SP		MD	Clayey SILT, orange brown, very stiff, moist, moderate plasticity
							Gravelly SAND, yellowish white
CORAL LIMESTONE	3.0	10.5					**END OF BOREHOLE AT 2.5m.**
	3.5	10.0					Hard to auger.
	4	9.5					

HAND AUGER

Log Scale 1:20

T+T DATATEMPLATE.GDT 4mm

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 | DRILL TYPE: 50mm Hand Auger | HOLE STARTED: 28/9/12

DRILL METHOD: Hand Auger | HOLE FINISHED: 28/9/12

R.L. 12.90 m | DRILLED BY: CWM

DATUM TGD2005 | DRILL FLUID: Nil | LOGGED BY: CWM | CHECKED: SRS

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION	DEPTH (m)	R.L. (m)	TESTS	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION / ROCK DESCRIPTION
TOPSOIL	0.5	12.5	• 123/34kPa	MH	M	St	Clayey SILT, dark brown, stiff, moist, high plasticity, many rootlets
VOLCANIC TUFF	1.0	12.0	• 189/49kPa	CH		VSt	Silty CLAY, with trace sand, dark brown with some red brown, very stiff, moist, high plasticity
			• 150/73kPa				0.5m: Changes to orange brown
	1.5	11.5	• 167/73kPa				
	2.0	11.0	• 157/57kPa			H	
	2.5	10.5	• 200/68kPa				
CORAL LIMESTONE	3.0	10.0					**END OF BOREHOLE AT 2.6m.**
	3.5	9.5					Hard to auger. No water inflow.
	4	9.0					

HAND AUGER

Log Scale 1:20

T+T DATATEMPLATE.GDT 4mm

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 1687637.28 mE | DRILL TYPE: 50mm Hand Auger | HOLE STARTED: 28/9/12

DRILL METHOD: Hand Auger | HOLE FINISHED: 28/9/12

R.L. 13.10 m | DRILLED BY: CWM

DATUM TGD2005 | DRILL FLUID: Nil | LOGGED BY: CWM | CHECKED: SRS

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION	TESTS	R.L. (m)	DEPTH (m)	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION / ROCK DESCRIPTION
TOPSOIL	150/41kPa	13.0	0	ML	M	VSt	Clayey SILT, dark brown, very stiff, moist, low plasticity, with many rootlets
VOLCANIC TUFF	223/85kPa	12.5	0.5	CH		H	Silty CLAY, dark red brown, very stiff to hard, moist, high plasticity
	183/81kPa	12.0	1.0			VSt	
	93/47kPa	11.5	1.5			St	
		11.0	2.0				Changes to orange brown
CORAL SAND				SP		MD	Course SAND, some gravel (coral sand)
CORAL LIMESTONE		10.5	2.5				**END OF BOREHOLE AT 2.4m.**
		10.0	3.0				
		9.5	3.5				
			4				

Log Scale 1:20

T+T DATATEMPLATE GDT 5mm

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 | DRILL TYPE: 50mm Hand Auger | HOLE STARTED: 28/9/12

DRILL METHOD: Hand Auger | HOLE FINISHED: 28/9/12

R.L. 13.10 m | DRILLED BY: CWM

DATUM TGD2005 | DRILL FLUID: Nil | LOGGED BY: CWM | CHECKED: SRS

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION	TESTS	R.L. (m)	DEPTH (m)	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION / ROCK DESCRIPTION
TOPSOIL	186/41kPa	13.0	0	ML	M	VSt	SILT, with some clay and minor fine sand, dark brown, very stiff, moist, low plasticity, some rootlets
VOLCANIC TUFF	167/27kPa	12.5	0.5	MH			SILT, with some clay, dark brown with some orange brown, very stiff, moist, high plasticity
	223/54kPa	12.0	1.0			H	Changes to orange brown
		11.5	1.5	CH		VSt	Silty CLAY, orange brown, very stiff, moist, high plasticity
	174/61kPa	11.0	2.0				
CORAL LIMESTONE		10.5	2.5				**END OF BOREHOLE AT 2.5m.** Hard to auger. No water inflow.
		10.0	3.0				
		9.5	3.5				
			4				

Log Scale 1:20

T+T DATATEMPLATE GDT 5mm

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 | DRILL TYPE: 50mm Hand Auger | HOLE STARTED: 28/9/12

DRILL METHOD: Hand Auger | HOLE FINISHED: 28/9/12

R.L. 12.90 m | DRILLED BY: CWM

DATUM TGD2005 | DRILL FLUID: Nil | LOGGED BY: CWM | CHECKED: SRS

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION	TESTS	R.L. (m)	DEPTH (m)	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION / ROCK DESCRIPTION
TOPSOIL	139/54kPa	12.5	0.5	ML	M	VSt	Clayey SILT, with minor fine sand, dark brown, very stiff, moist, moderate plasticity
							Changes to dark red brown
VOLCANIC TUFF	149/47kPa			CH			Silty CLAY, orange brown, very stiff, moist, high plasticity
	172/85kPa	12.0	1.0				
			1.5				
	169/56kPa	11.5	2.0				
CORAL LIMESTONE		11.0					SANDSTONE [Coral Limestone]
		10.5	2.5				**END OF BOREHOLE AT 2.1m.**
		10.0	3.0				Hard to auger.
		9.5	3.5				
		9.0	4				

HAND AUGER

T+T DATATEMPLATE.GDT amm

Log Scale 1:20

A-8-31

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 | DRILL TYPE: 50mm Hand Auger | HOLE STARTED: 28/9/12

DRILL METHOD: Hand Auger | HOLE FINISHED: 28/9/12

R.L. 13.30 m | DRILLED BY: CWM

DATUM TGD2005 | DRILL FLUID: Nil | LOGGED BY: CWM | CHECKED: SRS

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION	TESTS	R.L. (m)	DEPTH (m)	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION / ROCK DESCRIPTION
TOPSOIL		13.0	0.5	ML	M	VSt	Clayey SILT, with minor fine sand, dark brown, very stiff, moist, some rootlets
VOLCANIC TUFF	162/51kPa			CH			Silty CLAY, orange brown, very stiff, moist, high plasticity
	203/110kPa	12.5	1.0			H	
	178/93kPa					VSt	
	152/62kPa	12.0	1.5				
CORAL LIMESTONE		11.5	2.0				**END OF BOREHOLE AT 1.6m.**
		11.0	2.5				Hard to auger.
		10.5	3.0				
		10.0	3.5				
		9.5	4				

HAND AUGER

T+T DATATEMPLATE.GDT amm

Log Scale 1:20

A-8

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, 1687719.63 mE | DRILL TYPE: 50mm Hand Auger | HOLE STARTED: 28/9/12

DRILL METHOD: Hand Auger | HOLE FINISHED: 28/9/12 | DRILLED BY: CWM

R.L. 12.90 m | DRILL FLUID: Nil | LOGGED BY: CWM | CHECKED: SRS

DATUM TGD2005

GEOLOGICAL | ENGINEERING DESCRIPTION

GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MINERAL COMPOSITION	TESTS	R.L. (m)	DEPTH (m)	CLASSIFICATION SYMBOL	MOISTURE CONDITION	STRENGTH/DENSITY CLASSIFICATION	SOIL DESCRIPTION / ROCK DESCRIPTION
TOPSOIL	• 71/17kPa	12.5	0.5	ML	M	St	SILT, with some clay and minor fine sand, dark brown, stiff, moist, low plasticity, many rootlets
	• 118/25kPa		0.5			VSt	
VOLCANIC TUFF	• 189/51kPa	12.0	1.0	MH			Clayey SILT, orange brown with some black, very stiff, moist, moderate plasticity
	• 178/42kPa	11.5	1.5				
	• 139/25kPa	11.0	2.0				
		10.5	2.5	CH	M-W	St	CLAY, with some silt, orange brown, stiff, moist to wet, high plasticity
		10.0	3.0				Minor limestone gravel
		9.5	3.5				
CORAL LIMESTONE		9.0	4				END OF BOREHOLE AT 3.6m. Hard to auger (scala hit rock at 2.45m, 100mm from hand auger. Infilled void/cavity?).

HAND AUGER

Log Scale 1:20

T+T DATATEMPLATE.GDT mm.

A-8-32

SC1.xlsx

TONKIN & TAYLOR

SCALA PENETROMETER LOG

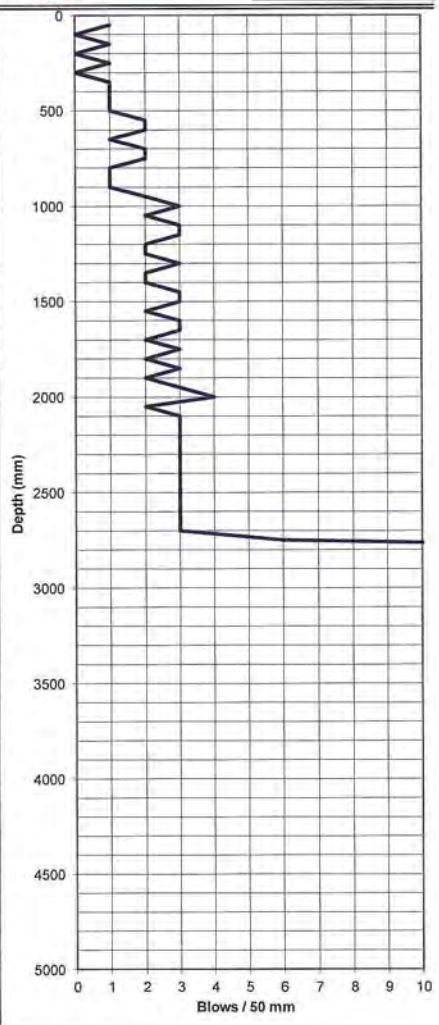
Job No: 750932 | Date: 27/09/2012 | Test No. SC1B

