Republic of Fiji
Ministry of Infrastructure and Transport
Fiji Electricity Authority (FEA)

THE PROJECT FOR THE EFFECTIVE AND EFFICIENT USE OF RENEWABLE ENERGY RESOURCES IN POWER SUPPLY IN REPUBLIC OF FIJI

FINAL REPORT

FEBRUARY 2015

Japan International Cooperation Agency
Tokyo Electric Power Services Company, Ltd.

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[Table of Volumes]

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Abbreviations

Abbreviations	Words
B/C	Benefit / Cost
CER	Certified Emission Reduction
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CO_2	Carbon Dioxide
C/P	Counterpart
D/C	Double Circuit
DF/R	Draft Final Report
DOE	Department of Energy
DoEnv	Department of Environment
DOF	Department of Forestry
DSM	Demand Side Management
EIA	Environmental Impact Assessment
EIB	European Investment Bank
EIRR	Economic Internal Rate of Return
FCC	Fiji Commerce Commission
FEA	Fiji Electricity Authority
FFI	Fiji Forest Industries
FIBO	Fiji Islands Bureau of Statics
FIP	Feed-in Premium
FIRR	Financial Internal Rate of Return
FIT	Feed-in Tariff
FJD	Fiji Dollar
FMS	Fiji Meteorological Service
F/S	Feasibility Study
FSC	Fiji Sugar Corporation
F/R	Final Report
GDP	Gross Domestic Product
GoF	Government of Fiji
IC/R	Inception Report
IDO	Industrial Diesel Oil
HFO	Heavy fuel oil
IBA	Important Bird Areas
IEA	International Energy Agency
IEE	Initial Environmental Examination
IPP	Independent Power Producer
IT/R	Interim Report
JBIC	Japan Bank for International Cooperation
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
LILO	Loop-In-Loop-Out
LOLE	Loss of Load Expectation
LOLP	Loss of Load Probability
LRMC	Long Run Marginal Cost
METI	Ministry of Economy, Trade and Industry of Japan
MWTPU	Ministry of Works, Transport and Public Utilities
NBSA	National Biodiversity Strategy and Action Plan

NEF	New Energy Foundation
NPV	Net Present Value
NEP	National Energy Policy
NLC	Native Lands Commission
O&M	Operation and Maintenance
OJT	On the Job Training
PAC	Fiji National Protected Area Committee
PCCPP	Peoples Charter for Change Peace and Progress
PDP	Power Development Plan
Pre-F/S	Preliminary Feasibility Study
PR/R	Progress Report
PS	Power Station
PWD	Public Works Department
PDPAT	Power Development Plan Assist Tool
RDSSED	Roadmap for Democracy and Sustainable Socio-economic Development
RE	Renewable Energy
RESCO	Renewable Energy Service Company
RETICS	Reliability Evaluation Tool for Inter-Connected Systems
REU	Rural Electrification Unit
RPS	Renewable Portfolio Standard
S/C	Single Circuit
SCF	Standard Conversion Factor
SEA	Strategic Environmental Assessment
SHM	Stake Holder Meeting
SHS	Solar Home System
TDR	Transmission Distribution Retail
TEPSCO	Tokyo Electric Power Services Co., Ltd.
TLTB	iTaukei Land Trust Board
TOR	Terms Of Reference
TWC	Tropik Wood Corporation
TWI	Tropik Wood Industries
VLIS	Viti Levu Interconnected System
WAF	Water Authority of Fuji

1. Introduction

1.1 Background and Objectives of the Project

The Fiji Electricity Authority (FEA) supplies electricity through its grid systems on three islands, Viti Levu, Vanua Levu and Ovalau, with a total installed capacity of 258MW.

The increase of fuel prices in the 2000s had a negative impact on the financial coffers of FEA and the Country as a whole. Against this background, in 2006 the Government of Fiji set the target of the ratio of renewable energy to fossil fuels utilized in on-grid power generation to be 90 : 10 by 2011[1].

FEA has in its Mission Statement published in 2011, "… aims to provide clean and affordable energy solutions to Fiji with at least 90% of the energy requirements through renewable sources by 2015". This means a target for maximum renewable energy generation using hydropower, biomass, and wind, either through FEA's generation or with assistance from the Independent Power Producers (IPPs). Considering the current situation, the further development and utilization of renewable energy, particularly exploitation of hydro and biomass energy should be accelerated in power sector.

Through the following five (5) activities, the Project, which covers Viti Levu and Vanua Levu in Republic of Fiji, aims at preparing hydropower development site map and overall development schedule until 2025, and examining/propounding the optimum composition of renewable energy resources in the power sector in Fiji until 2025, that will contribute to stabilization in power supply and reduction in fossil fuel consumption for power generation in the country by promoting renewable energy resources;

1) Collection and Analysis of Relevant Data and Information
2) Hydropower Potential Study
3) Preliminary design of prospective hydropower projects
4) Identification of biomass resources potential sites.
5) Preparation/Recommendations of hydropower development plan and optimum composition of renewable energy resources in the power sector until 2025

In addition, through the joint works with personnel concerned in Fiji, the Project contributed to technology transfer and human resource development in the area of hydropower development planning.

1.2 Project Areas

Viti Levu and Vanua Levu in Republic of Fiji

[1] In the next national energy policy (not yet officially endorsed as of Jan. 2015), the target of renewable energy share in electricity generation is 81% by 2020 and 100% by 2030.

1.3 Relevant Government Offices and Organizations

- Department of Energy, Ministry of Infrastructure and Transport
- Fiji Electricity Authority (FEA)

1.4 Project Schedule

From September 2013 to February 2015.

2. Power Supply and Demand Conditions

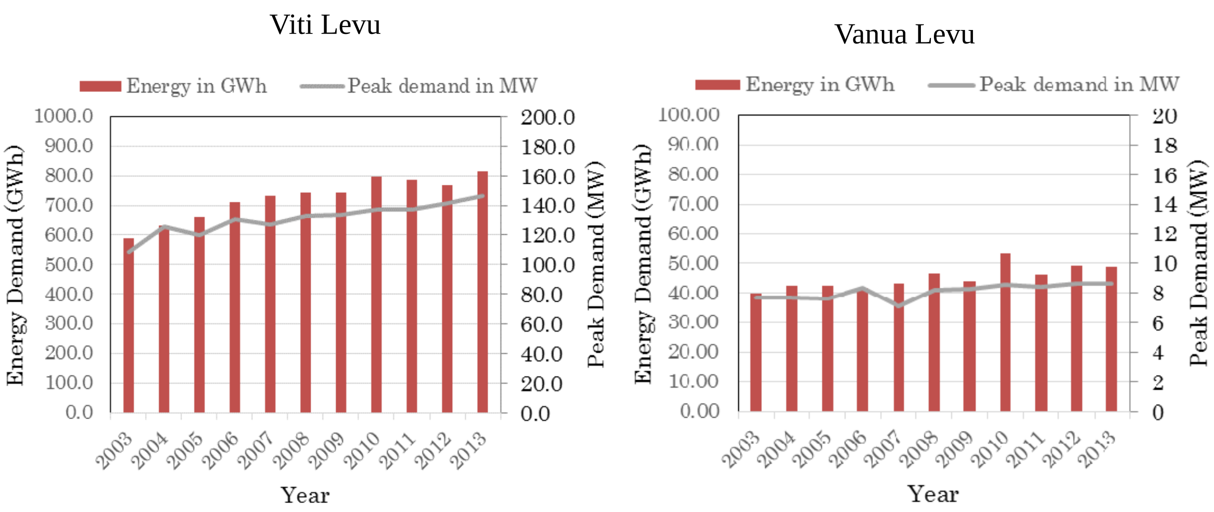
2.1 Power Demand Situation

Table 2.1-1 indicates transition of peak demand and electricity generation in islands of Viti Levu and Vanua Levu. Slight slowdown after the 2006 coup d'état can be seen but recovered in 2010. Growth rate of electricity generation recorded an average of 3.3% from 2003 to 2013, an increase of 140% in a decade. Growth rate of peak demand has increased from 108.5 MW in 2003 to 146.2 MW in 2013 which recorded an average growth rate of 3.0%/annum, an increase of 1.3 times in a decade.

Table 2.1-1 Annual Peak Demand and Electricity Generation (2003 - 2013)

Year	Peak Demand（MW）		Growth Rate (%)		Electricity Generation（GWh）		Growth Rate (%)	
	VLIS	Vanua Levu	VLIS	Vanua Levu	VLIS	Vanua Levu	VLIS	Vanua Levu
2003	108.5	7.7			588.5	39.85		
2004	125.7	7.7	15.9	0.1	631.0	42.26	7.2	6.1
2005	120.0	7.6	-4.5	-0.8	659.6	42.27	4.5	0.0
2006	130.8	8.3	9.0	9.5	711.0	41.52	7.8	-1.8
2007	127.1	7.1	-2.8	-14.9	732.5	43.13	3.0	3.9
2008	133.0	8.2	4.6	15.7	744.1	46.87	1.6	8.7
2009	133.3	8.3	0.2	1.1	741.8	43.73	-0.3	-6.7
2010	137.1	8.5	2.8	2.8	796.4	53.44	7.4	22.2
2011	137.2	8.4	0.1	-1.2	785.3	46.42	-1.4	-13.1
2012	141.2	8.6	2.9	2.1	768.0	49.21	-2.2	6.0
2013	146.2	8.6	3.6	0.3	814.4	49.03	6.0	-0.4
Average			3.0	1.2			3.3	2.1

(Source：FEA Annual Report 2013 (JICA Team reviewed)



(Source：FEA Annual Report 2013 (JICA Team reviewed)

Figure 2.1-1 Historical Records of Peak Demand and Energy Demand

2.2 Power Supply Situation

Main features of existing power plants are shown in Table 2.2-1.

Table 2.2-1 Installed Capacity, Available and Supply Capacity of Existing Power Plants

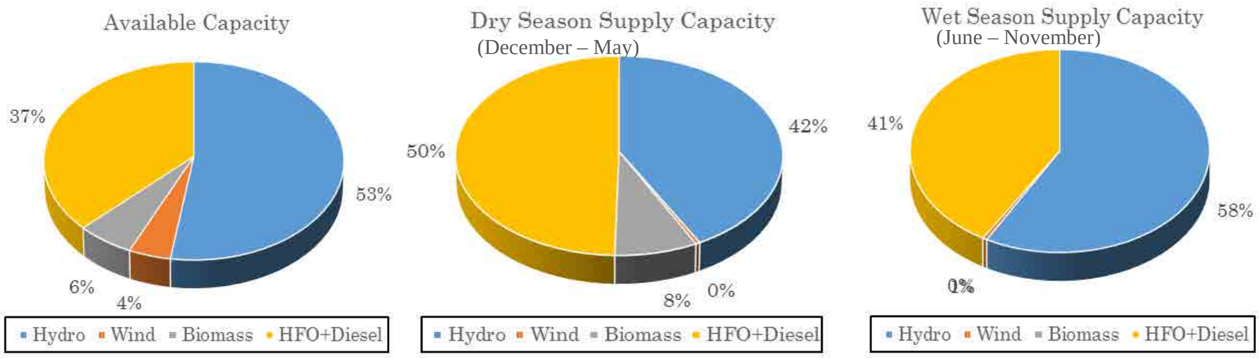
As of Dec 2013

Location	Power Plant Name	Source and Tyoe	Commissioning Year	Installed Capacity (MW)	Available Capacity (MW)	Supply Capacity (MW)
Viti Levu	Wailoa Power Station	Reservoir Type Hydropower	1978	83.20	75.00	66.20
	Wainikasou Power Station	Run of River Hydropower	2004	6.80	3.30	1.80
	Nagado Power Station	Run of River Hydropower	2006	2.80	1.50	1.00
	Nadarivatu Power Station	Run of River Hydropower	2012	44.00	40.00	3.90
	Butoni Wind Farm	Wind	2007	10.00	10.00	0.70
	Kinoya Power Station IDO	Diesel		29.80	28.00	28.00
	Kinoya Power Station HFO	Diesel		20.60	10.00	10.00
	Qeleloa	Diesel		1.40	1.00	1.00
	Vuda Power Station	Diesel		24.08	22.00	22.00
	Nadi Power Station	Diesel		2.08	2.00	2.00
	Sigatoka Power Station	Diesel		7.92	3.00	3.00
	Deuba Power Station	Diesel		4.20	2.60	2.60
	Lautoka (FSC)	Biomass	1987, 2006	3.0+9.3	7.30	7.30
	Penang (FSC)	Biomass	1981	3.00	1.00	1.00
	Sub-total			252.18	206.70	150.50
Vanua Levu	Wainikeu Power Station	Run of River Hydropower	1992	0.80	0.70	0.10
	Labasa Power Station	Diesel		13.52	11.24	11.24
	Savusavu Power Station	Diesel		3.24	3.00	3.00
	Korovou Power Station	Diesel		0.90	0.75	0.75
	Levuka Power Station	Diesel		2.80	2.30	2.30
	Labasa (FSC)	Biomass	1979, 1997	4.0+10.0	5.30	5.30
	Sub-total			35.26	23.29	22.69
	Total			287.44	229.99	173.19

(Source: FEA)

The total available capacity is only 80% (230 MW) of the total installed capacity (287MW) due to aging of facilities and so on. Since the supply capacity of the hydroelectric power plant decreases in dry season, the total supply capacity drops further to 173 MW. It should be noted that in rainy season the total supply capacity drops to 207 MW due to stop of power supply from the bagasse fueled power plants.

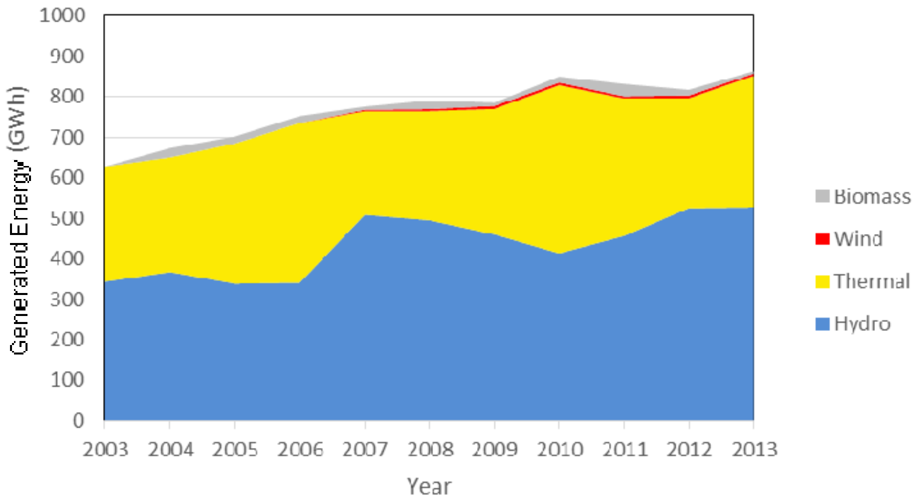
Generation mix of available and supply capacity by season is shown in Figure 2.2-1. The figure clearly points out a significant difference of supply capacity configurations in both seasons.



(Source: Project Team estimates based on FEA data)

Figure 2.2-1 Generation Mix of Available and Supply Capacity by Season

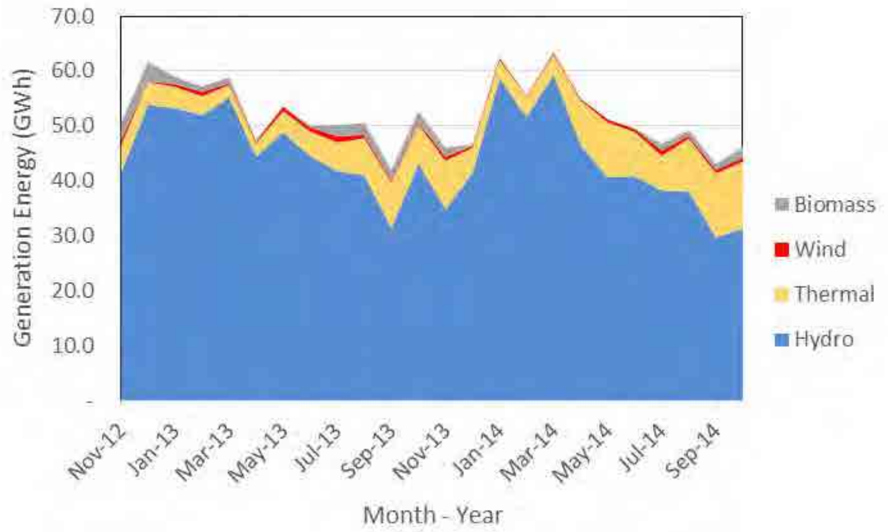
On the contrary, the generation mix of electricity generation is shown in Figure 2.2-2. It indicates the domination of hydropower and thermal power. Besides, annual capacity factor of Butoni Wind Farm (Installed capacity 10 MW) commissioned in 2006 stays as low as 6%.



(Source: Project Team estimates based on FEA data)

Figure 2.2-2 Generation Mix by Energy Source (2003-2013)

By the monthly generation mix, a large decrease in energy generated by hydropower can be seen during the dry months (Jun-Nov) as shown in Figure 2.2-3. On the other hand, biomass power generation fueled by bagasse generated power during dry season.



(Source: Project Team estimates based on FEA data)

Figure 2.2-3 Generation Mix of Electricity Generation (Nov. 2012- Sep. 2014)

3. Hydropower Potential Study

3.1 Overall of Hydropower Potential Study

A series of hydropower potential studies from potential site identification by map study to preliminary designs for prospective potential sites were implemented, as Figure 3.1-1 indicates.

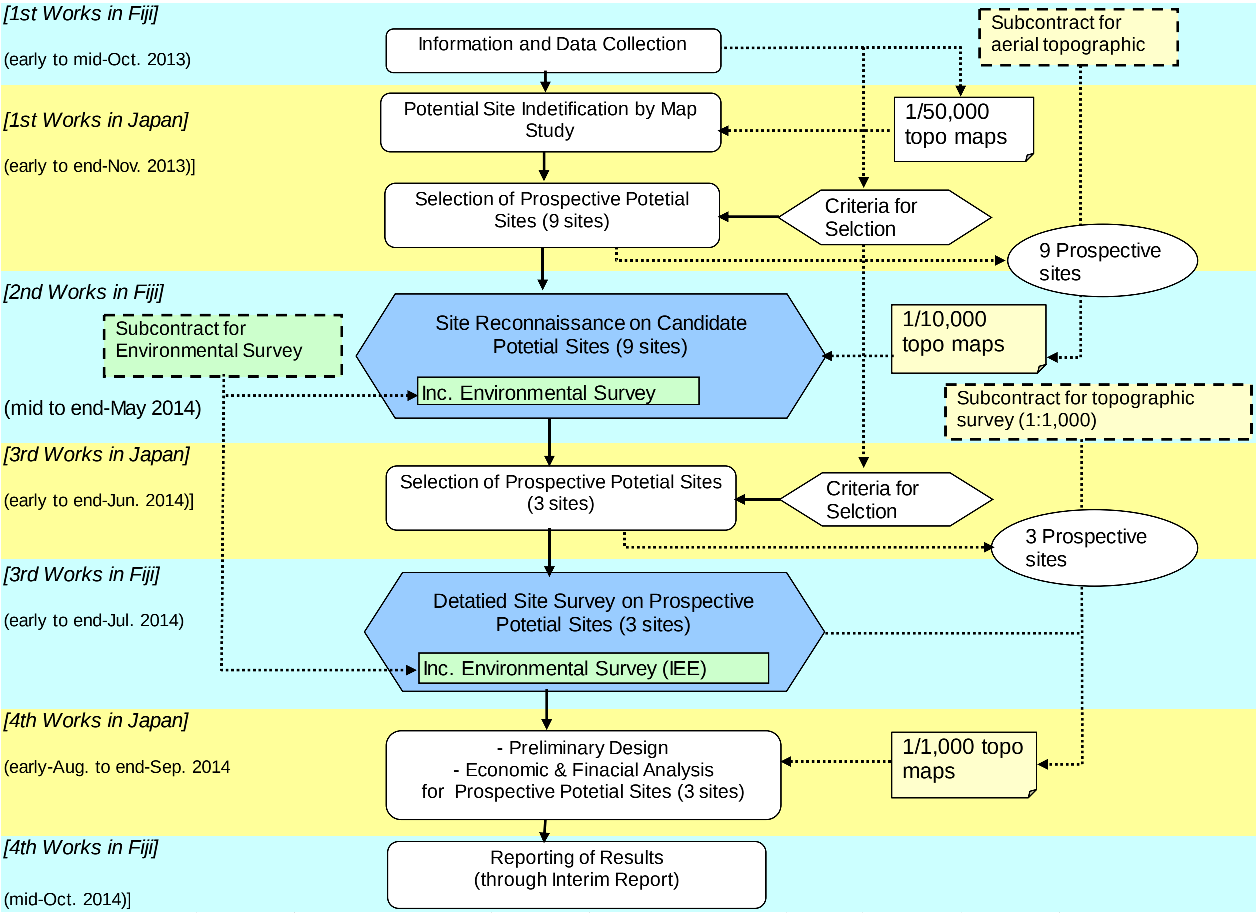


Figure 3.1-1 Identification and Prioritization of Hydropower Potential Sites

3.2 Identification of Hydropower Potential Sites

(1) Identification Criteria of Hydropower Potential

Through the discussions with the counterpart (C/P), the criteria for identifying and selecting hydropower potential sites were set as shown in Table 3.2-1.

Table 3.2-1 Identification Criteria of Hydropower Potential Sites

Items	Consideration Points	Criteria
Technological conditions		
- Generation Plan	- Installed capacity (P)	- More than 1,000kW
- Layout	- Length of waterway (L) - Length / Head (L/H)	- Less than 5,000m - Less than about 100
Topographical conditions		
- Approachability	- Road and traffic conditions to site	- Good approachability to the site
Natural/Social environmental conditions		
- Natural	- Protected area (e.g. natural parks)	- Avoid important protect area (national parks, Ramsar sites)
- Social	- Houses to be resettled	- No resettlement of villagers*

*: In consideration of the fact that there have been no resettlements in past hydropower projects in Fiji, hydropower potential sites that required any resettlement were not selected.

(2) Map Study on Identification of Hydropower Potential

Twenty-seven (27) hydropower potential sites identified in the existing study reports were reviewed based on the above-mentioned identification criteria by using the 1:50,000 topographical map, referring to the active faults distribution maps, other environmental protection areas, and Ramsar site maps, while ten (10) potential sites were newly identified by map study with the 1:50,000 topographical maps and longitudinal river profiles.

Main project features including installed capacity and maximum plant discharge for identified potential sites were determined based on the flow duration curves calculated by collected river discharge and rainfall data.

The project features of 37 identified potential sites (27 existing sites + 10 new sites) are shown in Table 3.2-2 for Viti Levu and Table 3.2-3 Vanua Levu..

Table 3.2-2 Project Features of identifying Hydropower Potential Sites in Viti Levu

No.	Site	Previous Report /New	Basin	CA (km^2)	P (kW)	Q (m^3/s)	He (m)	Annual Generated Energy (MWh)
Run-of-River Type								
1	Wainvau	Previous Report	Sigatoka	54.9	700	1.33	73.4	4,073
2	Nasa	Previous Report	Sigatoka	81.3	700	1.90	53.1	3,859
3	Sigatoka2	Previous Report	Sigatoka	26.4	400	0.60	93.2	2,458
4	Solikana	Previous Report	Sigatoka	32.3	700	0.83	113.0	3,852
5	Nasikawa1	New	Sigatoka	44.5	500	0.99	65.90	2,707
6	Narogevu	Previous Report	Sigatoka	10	400	0.21	298	2,767
7	Nabiaurua	Previous Report	Mba	20.7	1,000	0.64	213.9	7,878
8	Mba1U/S	New	Mba	172.2	3,600	5.36	84.6	21,046
9	Mba2D/S	New	Mba	215.9	2,000	6.45	39.5	12,161
10	Nakara	Previous Report	Mba	54.4	400	1.13	55.5	3,016
11	Tawa	Previous Report	Rewa	13.5	1,000	0.95	142.0	6,759
12	Nasoqo1	Previous Report	Rewa	33.7	3,100	2.61	149.7	17,292
13	Nasoqo2	New	Rewa	62	1,300	4.72	35.1	7,153
14	Naboubuqo	Previous Report	Rewa	40.7	3,000	3.17	113.3	16,046
15	Waqaitabua	Previous Report	Rewa	34.2	1,100	2.68	54.1	6,348
16	Waikonavona	Previous Report	Rewa	27.3	1,500	2.09	93.7	8,669
17	Waisare	Previous Report	Rewa	14	1,000	1.07	124.0	5,870
18	Nadara	Previous Report	Rewa	144	5,200	11.2	58.0	29,006
19	Nambua	Previous Report	Rewa	10	1,300	0.81	205.0	7,642
20	Wainivodi	Previous Report	Rewa	33.4	1,700	2.89	73.8	9,446
21	Wainisavuleve	Previous Report	Rewa	23.6	1,500	2.06	94.9	8,641
22	Wainimala	Previous Report	Rewa	83.5	2,200	7.70	36.6	12,307
23	Wainimakutu	Previous Report	Navua	61.7	1,000	3.82	35.2	5,999
24	Nakavika	Previous Report	Navua	115.5	3,100	7.19	54.7	16,951
25	Sovi	Previous Report	Rewa	143.3	2,300	12.69	23.4	12,716
26	Wainavadu	Previous Report	Rewa	38.1	2,700	3.33	102.6	14,975
27	Wainamoli	Previous Report	Navua	89.2	1,200	4.21	36.8	6,886
28	Waisoi	Previous Report	Rewa	17	2,100	1.41	186.0	11,321
29	Wairokodora	Previous Report	Rewa	5.5	1,900	1.47	167.0	10,591
Completion of F/S								
A-1	Qaliwana	Complete of F/S	Sigatoka					
A-2	Wailoa D/S	Complete of F/S	Rewa	143	7,300	25	36.4	44,900

(shaded): Less than 1,000kW

Table 3.2-3 Project Features of identifying Hydropower Potential Sites in Vanua Levu

No.	Site	Previous Report /New	Basin	CA (km^2)	P (kW)	Q (m^3/s)	He (m)	Annual Generated Energy (MWh)
Run-of-River Type								
30	Nadamanu	Previous Report	Lekutu	25.5	1,800	2.64	88.1	11,049
31	Saquru	Previous Report	Labasa	13.5	2,700	1.96	172.6	17
32	Navilevu	New	Wainunu	16.3	1,200	2.05	75.4	7,893
33	Nabuna	New	Wainunu	31.5	1,300	3.02	55.8	7,620
34	Davutu	New	Wainunu	28.2	1,200	2.81	55.3	7,164
35	Wailevu	New	Yanawai	34.7	2,000	3.23	76.9	11,241
36	Naisogocauca	New	Drakaniwai	16.4	1,500	2.52	77.3	9,572
37	Nuku	New	Wainunu	32.0	1,300	3.05	56.5	7,847

3.3 Selection of Candidate Prospective Potential Sites

(1) Prioritization of Hydropower Potential Sites

In order to prioritize the identified 37 potential, B/C (Benefit/Cost) of each site was calculated. The assumptions for B/C calculations are described in Table 3.3-1.

Table 3.3-1 Assumptions for B/C calculations

	Items		Assumptions
Economic Cost （C）	Construction Cost		Calculated in accordance with “Guideline and Manual for Hydropower Development Vol.1 Conventional Hydropower and Pumped Storage Hydropower (JICA)”
	Operation and Maintenance Cost		1% of Construction Costs
	Project Life		30 years
	Construction Period		5 years（detailed design 2yrs＋Construction 3yrs）
Economic Benefit （B）	Annual Generation		Annual Generation of Hydropower (GWh/annum）
	Installed Capacity		Firm Capacity of Hydropower（kW）
	Alternative Diesel Plant	Construction Cost	Calculated with a construction cost of USD 600/kW (Const. cost of Kinoya Diesel Power Plant (completed in 2005))
		Operation and Maintenance Cost	3% of Construction Costs (USD 18/kW/annum）
		Fuel Cost	USD 0.19/kWh (=0.25liter/kWh x FSD1.3*/liter x0.54 USD/FJD)
		Project Life	15 years
		Construction Period	1 year
Discount rate			10%

*: FSD 1,146/ton (average price in 2007: FEA Annual Report 2007) / 1,000 / 0.86

Nine (9) hydropower potential sites with 1.0 of B/C value or more were selected as candidate potential sites for site reconnaissance. The locations of the selected nine (9) potential sites are shown in Figure 3.3-1 for Viti Levu and Figure 3.3-2 for Vanua Levu.

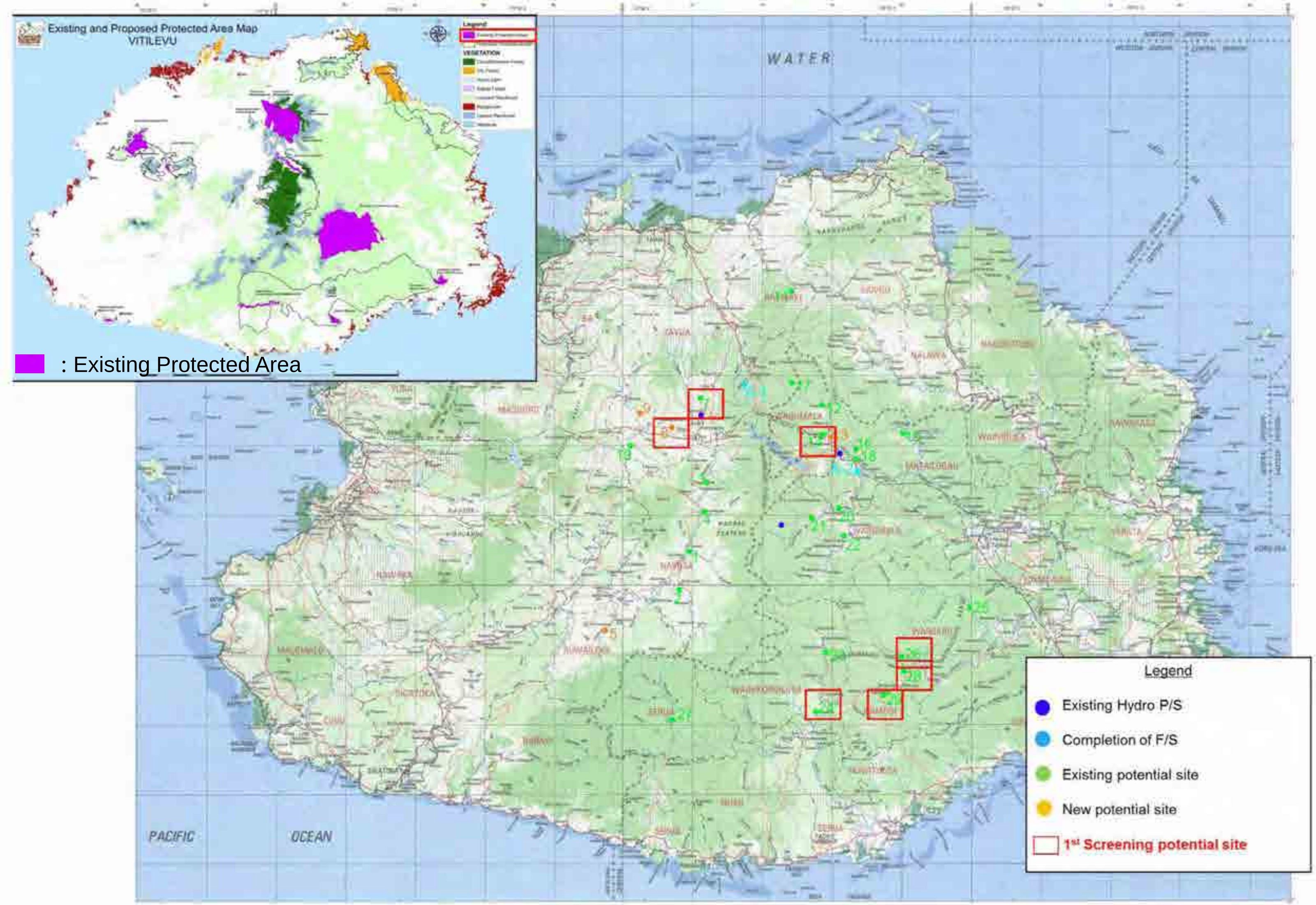


Figure 3.3-1 Selected Hydropower Potential Sites in Viti Levu

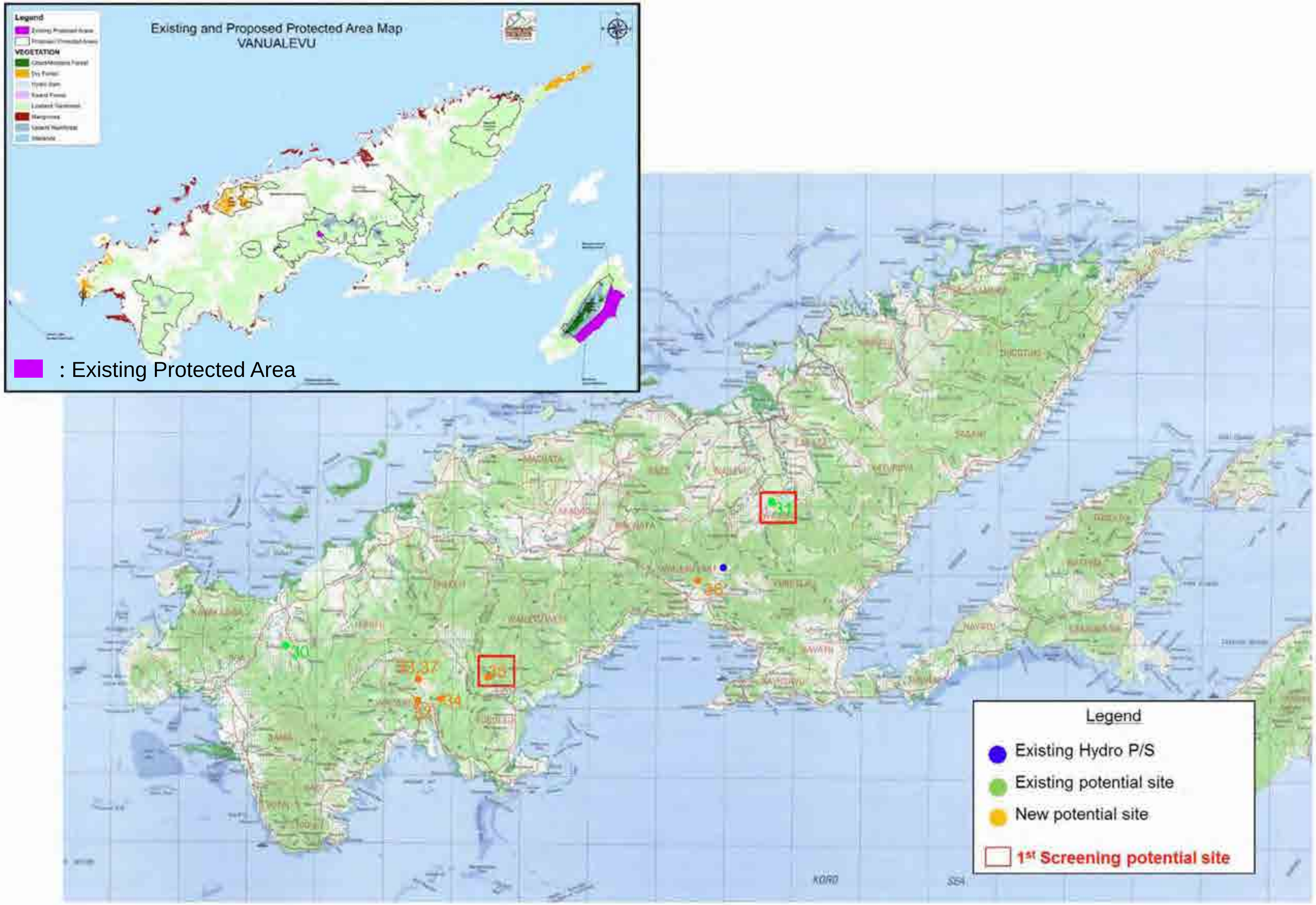


Figure 3.3-2 Selected Hydropower Potential Sites in Vanua Levu

(2) Site Reconnaissance on Candidate Potential Sites

The Project Team carried out the following site reconnaissance for 9 candidate hydropower potential sites together with officials of Department of Energy (DOE), Fiji Electricity Authority (FEA) and Water Authority of Fiji (WAF), during the Second Works in Fiji.

(3) Review of Power Generation Plans for Candidate Potential Sites

Based on the findings obtained through the site reconnaissance, the project features including facility layouts of all the nine candidate potential sites were reviewed. Subsequently, their construction costs and economic values (benefit / cost (B/C)) were also updated based on reviewed project features such as power output, maximum discharge and effective head.

3.4 Selection of Prospective Hydropower Potential Sites for Preliminary Design

(1) Setting of Evaluation Criteria for Selecting for Prospective Hydropower Potential Sites

In order to select 3 prospective hydropower potential sites for preliminary design from 9 candidate hydropower potential sites that were reviewed through the 1st site reconnaissance, the criteria for priority ranking of four ranks from Rank AA to Rank C for candidate hydropower potential sites were defined as shown Table 3.4-1.

Table 3.4-1 Criteria for Priority Ranking

Priority Rank	Criteria Screened
AA	It is economically superior, there is no significant natural / social environmental impacts and technical problems expected and priority power development area is high in Fiji.
A	It is economically superior and there are significant natural / social environmental impacts or technical problems expected.
B	It is economically feasible and there are significant natural / social environmental impacts or technical problems expected.
C	It is economically feasible and there are significant natural / social environmental impacts or technical problems expected.

Relation between priority rank, economic efficiency (benefit/cost (B/C)), primary evaluation score[1)] of environment and score of power supply reliability[2)] is defined as shown in Table 3.4-2.

1) *Scores to express the expected negative impacts on the natural and social environmental conditions on Flora and Fauna Fish, and Resettlement Compensatory and Cultural Heritage.*

2) *Scores to express regional deference to the needs for new hydropower sources.*

Table 3.4-2 Evaluation by Power Supply Reliability for Priority Ranking

Power supply reliability: 1		Primary evaluation score of environment		
		$1.0 \leqq y < 1.5$	$1.5 \leqq y \leqq 1.8$	$1.8 < x \leqq 2.0$
Benefit / Cost (B/C)	$x \leqq 1.0$	A	B	C
	$1.0 < x < 1.3$	AA	A	B
	$1.3 \leqq x$	AA	AA	A

Power supply reliability: 2		Primary evaluation score of environment		
		$1.0 \leqq y < 1.5$	$1.5 \leqq y \leqq 1.8$	$1.8 < x \leqq 2.0$
Benefit / Cost (B/C)	$x \leqq 1.0$	B	C	C
	$1.0 < x < 1.3$	A	B	C
	$1.3 \leqq x$	A	A	B

(2) Selection of Prospective Hydropower Potential Sites for Preliminary Design

Considering the results of ranking evaluation of candidate hydropower projects, the selection of three prospective hydropower potential sites for preliminary design were discussed with FEA, DoE and related organizations at the 2nd Stake Holder Meeting. In conclusion, the three (3) hydropower potential sites with a priority rank of "AA" as shown in Table 3.4-3 were selected as prospective hydropower potential sites to be studied for preliminary design.

Table 3.4-3 Ranking Evaluation of Candidate Hydropower Projects

Project Site	Location	Maximum Output P(kW)	Maximum Discharge Q(m^3/sec)	Effective Head He (m)	Annual Electricity Generation GE (MWh)	evaluation indicators			Priority Rank	Targeted site for Preliminary Design
		P(kW)	Q(m^3/sec)	He (m)	(MWh)	B/C	primary evaluation environment	power supply reliability		
No.8 Mba 1 U/S	**West, Viti Levu**	**9,200**	**15.0**	**74.7**	**24,836**	**1.2**	**1.2**	**1**	**AA**	✓
No.29 Waivaka	**South, Viti Levu**	**7,400**	**5.12**	**176.5**	**15,046**	**1.6**	**1.5**	**1**	**AA**	✓
No.35 Wailevu	**South, Vanua Levu**	**2,000**	**3.23**	**76.1**	**10,563**	**1.2**	**1.5**	**1**	**AA**	✓
No.7 Nabiaurua	West, Viti Levu	1,400	0.85	216.9	8,197	1.2	1.2	1	AA	
No.14 Naboubuco	Central, Viti Levu	2,700	3.53	96.9	15,308	1.4	1.4	2	A	
No.24 Nakavika	South, Viti Levu	2,600	7.17	45.7	14,205	0.9	1.9	1	C	
No.26 Wainavadu	South, Viti Levu	2,500	3.23	97.04	13,749	1.1	1.8	1	A	
No.28 Waisoi	South, Viti Levu	2,100	1.39	190.9	11,322	1.2	1.5	1	A	
No.31 Saquru	East, Vanua Levu	2,000	1.01	254.1	10,660	1.0	1.1	1	A	

4. Preliminary Design of Prospective Hydropower Potential Sites

4.1 General

Preliminary Designs on three (3) prospective hydropower potential sites selected in the previous section were carried out, and then economic and financial evaluations on their schemes were conducted. The locations of these sites are illustrated in Figure 4.1-1.

Figure 4.1-1 Locations of Three Prospective Hydropower Potential Sites for Preliminary Design

In the selection stage for three (3) prospective hydropower potential sites, all the hydropower schemes of these sites were examined as a run-of-river type. However, in order to contribute to the Government's target to generate 90% of total electricity generation by using renewable energy, these schemes were revised from run-of-type to reservoir type, which can have much larger installed capacity than a run-of-river type scheme, after the evaluation of the results on the detailed site surveys.

4.2 Layout of No.8 Mba 1 U/S Hydropower Scheme

The No.8 Mba 1 U/S Hydropower Scheme is situated just downstream of Nadarivatu Hydropower Station on the upper course of the Ba River.

As shown in Figure 4.2-1, No.1 Intake weir is located just downstream of the tailrace of Nadarivatu Hydropower Station, and the water taken at this intake weir is led to a point on the Savatu River, a right tributary of the Ba River, approximately 2.5 km upstream of the confluence of the Ba River and the Savatu River. A dam (No.2 Dam) is constructed at a point on the Savatu River, approximately 200 m upstream of the confluence, to storage the water led from both the Ba River and the Savatu River. From the reservoir, the water is led to the powerhouse located on the right bank of the Ba River, approximately 2 km downstream of the confluence of the Ba River and the Savatu River, through a pressured headrace tunnel, a surge tank and penstock.

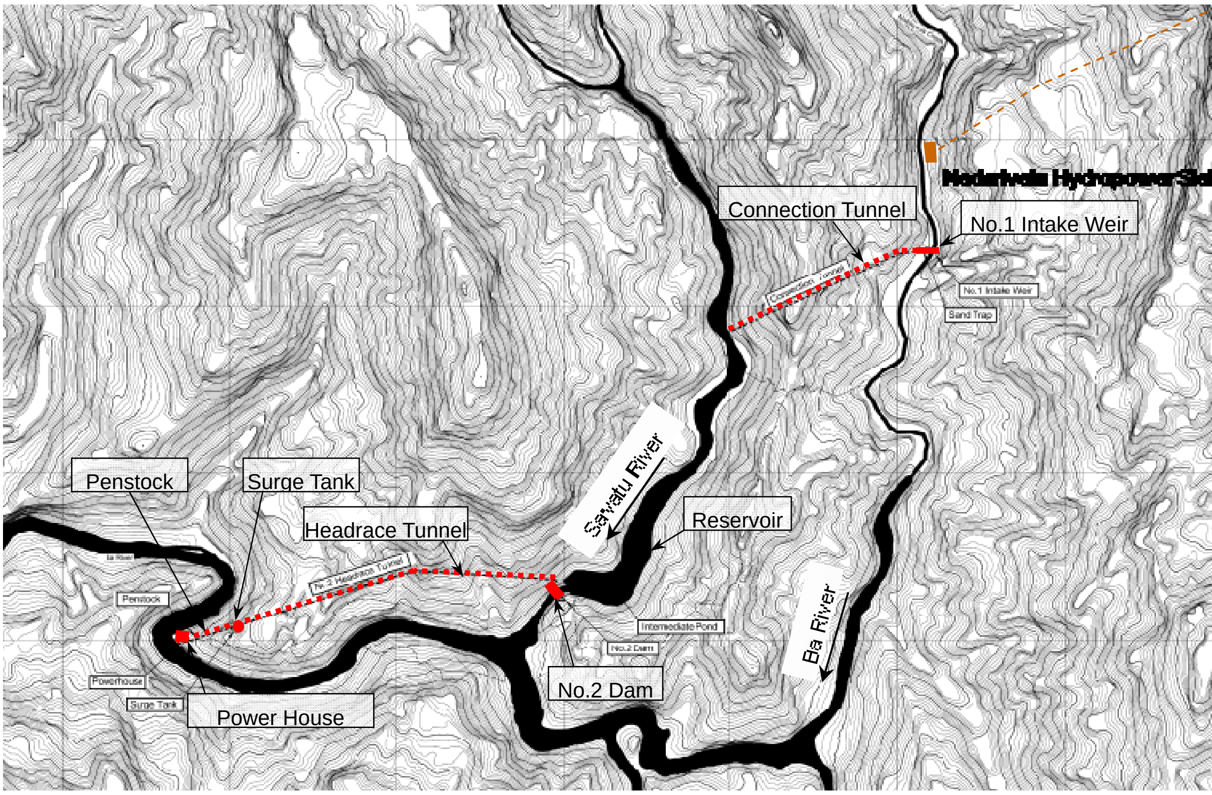


Figure 4.2-1 General Layout Plan for No.8 Mba 1 U/S Hydropower Scheme

4.3 Layout of No.29 Waivaka Hydropower Scheme

As shown in Figure 4.3-1, a main dam (No.2 Dam) of the No.29 Waivaka Hydropower Scheme is located approximately 2.5 km upstream of the confluence of the Waidina River and the Waivaka River, a right tributary of the Waidina River. In order to take more water, an intake (No.1 Intake Weir) is planned at a point on the Wairokodra River, which is out of Waivaka River Basin, and the water taken at the intake (No.1 Intake) is led to the reservoir on the Waivaka River through a connection tunnel. The power house is located on the left point of the Waivaka River, approximately 1.5 km downstream of the main dam (No.2 Dam).

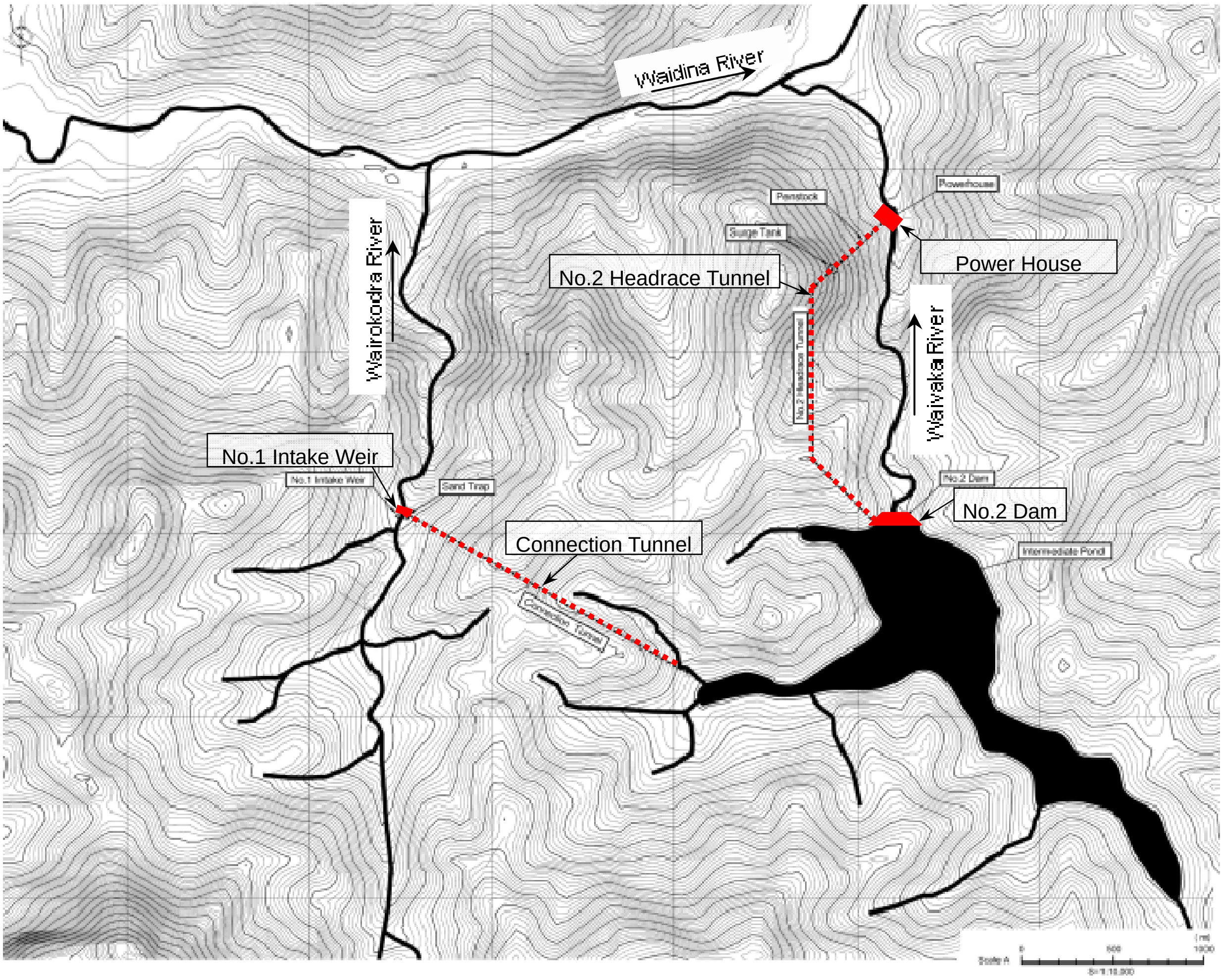


Figure 4.3-1 General Layout Plan for No.29 Waivaka Hydropower Scheme

4.4 Layout of No.35 Wailevu Hydropower Scheme

As a result of examination on alternative layout plans, No.35 Wailevu Hydropower Scheme consists of two (2) hydropower schemes due to the topographical conditions as shown in Figure 4.4-1. The upstream hydropower scheme (No.35-2), which has a dam and a reservoir with a storage capacity of 15 million m3, is a reservoir type with an effective head of approximately 39 m. On the other hand, the downstream hydropower scheme (No.35-1) is a run-of-river type with an effective head of approximately 100 m, but it generates electricity just like a reservoir type power station because it utilizes the river inflow regulated by the reservoir of No.35-2 scheme.

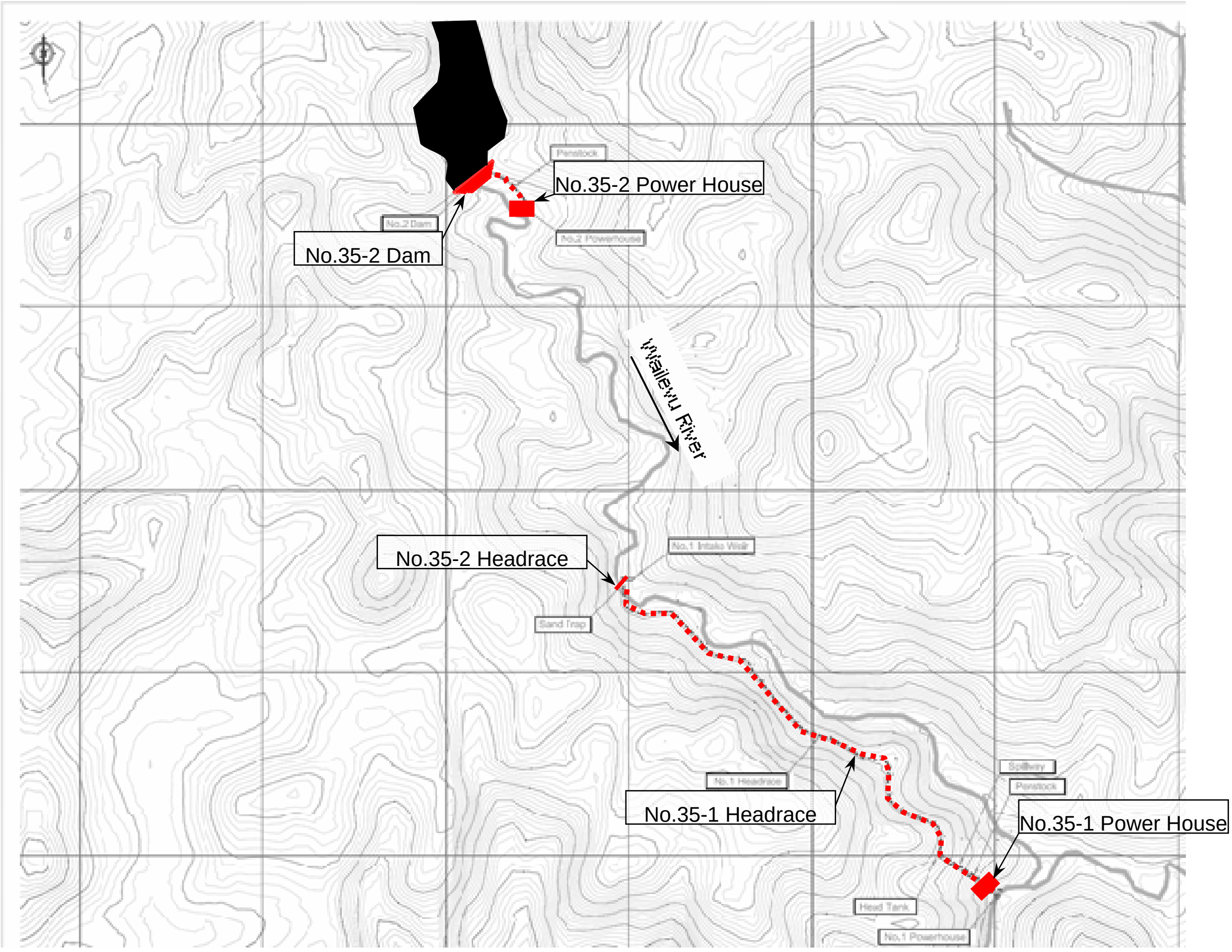


Figure 4.4-1 General Layout Plan for No.35 Wailevu Scheme

4.5 Transmission Schemes for the Prospective Potential Site

For the three prospective hydropower potential sites, transmission schemes are roughly considered as shown in Figure 4.5-1, Figure 4.5-2 and Figure 4.5-3.

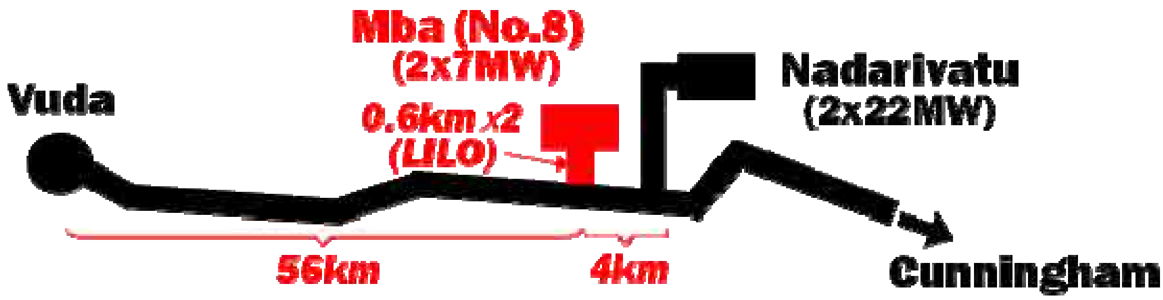


Figure 4.5-1 Transmission Schemes for the No.8 Mba 1 U/S Site

Figure 4.5-2 Transmission Schemes for the No.29 Waivaka Site

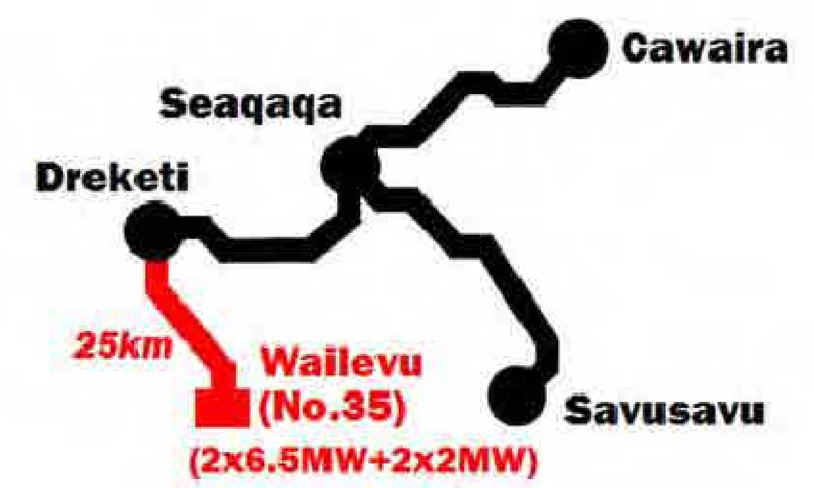


Figure 4.5-3 Transmission Schemes for the No.35 Wailevu Site

In order to ensure higher 132kV system reliability, the proposed 132kV transmission system configuration in VLIS for 2025 is shown in Figure 4.5-4.

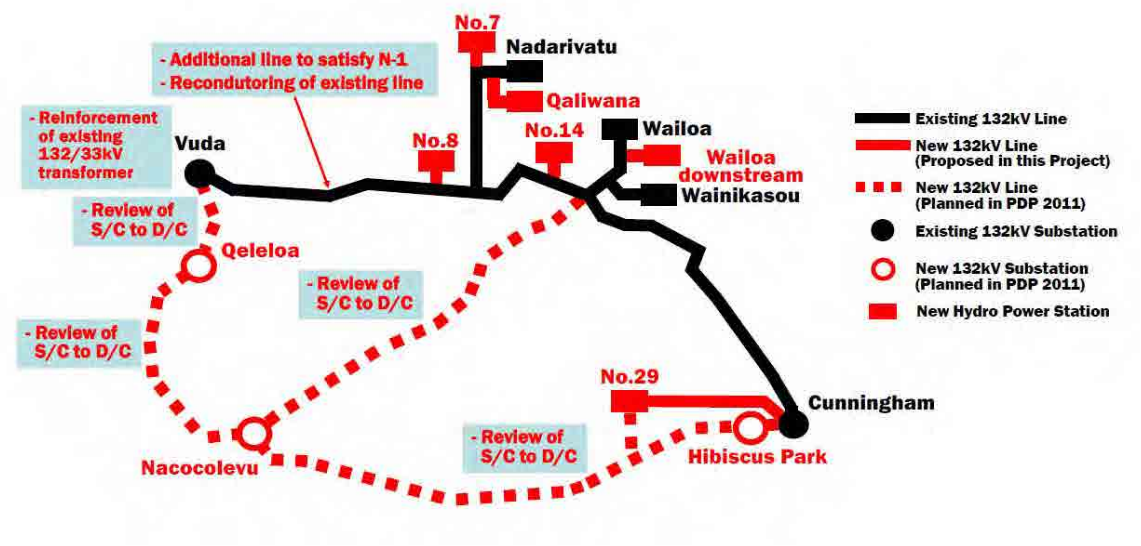


Figure 4.5-4 Proposed 132kV System Configuration in VLIS for 2025

4.6 Results of Preliminary Designs and Economic and Financial Analysis

The assumptions for the economic and financial analysis of three hydropower schemes were set in Table 4.6-1.