Project: Micro-Grid System in Tonga | Operated by: CWM

Location: Site B | Logged by: CWM | Sheet 1

RL: 12.91m | Checked by: ADP | of 1

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

A-8

SC2.xlsx

TONKIN & TAYLOR

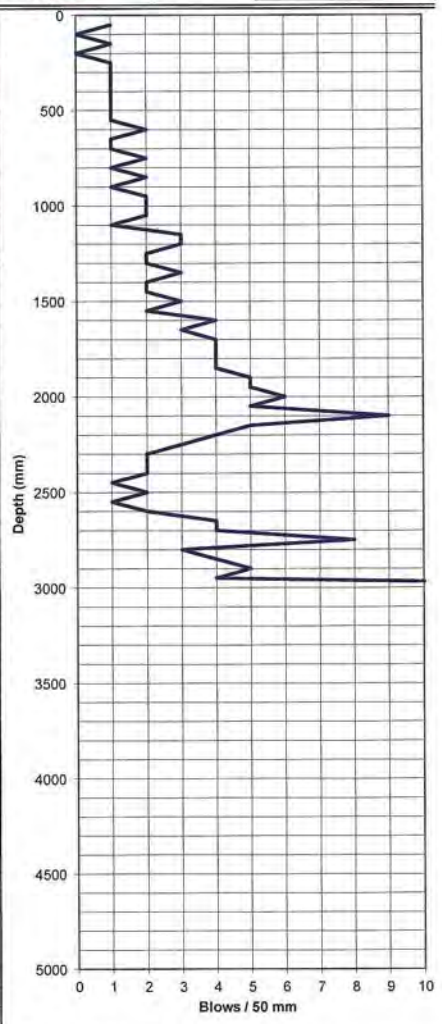
SCALA PENETROMETER LOG

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

SC3.xlsx

TONKIN & TAYLOR

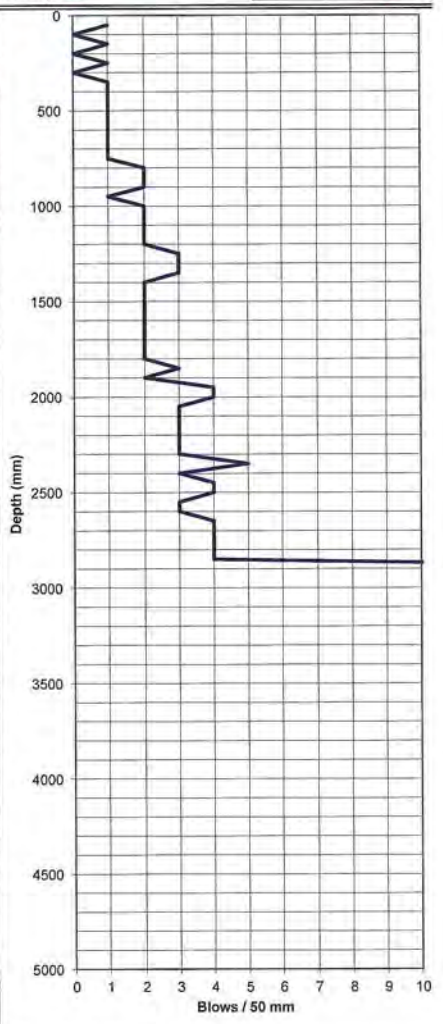
SCALA PENETROMETER LOG

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

SC4.xlsx

TONKIN & TAYLOR

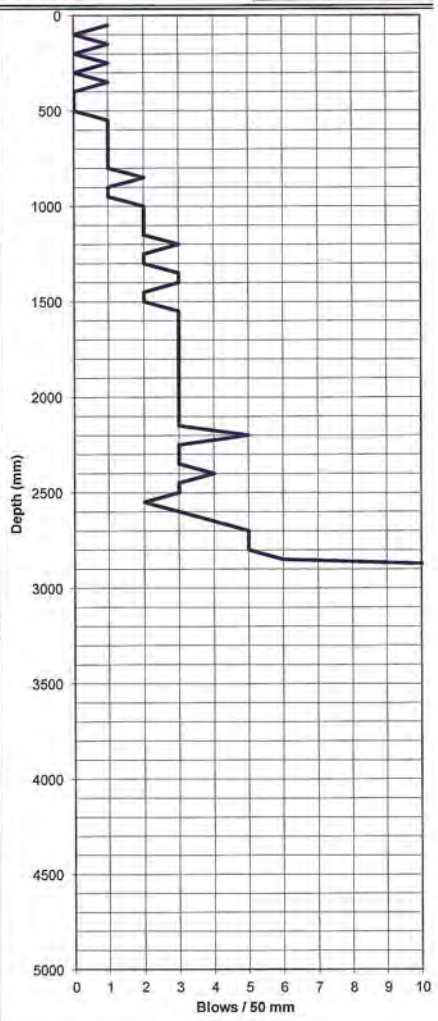
SCALA PENETROMETER LOG

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

SC5.xlsx

TONKIN & TAYLOR

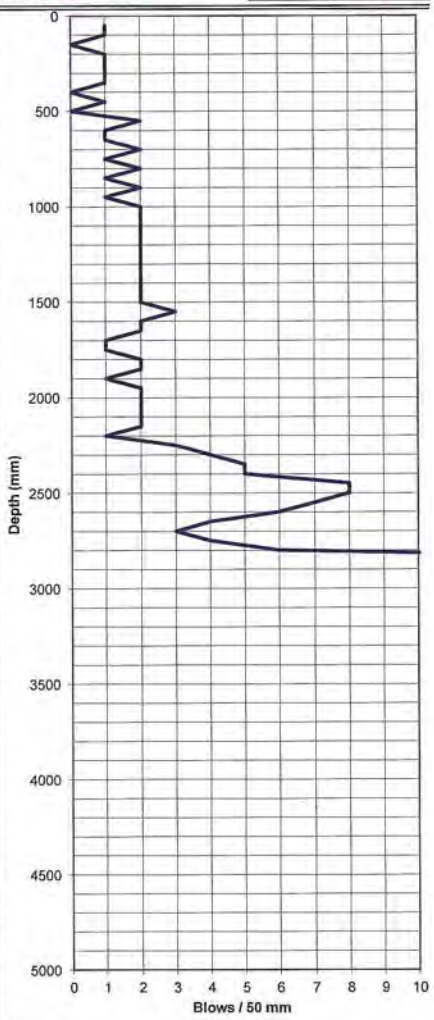
SCALA PENETROMETER LOG

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

SC6.xlsx

TONKIN & TAYLOR

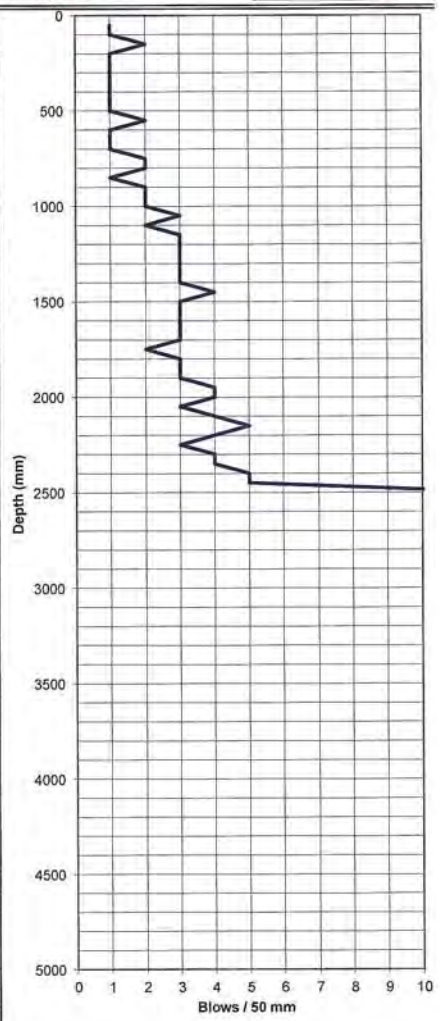
SCALA PENETROMETER LOG

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

SC7.xlsx

TONKIN & TAYLOR

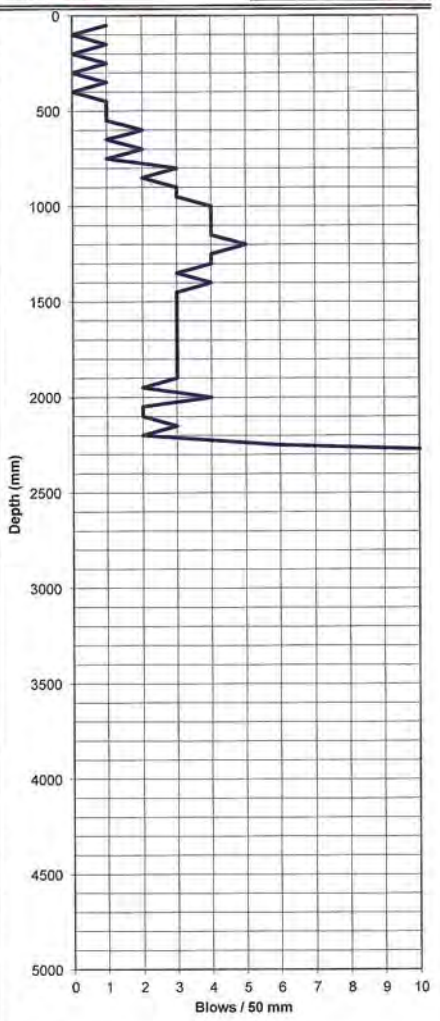
SCALA PENETROMETER LOG

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

SC8.xlsx

TONKIN & TAYLOR

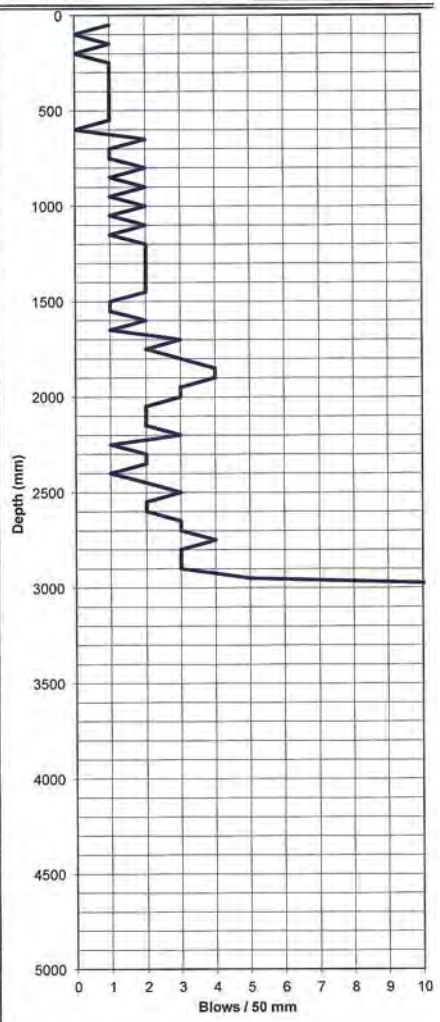
SCALA PENETROMETER LOG

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

SC9.xlsx

TONKIN & TAYLOR

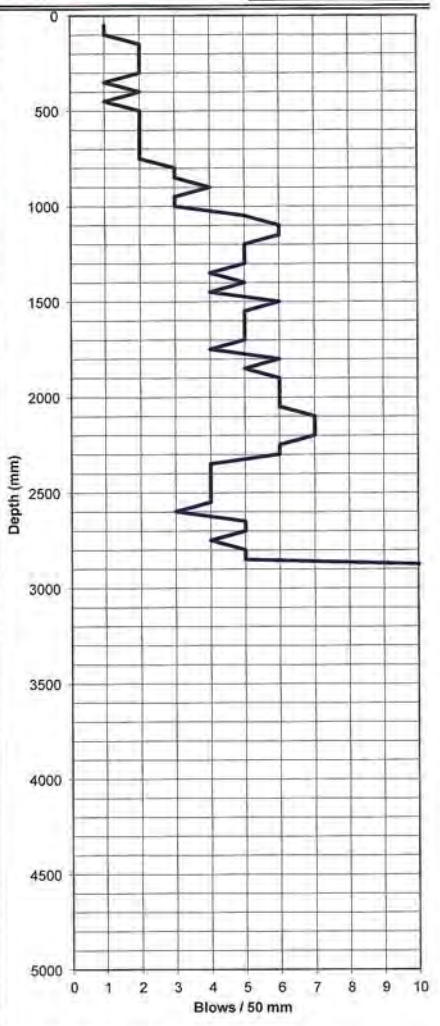
SCALA PENETROMETER LOG

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

SC10.xlsx

TONKIN & TAYLOR

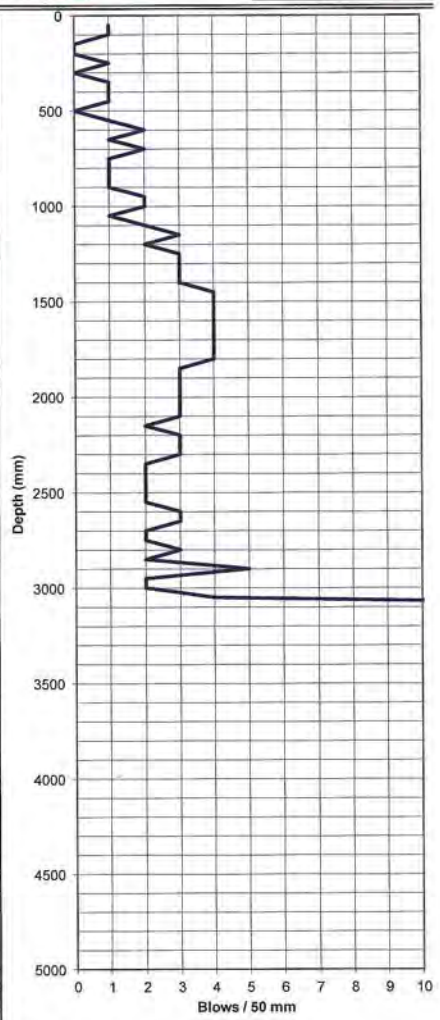
SCALA PENETROMETER LOG

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

SC11.xlsx

TONKIN & TAYLOR

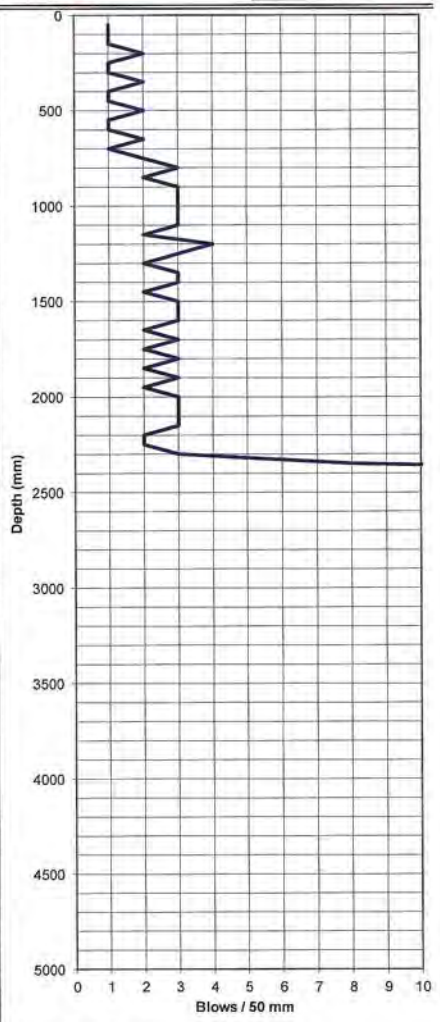
SCALA PENETROMETER LOG

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

SC12.xlsx

TONKIN & TAYLOR

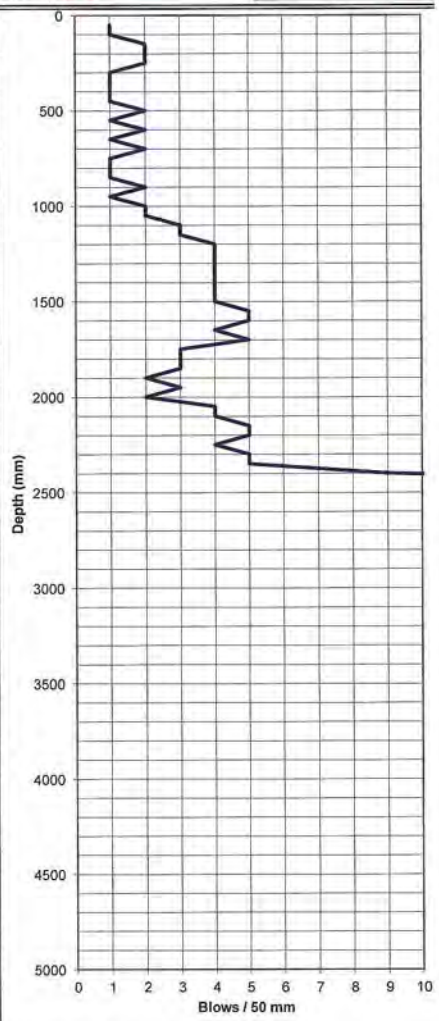
SCALA PENETROMETER LOG

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

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Auckland 1023, New Zealand
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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

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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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Form No.: P6
Form Date: January 2004

Plate No.: Page of

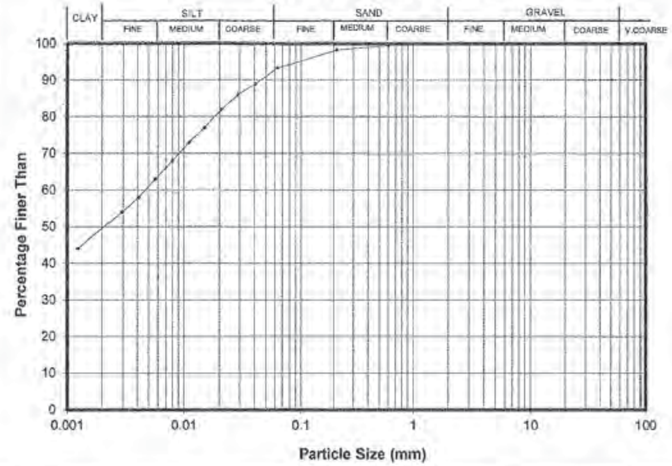
Site : **Vaini, Tongatapu, Tonga - Site B**

HA No.: **1** Sample No.: ---

Test Method Used : NZS 4402:1986 Test 2.8.4 Hydrometer

Your Job No.: **750932**
Our Job No.: **615931.000**
Depth: **1.1 (m)**

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing	Sieve (mm)	Total % Passing
2.00	100		
0.600	99		
0.212	98		
0.063	93		

Equivalent Particle Diameter D (mm)	% of Particles Finer than D
0.0408	89
0.0291	86
0.0209	82
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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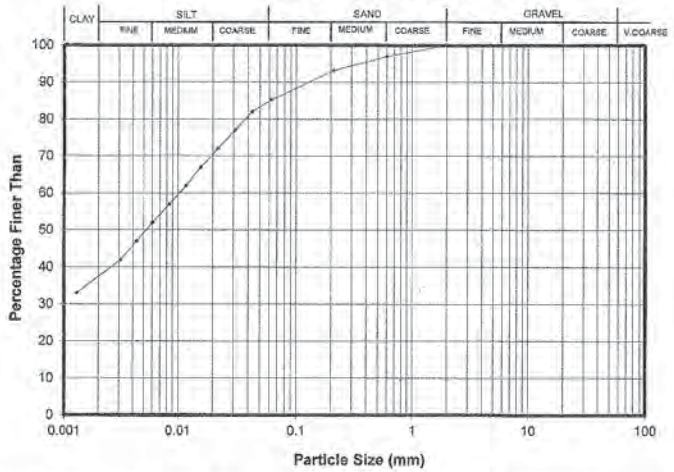
Form No.: P8
Form Date: January 2004
File: P:\615931.000\Working material\HA3_0.6m.xlsx

Plate No.: Page of Your Job No.: **750932**
Site : **Vaini, Tongatapu, Tonga - Site B** Our Job No.: **615931.000**
HA No.: **3** Sample No.: --- Depth: **0.6 (m)**
Test Method Used : NZS 4402:1986 Test 2.8.4 Hydrometer

PARTICLE SIZE ANALYSIS



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

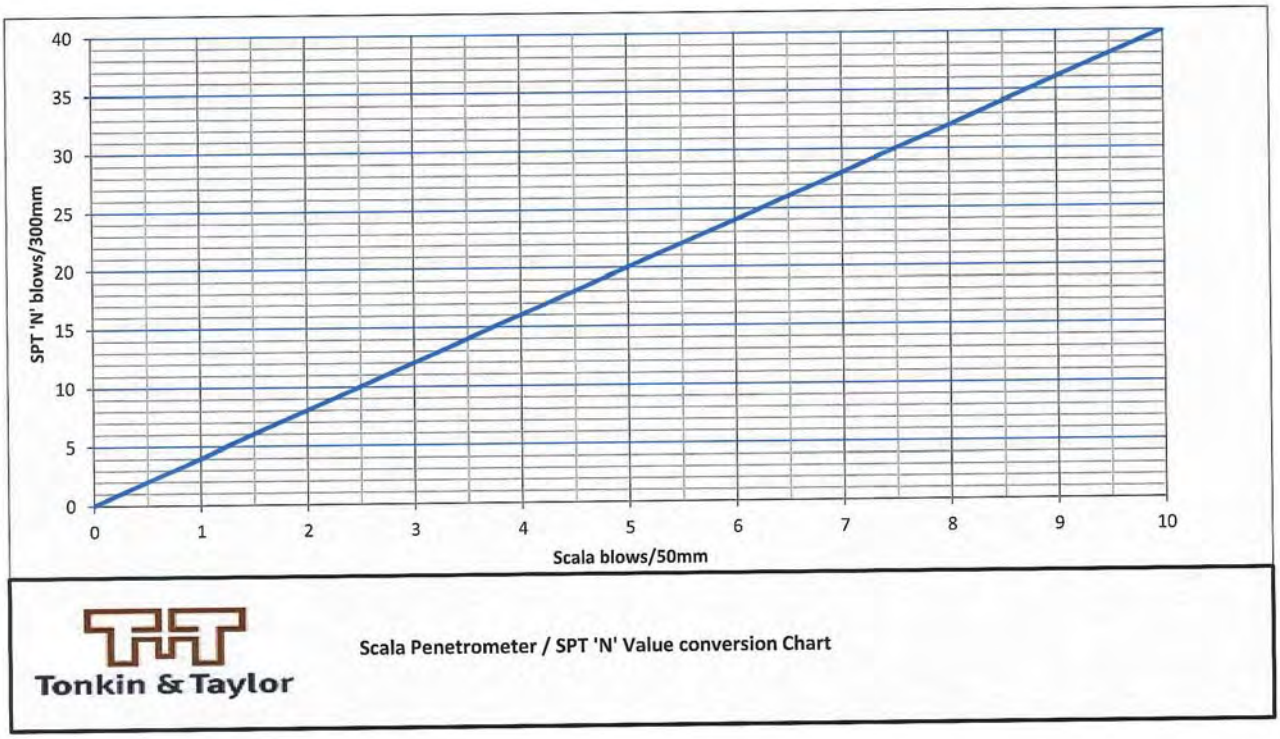
Equivalent Particle Diameter D (mm)	% of Particles Finer than D
0.0431	82
0.0309	77
0.0222	72
0.0159	67
0.0118	62
0.0084	57
0.0060	52
0.0043	47
0.0031	42
0.0013	33

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 : ASEC Date : 10/10/12

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


SPT 'N' blows/300mm
0
5
10
15
20
25
30
35
40
0
1
2
3
4
5
6
7
8
9
10
Scala blows/50mm
Tonkin & Taylor
Scala Penetrometer / SPT 'N' Value conversion Chart

A-9　風力発電のポテンシャル評価報告書

トンガ国風況データ整理・解析

報告書

平成 24 年 12 月

西日本技術開発㈱

目次

本報告書は、既存風況データを基に風況特性を整理・解析し、トンガ王国に導入可能な規模の風車を念頭に、エネルギー特性を求め、風力発電の導入可能性を評価したものである。

1. 前提条件

1.1. 既 存風況データ

既存風況データの諸元は表 1-1 のとおりである。

表 1-1　風力データ観測地点および既存風況データの諸元

風況データ観測地点	Lapaha サイト(トンガタプ島東岸のハマロビーチ付近) 南緯 21 度 11 分 22 秒、東経 175 度 05 分 35 秒、標高 28m
風況データ観測期間	2010 年 7 月～2011 年 10 月
風況データ解析期間	2010 年 8 月 1 日～2011 年 7 月 31 日
風況データ観測実施者	国土・環境・気候変動・天然資源省(MLECCNR)
風況データ仕様	風速計 6 点 ・地上高 30 m　磁北に対し 22.5 度と 202.5 度に設置 ・地上高 40 m　磁北に対し 22.5 度と 202.5 度に設置 ・地上高 50 m　磁北に対し 22.5 度と 202.5 度に設置
	風向計 2 点 ・地上高 37 m　磁北に対し 22.5 度に設置 ・地上高 48 m　磁北に対し 22.5 度に設置

1.2. 風況データ観測地点および風力開発予定地点

上述のとおり、MLECCNR によって Lapaha サイトの風況データが観測されたが、それとは別に TPL の風力開発予定地点があり、開発を検討している。

TPL の風力開発予定地点は風況データ観測地点から直線距離で約 6.5 km 離れている。(図 1-1)

しかし、両地点は周辺地形および標高がほぼ同じであることから、本評価は風車建設予定地点にも適合できるものと見做す。

TPL の風力開発予定地点については表 1-2 のとおりである。

なお今後、この風車建設予定地点においても、TPL によって風況データが観測される予定である。

表 1-2　TPL の風力開発予定地点

風力開発予定地点	Niutoua サイト(トンガタプ島東北岸のフィネヒカビーチ付近) 南緯 21 度 09 分 23 秒、東経 175 度 02 分 24 秒、標高 26m
計画実施者	TPL (トンガ電力公社)

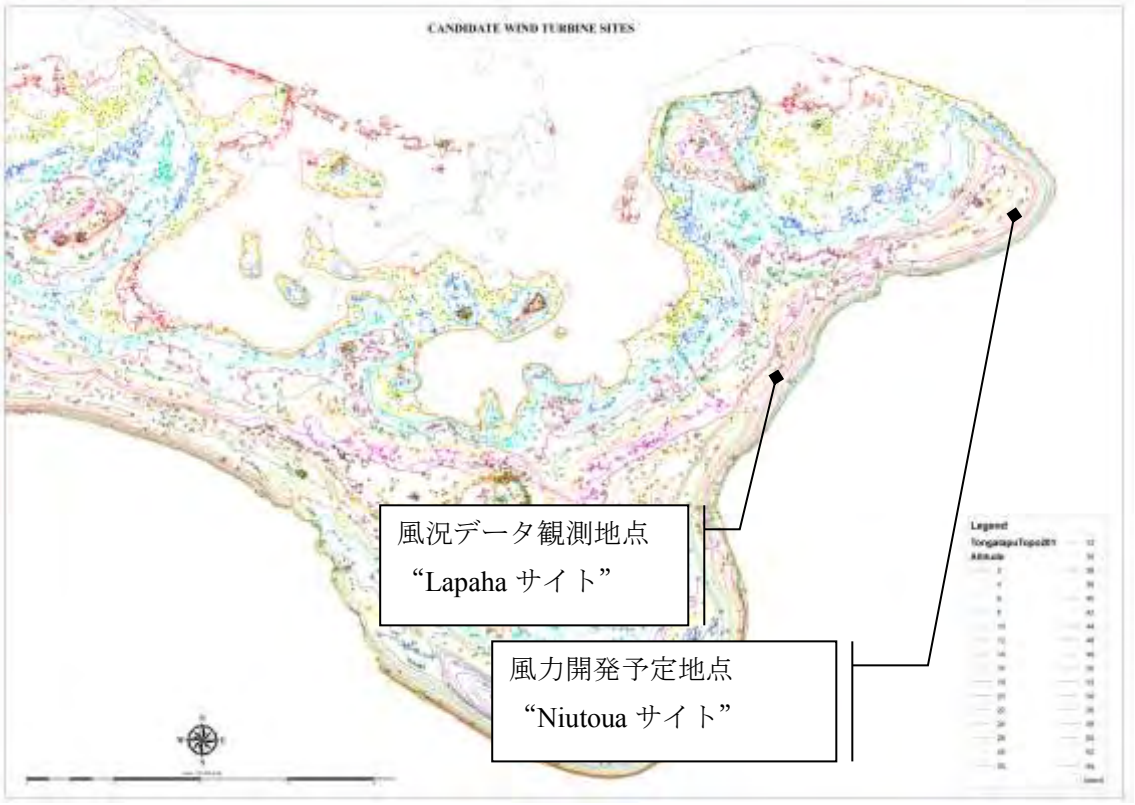


図 1-1　風況データ観測地点と風力開発予定地点

1.3.　風車モデル

離島であるトンガ国の状況を考慮し、中規模風車の導入が建設の観点から見て現実的である。典型的な 300 kW クラス風車の仕様と風車図を表 1-3 および図 1-2 に示す。一般的に 300 kW クラス風車のハブ高さは 40 m 程度であるため、主に地上高 40 m の風況データを解析するものとする。

表 1-3　典型的な 300 kW 風車の仕様

定格容量	300 kW
型式	水平軸型
方式	アップウィンド方式
ローター直径	33 m
ハブ高さ	41.5 m
定格風速	11.5 m/s
定格回転数	40.5 rpm
カットイン風速	3.0 m/s
カットアウト風速	25 m/s (10 分平均)
最適周速比	7.5
耐風速	70 m/s
設計寿命	20 年

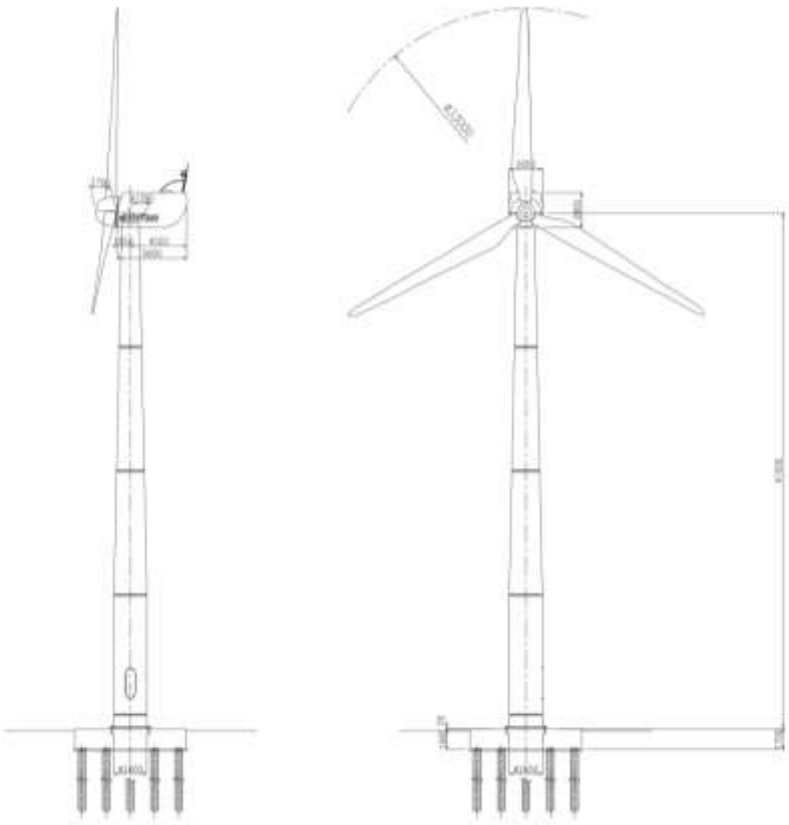


図 1-2　典型的な 300 kW クラス風車図

トンガ側の要望する風力発電設備容量は 500 kW となっている。

よって、定格出力 250 kW の風車 2 基を建設し、500 kW の設備容量とすることを想定する。なお、300 kW クラスの風車を 250 kW の定格出力として採用することとする。

表 1-4 に想定した風車構成を示す。

表 1-4　想定される風車構成

設備容量	構成
500 kW	定格出力 250 kW x 2 基

1.4. 本報告書における評価の目的

風力発電開発に係る環境影響調査は実施されておらず、本プロジェクトは直ちに実施段階に移行できる状況にない。

したがって本報告書ではポテンシャル評価（期待発電量含む）のみをおこなうものとする。

表 1-5 に本報告書における解析項目を示す。

表 1-5　解析項目

要　　因	解析項目	目　　的
風況特性	平均風速	風力開発の可否を判断
	風向出現率	卓越風向を判断
	時間別風向出現率	風向変動特性を判断
	風向別風速出現率と平均風速	風向と風速の関係を判断
	風速の鉛直分布	方位別の風速のシアーを判断
	乱れ強度	乱流の大きさを判断
	最大瞬間風速	最大瞬間風速を判断
	風速の出現率	風速分布を判断
エネルギー特性	風力エネルギー密度	風力開発の可否を判断
	風車の稼働率	
	風力エネルギー取得量、設備利用率	

2. 平均風速

2.1. 月別平均風速

高度 40m における月別の平均風速は、表 2-1 及び図 2-1 に示すとおりであり、

3 月～4 月、及び 7 月は 5.1～5.5m/s となっているが、その他の月は概ね 6.0m/s 以上で、特に 10 月～12 月は 7.0m/s 以上となっていた。年間の平均風速は、6.2m/s であった。

表 2-1　各高度における月別平均風速

単位：m/s

地上高	2011年							2010年					年平均
	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	
30m	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
40m	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
50m	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

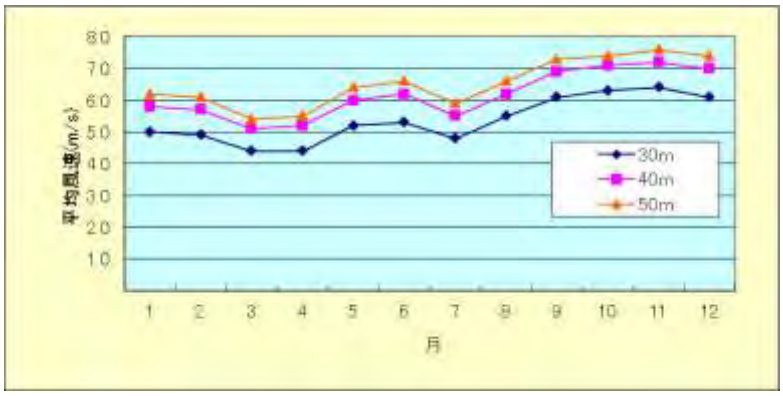


図 2-1　各高度における月別平均風速

2.2. 時間別平均風速

高度 40m における年間の時間別平均風速の日変化は、小さく（5.8～6.4m/s）、夜間から午前中が日中に比べやや弱くなる傾向が見られた。

1 月は、年間と同様な傾向となっているが、8 月は夜間から明け方に風速がやや強くなる傾向が見られた。

表 2-2　時間別平均風速と標準偏差

(単位:m/s)

年 月	項目	時間																								平均
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
11年 1月	風速	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
	偏差	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
2月	風速	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
	偏差	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
3月	風速	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
	偏差	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
4月	風速	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
	偏差	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
5月	風速	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
	偏差	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
6月	風速	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
	偏差	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
7月	風速	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
	偏差	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
10年 8月	風速	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
	偏差	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
9月	風速	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
	偏差	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
10月	風速	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
	偏差	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
11月	風速	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
	偏差	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
12月	風速	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
	偏差	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
年平均	風速	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
	偏差	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

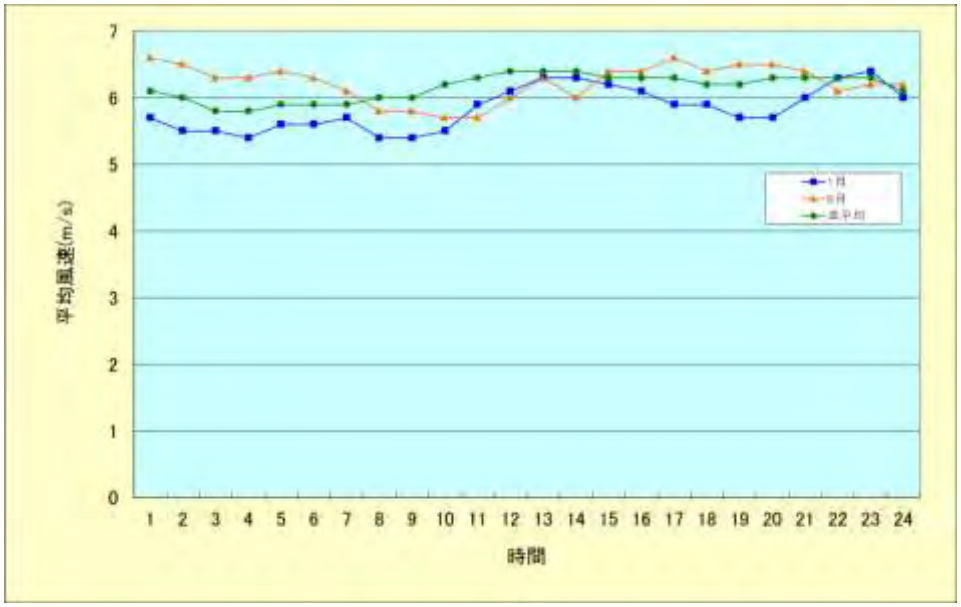


図 2-2　時間別平均風速

3. 風向出現率

3.1. 年間ならびに月別風向出現率

測定高度 40m における風向の出現頻度は、表 3-1 及び図 3-1a～1b に示すとおりである。

当該地点は貿易風帯に位置しており、年間を通して東系（東～南東）が卓越(年 53%)していた。その他の風向は、冬季～春季(1 月~5 月)は北北東～北東（約 11~14%)が、夏季～秋季（6 月～11 月）は南南東（約 9～15%）が多くなっていた。