Table 4.6-1 Assumptions for Economic and Financial Analysis

Project Life	40 years (Construction Period: 5 years)
Transmission and Distribution Loss	10%
Electricity Tariff	USD 0.19/kWh
Operation & Maintenance Cost	1% of Construction Cost

The results of preliminary designs and economic and financial analysis for three hydropower schemes are summarized in Table 4.6-2.

Table 4.6-2 Summarized Results of Preliminary Designs for Three Hydropower Schemes

	Unit	**No.8 Mba 1 U/S**	**No.29 Waivaka**	**No.35 Wailevu**	
				No.35-2 Wailevu	**No.35-1 Wailevu**
Type	-	Reservoir	Reservoir	Reservoir	Run-of-River
Maximum Output	kW	14,000	32,000	4,000	13,000
Maximum Discharge	m^3/sec	23.9	20.6	13.4	15.5
Effective Head	m	72.0	194.2	39.3	100.3
Electricity Generation	MWh	57,842	67,552	8,783	49,296
Plant Load Factor	%	47.20	24.10	25.90	43.30
Construction Cost	10^6 USD	62.3	88.7	75.1	
Hydropower		62.0	82.5	73.9	
Transmission		0.25	6.18	1.17	
EIRR	%	13.3	12.1	11.7	
(B/C)	-	1.3	1.2	1.1	
FIRR	%	12.9	10.5	10.7	
(B/C)	-	1.3	1.0	1.1	

5. Environmental and Social Considerations

Initial Environmental Examinations (IEE) on three (3) selected prospective hydropower potential sites were conducted in compliance with the environmental regulation in JICA's Guidelines for Environmental and Social Considerations

It was concluded that for the construction of any of the hydropower plants, there is no major environmental concerns in the Preliminary Design Stage. However, there might be moderate impacts that have to be mitigated.

The followings are environmental and social issues identified in the IEE Surveys, and recommendations to address these issues for each prospective hydropower potential site.

Table 5-1 Issues and Recommendations as IEE Survey Results

No.8 Mba 1U/S Site		
Task	Issue	Recommendation
1	Two to four farmhouses and scarce productive agricultural land will be inundated under the reservoir	Farmhouses and agricultural land to be surveyed in relation to the inundated zone.
2	The river flow of the mainstream Ba river in the stretch adjacent to Koro-Drala-Vatutokotoko will decrease and it brings about the possibility of water degradation and decrease of all nearby fish resources. The latter will affect upstream communities Buyabuya and Marou, though they will still have water flowing.	The hydropower scheme needs to minimize the negative impacts on water quality and fish resources by conducting thorough surveys of fish and other aquatic fauna.
3	To date the construction of dams and weirs across Fijian rivers for hydropower purposes has paid no meaningful attention to impacts on migratory fish and 'residual or compensatory flow' requirements.	Fish ladders and 'minimum ecological flow' requirements need to be incorporated into the design of the scheme.
4	The scheme will result in an imbalance of negative impacts to be received by the adjacent but non-landowning communities (Koro, Drala, Vatutokotoko) and the non-resident landowners of Navala (10 km downstream) who do not use the project site but will be due all benefits from the scheme.	Resolution of this imbalance in negative impacts and benefits of the scheme is likely to be key to the acceptance of this scheme by local communities.
5	If the Upper Ba Hydropower scheme is to operate efficiently and effectively in the long term, improvements in catchment management will be required to ensure a more sustained water supply and lower sediment transport to the Savatu reservoir. To achieve this will involve 10 additional landowning groups who stand to receive no benefits from the scheme under current arrangements.	Attention needs to be paid to enabling improved catchment management through the support of the landowners who are not otherwise beneficiaries of the scheme.
6	Disturbance to traditional lifestyles in Koro, Drala, Vatutokotoko and Buyabuya communities as a result of construction and influx of workers to the area will be significant. Such disturbance has been experienced previously during the construction of the Nadarivatu hydropower scheme.	Continued meaningful consultation with all affected communities is an important requirement going forward.
No.29 Waivaka Site		
Task	Issue	Recommendation
1	During operation, the primary effects will be related to the 'dewatering' of the lower Wairokodra and the lower Waivaka which will potentially impact on river habitat, sediment transport, water quality, riparian groundwater	Thorough surveys of fish and other aquatic fauna are required to clarify losses and changes which will occur as a result of water

	levels and the direct and indirect effects these have on the users of the water resources at the site.	diversion.
2	To date the construction of dams and weirs across Fijian rivers for hydropower purposes has paid no meaningful attention to impacts on migratory fish and 'residual or compensatory flow' requirements.	Fish ladders and 'minimum ecological flow' requirements need to be incorporated into the design of the scheme.
3	Disturbance to traditional lifestyles of the landowning and adjacent communities as a result of construction and influx of workers to the area may be significant. There is significant ongoing activity related to the prospect of a large mine in the vicinity of the proposed project which is evoking great social sensitivity.	Continued meaningful consultation with all affected communities is an important requirement going forward.
No.35 Wailevu Site		
Task	Issue	Recommendation
1	There will be inundation of mature native forest and valuable hardwood plantation. There are no known rare or threatened fauna and flora affected by the project, but the knowledge base for Vanua Levu forests is weak.	Detailed fauna and flora surveys of the native forest areas which will be affected are needed.
2	The mainstream Wailevu river will have no water, or only residual flow, in the two consecutive stretches or river about 2 km each from the dam to Power Station 2 and then down to Power Station 1 with resultant reduced water quality and removal of all nearby fish resources. This will affect the fish and crustacea of the upper catchment above the reservoir.	Thorough surveys of fish and other aquatic fauna are required to clarify losses and changes which will occur as a result of water diversion.
3	To date the construction of dams and weirs across Fijian rivers for hydropower purposes has paid no meaningful attention to impacts on migratory fish and crustacea, and 'residual or compensatory flow' requirements.	Fish ladders and 'minimum ecological flow' requirements need to be incorporated into the design of the scheme.
4	If the Wailevu Hydropower Scheme is to operate efficiently and effectively in the long term, high standard, low-impact logging plantation management will be required to ensure a sustained water supply and lower sediment transport to the Wailevu reservoir. To achieve this will involve three or four additional landowning groups who stand to receive no benefits from the scheme under current arrangements, and the lessee of the plantations, the Fiji Hardwood Corporation Ltd.	Attention will need to be paid to enabling high-standard management through the support of the landowners and Fiji Hardwood Corporation who are not otherwise beneficiaries of the scheme.
5	There will be disturbance to traditional lifestyles in all the landowner village communities as a result of construction and influx of workers to the area. However, the villages are relatively distant from the construction site and so the disturbance will be indirect.	Continued meaningful consultation with all affected communities is an important requirement going forward.
6	The water quality in the Wailevu appears to be very good and construction practices and mitigation measures will need to be designed and implemented to a high standard, especially as the rainfall is so high in the area. There are proven mitigation measures already practiced in Fiji for reducing erosion and river sedimentation risk from earthworks associated with dam construction but effective implementation is often problematic.	A very high standard of erosion and sedimentation control is required to maintain the high water quality of the Wailevu.

6. Biomass Power Potential

6.1 General Potential

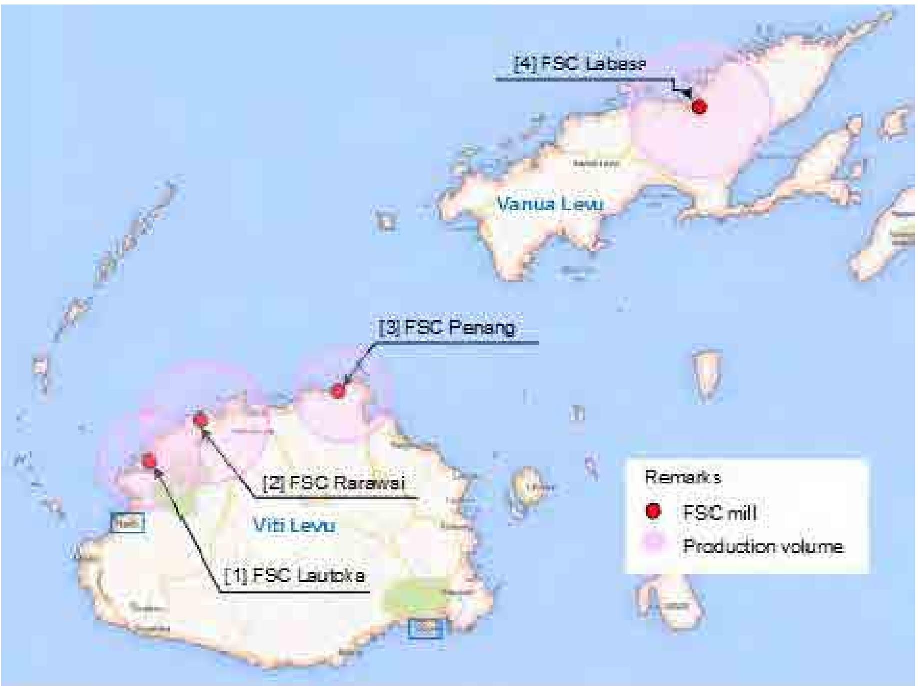
In Fiji, since early times, biomass energy was used mainly in people's lives, for example, firewood was used for cooking and livestock waste mixed with straw was used as fuel after drying. Major types of biomass in Fiji are (1) bagasse (sugarcane residues), (2) wood residues, and (3) general waste (organic waste from the city). JICA Project Team focused on examination of potential for (1) bagasse (sugarcane residues) and (2) wood residues.

6.2 Bagasse Potential

Sugar cane production is one of the key industries in Fiji. Fiji Sugar Corporation (FSC) is the state-owned enterprise in Fiji having monopoly on production of raw sugar in Fiji.

Sugar cane production has been declined in the past due to reduction of farmers as well as reduction of land area for harvest. FSC has, therefore, made every effort to restore productivity of sugar cane by improvement such as contract condition to increase harvest area, and breed improvement to increase density.

Figure 6.2-1 is a bagasse potential map, the potential of bagasse is eccentrically located in the east to north region where FSC mills are located in in Viti Levu, and its potential in Vanua Levu is focused in one place of Labasa area, since FSC Labasa is the sole source in the island.



(Source: JICA Project Team based on FSC, 2014)

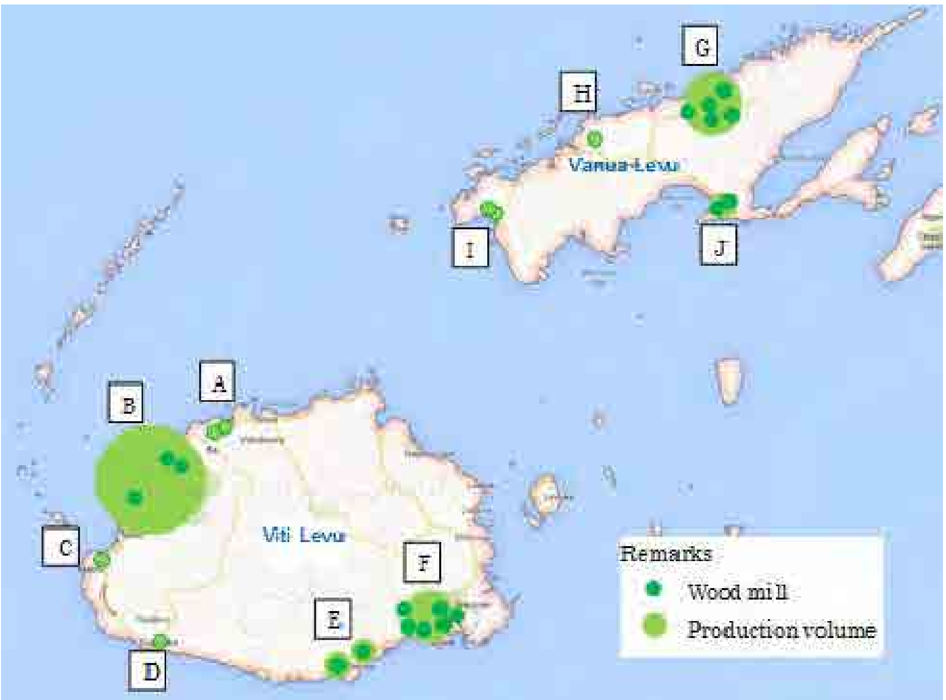
Figure 6.2-1 Bagasse Potential Map (mill-production basis)

In consideration of the theoretical generation capacity and FSC's plan for new power plants, the optimal development capacity of biomass power plants using bagasse are estimated at 68 MW in Viti Levu, 5 MW in Vanua Levu and 73 MW in total, for the power development plan.

6.3 Wood Residues Potential

Wood industry is also one of the major economic activities in Fiji.

Figure 6.3-1 is a potential map, indicating a location of mills and its production volume. Each green-colored circle indicates the mill location and a size of each greenish yellow-colored circle shows the production volume in a relative evaluation. Unlike in the case of bagasse, locations of the wood mills in both Viti Levu and Vanua Levu are scattered over a large area with a small size except Tropik Wood Industries Ltd, or sole large-scale mills in Viti Levu.



(Source: JICA Project Team based on DOE data, 2014)

Figure 6.3-1 Wood Residues Potential Map (production basis)

Considering such conditions of biomass potentials using wood residue, the optimal development capacity of biomass power plants using wood residue is expected to be only 4 MW, which is generated by the plant of Tropik Wood industries limited.

6.4 Financial Viability of Biomass Power Projects in Power Supply

In order to examine financial viability of biomass power projects, economic and financial rate of return are tentatively calculated in case of 5MW, 2.5MW, 1 MW bagasse project cases. The basic assumptions for calculations are described in Table 6.4-1.

Table 6.4-1 Summary of the Basic Assumptions for Power Projects by Bagasse

Installed Capacity	1) 5MW class 2) 2.5MW class 3) 1 MW class
Plant Load Factor	90%
Operating Period	30 Weeks / Year (8 months, excluding rainy season from January to April)
Plant Operation Ratio	80%
Auxiliary consumption ratio	3.0%
Electricity Sale	50% of full annual generation
Construction Cost	1) USD 2,500/kW 2) USD 4,500/kW 3) USD 8,750/kW 5MW class
Project Life	20 years (Construction Period: 2 years)
Operation and Maintenance Cost	3.5% of total gross revenue and 10% of construction cost (for sugar processing)
Purchase Price from IPP	0.1720USD/kWh (0.3308FJD/kWh)

The results of the calculation of bagasse power plant are shown in Table 6.4-2. Economic benefit is calculated as avoidable cost for alternative diesel thermal power plant construction cost. From these results, it should be necessary to have a certain capacity, around 5MW, in order to have enough revenue from electricity sale to have return on the investment cost more than 10%. It is difficult to be financially viable if the project facilities are 2.5MW and less.

Table 6.4-2 Result of Financial Viability of Power Plants by Bagasse

Plant Capacity	5MW	2.5MW
FIRR	16.5%	1.2%
EIRR	18.3%	-6.6%

In case of the power plant project by wood residue, even more cost is required for purchase of the wood residue from dispersedly located saw mills and transportation cost in addition to these projects by bagasse. As a result of tentative calculation of the power generation projects by wood residue as the same capacity of bagasse projects, it can infer that the project would be difficult to be financially viable, without large decrease of transportation cost and/or drastic increase of electricity tariff for power purchase.

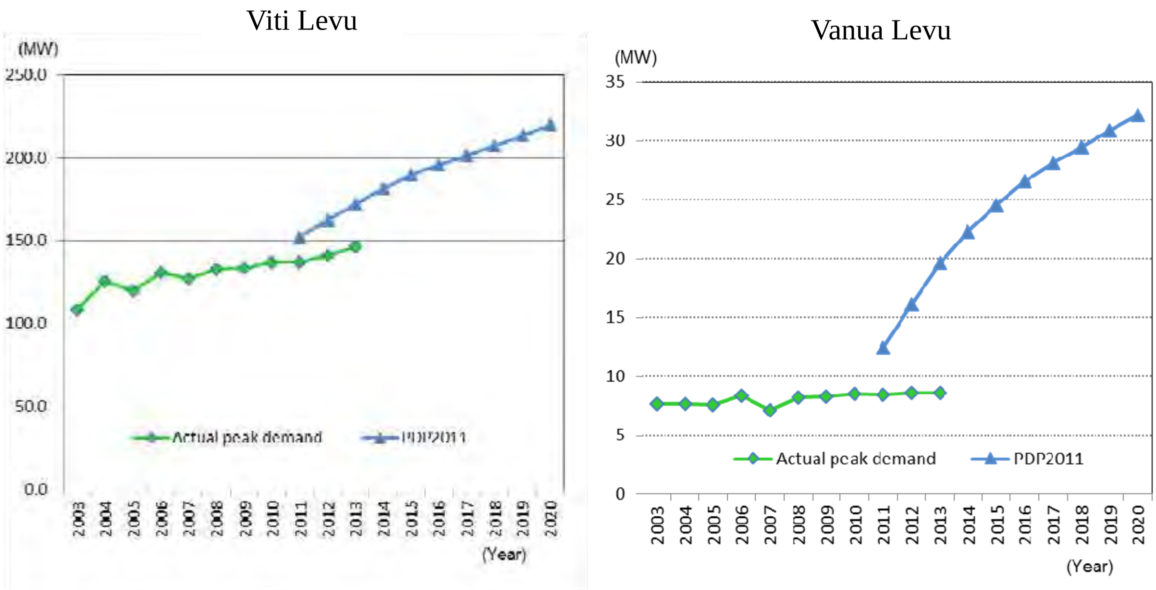
7. Review of Long-term Supply and Demand Plan

7.1 Current Status and Evaluation of Power Demand Forecast

(1) Demand Forecast

FEA forecasted power demand in Power System Development Plan (2011-2020).

A comparison of the actual value from 2003 to 2013 and the forecasted power demand is as shown in Figure 7.1-1 in terms of peak demand. According to these Figures, the forecasted values in Vanua Levu are far apart from the actual values. A drastic review is strongly required in the Power System Development Plan 2015-2025.



(Source: Power Development Plan (2011-2020))

Figure 7.1-1 Comparison of Actual and Forecasted Demand (Peak Demand)

(2) Power Development Plan of FEA

FEA also raised a target to generate 90% of total electricity generation by renewable energy power sources by 2015 in the Power System Development Plan (2011-2020).

Power development plan in the Power System Development Plan (2011-2020) is shown in Table 7.1-1.

Table 7.1-1 Development Plan up to 2020

Company name	Type	Capacity (MW)	Development year	Current status
Viti Levu Island				
Vuda	Biomass	18	2013	Committed by IPP
FSC Lautoka	Biomass	6	2013	Committed by IPP
Wailoa Downstream	Hydro	7	2014	Committed by FEA
Qaliwana	Hydro	10	2014	Committed by FEA
FSC Rarawai	Biomass	20	2015	Proposed by FEA/IPP
Namosi	Hydro	40	2017	Proposed to meet demand by renewable generation
Nausori	Biomass	40	2017	
Vanua Levu Island				
Labasa	Biomass	7.5	2013	Committed by IPP
Wairiki	Biomass	4	2013	Committed by IPP
Savusavu	Geothermal	4	2013	Proposed by FEA/IPP
Savusavu	Geothermal	4	2017	Proposed by FEA/IPP
Labasa	Biomass	7.5	2017	Proposed to meet demand by renewable generation
Saivou	Biomass	7.5	2017	
Obalau Island				
Nasinu	Biomass	3	2013	Proposed to meet demand by renewable generation
Viro-Stage 1	Biomass	1.8	2013	
Viro-Stage 2	Biomass	0.6	2017	

(Source: Power Development Plan (2011-2020), FEA)

The actual power development in Viti Levu and Vanua Levu largely differed from the plan as shown in Table 7.1-2.

Table 7.1-2 Current Power Development Plan

Location	Power Plant Name	Source and Tyoe	Installed Capacity (MW)	Supply Capacity (MW)	Commiss-ioning Year	Current Status
Viti Levu	Kinoya PS Extention	HFO thermal	35	35	2015	Procurement by FEA
	Wailoa Downstream	Hydro	7	1.3	2018	Consultant Selection
	Qaliwana	Hydro	10	1.9	2018	Consultant Selection
	Wainisavulevu weir raising *1	Hydro	3	1.8	2015	Under Construction
	Lautoka (FSC)	Biomass	5	4.5	2017	Committed by FEA
	Rarawai (FSC)	Biomass	5	4.5	2015	Committed by FEA
			40	36	2016	Committed by FEA
	Penang	Biomass	5	4.5	2017	Committed by FEA
	Sub-total		110	89.5		
Vanua Levu	Labasa	Biomass	10	9	2016	Committed by FEA
	Sub-total		10	9		
	Total		120	98.5		

*1 : One of 2units of Wainikasou HPP under rehabilitation will be restart

(Source: FEA annual report 2013, Project Team Evaluation)

(3) Power Transmission Development Project

FEA is taking next 3 conditions into consideration for making plan of the Power Transmission Development.

1） Assure system security and reliance
2） Distribute power to every household. Electrification of every village.
(Applies to the Islands of Viti Levu, Vanua Levu and Ovalau)
3） Coping with a system demand corresponding to renewable energy generation.

FEA is planning to extend and reinforce transmission lines and substations taking into account the above mentioned points.

7.2 Current Status and Evaluation of the Power Development Plan

(1) Issues on Power Supply Reliability

Any criteria regarding power supply reliability was not seen in the previous power development plan. Generally, it is necessary to set the target value of LOLP (Loss of Load Probability) or LOLE (Loss of Load Expectation), on a condition that the target value is satisfied, the most economical power supply composition and development pattern should be determined. In Southwest Asian countries (Vietnam, Indonesia, etc.), LOLP =0.27% or LOLE=24hr is set as annual power shortage duration.

Since FEA has set goal to generate 90% of total electricity generation by renewable energy power generation by 2015, it is essential to consider the fluctuation of supply capacity of renewable energy power sources on the basis of statistical probability.

① Hydropower: Fluctuation of high water flow, and drought. Fluctuation of the power supply of wet/dry season.
② Wind : Supply capability shall only be expected to the degree of annual capacity factor.
③ Bagasse : Power supply to the power system is limited to 30 weeks (June - December)

Besides, it is necessary to take into consideration actual error of power demand forecast as described below.

(2) Issues on Power Demand Forecast

As shown in Figure 7.1-1, since the power demand forecast in PDP (2011-2020) is far from actual results, it is necessary to reconsider so as to satisfy the target value described in Draft National Energy Policy (NEP) 2014 based on the actual power demand records.

Table 7.2-1 Target value in National Energy Policy 2014

Indicator	Baseline	Targets 2015	2020	2030
Access to modern energy services				
Percentage of population with electricity access	89%[3] (2007)	90%	100%	100%
Percentage of population with primary reliance on wood fuels for cooking	20%[4] (2004)	18%	12%	<1%
Improving energy efficiency[5]				
Energy intensity (consumption of imported fuel per unit of GDP in MJ/FJD)	2.89[6] (2011)	2.89 (0%)	2.86 (-1%)	2.73 (-5.5%)
Energy intensity (power consumption per unit of GDP in kWh/FJD)	0.23 (2011)	0.219 (-4.7%)	0.215 (-6.15%)	0.209 (-9.1%)
Share of renewable energy				
Renewable energy share in electricity generation	60%[7] (2011)	67%	81%	100%
Renewable energy share in total energy consumption	13%[8] (2011)	15%	18%	25%[9]

(Source：SE4All Report)

8. Power Development Plan

8.1 Economic Comparison of Various Powers by Screening

By calculating the power cost of each utilization rate from construction costs (fixed cost) and fuel costs (variable costs) of various powers, the optimal power supply of each of base, middle, and peak supply capability shall be examined.

(1) Construction Costs

By referring to Power Development Investment Cost described in P34 of SE4All report, the standard construction cost of each power source was set as shown in Table 8.1-1.

Table 8.1-1 Construction Cost of Each Power Source

	Construction cost
Hydro（Afflux type）	2000 USD/kW
Water（Reservoir type）	4000 USD/kW
Diesel Thermal（IDO）	700 – 1000 USD/kW
Diesel Thermal（HFO）	700 – 1000 USD/kW
Geothermal	3500 USD/kW

(2) Annual Fixed Cost

Annual fixed cost of each power source is calculated based on the above construction cost. Annual fixed cost generally differs, depending on the methods of depreciation, and hits maximum immediately after commissioning. Table 8.1-2 shows costs equalized by lifetime with an interest rate set at 10%. In addition, the lifetime of each power source was set as; 30 years for Geothermal, 15 years for Diesel Thermal, 40 years for Hydropower due to large share of civil engineering structures.

Table 8.1-2 Annual Fixed Cost by Power Source

	Construction cost（$/kW）	Expense ratio（%）			Annual expense（$/kW/year）
		Interest・Redemption	O&M expense	Total	
Hydro（Afflux type）	2000	10.23	1.0	11.23	224.5
Hydro（Reservoir type）	4000	10.23	1.0	11.23	449.2
Existing Diesel Thermal（IDO）	550	13.15	4.0	17.15	94.3
New Diesel Thermal（HFO）	850	13.15	4.0	17.15	145.8
Biomass	2500	11.75	4.0	15.75	393.8
Geothermal	3500	11.61	4.0	15.61	406.3

(3) Fuel Cost

As a fuel price forecast for the future, fuel price prediction up to 2030 which International Energy Agency (IEA) announced in 2009 was referred. Table 8.1-3 shows the mentioned forecast.

Table 8.1-3 IEA Projection

		2008	2015	2020	2025	2030
Oil	USD/bbl	97.19	86.67	100.00	107.50	115.00
Gas	USD/Mbtu	10.32	10.46	12.10	13.09	14.02
Coal	USD/tonne	120.59	91.05	104.16	107.12	109.40

Meanwhile, Table 8.1-4 indicates the actual results of fossil fuel supply cost during 2008-2012.

Table 8.1-4 Fossil Fuel Supply Cost

	Diesel Quantity (M litres)	Value (F$ M)	Unit Price	
			F$/litre	US$/bbl
2008	248	390	1.573	135
2009	189	218	1.153	99
2010	318	366	1.151	99
2011	276	410	1.486	128
2012	264	402	1.523	131

(Source：SE4All Report)

Based on the above actual results, the assumed price of HFO in year 2020 would be 100 USD/bbl as IDO price remains at 2009-2012 average price of 114 USD/bbl. The fuel prices at standard thermal power plants are calculated as shown in Table 8.1-5.

Table 8.1-5 Fuel Cost of Thermal Power

	Assumption (2020)		Fuel price (US Cent/Mcal)	Efficiency	Fuel cost (US Cent/kWh)
Diesel (IDO)	114.0 USD/bbl	9200 kcal/ℓ	7.8	33%	20.33
Diesel (HFO)	100.0 USD/bbl	9600 kcal/ℓ	6.6	33%	17.20

(4) Unit Generation Cost

Based on the above estimation of construction costs and fuel costs, the unit generation cost of each power source in year 2020 is calculated as follows.

In a field concerning base load supplier (Capacity factor of 70% or more), geothermal power generation is most economical than the other power sources. In a field of middle load supplier (Capacity factor of 30%-60%), hydropower (Run-of river type) is the most economical power source. In addition, hydro (Reservoir type) is the most efficient peak power source.

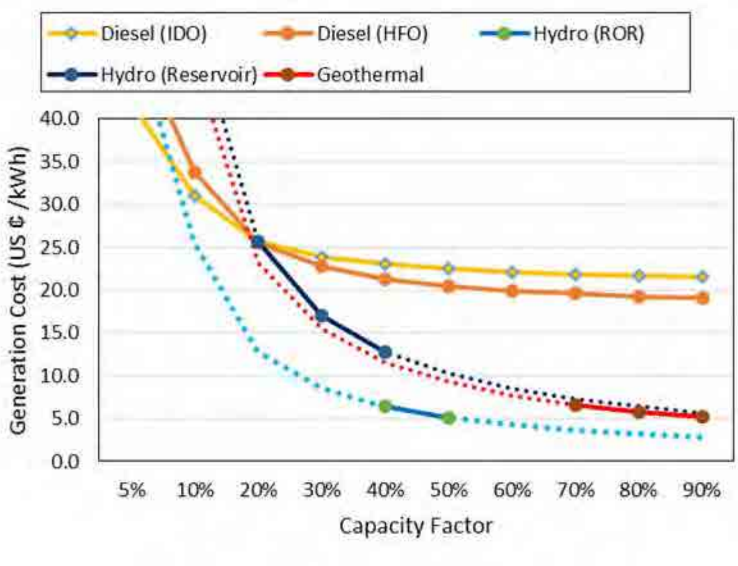


Figure 8.1-1 Generation Cost by Power Source

8.2 Creating the Supply and Demand Operation Simulation Data

Input data for PDPAT II (Power Development Plan Assist Tool) program was created in order to execute supply and demand operating simulation by utilizing PDPAT II.

(1) Power Demand Forecast

The Project Team forecasted the electricity generation demand after Year 2015 subject to the below preconditions.

① The GDP growth rate is assumed as 3%. Besides, guided from past actual value, the elasticity of electricity generation demand growth rate against GDP growth rate is assumed as 1.5.

② Considering the target to increase rural electrification rate from 90% in 2015 to 100% in 2020, it is appropriate to add 0.5% onto the electricity generation growth rate for 2015-2020.

③ The impact which population growth and DSM give to electricity generation demand is assumed to be offset

Moreover, High case was assumed in order to avoid shortage of supply capacity, since development of hydropower plant takes at least 6 years including Feasibility Study period. From the above preconditions, the demand forecast of electricity generation is set as shown in Figure 8.2-1.

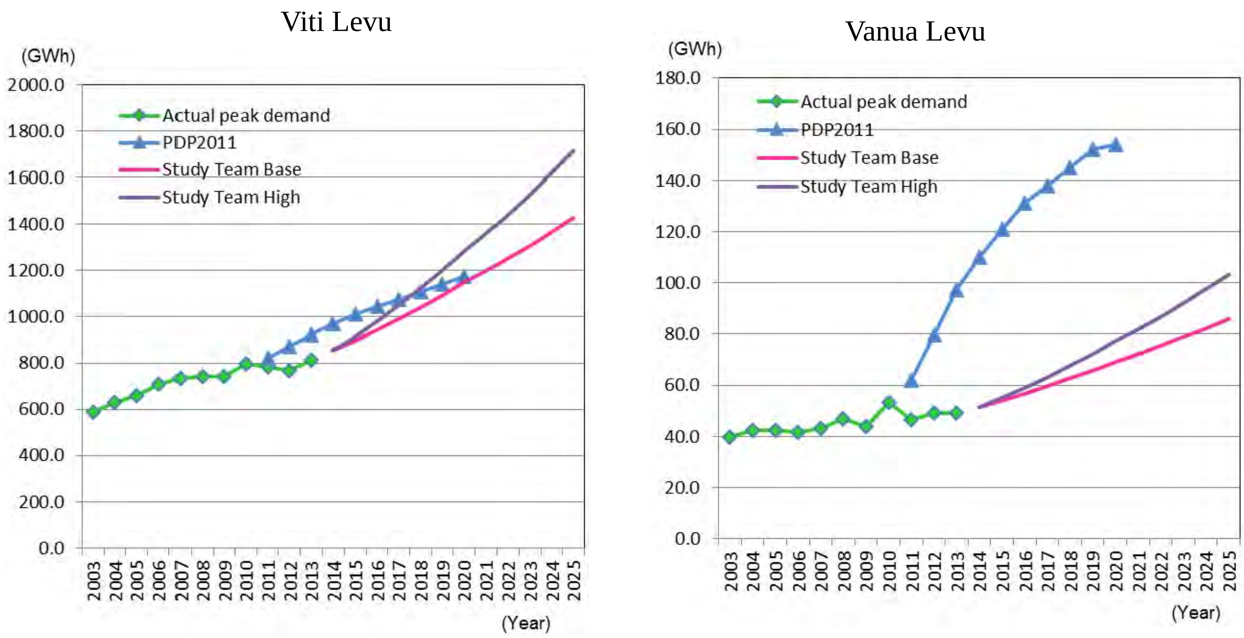


Figure 8.2-1 Demand Forecast of Electricity Generation (up to 2025)

Considering the air conditioning demand in summer, an annual load factor may fall gradually from 64% to 60% by 2025. The peak demand is forecasted according to the demand and annual load factor as shown in Figure 8.2-2.

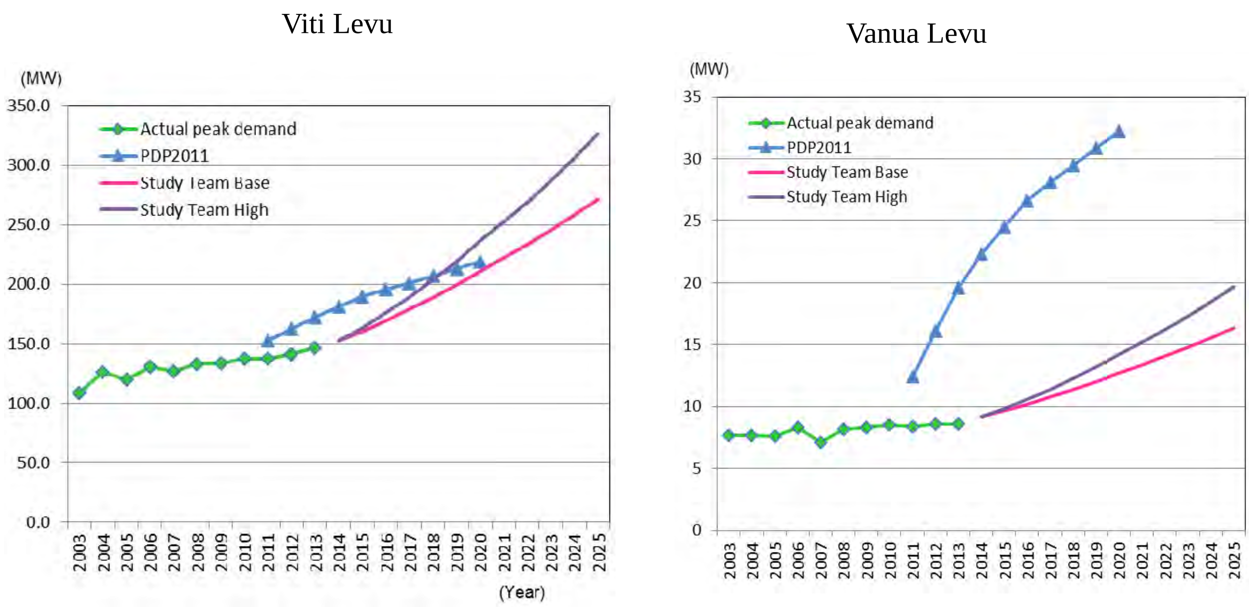


Figure 8.2-2 Demand Forecast of Peak Load (up to 2025)

According to the above forecast, the total peak demand of Viti Levu and Vanua Levu together in 2025 was assumed approximately 290 MW for Base case, and 350 MW for High Case.

(2) Current Status and Forecast of Peak Demand Shape

As recent trend in developing country, it becomes a common recognition that the growth of demand in daytime in the summer is getting larger as dissemination of air conditioners.

Under the above mentioned status, the forecast of change of the daily load curves was conducted.

The following trends of the daily load curve can be recognized based on the actual load curves of the maximum demand date in summer from 2010 to 2013.

- Peak demand has occurred at around 14:00.
- Evening peak demand around 20:00, evening lighting peak, has declined.
- Gap (Minimum load / Maximum load) has gradually increased, the growth rate of maximum load is 1.7%, and the growth rate of the minimum load is -0.4%.

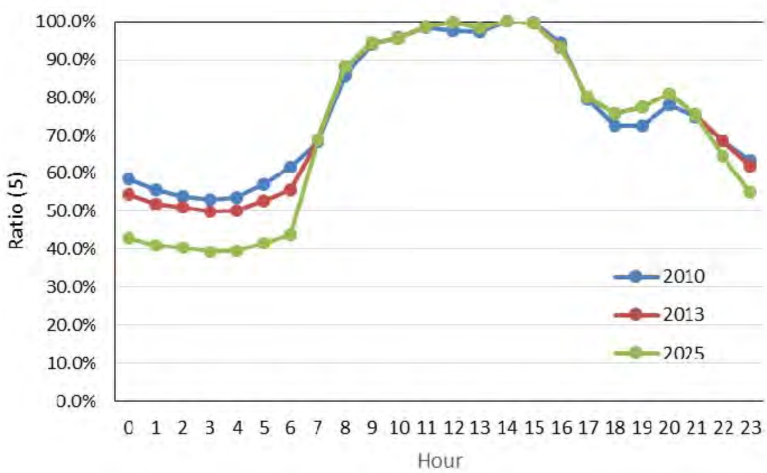
Table 8.2-1 shows mean power of the monthly 3days maximum demand at 2 p.m. and minimum demand at 3 a.m. from 2010 to 2013.

Table 8.2-1 Trend of Daily Peak Load and Minimum Demand

	2010	2011	2012	2013	Average increase	
					(MW)	(%)
Maximum	135.9	135.0	138.6	143.0	2.3	1.7
Minimum	72.2	71.6	71.7	71.4	-0.2	-0.4

(Source: JICA Project Team prepared based on the FEA data)

Although maximum demand has been growing by 2.3MW per year, minimum load has not been grown. If it is assumed that the trend of every hour-wise growth rate continues up to 2025, the daily load curve in 2025 could be forecasted as shown in Figure 8.2-3.

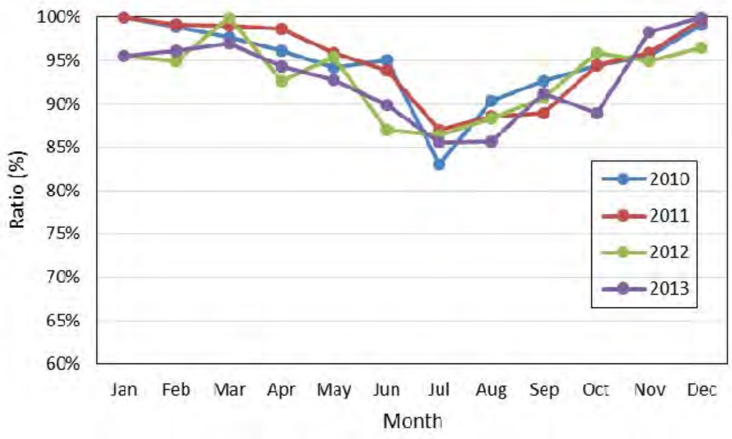


(Source: The JICA Project Team prepared based on the FEA data)

Figure 8.2-3 Forecast of Daily Load Curve in 2025（Peak Load Date）

(3) Seasonal Difference

Peak demand of every month from 2010 to 2013 is shown in Figure 8.2-4. Peak demand in winter season is around 90 % of that of summer season in every year.



(Source: JICA Project Team prepared based on the FEA data)

Figure 8.2-4 Monthly Peak Demand

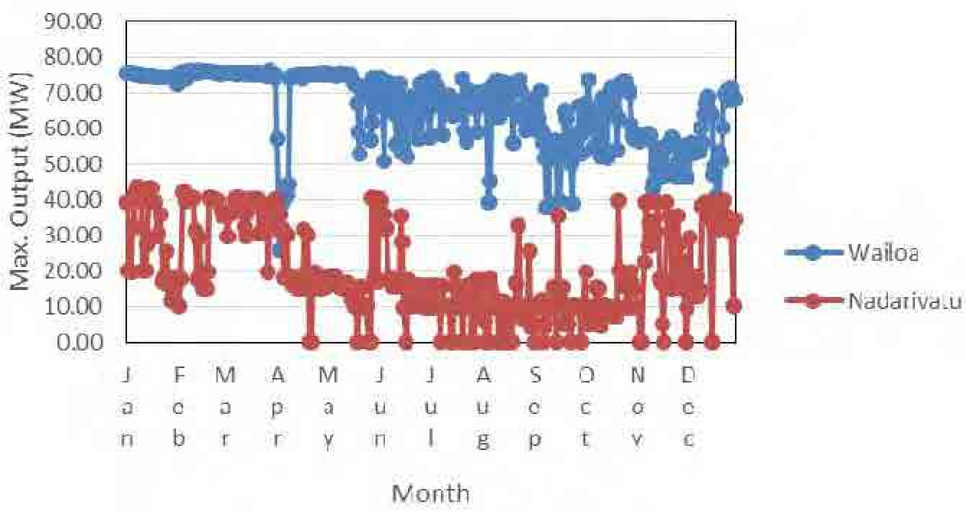
(4) Data of Power Plant Facilities

a. Hydropower Plant Features

(a) Monthly maximum and minimum output

Referring to operation records of daily maximum output of every power plant, monthly maximum output and minimum output are assumed.

Figure 8.2-5 shows operation record, daily maximum output of Wailoa hydropower plant of a reservoir type in 2012 and Nadarivatu hydropower plant of a run-of-river type in 2013.



(Source: JICA Project Team prepared based on the FEA data)

Figure 8.2-5 Annual Operation Records of Large Scale Hydropower Plants

Daily maximum outputs of the only one reservoir type hydropower of Wailoa Hydropower Station were recorded at around the available capacity of 75 MW even in the dry season, while the capacity factor was 72.7%. However, daily maximum outputs of the run-of-river type of

Nadarivatu Hydropower Station in the dry season from May to October were declined largely to around 1/4 of the available capacity of 40 MW, while the capacity factor was 28.0%.

(b) Monthly electricity generation

Monthly mean electricity generation of the each existing hydropower plant was calculated based on the operation records.

As for the hydropower projects which will be commissioned near future, monthly electricity generation described in the F/S report was applied. As for the hydropower projects which F/S report could not be obtained, the monthly electricity generation was calculated in reference to the operation record of the existing hydropower plant which is located in the vicinity river basin.

(c) Future hydropower development projects

As described in the Chapter 3, six prospective hydropower potential sites in Table 8.2-2 are nominated from the viewpoints of economic efficiency and environmental & social consideration in the Study.

Table 8.2-2 List of the Prospective Hydropower Potential Sites

Location	Power Plant Name	Type	Installed Capacity (MW)	Supply Capacity (MW)	Electricity generation (GWh)	Capacity Factor (%)
Viti Levu	Mba (No.8)	Reservoir	14	10.6	57.8	57.2
	Waivaka (No.29)	Reservoir	32	28.3	67.6	24.1
	Nablaurua(No.7)	Run-of-river	1.4	0.6	8.3	67.7
	Naboubuca (No.14)	Run-of-river	2.7	0.9	20.4	86.3
	Sub-total		50.1	40.4	154.7	-
Vanua Levu	Wailevu (No.35)	Reservoir	17	14.6	58.1	39.0
	Saquru (No.31)	Run-of-river	2	0.2	9.6	54.8
	Sub-total		19	14.8	67.7	-
Total			69.1	55.2	222.4	-

b. Thermal Power Plant Features

The thermal power plants which available capacity is more than 3 MW were categorized according to the categorization as shown in Table 8.2-3.

(a) Categorization of thermal power plants

Thermal power plant features were categorized by such as fuel type, generation type and unit capacity, as shown in Table 8.2-3. Since actual records of outrage rate could not obtained, the forced outage rate of thermal power was set as follows in reference to the other countries' thermal power plant operation records.

Table 8.2-3 Categorization of Thermal Power Plants

No.	Fuel type	Other information	Unit capacity (MW)	Efficiency (maximum output)	Minimum output	Forced Outage rate	Corresponding Plants
21	Existing Diesel	IDO	3-5	33.0%	40%	10%	Vuda, Lautoka, Sigatoka, Kinoya PS
24	Existing Diesel	HFO	3-5	33.0%	40%	10%	Kinoya PS
25	New Diesel	HFO	3-5	45.0%	40%	8%	Kiniya PS extention New Plants

(b) Future thermal power development projects

Since Kinoya PS extension project of 35MW is described as a future thermal power development project in the annual report 2013 of FEA, diesel power generation with HFO is only considered as a future thermal power development project.

c. Future Power Development Project with Renewable Energy

(a) Biomass power plants

As described in the Chapter 6, the following two prospective biomass power potential sites in the following table are nominated from the viewpoints of biomass supply capacity forecasted in the Study.

(b) Geothermal power plants

Geothermal potential sites more than 3MW among geothermal potential sites described in SE4All report were nominated as development projects as shown in Table 8.2-4.

Table 8.2-4 List of Prospective RE Power Development Projects

Location	Power Plant Name	Source and Type	Installed Capacity (MW)	Supply Capacity (MW)	Generation Energy (GWh)
Viti Levu	Lautoka (FSC)	Biomass	5	4.5	16.6
	Tavua	Geothermal	6	6	44.7
	Busa	Geothermal	4	4	29.8
	Sub-total		15	14.5	16.6
Vanua Levu	Labasa	Biomass	10	9	33.3
			3	2.7	10.0
			4	3.6	13.3
	Savusavu	Geothermal	8	8	59.6
	Waiqele	Geothermal	8	8	59.6
	Sub-total		25	23.3	116.1
Total			40	37.8	132.7

(5) Proper Supply Reserve Margin based on the Supply Reliability Criteria

a. Base Case Study

The relationship between LOLE and the supply reserve margin was obtained, taking into consideration the generation mix forecast around 2020 (with the demand size of approx. 230 MW), and the appropriate supply reserve margin was determined to achieve the targeted supply reliability criteria.

b. Input Data

(a) Error in demand forecast

Error in the demand forecast, which is 2% of the forecasted demand, is estimated as the standard deviation.

(b) Generation facility composition and forced outage rate

The generation mix and their forced outage rates are as shown in Table 8.2-5.

Table 8.2-5 Generation Mix and Forced Outage Rate

	Available Capacity (MW)	Ratio	Max. Unit Capacity	Outage Rate
Hydropower	120.5	52.5%	20MW	2%
Wind	10.0	4.3%	1MW	5%
Oil-fired thermal	85.9	37.3%	3-5MW	8% - 10%
Biomass fired thermal	13.6	5.9%	3-20MW	10%
Total	230.0	100%		

(Source: JICA Project Team prepared based on the FEA data)

(c) Output fluctuation probability of hydropower plant

Approximately 6% (7 MW) in wet season and 12% (15 MW) in dry season is estimated respectively as the standard deviation of supply capacity fluctuation possibility of hydropower plant.

c. Relationship between LOLE and Supply Reserve Margin in 2020

The relationship between LOLE and the supply reserve margin determined based on the inputted data as described above is shown in Figure 8.2-6.

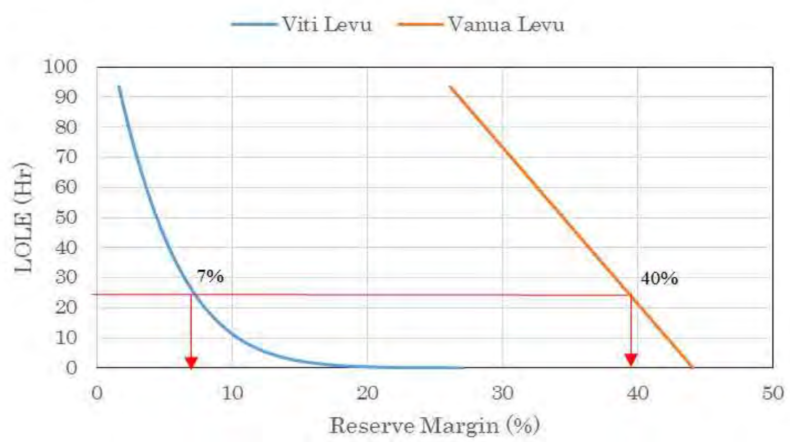


Figure 8.2-6 Relationship between LOLE and Supply Reserve Margin

When referring to examples in other countries, 24 hours in LOLE value is targeted as the supply reliability criterion in Thailand and Vietnam as well. Accordingly, 24 hours or less should be targeted in the LOLE value.

When the above-described supply reliability criterion is taken into consideration in the case of no interconnection power line, approx.7% in Viti Levu and 40% in Vanua Levu would be needed as the supply reserve margin in 2020.

d. Supply Reliability Study in 2025

The results of studying the reserve supply capacity by using demand profile and composition of power plants expected in 2025 is shown in Figure 8.2-7.

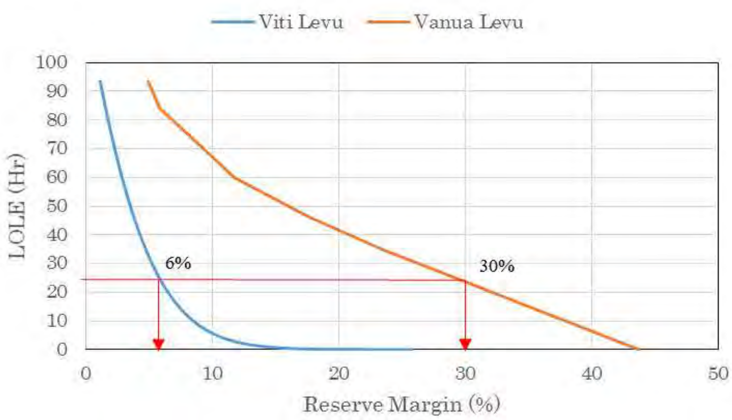


Figure 8.2-7 Relationship between LOLE and Supply Reserve Margin in 2025

In the study of the case in 2025, the supply reserve margin required to secure the comparable supply reliability level can be about 1% lower than the result of studying the projected status of 2020 in Viti Levu and about 10% lower than the result of 2020 in Vanua Levu. This seems to be due to the following reasons:

- As the demand profile takes a greater peak, peak hours with high demand will become shorter.
- The ratio of unit capacity of power plant newly developed against its peak demand is getting smaller, especially in the case of Vanua Levu.

e. Supply Reliability Study in the Case of Interconnection between Viti Levu and Vanua Levu in 2025

The relation between the amount of reduction of reserve capacity and interconnection capacity of Viti Levu and Vanua Levu is analyzed. The amount of reduction of reserve capacity by interconnection in 2025 was calculated by RETICS (Reliability Evaluation Tool for Inter-Connected Systems) as a tool of system reliability analysis. The calculation results are shown in Figure 8.2-8.

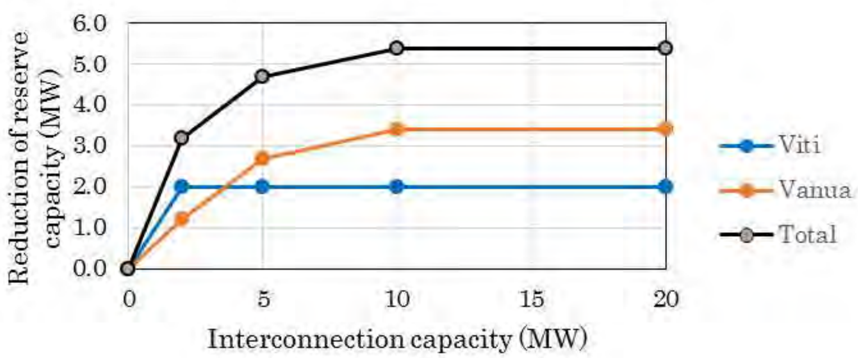


Figure 8.2-8 Relationship between Amounts of Reduction Reserve Capacity and Interconnection Capacity in 2025

The necessary reserve capacity of Viti Levu or Vanua Levu is 14.0MW (5.1%) or 1.1MW (6.5%) respectively and that of the total system is 15.1 MW (5.2%), if interconnected with the interconnection capacity of more than 10 MW.

Meanwhile, the construction cost of the interconnection between Viti Levu and Vanua Levu was estimated as shown in Table 8.2-6. 132 kV line is to be selected, if interconnected, since it is more economical than 33 kV line in terms of unit cost. And its annual cost is estimated as 30.4 million USD/annum.

Table 8.2-6 Rough Cost Estimate of Interconnection

Voltage	Transmission Capacity	Description	Cost (Million USD)
132kV	88MW*1	Submarine × LPE cable 2×70km	210*2
		SVC	35*3
		4×132/33kv transformer	17*1
Tota1			262
33kV	6.5MW*1	Submarine × LPE cable 2×70km	158*2
		SVC	35*3
Tota1			193

*1 Based on PDP 2011 (Exchange rate: 1FJD＝0.52USD, as of Oct. 9, 2014, Reserve Bank of Fiji)
*2 Based on Interconnection Feasibility Study - Task 8 Cost Estimate Study, Aug. 2011, Siemens
*3 Based on 100 Per Cent Renewables Study - Electricity Transmission Cost Assumptions, Sep. 2012, AEMP

(6) Study on Optimal Power Supply Configuration in 2025

At the power system which peak demand will get to the scale of 290 MW around 2025, it is precondition that all ongoing hydropower projects and prospective hydropower potential sites found in this Project are to be developed, and the each optimal configuration ratio of biomass and geothermal power plant was studied. Next, the economy comparison study on with or without of interconnection between Viti Levu and Vanua Levu was conducted.

a. Optimal configuration rate of Biomass and Geothermal Power Plant

(a) Calculation assumptions

There are two types of biomass power plant, one utilizes Bagasse as fuel and the other utilizes wood waste as fuel. Bagasse biomass power plant is to be operated continuously from June to December (for 30 weeks) without output change and the development potential is limited to 100 MW including existing power plants.

Besides, since wood waste biomass power plant can operate continuously from May to December (for 35 weeks) longer than bagasse power plant and the economic development potential is limited to only 5 MW, it is to be developed initially.

Meanwhile, geothermal projects of over 3 MW among geothermal potential sites described in SE4ALL Report were considered as a development capacity. The total capacity is 26 MW (10 MW in Viti Levu, 16 MW in Vanua Levu).

(b) Calculation results by demand supply balance operational simulation

The calculation results of the annual generation expense is shown in Figure 8.2-9 in the case that development capacity of bagasse biomass power plants is varied without geothermal power development or with geothermal power development of 10 MW. Here, the base case of development capacity of biomass power plant is set as 72 MW (Bagasse 68MW+Wood residue 4MW) in Viti Levu and 5 MW (only Bagasse) in Vanua Levu.

The annual expense decreases along with the increase of development capacity of biomass power plant in Viti Levu. However, since there is no more development potential more than that of the base case, the cases of increasing development capacity of biomass power plants in Vanua Levu were considered under the condition of interconnection between the two islands, on the contrary, the annual generation expense increased. This is deemed to be caused mainly by little economic power exchange due to power loss of interconnection line.

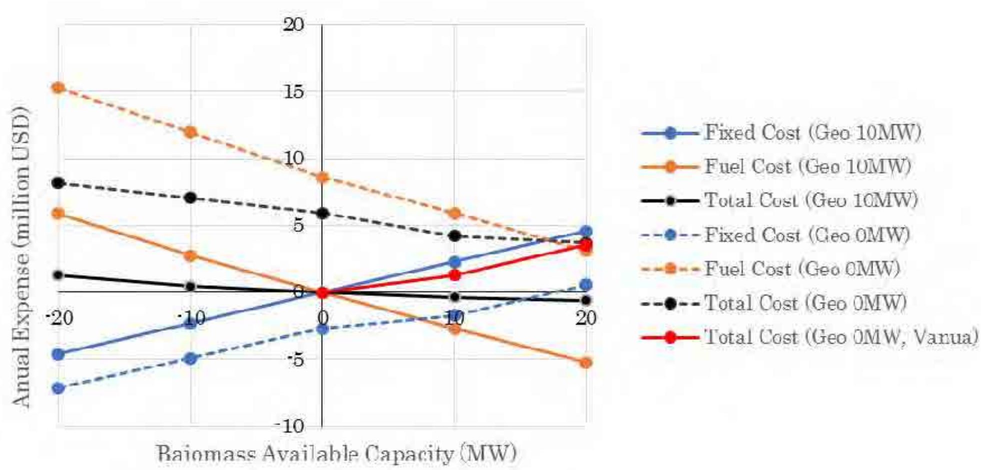


Figure 8.2-9 Cost Comparison between Biomass and Diesel (HFO)

On the basis that the above optimal development capacity of biomass power plants of 77 MW and geothermal power plants of 10 MW, the calculation results of the annual generation expense is shown in Figure 8.2-10 in the case that development capacity of geothermal power plants is varied. In the case that geothermal power plants are developed in Viti Levu, the annual generation expense decreases monotonously in line with increase of development capacity. However, since there is no more development potential more than that of the base case, the cases of increasing development capacity of geothermal power plants in Vanua Levu were considered as well. As the results, the annual generation expense in the case of 4 MW decreased a bit and that in the case of 8 MW increased.

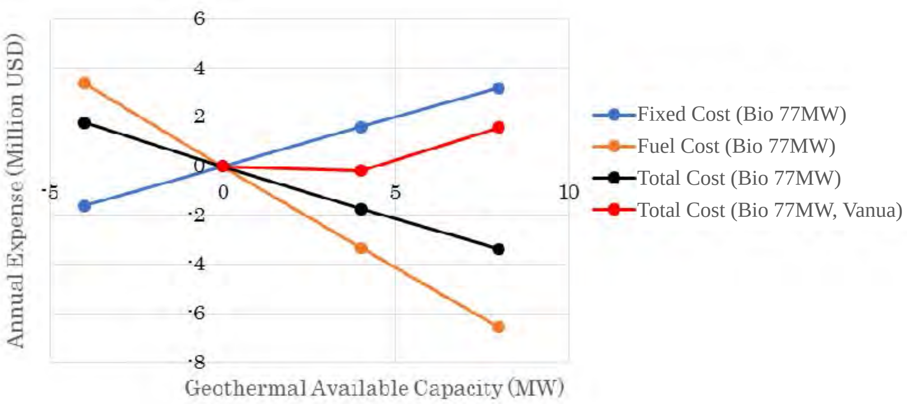


Figure 8.2-10 Cost Comparison between Geothermal and Diesel (HFO)

b. Economy comparison of with or without of interconnection

The above study was carried out in consideration of the interconnection between Viti Levu and Vanua Levu and the total necessary supply reserve margin is set as 5.2%. As for the case without system interconnection, the required supply reserve margins of Viti Levu and Vanua Levu in 2025 are 6% (12 MW) and 30% (5 MW) respectively. As the results, the reduction advantage of the annual generation expense is totally 1.52 million USD/annum

On comparing the reduction advantage to the annual expense of 132 kV interconnection line of 30.4 million USD/annum, it is evident that without case of interconnection line be more economical.

Accordingly, the system interconnection is not considered in the subsequent study on the optimal power supply configuration.

c. Optimal power supply configuration in 2025

Based on the above study results on the optimal power supply configuration in 2025, kWh balance of Viti Levu are as shown in Figure 8.2-11. The supply demand balance becomes the tightest in April and May and the reserve margin is also minimum through the year.