なお、風向計のアームが磁北に対して 22.5 度、東側に取り付けられていることから、風向の生データに+22.5 度の補正をおこなった。また、トンガ国における磁気偏角は東側 13.0 度であるが、風向生データは補正されているものと見做した。

表 3-1　月別風向出現率

(単位:%)

年　月	静穏	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	データ数
11年 1月	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
2月	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
3月	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
4月	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
5月	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
6月	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
7月	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
10年 8月	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
9月	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
10月	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
11月	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
12月	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
年　間	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

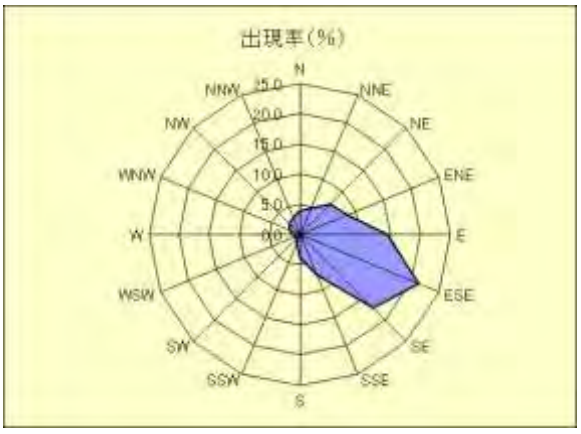


図 3-1a　年間風配図

注）貿易風；亜熱帯高圧帯から赤道低圧帯へ恒常的に吹く東寄りの風

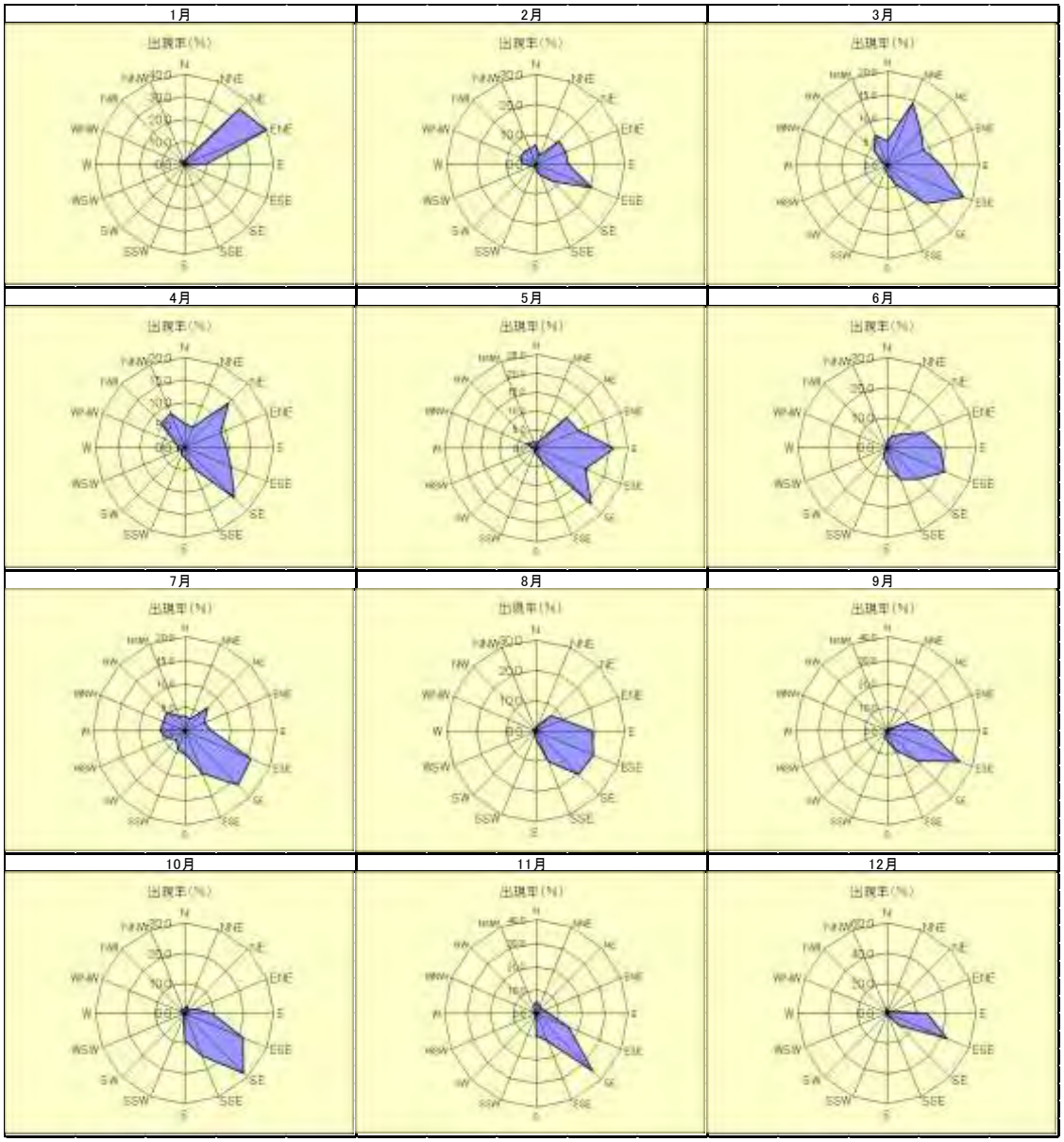


図 3-1b　月別風配図

3.2. 時間別風向出現率

高度 40m における年間の時間別風向出現率は、終日、東～南東の風向が卓越するが、特に日中から夕方(12 時～19 時)にかけては、東南東の出現が多くなっていた。また、朝方～夕方(10 時～18 時)にかけては、南東の出現が減少するのに対し、東南東及び東の出現が多くなっていた。

表 3-2　時間別風向出現率

(単位：%)

時間	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	計
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
平均	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

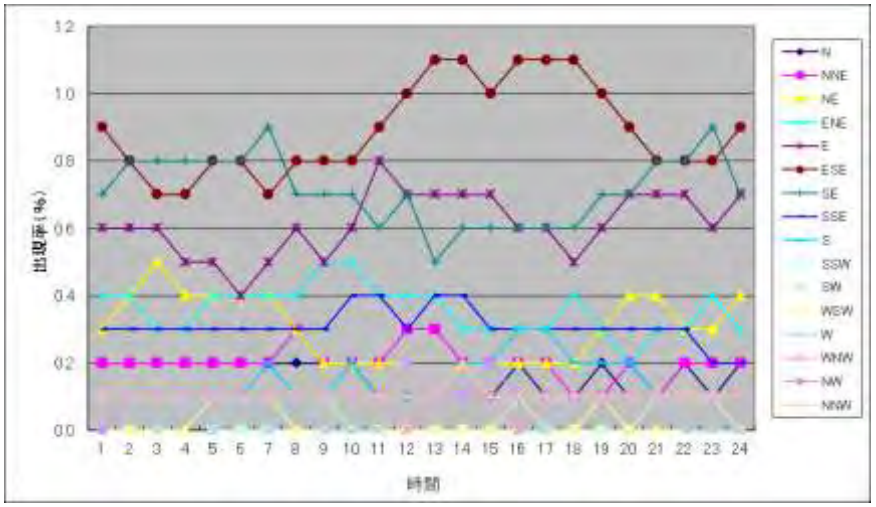


図 3-4　時間別風向出現率

4. 風向別風速階級別出現率と平均風速

風向出現率は、東南東が 21.3%の出現で卓越しており、東南東を中心とした東~南東の出現がほとんどで全体の 53%を占めていた。なお、風向の出現率と平均風速の傾向とは概ね一致していた。

表 4-1　風向別風速階級別出現頻度

(単位:%)

風速	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							
平均風速(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
風向出現率(%)	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

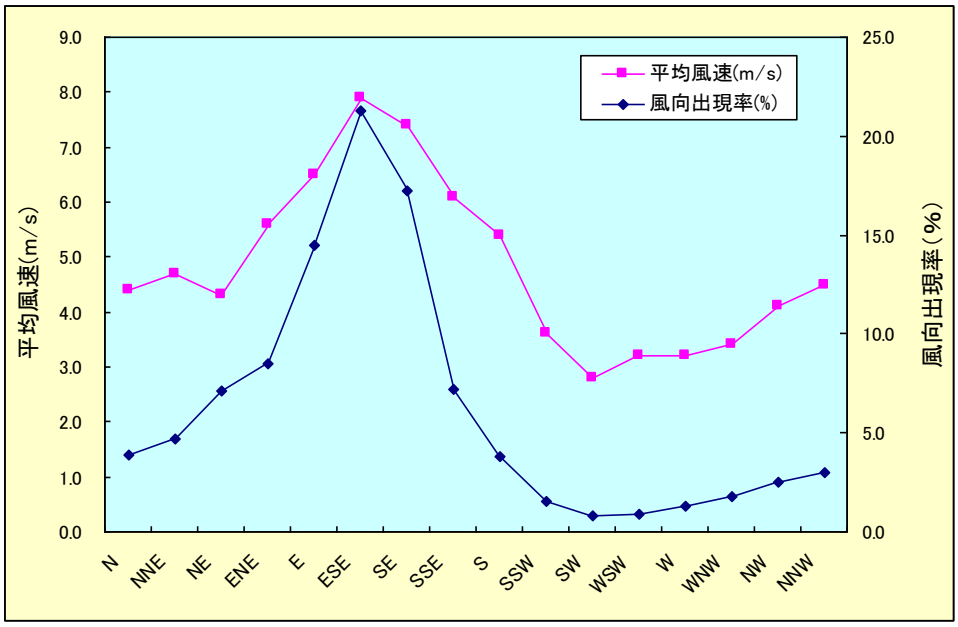


図 4-1　風向出現率と平均風速

5. 風速の鉛直分布

一般的に、風速は高度が増すにつれ増大する。地上付近から高度 300m 程度までの風速にはべき法則が当てはまると言われている。そこで、風速の鉛直分布を明らかにするため、べき指数を算出した。

べき法則は次式で定義される。

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

U ：高度Z における風速(m/s)

U_1: 高度Z_1における風速(m/s)

$1/n$: べき指数

べき指数は、地表面の粗度状態や大気安定度により変化するが、大気安定度が中立の場合のべき指数は、下表のとおりである。

べき法則の指数ｎ値の値

地面状態	n値
平坦な地形の草原・海岸地方	7～10
田園	4～6
市街地	2～4

高度 40m と高度 50m のデータを用いたべき指数（ｎ値）の算出結果は、表 5-1 に示すとおりであり、全方位で 3.5 であり、地面状態は市街地の値となっている。

方向別に見ると、卓越風向である東南東はｎ値が 5.2 であり、田園の値となっていた。他風向は、4.0 以下（市街地の値）となっており、周辺の樹木の影響等が表れているものと考えられる。

表 5-1　風向別べき指数

風向	平均風速(m/s)		n値	出現頻度(回)
	40m	50m		40m
N	4.4	4.8	2.3	332
NNE	4.7	4.7	ー	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	ー	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
全方位	6.2	6.5	3.5	8760

注）表中のーは、n 値がマイナス値もしくは１０以上の値。

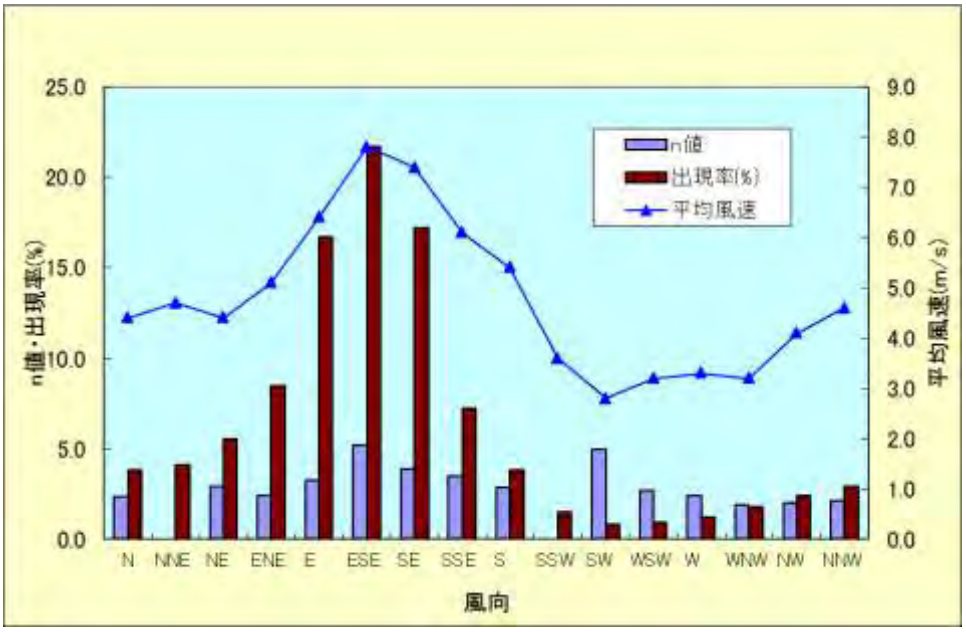


図 5-1　風向別べき指数

6. 乱れ強度

高度 40m における乱れ強度は、全方位平均で 0.15 で、下表の「地形タイプと乱れ強度の関係」に当てはめると平野のタイプを示した。なお、風速 15m/s 前後の乱れ強度は 0.11 であり、NEDO「高所風況精査マニュアル」の乱れ強度評価基準の 0.18 以下を十分満足していた。

地形タイプと乱れ強度の関係

地形タイプ	TI
海・湖	0.10
平野	0.15
丘陵地帯	0.20
低い山地	0.25
高い山地	0.30

表 6-1　風向別風速階級別乱れ強度（高度 40m）

風速(V)	風　向																
(m/s)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	計
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																	
計	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

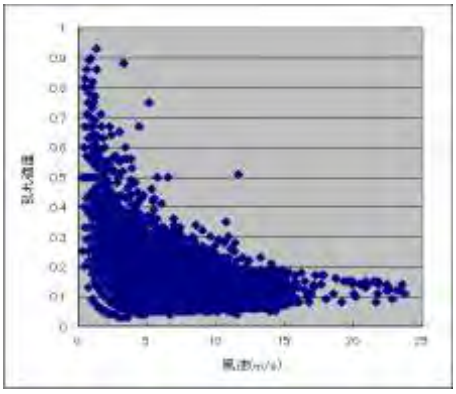


図 6-1　乱れ強度と風速の関係（高度４０m）

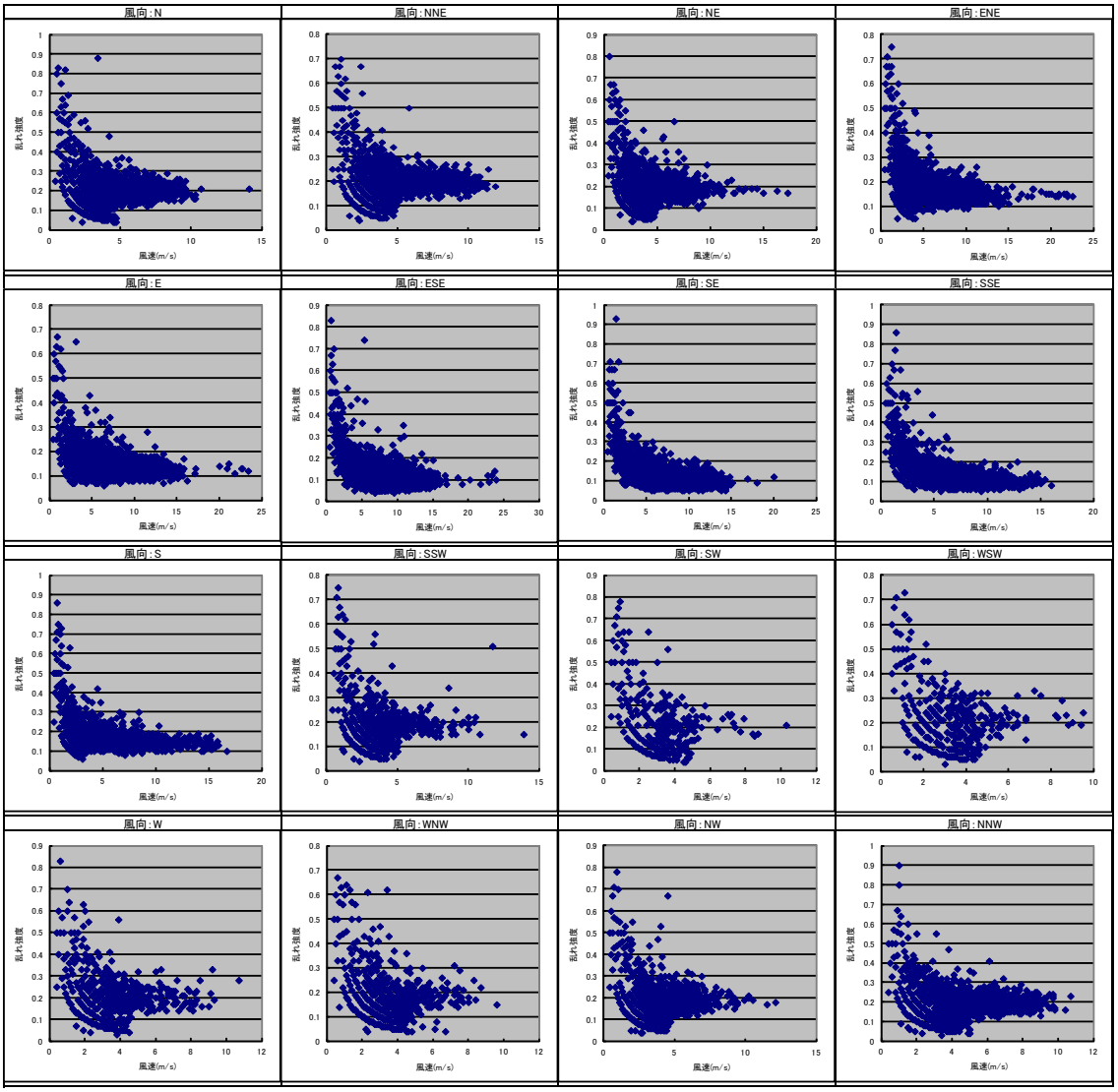


図 6-2　乱れ強度と１０分間平均風速との関係

7. 最大瞬間風速

観測期間中の最大瞬間風速は、32.9m/s（2011 年 1 月 25 日 1 時 00 分）であった。

300kW 級風車の耐風速は 70m/s で、観測期間中はこれを上回る風速の出現はなかった。

表 7-1　最大風速と最大瞬間風速[地上高 40m]

（単位:m/s）

月	2011							2010					期間最大
	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	
最大風速	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
最大瞬間風速	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

最大瞬間風速起時:2011年 1月25日　1:00

8. 風速の出現率

風速の階級別出現率は、4m/s 以上 5m/s 未満の階級の出現（14.3%）が最も多く、6m/s 以上の風速の出現率は、全体の約 48%を占めていた。なお、定格出力となる風速 12m/s 以上 25m/s 未満の出現率は、全体の約 3%であった。

風速の出現率分布は、ワイブル分布で近似出来ることが知られている。本調査においてもワイブルパラメータの形状定数 k 及び尺度定数 c を最小二乗法により算出した。なお、ワイブル関数は以下に示すとおりである。

算出した結果は、表 7-2 に示すとおりであり、年間のワイブルパラメータは、c=7.17、k=2.21 であった。

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

ここに、

$f(V)$ ： 風速 V の出現率（%）

c ： 尺度定数

k ： 形状定数

表 8-1　月別風速階級別出現率

(単位:%)

風速(m/s)	2011年							2010年					年間
	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	
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													
計	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

表 8-2　月別及び年間のワイブルパラメータ

定数	2011年							2010年					年間
	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	
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

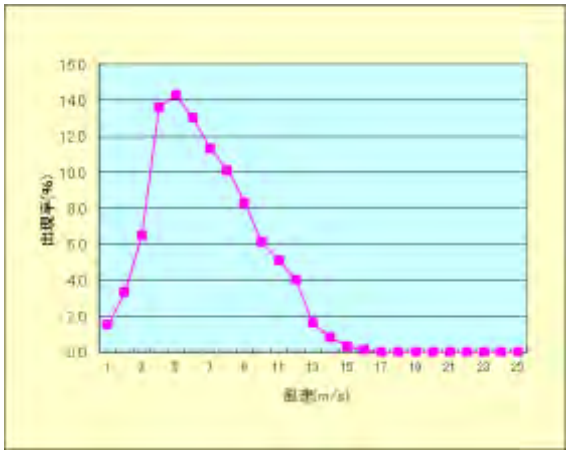


図 8-1　年間の風速出現率

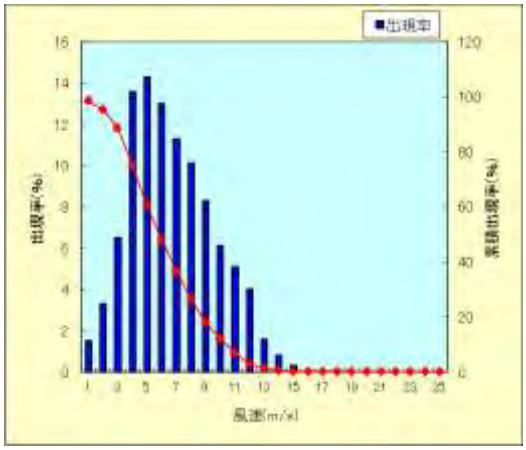


図 8-2　年間の累積風速出現率

9. 風力エネルギー密度

風力開発の潜在的量を評価するための風力エネルギー密度を、空気密度を標準大気（気温；15℃、大気圧；1013hPs、蒸気圧；17.05hPs）と当該地点（現地大気）の年平均値（気温；24.2℃、大気圧；1012.7hPs、蒸気圧；29.8hPs）を用いて算出した。なお、風力エネルギー密度は、次式により算出した。

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

P_0: 年間の風力エネルギー密度（w/㎡）

ρ：空気密度（kg/m^3）

v :1時間平均風速(m/s)

n ：対象期間の時間数

高度 40m におけるエネルギー密度は、全方位の標準大気では 244W/㎡、現地大気では 235W/㎡となっており、標準大気に比べ約 3%小さい結果となっている。

風向別では、東南東が最も大きく（405W/㎡;標準大気、390W/㎡;現地大気）、次に東（360W/㎡；標準大気、347W/㎡；現地大気）となっていた。

エネルギー取得率もエネルギー密度と同様に、東南東が 35.4%と最も大きく、次いで

東南の 25.3%となっていた。なお、東～南東の 3 方位だけでエネルギー取得率の約 76%を占めていた。（エネルギー取得率は、標準大気、現地大気の差異はなかった。）

表 9-1　風向別エネルギー密度及びエネルギー取得率

風向	ｴﾈﾙｷﾞｰ密度(W/㎡)		ｴﾈﾙｷﾞｰ取得率(%)	
	標準大気	現地大気	標準大気	現地大気
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
全方位	244	235	100.0	100.0

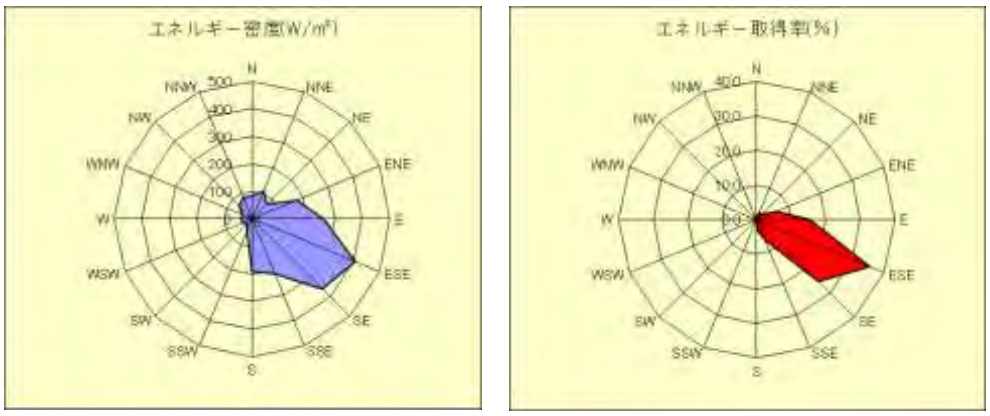


図 9-1　風向別エネルギー密度及びエネルギー取得率（標準大気）

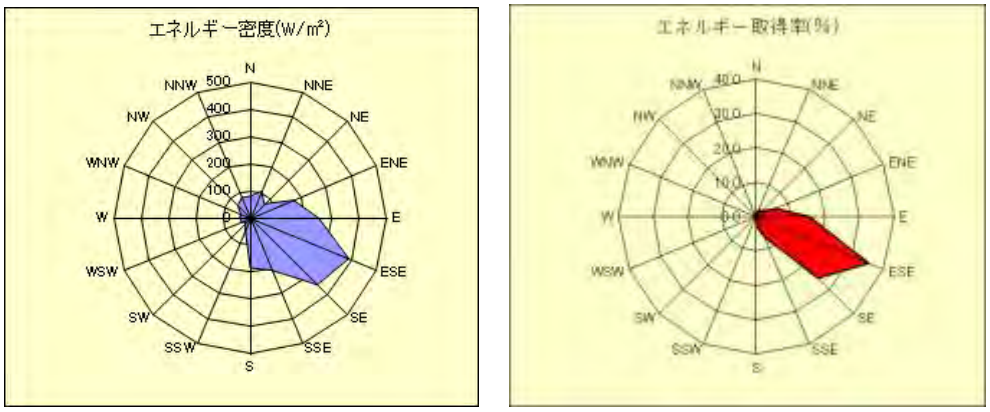


図 9-2　風向別エネルギー密度及びエネルギー取得率（現地大気）

10. 風車の稼働率

風車の稼働率の算定には、高度 40m の風速測定値を用いた。算定した結果は、表 10-1 及び図 10-1 に示すとおりである。

風車の稼働率は、年間で 88.7%であり、月別に見ると、2 月が 93. 8%と最も高く、7 月が 76. 7%と最も低かった。

ここで言うところの“稼働率”とは、運転可能な風速が得られた時間の合計値の、同期間の全暦時間に対する比を指す。

表 10-1　月別の風車稼働率

（単位:%）

年 月	250kW風車
11年 1月	86.8
2月	93.8
3月	85.9
4月	90.8
5月	83.6
6月	90.6
7月	76.7
10年 8月	91.9
9月	93.1
10月	89.9
11月	93.8
12月	88.3
年　間	88.7

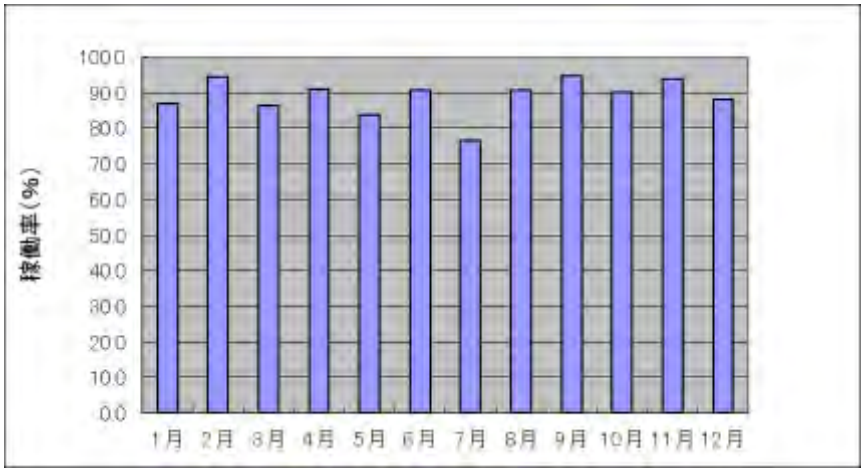


図 10-1　風車の稼働率

11. 風力エネルギー取得量及び設備利用率

11.1. 風力エネルギー取得量

高度 40m の 1 時間平均風速を 250kW 級風車の風車性能曲線（標準大気）に対応させ、毎時の値を累積して風力エネルギー取得量を算定した。

エネルギー取得量算定に使用した風車性能曲線は、300kW 級風車の定格出力を 250kW に設定したものを使用して行った。

その結果、年間の風力エネルギーの取得量は、565MWh であった。風力エネルギー取得量が最も多い月は 10 月で約 69MW h 、最も少ない月は 4 月で、約 24MW h となっていた。

なお、現地大気で算定した、風力エネルギー密度が標準大気での算定に対し、約 3%程度小さくなることから、風力エネルギー取得量も約 3%程度少なくなるものと考えられる。

250 k W級風車の風車性能曲線は、図 11-3 に示すとおりである。

表 11-1　月別風力エネルギー取得量

風車No.	項　目	2010年					2011年							計
		8月	9月	10月	11月	12月	1月	2月	3月	4月	5月	6月	7月	
トンガ	ｴﾈﾙｷﾞｰ取得量(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
	平均風速(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
	稼動率（%）	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
	設備利用率（%）	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