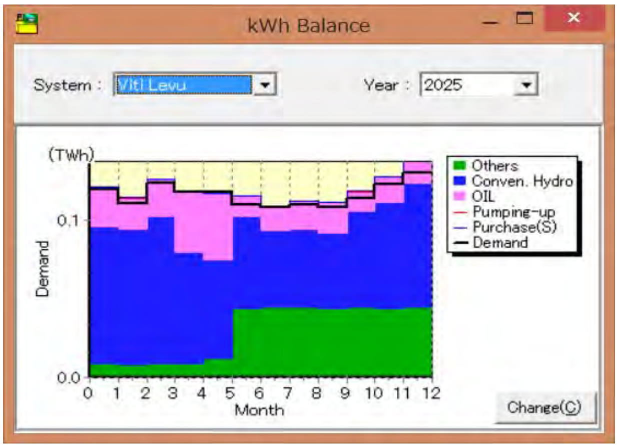


Figure 8.2-11 kWh Balance of Viti Levu in 2025

Besides, simulation results of the weekly operation in summer (Mar.) and in winter (Sep.) in Viti Levu are shown in Figure 8.2-12.

In summer (Mar,) **In winter (Sep.)**

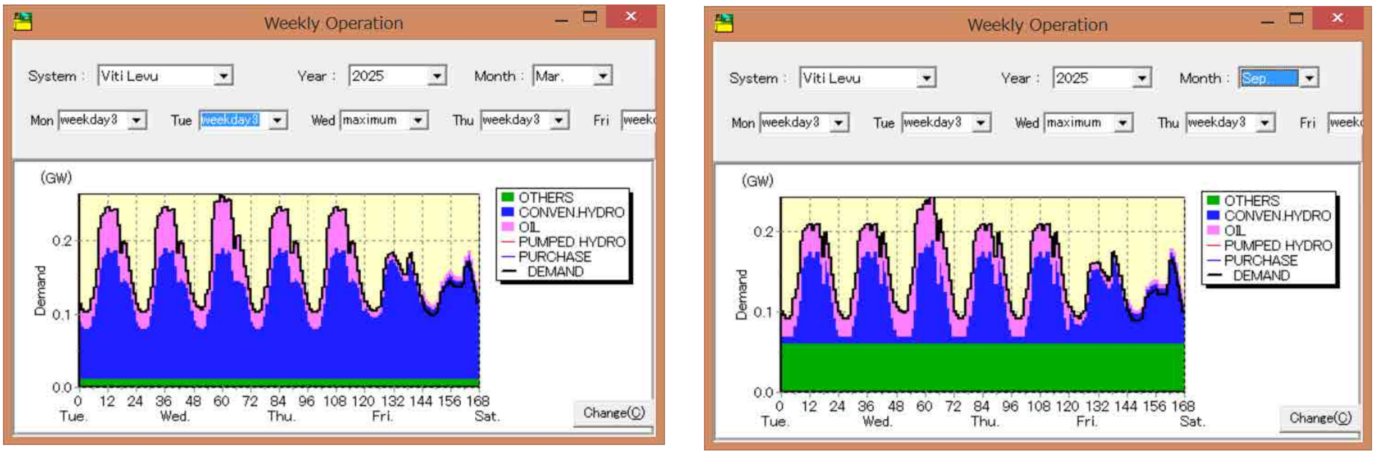


Figure 8.2-12 Weekly Operation of Vanua Levu in 2025

Since baiomass power plants stop during summer season and amount of electricity generation and supply capacity of hydropower plants decrease in winter, diesel power plants have to operate on weekdays and monthly maximum days to meet the demand.

Optimal power supply configration in Viti Levu and Vanua Levu in 2025 is shown in Figure 8.2-13. Configration ratio of Diesel (HFO) of 27% is optimal. Consequently, electricity generation supplied by renewable energy (incl. hydropower) account for 82 % in 2025 as shown in Figure8.2-14.

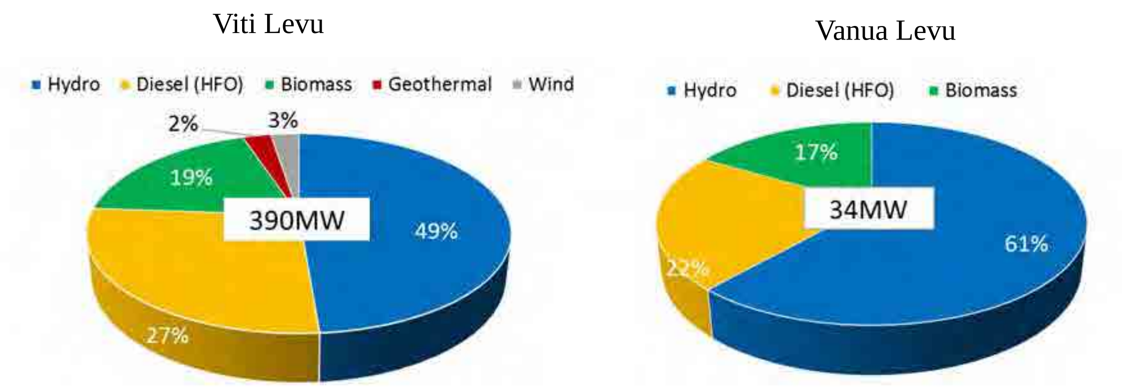


Figure 8.2-13 Optimum Generation Mix in 2025 (Available Capacity Base)

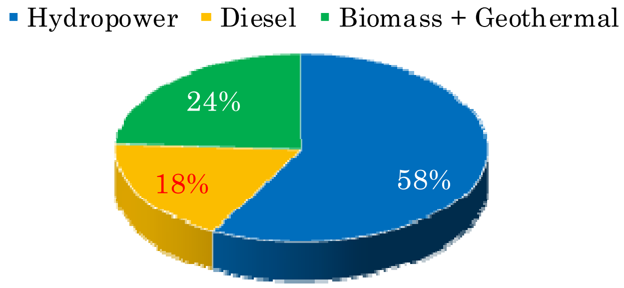


Figure 8.2-14 Total Electricity generation Mix in 2025

8.3 Power Development Plan from 2015 to 2025

Based on the above study results, the optimal long term power development plan during decade (2015 – 2025) is proposed targeting minimization of total present value of power supply cost.

(1) Calculation Assumptions

Calculation assumptions of power plants are basically the same as those described in Section 8.2.

(2) Power Demand forecast

Peak demand forecasts in May of Base case, when demand supply balance is the tightest, are as follows.

Table 8.3-1 Peak Demand Forecast in May

(MW)

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Viti	140.3	147.4	155.7	164.5	173.8	183.7	194.1	204.2	214.8	225.9	237.7	250.0
Vanua	8.4	8.9	9.4	9.9	10.5	11.1	11.7	12.3	12.9	13.6	14.3	15.1
Total	148.8	156.2	165.1	174.4	184.3	194.8	205.8	216.5	227.7	239.5	252.0	265.1

(3) Basic Development Policy of Each Power Source

(a) Hydropower Plant

In addition to currently developing power projects, based on the potential study on hydropower, the constructions of 6 prospective hydropower potential sites are to be stared by 2025. Meanwhile, development period of hydropower was set that 1.5 years for Feasibility Study (FS) and 3.5 years for construction are necessary at least, that is, total 5 years is needed at earliest, that is, the commissioning year is to be after 2020.

(b) Biomass power plant

Based on the results of potential study on Biomass power described in Chapter 6 in line with product prediction of bagasse and wood waste, the supply capacity of each mill to the power grid is taken into account.

(c) Geothermal power plant

Geothermal projects of over 3 MW in Viti Levu among geothermal potential sites described in SE4ALL Report (total 10 MW) are considered as a development capacity within 2015.

(d) Decommissioning plan of the existing generation facilities

The existing Diesel power facilities using IDO are to be decommissioned or replaced by modern Diesel power facilities using HFO as early as possible.

(e) Generation facilities of which commissioning year is varied

The commissioning year of the following two kinds of power source was varied.

- New Bagasse Biomass power plants
- Diesel power plants

(4) Least Cost Power Development Plan from 2015 to 2025

According to the above development policy, commissioning year of biomass and diesel power is varied securing necessary power supply reserve and total present value as of 2014 of generation expense from 2015 to 2025 is calculated by demand supply balance simulation.

The overall generation unit cost (LRMC) of the above long term development plan from 2015 to 2025 is shown in Table 8.3-2. The overall generation unit cost in 2025 is estimated to be 15% down against the 13.4 US cent/kWh in 2015.

Table 8.3-2 Overall Generation Unit Cost

(US cent/kWh)

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Unit Cost	13.4	12.3	12.6	12.6	12.0	11.9	11.9	11.6	11.7	11.6	11.5

Available capacity configuration ratio and electricity generation ratio of each power source from 2015 to 2025 are shown in Figure 8.3-1. Electricity generation produced by renewable energy power sources including hydropower accounts for 86% in 2022 at the maximum, after that, the share is declined to 82%, since there is not any power development of large scale renewable energy power sources except geothermal power. Accordingly, it is recommended in order to increase the share of electricity generation by hydropower and renewable power sources including hydropower up to more than 85% that further finding and developing hydropower potential and development of wind farm on which DOE has started potential study is to be progressed.

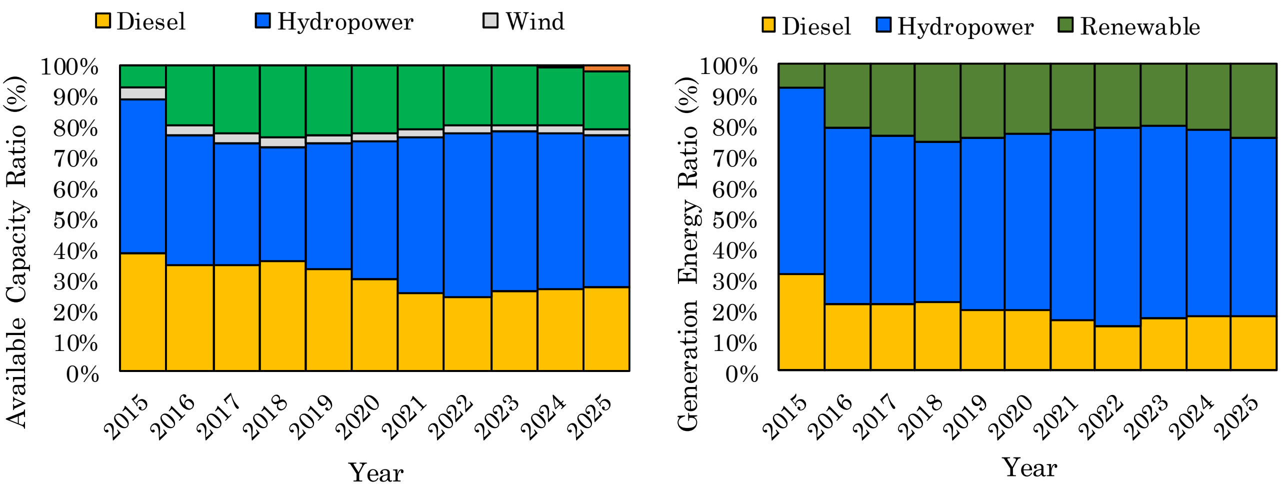


Figure 8.3-1 Generation Capacity Mix and Electricity Generation Mix (2015-2025)

8.4 Long Term Investment Plan

(1) Calculation assumptions

Yearly deployment of construction cost of a hydropower or a thermal (diesel) power plant is assumed as shown in Table 8.4-1. And interest rate during construction is assumed as 10%.

Table 8.4-1 Assumptions of Year Allocation of Construction Cost

Year	5 years ago	4 years ago	3 years ago	2 years ago	1 year ago
Hydropower	15%	20%	20%	30%	15%
Diesel Power			30%	50%	20%

(2) Calculation results

Long term investment cost by FEA in order to achieve the long term power development plan proposed in Section 8.3 is estimated as shown in Table 8.4-2. Meanwhile, considering that a biomass (bagasse / wood waste) power plant is developed by IPP such as FSC / Tropik Woods, those investment costs are excluded.

Table 8.4-2 Long Term Investment Cost by FEA

(million USD)

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Viti	13.6	16.3	33.0	41.8	42.0	42.8	31.9	14.4	14.4	12.7	5.4	0.0
Vanua	2.1	3.6	3.9	9.2	12.8	15.7	19.6	11.9	0.8	0.0	0.0	0.0
Total	15.7	20.0	36.9	51.1	54.9	58.5	51.5	26.3	15.3	12.7	5.4	0.0

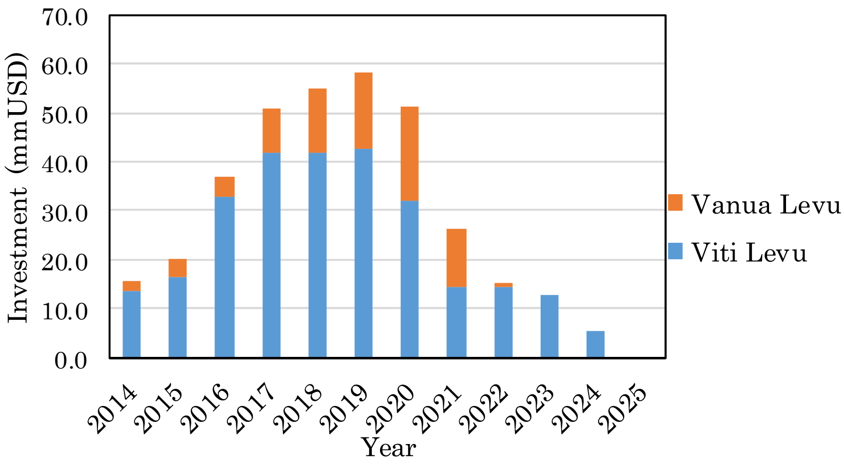


Figure 8.4-1 Long Term Investment Cost by FEA

8.5 Issues on Financing Plan for Proposed Hydropower Projects

Total investment cost for hydropower development by FEA between 2014 and 2022 is estimated to be is nearly USD 248.9 million, which account for approximately 72% of total investment cost. Total investment cost for proposed projects in this study has a share of 82% to total hydropower development investment cost during the same period.

For development of proposed hydropower projects in this survey, if all would be financed by IPP, it would be roughly estimated that funding cost might be at least 8.9% (USD 18.58 Million)[2] . For IPP side, it is necessary that electricity sales revenue should cover the investment and O & M cost and also the profit margin; therefore, most probably they require that the conditions on power purchase agreement assure to cover them. Thus, in long-term perspective, this cost may have to be ultimately covered by the Fijian government side. Currently, the electricity tariff for IPP is stipulated to be 0.3308 FJD per kWh as a minimum rate which is less than the weighted average of electricity tariff for consumers 0.3743 FJD/ kWh. Should the IPP require the higher electricity tariff than this minimum rate, financial sustainability of FEA might be risked unless the increase of electricity tariff of consumers or any other means will be implemented.

Given the current financial situation of FEA as described in the Chapter 3, that is, financial cost will increase in the near future and difficulty in increasing dramatically the electricity tariff due to social purpose, the finance by the concessional loans by any foreign international development institutions can be more sound option, considering the merit of the longer repayment period including grace period and the lower interest rate For example, the general lending terms of the Japanese ODA loan for

[2] It is assumed to be the finance from all commercial loans, based on the average long-term interest rate of the commercial bank loan during the past 10 years in Fiji. Namely, lending terms are assumed to be annual interest rate of approximately 7.2%, repayment period of 15 years ,and semi-annual installment.

upper middle income country (annual fixed interest rate: 1.7%, repayment period 25 years, including grace period 7 years) for the project cost, funding cost is estimated to be 3.0%, that is less than 4.6% of the current weighted average funding cost of FEA. If the preferential terms (annual fixed interest rate: 0.6%, repayment period 40 years, including grace period 10 years) can be applied as the project contributing to the climate changes, funding cost would be 1.6%.

Republic of Fiji
Ministry of Infrastructure and Transport
Fiji Electricity Authority (FEA)

THE PROJECT FOR THE EFFECTIVE AND EFFICIENT USE OF RENEWABLE ENERGY RESOURCES IN POWER SUPPLY IN REPUBLIC OF FIJI

FINAL REPORT
VOL.Ⅱ MAIN REPORT

FEBRUARY 2015

Japan International Cooperation Agency

Tokyo Electric Power Services Company, Ltd.

Final Report

Volume Ⅱ Main Report

on

the Project for the Effective and Efficient Use of Renewable Energy Resources in Power Supply in Republic of Fiji

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Abbreviations

Abbreviations	Words
B/C	Benefit / Cost
CER	Certified Emission Reduction
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CO_2	Carbon Dioxide
C/P	Counterpart
D/C	Double Circuit
DF/R	Draft Final Report
DOE	Department of Energy
DoEnv	Department of Environment
DOF	Department of Forestry
DSM	Demand Side Management
ECR	Economical Continuous Rating
EIA	Environmental Impact Assessment
EIB	European Investment Bank
EIRR	Economic Internal Rate of Return
FCC	Fiji Commerce Commission
FEA	Fiji Electricity Authority
FFI	Fiji Forest Industries
FIBO	Fiji Islands Bureau of Statics
FIP	Feed-in Premium
FIRR	Financial Internal Rate of Return
FIT	Feed-in Tariff
FJD	Fiji Dollar
FMS	Fiji Meteorological Service
F/S	Feasibility Study
FSC	Fiji Sugar Corporation
F/R	Final Report
GDP	Gross Domestic Product
GoF	Government of Fiji
IC/R	Inception Report
IDO	Industrial Diesel Oil
HFO	Heavy fuel oil
IBA	Important Bird Areas
IEA	International Energy Agency
IEE	Initial Environmental Examination
IPP	Independent Power Producer
IT/R	Interim Report

JBIC	Japan Bank for International Cooperation
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
LILO	Loop-In-Loop-Out
LOLE	Loss of Load Expectation
LOLP	Loss of Load Probability
LRMC	Long Run Marginal Cost
METI	Ministry of Economy, Trade and Industry of Japan
MWTPU	Ministry of Works, Transport and Public Utilities
NBSA	National Biodiversity Strategy and Action Plan
NEF	New Energy Foundation
NPV	Net Present Value
NEP	National Energy Policy
NLC	Native Lands Commission
O&M	Operation and Maintenance
OJT	On the Job Training
PAC	Fiji National Protected Area Committee
PCCPP	Peoples Charter for Change Peace and Progress
PDP	Power Development Plan
Pre-F/S	Preliminary Feasibility Study
PR/R	Progress Report
PS	Power Station
PWD	Public Works Department
PDPAT	Power Development Plan Assist Tool
RDSSED	Roadmap for Democracy and Sustainable Socio-economic Development
RE	Renewable Energy
RESCO	Renewable Energy Service Company
RETICS	Reliability Evaluation Tool for Inter-Connected Systems
REU	Rural Electrification Unit
RPS	Renewable Portfolio Standard
S/C	Single Circuit
SCF	Standard Conversion Factor
SEA	Strategic Environmental Assessment
SHM	Stake Holder Meeting
SHS	Solar Home System
TDR	Transmission Distribution Retail
TEPSCO	Tokyo Electric Power Services Co., Ltd.
TLTB	iTaukei Land Trust Board
TOR	Terms Of Reference

TWC	Tropik Wood Corporation
TWI	Tropik Wood Industries
VLIS	Viti Levu Interconnected System
WAF	Water Authority of Fuji

Chapter 1 Introduction

1.1 Background

The Fiji Electricity Authority ("FEA") supplies electricity through its grid systems on three islands, Viti Levu, Vanua Levu and Ovalau, with a total installed capacity of 258 MW. The breakdown is as follows:

Hydro : 137.40 MW (including the Nadarivatu Hydro Scheme),
Wind : 10 MW
Diesel : 110.60 MW

The increase of fuel prices in the 2000s had a negative impact on the financial coffers of FEA and the Country as a whole. Against this background, in 2006 the Government of Fiji set the target of the ratio of renewable energy to fossil fuels utilized in on-grid power generation to be 90 : 10 by 2011[1].

FEA has in its Mission Statement published in 2011, "… aims to provide clean and affordable energy solutions to Fiji with at least 90% of the energy requirements through renewable sources by 2015". This means a target for maximum renewable energy generation using hydropower, biomass, and wind, either through FEA's generation or with assistance from the Independent Power Producers (IPPs). Considering the current situation, the further development and utilization of renewable energy, particularly exploitation of hydro and biomass energy should be accelerated in power sector.

In this situation, the Government of Fiji has requested the Government of Japan to undertake a Project for the Effective and Efficient Use of Renewable Energy Resources in the Republic of Fiji's Power Supply ("the Project"). In response to the request from the Government of Fiji, Japan International Cooperation Agency ("JICA") implemented the Detailed Planning Survey from 26th May to 12th June 2012 in Fiji to develop a detailed plan of the Project, and the "RECORD OF DISCUSSIONS ON THE PROJECT FOR THE EFFECTIVE AND EFFICIENT USE OF RENEWABLE ENERGY RESOURCES IN POWER SUPPLY IN THE REPUBLIC OF FIJI AGREED UPON AMONG MINISTRY OF WORKS, TRANSPORT, AND PUBLIC UTILITIES, FIJI ELECTRICITY AUTHORITY AND JAPAN INTERNATIONAL COOPERATION AGENCY" ("Record of Discussions") was signed on 25th April 2013. The Project is implemented in line with the contents of the signed Record of Discussions.

[1] In the next national energy policy (not yet officially endorsed as of Jan. 2015), the target of renewable energy share in electricity generation is 81% by 2020 and 100% by 2030.

1.2 Outline of the Project

1.2.1 Title of the Project

The Project for the Effective and Efficient Use of Renewable Energy Resources in Power Supply

1.2.2 Purpose of the Project

Through the following five (5) activities, the Project's objectives are to prepare a hydropower development site map and the overall development schedule up until 2025; as well as to examine and propound the optimum composition of renewable energy resources in the power sector in Fiji until 2025, which will contribute to stabilizing the power supply and reducing in fossil fuel consumption for power generation in the country by promoting renewable energy resources,

1) Collection and analysis of relevant data and information
2) Hydropower potential study
3) Preliminary design of prospective hydropower projects
4) Identification of biomass resources potential sites in both Viti Levu and Vanua Levu.
5) Preparation and recommendations for a hydropower development plan and the optimum composition of renewable energy resources in the power sector until 2025

In addition, through the joint works with personnel concerned in Fiji, the Project will contribute to a technology transfer and the development human resources in the area of hydropower development planning.

1.2.3 Project Areas

Viti Levu and Vanua Levu in Republic of Fiji

1.2.4 Relevant Government Offices and Organizations

- Department of Energy, Ministry of Infrastructure and Transport
- Fiji Electricity Authority (FEA)

1.3 Team and Schedule of the Project

1.3.1 Technical Directions

The JICA Project Team carried out the Project taking into account the above described issues and the subjects to be carefully considered. The technical directions for the Project were as follows:

(1) Collection and analysis of relevant data and information
(2) Hydropower potential study
(3) Preliminary design of prospective hydropower projects
(4) Identification of biomass resources potential sites in both Viti Levu and Vanua Levu
(5) Preparation and recommendations for a hydropower development plan and the optimum composition of renewable energy resources in the power sector until 2025

(1) Collection and Analysis of Relevant Data and Information

Prior to conducting potential studies on hydropower and biomass, the JICA Project Team evaluated all renewable resources available in Fiji including hydro, wind, solar, geothermal and biomass energies through reviewing the information and data on Fiji's power sector. This included development situations and the future potentials of renewable energies, as well as the policy of the existing power development plan to confirm the importance and necessity of hydropower and biomass power development in the power sector..

(2) Hydropower Potential Study

Figure 1.3.1-1 shows the work flow of prioritization of the potential hydropower sites.

The JICA Project Team discussed the following factors with the counterpart ("C/P") and set the criteria for identifying and selecting the hydropower potential sites.

- Natural and social environmental conditions
- Topographical and geological conditions
- Technological and economic conditions

Based on the above-mentioned project selection criteria, the past hydropower potential sites were reviewed, and an alternative plan was made if necessary. Subsequently, the JICA Project Team will a conduct hydropower potential study using 1:50,000 scale topographical maps.

For all potential sites, the JICA Project Team will estimate the approximate power station construction costs by multiplying the rough construction cost integration method with the price adjustment factor of Fiji.

The potential sites will be prioritized on the following points, and about 10 prospective hydropower projects will be selected.

- Construction unit cost of each site
- Distance from the nearest substation
- Road and traffic condition to the site

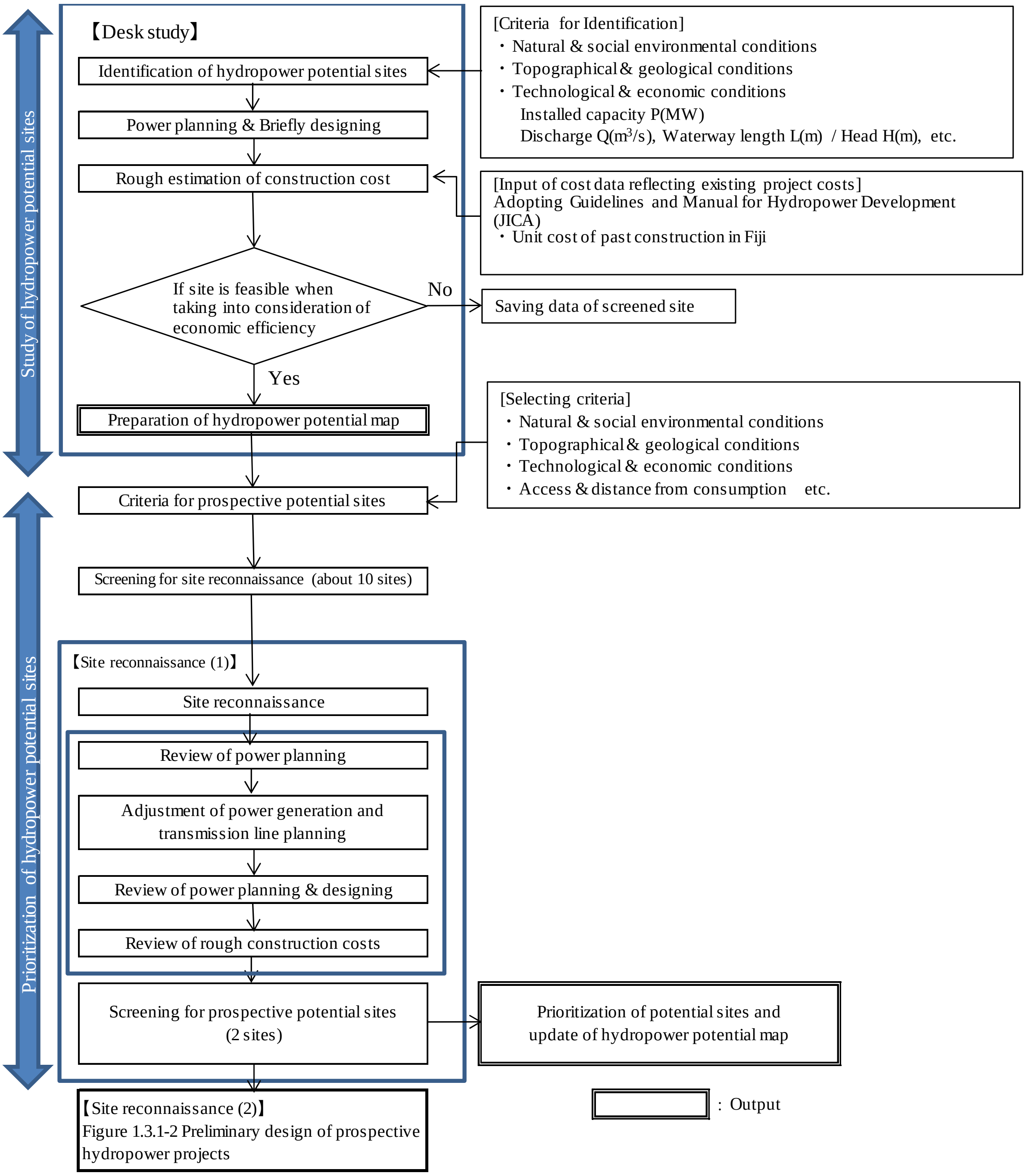


Figure 1.3.1-1 Identification and Prioritization of Hydropower Potential Sites

(3) Preliminary Design of Prospective Hydropower Projects

The preliminary design of prospective hydropower projects was carried out in line with the work flow shown in Figure 1.3.1-2.

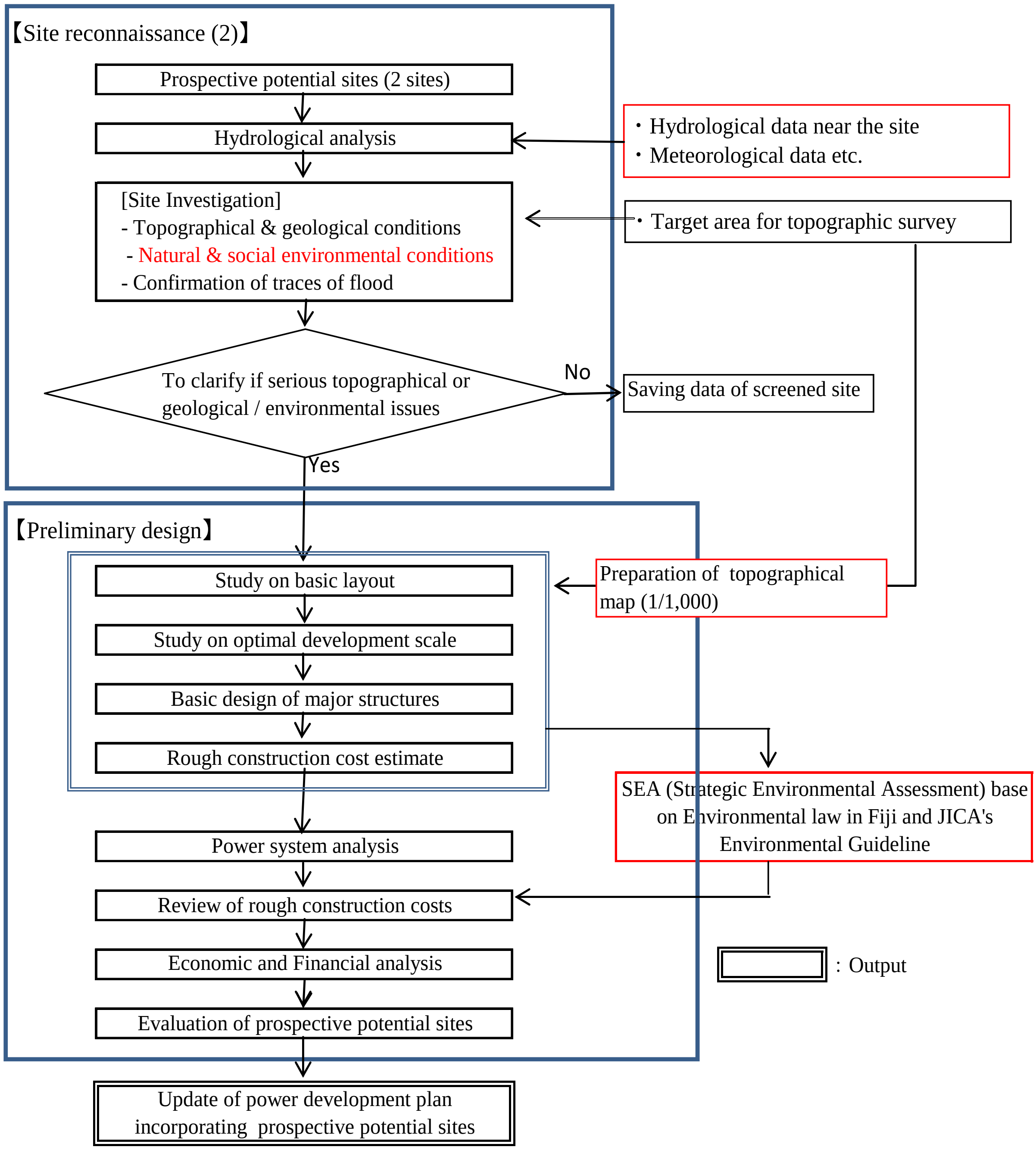


Figure 1.3.1-2 Preliminary Design of Prospective Hydropower Projects

(4) Identification of Biomass Resources Potential Sites in both Viti Levu and Vanua Levu

The power generation using bagasse, which has recently been a downward trend in the harvest of sugarcane, is limited to the dry season (from June to November). On the other hand, since it was a trend that the latest timber production volume increased in Fiji, it was highly likely that the biomass power generation was done through using forestry residue.

The JICA Project Team discussed the following factors with C/P and set the criteria for identifying and selecting the biomass power potential sites.

- Location of the manufacturing stations for biomass energy
- Their production scales and seasonal changes
- Road and traffic condition to the potential sites

The JICA Project Team surveyed the biomass potential sites - the thirty-nine sawmills in Fiji and calculate the power generation capacity for utilizing them. In addition, the potential map based on the investigation of biomass power generation was prepared.

(Source: Report on the Detailed Planning Survey for the Maximum and Effective Use of Renewable Energies in Electricity Power Supply in Fiji, June 2012, JICA)

Figure 1.3.1-3 Major Sawmills and Forestry Residue

If the promising candidate site is confirmed through these studies, its preliminary design will be carried out in order to evaluate the potential for commercialization.

(5) Preparation and Recommendations for a Hydropower Development Plan and the Optimum Composition of Renewable Energy Resources in the Power Sector Until 2025

The optimum composition of renewable energy resources in the power sector until 2025 was prepared as follows:

1) Review and analysis of power demand forecast

Based on supply demand forecast of primary energy (e.g. hydro, biomass), power demand will be forecasted by island and by sector (industry, commercial, and residential), while based on the forecasted power demand (consumption (kWh)), peak demand for each month and daily load curve (for peak times, weekdays, and holidays) are predicted.

2) Proposal of optimal power development plan up to 2025

Figure 1.3.1-4 shows the image of optimum composition of power resources in 2025.

At present the generation capacity of all hydropower stations accounts for nearly 60% of total generation capacity in Fiji. Since supply capacity of hydropower station changes seasonally, it is necessary to determine the power supply capacity for power supply planning statistically based on the optimal reservoir capacity time (peak duration) of the hydropower stations, seasonal changes in rainfall, and so on. On the other hand, the biomass power generation using bagasse has become a seasonal operation for the period from June to November, during which hydroelectric power generation decreases due to the dry season. It is, therefore, noted that the optimum power supply operation may be realized by seasonally combining hydropower with biomass power generation.

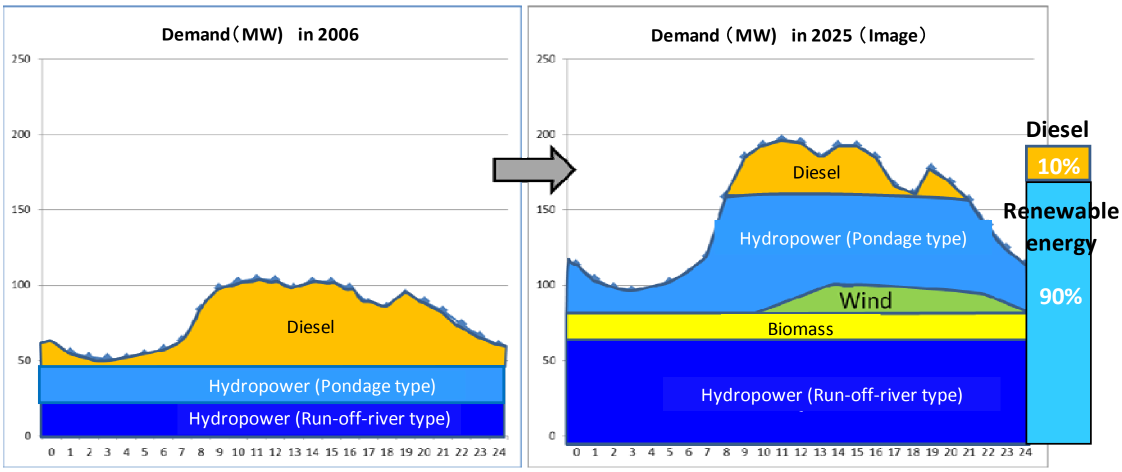


Figure 1.3.1-4 Image of Composition of Power Resources in 2025 in a Daily Load Curve

1.3.2 Operational Directions

The JICA Project Team carried out the Project taking into account the above described issues and the subjects to be carefully considered. The technical directions for the Project are as follows:

(1) Effective and efficient field survey
(2) Cooperative relations with counterpart agencies
(3) Close discussion and communication with JICA
(4) Ensuring safety during the work period in Fiji
(5) Technology transfer and the development of human resources on hydropower development planning through the joint works for the Project

(1) Effective and Efficient Field Survey

The JICA Project Team was divided into two groups for effectively and efficiently carrying out the site reconnaissance to potential hydropower sites. Also, if necessary, the Team arranged the field survey schedule in close coordination with the counterpart agencies, and visit the sites together with counterpart personnel who are familiar with the sites.

In order to collect data and information related to environmental and social considerations in and around the sites efficiently within a limited period, the JICA Project Team utilized an experienced local consultant for the environmental survey.

(2) Cooperative Relations with Counterpart Agencies

The JICA Project Team carried out the Project, fully taking into consideration information sharing with the counterparts, in very close cooperation with the counterpart agencies including DOE and FEA.

Before commencing the Project, the JICA Project Team shared information such as the objective, procedures and expected outputs of the Project with the counterpart agencies. In each work period in Fiji, tasks and goals of the works should be confirmed at the beginning of the relevant work period. Furthermore, outputs for that work period and tasks for the next work period should be confirmed at the end of the relevant work period between both parties

(3) Close Discussion and Communication with JICA

For implementing the Project, the JICA Project Team made its utmost efforts to contribute to the enhancement of cooperative relationships between Fiji and Japan through close communication with JICA, and to accomplish the results which will be technically and economically appropriate for Fiji through a series of discussions with JICA.

(4) Ensuring Safety During the Work Period in Fiji

The works in Fiji was carried out in full consideration of safety and health. In particular, site reconnaissance will be implemented by carefully preparing all necessary information to ensure safety and also through closely following the instructions issued by the counterpart agency and JICA's Fiji Office.

(5) Technology Transfer and the Development of Human Resources on Hydropower Development Planning Through the Joint Works for the Project

The Project Team carried out seminars/workshops on the criteria for identifying potential hydropower sites and methods for selection of prospective hydropower sites. The Team also executed site reconnaissance jointly with counterpart personnel in Fiji for the purpose of sharing the information with the counterpart agencies and to contribute to technology transfer and the development of human resources in the area of hydropower development planning.

The JICA Project Team also analyzed how staff members in charge of power and transmission development planning in DOE and FEA are trained, and, if necessary, recommend ways to address the training needs particularly with relevance to the Project.

1.3.3 JICA Project Team Members

The members of the JICA Project Team were shown in Table 1.3.3-1.

Table 1.3.3-1 Team Members of the JICA Project Team

No	Position	Name	Organization
1	Team Leader/ Power Development Planning	Masahiko NAGAI	TEPSCO
2	Hydropower Planning/Civil Engineering	Masayuki ITO	TEPSCO (IIEP)
3	Electrical Engineering	Hiroshi WATABE /Yoshiyuki TAKAHASHI[2]	TEPSCO /TEPSCO
4	Power System Planning	Shinichi FUNABASHI	TEPSCO
5	Renewable Energy (Biomass) A	Naoyuki TSUDA /Toshiyuki KOBAYASHI[3]	TEPSCO /TEPSCO
6	Renewable Energy (Biomass) B	Tomoyuki KONDO[4]	TEPSCO
7	Environmental & Social Considerations	Nobuki HAYASHI /Noboru MATSUSHIMA[5]	TEPSCO /TEPSCO (JWRC)
8	Economic & Financial Analysis	Mitsue MISHIMA	TEPSCO (OPMAC)
9	Hydrology & Meteorology Analysis	Tadahisa YOSHIARA	TEPSCO
10	Geological Analysis	Kiminori NAKAMATA	TEPSCO (IIEP)

[2] TAKAHASHI replaced WATABE in July 2014
[3] KOBAYASHI replaced TSUDA in April 2014
[4] KONDO joined in June 2014
[5] MATSUSHIMA replaced HAYASHI in April 2014

1.3.4 Project Schedule

The Project was implemented over a period of nineteen (19) months, from September 2013 to February 2015. The overall work flow of the Project is shown in Figure 1.3.4-1.

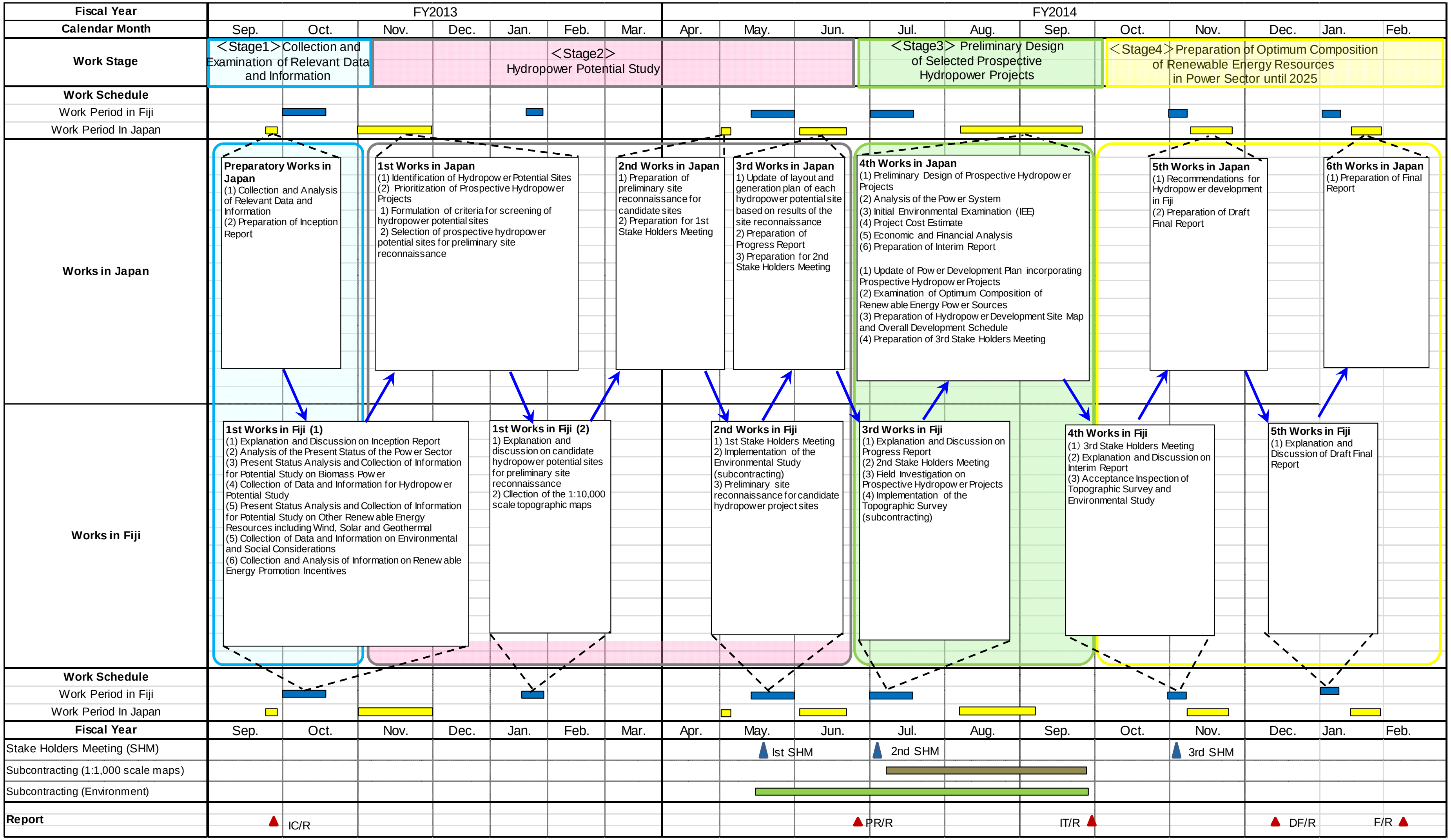


Figure 1.3.4-1 Overall Work Schedule

Chapter 2 Overview of Fiji

2.1 Present Socio-Economic Situation

2.1.1 Politics and Government

(1) Politics

Politics in Fiji normally take place in the framework of a parliamentary representative democratic republic wherein the Prime Minister of Fiji is the head of government and the President the head of state, and of a multi-party system. Executive power is exercised by the government, legislative power is vested in both the government and the Parliament of Fiji, and the judiciary is independent of the executive and the legislature.

(2) Central Government

The current government consists of the President, Prime Minister, Prime Minister's Office, Attorney-General and 16 ministries as shown in Figure 2.1.1-1.

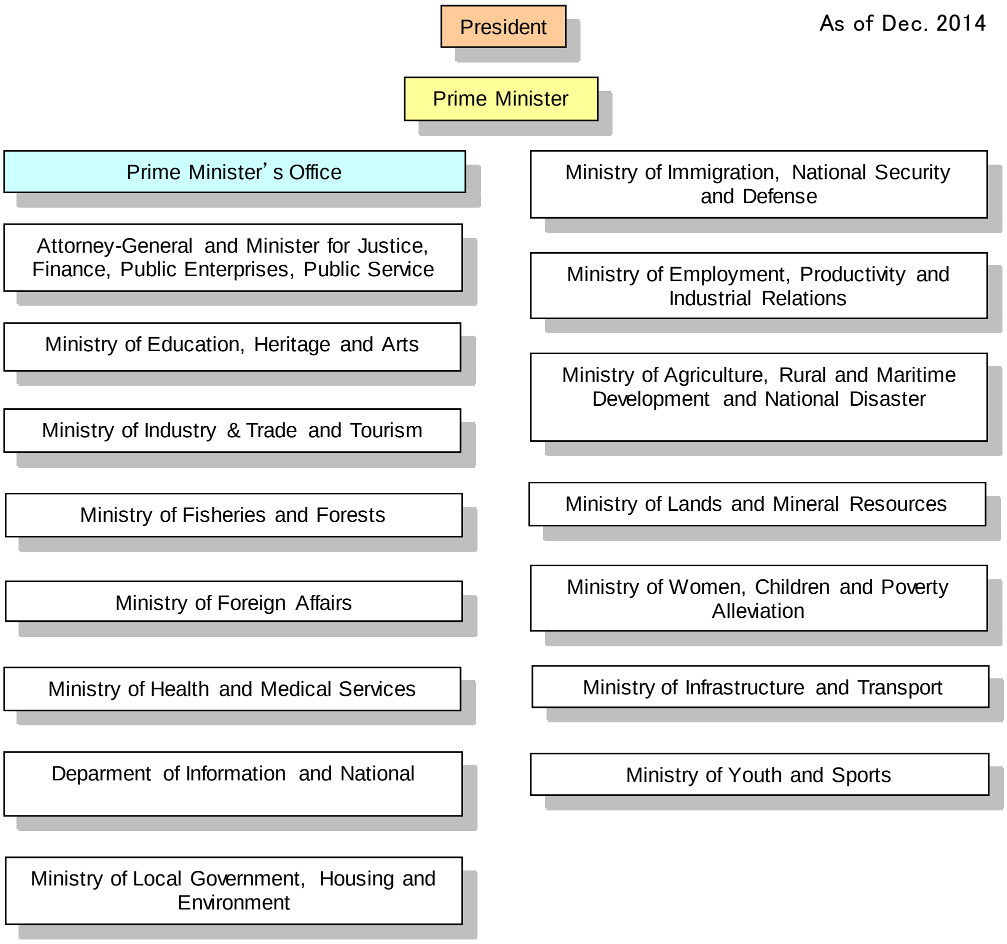


Figure 2.1.1-1 Organization of Fiji Government

(3) Local Administration

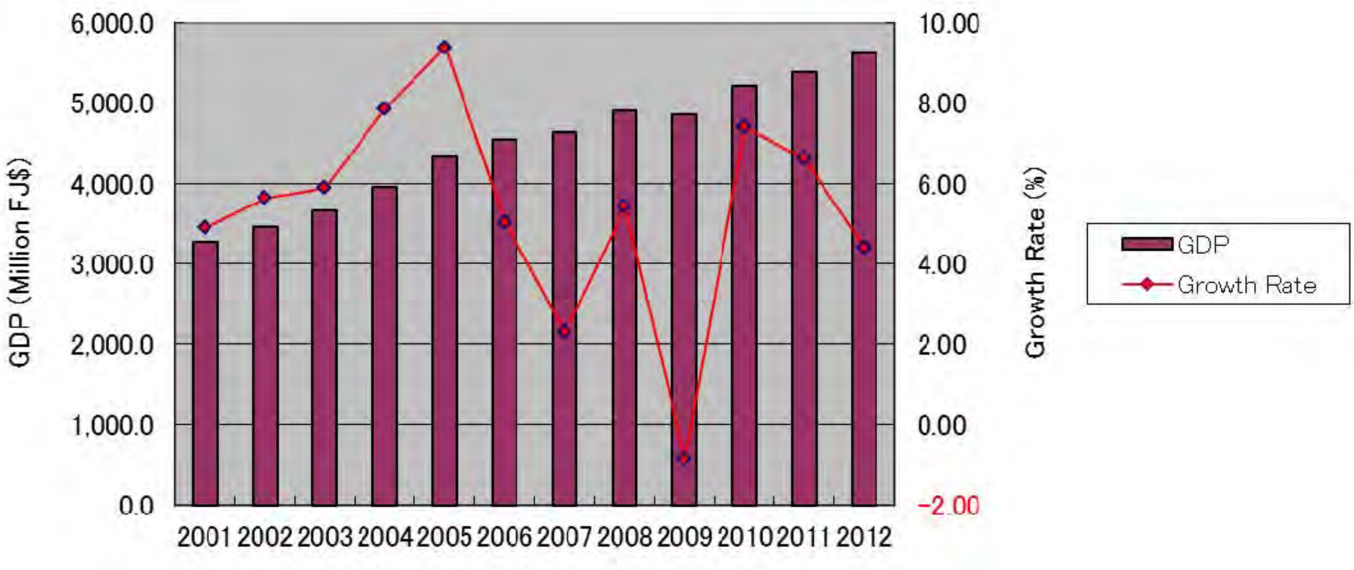
Fiji is divided into four major divisions: "Central", "Western", "Northern", and "Eastern". These divisions are further divided into 14 provinces. Each of the provinces are divided into districts, which consist of villages.

In Fiji, there are two kinds of local administration systems: the traditional Fijian administration system and the central government administration system. iTaukei Affairs Board has jurisdiction over traditional Fijian administrative organizations. Each province is administrated by a provincial council, which itself is subject to the iTaukei Affairs Board, which amongst many other aspects of modern Fijian culture, is variously considered to be the "guardian" of the traditional Fijian administration system. Roko Tui is the title for the executive head of any one of Fiji's 14 provincial councils. In the central government administration, there are commissioners at the divisional level, and district officers and their assistants at the district level.

2.1.2 Economic Situation

(1) Key Economic Indicators

According to the materials issued by the Fiji Bureau of Statistics, changes in Fiji's Gross Domestic Product (GDP) and its growth rate are shown in Figure 2.1.2-1.

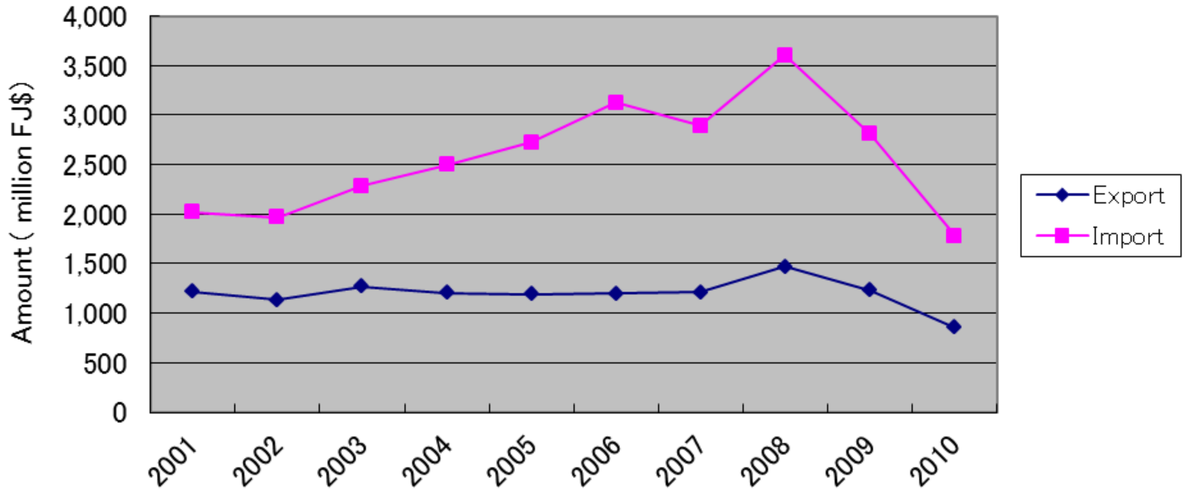


(Source: Website, Fiji Bureau of Statistics)

Figure 2.1.2-1 GDP and GDP Growth Rate

Fiji's GDP per capita is around 3,200 USD. It is categorized as a high middle-income country according to DAC and a low middle-income country according to the World Bank.

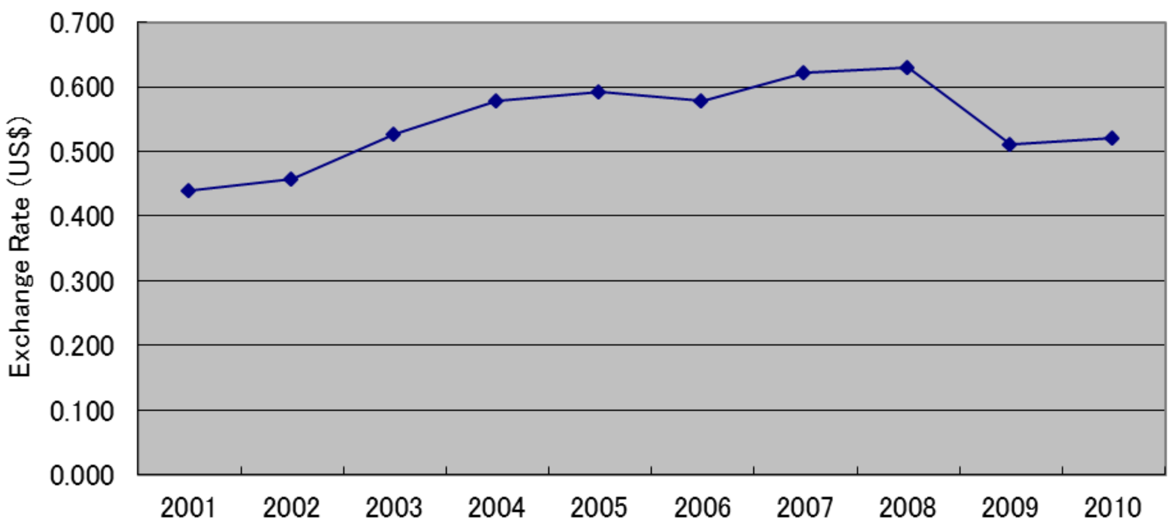
Fiji has run a current account deficit since the 1980s and also for the 10 years from 2001 to 2010. As is shown in Figure 2.1.2-2, the import volume increased prior to 2008 but declined thereafter. On the other hand, the export volume had stayed almost constant, however, due to the fact that exports of sugar and clothing have decreased since 2009, total export volume also has decreased.



(Source: Key Statistics December 2011, Fiji Bureau of Statistics)

Figure 2.1.2-2 Exports and Imports

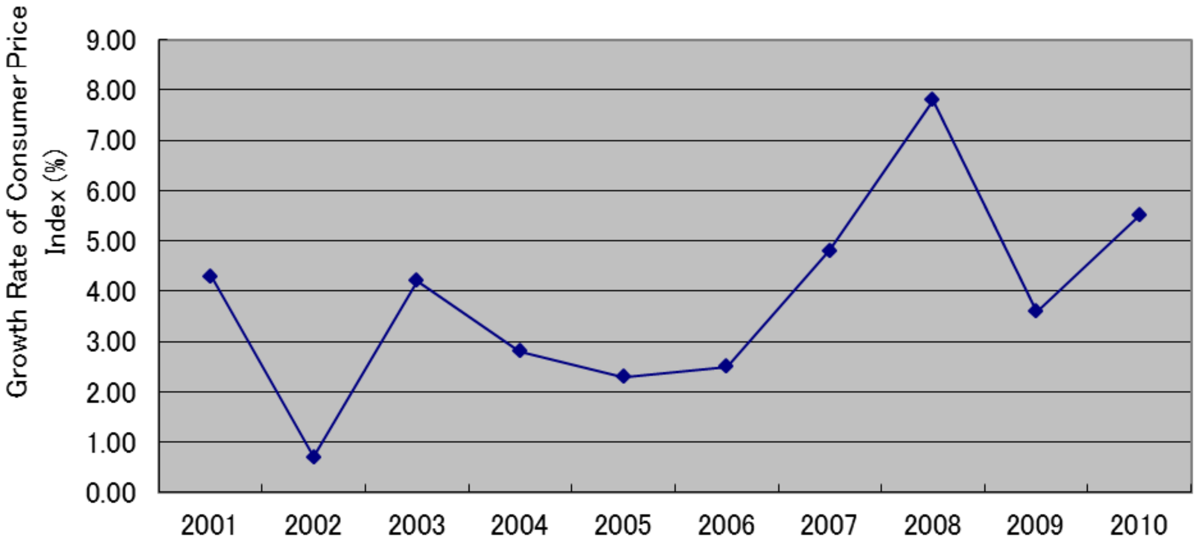
In terms of the exchange rate between the Fiji dollar and the US dollar, the Fiji dollar fell in value since 2001 until 2008 (when it gained in value). However, as shown in Figure 2.1.2-3, since 2009 its value has stayed relatively stable between 0.5 and 0.6 USD.



(Source: Key Indicators for Asia and the Pacific 2011 42nd Edition, Asian Development Bank)

Figure 2.1.2-3 Fiji Dollar/US Dollar Exchange Rate

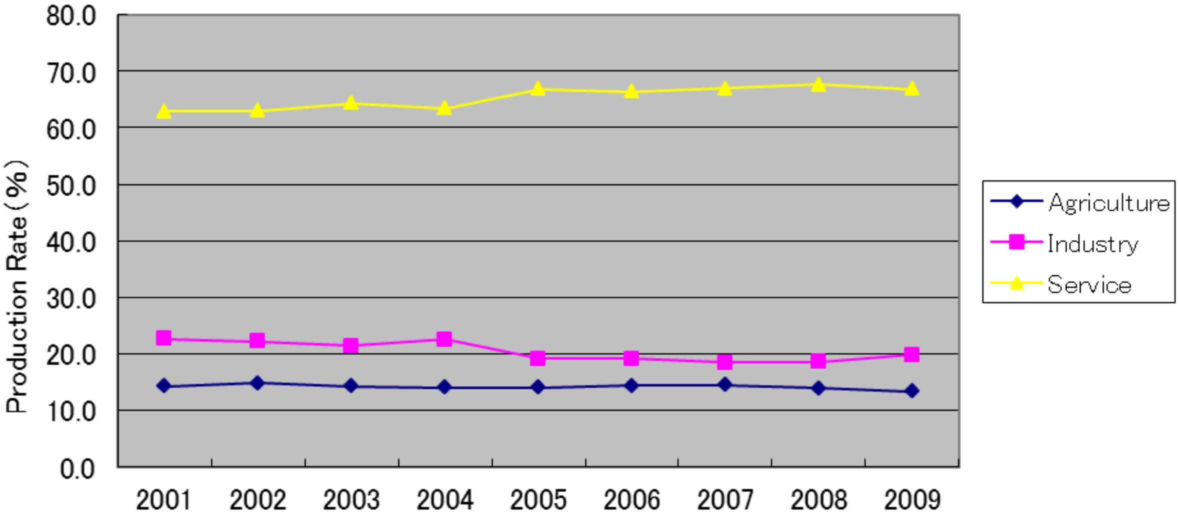
Although the growth rate of consumer price index varied from year to year as shown in Figure 2.1.2 4, it has been relatively stable since the growth rate for the decade between 2001 and 2010. The average growth rate is 3.85%.



(Source: Key Indicators for Asia and the Pacific 2011 42nd Edition, Asian Development Bank)

Figure 2.1.2-4 Growth Rate of Consumer Price Index

As shown in Figure 2.1.2-5, the production percentage of industry has been almost the same over the past decade from 2001 to 2010. In the Fijian sugar industry, which employed many people, sugarcane harvest declined significantly in 2010. This is due to aging transportation equipment and machinery and problems related to the extension of farmland lease periods.

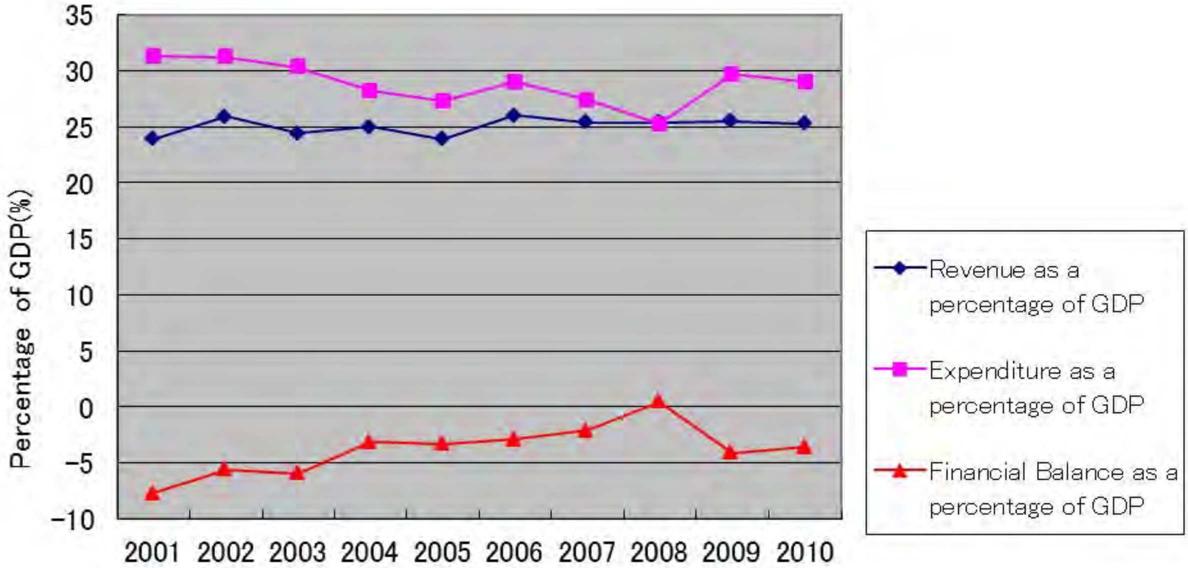


(Source: Key Indicators for Asia and the Pacific 2011 42nd Edition, Asian Development Bank)

Figure 2.1.2-5 Production Percentage of Industry

(2) Financial Situation

Fiji has had chronic budget deficits as shown in Figure 2.1.2-6. Although according to the "Economic and Fiscal Update: Supplement to the 2008 Budget Address", Fiji's government aimed to reduce the budget deficit to less than 1.0% of GDP by 2010. Nevertheless, the situation has not improved greatly.



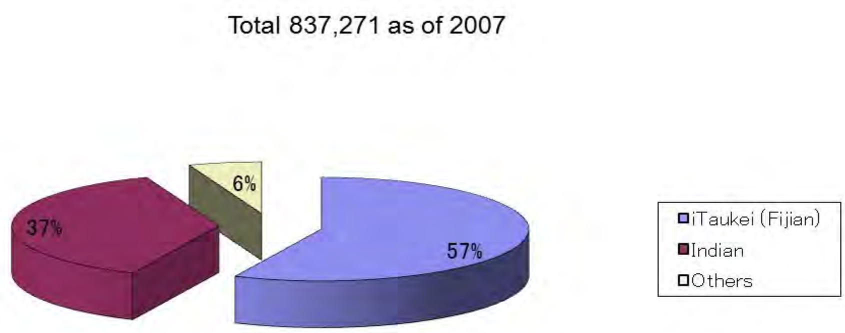
(Source: Key Indicators for Asia and the Pacific 2011 42nd Edition, Asian Development Bank)

Figure 2.1.2-6 Key Financial Index as a Percentage of GDP

2.1.3 Social Situation

(1) Population

As shown in Figure 2.1.3-1, 37% of Fiji's population is descended from indentured Indians brought in the British during the 19th century. At the time, the census confirmed that the population of Fiji in 2007 had reached 837,271. A subsequent estimate carried out in 2009 claimed that those numbers had increased to 849,000, which would make Fiji the 154th most populous country on earth.

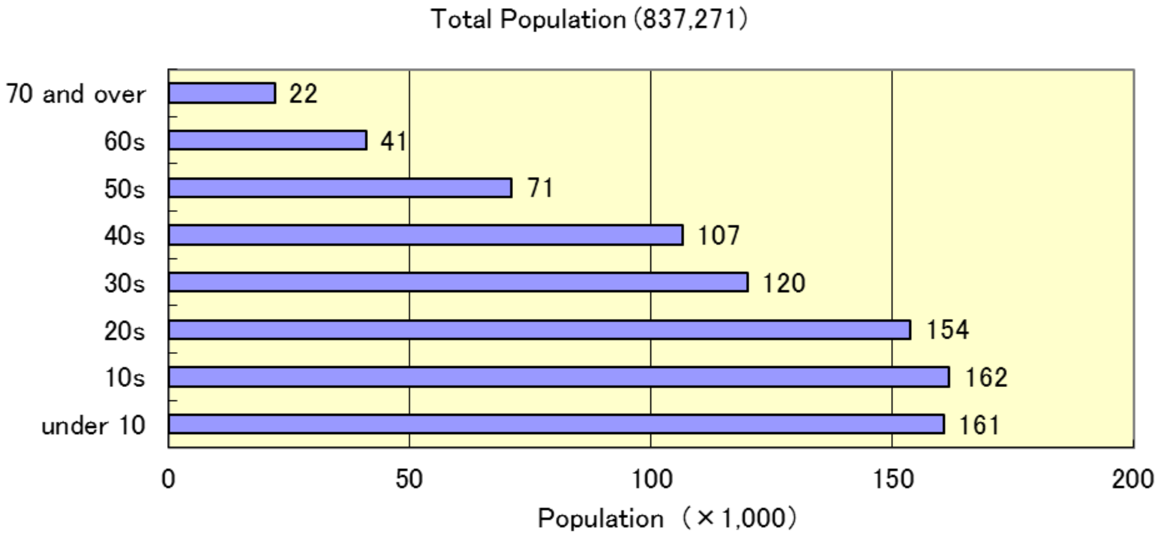


(Source: Fiji facts and Figures as at 1st July 2010, FBOS)

Figure 2.1.3-1 Population Structures by Ethnic Groups

As for population density, the surface area of Fiji equates to 18,274 km^2, which it is the 155th largest country in the world. Based on the 2009 estimates, the density figures are consistent with the nation's size. There is an average of 46.4 people living in each square kilometer of Fijian territory. This makes Fiji the 148th largest country in terms of population density alone.

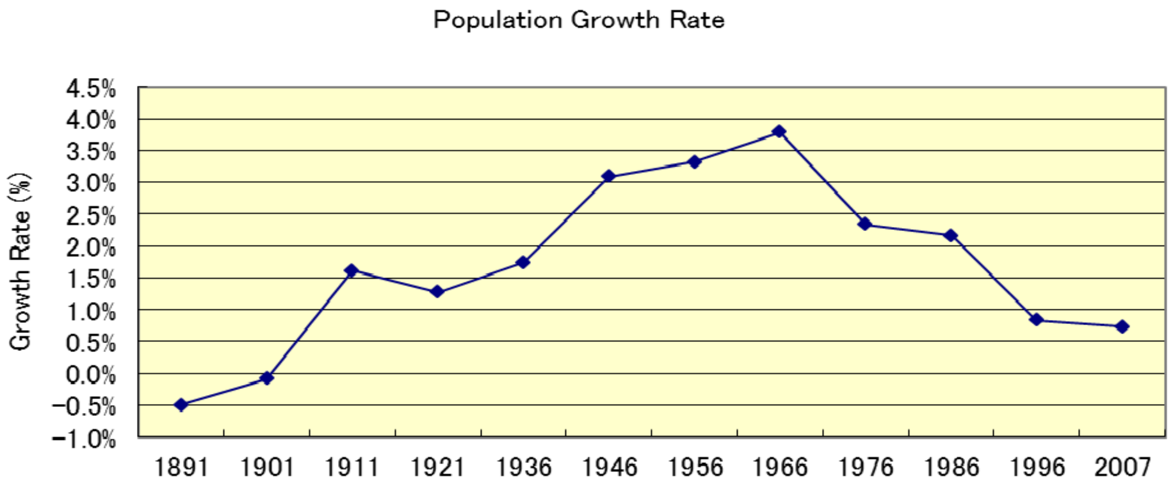
Based on a population figure of 827,271, it gives us the following statistics as shown in Figure 2.1.3-2: 38.5% of the population were aged between 0 and 19. In addition, 18.4% were between the ages of 20 and 29, while just 7.5% of the country were aged 60 and over, which is considerably below the average percentages for all countries in the world.



(Source: Fiji facts and Figures as at 1st July 2010, FBOS)

Figure 2.1.3-2 Population Age Distribution

According to the data from the Fiji Bureau of Statistics (FBOS), the population growth rate had been as high as 3 to 4% in the 1950's and 1960's. However, it has recently fallen to a low of around 0.7% from 1996 to 2007. Changes in the population growth rate are shown in Figure 2.1.3-3.



(Source: Fiji facts and Figures as at 1st July 2010, FBOS)

Figure 2.1.3-3 Population Growth Rate

(2) Employment

Fiji's islands are abundant in forest, mineral and fishery resources. The people are employed in traditional subsistence farming; the three major industries of tourism, sugar and clothing; the copra plantations; the gold and/or silver mining industries; and the home industry.

According to the 2007 census, the unemployment rate was 8.6%, which rose from 3.7% when compared with the 1996 census. This is largely because of the decline of the sugar and clothing industries in recent years, which has resulted in hundreds of lost jobs.

(3) Land Ownership

Land ownership in Fiji is roughly classified into the following three categories of land:

1) native Fijians' Land ("native land")
2) land previously owned by western people before the land law was established ("freehold land")
3) state land

Native land is owned by native Fijian groups called the "Mataqali", and managed by the iTaukei Land Trust Board in accordance with the law. Sales of native land is prohibited by law and only freehold land can be sold. 87% of Fiji Island, 82% of Viti Levu, and 92% of Vanua Levu are native land, while around 13% of the whole country is either freehold land or state land.

Leased native land used for agriculture accounts for around 70% of all native land. The remaining 30% of the native land is used, amongst other things, for forests, and houses.

2.2 Geography and Climate

2.2.1 Geography

Fiji is a group of volcanic islands in the South Pacific Ocean, lying about 4,450 km southwest of Honolulu and 1,770 km north of New Zealand. Of the 322 islands and 522 smaller islets making up the archipelago, about 106 are permanently inhabited. Viti Levu, the largest island, covers about 57% (area: 10,429 km^2) of the nation's land area (area: 18,333 km^2), hosts the two official cities (the capital Suva, and Lautoka) and most other major towns, such as Ba, Nasinu, and Nadi (the site of the international airport). It also contains around 69% of the population. Vanua Levu, 64 km to the north of Viti Levu, covers just over 30% (area: 5,556 km^2) of the land area though it is home to only around 15% of the population. Its main towns are Labasa and Savusavu.

Both islands are mountainous, with peaks up to 1300 m rising abruptly from the shore, and covered with tropical forests. Heavy rains (up to 3,040 mm annually) fall on the windward (southeastern) side, covering these sections of the islands with dense tropical forest. Lowlands on the western portions of each of the main islands are sheltered by the mountains and have a well-marked dry season favorable to crops such as sugarcane.

Areas and features of major islands are shown in Table 2.2.1-1.

Table 2.2.1-1 Areas and Features of Major Islands

Name of Island	Area (km^2)	Percentage (%)	Features
Viti Levu	10,429	56.9	Volcanic island. 29 mountains 900 m or higher above sea level. More than 50 rivers.
Vanua Levu	5,556	30.3	Volcanic island. Some mountains 1,000 m or higher above sea level . More than 40 rivers and 20 hot-spring areas.
Taveuni	470	2.6	Volcanic island. The highest mountain 1,230 m above sea level.
Kadavu	411	2.2	Volcanic island. The highest mountain 835 m above sea level.
Gau	140	0.8	Rough and hilly terrain. The highest mountain 550m above sea level
Koro	104	0.6	Rough terrain. Two mountains over 700 m above sea level.
Others (over 300)	1,223	6.6	Low above sea level and/or coral islands
Total	18,333	100	

(Source: PIREP Fiji National Report, 2004)

2.2.2 Climate

The climate in Fiji is tropical marine and warm all year round with minimal extremes, but its condition varies from place to place. In particular, precipitation varies greatly depending on the country's topographical features. Moisture-containing south-east trade winds are broken by the islands and form clouds. In Viti Levu and Vanua Levu, which have relatively high mountains, these south-east trade winds form humid areas in the east and south slopes of the islands and dry areas in west and north slopes of the islands. On the other hand, smaller islands with no high mountains or coral islands have little precipitation and much solar radiation.

Fiji does have a wet season. The wet season is normally from November to April and results from the southerly movements of the South Pacific Convergence Zone. The wet season is characterized by heavy, brief local showers and contributes to most of Fiji's annual rainfall. Annual rainfall on the main islands is between 2,000 mm and 3,000 mm on the coast and low lying areas, and up to 6,000 mm in the mountains.

Typically the smaller islands in Fiji receive less rainfall than the main Island with various amounts according to their location and size, ranging from 1,500 mm to 3,500 mm. Cyclones do occur in Fiji and are normally confined to wet season.

The warm season is from November to April and the cooler season lasts from May to October. The average temperature in the cool season is 22 °C.

2.3 National Development Plan and Energy Policy

2.3.1 National development Plan

(1) National Development Plan

The Roadmap for Democracy and Sustainable Socio-economic Development (RDSSED) 2009-2014 sets out a framework to achieve sustainable democracy, good and just governance, socio-economic development and national unity. The key foundation of the Roadmap is the Peoples Charter for Change Peace and Progress (PCCPP) which was compiled through an unprecedented nationwide consultation process, involving a wide range of stakeholders. The Roadmap is logically aligned to the mandate handed down by His Excellency, the President in 2007, as well as the Strategic Framework for Change announced by the Prime Minister on 1st July 2009.

In order to ensure an inclusive approach, ownership and successful implementation, the Roadmap has been compiled in consultation with the private sector, civil society and government to take on board the current political, social and economic situation, both on the domestic and international fronts.

(2) Mission and Strengthening Good Governance

The objective of the Roadmap is to implement policies to achieve the Vision of “A Better Fiji for All” which is consistent with the Peoples Charter. To achieve this vision, the overarching objective is to rebuild Fiji into a non-racial, culturally vibrant and united, well governed, truly democratic nation that seeks progress and prosperity through merit-based equality of opportunity and peace. The following 6 items are described as strategic priorities for good governance.

- Formulating a New Constitution
- Electoral and Parliamentary Electoral Reforms
- Strengthening Law and Justice
- Strengthening Accountability and Transparency
- Ensuring Effective, Enlightened and Accountable Leadership
- Enhancing Public Sector Efficiency, Effectiveness and Service Delivery
- Developing an Integrated Development Structure at Divisional Level

(3) Objectives of Energy Sector

The Roadmap sets forth the goal, the policy objectives and the strategies of energy sector as follows:

The goal is to facilitate the development of a resource efficient, cost effective and environmentally sustainable energy sector.

The policy objectives are that the community has increased secure access to affordable and reliable energy supplies.

The strategies are:

- Enact/enforce appropriate legislation to improve sustainable energy use, including the National Energy Policy (NEP) and Renewable Energy Based Rural Electrification Act.
- Monitor customer satisfaction through survey and develop and implement an awareness program.
- Establish a reliable energy information system for end use decision making at all levels.
- Assess Fiji's energy security situation to guide future policy decisions.
- Greater collaboration within the industry and with other sectors and strengthens private sector involvement in all forms of energy, including review of tariffs, cost recovery and competition in energy production.
- Reduce inefficient use of energy through energy efficiency research, demonstration, energy audits, regulation, and building codes, and create a robust market for energy.
- Promote measures to reduce fossil fuel consumption, including in the transport sector, and encourage alternative fuels for the power, transport and other sectors efficiency services.
- Develop and implement a national electrification master plan covering both grid and stand–alone systems.
- Formation of an appropriate independent regulatory agency and review the Electricity Act.
- Assess local renewable energy resource potential, undertake research, identify technologies appropriate to Fiji.
- Encourage competition in the generation of energy.

2.3.2 National Energy Policy

(1) Outline of National Energy Policy

The National Energy Policy (NEP) is supposed to be reviewed and issued every five years, but the National Energy Policy (2015 – 2020) has not been issued officially at present.

The existing National Energy Policy (2007 – 2011) was issued by Department of Energy (DOE) in November 2006, and it provides a common framework for all (both public and private) associated with the energy sector to work towards for optimum utilization of energy resources for the overall growth and development of the economy over the next five years.

This National Energy Policy (2007 – 2011) is closely aligned to the National Strategic Development Plan (2007 -2011), and it focuses on the following four key strategic areas:

- National Energy Planning
- Energy Security
- Power Sector
- Renewable Energy

The National Energy Policy aims to:

- strengthen the capacity for energy planning through appropriate policy, regulatory and

- implementation frameworks and effective and efficient management;
- enhance energy security through greater participation and collaboration within the industry;
- increase access to affordable and reliable electricity services; and
- research, promote and utilize renewable energy applications.

(2) Energy Sector Policies

1) Vision and Mission

The National Energy Policy sets forth its vision and mission as follows:

- Vision: A sustainable energy sector for Fiji
- Mission: To provide an enabling environment for a sustainable energy sector

2) Outline of Key Strategic Areas

① National Energy Planning

Policies in this area are as follows:

- Strengthen the capacity of DOE to plan, formulate, implement and manage the energy policy and other energy related policies and regulations.
- Ensure appropriate policy and regulatory frameworks for the provision of energy services.
- Strengthen coordination and consultation with other sectors and the external environment on energy developments.
- Enhance energy information and data management programs for planning purposes.

② Energy Security

There are five principal issues of energy security from a national perspective:

- Domestic production capacity of alternative fuels.
- Dependence on imports.
- The degree of import concentration.
- Fuel stocks relative to imports.
- The ability to secure an alternative source for petroleum imports in the event of an interruption from one or more suppliers.

Policies for overcoming the above issues are set forth as follows:

- Promote the development of indigenous energy sources such as hydropower, geothermal, solar, wind and biomass.
- Promote energy efficiency and energy conservation in all sectors.
- Strengthen energy security and improve energy supply mix for the country.

③ Power Sector

The policies of the power sector are set forth in three sections as follows:

<Policies on FEA>

- FEA “to operate as a successful business and, to this end, to be as profitable and efficient as comparable businesses which are not owned by the State".

- FEA "to focus on commercial activities, and for this purpose any activity of a government policy formulation or regulatory nature will, wherever possible, be transferred from FEA to a department, separate regulatory authority or other agency".
- FEA "to be appropriately compensated for any non-commercial obligations".

<Policies for promoting private sector investor and IPPs>

- Procurement guidelines using international competitive bidding.
- Specification of standards to apply to all project studies and investigations.
- Discrete procedural steps to ensure that information about the project provides an adequate and appropriate basis for negotiating the commitments entered into at each stage of the implementation process.
- Defined responsibilities of government agencies, stipulating contact points and coordinating functions for greater ease of investors.
- Time lines for meeting obligations and giving approvals.
- Regulations and model contracts providing a basis from which concessions and power purchase agreements will be negotiated.

<Rural electrification criteria for the establishment of priority target key areas>

- Contributions from the villages. Villages where contributions to the required up-front investment exceed the current 10 % compulsory contribution.
- Focal villages and settlements where joint infrastructure development is possible and infrastructure service packages promise to trigger economic development.
- Areas identified as most likely to optimize income-raising and socio-economic benefits from electricity supply.
- Locations where environmental protection and rural development measures are complemented by electricity supply.
- Locations where organizational initiative is demonstrated as adequate to assure reliable and expanded supply.
- Villages where electrification complements social, economic, and environmental priorities of localities.

④ Renewable Energy

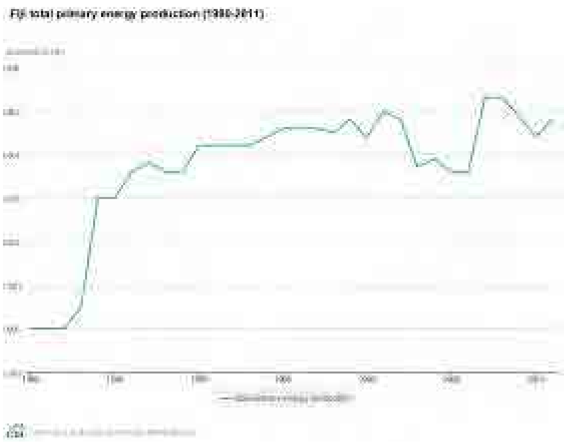
The government believes that renewable energies can in many cases provide the least cost energy service, particularly when social and environmental costs are included, and will therefore provide focused support for the development, demonstration and applications of renewable energy. In particular, government will facilitate the sustainable production and management of solar power and non-grid electrification systems, such as the further development of solar home systems (SHS), solar pump water supply systems, solar systems for schools and clinics and solar water heating systems for homes and institutions. All of the above will be largely targeted at rural communities.

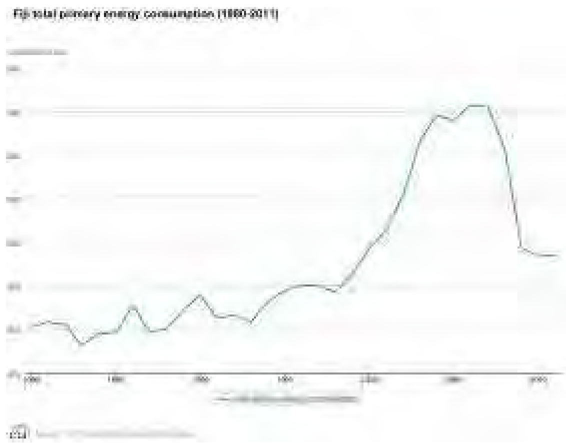
In the urban and modern sector, Government will promote grid connected renewable energy generation based on wind, geothermal and hydropower. Government will thoroughly analyze the feasibility of a biofuel program with the objective to stabilize agricultural production and income in Fiji's traditional export crop sectors sugar and coconut. As a medium term target a 5% renewable energy based addition to biofuel blends (alcohol for petrol and vegetable oils or derivatives) is considered appropriate. Dedicated biofuel based electricity generation is also considered as a larger scale option. As a longer term target (2015) a mandatory 10% share of bio-fuels in diesel and petrol supply will be considered.

2.3.3 Basic Information on Energy

(1) Supply and Demand Conditions for Primary Energy

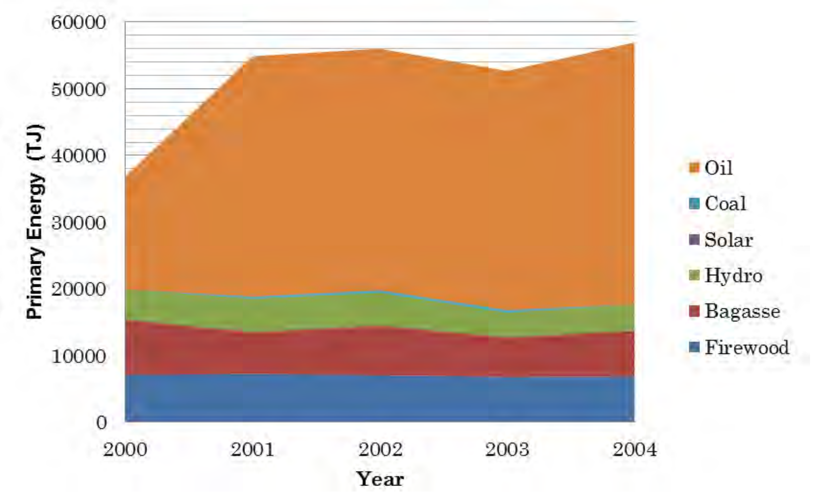
Domestic supply and demand conditions for primary energy in Fiji are shown in Figure 2.3.3-1 and Figure 2.3.3-2. Natural resources in Fiji include firewood, bagasse, hydropower, and solar power, while Fiji relies on imports for 100% of its fossil fuels such as coal, oil and gas.





(Source: Independent Statistics & Analysis, U.S. Energy Information)

Figure 2.3.3-1 Total Primary Energy Production and Consumption



(Source: Independent Statistics & Analysis, U.S. Energy Information)

Figure 2.3.3-2 Total Primary Energy Production and Consumption

(2) Fossil Fuel Consumption

Table 2.3.3-1 shows fossil fuel consumption by industry. Transportation accounts for more than 50% of total fossil fuel consumption, electricity 26%, and commerce and industry 11%.

Table 2.3.3-1 Total Primary Energy Production and Consumption

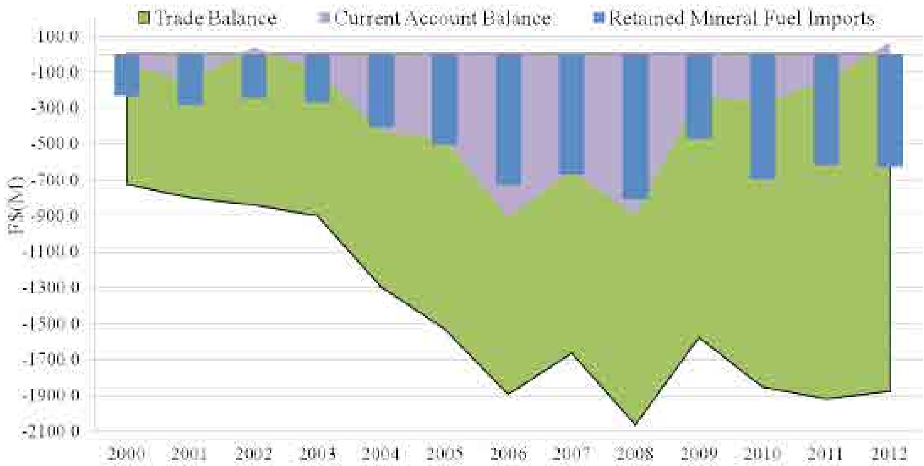
Fuel	Total Import	Sector				
		Traffic	Electricity	Domestic	Commerce	Industry
Gasoline	60.6	55	0	0.1	0	5.5
Diesel (traffic)	83.8	76.9	1	0	1.7	4.2
Diesel (industry)	105.1	0	91	0	0	14.1
Heavy oil	12.1	8.8	0	0	0	3.3
Kerosene	17	0	0	16.4	0.3	0.3
Gasoline (aviation)	38.6	38.6	0	0	0	0
Jet fuel	12.8	12.8	0	0	0	0
LPG	20	0	0	12.3	7	0.7
Total	350	192.1	92	28.8	9	28.1
Ratio	***100***	***55***	***26***	***8***	***3***	***8***

(Source: Pacific Regional Assessment Report 2004, UNDP)

(3) Fossil Fuel Price

Fiji is 100% dependent on imports for fossil fuels (coal, oil, and gas). Total retained imports of the three major liquid fossil fuels amounted to 364 million liters in 2011 representing a value of 583 million FJD. On top of that, approximately 11,000 tons of LPG was imported. Fuel imports account for 30% of total import value. As shown in Figure 2.3.3-3, fuel imports have a significant impact on the current account and trade deficits. In addition, there is a significant risk of fuel supply interruptions.

The latest import statistics for the main liquid fuels as displayed in Table 2.3.3-2 below shows the dominance of diesel fuel accounting for three quarters of all imports. Diesel fuel is consumed mainly by the power sector.



(Source : Reserve Bank of Fiji (Fiji SE4ALL Report))

Figure 2.3.3-3 Retained Fuel Imports and Current Account

Table 2.3.3-2 The Latest Import Statistics for the Main Liquid Fuel

Year	Motor Spirit		Aviation Turbine		Diesel		TOTAL	
	Quantity (million litres)	Value (F$M)	Quantity (million litres)	Value (F$M)	Quantity (million litres)	Value (F$M)	Quantity (million litres)	Value (F$M)
2008	43	71	103	307	248	390	394	768
2009	45	58	82	126	189	218	316	402
2010	78	100	121	133	318	366	517	599
2011	70	99	17	17	276	410	363	526
2012	69	101	19	14	264	402	352	517

(Source: Fiji Bureau of Statistics / Reserve Bank of Fiji 2012 (Fiji SE4ALL Report))

Modern household fuels such as LPG and kerosene are price regulated in Fiji. Fiji Commerce Commission (FCC) adjusts maximum retail prices regularly in response to market developments. Table 2.3.3-3 shows regulated maximum retail prices for all controlled fuels as of April 2013.

Table 2.3.3-3 Maximum Retail Prices for Fuels, April 2013

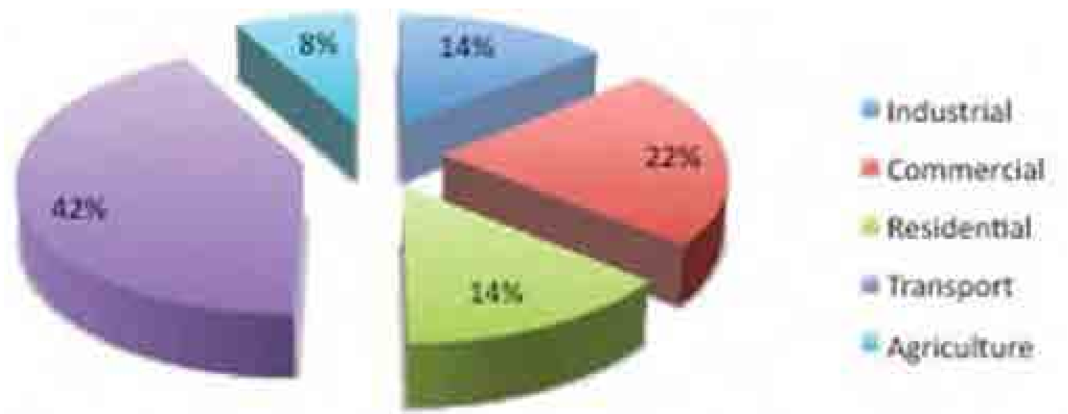
Product	FJD/litre	FJD/Ton	FJD/MJ	MJ/litre
LPG	2.14	3820	0.084	25.5
ULP	2.58	3510	0.076	34
Diesel	2.29	2726	0.059	38.6
Kerosene	2.54	3215	0.069	36.6
Premix	1.86	2548	0.055	34

(Source: Fiji Commerce Commission (Fiji SE4ALL Report))

(4) Energy Demand by Sector

Fiji's energy demand is driven by household consumption of electricity and transport fuels and by the need of its major industries (i.e. agriculture and forestry, fisheries, tourism and mining).

A breakdown of energy demand by sectors is illustrated in Figure 2.3.3-4 below. This shows a dominance of the transport sector which consumes 42% of all modern energy in Fiji.



(Source : Fiji Bureau of Statistics and DOE (Fiji SE4ALL Report))

Figure 2.3.3-4 Energy Demand by Sector (2012)

Chapter 3 Power Sector

3.1 Power-related Laws and Regulations

Below is an outline of significant laws and regulations relevant to the energy including power.

◆ Electricity Act

The act, established in 1966, is the legal basis for FEA and regulates power supply responsibilities and its limit as a state-owned entity. FEA has an obligation to provide stable electricity at an adequate cost whilst also supplying electricity for Fiji's economic growth.

◆ Public Enterprise Act (1996)

The act forms the legal basis to cover the reformation of specific government-based business organizations.

◆ Hotel Aid Act (1964)

The act guarantees the provision of incentives such as a depreciation increase and an income tax exemption for investors in the tourism sector when selling surplus private electricity to the grid.

◆ Commerce Act (1998)

The act gives FCC an authority to promote competition for consumer benefit. The commission supports infrastructure, equipment, and negotiations (with FEA) related to the service channel. It is intended to harmonize economic efficiency and social and environmental impacts. In addition, the commission regulates FEA's electricity charges.

◆ Renewable Energy Service Company Bill

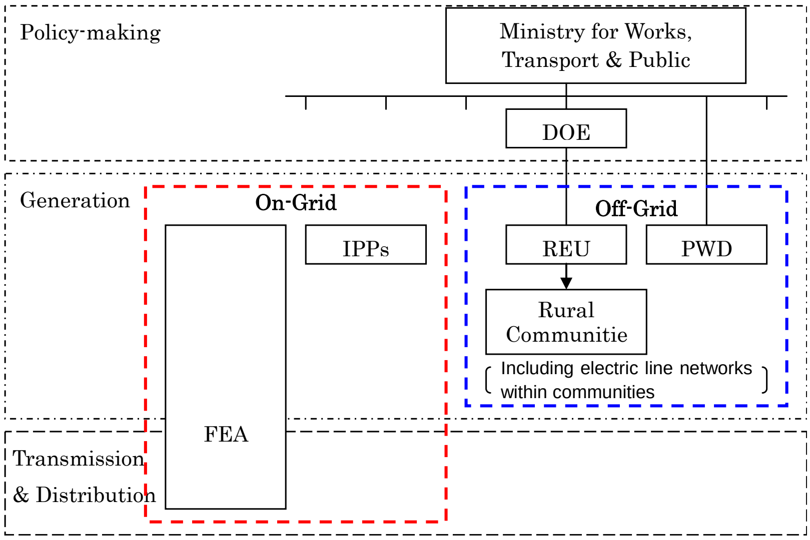
The cabinet approved the charter in 1993 for the establishment of RESCO.

3.2 Power Sector Structure

3.2.1 Electric Utility System in Fiji

In Fiji, DOE is in charge of overall national energy policy. FEA, a state-owned enterprise established in 1966, is in charge of power supply, including generation, transmission and distribution. The sugar and wood industries (both are IPPs) sell surplus electricity to FEA.

With regards to rural electrification, DOE is promoting REU under the rural electrification policy (1993) and their primary scopes of the works are a grid extension to the un-electrified area, and the installation of diesel FEA grid extension, generators, solar, and small hydro units. These off-grid installations will be transferred to rural community after the first three years of operation. In addition, the Department of Works is responsible for the operation and maintenance of power supply for six (6) government stations in the outer islands namely Kadavu, Rotuma, Lakeba, Vanua Balavu, Nabouwalu and Taveuni. A diagram as shown in Figure 3.2.1-1 illustrates the structural organization of the electric power industry in Fiji.



(Source: Pilot Study for Project Formation for Comprehensive Renewable Energy Power Development, July 2008, JBIC)

Figure 3.2.1-1 Electric Power Structural Organization Diagram in Fiji

3.2.2 Department of Energy (DOE)

DOE is responsible for formulating and executing energy policy and to supervise the energy sector. In response to the transfer of energy conservation, promotion of renewable energy and rural electrification units (hereinafter referred to as "REU") from PWD to DOE in 1993, rural electrification program became a part of the responsibility of DOE. The number of staff in 2005 was 37 but in 2014, it was increased to 64.

3.2.3 Fiji Electricity Authority (FEA)

FEA is a 100% state-owned public corporation founded in 1966 which is in jurisdiction of Ministry of Finance and Ministry for Infrastructure & Transport, Ministry of Public Enterprises & Public Sector Reform. Annual audit is held to retain efficient operation despite being a state-owned entity.

FEA domestically has responsibilities for the power development and supply expansion when "Financially capable and economically sound". While being a power supplier (Generation, Transmission, and Distribution) FEA acts as a regulatory body of power sector. There are regulatory units within FEA which bears the responsibility and have authority to approve electric appliances and its parts to be used in Fiji, issue new IPP license, issue license to the electrical construction company and electricians and to supervise electricity construction.

3.3 Electricity Tariff System

3.3.1 Electricity Tariff System

Empowered by the Commerce Commission Act (1998) and the Electricity Act (1985), FEA determines the Electricity tariff and Commerce Commission approves it. In December 2012, the weighted average tariff was reduced from 0.394FJD/kWh (0.21USD/kWh) to 0.365FJD/kWh (0.19USD/kWh). Current FEA tariff valid since January 2013 is shown in Table 3.3.1-1 below.

Household tariff is fixed at 0.3310 FJD/kWh (0.172USD/kWh). However, households with consumption lower than 75kWh/month are subsidized 0.169FJD/kWh (0.09USD/kWh) and charged 0.172 FJD/kWh (0.09 USD/kWh).

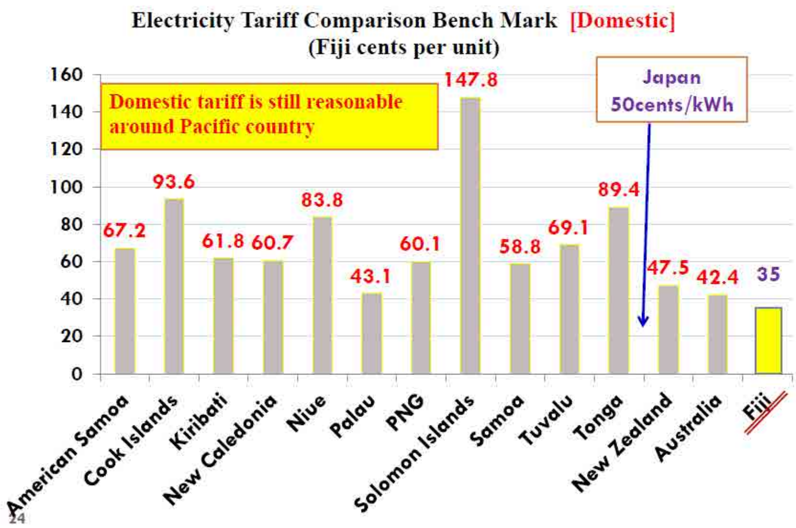
Table 3.3.1-1 Current FEA Tariff Valid since January 2013

Tariff Categories	Existing tariff rates	Revised Tariff rate	Increase /(Decrease)
Domestic Category			
Domestic Tariff (<=75 kWh per month) c/kWh	34.84*	33.10	(1.74)
Domestic Other Tariff (>75 kWh per month) c/kWh	34.84	33.10	(1.74)
Commercial & Industrial Category			
Commercial & Industrial Tariff –up to 14,999 kWh per month, c/kWh	42.00	39.90	(2.10)
Commercial & Industrial Tariff – in excess of 14,999 kWh per month, c/kWh	44.00	41.80	(2.20)
Maximum Demand Tariff			
(1) Demand > 1000kW			
Demand charge $ per kW per month	40.20	38.19	(2.01)
Energy charge c/kWh	33.50	31.63	(1.68)
(2) Demand 500 - 1000kW			
Demand charge $ per kW per month	38.50	36.57	(1.92)
Energy charge c/kWh	31.00	29.45	(1.55)
(3) Demand 75 - 500kW			
Demand charge $ per kW per month	36.20	34.39	(1.81)
Energy charge c/kWh	28.50	27.07	(1.42)
For Maximum Demand and Commercial & Industrial consumers who elect to take a power supply directly at the high voltage, a discount of 4% is allowed.			
Excess Reactive Energy penalty fee c/kWh	44.00	41.80	(2.20)
Institution Tariff c/kWh	34.84	33.10	(1.74)
Street Light Tariff c/kWh	34.84	33.10	(1.74)

* *The customer will pay only 17.20 cents /unit and the rest will be subsidized by the government*

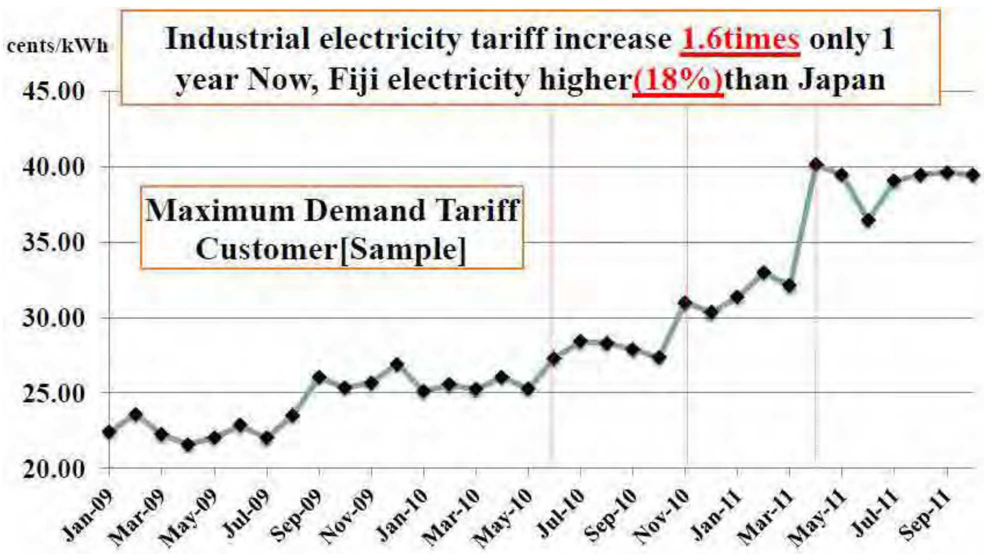
(Source：Fiji Commerce Commission (Fiji SE4ALL Report))

As shown in Figure 3.3.1-1, the tariff rates in Fiji are still low when compared with domestic tariff rates in other Pacific countries. This is mainly because around 50% of the country's electricity requirements are met from hydropower as of 2010. On the other hand, as illustrated in Figure 3.3.1-2, the industrial tariff rates have been raised by 1.8 times in recent three years, and are 18% higher than those in Japan. Such high industrial tariff rates have had a negative impact on Fiji's industrial competitiveness.



(Source: Final Presentation for FEA, JICA Senior Volunteer Mr. Tadashi ARAI, March 2012)

Figure 3.3.1-1 Comparison between Domestic Tariff Rates in Pacific Countries



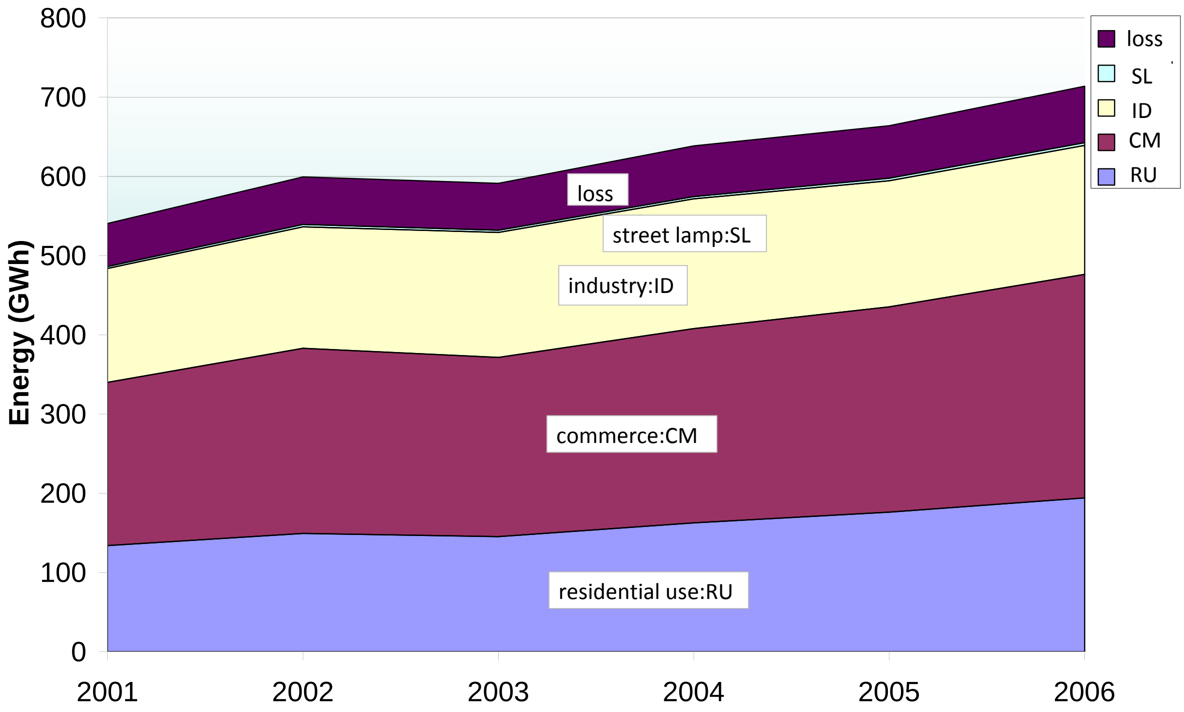
(Source: Final Presentation for FEA, JICA Senior Volunteer Mr. Tadashi ARAI, March 2012)

Figure 3.3.1-2 Industrial Tariff Rates (Jan. 2009 – Oct. 2011)

3.4 Power Supply and Demand Situation

3.4.1 Power Demand Situation

Figure 3.4.1-1, below, shows power consumption from 2001 to 2006 which indicates commercial use of around 40% as opposed to about 25% consumption by consumers and industry.



(Source: FEA)

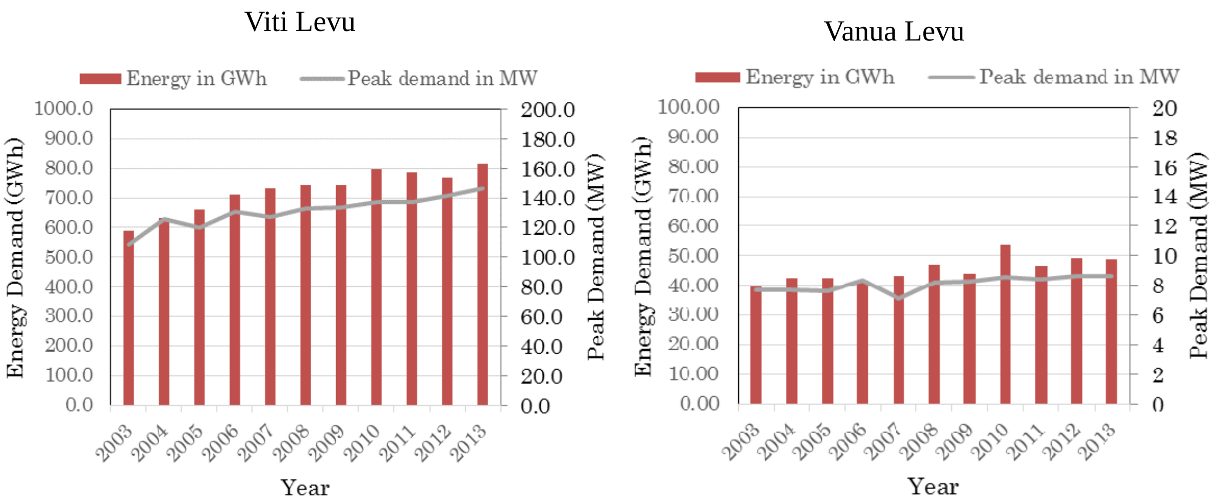
Figure 3.4.1-1 Energy Demand by Sector

Table 3.4.1-1 and Figure 3.4.1-2 indicate the transition of peak demand and energy generation in the islands of Viti Levu and Vanua Levu. A slight slowdown after the 2006 coup d'état can be seen but this recovered in 2010. The growth rate of energy generation recorded an average of 3.3% from 2003 to 2013, an increase of 140% in a decade. Growth rate of peak demand has increased from 108.5MW in 2003 to 146.2MW in 2013 which recorded an average growth rate of 3.0%/annum, an increase of 1.3 times in a decade.

Table 3.4.1-1 Annual Peak Demand and Electricity Generation (2003 - 2013)

Year	Peak Demand (MW)		Growth Rate (%)		Electricity Generation (GWh)		Growth Rate (%)	
	VLIS	Vanua Levu	VLIS	Vanua Levu	VLIS	Vanua Levu	VLIS	Vanua Levu
2003	108.5	7.7			588.5	39.85		
2004	125.7	7.7	15.9	0.1	631.0	42.26	7.2	6.1
2005	120.0	7.6	-4.5	0.8	659.6	42.27	4.5	0.0
2006	130.8	8.3	9.0	9.5	711.0	41.52	7.8	-1.8
2007	127.1	7.1	-2.8	-14.9	732.5	43.13	3.0	3.9
2008	133.0	8.2	4.6	15.7	744.1	46.87	1.6	8.7
2009	133.3	8.3	0.2	1.1	741.8	43.73	-0.3	-6.7
2010	137.1	8.5	2.8	2.8	796.4	53.44	7.4	22.2
2011	137.2	8.4	0.1	-1.2	785.3	46.42	-1.4	-13.1
2012	141.2	8.6	2.9	2.1	768.0	49.21	-2.2	6.0
2013	146.2	8.6	3.6	0.3	814.4	49.03	6.0	-0.4
Average			3.0	1.2			3.3	2.1

(Source：FEA Annual Report 2013 (JICA Project Team reviewed))



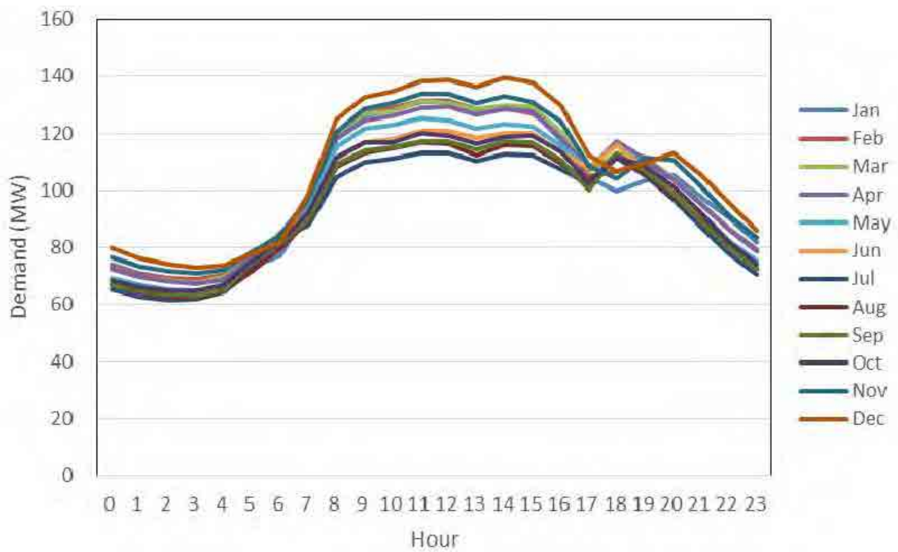
(Source：FEA Annual Report 2013 (JICA Project Team reviewed)

Figure 3.4.1-2 Historical Records of Peak Demand and Energy Demand

In order to overview the seasonal variation curve, the average daily load curve of a weekday in Viti Levu (2013) is shown in Figure 3.4.1-3. Peak demand is recorded in the summer season (Dec-Mar) while demand in the winter months (Jul-Sep) is comparatively low.

The peak demand time is around 15:00 HRS due to the demand for air conditioning in the summer months. In the winter months the peak demand time is around 17:00 HRS, which is highly likely to be due to the demand for lighting.

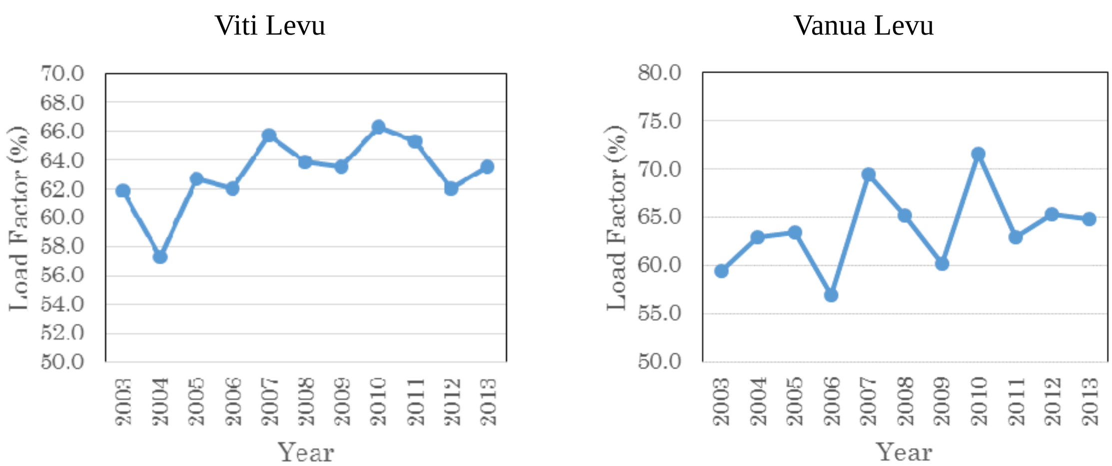
The seasonal gap of the monthly peak demand between summer and winter may grow bigger if we consider that in the near future there may be more widespread use of air conditioners and electric heating systems.



(Source：JICA Project Team)

Figure 3.4.1-3 Mean Daily Load Curve (Weekday) of Viti Levu in 2013

The transitions for the annual load factors in Viti Levu and Vanua Levu are shown in Figure 3.4.1-4. The rising trend in annual load factor between 2003 and 2010 was led by the rise in electricity intensity and the improvement in living standards. Expansion of industrial and household power usage in line with the economic development also affected the load factor transitions. However, the most recent load factors, over the past 3 years, in Viti Levu have decreased. In fact, over the past three years the average load factors in both Viti Levu and Vanua Levu is approximately 64%.



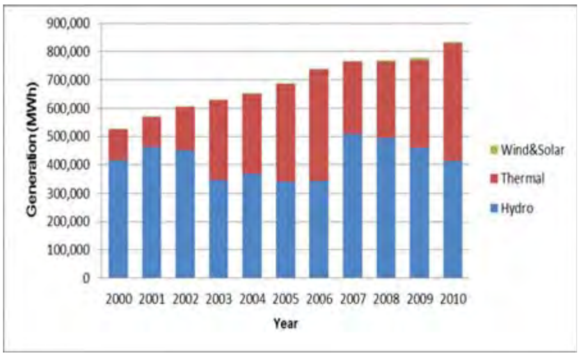
(Source: JICA Project Team)

Figure 3.4.1-4 Historical Records of Load Factor in Viti Levu (2003-2013)

3.4.2 Power Supply Situation

As shown in Figure 3.4.2-1, during 2010 around 50% of the energy was generated from hydropower and around half from diesel. In 2006, a wind power station was put into operation, and its power generation from January to November 2006 was around 3,300 MWh, which accounted for just a fraction of a percent of the total generation. The annual power generation growth rate for the past ten years is around 4.8%.

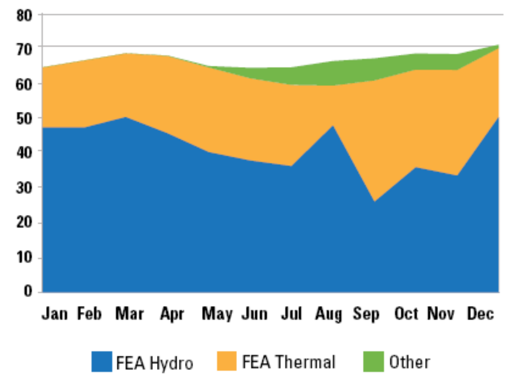
Figure 3.4.2-2 shows the monthly generation mix of FEA system for the year 2009. It indicates that for the dry season from June to November, the energy generated by hydro decreases, while other generation (biomass power generation using bagasse) is seasonally operated.



(Source: FEA Annual Report 2010)

Figure 3.4.2-1 Yearly Generation Mix

(GWh)



(Source: Power Development Plan (2011-2020), FEA)

Figure 3.4.2-2 Monthly Generation Mix in GWh for the year 2009

3.5 Existing Main Power Stations and Transmission Facilities

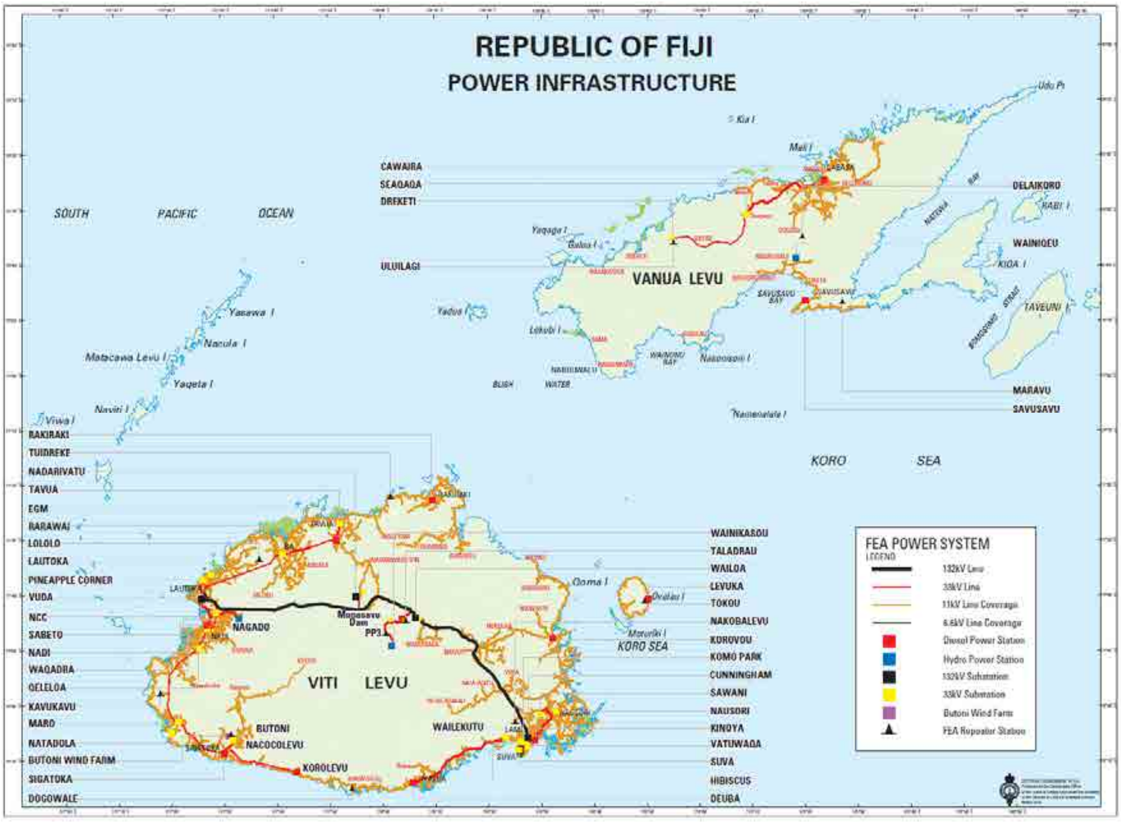
3.5.1 Existing Main Power Stations and Transmission Facilities

FEA supplies electric power to three islands (Viti Levu, Vanua Levu, and Ovalau).