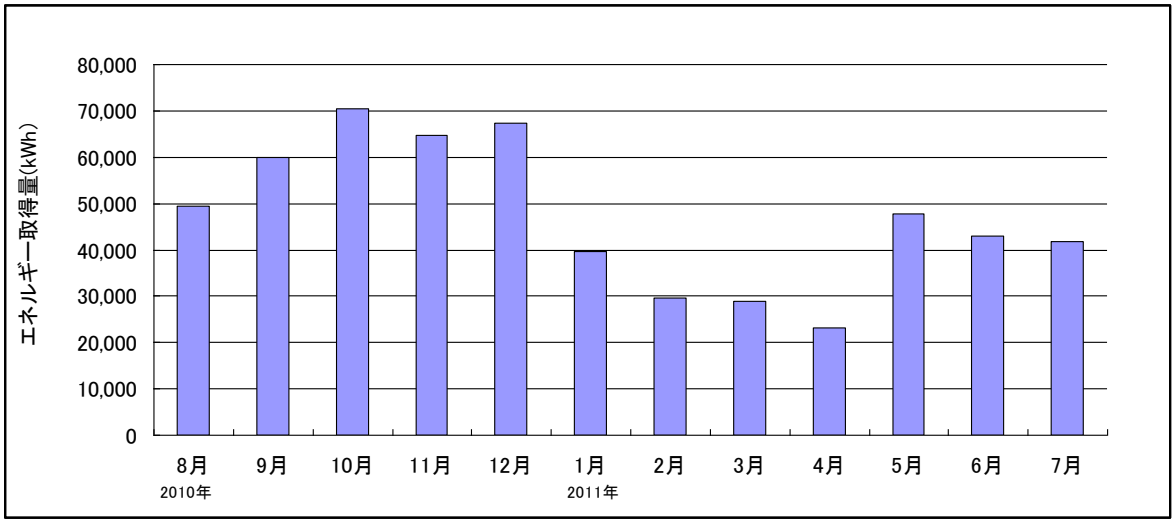


図 11-1　月別風力エネルギー取得量

表 11-2　風向別エネルギー取得量

風車No.	項　目	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	計
トンガ	ｴﾈﾙｷﾞｰ取得量 (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

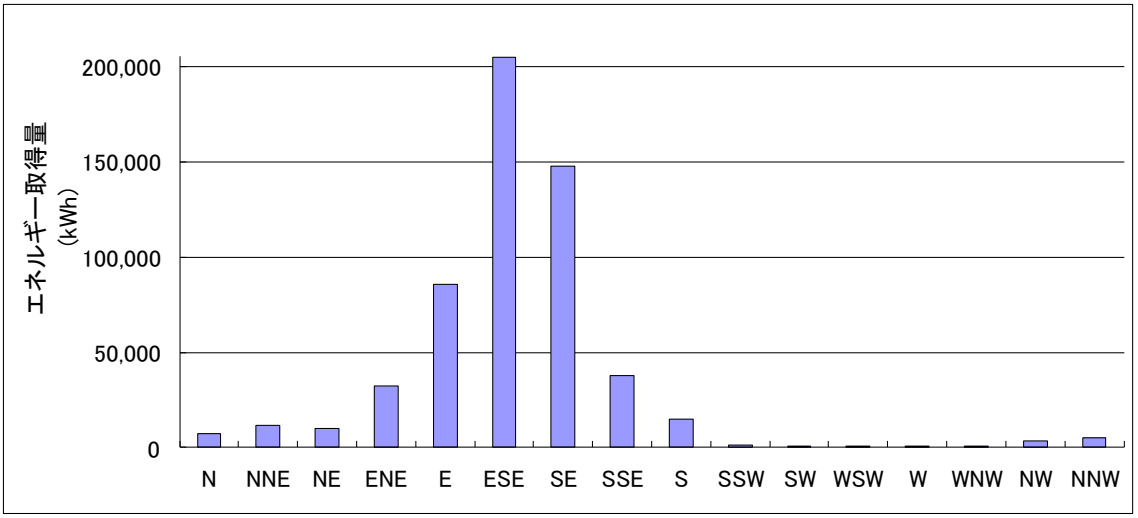


図 11-2　風向別エネルギー取得量

風速 (m/s)	発電出力(kW) ２５０ｋＷ風車
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
カットイン風速 (m/s)	3.0
定格風速 (m/s)	11.5
カットアウト風速 (m/s)	25.0

注）空気密度1.225kg/㎥時の標準性能曲線

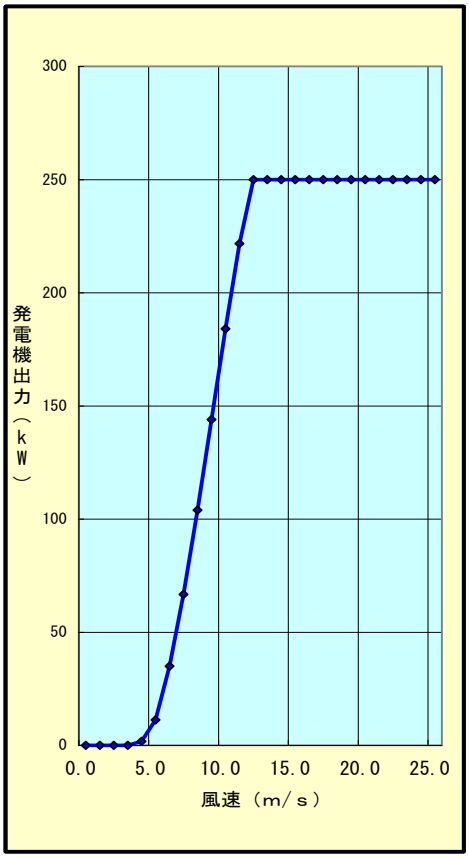


図 11-3　250kW 風車の風車性能曲線

11.2. 風車の設備利用率

標準大気で算定した、発電量に基づいて算定した風車設備利用率は、表 11-3 及び図 11-4 に示すとおりであり、年間の設備利用率は 25.8%であり、10 月が最も高く 37. 0%、4 月が最も低く 13.3%であった。

なお、現地大気を用いた場合は、標準大気で算定した設備利用率の約 3%減となるものと考えられる。

表 11-3　月別風車設備の利用率

（単位:%）

年 月	250kW風車
11年 1月	21.6
2月	17.6
3月	14.8
4月	13.3
5月	25.8
6月	23.7
7月	22.4
10年 8月	27.5
9月	32.9
10月	37.0
11月	36.2
12月	36.0
年 間	25.8

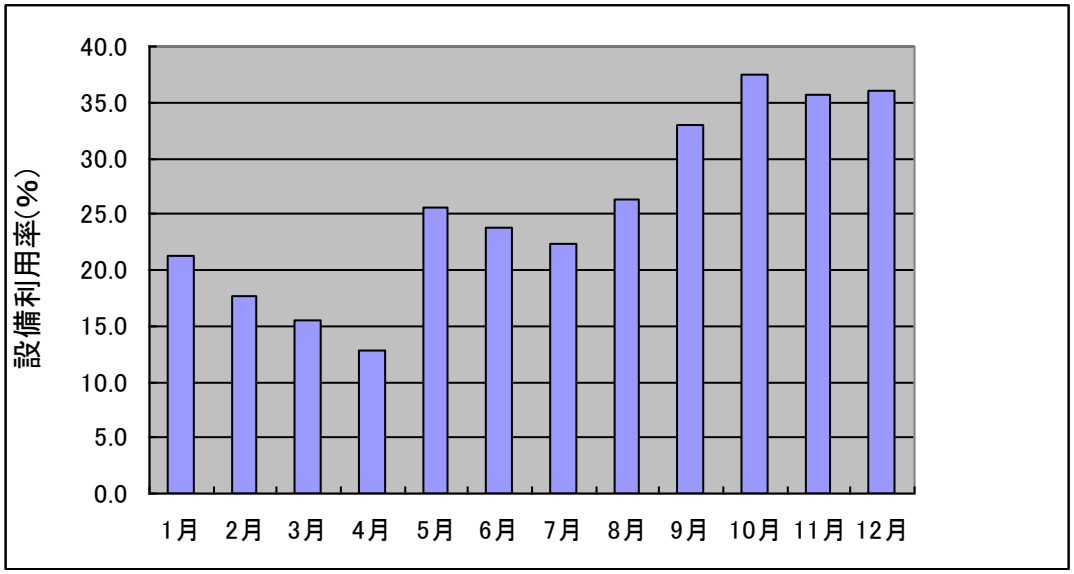


図 11-4　月別風車の設備利用率

12. まとめ

12.1. 風況特性

- 年平均風速（地上高40m）は、6.2m/sで、月別では10月～11月最も強く(7.2m/s)、3月～4月及び7月にやや弱くなる（5.1～5.5m/s）傾向が見られた。

- 風向の出現は、東(14.5%)、東南東（21.3%）及び南東（17.2%）の出現が多く、この３方向の風が卓越している。東～南東(53.0%)が主風向と考えられる。

- べき指数（ｎ値）は、全方位でn=3.5（市街地の値に相当）であった。
  卓越風向の東南東は、n= 5.2で田園の値であった。

- 乱れ強度は、全方位の平均で0.15で、平野のタイプを示していた。また、風速15m/s前後の乱れ強度は、0.11で、評価基準の0.18以下を十分満足していた。

- 観測期間中の最大瞬間風速は、32.9m/s（2011年1月25日1時00分）であった。
  300kW級風車の対風速は70m/sであり、この値を下回っていることから、当該地域において風車の耐風速を上回るような可能性は少ないものと考えられる。

- 風速階級別出現率は、4m/s以上5m/s未満の階級の出現率（約14%）が最も多い。また、定格出力となる風速12m/s以上25m/s未満の風速の出現率は全体の約3%出現していた。

- 年間のワイブルパラメータは、C=7.17、K=2.21であった。

12.2. 風力エネルギー

エネルギー密度は全方位の標準大気では 244W/㎡、現地大気では 235W/㎡で、標準大気に比べ 3%程度小さい。

風力発電開発が有望とされるエネルギー密度は 240W/㎡（地上高 30m）以上とされているが、上記結果では、NEDO の基準を若干下回るものと考えられる。

しかしながら、昨今の国内風力発電事業実施の目安は、風車ハブ高さで風速 6m/s 以上となっており、地上高 40m で風速 6.2m/s であり、事業化に向けて期待出来る値となっている。

12.3. 設備利用率及び稼働率

設備利用率および風車の稼働率は、それぞれ 25.7%、88. 7%であり、NEDO の基準値（設備利用率 20%以上、風車の稼働率 45%以上）を十分満足していた。

12.4. 総合評価

風況の解析結果によれば、年平均風速や年間風力エネルギー密度等の風速条件は、概ね基準に、設備利用率及び風車の稼働率は、基準を十分満足していることから、風力開発の導入可能性は十分あると評価される。

なお、風速の鉛直分布解析の結果、べき指数 n が市街地の値を示していることから、風車配置検討の際は地表面粗度の影響を考慮（周辺樹木の伐採等）する必要があると考えられる。また、複数基の配置の場合、風車間の干渉による風速の減速等を避けるため、東北東の方向に直角に最低３D〔D：ブレードの直径(m)〕の離隔を確保する必要があると考えられる。

風況の解析結果は表 12-1 に示すとおりである。

また、設備容量 500MW 風車が得るエネルギー取得量は標準大気条件および現地大気条件において、以下のように見積られる。

構成	エネルギー取得量	条件
設備容量 500kW 風車（250kW 風車 x 2 基）	1,130 MWh/年	標準大気条件
	1,096 MWh/年 (約 1.1GWh/年)	現地大気条件

なお、上記のエネルギー取得量はグロス出力である。

ネット出力を想定する場合、停止ロス（計画保守による停止）、機械的ロス（減速機によるロス、風向追従遅れによるロス等）および電気的ロス（変圧器ロス、連系点までの送電ロス等）を考慮する必要があり、一般的に総計 20%程度と見積もることができる。

すなわち、グロス出力から 20%程度を減じた値がネット出力（正味出力）と想定することができる。

表 12-1　風況解析結果

解析項目		解析結果	評 価	備 考
平均風速	年平均値	6.2 m/s	良（基準 1）	
	最大値	7.2 m/s		11 月
	最小値	5.1 m/s		3 月
風向	卓越風向	東南東(21.3%)		
	風軸	東南東-西北西 （東-西） （南東-北西） 58.6%	概ね良（基準 2）	風軸とは、16 方位の風向を対象に、主風向とその隣にある 2 風向と、これらの風向と対称となる風向の合計 6 方位を指す。
風向と風速の関係		ほぼ一致		
瞬間最大風速		32.9 m/s	良（基準 3）	2011 年 1 月 25 日1時 00 分
乱れ強度	全方位	0.15	良（基準 4）	
	風速 15m/s	0.11		
風速の鉛直分布（べき指数:n）		3.5	否（基準 5）	卓越風向（東南東）は 5.2 で、概ね良
ワイブルパラメータ	形状定数（k）	7.17		
	尺度定数（c）	2.21		
風力エネルギー密度（全方位）		244 W/m^2（235 m^2）	概ね良（基準 6）	（）内は現地大気で算定した値
稼動率		88.7%	良（基準 7）	
エネルギー取得量		565 MW		定格出力 250 kW 風車の場合
設備利用率		25.8%	良（基準 8）	

基準 1：年平均風速が 6 m/s 以上。
基準 2：風軸上の年間風向出現率が 60%以上。
基準 3：瞬間最大風速が風車の耐風速(70 m/s)以下。
基準 4：乱れ強度は 1.8 以下（風速 15 m/s 前後の乱れ強度）。
基準 5：べき指数（n 値）は大きくシアーが少ないこと。
基準 6：風力エネルギー密度は、240 W/m^2 以上。
基準 7：風車の年間稼働率は 45%以上。
基準 8：風車の年間設備利用率は 20%以上。

注）上記基準は NEDO（新エネルギー・産業技術総合開発機構）が定めた以下のマニュアルおよびガイドブックより引用した。

・風況精査マニュアル（1997 年 12 月　概要版）
・高所風況精査マニュアル（2006 年 2 月）
・風力発電導入ガイドブック（2008 年 2 月　改訂第 9 版）