In Viti Levu, a 132kV transmission line runs through the island, enabling hydropower generation at Wailoa (83.2MW), Wainikasou (6.8MW) and Nadarivatu (44MW) to be mainly transferred to Cunningham and Vuda respectively. In addition, a 33kV transmission network encircles most of the island except for its northeastern region. Then the power is reduced to 11kV at the zone substation located adjacent to the load center and is supplied to customers through the 11kV/0.415kV distribution network.

On the other hand, in Vanua Levu, there are two independent 11kV systems of Labasa and Savusavu. However, a new 33kV transmission line from Labasa to Dreketi via Seaqaqa of approximately 70km has just been commissioned at the beginning of 2014. The 33kV voltage was reduced at the Seaqaqa and Dreketi zone substations to 11kV and the power is supplied to customers through the 11kV/0.415kV distribution network.

Existing power system is shown in Figure 3.5.1-1.



(Source: FEA Annual Report 2013)

Figure 3.5.1-1 Existing Power System of FEA

Labasa and Savusavu in Vanua Levu are divided into two separate power systems (11kV) which are not interconnected. Both systems are supplied power by mainly diesel and the Wainikeu hydro power plant (0.8MW) is connected with the Savusavu system.

Apart from FEA and FSC and Tropic Wood Industries Ltd (TWL), which are state owned companies, are the other producers of power. FSC provides biomass power generation from by bagasse and TWC generates power from wood waste. However, the period for bagasse biomass power generation is restricted to 22 weeks (June-Nov).

Table 3.5.1-1shows existing power plants.

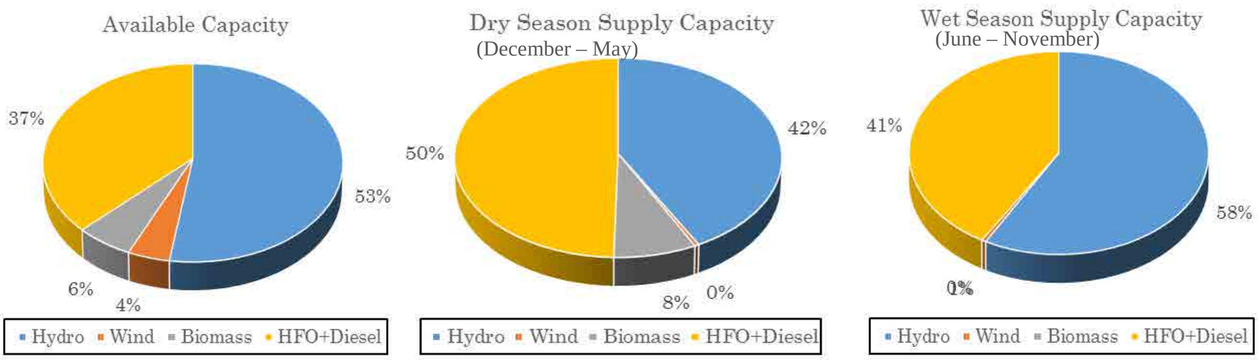
Table 3.5.1-1 Installed Capacity, Available and Supply Capacity of Existing Power Plants

As of Dec 2013

Location	Power Plant Name	Source and Tyoe	Commissioning Year	Installed Capacity (MW)	Available Capacity (MW)	Supply Capacity (MW)
Viti Levu	Wailoa Power Station	Reservoir Type Hydropower	1978	83.20	75.00	66.20
	Wainikasou Power Station	Run of River Hydropower	2004	6.80	3.30	1.80
	Nagado Power Station	Run of River Hydropower	2006	2.80	1.50	1.00
	Nadarivatu Power Station	Run of River Hydropower	2012	44.00	40.00	3.90
	Butoni Wind Farm	Wind	2007	10.00	10.00	0.70
	Kinoya Power Station IDO	Diesel		29.80	28.00	28.00
	Kinoya Power Station HFO	Diesel		20.60	10.00	10.00
	Qeleloa	Diesel		1.40	1.00	1.00
	Vuda Power Station	Diesel		24.08	22.00	22.00
	Nadi Power Station	Diesel		2.08	2.00	2.00
	Sigatoka Power Station	Diesel		7.92	3.00	3.00
	Deuba Power Station	Diesel		4.20	2.60	2.60
	Lautoka (FSC)	Biomass	1987, 2006	3.0+9.3	7.30	7.30
	Penang (FSC)	Biomass	1981	3.00	1.00	1.00
	Sub-total			252.18	206.70	150.50
Vanua Levu	Wainikeu Power Station	Run of River Hydropower	1992	0.80	0.70	0.10
	Labasa Power Station	Diesel		13.52	11.24	11.24
	Savusavu Power Station	Diesel		3.24	3.00	3.00
	Korovou Power Station	Diesel		0.90	0.75	0.75
	Levuka Power Station	Diesel		2.80	2.30	2.30
	Labasa (FSC)	Biomass	1979, 1997	4.0+10.0	5.30	5.30
	Sub-total			35.26	23.29	22.69
	Total			287.44	229.99	173.19

(Source: FEA)

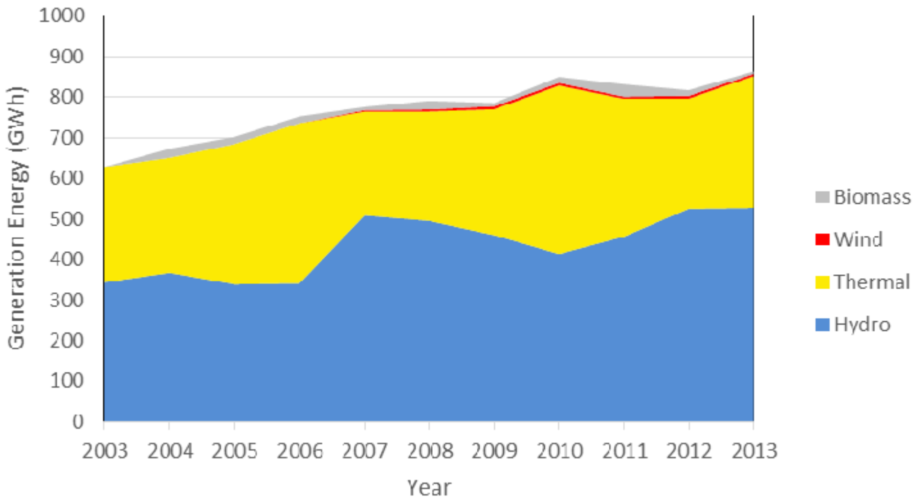
The total available capacity (230MW) is only 80% of the total installed capacity (287MW) due to mainly the aging of facilities and other factors subsequently described. Since the supply capacity of the hydroelectric power plant is reduced in dry season, the total supply capacity drops further to 173MW. It should be noted that, in the rainy season, as mentioned above, the total supply capacity drops to 207MW due to the seasonal ceasing of the power supply from the bagasse fueled power plants. Figure 3.5.1-2 shows the generation mix of available capacity and the supply capacity for each season. The figure clearly illustrates a significant difference of supply capacity configurations in both seasons.



(Source: JICA Project Team estimates based on FEA data)

Figure 3.5.1-2 Generation Mix of Available and Supply Capacity by Season

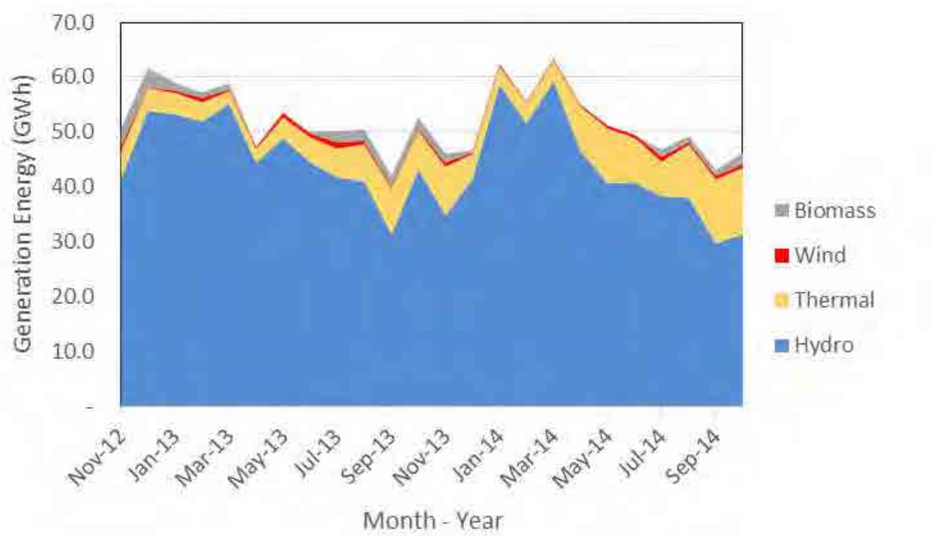
On the contrary, the mix of electricity generation is shown in Figure 3.5.1-3. It indicates that hydropower and thermal power are the dominant sources of generation. It is notable that the annual capacity factor of the Butoni Wind Farm (installed capacity 10MW), which was commissioned in 2006, stays as low as 6%.



(Source: JICA Project Team estimates based on FEA data)

Figure 3.5.1-3 The Mix of Electricity Generation (2003-2013)

As shown in Figure 3.5.1-4, a large decrease in energy generated by hydropower can be seen during the dry months (Jun-Nov). On the other hand, energy during these months was generated through biomass power from bagasse.



(Source: JICA Project Team estimates based on FEA data)

Figure 3.5.1-4 The Mix of Electricity Generation (Nov. 2012- Sep. 2014)

3.6 Financial Analysis of FEA

3.6.1 Financial Analysis of FEA

During past 4 years, FEA has increased its revenue from electricity sales and made a net profit every year. This increase in revenue was mainly attributed to the rise in the electricity tariffs in 2010 and 2011. FEA's main financial results in recent years are shown in Table 3.6.1-1.

Fluctuations in operating expenses have generally occurred in conjunction with the changes in fuel costs. In 2010, there was a rise in the average fuel price and fuel consumption due to increase of thermal power generation, which covered the decrease in hydropower generation brought on by a severe drought during the same year. Operating expenses accordingly increased from 165.9 million FJD to 214.7 million FJD; however, the two electricity tariffs during 2010 covered the operating cost and brought the profit in the year.

From 2010 to 2011, revenue from electricity sales increased by 27% as a result of the tariff increase. Although the fuel cost was at its highest in 2011, during the past four years the increase in revenue brought a large increase annual net profits, 51.9 million FJD in 2011 which was up from 8.4 million FJD in 2010. The main reasons for this increase were the excellent performance in hydropower generation and the tariff increases.

Net profit in 2012 was 75.3 million FJD, an increase of 45% from previous year, despite the unexpected expenditure caused by the flood early in the year. This was achieved partially by rise in hydropower generation from the Monasabu Dam scheme and the commissioning of Nadarivatu hydropower plant. In addition, the decrease in the average fuel price per metric tonne and the income tax benefit from Ministry of Finance contributed to increased net profit. The main income tax benefit from the Ministry of Finance was a grant of 40% as a fuel investment allowance for the Nadarivatu hydro project (24.7 million FJD). As a result, there was an increase of 13.5 million FJD in net profit from the profit before income tax.

In 2013, despite there being a 5% reduction in the electricity tariff for all tariff bands during the year, profit after income tax was 32.5million FJD, owing to the timely commissioning of Nadaribatu hydropower plant which produced 98,600 MWh of electricity (nearly achieving its target of 100,000MWh). The difference from the previous year's profit after income tax of 75,345 million FJD is largely due to the incidental allowance from the Ministry of Finance and the substantial increase in fuel cost by approximately 17% - compared to 2012 – which occurred as a result of the increase in electricity demand by 6.6% in year 2013. The finance cost decreased by approximately 1 million FJD during 2013 since FEA refinanced the 30million US$ China Development Bank loan with a Westpac Banking Corporation loan at lower interest rate1.

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[1] The interest rate for the CDB loan was 7.15% per annum, which was effective for 60 months from the date of the agreement. After this 60 month period the rate would then change to the London Interbank Offered Rate (LIBOR) plus a margin of 3.20% per *a*nnum. Theinterest rate for the Westpac Banking Corporation loan is3.25% per annum (FEA Annual Report 2013).

Table 3.6.1-1 Main Financial Results

Unit: 1,000 F$

Items	2009	2010	2011	2012	2013
1. Revenue from Electricity Sales	179,605	226,945	288,778	290,451	292,916
2. Other Operating Revenue	10,556	4,654	16,766	5,852	4,983
3. Operating Expenses	(165,985)	(214,782)	(242,075)	(218,092)	(236,741)
Fuel Cost	(77,270)	(126,756)	(137,881)	(105,136)	(122,606)
Depreciation	(28,819)	(29,655)	(29,914)	(34,522)	(36,312)
4. Finance Cost	(10,176)	(12,631)	(12,054)	(18,649)	(17,718)
Profit before Finance Costs and Income Tax	13,620	16,817	63,469	78,211	61,158
Profit before Income Tax	431	12,998	52,427	61,836	41,024
Profit after Income Tax (Net Profit)	2,445	8,404	51,910	75,345	32,581

(Source: FEA "Annual Report" 2010, 2011, 2012 and 2013)

With the increase in net profit, financial indicators such as return on total asset (ROA), return on shareholder fund (ROSF), and profit margin on sales have improved in 2011 and 2012, as shown in Table 3.6.1-2. In year 2013, it has decreased to 5.5%. However, according to the FEA annual report, it was 9.78% account is taken of the 25 million FJD non-commercial obligation cost (NCO). The shareholders' equity ratio has increased since 2011; it was 56.4% in 2013. The current ratio has also improved to more than 100% - 125.4% in 2012 and 176.3% in 2013 respectively. With these positive financial results, FEA was able to implement capital expenditure of 38million FJD and repay its matured bonds and loans.

Currently, FEA's financial management appears to be sound. According to FEA's annual report, for next the few years, it will have to prepare for debt repayments of 27 million FJD in 2014, 39 million FJD in 2015 and 32million FJD in 2017, while also planning for capital expenditure of 210 million FJD during the same period. This all means that is necessary for FEA to will continue its effective and solid financial management.

Table 3.6.1-2 Financial Indicators

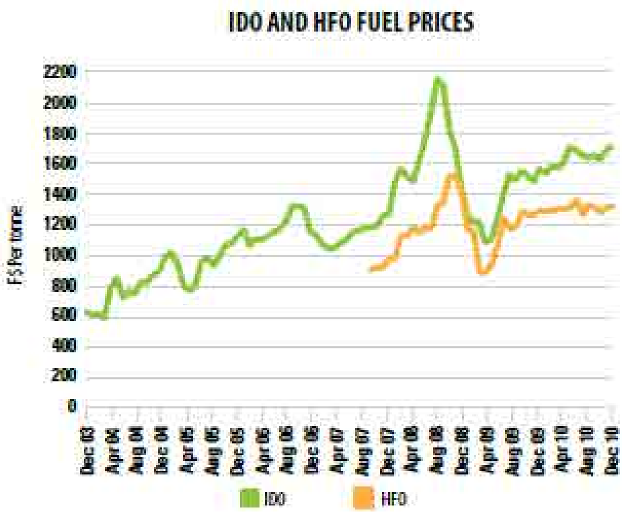
Items	2009	2010	2011	2012	2013
Financial Results (Unit: 1,000F$)					
(1) Total Assets	880,279	925,574	983,010	1,031,482	1,042,258
(2) Current Assets	138,180	104,924	88,009	99,047	114,634
(3) Current Liabilities	141,714	132,677	91,187	78,984	65,036
(4) Capital and Reserves	402,700	414,700	472,052	551,894	587,941
(5) Total Revenue	179,605	231,599	305,554	296,303	297,899
(6) Net Profit	2,445	8,404	51,910	75,345	32,581
Financial Indicators					
Return on Total Assets (%) (6)/(1)	0.3%	0.9%	5.3%	7.3%	3.1%
Return on Shareholder Fund (%) (6)/(4)	0.6%	2.0%	11.0%	13.7%	5.5%
Profit Margin on Sales(%) (6)/(5)	1.4%	3.6%	17.0%	25.4%	10.9%
Current Ratio(%) (2) /(3)	97.5%	79.1%	96.5%	125.4%	176.3%
Total Assets Turnover (times) (5) /(1)	0.2	0.3	0.3	0.3	0.3
Shareholders' Equity Ratio (%) (4)/(1)	45.7%	44.8%	48.0%	53.5%	56.4%

(Source: FEA "Annual Report" 2010, 2011, 2012, 2013)

3.7 Main Issues in the Power Sector

3.7.1 Main Issues in the Power Sector

The main issues in Fiji's power sector include high prices of imported fossil fuels the and increase of their usage. As shown in Figure 3.7.1-1, the price of industrial diesel oil (IDO) in Fiji nearly tripled from 2003 to 2010, and fuel consumption for power generation also increased yearly. In 2010, FEA's revenue from electricity sales was 226.9 million FJD, while the net thermal fuel cost was 126.8 million FJD, which accounted for around 60% of FEA's annual expenditure. Since these factors seriously affected the financial performance of FEA, it was forced to increase tariff rates in April 2011. The effect of these tariff rates increases was a decrease of competitiveness in industry and an increase in the strain placed on the global environment from the rise in CO_2 emissions.



(Source: FEA Annual Report 2010)

Figure 3.7.1-1 Fuel Price in Fiji

In light of these circumstances, there is an urgent need for Fiji's power sector to reduce fuel costs through a diversification of power resources.

3.8 Development Status and Issues of Hydropower

In Fiji, there are many areas with an annual rainfall of more than 3,000 mm. In particular, within certain parts of central Viti Levu certain areas have in excess of 4,000m of annual rainfall. Hydropower generation utilizing rich water resources, which has been important domestic resource for Fiji and the mainstay of the power supply, is expected to continuously play an important role in the power sector.

3.8.1 Utilization of Hydropower

The generation capacity of the Wailoa Hydropower Station, which is Fiji's largest power station with an installed capacity of 83 MW, accounts for around 40% of the total generation capacity in Fiji. At present, Fiji's total hydropower generation capacity is 137.6 MW – consisting of the genartion capacity of the Wailoa Hydropower Station, four other existing hydropower stations, and the Nadarivatu Hydropower Station, which began operation in 2012 – which is nearly 60% of FEA's total generation capacity. Table 3.8.1-1 lists Fiji's existing hydropower stations, those currently under construction, and those planned.

Table 3.8.1-1 Power Development Plan until 2020

Status	Name of Project/Location	Executing agency	Installed capacity	Type	Remarks
Existing	Wailoa Hydro (Viti Levu)	FEA	83.2 MW	Reservoir type	Available Supply Capacity to grid : 72 MW, Equipment replacement from 2012
	Wainikasou Hydro (Viti Levu)	FEA	6.8 MW	Run-of-river	Available Supply Capacity to grid : 3 MW
	Nagado Hydro (Viti Levu)	FEA	2.8 MW	Run-of-river	Available Supply Capacity to grid :1.9 MW
	Wainiqeu Hydro (Vanua Levu)	FEA	0.8 MW	Run-of-river	Full operation for 5 to 6 months a year Capacity falls to until 100 kW in dry season
	Buca Micro Hydro (Vanua Levu)	Turkey	30 kW	Run-of-river	Commissioned in Jan. 2011
	Nadarivatu Hydro (Viti Levu)	FEA	44 MW	Run-of-river	Commissioned in Sep. 2012
Under-construction	Wainisavulevu (Viti Levu)	FEA	(7.63 GWh)	Run-of-river	Weir Raising
Proposed	Qaliwana Hydro (Viti Levu)	FEA	10 MW	Reservoir type	Upstream Nadarivatu
	Nabou upstream Hydro (Viti Levu)	FEA	n/a	n/a	Pre-F/S in 2011 by a NZ consultant
	Wailoa downstream Hydro (Viti Levu)	FEA (assumed)	approx. 7 MW	Run-of-river	F/S in 2009 by JETRO
	Wailoa Hydro (expansion) (Viti Levu)	FEA (assumed)	21 MW	Run-of-river	EIA completed in 2006 New 2600 m long tunnel with a diameter of 3 m
	Namosi Hydro (Viti Levu)	IPP (assumed)	22.4 MW in total	Run-of-river	5 candidate sites, F/S conducted in 2006

(Source: Report on the Detailed Planning Survey for the Maximum and Effective Use of Renewable Energies in Electricity Power Supply in Fiji, June 2012, JICA)

3.8.2 Past Hydropower Potential Studies and their Issues

As of yet there has been no comprehensive information put together on hydropower potential in Fiji.

In the JBIC study "Pilot Study for Project Formation for Comprehensive Renewable Energy Power Development" conducted from 2007 to 2008, the hydropower potential study on run-of-river type hydropower potentials with an installed capacity of more than 1 MW throughout Fiji was carried through a map study using 1:50,000 scale topographical maps. Unfortunately, the accuracy of these maps, specifically with regard to elevation, is not good enough to identify the optimum layout for the hydropower facilities, and to obtain detailed information concerning the topographical/geological features, river flow duration, power demand for the area, power system interconnection, and natural environment around potential sites. It is, therefore, necessary to update evaluations on each potential site by collecting additional information, including through commissioning a study using 1:10,000 scale topographical maps to gain much more accurate information on the sites. In addition, as it is likely from such evaluations that prospective hydropower potential sites would be identified as priority projects for development, there would also be a need for further activities including the implementation of the preliminary designs.

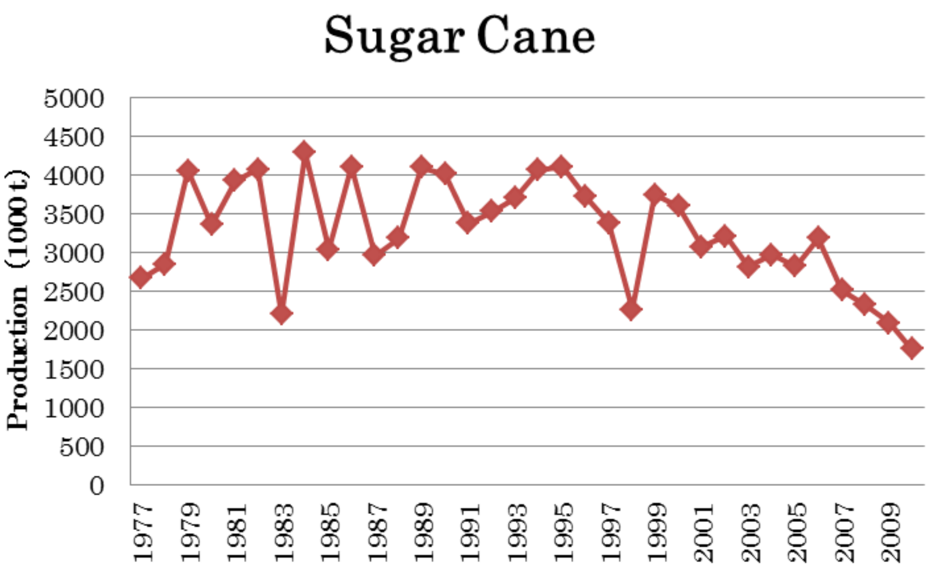
3.9 Development Status and Issues of Biomass Power Generation

In Fiji bagasse, wood chips, and forestry residue are expected to be used as the basis for biomass power generation.

3.9.1 Biomass Power Generation using Bagasse

With regard to biomass generation using bagasse, Fiji Sugar Corporation (FSC) has introduced cogeneration stations with installed capacities of 12 MW and 10 MW to its own factories in Lautoka and Labasa, respectively. It has also supplied surplus power from these to FEA's power systems. However, these biomass power stations have often failed to provide a stable power supply to FEA as they can operate only when bagasse is produced from June to November and because plant equipment such as the boiler often breaks down. Such a unstable power supply to FEA systems has led to lower power selling rates of 0.13 FJD /kWh (0.068 USD/kWh) although the power selling price from IPPs is regulated to be 0.23 FJD /kWh (0.12 USD/kWh) normally.

As shown in Figure 3.9.1-1, the production of sugarcane has dipped after peaking in 1980s, and was around 1,700,000 per annum in 2010, which is only 40% of its peak. If this downward trend continues, the potential of biomass power generation using bagasse will also decline.



(Source: Key Statistics December 2011, Fiji Bureau of Statistics)

Figure 3.9.1-1 Sugarcane Production

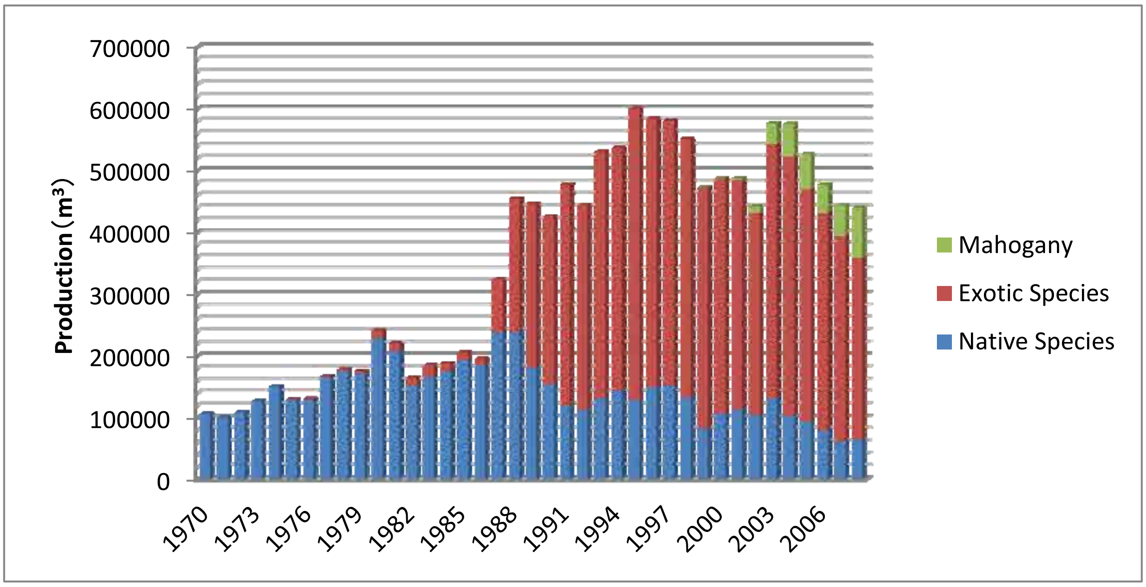
3.9.2 Biomass Power Generation using Forestry Residue

With regard to biomass power generation using forestry residue, Fiji's largest timber company, Tropik Forestry has introduced biomass power generation stations using forestry residue with installed capacities of 3 MW and 9.3 MW, respectively.

As shown in Figure 3.9.2-1, the amount of wood production in Fiji increased sharply in the early 1990s and has continued to be more than 400,000 m^3 per annum since then.

Forestry residue, such as sawdust and woodchips, comes from the process when logs are cut into lumber, and it typically amounts to around 40% to 60% of the raw material from this process. However, this large quantity of forestry residue has not been utilized efficiently; it has mostly been simply for landfill and/or dumped into peoples' backyards. Therefore, it is expected that more efficient use of forestry residue should be made for biomass power generation.

The amount of forestry residue such as sawdust and woodchips wasted when logs are cut into lumber is 40 to 60% of raw material. However, such large amount of forestry residue has not been utilized efficiently, but mostly has been just used for landfill and/or dumped into backyard. It is, therefore, expected to efficiently make use of such forestry residue for biomass power generation.



(Source: Key Statistics December 2011, Fiji Bureau of Statistics)

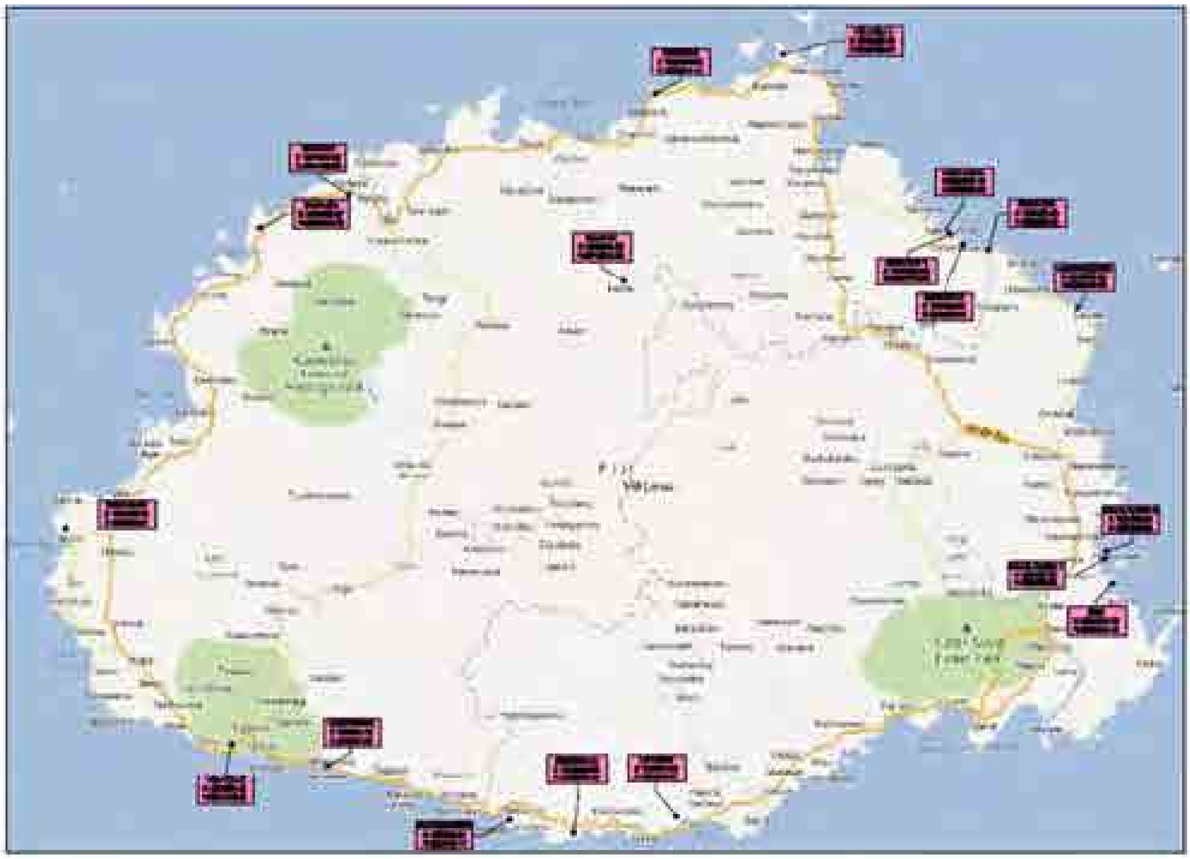
Figure 3.9.2-1 Wood Production in Fiji

3.10 Development Status and Issues of Power Generation concerning Other Renewable Energy Resources

3.10.1 Wind Power

Butoni Wind Farm (10 MW) is an existing wind power station in Fiji, which has been in operation since 2006. According to the information from FEA's Vuda load dispatching center, this wind power station rarely performs maximum power, and has wide fluctuations in output with an output of 5 MW at the maximum. The load dispatching center expects this wind power station to only produce less than 1 MW of power for daily operation planning in load dispatching.

Prior to 2012 all year round observance of wind power records, which make it possible to evaluate accurate wind power potentials, have not been conducted in Fiji. However, for a period of three year from 2012, DOE has implemented a plan to observe wind power at 15 points in Viti Levu, as shown in Figure 3.10.1-1. The data for evaluating wind power potentials is still insufficient, and it is necessary to wait for the results of the above-mentioned wind power observations.



(Source: Key Statistics December 2011, Fiji Bureau of Statistics)

Figure 3.10.1-1 Candidate Wind Observation Points

3.10.2 Solar Power

With regard to solar power utilization in Fiji, there are no plans to connect solar power stations to the power system; up until now only solar home systems (SHS) have been introduced. Around 1,400 SHS units have been installed with a further 3,000 SHS units scheduled to be installed in future.

Figure 3.10.2-1 shows the monthly average horizontal global insolation rate as observed in various locations throughout the country.

At present it appears that Fiji's only solar power generating facilities are/will be the installations of SHS that have a relatively high generation cost for un-electrified areas.

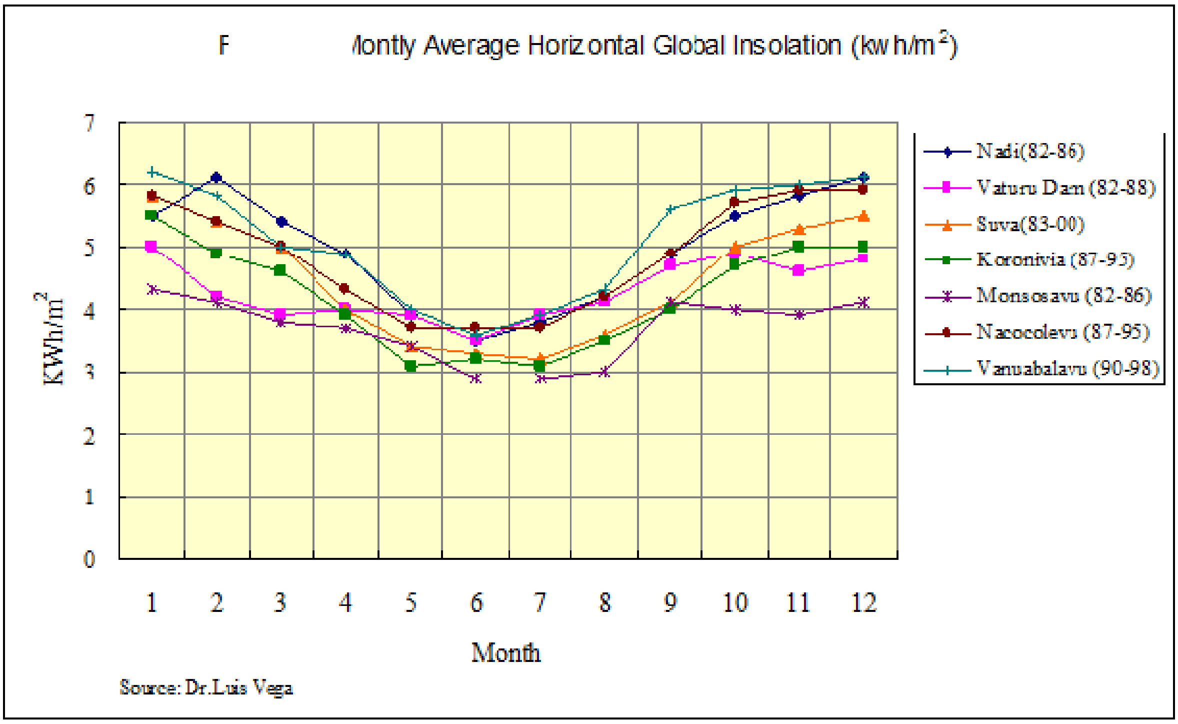
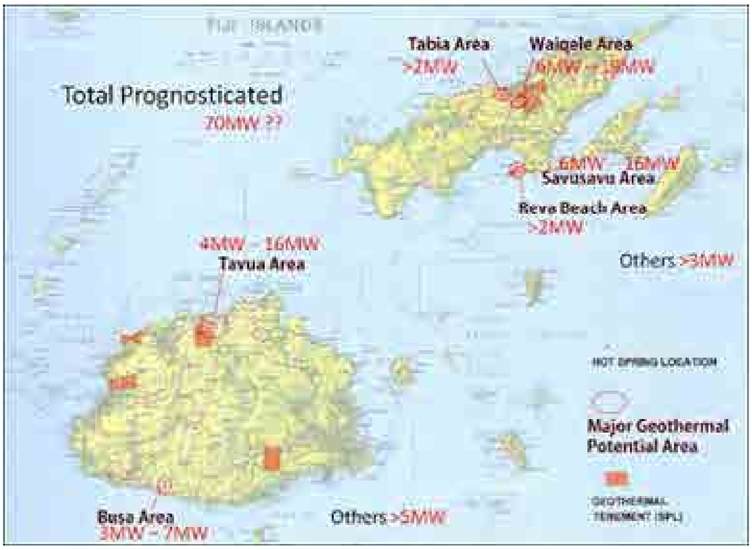


Figure 3.10.2-1 Monthly Average Insolation

3.10.3 Geothermal Power

It is said that there are 55 natural hot springs sites throughout Fiji. Preliminary surveys on 14 of these hot springs have been carried out, but geothermal potential at every site has been found to be small in scale. These geothermal power potentials produce a relatively small output of power when compared to other renewable sources – the total power output for Vitu Levu is 15 MW and 23 MW for Vanua Levu; a grand total of 38 MW for both islands. Figure 3.10.3-1 shows locations of geothermal potential sites.



(Source: METI Prelim. Study, March 2009)

Figure 3.10.3-1 Locations of geothermal potential sites

Normally considerable expense is required to carry out surveys for developing geothermal power. However, the surveys for developing stations for binary geothermal power generation – which use hot spring water, a proven geothermal source – are generally much cheaper to conduct. In Fiji a study on the feasibility of binary geothermal power generation using hot spring water has still not been carried out. Thus, it is recommended that such a feasibility study be undertaken.

3.11 Issues in Introducing Renewable Energy Resources

The main two issues concerned with introducing renewable energy are technical and institutional.

3.11.1 Technical Issues

In Fiji comprehensive renewable energy potentials have not been obtained and a specific development plan for renewable energy has not yet been made.

With regard to hydropower potentials, pre-F/S and/or F/S for some specific sites have been conducted, but their results have not been compared through the use of comprehensive and uniform criteria such as B/C (benefit/cost) values based on firm capacity. Also, specific projects have not been prioritized for development. In the Fiji power development plan for the period up until 2020, three hydropower projects are listed, but it is unclear how these projects were selected.

On the other hand, with regard to biomass power generation, although it is considered relatively easy to identify its potentials, development plans (e.g. F/S) based on such biomass power potentials have not been conducted. Furthermore, for wood companies it is very difficult to evaluate whether to develop a biomass power station using their biomass resources, as these do not have the knowledge and skills needed to develop a power station.

Therefore, to further develop power generation using renewable energy resources, it is essential to prioritize the comprehensive identification of all available renewable energy potentials and to show their development scenario clearly.

Renewable energies, particularly hydropower and wind power, are often affected by seasonal changes or droughts. In planning that renewable energy should 90% of supply capacity, it is necessary to evaluate the supply capacity of each power station based on statistical probability. Prioritization of hydropower projects should be made mainly by comparing their B/C values based on firm capacity. However, Fiji's hydropower power development plan did not prioritize hydropower projects based on this. Thus, in this respect, the Project, which includes above-mentioned prioritization of hydropower development projects, is considered as complementary to Fiji's power development plan.

3.11.2 Issues in Institutional Aspects

The present incentives offered to IPPs that use renewable energies include the duty free import of all types of renewable energy equipment, a long-term (15 year) power purchase agreement, and a feed-in tariff of 0.23 FJD /kWh(0.12 USD/kWh). These incentives were not effectively led to an increase in IPPs using renewable energies, because of the tariff rate that remained low compared to other countries' feed-in-tariff rates. However, in May 2014, the feed-in-tariff was revised to 0.3308 FJD /kWh (0.172 USD/kWh) to attract more renewable IPPs.

Chapter4 Collection and Examination of Relevant Data and Information

4.1 Data and Information Collection

4.1.1 Analysis and Review of Reports and Basic Data/Information

The JICA Project Team collected the following relevant materials to review the present situation and future plan for renewable energy development.

< Relevant Materials >

a. Materials on policy and higher plan

- Road Map for Democracy and Sustainable Socio-Economic Development 2010-2014
- National Energy Policy
- FEA's Power Development Plan (2011-2020), Annual Report, etc.

b. Data and Information on Renewable Energy Development

- Pilot Study for Project Formation for Comprehensive Renewable Energy Power Development (2008, JBIC)
- Hydropower Renewable Energy Development Project in the Wailoa Downstream in Republic of Fiji (2009 JETRO)

4.1.2 Collection of Data and Information on the Present Status of the Power Sector

In order to understand the present status of the power sector, the JICA Project Team collected the following data and information.

① The National Development Plan, National Energy Policy and Energy Balance.

② The Power Development Plan, Transmission Line Extension Plan and Rural Electrification Plan.

③ Potential data of renewable energy resources such as hydro, wind, solar and biomass, which are provided by DOE and FEA.

④ Renewable energy promotion incentives - mainly feed-in tariff systems in other major countries.

⑤ The operation data from existing hydropower stations and other power stations.

⑥ The status and progress of on-going and planned hydropower projects and factors, if any, which hindered the smooth implementation of the projects.

⑦ The basic data required for hydropower development such as meteorology, hydrology, geography, topography, geology, sedimentation, and information for previously identified hydropower potential sites.

⑧ The data related to environmental and social considerations, including mitigation measures of hydropower development projects if adverse impacts are predicted in Fiji.

4.2 Hydropower Generation

4.2.1 Existing Hydropower Stations

The notable power stations among existing Fiji's power facilities are: 1) the Wailoa Hydropower Station (installed capacity of 83 MW), which accounts for around 40% of the total power generation capacity of FEA's power stations; and 2) the Nadarivatu Hydropower Station (installed capacity of 42 MW, put in operation after September 2012), which has become the second largest power station after the Wailoa Hydropower Station. The generation mix in Viti Levu has been much changed due to the fact that the power generation amount from hydropower, after commissioning of the Nadarivatu Hydropower Station in 2012, has been accounting for nearly 60% of FEA's power generation facilities.

The location map of the central area of Viti Levu where there are three major hydropower stations is shown in Figure 4.2.1-1.

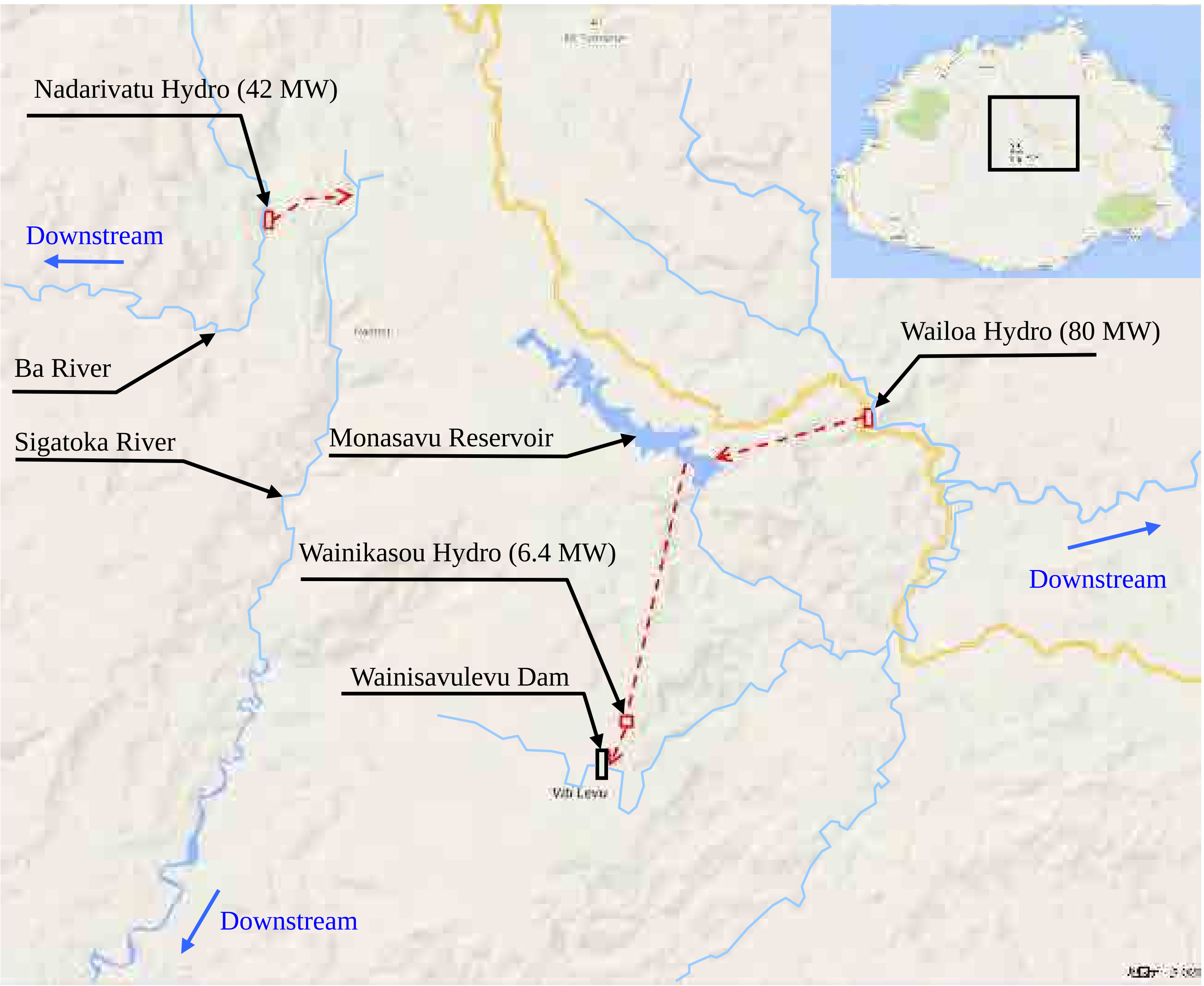


Figure 4.2.1-1 Hydropower Stations in the Central Area of Viti Levu

(1) Wailoa Hydropower Station and Monasavu Reservoir

Wailoa Hydropower Station, the largest hydropower station in Fiji, is located in the central part of Viti Levu, and connected to the 132 kV transmission line between Suva and Vuda. This hydropower station was completed in 1983 with support from donors such as the World Bank and European Investment Bank (EIB). Table 4.2.1-1 shows the major technical features of the power station.

Table 4.2.1-1 Major Features of Wailoa Hydropower Station

Item	Features
Type of Generation	Reservoir type (Monasavu Reservoir: high water level: EL. 745 m, Low water level: 710 m)
Dam Type	Rock fill type (height: 85 m, Crest length: 465 m)
Headrace Length	Approx. 17 km
Maximum Discharge	16.8 m3/s
Maximum Head	618 m
Water Turbine Type	Pelton Turbine x 4 units
Capacity of Generator	20.8 MW x 4 units

MonasavuReservoir and Wailoa Hydropower Plant

(2) Wainikasou Hydropower Station and Wainisavulevu Weir

The project Wainikasou Hydropower Station project was planned as a part of the small hydropower development in Fiji by MHW New Zealand Limited. (Vaturu and Wainikasou Hydro Projects, Fiji, Hydropower (run-of-river) 2004-2005).

In June 2005, the scheme negotiated the world's first bank-intermediated carbon credit transaction, securing a deal with the Netherlands-based international bank ABN Amro for the purchase of 100% of the Certified Emission Reductions ("CER") created from the project.

Wainikasou Hydropower Station with an installed capacity of 6.3 MW was completed in May 2004, and is located at an altitude of about 1,000 meters and about 10 km south of Monasuvu Reservoir. This run-of-river hydropower station was built around existing infrastructure that diverts water from

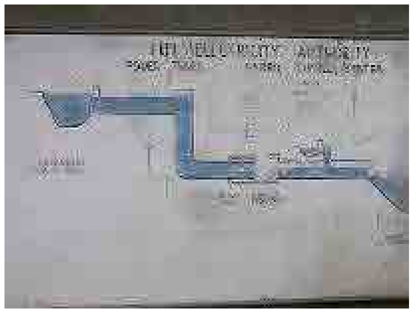
Wainisavalu Creek to Monasavu Reservoir for use by the 82 MW Wailoa Hydropower Station. There are six weirs - Wainikasou, Wainisavulevu, Nabilabila, Wainaka, Wainimaliwa and Wainibua - supplying water to the Monasavu Dam. To better manage water flows, a 1.5 m adjustable gate has been added to the existing diversion weir (the Wainisavaulevu weir). The powerhouse structure contains two horizontal Francis turbine generators. A 30 kilometer-long 33 kV transmission line connects to a FEA's substation.

Installed capacity: 6.3 MW
Design discharge: 2.2 m^3/s
Gross head: 116.8 m

Since the original capacity of the Wainisavulevu weir is about 500,000 m3, which is relatively small to effectively utilize the water usage of Wainisavulevu Creek, FEA decided to raise the weir so that the weir can store 10 times that amount. This weir raising project will enable FEA to optimize water usage and help it meet the 138 MW demand for electricity on Viti Levu. The project which commenced construction in late 2011 will result in the height of the Wainisavulevu weir being increased by eight meters allowing it to store more water.

Initially estimated to cost 27.8million USD, the project, which is implemented in the form of a partnership between FEA and Chinese company Sinohydro, had its cost revised to 40million USD following further surveys at the site. The project is expected to be completed in December 2014 and provide the Viti Levu grid with an average additional energy yield of 10 GWh per annum with a maximum of 21 GWh per annum





Wainisavulevu Weir and Wainikasou Hydropower Plant

(3) Nadarivatu Hydropower Station

Nadarivatu Hydropower Station with a maximum capacity of 42 MW, the latest hydropower station among FEA's hydropower station, is located around 21 km west northwest of Wailoa Hydropower Station in the remote central area of Viti Levu.

The Nadarivatu Hydropower Project was first identified in 1977 during a hydropower study. Detailed plans for the project were developed in 2002 and major construction began in 2009. The power station was commissioned on 7 September 2012, but an inauguration ceremony led by Prime Minister Frank Bainimarama was held a week later on 14 September. The total project cost was 150 million USD. Funding and loans for the project were provided by several organizations, including the China

Development Bank (70 million USD), FEA bonds (50 million USD), ANZ Bank (30 million USD).

The 40 -meter -high concrete gravity dam, including three radial gates and two sluice gates, diverts water from the confluence of the Nukunuku River and Qaliwana River, which are tributaries of Sigatoka River, through a 3,225 m long headrace/2-meter-diameter buried steel penstock tunnel to a power station along the Ba River to the southwest. The power station contains two 20.85 MW Pelton (with 6 jet-units) turbine-generators with a maximum discharge of 15.0 m^3/s. The drop in elevation between the reservoir and the power station affords a gross head of 335.7 m. A 132 kV, 5-kilometer-long transmission line connects it to the existing FEA's transmission system through a switching station. The design services for the project were undertaken by MWH New Zealand Limited, while the construction was undertaken by the Chinese company Sinohydro.

The hydropower station is a run-of-river type with daily regulating, designed to generate 103 GWh of electricity annually by using a reservoir with an effective storage capacity of 1,009,000 m^3 (H.W.L.: EL. 529.5 m, L.W.L.: EL. 515 m, effective drawdown: 24.5 m)

Information on the operation of the power station obtained from its operators is shown below:

- Normally the power station is operated only during the daytime to provide electricity to meet the daytime demand, and not during the night time for water storage in the reservoir.
- When the flood flow discharge is 500 m^3/s or more (design flood discharge: 3,250 m^3/s), the generation should be stopped.
- There was no resettlement for this project

Nadarivatu Hydropower Station

(4) Wainikeu Hydropower Station

Wainikeu Hydropower Station is the only hydropower station connecting to a grid (Savusavu system) in Vanua Levu, which is a run-of-river hydropower station located about 15 km north of Savusavu, the largest town in Vanua Levu. The main features of the power station are shown below.

- Installed Capacity: 800 kW (400 kW x 2)
- Maximum Discharge: 1.27 m^3/s (0.635 m^3/s x 2)
- Effective Head: 86.2 m
- Intake Weir: Tyrolean Type Intake

- Water Turbine: Horizontal Francis
- Generator: Synchronous generator
- Headrace: Pressured type steel pipe, 1 x ϕ 850 mm x 2,553 m
- Penstock: Steel pipe, 1 x ϕ 800 mm x 342 m
- Commissioning Date: March, 1992

The hydropower station was completed with support from China.



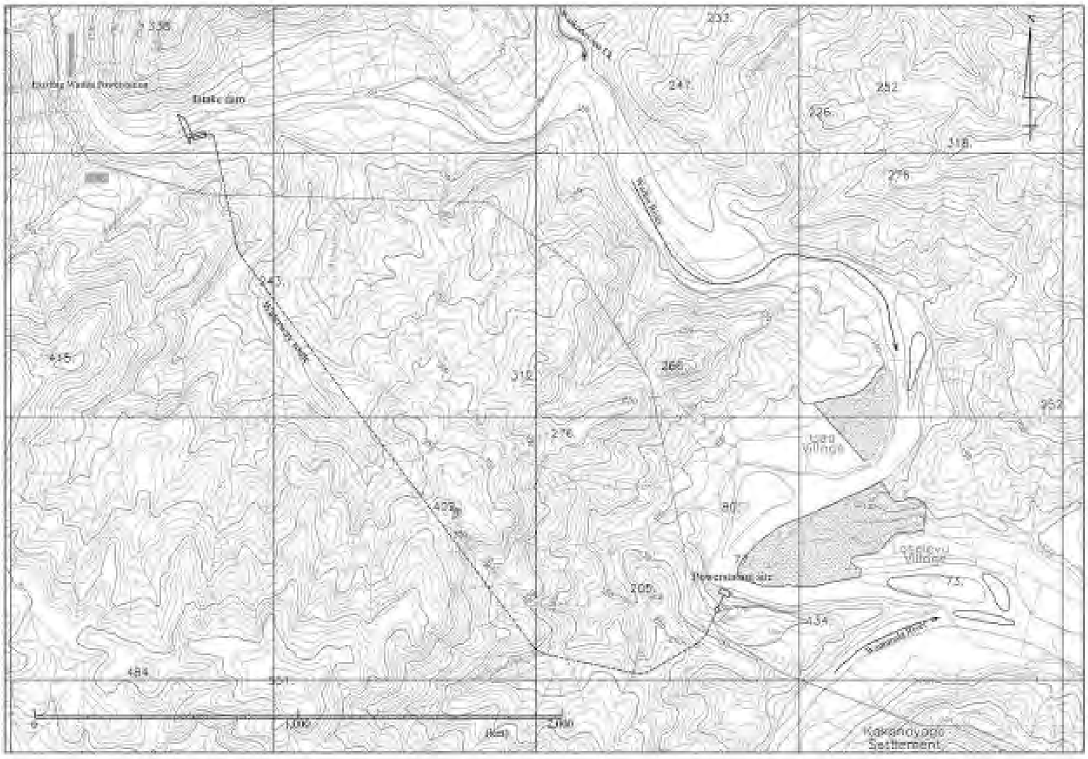
Wainikeu Hydropower Plant

4.2.2 Planned Hydropower Stations

(1) Wailoa Downstream Hydropower Station

The existing Wailoa Hydropower Station was designed to use water diverted from the Monasuvu Reservoir which collects water not only from its catchment area of the Nanuku River but also from the Wainikasou, Wainisavulevu, Nabilabila, Wainaka, Wainimaliwa and Wainibua Creeks through the existing water diversion system that links the Wainisavulevu weir to the Monasavu Reservoir. The amount of river flow discharge downstream of the Wailoa Hydropower Station has, therefore, been significantly increased after the facility started its operation. Under these situations, the Wailoa Downstream Hydropower Project was planned to take water just downstream of the Wailoa Hydropower Station to utilize such an increased river flow discharge effectively and efficiently. There have been two feasibility grade studies on this new hydropower scheme, which are the study (reservoir type, installed capacity: 37.4 MW) by Australian consultant, Hydro Tasmania, and the study (run-of-river type, installed capacity: 7.4 MW) carried out in 2009 by Japan External Trade Organization (JETRO).

The general plan of the Wailoa Downstream Hydropower Project designed by JETRO is shown in Figure 4.2.2-1.



(Source: Study on Hydropower Renewable Energy Development Project in the Wailoa Downstream in Republic of the Fiji, March 2009, JETRO)

Figure 4.2.2-1 General Plan of Wailoa Downstream Hydropower Project

(2) Qaliwana Hydropower Station

The Qaliwana Hydropower Station is planned to be on the upper reach of the Nadarivatu Hydropower Project. FEA expects IPP to develop this project as well as the Wailoa Downstream Project.

(3) Somosomo Hydropower Station

Since the mid - 1970’s the Department of Energy has studied the Somosomo Hydropower Project - located in Taveuni Island for providing electricity to several large villages and settlements in the area, the main commercial center at Taveuni, a number of hotels, several large boarding schools - and the Waiyevo Government Station. The proposed scheme is intended to be located at the Naibili Creek. The current design is intended to be a 700 kW run-of-river type with a maximum discharge of 0.16 m^3/s and an effective head of 590 m. A number of engineering studies have been undertaken at the site by New Zealand Consultants.

The output from the scheme will be transmitted throughout the proposed area using high voltage and low voltage transmission and distribution lines. It is intended that all electrical works will be undertaken using the prevailing FEA standards.

The Somosomo Hydro Project is currently under construction by the Human Construction Engineering Group Corporation, China. The hydro project is funded by the People’s Republic of China. Together with the Government of Fiji with a total grant of 10 million USD.

4.3 Biomass Power Generation

4.3.1 Existing Biomass Power Generation

Major existing power generation using biomass in Fiji at present includes power generation by introducing a co-generation system utilizing bagasse in sugar mills owned and operated by Fiji Sugar Corporation Limited (FSC) and power generation by introducing a co-generation system utilizing wood residue in a sawmill of Tropik Wood Industries Limited, a major sawmill company in Fiji. Both companies utilize generated electricity for their own energy consumption in the factories and the remaining electricity is provided to FEA's grid under a power purchase contract with FEA.

The outlines of biomass power plants providing electricity to FEA's power grids as of October 2013 are shown in Table 4.3.1-1.

Table 4.3.1-1 Existing Biomass Power Plants providing Electricity to FEA's grids

Place	FSC Lautoka Mill	FSC Labasa Mill	Tropik Wood Lautoka Industry
Installed Capacity	12 MW	10 MW	3 MW + 9.3 MW
Fuel	Bagasse	Bagasse	Wood residue
Remarks	Seasonal operation (from June to October)	Seasonal operation (from June to October)	As of Oct. 2013, max. capacity is 7.5 MW due to boiler failure

(1) Sugar Mills

Fiji Sugar Corporation (FSC) is the government-owned sugar milling company that has a monopoly on production of raw sugar in Fiji. It is also the largest public enterprise in the country employing nearly 3,000 people, while another 200,000 or more depend on it for their livelihoods in the rural sugar cane belts of Fiji. It operates four sugar mills: the Lautoka mill, the Rarawai mill in Ba, the Penang mill in Rakiraki in Viti Levu, and the Labasa mill in Vanua Levu. Each mill has a co-generation system, and their total generation capacity is 31 MW. As shown in Table 4.3.1-1, the Lautoka and Labasa mills provide surplus electricity to FEA's grids.

The existing power plants have often failed to provide a stable power supply to FEA due to the fact that they can operate only when bagasse is produced from June to November, and often plant equipment such as boilers breaks down. Such an unstable power supply to FEA systems has led to lower power selling rates of 0.07 USD/kWh (0.13 FJD/ kWh), although the power selling price from IPPs is usually regulated to be 0.12 USD/kWh (0.23 FJD/ kWh).

Co-generation System at FSC Labasa Mill

(2) Sawmills

In Fiji, there are two major sawmill companies - Fiji Forest Industries ("FFI") and Tropic Wood Industries ("TWI") - have small, medium and large sawmills scattered over the country. The total number of these sawmills in Fiji is 39. Most of these sawmills have not utilized their wood residues, that were produced in the course of sawing up logs, instead these have just been piled up in and around the sawmills. Only the TWI Lautoka sawmill, having installing a co-generation system with an installed capacity of 3.0 MW and 9.3 MW, utilizes its wood residue for generation. Its generated electricity is provided to FEA's grid.

Since all the wood residue including residue to be utilized for generation is piled up out in the open, the wood residue often contains a high moisture content. According to a TWI engineer, such a high moisture content often leads to the failure of the 9.3 MW boiler, which results in reducing maximum generation capacity from 9.3 MW to 7.5 MW.

Lautoka Sawmill of Tropik Wood Industries

(3) Other

Since the period 2001 and 2002, as shown in Table 4.3.1-2, the Department of Energy ("DOE") implemented rural electrification pilot projects through small-scale bio-fuel power plants using coconut oil in the period from 2000 to 2001. However these power plants are currently not operating due to technical and operational problems.

Table 4.3.1-2 Bio-fuel Generation Pilot Projects by DOE

Name of Project	Lomaloma Copra Biofuel Project	Welagi Copra Biofuel Project
Location	Sawana, Vanua Balave	Welagi vallage, Tveun
Installed Capacity	90 kVA	45 kVA
Number of Households Electrified by Project	198households	57households
Year of Commission	April 2000	July 2001
Operation after Commission	Due to the oil mill's closuree, the plant began to operate on diesel fuel from 2003.	Due to generator troubles, the plant has not operated since 2004.

(Source: "Biofuels in Fiji" – DOE 17 Nov. 2005)

The Department under the Biofuel Project had implemented seven (7) biofuel mills in the maritime zones including Koro, Rotuma, Cicida, Gau, Rabi and Vanua Balavu, as shown in Table 4.3.1-3. An additional two (2) mills are still under construction at Moala and Matuku in the Lau Group and are expected to be completed early 2015. The renewable diesel is a mixture of 20% Coconut Oil (CNO) and 80% diesel and this will be used to run village diesel generators in these island communities. In addition, plans are also underway to install Dual Fuel Kit (DFK) on the generators to run solely on CNO.

Table 4.3.1-3 Bio-fuel mills Pilot Projects implemented by DOE

Name of Project	Koro	Rotuma	Cicida	Lakeba	Gau	Rabi	Vanua Balavu
Location	Nacamaki	Ahau	Mabula	Nasaqlau	Qarani	Tabiang	Boitaci
Installed Capacity	5,000 ltr/wk	5,000 ltr/wk	5,000 ltr/wk	5,000 ltr/wk	5,000 ltr/wk	5,000 ltr/wk	5,000 ltr/wk
Number of Households Electrified by Project	74	448	195	559	612	456	383
Year of Commission	2010	2011	2011	2013	2013	2013	2013
Operation after Commission	The biofuel mills are supplying the villages with renewable diesel (20% CNO + 80% diesel additive) for electricity generation. In terms of profitability, it is marginal at the moment with plans to improve via marketing of access CNO.						

(Source: DOE)

4.3.2 Planned Biomass Power Generation

(1) Bagasse

FSC is planning to increase its generation capacity by adding new co-generation plants, as shown in Table 4.3.2-1.

Table 4.3.2-1 FSC Renewable Project

Location	FSC Rarawai Mill	FSC Labasa Mill	FSC Rarawai Mill
Generation Capacity	20 MW×2 units	10 MW	5 MW
Fuel used	Bagasse, Woodchips, HFO	Bagasse, Woodchips, HFO	Bagasse, Woodchips
Commissioning Schedule	Testing and Commissioning in October 2015	Commissioning in April 2014	Test and Commissioning in January 2014
Operation Period	Full-year	Full-year	Crushing season (from June to October)
Turbine Type	Condensing Turbine	Condensing Turbine	Back-pressured Turbine
Project Cost	200 million FJD	17.3 million FJD	6.3 million FJD

(Source: "FSC Renewable Project" obtained from FSC in Oct.2013)

The amount of sugar production in Fiji has been declining yearly due to the fact that recently sugarcane planting has been decreasing because of problems related to lease land and/or other issues. In this situation, in order to ensure a more stable energy supply and a higher income from selling electricity, FSC intends to increase the electricity generation of its power plants throughout the year by purchasing and using wood chips from neighboring sawmills in the off-season.

(2) Wood Residue

There are sawmill companies, other than TWI, who are interested in introducing co-generation plants to sell surplus electricity to FEA. Valebasoga Tropikboards Limited, located in Labasa, Vanua Levu, is one such company. Valebasoga Tropikboards Limited's relevant data and intentions are shown below.

- In 1994, it started operation, producing mainly plywood. 50% of its products are sold to the domestic market, and 50% to foreign countries. Valebasoga Tropikboards Limited does its trees logging around 50 km away from its sawmill.
- Its annual average production is 40 m3/day, while the amount of wood residue is 50 to 60 m3/day.
- Although part of the wood residue is combusted in a boiler and is sold as firewood to the

locality at a low price (35 FJD/ truck bed), most of the wood residue is piled up on the premises behind the sawmill.

- The electricity used for the sawmill is purchased from FEA, and costs 40,000 FJD monthly.
- The company has a willingness to introduce a co-generation system in future by obtaining technical and financial support.

		
Sawmill of Valebasoga Tropikboards Ltd.		

4.4 Wind Power Generation

4.4.1 Existing Wind Power Generation

Butoni Wind Farm is the only wind power station in Fiji, completed in 2007. There are 37 wind turbines with a unit capacity of 275 kW along the Butoni ridge line near Sigatoka town to create a 10 MW wind farm anticipated to produce 11.5 GWh of electricity a year.

These turbines were installed 55 meters high, have two blades (32 m diameter) and generate electricity between wind speeds of 4 to 20 m/s. Five km long overhead 33 kV transmission lines were constructed from the substation to the electrical grid, adjacent to the Sigatoka Valley Road. Following a cyclone warning, teams of people are required to operate 20 ton cranes to lower the turbines and towers to the ground. These have been designed to be easily lowered to the ground in response to cyclone warnings and fixed in place until high winds have abated to prevent turbine damage.

The total project cost is 40 million FJD, and the cost per unit is about 1 million FJD.

The information on operation of the power station obtained from the operators working for this power station is shown below:

- Energy output is around 800 MWh/month. Capacity utilization in the dry season is higher than that in rainy season.
- Operational data for each wind turbine is transmitted to the control room through SCADA (fiber-optic), and data related to generation is automatically transmitted to FEA's National Control Center.
- When wind velocity is 18 m/s or more, the power generation automatically stops.
- This wind farm is operated and maintained by 6 members of FEA stuff (3 parties of 2 people).



Butoni Wind Farm

4.4.2 Planned Wind Power Generation

As previously mentioned in Sub-section 3.10.1, the data for evaluating wind power potentials in Fiji is still insufficient, and it is necessary to wait for the results of the wind power observations which are planned by DOE. In this current situation, there are no specific plans for any future wind power projects other than the existing Butoni Wind Farm.

4.5 Geothermal Power Generation

4.5.1 Existing Geothermal Power Plant

At present, there are no geothermal power plants in Fiji, although it is said that there are 55 natural hot springs sites throughout Fiji. One of main reasons why no geothermal power plants have materialized so far is that the geothermal potential at every site has been found to be too small in scale.

4.5.2 Geothermal Potential Sites

The JICA Project Team performed field reconnaissance at both Savusavu and Waiqele springs in Vanua Levu which are noted in the role of geothermal resources by Ministry of Economy, Trade and Industry of Japan ("METI") in 2009 from the view point of developing a geothermal power plant. It is expected that both Savusavu and Waiqele sites would have a capacity of 8 MW for electric power generation.

The results of the reconnaissance at these two sites are as follows:

(1) Savusavu Site

Two spring sites have been ascertained – the inshore Savu-1, and Savu-2, which 200m further island than Savu-1. Hot springs are gushing out in an area of 20m diameter at the left bank of the Nakama stream in Savu-2. The water is clear and there is no hydrogen sulfide but it is salty.

Soft coral reef limestone is exposed to Savu-1. The hot spring sprang out from a broad cavity, but it was not possible to confirm the gush point. Boiling water flows into the sea while slightly eroding the surface of the bedrock. The flow rate is estimated around 40 l /min by eye measurement.

Several boiling springs are exposed on the riverside of the Savu-2 site, and two of them are used for cooking by the local residents (please refer to Photo-2 below). Some traces of gushing also are scattered about there, however, it is expected they may come flooding back in a high-water season. These springs are estimated in totally to bubble at 60 l/min on the gravel bed.

Photo-1 Whole View of the Savusavu Site

Photo-2 Close-up View of the Savu-2 Site

(2) Waiqele Site

The JICA Project Team visited two locations (Nakama-1 and 2) along the Waileve stream in Waiqele district which is about 6 km SSW of Labasa (see Photo-3). The spring of Nakama-1 where the springing rate is estimated at about 60 l/min swells up from the bottom of a small stream flowing down through the farm. Furthermore, some fumarolic gas floats about the river, which is about 50m from the aforementioned spring. The water is clean and a slight sulfur smell floats around. A small amount of travertine covers the surface of some river bed pebbles.

The Nakama-2 site is located at the side of a Hindu temple. Since the water is collected in the well shown in Photo-4(below), the exact flow rate of the hot spring is impossible to identify, but the overflow rate is roughly estimated at about 40 l/min.

Photo-3 Whole View of the Waiqele Site

Photo-4 Close-up View of the Nakama-2 Site

4.6 Overview of Environmental and Social Considerations

4.6.1 Current Status and Issues of Environmental and Social Considerations

Prior to 2005, there was no legislation concerning Social Environmental Consideration in Fiji. The main environmental law in Fiji is the Environmental Management Act 2005 ("EMA 2005"). The Department of Environment is under the jurisdiction of the EMA 2005. The Act defines the legal framework of environmental impact assessment, comprehensive natural resource management and waste management & pollution control.

Also the Environment Management (EIA Process) Regulations 2007 and the Environment Management (Waste Disposal & Recycling) Regulations 2007 were promulgated as regulations concerning the EMA 2005 in January 2008.

4.6.2 EIA Process of Development Projects

After the proposal of the development project is submitted, the process of approval right up to the determination of the EIA from screening is shown in Figure 4.6.2-1 ("EIA PROCESS"). There is no concept of Initial Environmental Examination (IEE) in the law of Fiji or the EMA 2005; only the term Environmental Impact Assessment ("EIA") is used.

First, the development project proposal is submitted to the EIA approval agency. So it receives a screening of whether or not it is necessary to carry out an EIA. During screening by the 2008 EIA guidelines, each development project is classified as category 1 to 3 by projects that may require an assessment:

- Category 1: An EIA is required. It must be approved by the (Environmental Director Normal) EIA Administrator.
- Category 2: An EIA is required. Must be approved by the responsible approving authority (refer to the relevant government agencies and project implementation agency usually).
- Category 3: As long as it is not requested by the EIA Administrator, no EIA is required. However, this category is limited to emergency assistance or very small construction projects.

A hydroelectric project is clearly a project of category 1. Regardless of the size of the power plant, an EIA is required for all projects. The approval of the EIA is necessary according to the EIA Administrator.

Then the scope of the EIA is determined at the scoping stage. Information that is gathered through formal/informal meetings with relevant organizations and other residents affected directly/indirectly by the project is described from the scoping stage onwards.

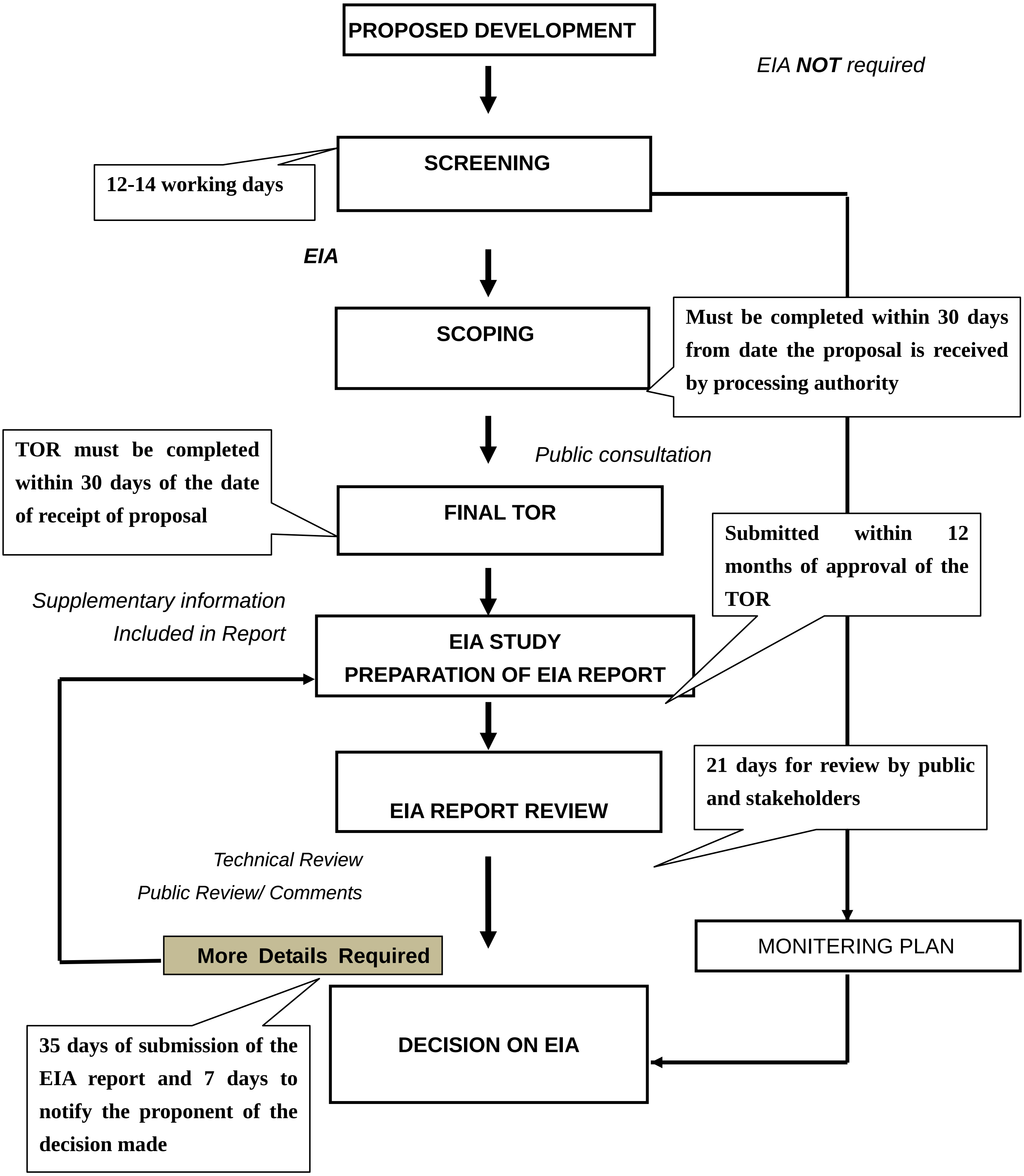
In accordance with the results of the scoping stage, I created the work flow of the EIA draft. Before work starts on-site, the Terms of Reference ("TOR") for the Environmental Survey have to be approved by the Environment Agency. Thereafter, the EIA is carried out with the following TOR. Given the scale projects and content, TOR is determined according to each case. The EIA guidelines are shown in Table 4.6.2-1 standard items of EIA.

After the EIA report is created and submitted, third party reviews and public comments or an EIA committee is carried out. Then the Department of Environment ("DoEnv") determines finally whether the EIA will be either approved (including conditions of the case to approval) or denied. At this stage, if further detailed examination is need, the study of implementation will be requested. Also within 21 days after the decision development operators can also objection to the Environment Agency.

According to the EMA 2005, development project operators must make an Environmental Monitoring Plan and implement it, and such monitoring plans should include all components of a standard EIA. It is decided that the EIA approval agency conducts the confirmation of compliance with this.

Table 4.6.2-1 Components of the EIA, Responsibilities

I. Executive Summary
II. Project Description
III. Introduction
1.0 Description of Existing Environment
1.1 Physical Environment
1.2 Biological Environment
1.3 Socio-cultural Environment
2.0 Potential Significant Environmental Impacts
2.1 Design and Engineering
2.2 Operation and Maintenance
2.3 Construction
2.4 Ecological Impacts
2.5 Vulnerability of the Project to Natural Disasters
2.6 Carrying capacity
3.0 Social Studies
4.0 Mitigation and Abatement Measures
5.0 Summary & Conclusion
6.0 Environment Management/Monitoring Plan (EMP)
7.0 References
8.0 Appendices



Source: Appeal EIA Guidelines prepared by the Department of Environment of Fiji

Figure 4.6.2-1 EIA PROCESS

4.6.3 Related Laws and Regulations

Below Table 4.6.3-1 shows corresponding important acts for consideration of Social Environmental by development projects. These become an appropriate reference, if applicable to the project content. Also, additional research is required to take necessary measures depending on circumstances, if there are historical heritages and endangered species protected by law at project sites, in accordance with related laws and regulations.

Table 4.6.3-1 Important Corresponding Acts for Social Environment Consideration by Development Projects

Laws and regulations	Important referenced matters
Rivers and Streams Act, Cap136, 1985	It has been determined that there is a vested ownership in the nation; the river set the easement of five meters width of the river bank. The land department considers the application for tenancy and repair of the riverbed.
Subdivision of Land Act, Cap140	This law, which is applied to the land of the district by the Minister (Ministry of Strategic Planning, National Development and Statistics), was published in the Official Gazette. This subject of this law is the land readjustment of the boundaries of the city and normal urbanization outside the region.
Native Land Act, Cap133, 1978 Native Land Trust Act, Cap134, 1985	The Native Land Act determines the nature of Native Land whereas the Native Land Trust Act institutes the iTaukei Land Trust Board (TLTB) as the administrator of native land on behalf of the landowners. All the project components, other than those in the river are situated on native land.
National Trust Act 1970 & Amendment Act 1998	This governs the registration and protection of local national heritage.
State Acquisition of Land Act, Cap135	This governs land expropriation and land compensation by the state for the public benefit.
Forestry Act	This governs the protection of forest and nature reserves in the places specified.
Preservation of Objects of Archaeological and Paleontological Interest Act, Cap 264,1940	This describes designated historic heritages on a national level. If structures of historical value are found by investigation of the Fiji Museum, it will take measures for the adoption in accordance with the law, to preserve such sites.
Endangered and Protected Species Act, 2002	This defines the protected species that are considered as important in the Washington Convention (CEITES) or Fiji. It also covers endangered species of domestic and foreign trade, ownership, and transportation limitations.

4.6.4 Natural Environment (National Protected Areas)

According to the Endangered and Protected Species Act 2002, the Fiji Islands CITES2 Management Authority and Fiji Islands CITES Council shall conduct a survey of habitat and management of import and export for the flora and fauna of the following.

- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) : Flora and fauna that are described in Annex I - III
- Although not described in CITES, other flora and fauna that are described in the Act which are considered important in Fiji

In addition, Fiji has signed another international treaty; the Convention on Biological Diversity, the Convention on the Protection of Natural Resources and the Environment of the South Pacific (Noumea Convention and The Ramsar Convention).

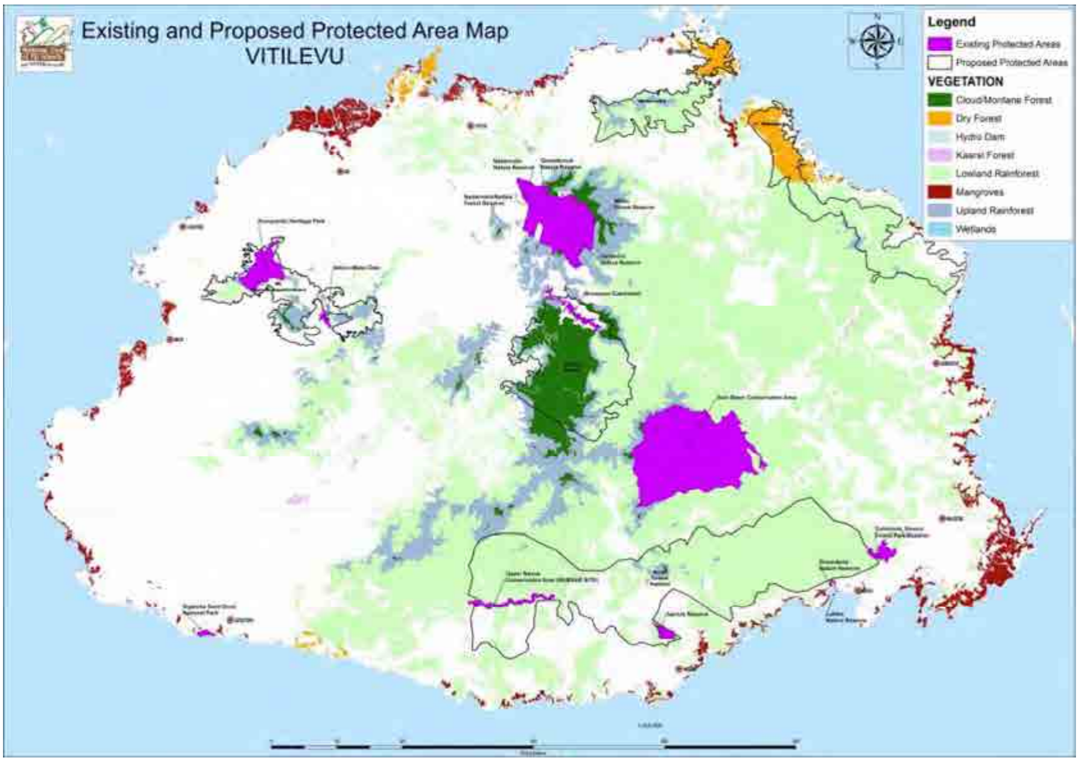
In Fiji there are 23 National Environmental Protected Areas that are state-environmental-protection -districts as stipulated under the Forestry Act and the National Trust Act. The total area for these has reached approximately 427 km^2, which corresponds to about 2.3% area of the country (18,333 km^2).

The Upper Navua Conservation Area (615ha) is one of international treaties in the protected areas that have registered in the Ramsar Convention. In Fiji there are no UNESCO world heritage sites. However there are four locations that have been nominated for the candidate list in 1999 - these are Levuka (township and island) in Obalau; the Sigatoka Sand Dunes; the Sovi Basin; and the Yaduatabа Crested Iguana Sanctuary.

Apart from these, there already exist a number of protected areas and further are a part of a proposal for new sites. The Fiji National Protected Area Committee (“PAC”) was established by the National Environment Council, which is based on section (8) of The EMA 2005. PAC has investigated about expansion of the established range of protected areas, and 16 areas are currently proposed in Vanua Levu and Viti Levu.

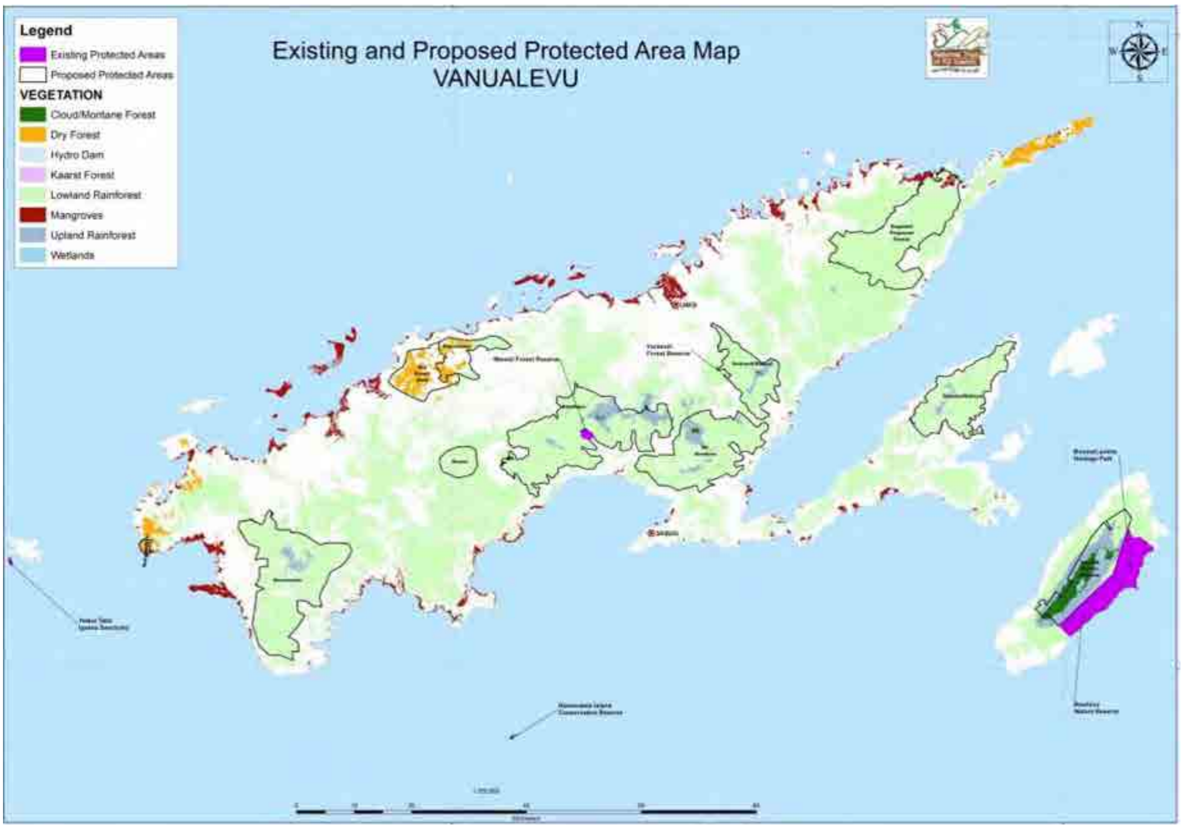
Figure 4.6.4-1 shows the position of the protected areas of the already registered proposed areas in Viti Levu. Figure 4.6.4-2 shows the position of the protected areas of the already registered proposed areas in for Vanua Levu.

Portions which overlaps with the protected areas of the above should also be included these Figures. However important bird habitats as designed by the international organization Birdlife International and the Key Biodiversity Areas (Important Bird Areas: “IBA”) in Vanua Levu and Viti Levu are shown in Figure 4.6.4-3. The National Biodiversity Strategy and Action Plan (“NBSA”) was established in 2007 which Fiji has listed as a specific implementation plan of biodiversity conservation on the base of the Implementation Framework 2010-2014.



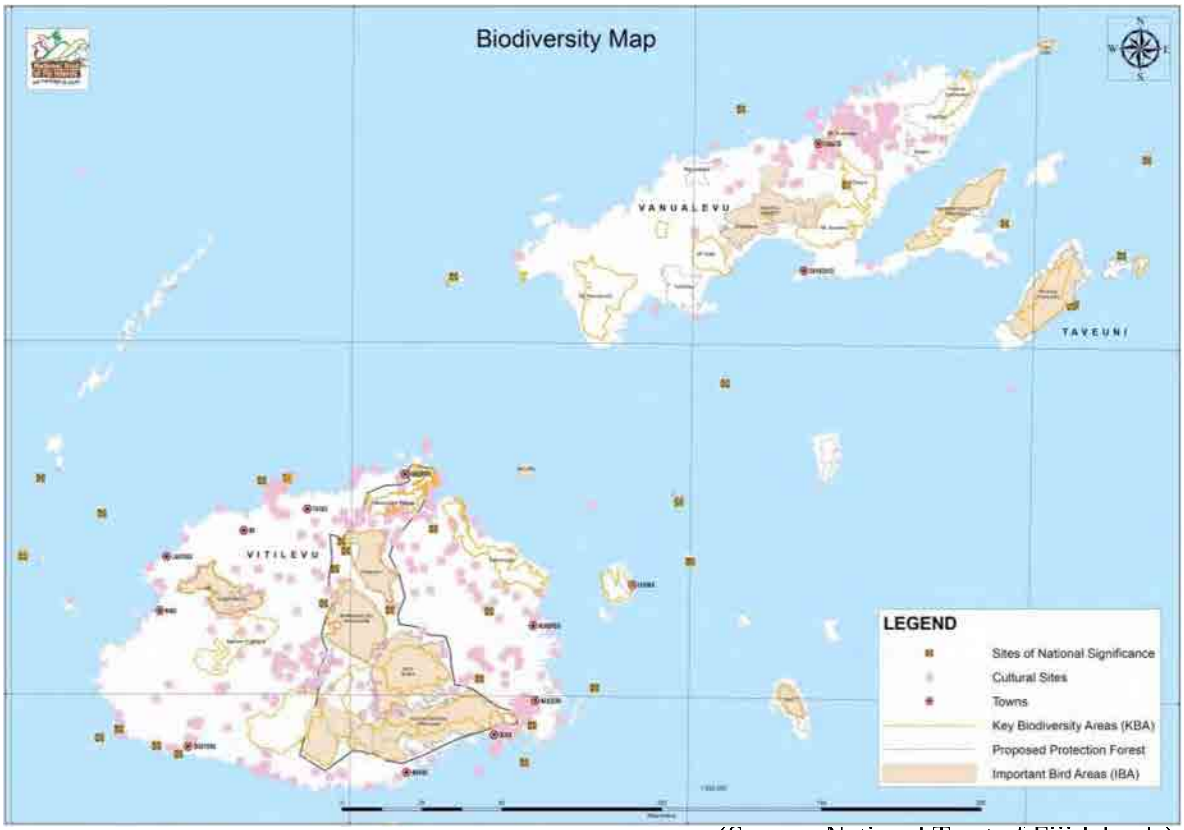
(Source: National Trust of Fiji Islands)

Figure 4.6.4-1 Viti Levu Protected Area Map



(Source: National Trust of Fiji Islands)

Figure 4.6.4-2 Vanua Levu Protected Map



(Source: National Trust of Fiji Islands)

Figure 4.6.4-3 Biodiversity Map

4.6.5 Social Environment (Culturally Important Sites, Land Ownership, Villager)

(1) Culturally Important Sites

Under the Preservation of Objects of Archaeological and Paleontological Interest Act, Fiji's historical heritage is defined. According to the Fiji Museum database, there are a number of sites of cultural or archaeological importance to the Mataquali located within the catchment areas under this Act..

(2) Land Ownership

1) Fijian Laws and Regulations

Fiji has three distinct classes of land, - native land, leased land and freehold land. The rights for compensation vary according to the category of landholding. Native land comprises some 87% of the total land area of Fiji and belongs to native Fijians. An additional 8 % is freehold land and 5% is owned by the State.

2) Native Land

Native land is held under traditional principles and is protected by the Native Lands Act of 1905. All native land has been mapped and records are held by the Native Lands Commission ("NLC").

Native land is inalienable and is collectively owned by the Mataqali, which are clans whose membership is based on patrilineal descent. Native land involves two categories, with some 38%

being Native Reserve Land which has been set aside to meet the subsistence and development needs for present and future generations of native Fijians. Non-reserve land is not subject to such restriction and may be leased to qualifying individuals.

Although technically native reserve lands are solely for Mataqali use and not available for official leasing, there are instances where native reserve land has been leased. This is largely undertaken where land is required for national development purposes and requires that the land is “de-reserved” with the NLC. It is then subject to the laws and regulations governing native land leases.

3) Process of Land Leasing / Acquisition and Compensation

A. Native Land

Background Information:

In Fiji, native land cannot be sold, only leased (Native Lands Act of 1905). All dealings concerning the leasing of native land have to be undertaken with the iTaukei Land Trust Board (TLTB). This is a statutory body set up in 1940 to protect native land interests through acting on behalf of native Fijians in lease transactions.

The types of leases available in the TLTB System are tabulated in Table 4.6.5-1.

Table 4.6.5-1 Types of Leases available in the TLTB System[1]

A) Agricultural Leases
B) Commercial Leases
C) Industrial Leases
D) Residential Leases
E) Other Leases (category for hydropower projects as in this case) This category is divided into the following sub-categories: a) Educational – this provides for school leases, libraries and related leases; **b) Government / Local Government – embodies leases for the provision of public utilities, water catchments, inter alia;** c) Recreational – includes leases for camping sites, playgrounds and other recreational spaces; d) Religious – encompasses leases for churches, mosques and temples; and e) Other – cable way leaves, pipeline way leaves, tramways, and easements are included here. **Duration:** The NLTA governs such leases, hence, a lease may have a term not exceeding ninety-nine (99) years
F) Concessive and Licenses (e.g. Forest Logging Licenses, Gravel/Sand/Soil Extra Licenses)

[1]Compare official website of the iTaukei Land Trust Board: http://www.tltb.com.fj/

The leasing process of native land is illustrated in Figure 4.6.5-1.

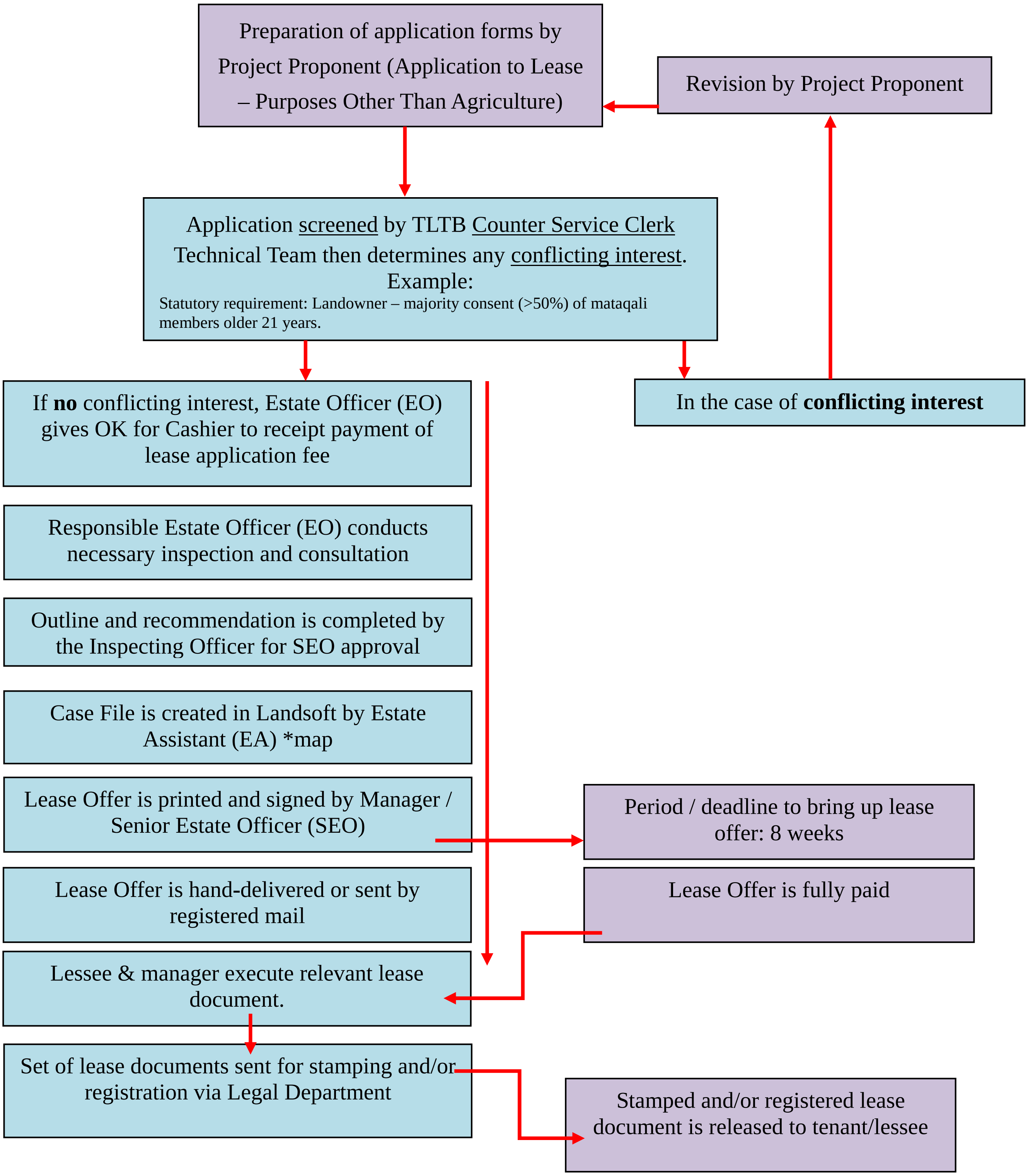


Figure 4.6.5-1 Leasing Process of Native Land (Lease Application Procedure)

B. Non-Native Land

Acquisition of land by the State or any of its agencies is subject to the State Acquisitions of Land Act (SALA) of 8th November 1940, which stipulates that such acquisition must recognize the full value of the land as determined by the courts. The acquiring agency shall pay compensation which takes into account:

1. the market value of the land at the date of the notice of intention to take such land
2. the damage sustained by the person interested (taking of any standing crops or trees of relevant area)
3. the damage, if any, sustained by the person interested, at the time of taking possession of the land, by reason of severing such land from his other land
4. the damage, if any sustained by the person interested, at the time of taking possession of the land, by reason of the acquisition injuriously affecting his other property, real or personal, in any other manner, or his earnings
5. if, in consequence of the acquisition of the land, the person interested is compelled to change his residence or place of business, the reasonable expenses, if any, incidental to such change

Compensation for land is paid at market values effective from the date at which notice of the State's intention to acquire the land is given. Structures are, however, compensated only at book/depreciated values. Compensation also covers crops and trees, damage to portions of land not acquired (if any), changes in use and restrictions on use of any acquired portions – and any reasonable expenses associated with necessary changes of residence or places of business.

(3) Villagers and Livelihood

The majority of the villagers are farmers that cultivate gardens in their land holdings or with agreement those of the other Mataqali. Land is not intensively farmed, however there are garden areas, where crops are grown for subsistence needs and to be sold for cash in nearby towns. Cassava (tavioka), yaqona, plantains (vudi), taro (dalo), yams (uvi), tomatoes, cabbage and cucumber are grown. Houses in all villages are generally made from permanent materials (tin, concrete block) or timber and usually contain a single living room occasionally with bedrooms, and an outside kitchen and toilets. All houses are traditional bures (traditional Fijian house), built using a mixture of wood, bamboo, thatched roofs and stone foundations.

4.6.6 EIA Examples of Hydropower Project

There are two hydropower projects in the EIA in Fiji, the Nadarivatu project in 2008 of Viti Levu and the Somosomo projects of Taveuni in 2009. There are no resettlement issues within the scope of both projects, which would have a significant impact on the social environment. All relevant aspects of the natural and social environment with regard to both the construction and operation through to the implementation of the hydropower project are covered within these investigations.

Through construction, as shown in Table 4.6.6-1 below, because of the potential impact on the vegetation and surrounding residents, including noise, vibration, turbid water, dust, exhaust gas and waste, changes had to be made with regard to the traffic volume. Most of the plants and animals around the project area are endemic species; these also include flora and fauna that are vulnerable species of the IUCN. The bat is classified as a sensitive rare species. This EIA report proposes that impacts can be reduced by mitigation measures.

In the Somosomo hydropower project, since it is located in the water source of downstream residents, there was a particular concern regarding the water use and public health of residents. On the other hand, the Nadarivatu hydropower project site is very near to No.8th project (Upper Ba River), which is an important reference for considering the natural and social environment of this study.

Since the diesel generator and the first scheme is designed for the comparison of alternatives in 2004, design changes have occurred twice to the Nadarivatu in 2006 and 2007. The reservoir area of the initial adjustment land was planned with an output of 54 kw by 38ha. With regard to this initial draft, it was pointed out there was a possibility of significant impact on the habitat of bats and two vulnerable IUCN bird species. By ultimately limiting the reservoir area to 9ha, and 42 kW reduced output, it was possible to avoid affecting the vulnerable IUCN species. Finally, the EIA concluded that through the implementation of these mitigation measures, all problems, except for that of downstream fish, were reduced.

Table 4.6.6-1 Changes of the EIA in Nadarivatu Hydroelectric Project

Year	Remarks
2004	The start of the scheme design: Comparison with alternatives of diesel power generation
2006	1st design change: output 54 kw reservoir area: 38 ha
（Pointed out the possibility of vulnerable species loss）	（IUCN vulnerable two birds species and bat）
2007	2nd design change: output 42 kw reservoir area: 9 ha
2008	The final EIA conclusion: pointed out only a reduction in the number of downstream fish

(Source: JICA. The Detailed Planning Survey for the maximum and effective use of renewable energies in electricity power supply in Fiji. 2012)

4.7 Comparison on Present Renewable Energy Promotion Incentives between Fiji and Other Countries

4.7.1 Present Renewable Energy Promotion Incentives in Fiji

(1) Policy targets

Policy targets for the increased development of renewable energy technologies have been identified in 144 countries (Source: Renewables 2014 Global status report) as of early 2014.

Renewable energy targets take many forms. A common target is an increase in the renewable shares of primary and final energy or share of electricity generation. Targets most often focus on a specific future year, but some are set for a range of years or with no year reported.

In case of Fiji, there are two targets as follows:

- Share of final energy from renewables : 23 % by 2030
- Share of electricity generation from renewables: 100% by 2030 (67% as of 2012)

(2) Tax incentives for renewable energy development

In the case of Fiji, there are two tax incentives for renewable energy development as follows:

- Five years tax incentive (only VAT paid) for imported renewable energy equipment including solar, hydro, biomass, bio gas, wind, solar water heaters, solar water pumps, and geothermal.
- Five year tax holiday is available to a taxpayer undertaking a new activity in renewable energy.

(3) IPP tariff scheme

Fiji's energy situation depends on imported fuels. Due to a rising fuel price, CO_2 reduction, and the production of domestic energy, action is required through renewable energy to reduce the reliance on imported fossil fuels. Thus Fiji's government is providing incentives to Independent Power Producers (IPP) who are planning to develop power projects by using renewable energy in order to sell their electricity to FEA.

One of incentives is a minimum guaranteed system of a buying rate of electricity for IPP. This scheme started from 2010. At first, the IPP rate was a fixed price of 0.23 FJD / kWh from June 2010. It was determined by the average tariff rate and TDR (Transmission Distribution Retail). The calculation formula is as follows;

The IPP rate / kWh = average tariff (0.33 FJD) – TDR (0.10 FJD)

In November 2010, a minimum guaranteed system was launched since FEA offered higher tariff rates to investors to enter into generation by renewable energy. Moreover the average tariff rate was increased from 0.33 FJD to 0.39 FJD and TDR was increased from 0.10 FJD to 0.13 FJD. However, 0.27 FJD/ kWh was approved as the minimum IPP rate since the cost structure for IPPs are different in different parts of Fiji. A higher tariff rate attracts investors in high cost regions such as Vanua Levu or the outer islands.

Furthermore the formula was revised in May 2014 because of expansion of the use of renewable energy and reduction of the use of fossil fuel. The revised IPP rate is based on the unit cost of fossil fuel power (approximately 0.48 FJD), TDR (0.13 FJD) and the FEA profit (0.02 FJD). The revised IPP rate is 0.3308 FJD / kWh. Table 4.7.1-1 shows IPP rate and Electricity Tariff (Residential) in Fiji. IPP rates is roughly equivalent to electricity tariff (>75 kWh) for residential.

Table 4.7.1-1 IPP rate and Electricity Tariff (Residential) in Fiji

Item / Country	**IPP rates (Minimum)**	**Electricity Tariff (Residential) / kWh (As of 2014)**
Fiji	0.3308 FJD (0.167 USD)	<75 kWh : 0.172 FJD (0.087 USD) >75 kWh : 0.331 FJD (0.167 USD)

1 USD = 1.98 FJD

4.7.2 Present Renewable Energy Promotion Incentives in Other Countries

(1) Policy Targets in Other Countries

Almost all countries have some policy targets for expanding renewable energy. For example, Table 4.7.2-1 shows the share of electricity generation from renewables in Other Countries. Targets often focus on a specific future year.

Table 4.7.2-1 Share of electricity generation from renewables in Other Countries

Item / Country	**Share (As of 2012)**	**Target**
Germany	21%	40-45% by 2020
Spain	30%	38.1% by 2020
Italy	31%	26% by 2020
France	16%	27% by 2020
Japan	13%	Non Target

(Source: RENEWABLES 2013 GLOBAL STATUS REPORT)

(2) Renewable Energy Support Policies in Other Countries

Some countries have their own renewable energy support policies. Table 4.7.2-2 shows renewable energy support policies in other countries.

Table 4.7.2-2 Renewable energy support policies in other countries

Incentives	Summery	Other Countries
Renewable Portfolio Standard (RPS)	RPS is a legislation that sets a minimum percentage of electricity generated by renewable energies in terms of electricity sold, and presents target achievement options such as figure trade among electric utilities.	JAPAN (from 2002 to 2012) United Kingdom
Feed-in tariff (FIT) / Feed-in premium (FIP) payment	FIT obliges electric utilities to purchase electricity generated from renewable energy sources based on a fixed-period contract with fixed price. FIP means that the renewable energy producer sells electricity at market prices with fixed premiums.	Germany(FIT) JAPAN(FIT) France(FIT) Netherlands(FIT/FIP)
Capital subsidy or rebate	One-time payment by the government to cover a percentage or all of the capital cost for renewable energy development.	Denmark JAPAN Spain United States
Tax incentives	Includes all tax incentives such as investment tax credits, production tax credits, and reductions in taxes on sales, energy, carbon, excise, value added (VAT), etc.	Denmark United Kingdom United States

(3) FIT in Other Countries

This section covers FIT situation in other countries. FIT remains the most widely adopted renewable power generation policy employed at the national and state/provincial levels. As of early 2013, 71 countries and 28 states/provinces had adopted some form of FIT policy. For renewable power producers, FIT rates are guaranteed by law during fixed-term period. FIT rates are periodically reconsidered in accordance with the construction cost and growth of renewable energy. Following this FIT rates are systematically decreased. However revised FIT rates do not affect FIT contractors that have already contracted with old FIT rates.

- FIT Target in Other Countries

  Table 4.7.2-3 shows FIT target in other countries. FIT targets in each country contain solar PV, wind power, biomass and hydropower. The target depends on the capacity of each power station.

  Spain abolished FITs in 2013 since the Power Companies deficits were increased by rejecting an amendment of the electricity bill in spite of high FIT rates. As an alternative to FIT, a new system for initial investment and operation cost is being developed.

Table 4.7.2-3 FIT Target in Other Countries (As of 2012)

Method / Country	Solar PV	Wind power	Biomass	Geo thermal	Hydro power	Note
Germany since 1990	✔	✔	✔	✔	✔	Hydro: Under 5,000 kW or renovation under 150,000 kW Biomass: Under 20,000 kW
Spain from 1994 to 2013	✔	✔	✔	✔	✔	Solar: Under 20 kW(roof) 20-2,000 kW(ground mounted) Hydro: Under 10,000 kW ☆FIT abolishment in 2013
Italy since 1992	✔	✔	✔	✔	✔	Wind power: Under 200 kW Hydro, Geothermal, Biomass: Under 1,000 kW
France since 2001	✔	✔	✔	✔	✔	All methods : Under 12,000 kW
Japan since 2009	✔	✔	✔	✔	✔	Hydro: Under 30,000 kW

➢ Fixed-Term Period and FIT rates

The fixed-term periods and FIT rates are usually determined for each renewable technology in order to take account of their differing generation costs (installation and operation), and to ensure profitability. The fixed-term periods and FIT rates are set by governments. Table 4.7.2-4 shows the relevant fixed-term periods. Almost all of these are between 15 years or 20 years.

Table 4.7.2-4 Fixed-Term Periods (As of 2012)

Method / Country	Solar PV	Wind power	Biomass	Geo thermal	Hydro power	Note
Germany	20 years	20 years	20 years	20 years	20 years	Wind power: Revising after 6th year Hydro(Renovation): 15years
Spain	30 years	20 years	15 years	20 years	25 years	Offshore wind power: 25 years
Italy	20 years	15 Years	15 years	15 years	15 years	Solar thermal: 25 years
France	20 years	15 years On shore	15 years	15 years	20 years	Offshore wind power: 20 years Wind power: Revising after 11th year
Japan	10 &20 years	20 years	20 years	15 years	20 years	Solar PV Under 10 kW: 10 years More than 10 kW: 20 years

Table 4.7.2-5 shows FIT rates for solar PV and the electricity tariffs (Residential).Japan implemented minimum tariffs for solar PV that was amongst the highest in the world as of 2012. FIT rate is lower than electricity tariff in Germany. At the beginning (around 2000) of FIT for solar PV in Germany, the rates were approximately EUR 0.5. Present FIT rates are about a third of the beginning FIT rates.

Table 4.7.2-5 FIT rates for Solar PV and the Electricity Tariffs (Residential)

Item / Country	**FIT rates** (As of 2012)	**Electricity Tariff (Residential) / kWh (As of 2014)**	**Note**
Germany	0.23-0.32 USD (0.18-0.25 EUR)	0.37 USD	FIT rates are revised every month since Apr.2012. Approximately 0.12-0.16 USD in July 2014.
Spain	0.16-0.34 USD (0.12-0.27 EUR)	0.21 USD	New system is under construction.
Italy	0.19-0.34 USD (0.15-0.27 EUR)	0.28 USD	Annual purchase budget is capped. (6.8 billion EUR in 2013)
France	0.15-0.59 USD (0.11-0.46 EUR) (as of 2011)	0.19 USD	An annual installation cap is 1 million kW since 2013.
Japan	0.33-0.41 USD	0.19-0.29 USD	0.29-0.36 USD in 2014

1 EUR = 1.286 USD, 1 USD = 102 JPY

Table 4.7.2-6 shows FIT rates of Other Renewable Energies. Japan implemented FIT rates that were amongst the highest in the world.

Table 4.7.2-6 FIT rates of Other Renewable Energies

Item / Country	**Wind power**	**Biomass**	**Geo thermal**	**Hydropower**
Germany	0.045 – 0.193 USD (0.035-0.15 EUR) (as of 2012)	0.077 – 0.183 USD (0.06-0.143 EUR) (as of 2012)	0.322 USD (0.25 EUR) (as of 2012)	0.081 – 0.163 USD (0.063-0.127 EUR) (As of 2012)
Spain	0.094 -0.105 USD (0.073-0.081 EUR) (as of 2012)	0.09-0.226 USD (0.07-0.176 EUR) (as of 2012)	0.093 -0.099 USD (0.072-0.077 EUR) (as of 2012)	0.10 -0.112 USD (0.078-0.087 EUR) (As of 2012)
Italy	0.386 USD (0.3 EUR) (as of 2012)	0.36 USD (0.28 EUR) (as of 2012)	0.257 USD (0.2 EUR) (as of 2012)	0.283 USD (0.22 EUR) (as of 2012)
France	0.036-0.167 USD (0.028-0.13 EUR) (as of 2008)	0.104-0.257 USD (0.081-0.20 EUR) (as of 2011)	0.167-0.257 USD (0.13-0.20 EUR) (as of 2010)	0.087 - 0.114 USD (0.068-0.089 EUR) (as of 2012)
Japan	0.226-0.566 USD (since 2012)	0.128 - 0.382 USD (since 2012)	0.255 -0.392 USD (since 2012)	0.235-0.333 USD (since 2012)

1 EUR = 1.286 USD, 1 USD = 102 JPY

- Problems on FIT

  There are two problems with FIT. The first is the annual introduction capacity of renewable energy. For example, an annual introduction capacity of solar PV was five times growth (approximately 500 MW to 2,500 MW) in Spain. As a result of the growth, Power Companies' deficits increased by rejecting an amendment of the electricity bill in spite of high FIT rates. As a prevention policy, some countries have an annual installation cap or a cap of annual purchase budget. It is highly important to always reconsider FIT rates.

  The second problem is the fluctuation output of unstable renewables. Unstable renewable energy depends on a weather conditions and the output is a lack of stability. This is a bad influence on the controls of the power system (frequency and output). Therefore it is important to consider the balance between renewable energy and the spinning reserve capacity.

Chapter 5 Hydropower Potential Study

5.1 Overall Hydropower Potential Study

5.1.1 Overall Hydropower Potential Study

Figure 5.1.1-1 shows the work flow of prioritization of the candidate hydropower potential sites.

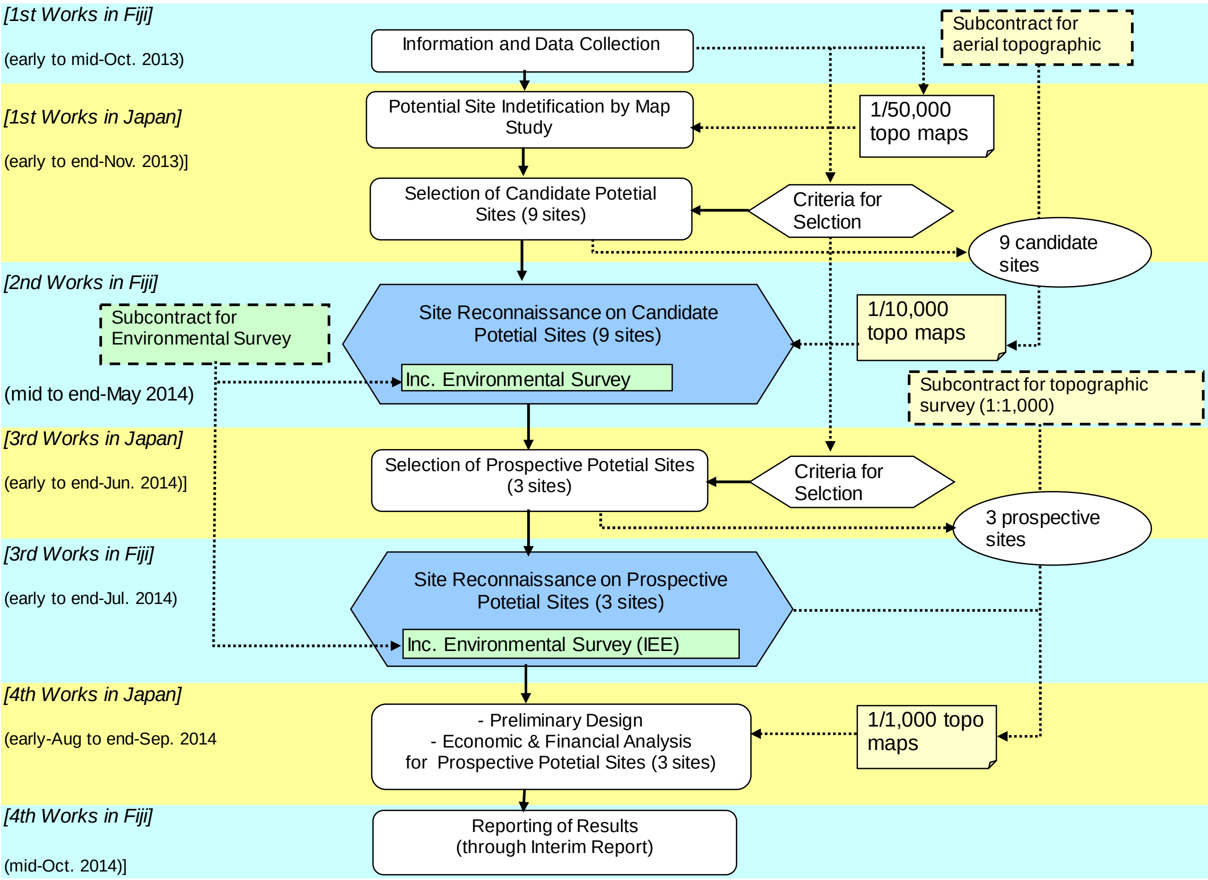


Figure 5.1.1-1 Identification and Prioritization of Hydropower Potential Sites

5.2 Identification of Hydropower Potential Sites

5.2.1 Information and Data Collection

In order to identify and evaluate the hydropower potential sites, the following information and data were collected.

(1) Existing Study Reports on Hydropower Potential in Fiji

Three study reports on hydropower potential sites in Fiji as shown below were available for the team. The reports stipulated fifty three (53) hydropower potential sites in total, which were evaluated with the research firms' own criteria for optimum development scale, choice of the generator type, etc. Since twenty six (26) potential sites of the fifty three (53) overlap with each other in the reports, the remaining twenty seven (27) sites are identified by the JICA Project team.

① Pilot Study for Project Formation for Comprehensive Renewable Energy power Development (2008, JBIC)
② Small Hydro Site Identification in Fiji Concept Studies (2007, Barefoot power Pty. Ltd.)
③ Wailoa Basin Hydropower Development Master Plan Final Report (2007, Hydro-Tasmania)

(2) Meteorological and Hydrological Data

The number of the rain gauging stations and the river flow gauging stations in Viti Levu and their locations are shown in Table 5.2.1-1, Figure 5.2.1-1 Rain Fall Stations in Viti Levu, and Figure 5.2.1-2 respectively.

Table 5.2.1-1 Number of Rainfall and River Flow Gauging Stations in Viti Levu

Area	Rain Gauging Station	River Flow Gauging Station
Northern	13	1
Central／Eastern	27	9
Western	24	26
Total	64	36

(Source: Water Authority of Fiji (WAF))

The data of the rainfall and river flow gauging stations in Viti Levu and Vanua Levu from the Water Authority of Fuji (WAF) and the Fiji Meteorological Service (FMS) was available for the JICA Project team, and also some part of hydrological data from the JICA study report "The Study on Watershed Management and Flood Control for the Four Major Viti Levu Rivers" conducted in 1998 was available for the team.