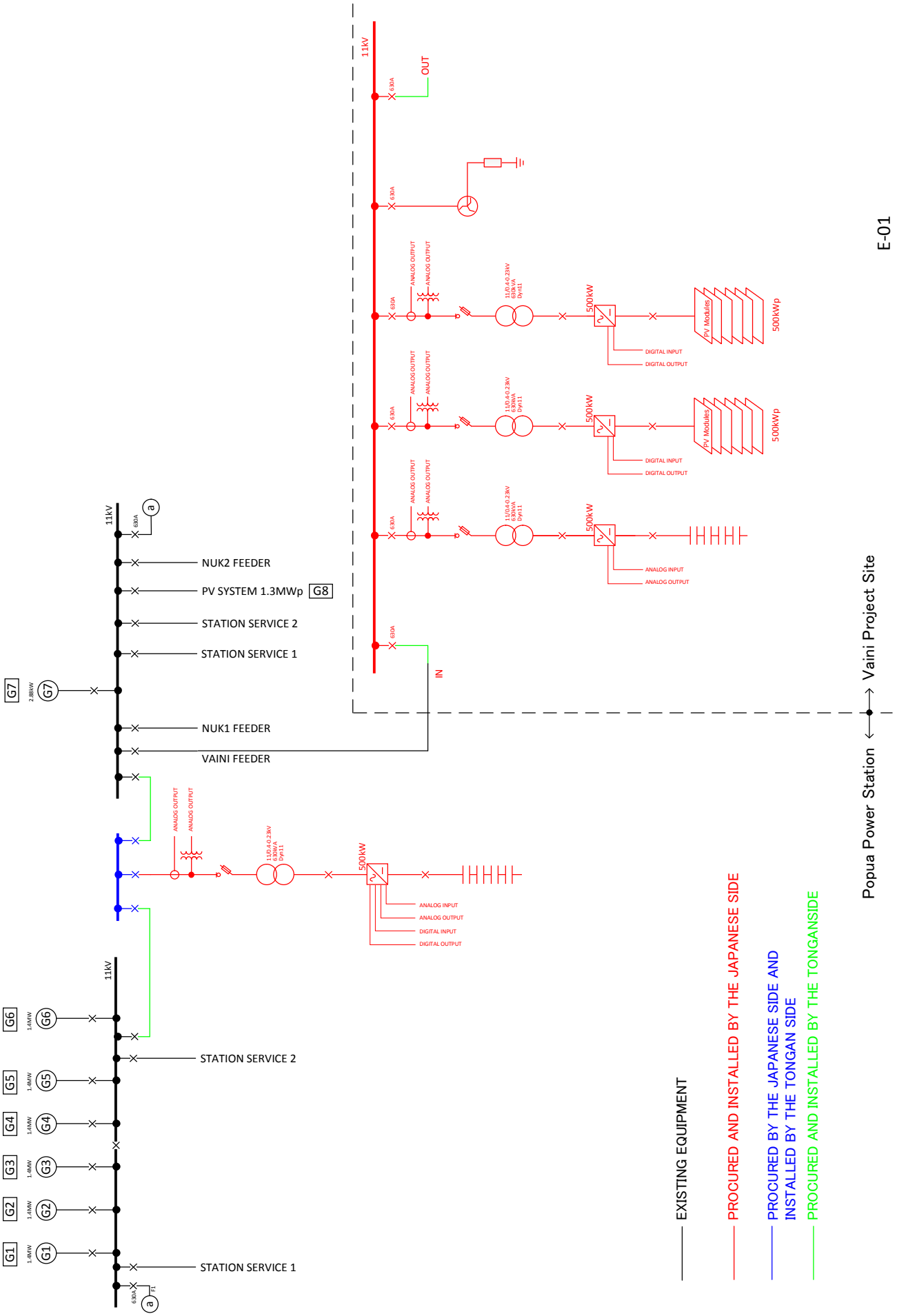
A-10 概略設計図

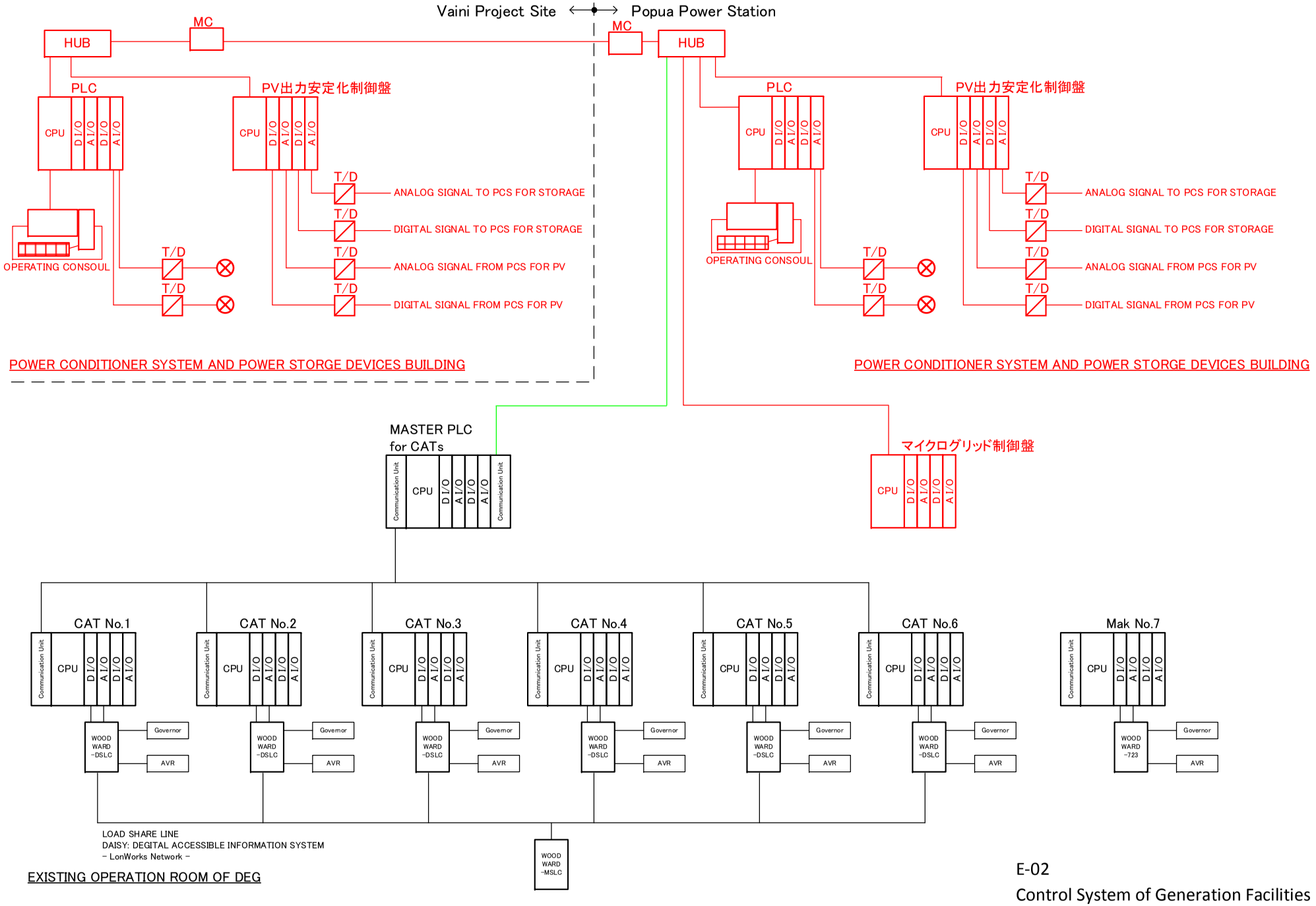
Drawing List

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





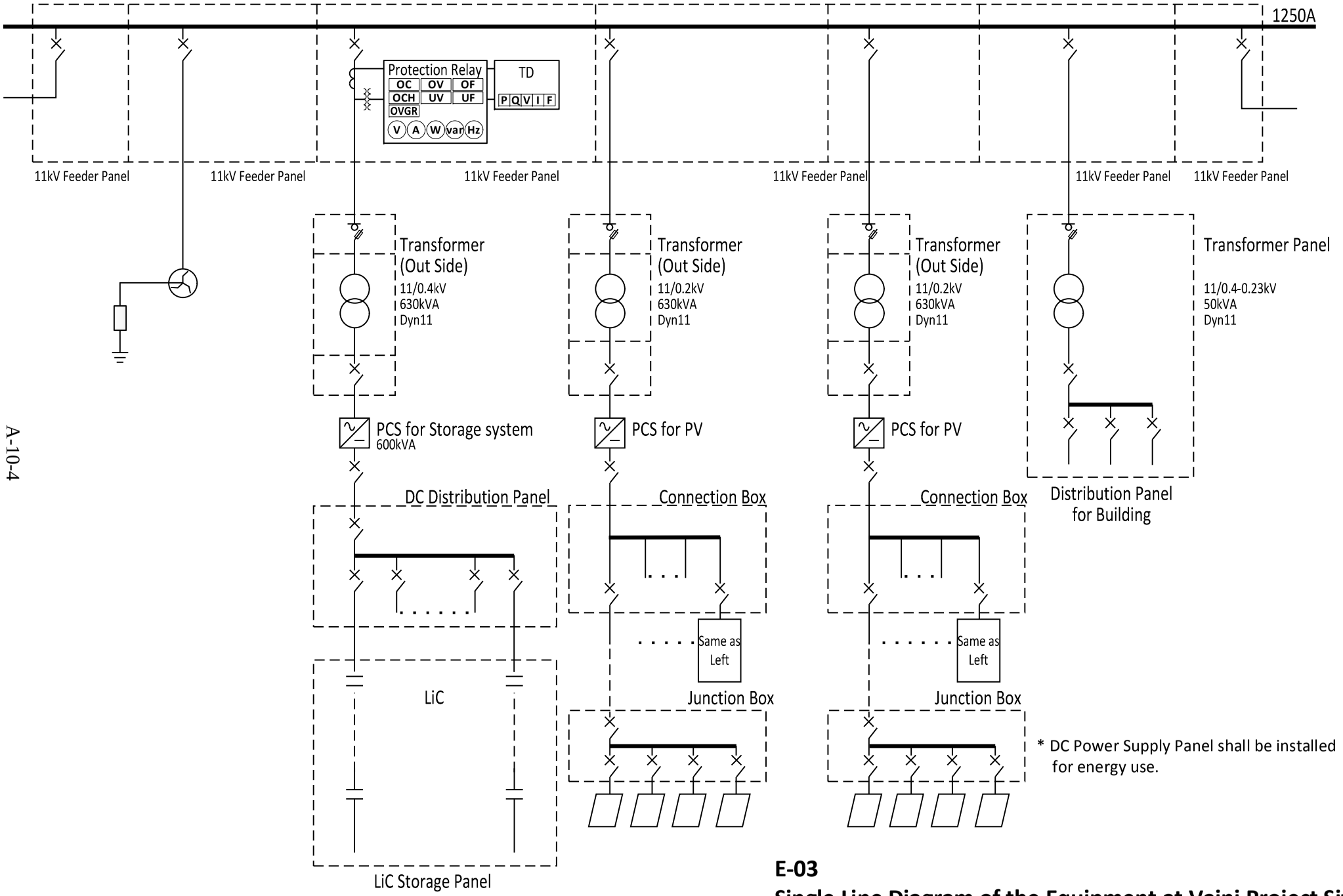
A-10-3

A-10

E-02

Control System of Generation Facilities

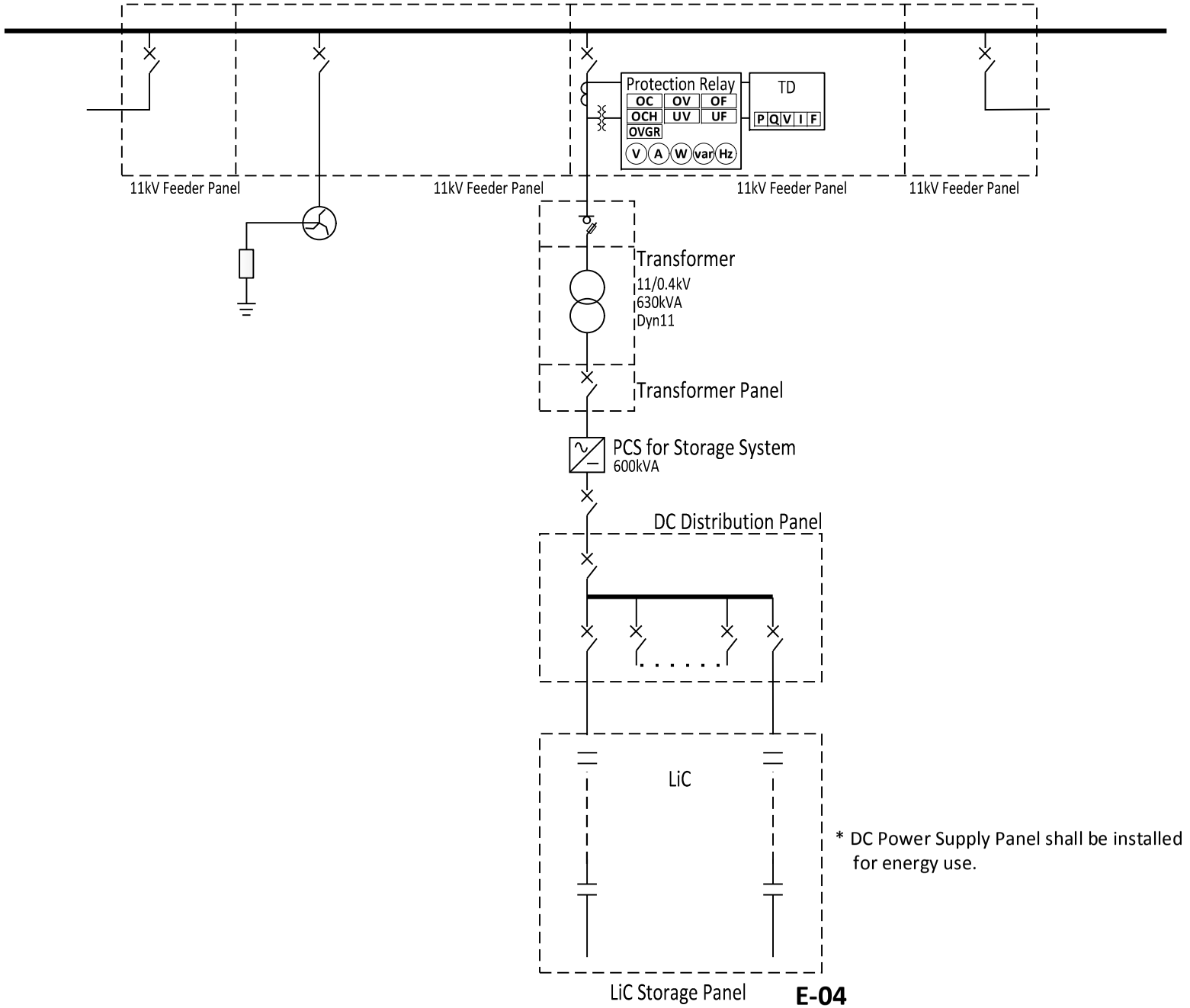
発電設備システムの制御システム



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



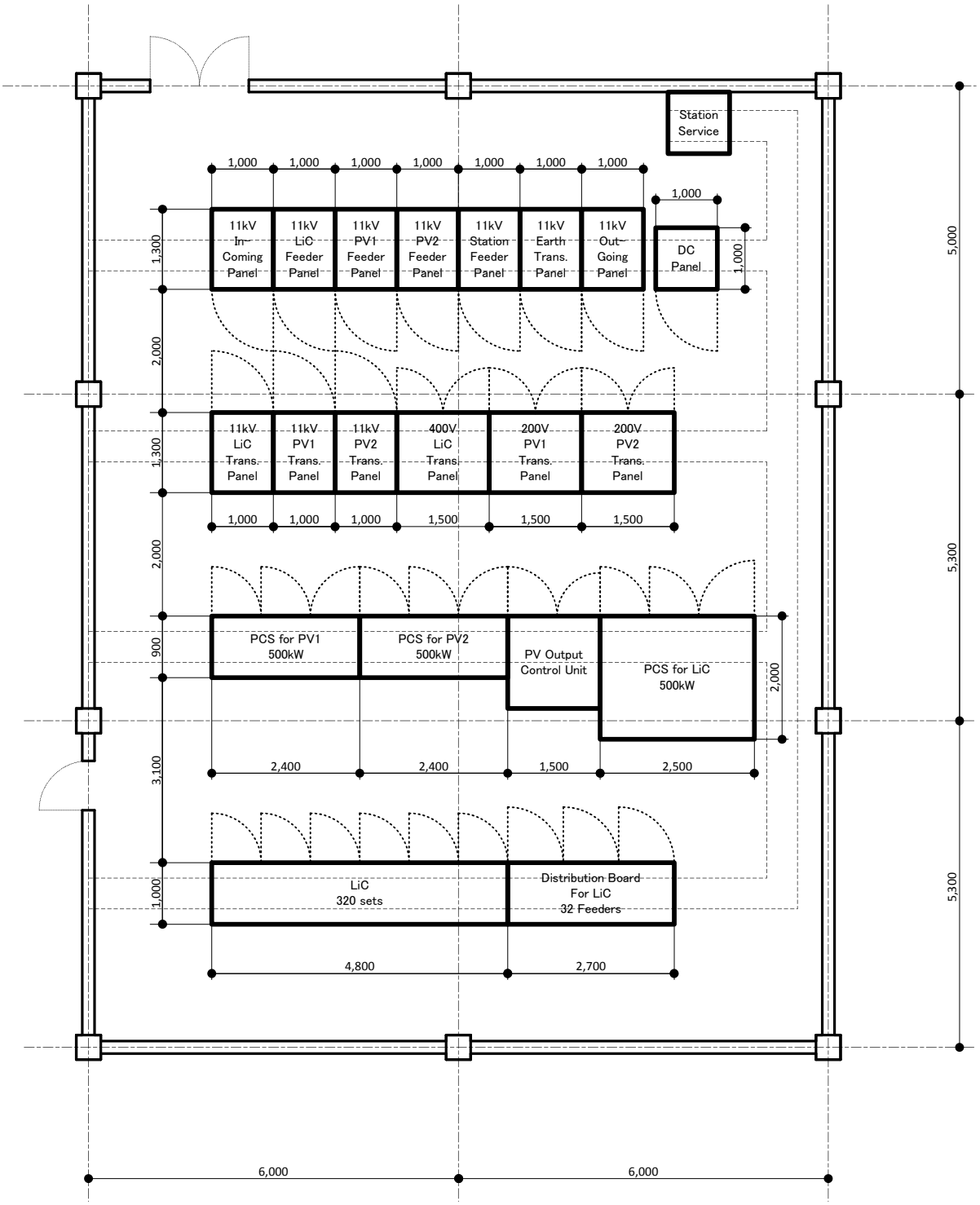
* DC Power Supply Panel shall be installed for energy use.

E-04

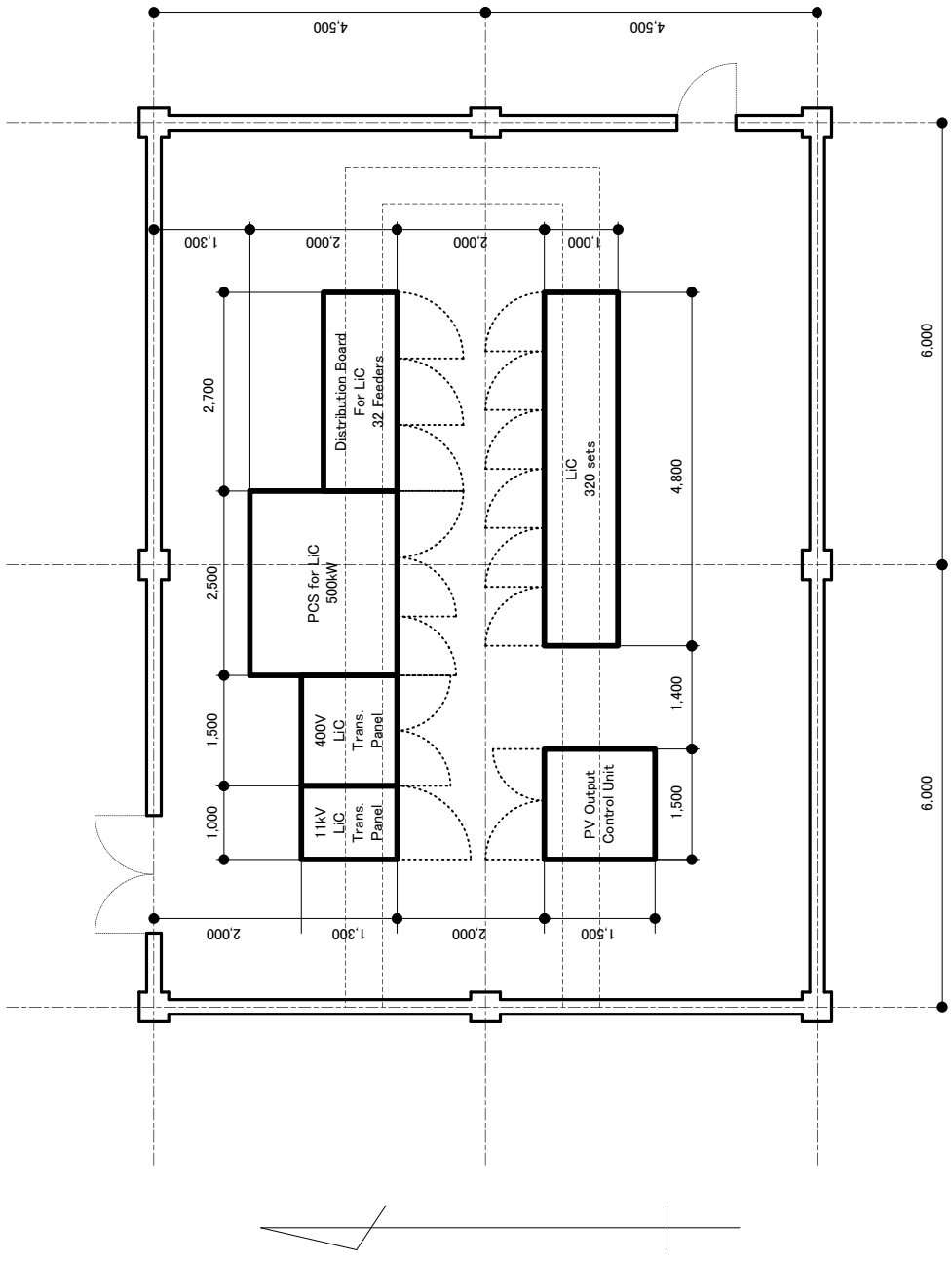
Single Line Diagram of the Equipment at Popua Power Station

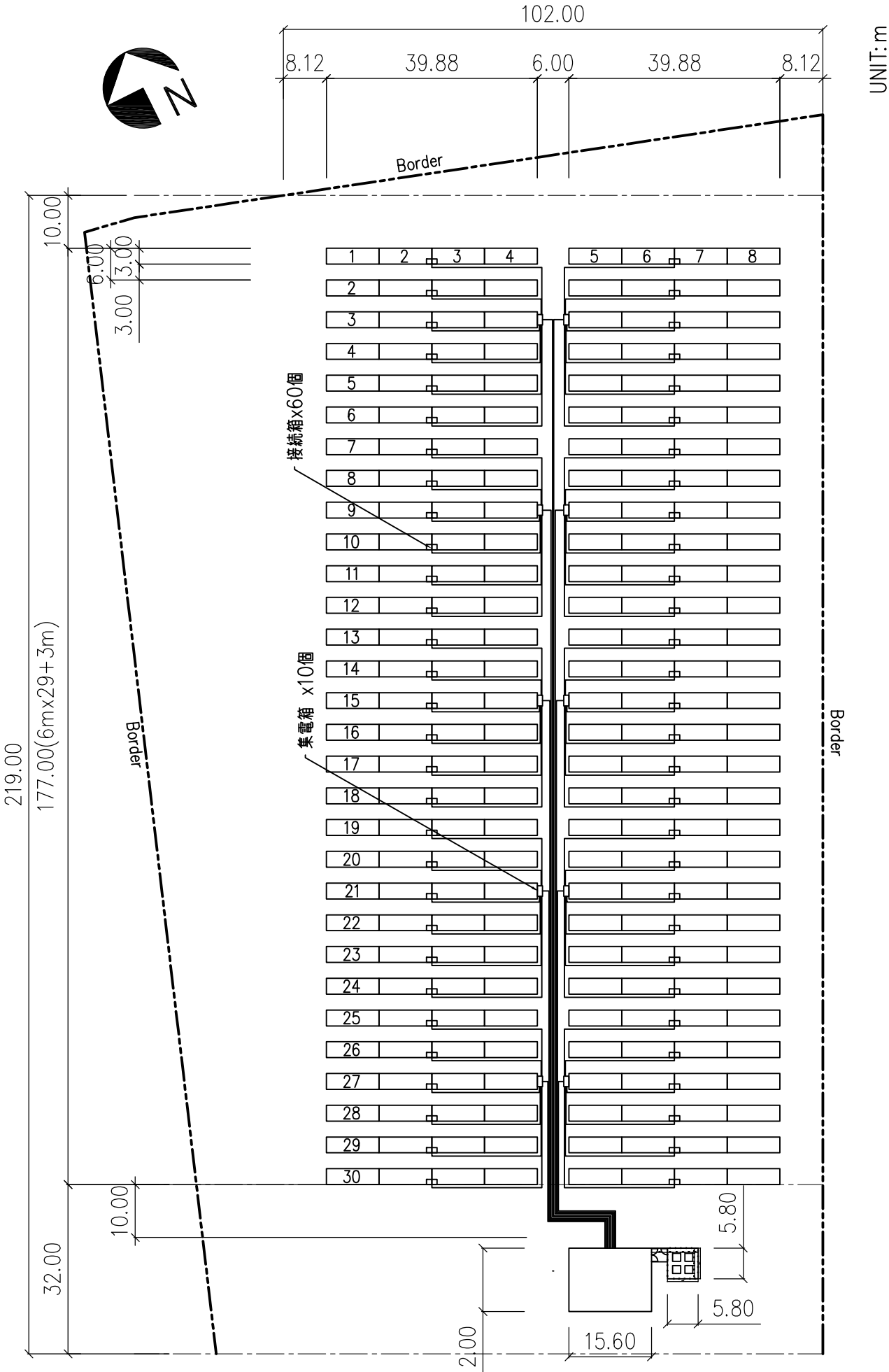
ポプア発電所側の対象設備の単線結線図

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



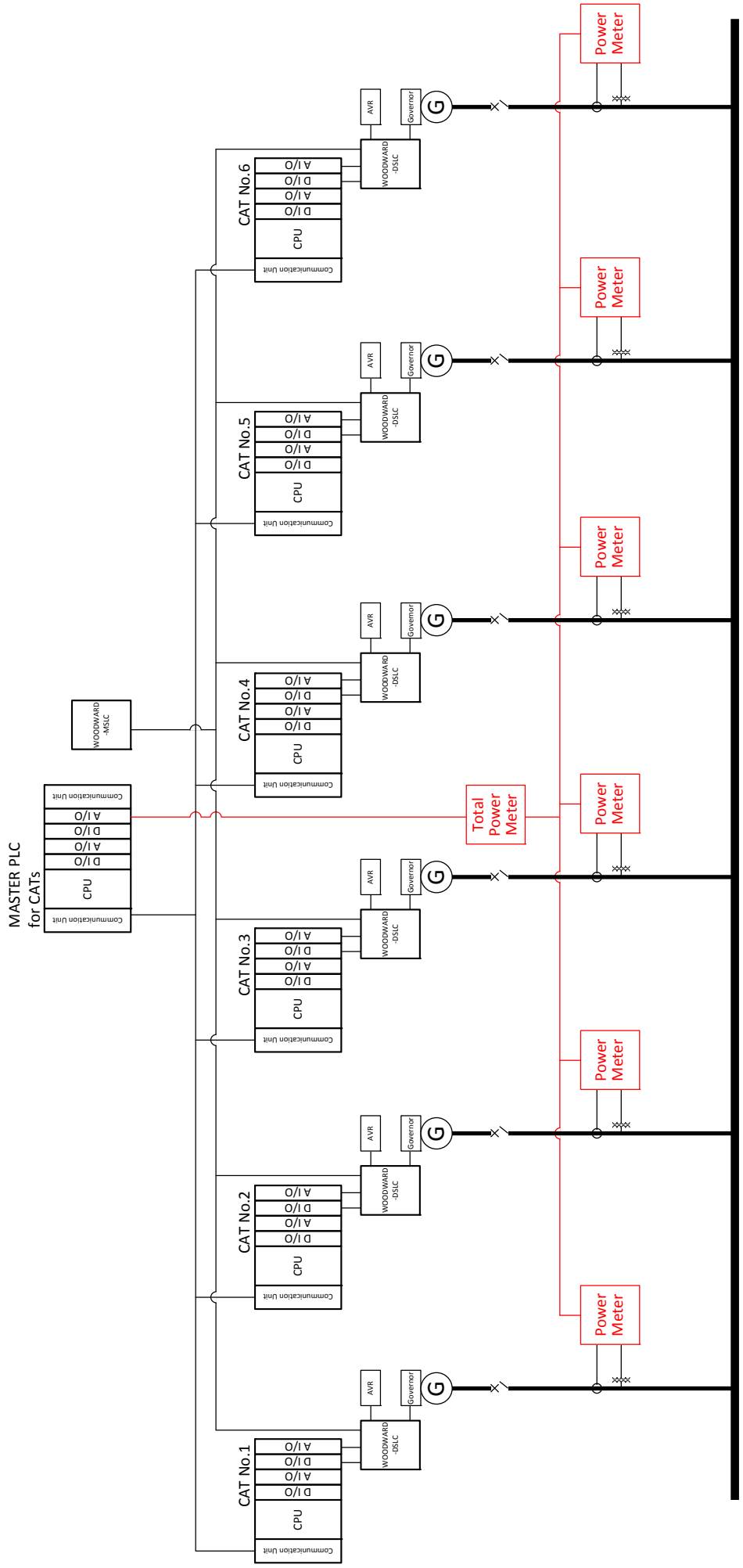
E-06
Layout of the Equipment at Popua Power Station
ポプア発電所側の対象設備の機材配置





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



A-11　収集資料リスト

収集資料リスト

調査名：マイクログリッドシステム開発・導入計画準備調査（トンガ王国）

番号	資料の名称	形態 図書・ビデオ 地図・写真等	オリジナル ・コピー	発行機関	発行年
1	TERM Structure	電子媒体	コピー	Tonga Energy Road Map	Aug. 2012
2	TPL Organisation Chart August 2012	電子媒体	コピー	Tonga Power Limited	Aug. 2012
3	Meteorological Data for Fua'amotu 2011	電子媒体	コピー	Tonga Meteorological Service	Sep. 2012
4	Single Line Diagram	電子媒体	コピー	Tonga Power Limited	Aug. 2012
5	All Data TPL 2011	電子媒体	コピー	Tonga Power Limited	Aug. 2012
6	Trans Data TPL 20120821	電子媒体	コピー	Tonga Power Limited	Aug. 2012
7	Conductor Clearances	電子媒体	コピー	Tonga Power Limited	Dec. 2009
8	TPL Annual Report 2009	電子媒体	コピー	Tonga Power Limited	Oct. 2009
9	TPL Annual Report 2010	電子媒体	コピー	Tonga Power Limited	Oct. 2010
10	TPL Annual Report 2011	電子媒体	コピー	Tonga Power Limited	Oct. 2011
11	TPL Draft FS- 30 June 2012	電子媒体	コピー	Tonga Power Limited	Oct. 2012
12	Summary of donor activities	電子媒体	コピー	Tonga Energy Road Map	Jun. 2012
13	TERM Donor Project Matrix	電子媒体	コピー	Tonga Energy Road Map	Oct. 2012
14	Land Act	電子媒体	コピー	Ministry of Land, Environment, Climate Change and Natural Resources (MLECCNR)	2007
15	Major EIA, Popua 1MW Solar Farm	電子媒体	コピー	Tonga Power Limited	Feb. 2011
16	Environmental Impact Assessment Regulations 2010	電子媒体	コピー	MLECCNR	Oct. 2010
17	Environmental Impact Assessment Act 2003	電子媒体	コピー	MLECCNR	Sep. 2003
18	Birds and Fish Preservation Act	電子媒体	コピー	MLECCNR	1988
19	Birds and Fish Preservation Amendment Act 1989	電子媒体	コピー	MLECCNR	Dec. 1989
20	EIA Project Procedure Flowchart	電子媒体	コピー	MLECCNR	Aug. 2012
21	Environment Management Act 2010	電子媒体	コピー	MLECCNR	Aug. 2010
22	Hazardous Wastes and Chemicals Act 2010	電子媒体	コピー	MLECCNR	Aug. 2010
23	Parks and Reserves Act	電子媒体	コピー	MLECCNR	1988
24	Declaration of Parks and Reserves	電子媒体	コピー	MLECCNR	1988
25	Renewable Energy Amendment Act 2010	電子媒体	コピー	MLECCNR	Sep. 2010
26	Waste Management Act 2005	電子媒体	コピー	MLECCNR	Jan. 2006
27	Waste Management Amendment Act 2009	電子媒体	コピー	MLECCNR	Apr. 2010
28	Renewable Energy Act 2008	電子媒体	コピー	MLECCNR	Jun. 2009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