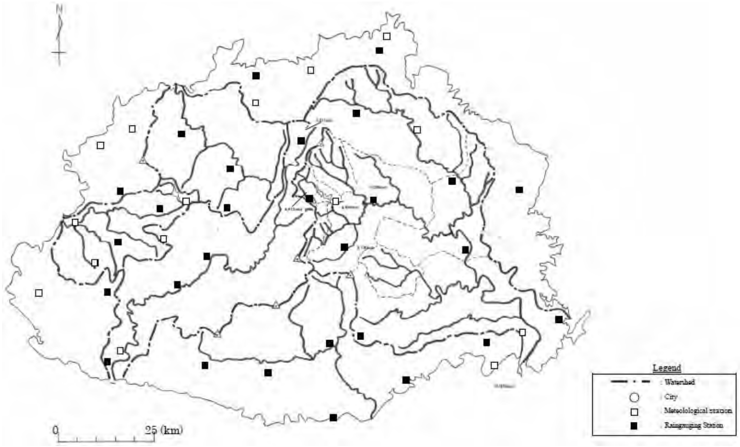


Figure 5.2.1-1 Rain Fall Stations in Viti Levu

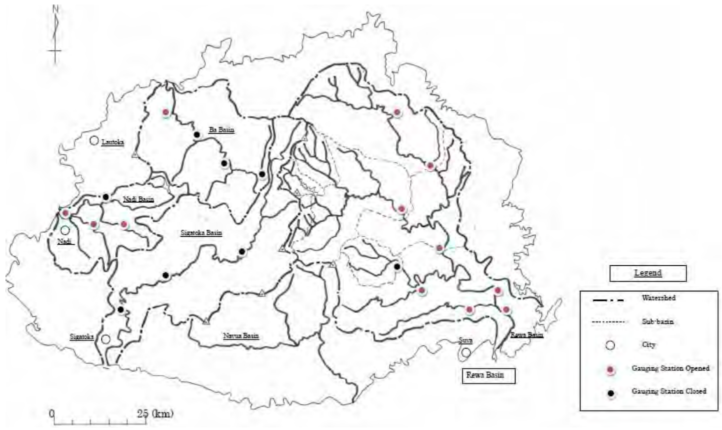
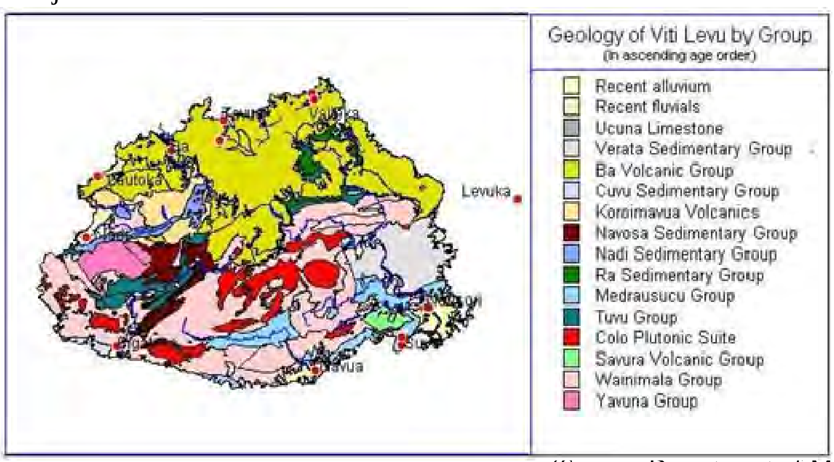


Figure 5.2.1-2 River Flow Gauging Stations in Viti Levu

(3) Geological Data

Figure 5.2.1-3 shows Identification and Prioritization of Hydropower Potential Sites. The geological data including the geological maps published by the Department of Mineral Resources were available for the JICA Project team.

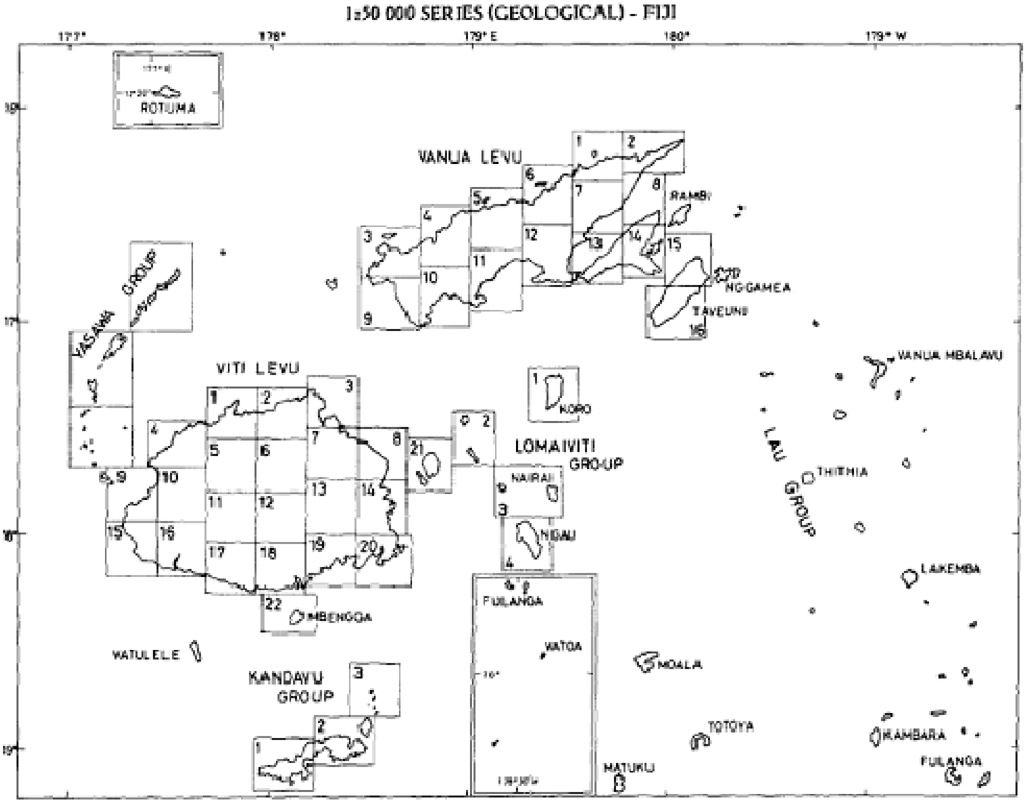


(Source: Department of Mineral Resources, Fiji)

Figure 5.2.1-3 Identification and Prioritization of Hydropower Potential Sites

(4) Topographical Data

In Fiji, the 1:50,000 topographic maps covering the whole country are available. As shown in Figure 5.2.1-4, the whole of Viti Levu is covered by twenty (20) such maps, and Vanua Levu is with thirteen (13).



(Source: EPISODES, vol. 1981, No.3, Fiji)

Figure 5.2.1-4 1:50,000 scale Topographic Maps in Fiji

(5) Data and Information on Environmental and Social Considerations

In order to take into account environmental and social considerations on the potential sites, the information on the Fiji's natural reserves, including the national parks and the protected areas, were obtained from the National Trust of Fiji and were available for the JICA Project team.

5.2.2 Identification of Hydropower Potential Sites

(1) Identification Criteria of Hydropower Potential

The JICA Project Team discussed the following factors with the counterparts and set the criteria for identifying hydropower potential sites, as shown in Table 5.2.2-1.

- Technological and economic conditions
- Topographical and geological conditions
- Natural/social environmental conditions

Table 5.2.2-1 Identification Criteria for Identifying Hydropower Potential Sites

Items	Consideration Points	Criteria
Technological conditions		
- Generation Plan	- Installed capacity (P)	- More than 1,000 kW
- Layout	- Length of waterway (L) - Length / Head (L/H)	- Less than 5,000 m - Less than about 100
Topographical conditions		
- Approachability	- Road and traffic conditions to site	- Good approachability to the site
Natural/Social environmental conditions		
- Natural	- Protected area (e.g. National Parks)	- Avoid important protected area (National Parks, Ramsar sites)
- Social	- Houses to be resettled	- No resettlement of villagers*

*: In consideration of the fact that there have been no resettlements in past hydropower projects in Fiji, hydropower potential sites that required any resettlement were not selected.

(2) Work Flow of Map Study on Identification of Hydropower Potential

Figure 5.2.2-1 shows the work flow of the map study on the identification of the hydropower potential sites.

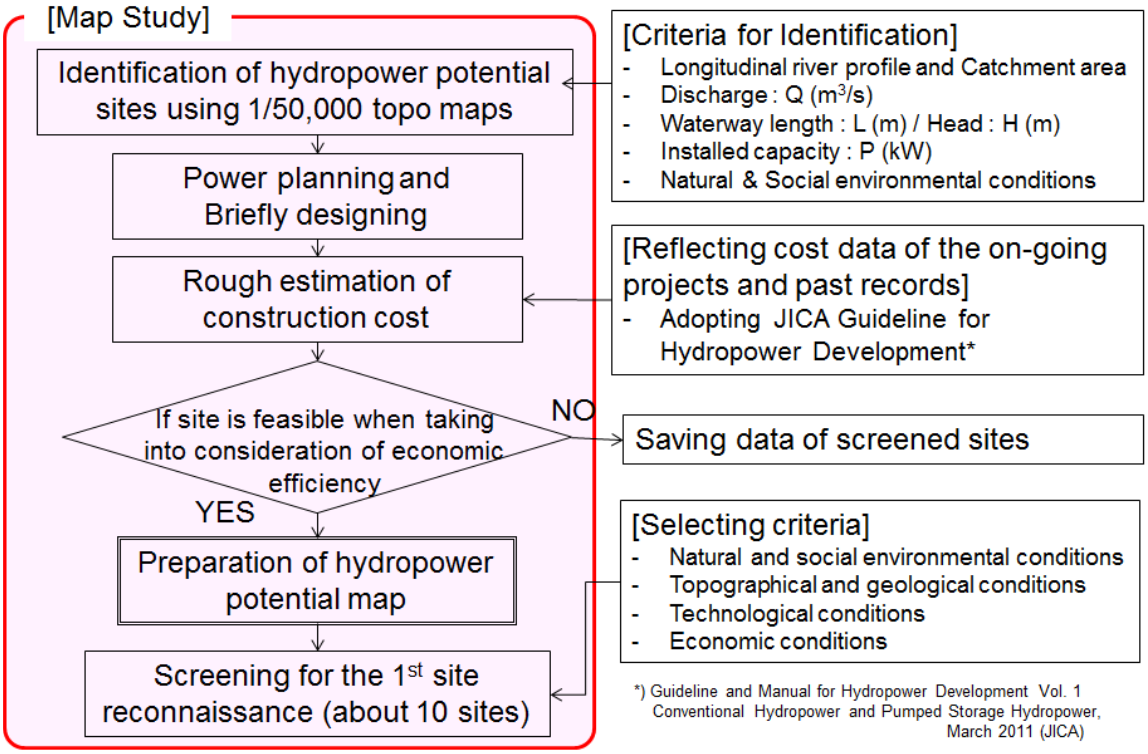


Figure 5.2.2-1 Map Study on the Identification of Hydropower Potential Sites

(3) Hydrological Analysis of Hydropower Potential Sites

The JICA Project team applied the river discharge converted from the measured water level data of the rectified gauging stations to the hydrological analysis of the potential sites. In case of the rectification of the gauging stations, the river discharge is estimated by using the rainfall data provided by FMS.

1) Viti Levu

The rainfall and river flow gauging stations in Viti Levu utilized for hydrological analysis of hydropower potential sites are shown in Figure 5.2.2-2.

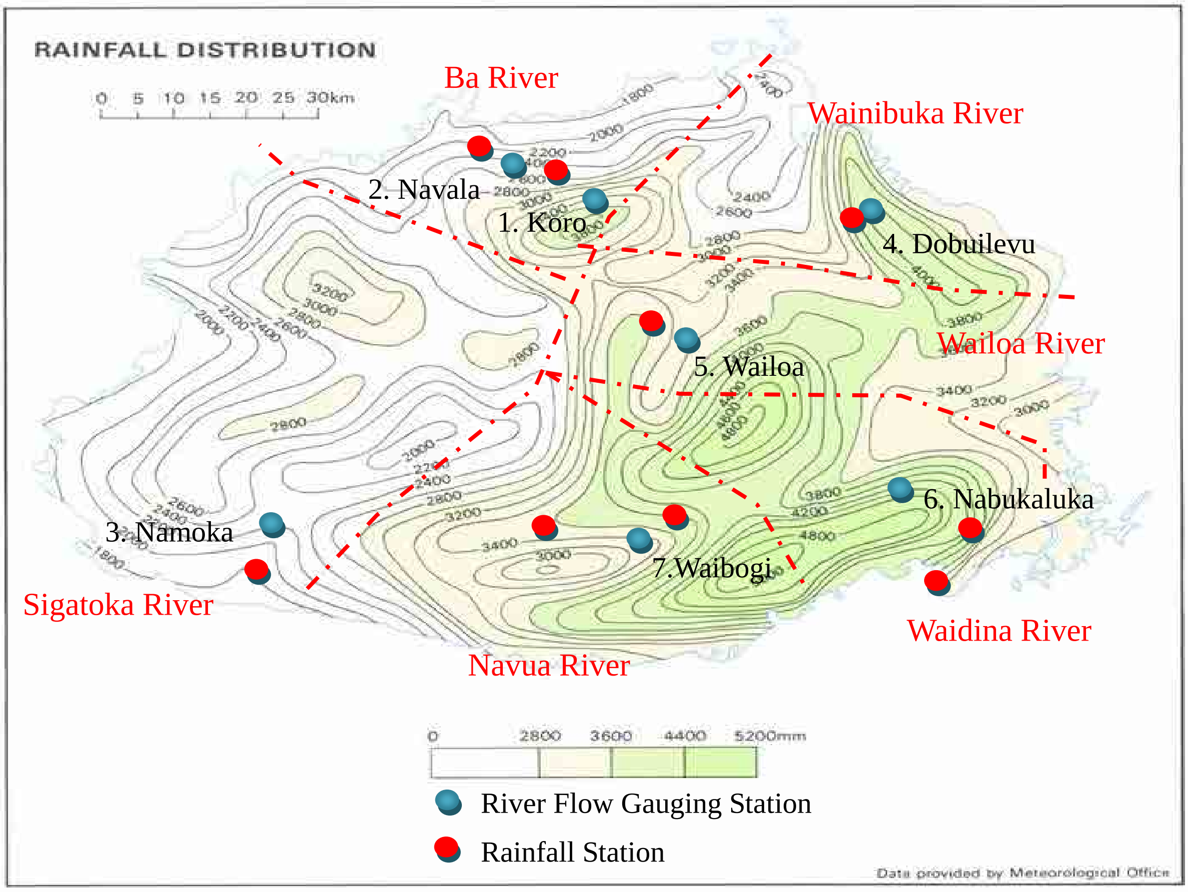


Figure 5.2.2-2 Rainfall and River Flow Gauging Stations in Viti Levu Utilized for Analysis

Regarding the discharge calculated from the existing water level data of the river gauging stations, according to WAF, the relationship between the water levels and the discharges at the gauging stations in Viti Levu have not been reviewed since 1992. Therefore, only river discharge calculated at gauging stations before 1992 was used as reliable river discharge data for the hydrological analysis. The period of the river discharge data utilized for hydrological analysis of hydropower potential sites is shown in Table 5.2.2-2.

Table 5.2.2-2 River Discharge Utilized for Hydrological Analysis

Gauging Station	River	Period of adopting data
1. Koro	Ba	1990
2. Navala	Ba	1983 - 1991
3. Namoka	Sigatoka	1979 - 1983
4. Dobuilevu	Wainibuka	1984 - 1989
5. Wailoa	Wailoa	1980 - 1989
6. Nabukaluka	Waidina	1970 - 1991
7. Waibogi	Navua	1982 - 1990

Based on the above-mentioned river discharge data, the specific flow duration curves of six (6) major rivers were calculated as shown in Figure 5.2.2-3.

In this map study, the maximum plant discharge of 35% probability of river discharge, which is approximately 70% of the river flow utilization factor, was set to calculate the installed capacity and electricity generation as a run-of river type.

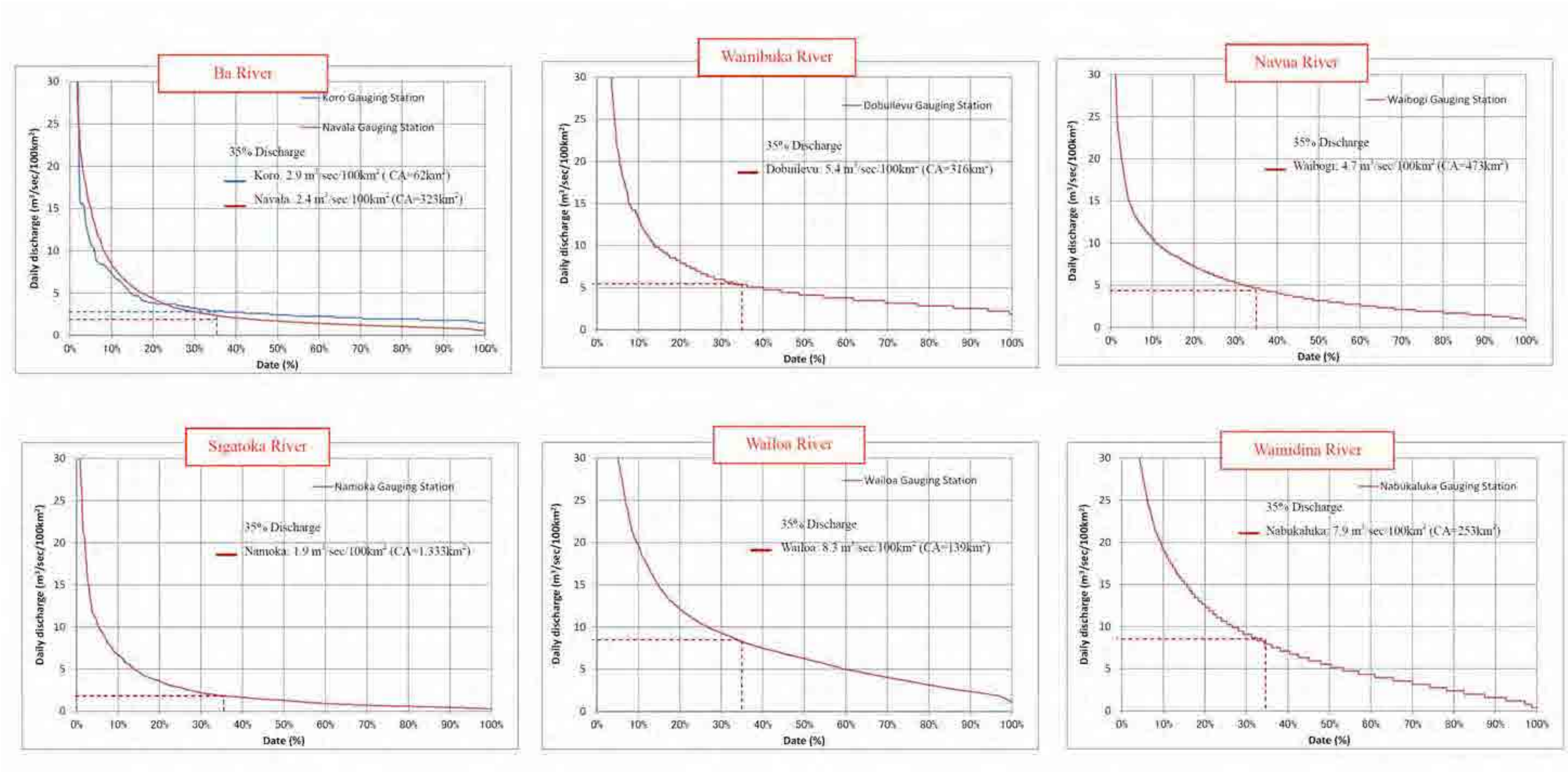


Figure 5.2.2-3 Flow Duration Curves of the Six (6) Main Rivers in Viti Levu

2) Vanua Levu

According to WAF, the correlations between the water levels and the discharges at all the gauging stations in Vanua Levu have not been reviewed. Therefore, the JICA Project team took it upon themselves to estimate the river discharges with the rainfall data provided by FMS.

In fact, the duration curves of the rainfall, the hydrological parameters such as the run-off coefficient and the minimum specific discharge and the catchment areas of Vanua Levu make the duration curves, as follows.

The available rainfall stations in Vanua Levu are shown in Figure 5.2.2-4. The periods of the rainfall data are shown in Table 5.2.2-3.

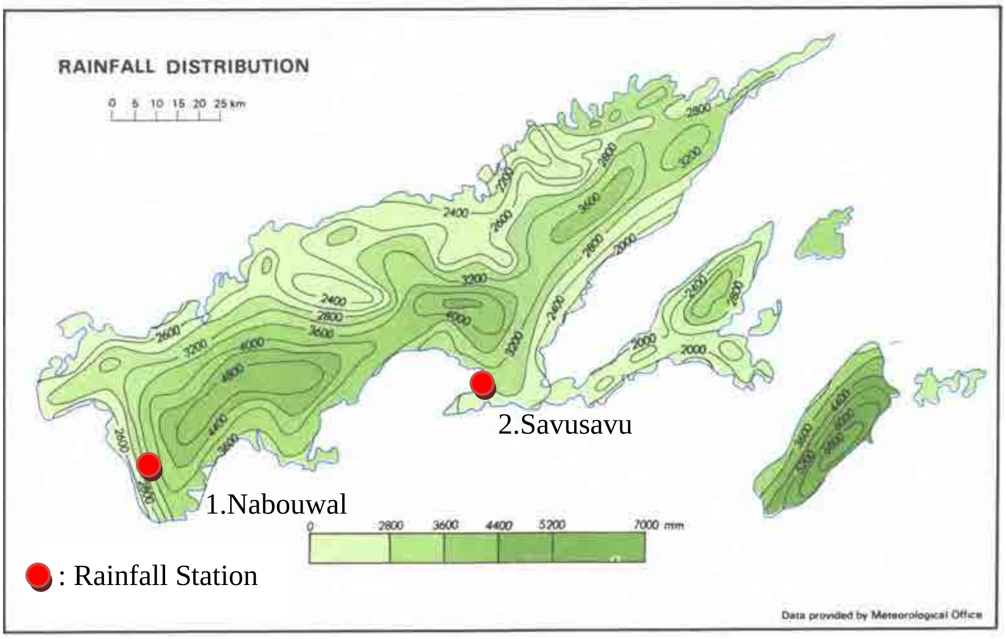


Figure 5.2.2-4 Rainfall Stations Utilized for Analysis in Vanua Levu

Table 5.2.2-3 Rainfall Data Utilized for Hydrological Analysis

Rainfall Station	Adopting potential area	Period of adopting data
1. Nabouwal	West	1980 - 2013
2. Savusavu	East	1980 - 2013

The hydrological parameters, "Run-off Coefficient" and "Minimum Specific Discharge", were set by reference to the result of the hydrological analysis in Viti Levu, because both of the islands, Vanua Levu and Viti Levu, are very close to each other and their respective hydrological conditions are judged to be similar.

a) Run-off coefficient

The JICA Project team judges the parameters of Viti Levu should apply to that of Vanua Levu. The parameters of Viti Levu is as follows:

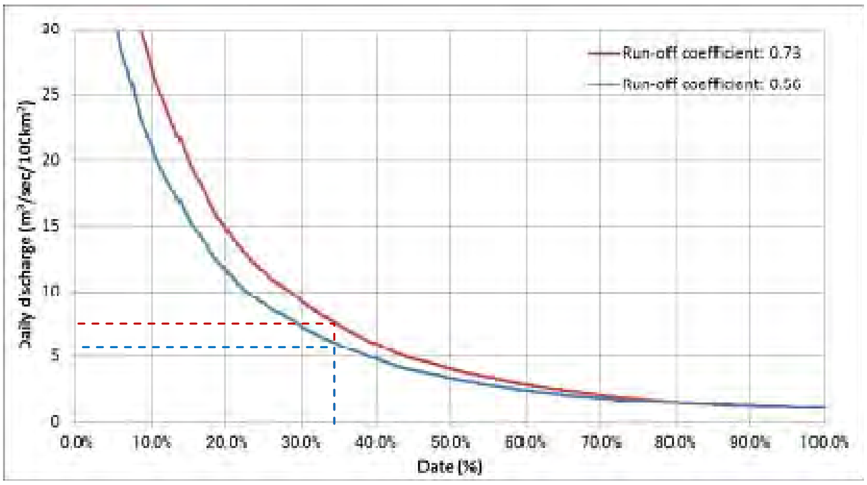
- Annual rainfall less than 3,000 mm - 0.56
- Annual rainfall more than 3,000 mm - 0.73

b) Minimum Specific Discharge of Duration Curve (m 3/ s/ 100 km2)

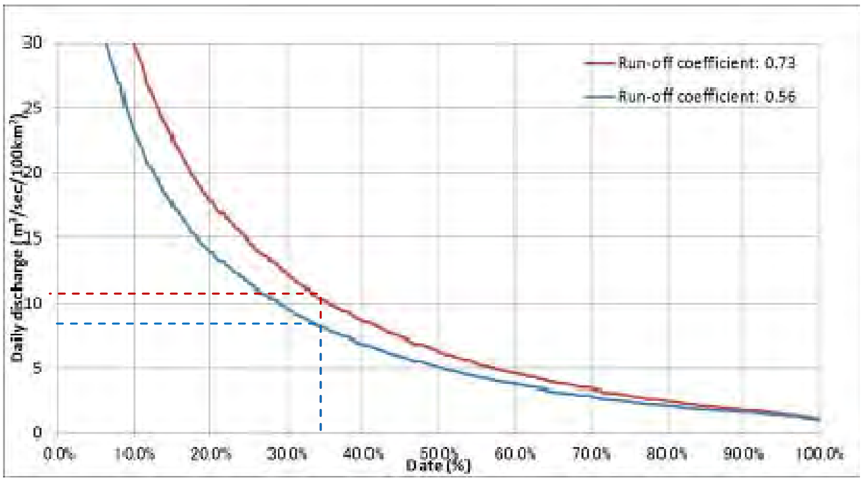
The JICA Project team judged that the minimum discharge of the duration curve of the Waidina River in Viti Levu, 1 m3/ s/100 km2, should apply to that of all the rivers in Vanua Levu, because the annual amount of the rainfall of the Waidina River in Viti Levu is roughly the same as that of Vanua Levu.

In the map study, the maximum plant discharge of 35% probability of the duration curve, which is approximately 70% of the flow utilization factor, was set to estimate the installed capacity and the electricity generation as a run-of river type as well as the case for Viti Levu.

The duration curves of river discharges estimated by the above-mentioned method are shown in Figure 5.2.2-5.



Specific Flow Duration Curve for the Western Area of Vanua Levu



Specific Flow Duration Curve for the Eastern Area of Vanua Levu

Figure 5.2.2-5 Flow Duration Curves in Vanua Levu

(4) **Longitudinal River Profile and the Catchment Areas of Hydropower Potential Sites**

In order to identify hydropower potential sites, the longitudinal river profiles with the catchment areas of main rivers were drawn by using 1:50,000 scale topographic maps. The longitudinal river profiles and the catchment areas of main rivers in Viti Levu are shown in Figure 5.2.2-6 to Figure 5.2.2-11.

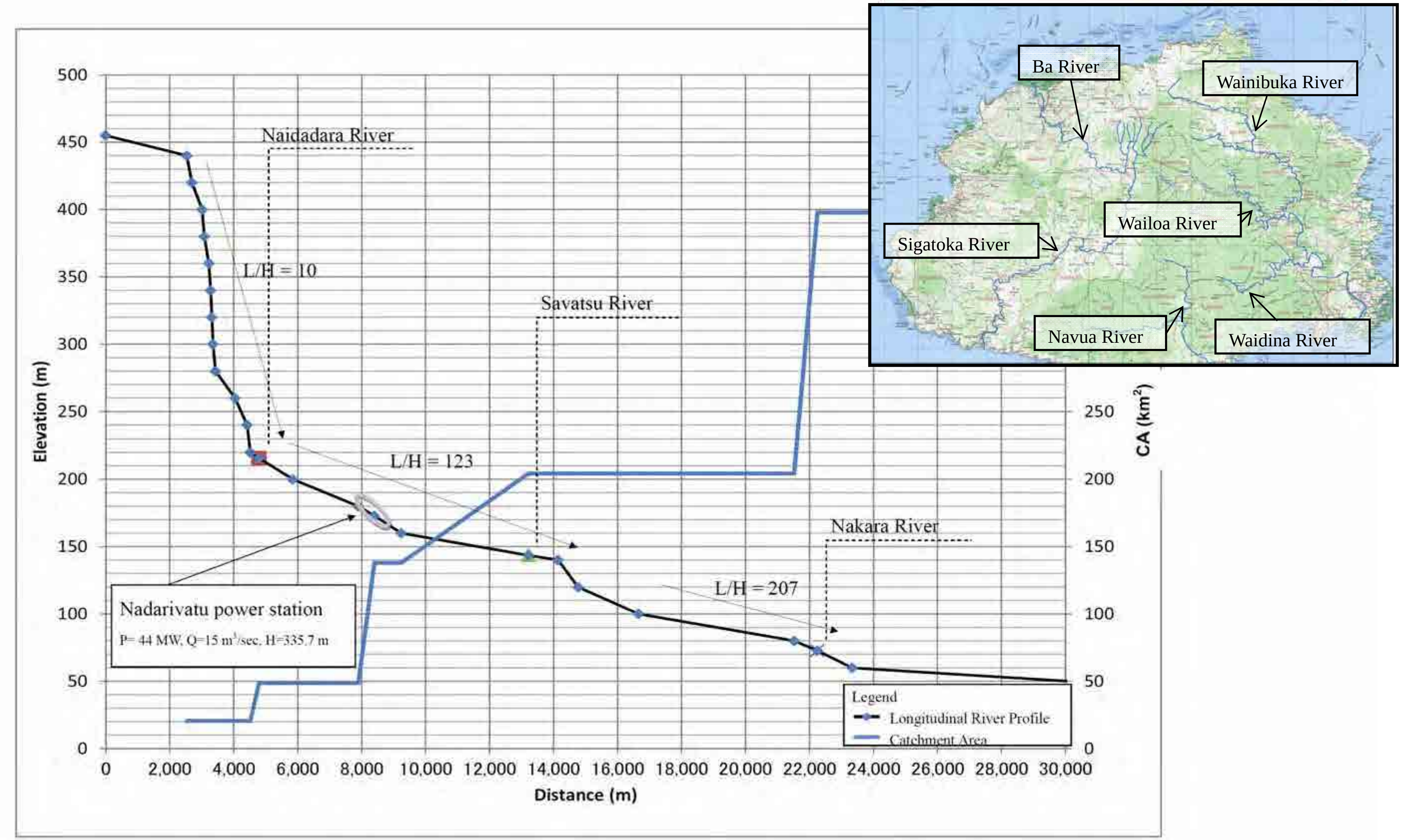


Figure 5.2.2-6 Longitudinal River Profile and Catchment Area of the Ba River for a Hydropower Potential Site

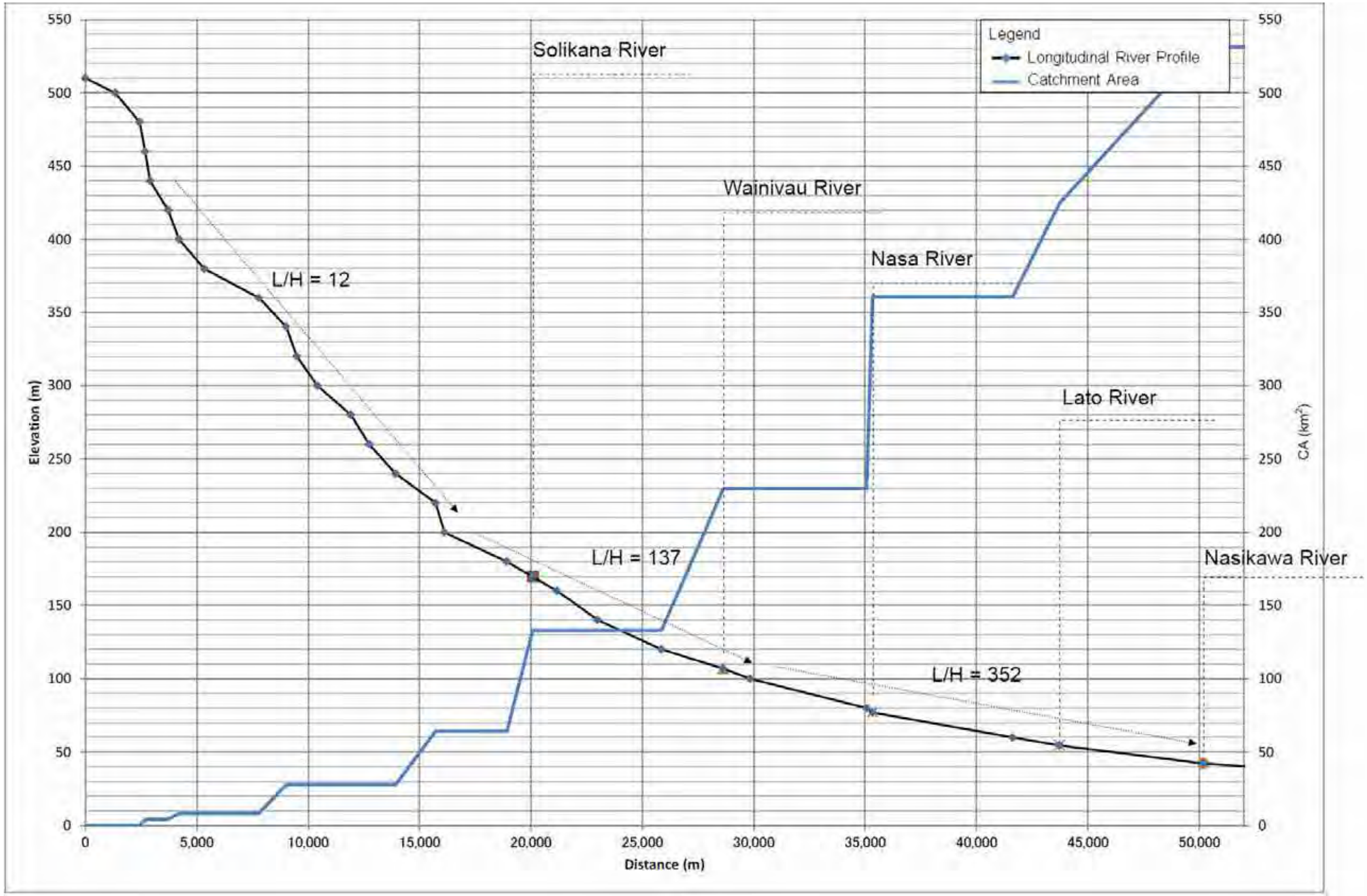


Figure 5.2.2-7 Longitudinal River Profile and Catchment Area of the Sigatoka River for a Hydropower Potential Site

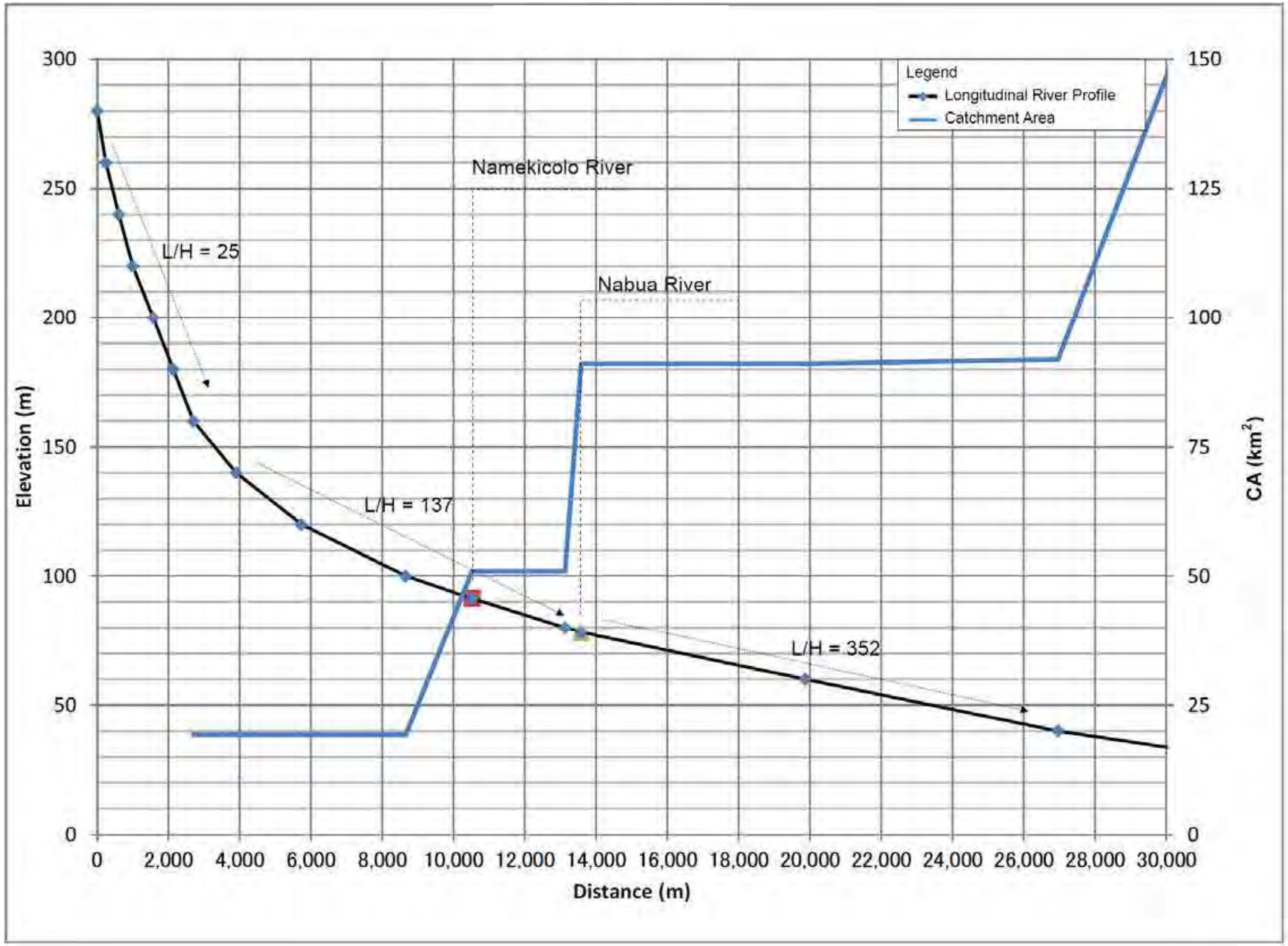


Figure 5.2.2-8 Longitudinal River Profile and Catchment Area of the Wainibuka River for a Hydropower Potential Site

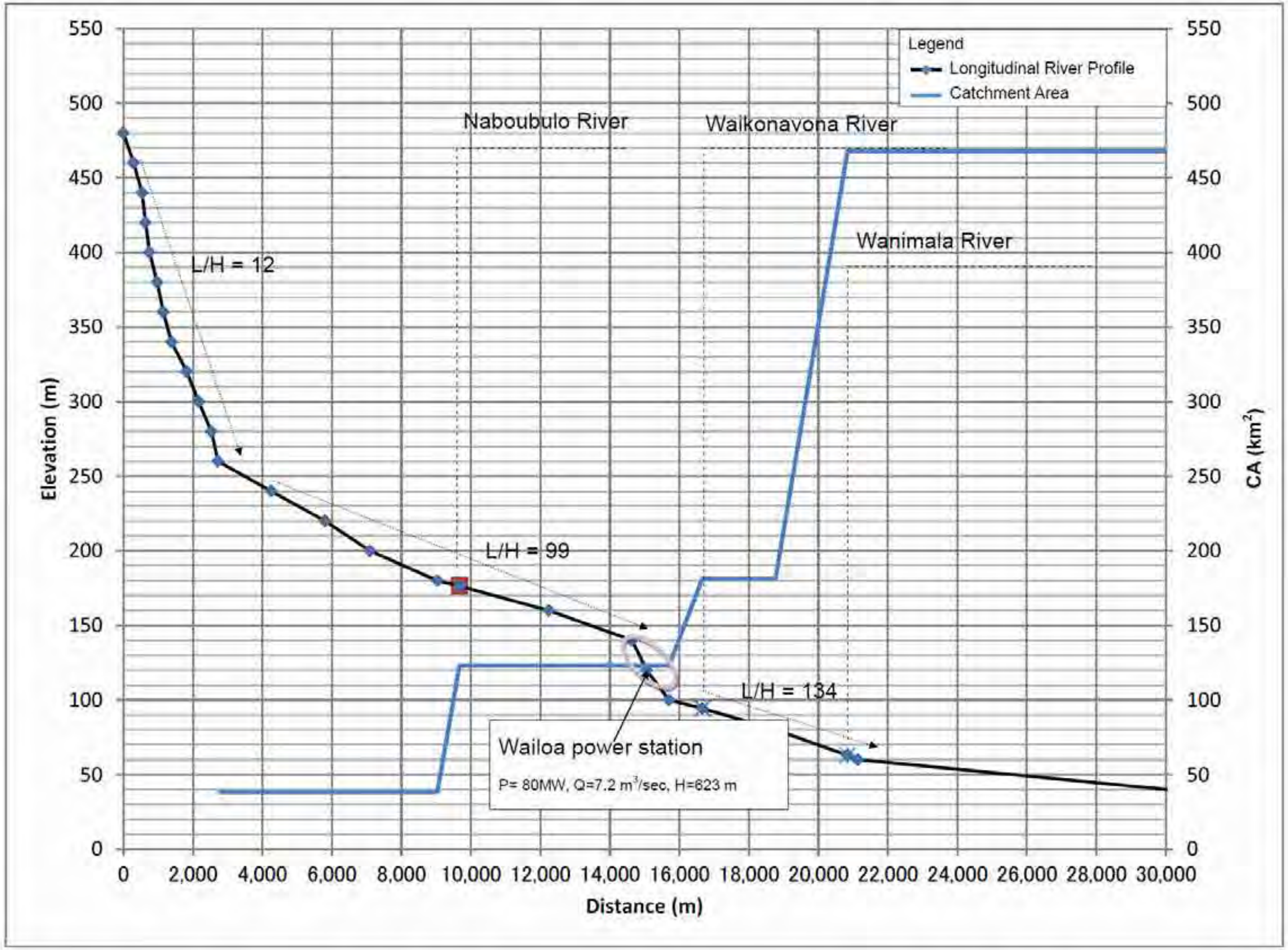


Figure 5.2.2-9 Longitudinal River Profile and Catchment Area of the Wailoa River for a Hydropower Potential Site

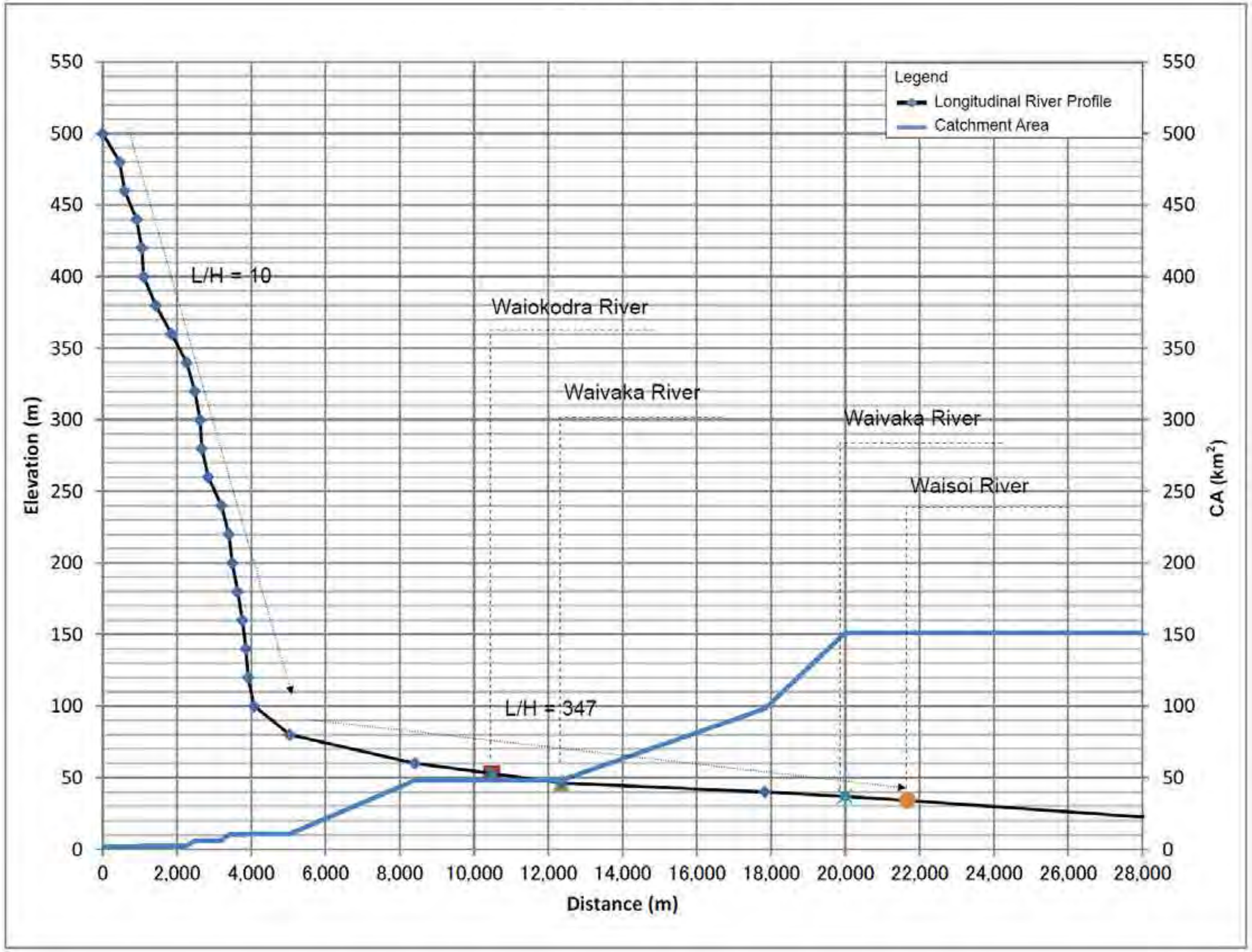


Figure 5.2.2-10 Longitudinal River Profile and Catchment Area of the Waidina River for a Hydropower Potential Site

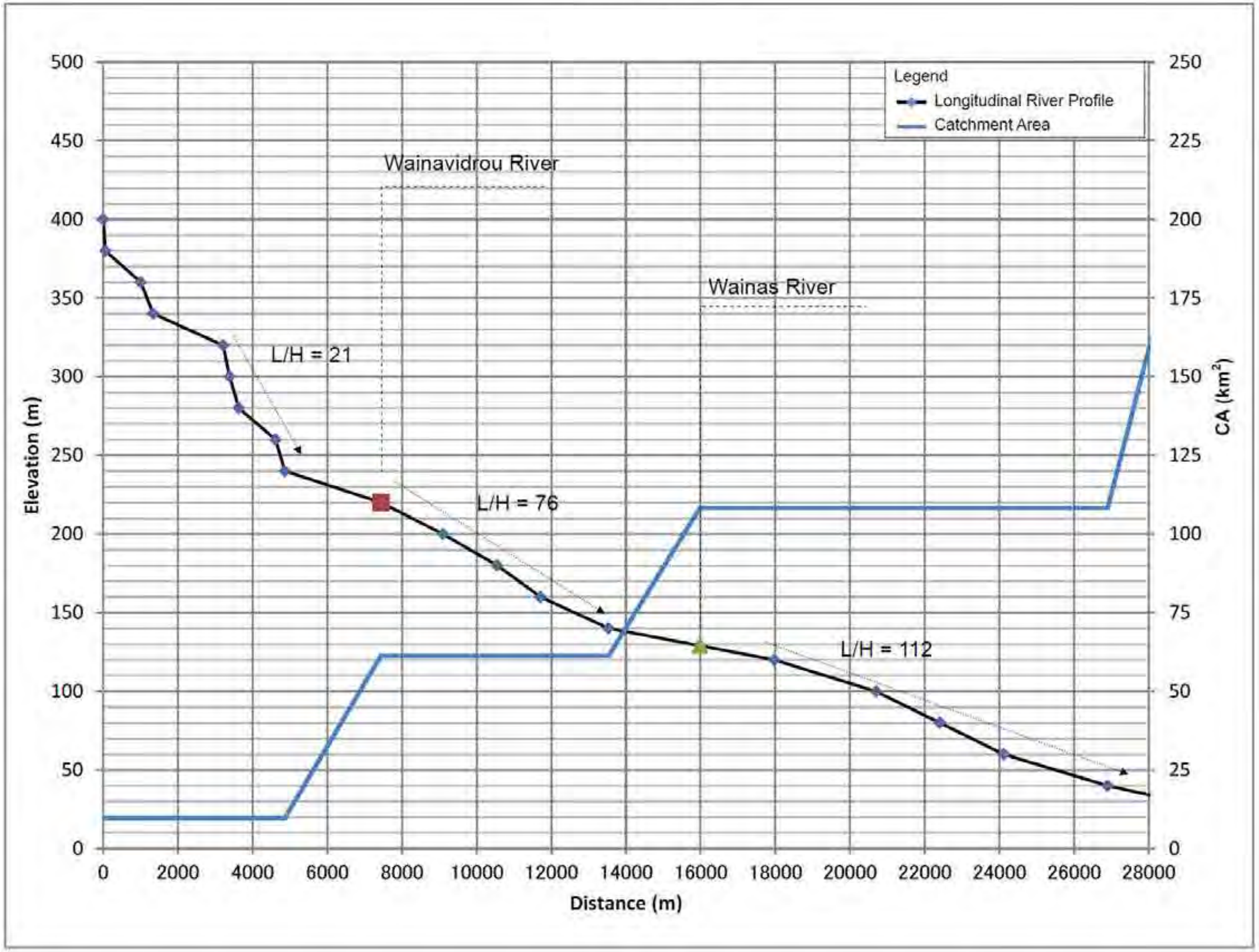


Figure 5.2.2-11 Longitudinal River Profile and Catchment Area of the Navua River for a Hydropower Potential Site

(5) Map Study on the Identification of Hydropower Potential

As mentioned in 5.2.1 (1), twenty-seven (27) hydropower potential sites identified in the existing study reports were reviewed based on the above-mentioned identification criteria by using the 1:50,000 topographical map, referring to the active faults distribution maps, the environmental protection area maps, and the Ramsar site maps.

Ten (10) new potential sites were identified by the map study with the 1:50,000 topographical maps and the longitudinal river profiles.

The main project features including the installed capacity and the maximum plant discharge for the identified sites were determined based on the flow duration curves shown in Figure 5.2.2-3 and Figure 5.2.2-5.

The locations of 37 sites (27 existing sites + 10 new sites) identified through the above-mentioned map study are shown in Table 5.2.2-4 and Figure 5.2.2-12 for Viti Levu and Table 5.2.2-5 and Figure 5.2.2-13 for Vanua Levu.

Table 5.2.2-4 Project Features of the Identified Hydropower Potential Sites in Viti Levu

No.	Site	Previous Report /New	Basin	CA (km^2)	P (kW)	Q (m^3/s)	He (m)	Annual Generated Energy (MWh)
Run-of-River Type								
1	Wainvau	Previous Report	Sigatoka	54.9	700	1.33	73.4	4,073
2	Nasa	Previous Report	Sigatoka	81.3	700	1.90	53.1	3,859
3	Sigatoka2	Previous Report	Sigatoka	26.4	400	0.60	93.2	2,458
4	Solikana	Previous Report	Sigatoka	32.3	700	0.83	113.0	3,852
5	Nasikawa1	New	Sigatoka	44.5	500	0.99	65.90	2,707
6	Narogevu	Previous Report	Sigatoka	10	400	0.21	298	2,767
7	Nabiaurua	Previous Report	Mba	20.7	1,000	0.64	213.9	7,878
8	Mba1U/S	New	Mba	172.2	3,600	5.36	84.6	21,046
9	Mba2D/S	New	Mba	215.9	2,000	6.45	39.5	12,161
10	Nakara	Previous Report	Mba	54.4	400	1.13	55.5	3,016
11	Tawa	Previous Report	Rewa	13.5	1,000	0.95	142.0	6,759
12	Nasoqo1	Previous Report	Rewa	33.7	3,100	2.61	149.7	17,292
13	Nasoqo2	New	Rewa	62	1,300	4.72	35.1	7,153
14	Naboubuqo	Previous Report	Rewa	40.7	3,000	3.17	113.3	16,046
15	Waqaitabua	Previous Report	Rewa	34.2	1,100	2.68	54.1	6,348
16	Waikonavona	Previous Report	Rewa	27.3	1,500	2.09	93.7	8,669
17	Waisare	Previous Report	Rewa	14	1,000	1.07	124.0	5,870
18	Nadara	Previous Report	Rewa	144	5,200	11.2	58.0	29,006
19	Nambua	Previous Report	Rewa	10	1,300	0.81	205.0	7,642
20	Wainivodi	Previous Report	Rewa	33.4	1,700	2.89	73.8	9,446
21	Wainisavuleve	Previous Report	Rewa	23.6	1,500	2.06	94.9	8,641
22	Wainimala	Previous Report	Rewa	83.5	2,200	7.70	36.6	12,307
23	Wainimakutu	Previous Report	Navua	61.7	1,000	3.82	35.2	5,999
24	Nakavika	Previous Report	Navua	115.5	3,100	7.19	54.7	16,951
25	Sovi	Previous Report	Rewa	143.3	2,300	12.69	23.4	12,716
26	Wainavadu	Previous Report	Rewa	38.1	2,700	3.33	102.6	14,975
27	Wainamoli	Previous Report	Navua	89.2	1,200	4.21	36.8	6,886
28	Waisoi	Previous Report	Rewa	17	2,100	1.41	186.0	11,321
29	Wairokodora	Previous Report	Rewa	5.5	1,900	1.47	167.0	10,591
Completion of F/S								
A-1	Qaliwana	Complete of F/S	Sigatoka					
A-2	Wailoa D/S	Complete of F/S	Rewa	143	7,300	25	36.4	44,900

(shaded) : Less than 1,000kW

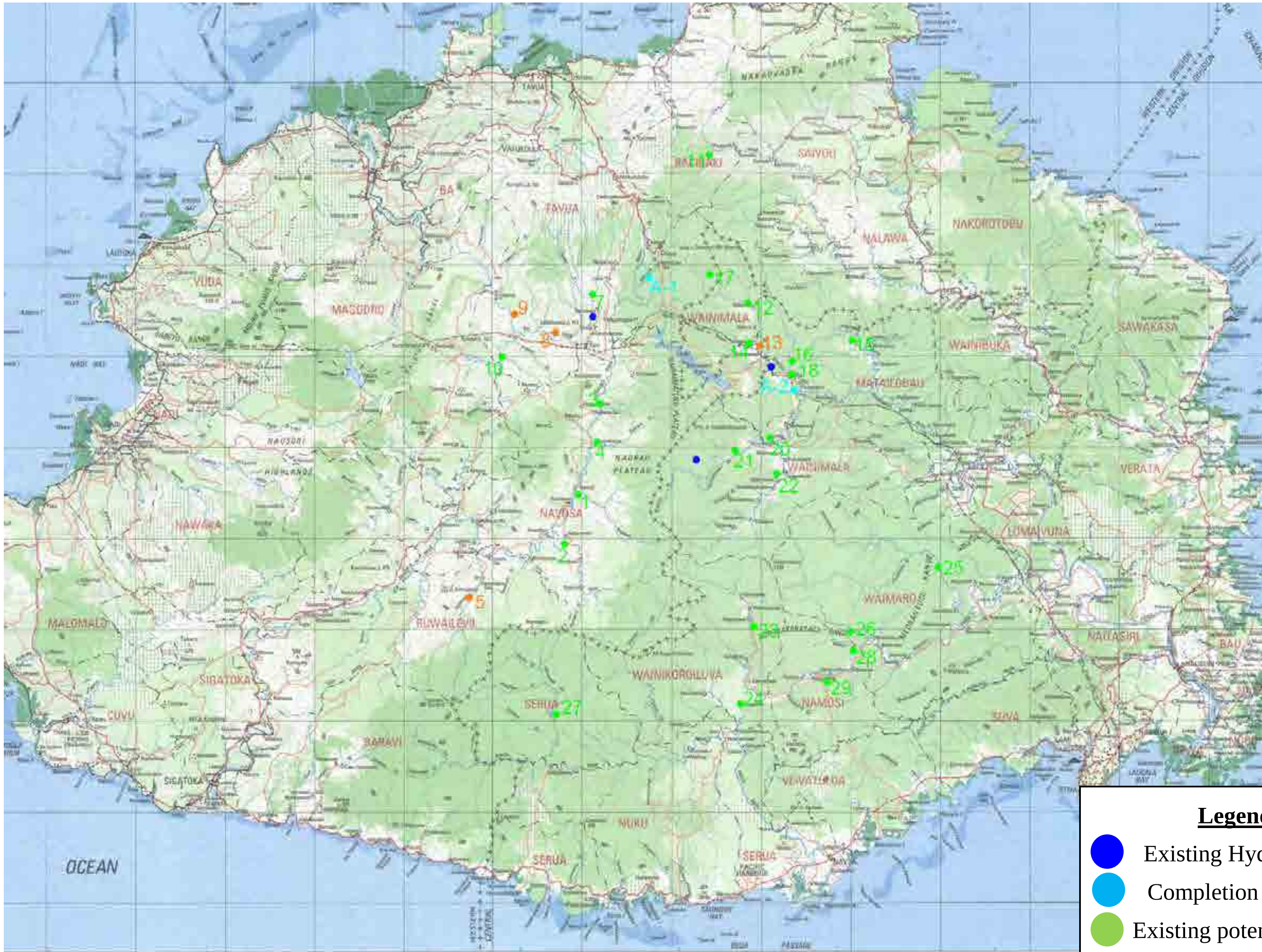


Figure 5.2.2-12 Identified Hydropower Potential Sites in Viti Levu

Table 5.2.2-5 Project Features of Identified Hydropower Potential Sites in Vanua Levu

No.	Site	Previous Report /New	Basin	CA (km^2)	P (kW)	Q (m^3/s)	He (m)	Annual Generated Energy (MWh)
Run-of-River Type								
30	Nadamanu	Previous Report	Lekutu	25.5	1,800	2.64	88.1	11,049
31	Saquru	Previous Report	Labasa	13.5	2,700	1.96	172.6	17
32	Navilevu	New	Wainunu	16.3	1,200	2.05	75.4	7,893
33	Nabuna	New	Wainunu	31.5	1,300	3.02	55.8	7,620
34	Davutu	New	Wainunu	28.2	1,200	2.81	55.3	7,164
35	Wailevu	New	Yanawai	34.7	2,000	3.23	76.9	11,241
36	Naisogocauca	New	Drakaniwai	16.4	1,500	2.52	77.3	9,572
37	Nuku	New	Wainunu	32.0	1,300	3.05	56.5	7,847

Figure 5.2.2-13 Identified Hydropower Potential Sites in Vanua Levu

(6) Natural and Social Environmental Conditions of the Hydropower Potential Sites

The existing and proposed protected area maps in Viti Levu and Vanua Levu are shown in Figure 5.2.3-1 and Figure 5.2.3-2, respectively. Since five (5) potential sites of thirty seven (37) sites identified by the map study are located in the existing or proposed protected areas, they were excluded from the candidate sites for the preliminary site reconnaissance.

(7) Rough Cost Estimation of the Hydropower Potential Sites

For the economic evaluation of the identified sites, the construction costs of every potential site were roughly estimated by the method shown in "Guideline and Manual for Hydropower Development Vol.1 Conventional Hydropower and Pumped Storage Hydropower (JICA) in Japan".

The construction unit costs used in the JETRO study "Study on Hydropower Renewable Energy Development Project in the Wailoa Downstream in Republic of the Fiji Islands" conducted in 2008, were applied for the above project cost estimation.

5.2.3 Prioritization of Hydropower Potential Sites

In order to prioritize the identified 37 potential, B/C (Benefit/Cost) of each site was calculated. The assumptions for B/C calculations are described in Table 5.2.3-1.

Table 5.2.3-1 Assumptions for B/C Calculations

<table>
<tr><th></th><th colspan="2">Items</th><th>Assumptions</th></tr>
<tr><td rowspan="4">Economic Cost （C）</td><td colspan="2">Construction Cost</td><td>Calculated in accordance with "Guideline and Manual for Hydropower Development Vol.1 Conventional Hydropower and Pumped Storage Hydropower (JICA)"</td></tr>
<tr><td colspan="2">Operation and Maintenance Cost</td><td>1% of Construction Costs</td></tr>
<tr><td colspan="2">Project Life</td><td>30 years</td></tr>
<tr><td colspan="2">Construction Period</td><td>5 years（detailed design 2yrs＋Construction 3yrs）</td></tr>
<tr><td rowspan="7">Economic Benefit （B）</td><td colspan="2">Annual Generation</td><td>Annual Generation of Hydropower (GWh/annum）</td></tr>
<tr><td colspan="2">Installed Capacity</td><td>Firm Capacity of Hydropower（kW）</td></tr>
<tr><td rowspan="5">Alternative Diesel Plant</td><td>Construction Cost</td><td>Calculated with a construction cost of USD 600/kW (Const. cost of Kinoya Diesel Power Plant (completed in 2005))</td></tr>
<tr><td>Operation and Maintenance Cost</td><td>3% of Construction Costs (USD 18/kW/annum）</td></tr>
<tr><td>Fuel Cost</td><td>USD 0.19/kWh (=0.25liter/kWh x FSD1.3*/liter x0.54 USD/FJD)</td></tr>
<tr><td>Project Life</td><td>15 years</td></tr>
<tr><td>Construction Period</td><td>1 year</td></tr>
<tr><td colspan="3">Discount rate</td><td>10%</td></tr>
</table>

*: FSD 1,146/ton (average price in 2007: FEA Annual Report 2007) / 1,000 / 0.86

Nine (9) hydropower potential sites with 1.0 of B/C value or more were selected as candidate potential sites for site reconnaissance. The locations of the selected nine (9) potential sites are shown in Table 5.2.3-2, Figure 5.2.3-1 and Figure 5.2.3-2. Site maps of them are shown in Appendix 5-2.

Table 5.2.3-2 Prospective Hydropower Potential Sites Screened

Potential site (Generation type)	Previous report, New site	Features (P, Q, He, Annual electricity generation, etc.)	Construction cost (x1,000 USD)	USD / kWh, B / C	Evaluation of environmental conditions
7.Nabiaurua (Run-of-river)	Previous	1.0 MW, 0.63 m^3/s, 213.9 m, 7,878 MWh	10,401	1.32, 1.0	No significant impact
8.Mba 1 U/S (Run-of-river)	New	3.6 MW, 5.36 m^3/s, 84.6 m, 21,046 MWh	25,147	1.19, 1.2	No significant impact
14.Naboubuco (Run-of-river)	Previous	3.0 MW, 3.17 m^3/s, 113.3 m, 16,046 MWh	18,896	1.18, 1.2	No significant impact
24.Nakavika (Run-of-river)	Previous	3.1 MW, 7.19 m^3/s, 54.7 m, 16,951 MWh	22,560	1.33, 1.0	No significant impact
26.Wainavadu (Run-of-river)	Previous	2.7 MW, 3.33 m^3/s, 160 m, 14,975 MWh	21,104	1.41, 1.0	No significant impact
28.Waisoi (Run-of-river)	Previous	2.1 MW, 1.41 m^3/s, 186 m, 11,321 MWh	13,365	1.18, 1.2	No significant impact
29.Wairokodora (Run-of-river)	Previous	1.9 MW, 1.47 m^3/s, 167 m, 10,591 MWh	12,800	1.21, 1.1	No significant impact
31.Saquru (Run-of-river)	Previous	2.7 MW, 1.96 m^3/s, 172.6 m, 11,241 MWh	17,000	1.20, 1.1	No significant impact
35.Wailevu (Run-of-river)	New	2.0 MW, 3.23 m^3/s, 76.9 m, 11,241 MWh	11,241	1.48, 1.0	No significant impact

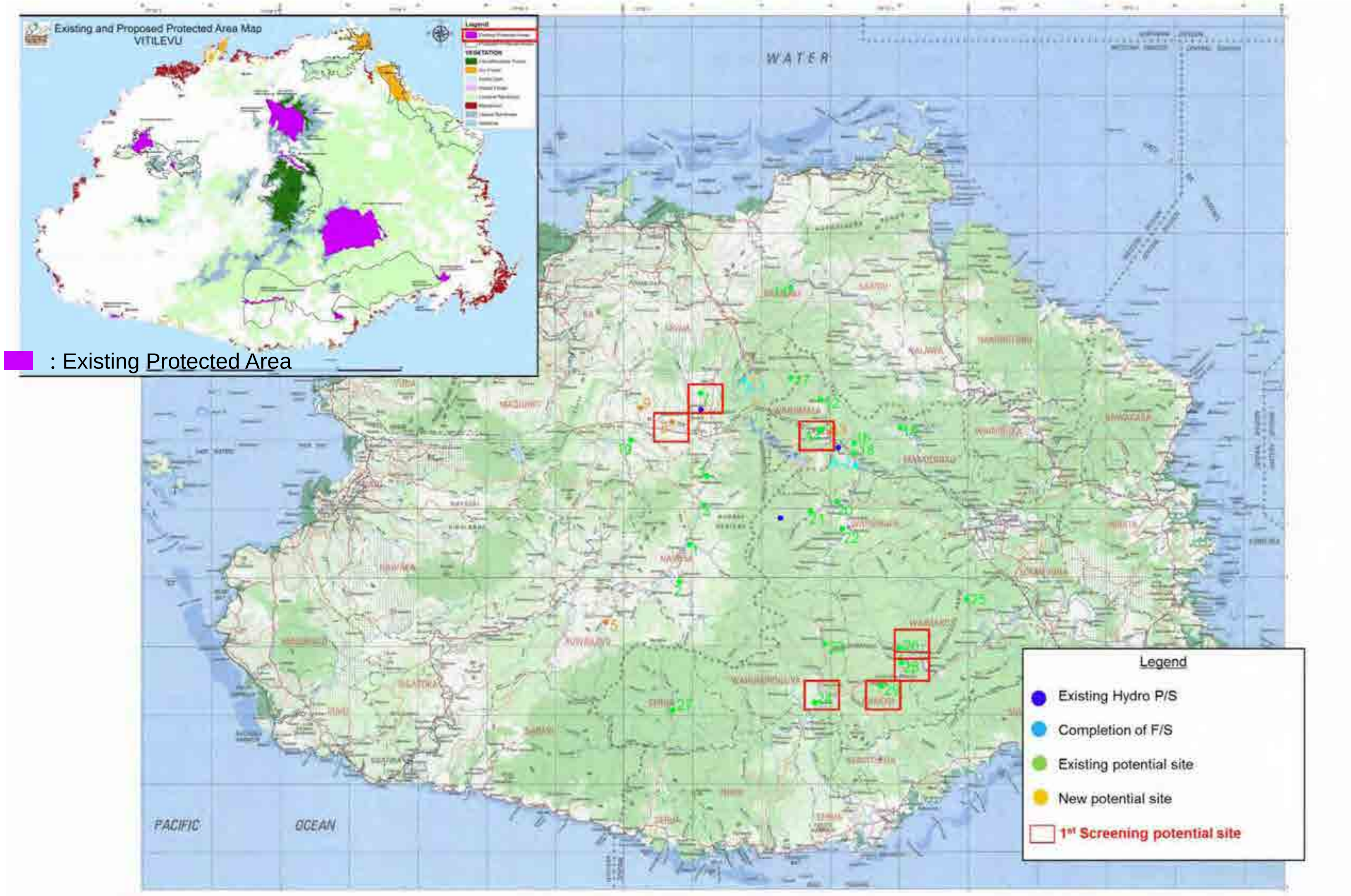


Figure 5.2.3-1 Selected Hydropower Potential Sites in Viti Levu

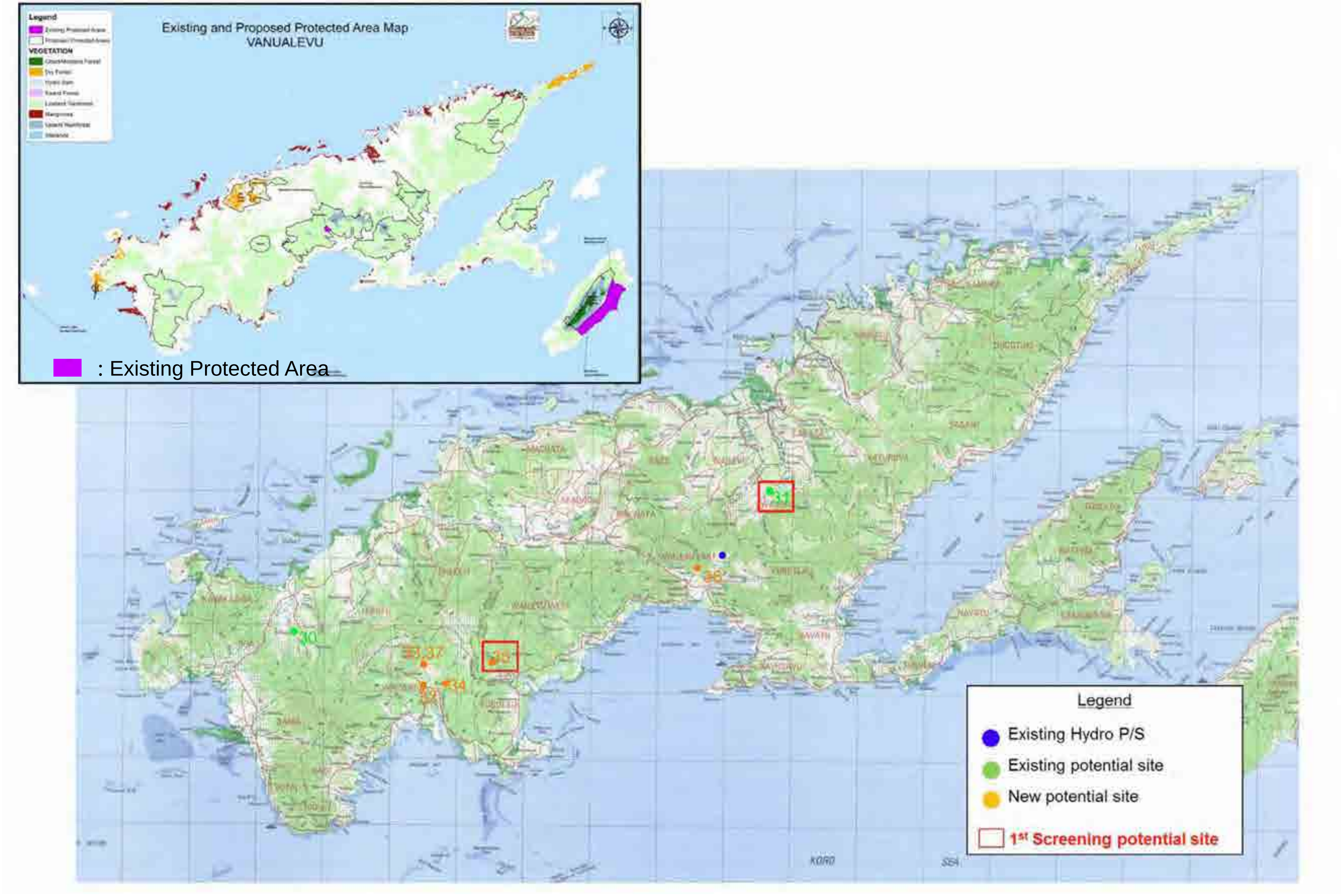


Figure 5.2.3-2 Selected Hydropower Potential Sites in Vanua Levu

5.3 Site Reconnaissance to Candidate Potential Sites

5.3.1 Implementation of the Site Reconnaissance Surveys at the Candidate Potential Sites

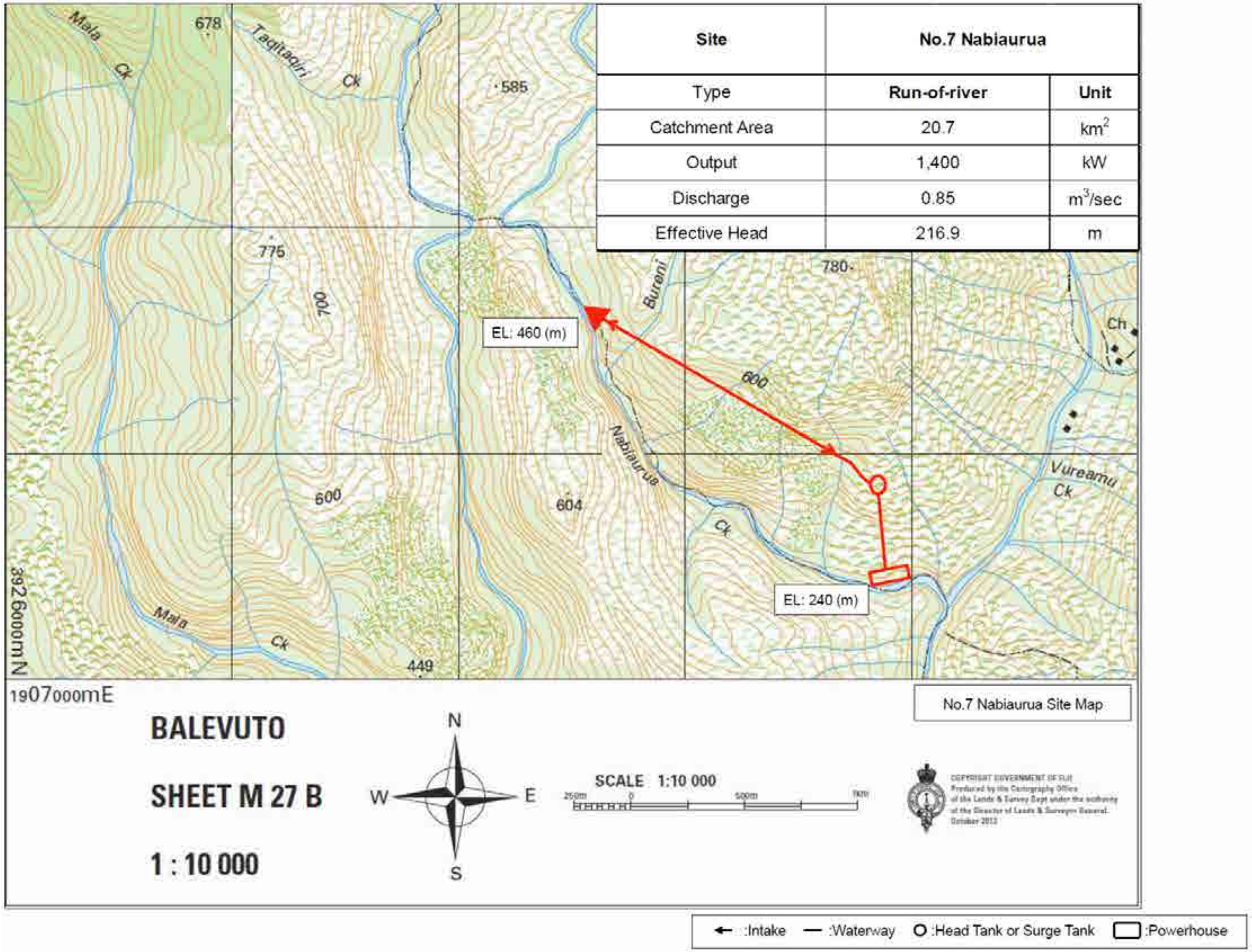
In May 2014, the JICA Project Team carried out the following site reconnaissance surveys at nine (9) candidate hydropower potential sites, which were selected as mentioned in previous sub-clause 5.2, together with the officials of the Department of Energy (DOE), Fiji Electricity Authority (FEA) and WAF.

The findings of the site reconnaissance survey on the geographical and geological conditions, the hydropower plans and the natural and social environmental conditions of each site as well as the photographs on the sites are summarized as shown in Appendix 5-3.

5.3.2 Review of the Power Generation Plans for the Candidate Potential Sites

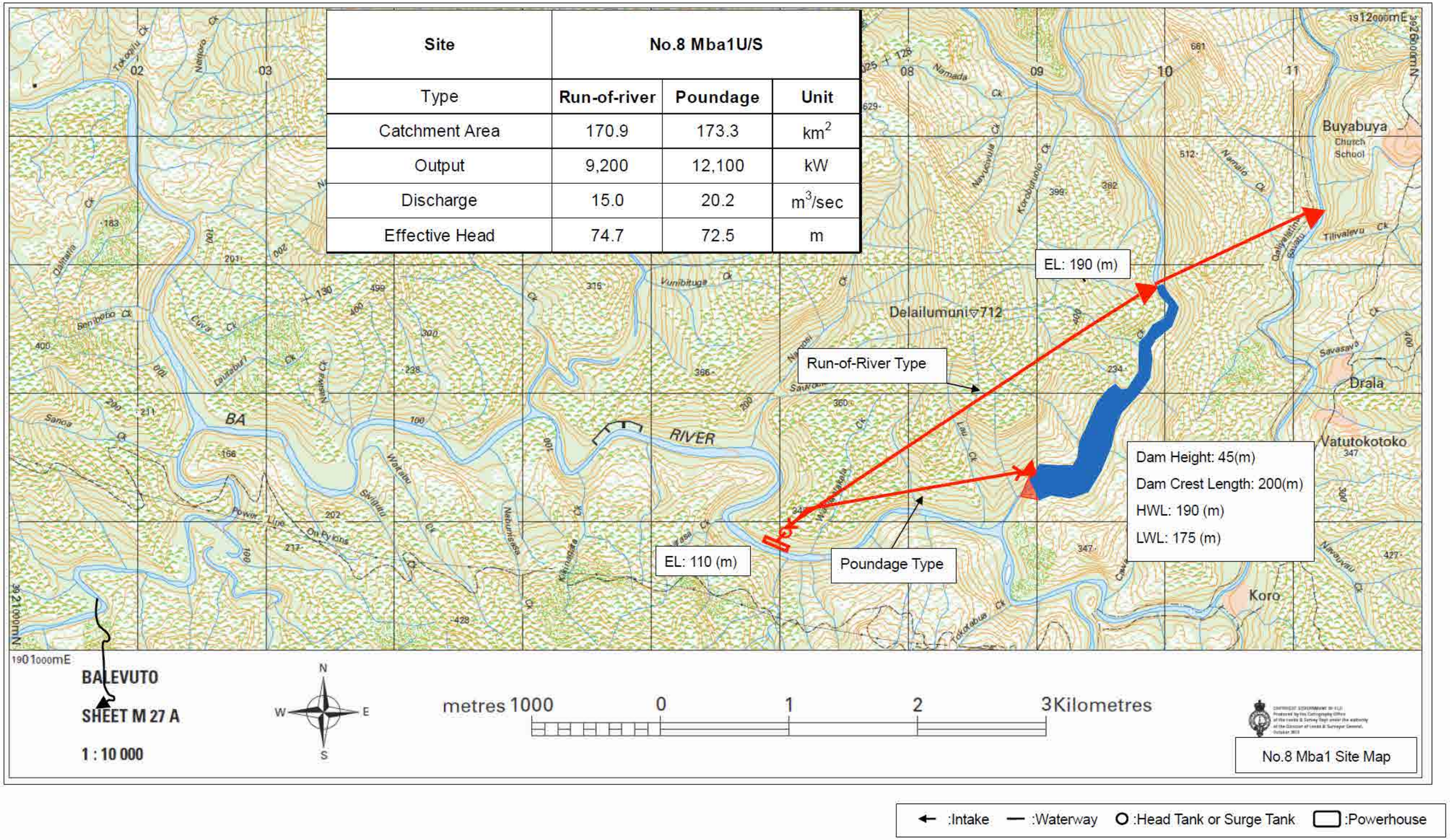
Based on the findings obtained through the site reconnaissance survey, the project features including the facility layouts of all the nine (9) candidate potential sites were reviewed. Subsequently, their construction costs and economic values (benefit / cost (B/C)) were also updated based on the reviewed project features such as power output, maximum discharge and effective head.

The reviewed project features and facility layouts for the nine (9) candidate hydropower potential sites are shown in Figure 5.3.2-1 to Figure 5.3.2-9.



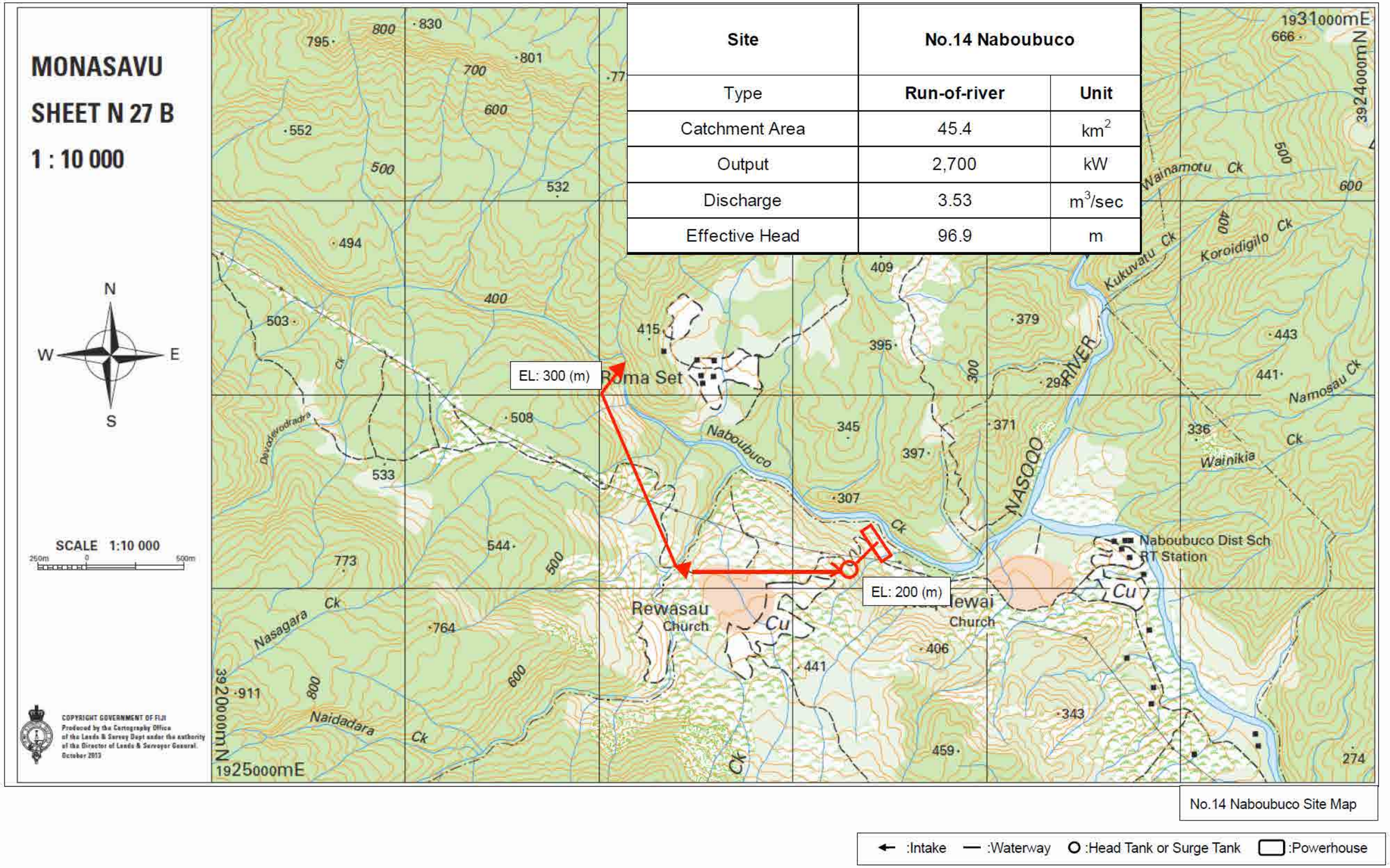
Site	No.7 Nabiaurua	
Type	Run-of-river	Unit
Catchment Area	20.7	km^2
Output	1,400	kW
Discharge	0.85	m^3/sec
Effective Head	216.9	m

Figure 5.3.2-1 Reviewed Plan of the No.7 Site - Nabiaurua



Site	No.8 Mba1U/S		
Type	Run-of-river	Poundage	Unit
Catchment Area	170.9	173.3	km^2
Output	9,200	12,100	kW
Discharge	15.0	20.2	m^3/sec
Effective Head	74.7	72.5	m

Figure 5.3.2-2 Reviewed Plan of the No.8 Site - Mba 1



Site	No.14 Naboubuco	
Type	**Run-of-river**	**Unit**
Catchment Area	45.4	km^2
Output	2,700	kW
Discharge	3.53	m^3/sec
Effective Head	96.9	m

Figure 5.3.2-3 Reviewed Plan of the No.14 Site - Naboubuco

Site	No.24 Nakavika	
Type	Run-of-river	Unit
Catchment Area	115.3	km^2
Output	2,600	kW
Discharge	7.17	m^3/sec
Effective Head	45.7	m

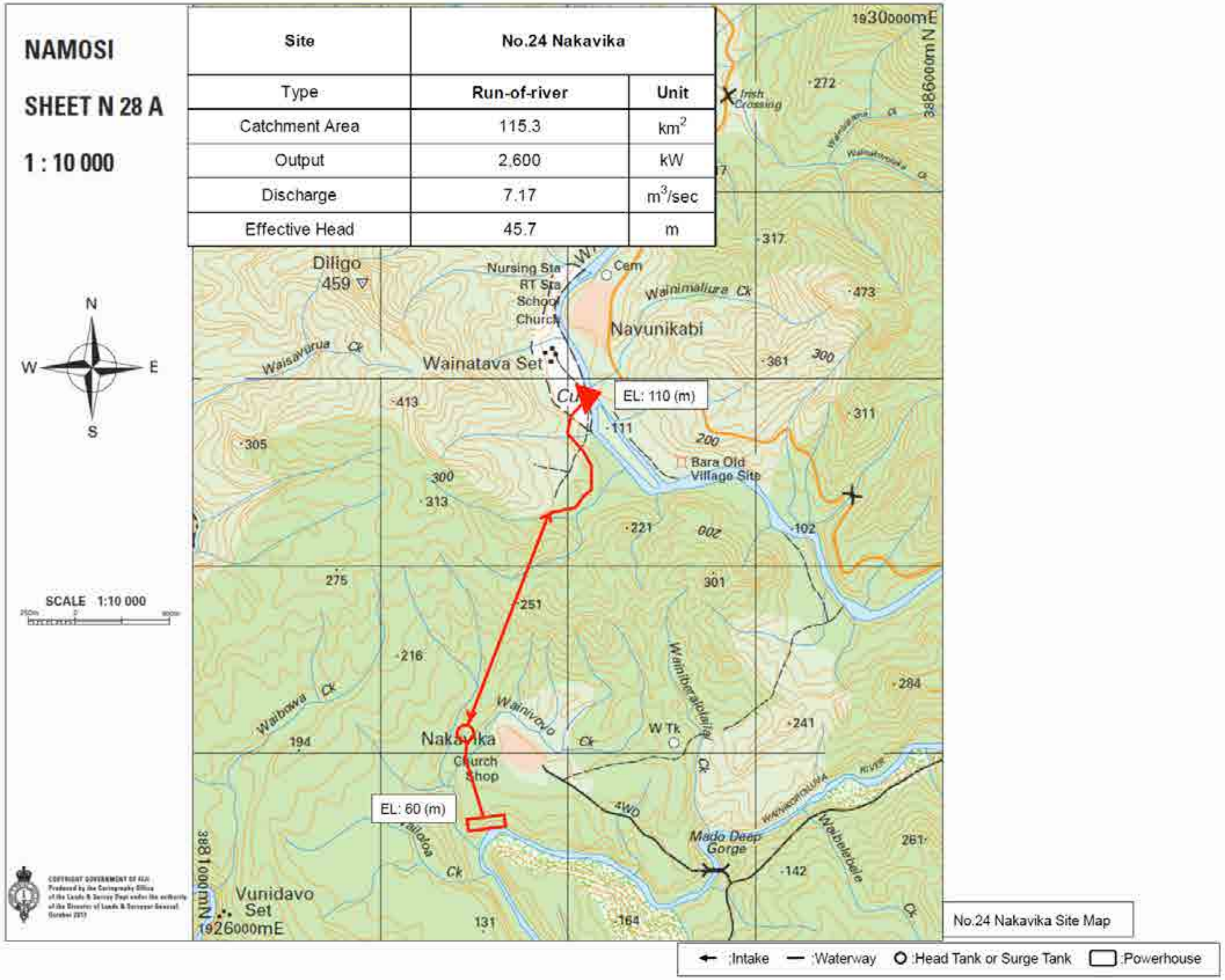
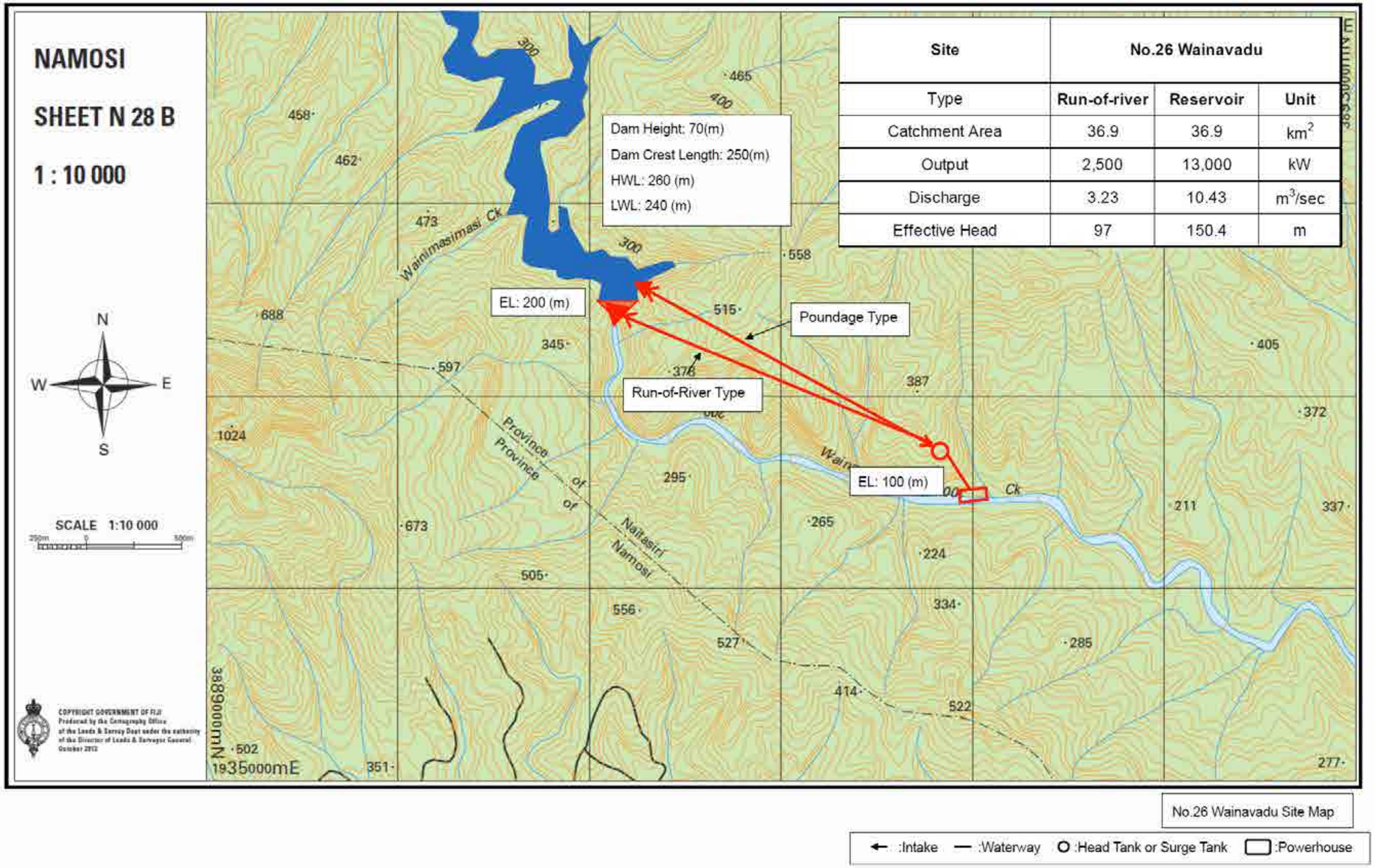
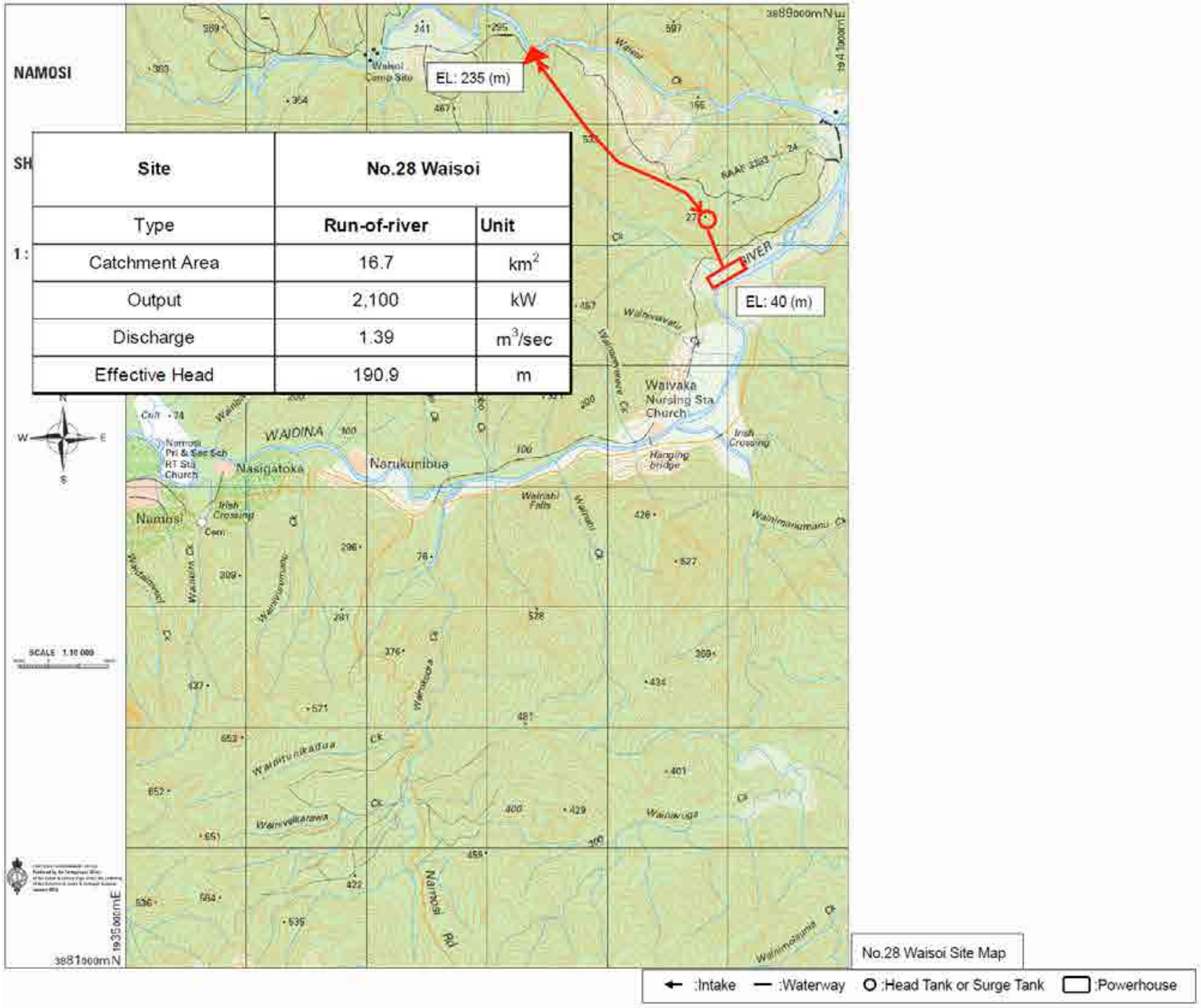


Figure 5.3.2-4 Reviewed Plan of the No.24 Site - Nakavika



Site	No.26 Wainavadu		
Type	Run-of-river	Reservoir	Unit
Catchment Area	36.9	36.9	km^2
Output	2,500	13,000	kW
Discharge	3.23	10.43	m^3/sec
Effective Head	97	150.4	m

Figure 5.3.2-5 Reviewed Plan of the No.26 Site - Wainavadu



Site	No.28 Waisoi	
Type	Run-of-river	Unit
Catchment Area	16.7	km^2
Output	2,100	kW
Discharge	1.39	m^3/sec
Effective Head	190.9	m

Figure 5.3.2-6 Reviewed Plan of the No.28 Site - Waisoi

Site	No.29 Wairokodra	
Type	Run-of-river	Unit
Catchment Area	5.3	km^2
Output	2,600	kW
Discharge	1.45	m^3/sec
Effective Head	226.0	m

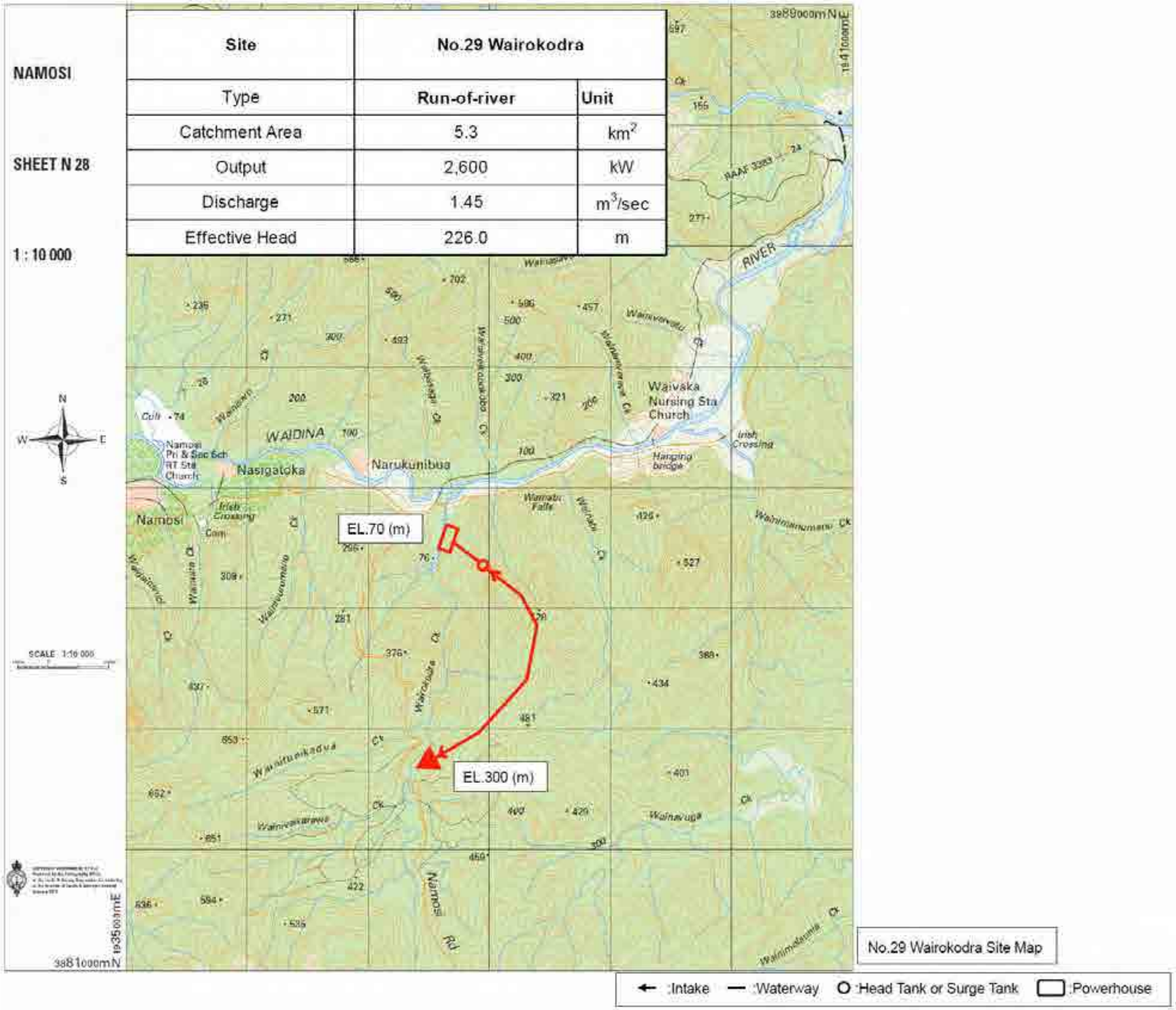
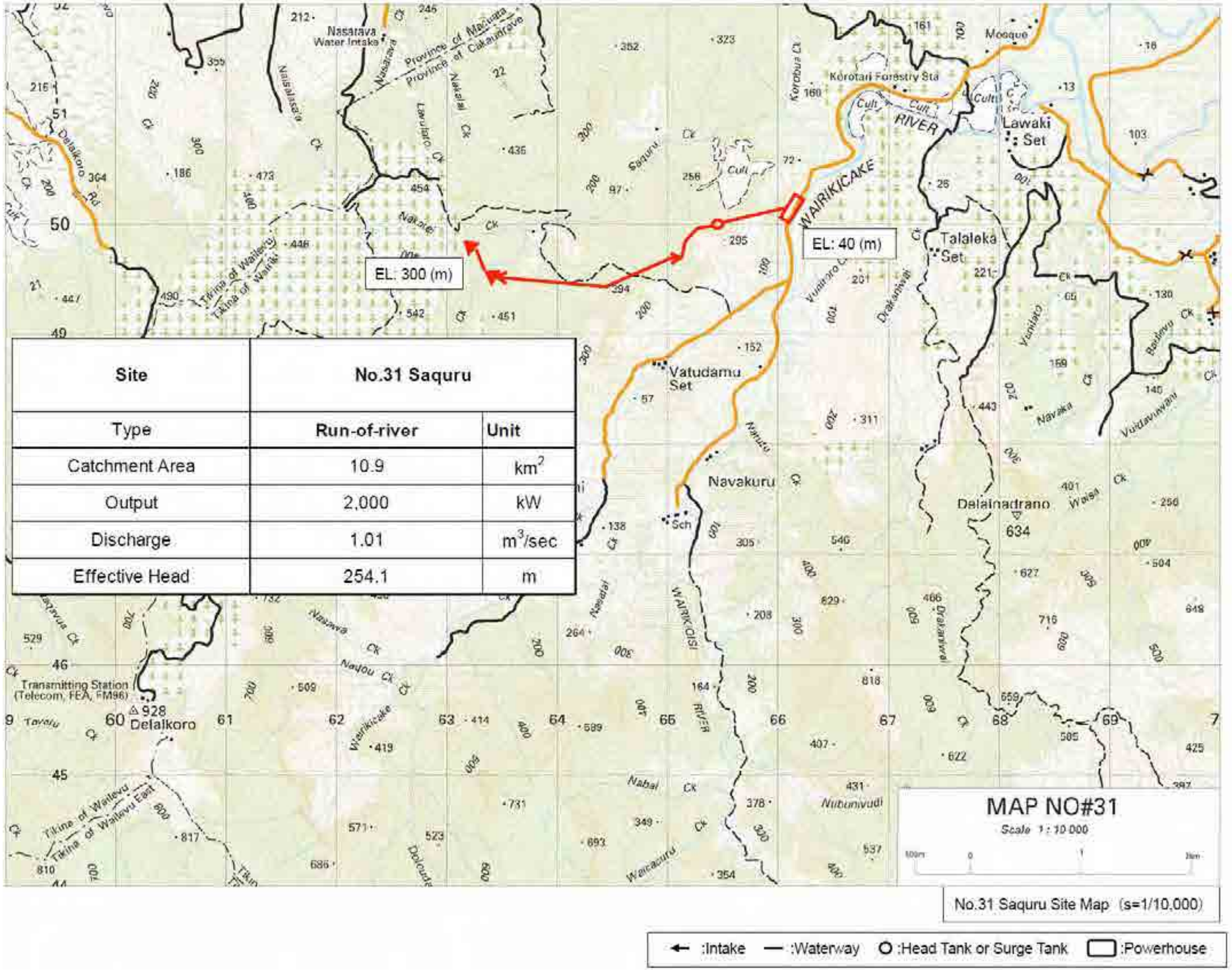
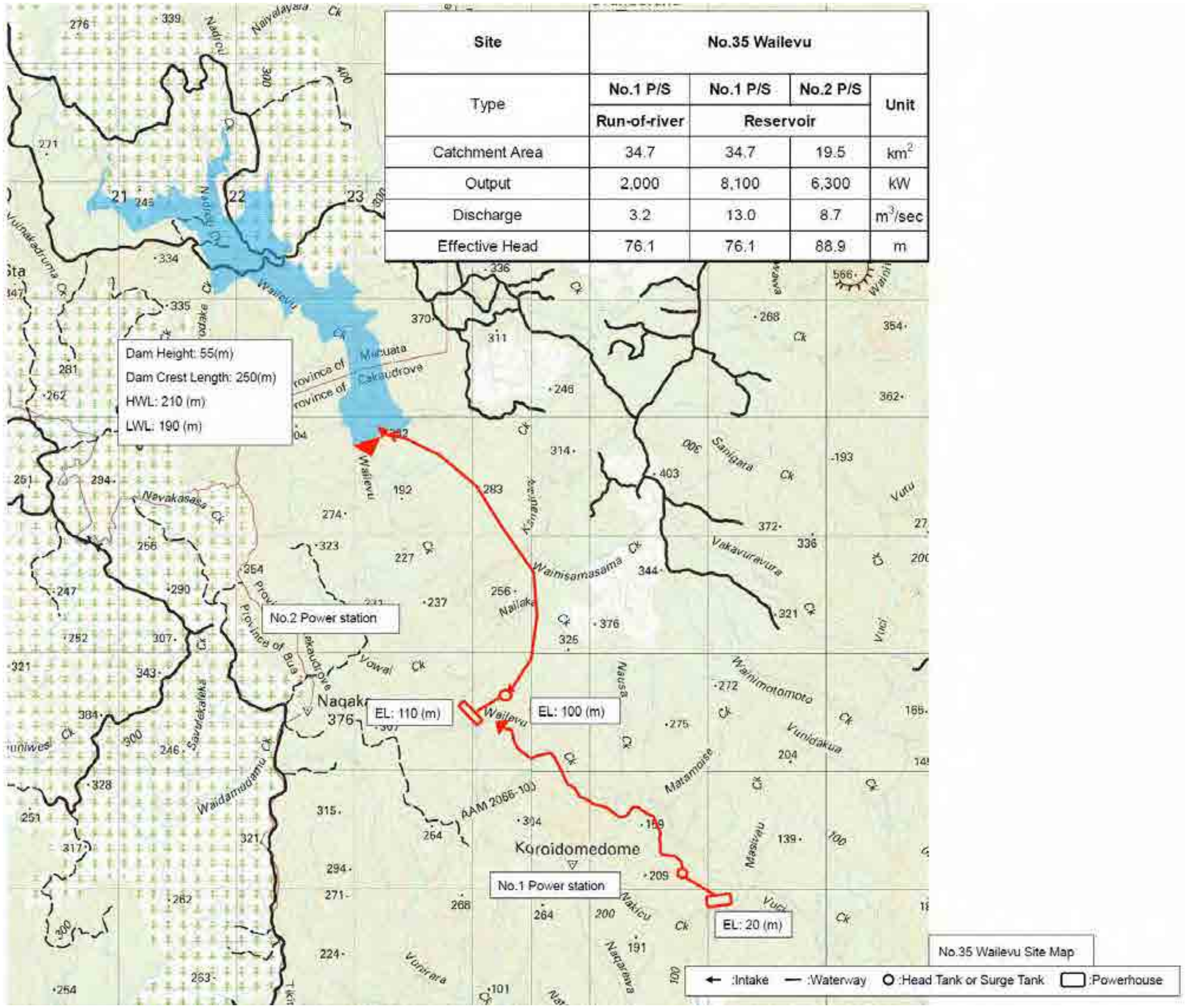


Figure 5.3.2-7 Reviewed Plan of the No.29 Site - Wairokodora



Site	No.31 Saquru	
Type	Run-of-river	Unit
Catchment Area	10.9	km^2
Output	2,000	kW
Discharge	1.01	m^3/sec
Effective Head	254.1	m

Figure 5.3.2-8 Reviewed Plan of the No.31 Site -Saquru



Site	No.35 Wailevu			
Type	No.1 P/S	No.1 P/S	No.2 P/S	Unit
	Run-of-river	Reservoir		
Catchment Area	34.7	34.7	19.5	km^2
Output	2,000	8,100	6,300	kW
Discharge	3.2	13.0	8.7	m^3/sec
Effective Head	76.1	76.1	88.9	m

Figure 5.3.2-9 Reviewed Plan of the No.35 Site - Wailevu

5.4 Evaluation Criteria for Selecting the Prospective Hydropower Potential Sites for Preliminary Design

5.4.1 Setting of the Evaluation Criteria for Selecting the Prospective Hydropower Potential Sites

In order to select the prospective potential sites for preliminary design from nine (9) candidate hydropower potential sites that were reviewed through the reconnaissance surveys in May 2014, as described in the previous sub-clause 5.3, the evaluation criteria for screening the potential sites were determined on economic aspects, environmental aspects, and the prioritization of power supply reliability. The flowchart for selecting the three prospective hydropower potential sites is shown in Figure 5.4.1-1.

Three (3) prospective potential sites were selected thorough Figure 5.4.1-1.

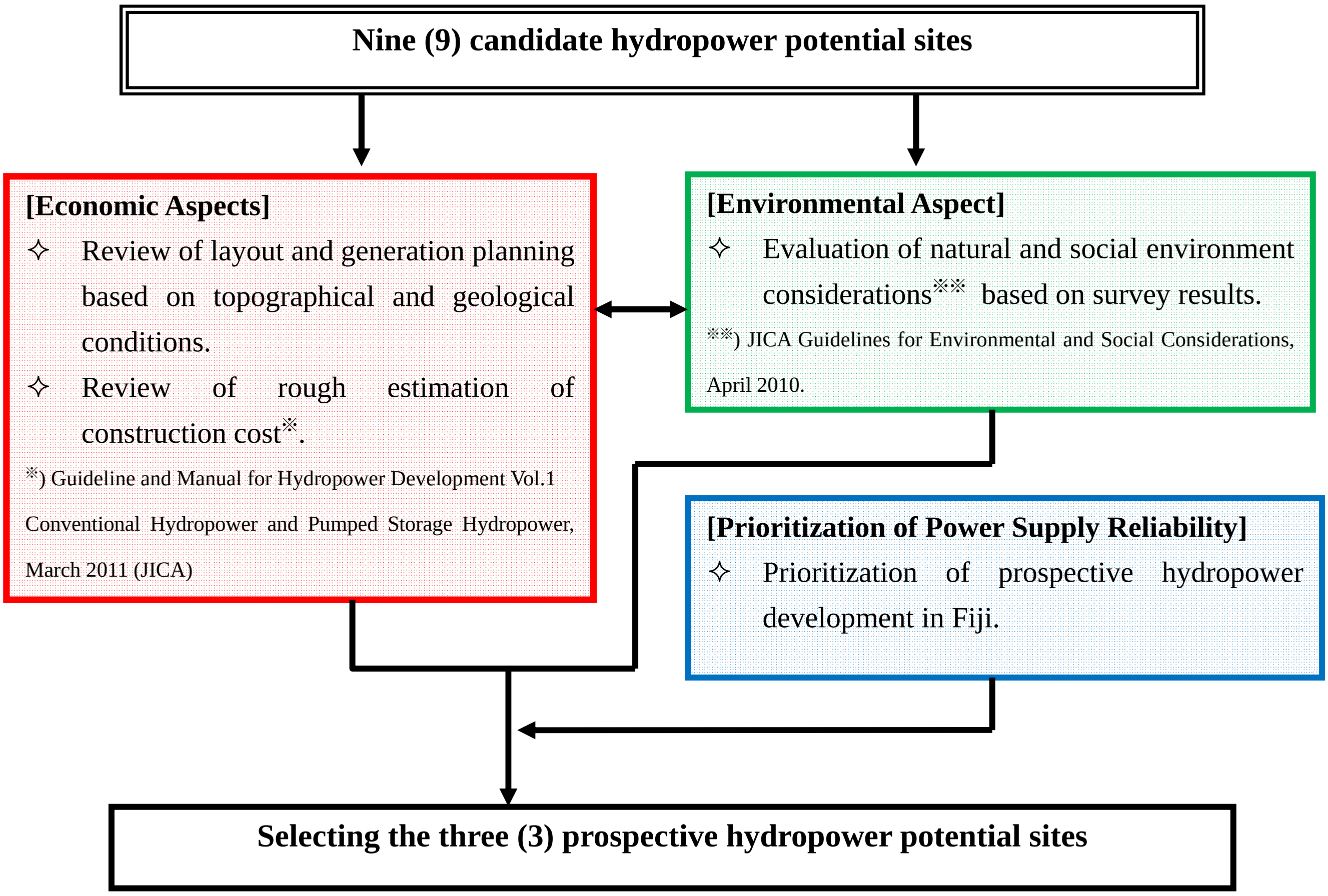


Figure 5.4.1-1 Flowchart for the Three Selected Prospective Hydropower Potential Sites

(1) Evaluation of the Natural and Social Environmental Aspects of the Candidate Hydropower Potential Sites

In order to evaluate the candidate hydropower potential sites in terms of the natural and social environmental conditions on Flora and Fauna Fish, and Resettlement Compensatory and Cultural

Heritage, as shown in Table 5.4.1-1, the JICA Project Team evaluated each site and calculated scores to express the expected negative impacts on these.

Table 5.4.1-1 Natural and Social Environmental Evaluation of the Candidate Hydropower Potential Sites

Site	**Natural Environment**			**Social Environment**		**Average Score**
	Protected Area	Flora	Fauna	Resettlement, Compensatory	Cultural Heritage	
[Viti Levu]						
7.Nabiaurua	1	1	1	1	2	1.20
8.Mba 1 U/S	1	1	1	1	2	1.20
14.Naboubuco	1.5	2	1.5	1	1	1.40
24.Nakavika	1.5	2	2	2	2	1.90
26.Wainavadu	2	2	2	2	1	1.80
28.Waisoi	1.5	2	1	2	1	1.50
29.Wairokodora	1.5	2	2	1	1	1.50
[Vanua Levu]						
31.Saqaru	1.5	1	1	1	1	1.10
35.Wailevu	1.3	2	2	1	1	1.46

Scores of Expected environmental negative impacts:
3 = Major
2 = Unknown or can be mitigated
1 = No significant impacts

(2) Prioritization of Power Supply Reliability

The exact necessity of hydropower generation varies from region to region, as this is wholly dependent on each particular region's area, lack of the electric power, and existing transmission facilities.

Taking into consideration such regional deference to the needs for new hydropower sources, the scores for the prioritization of power supply reliability are determined as shown in Figure 5.4.1-2.

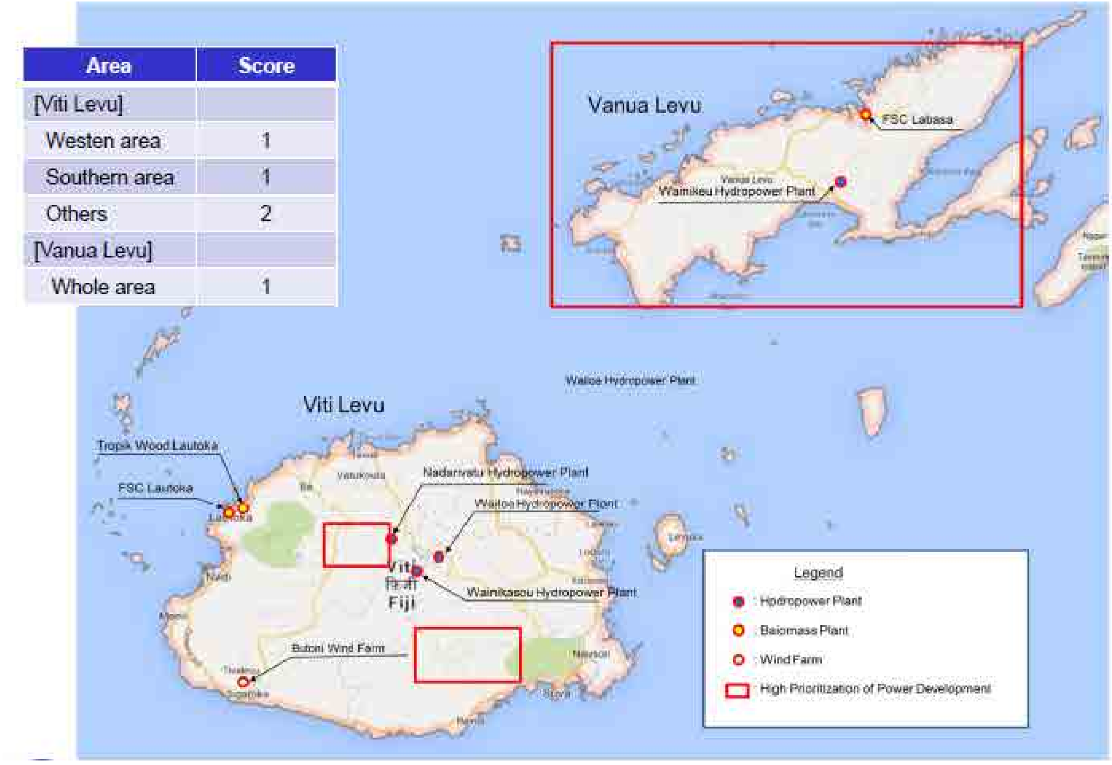


Figure 5.4.1-2 Prioritization of the Power Supply Reliability in Viti Levu and Vanua Levu

(3) Criteria for Priority Ranking

The criteria for priority ranking for the candidate hydropower potential sites consisted of four ranks - from AA to C - were defined as shown in Table 5.4.1-2.

Table 5.4.1-2 Criteria for Priority Ranking

Priority Rank	Criteria Screened
AA	It is economically superior, there is no significant natural / social environmental impacts and technical problems expected and priority power development area is high in Fiji.
A	It is economically superior and there are significant natural / social environmental impacts or technical problems expected.
B	It is economically feasible and there are significant natural / social environmental impacts or technical problems expected.
C	It is unfeasible and there are significant natural / social environmental impacts or technical problems expected.

(4) Priority Ranking

The Relationship between the priority rank, economic efficiency (benefit/cost (B/C)), primary evaluation score[1)] of environment, and power supply reliability score[2)] were defined as shown in Table 5.4.1-3.

1) Scores to express the expected negative impacts on the natural and social environmental conditions on Flora and Fauna Fish, and Resettlement Compensatory and Cultural Heritage.

2) Scores to express regional deference to the needs for new hydropower sources.

Table 5.4.1-3 Evaluation by Power Supply Reliability for Priority Ranking

Power supply reliability: 1		**Primary evaluation score of environment**		
		1.0 ≦ y < 1.5	*1.5 ≦ y ≦ 1.8*	*1.8 < x ≦ 2.0*
Benefit / Cost (B/C)	*x ≦ 1.0*	A	B	C
	1.0 < x < 1.3	AA	A	B
	1.3 ≦ x	AA	AA	A

Power supply reliability: 2		**Primary evaluation score of environment**		
		1.0 ≦ y < 1.5	*1.5 ≦ y ≦ 1.8*	*1.8 < x ≦ 2.0*
Benefit / Cost (B/C)	*x ≦ 1.0*	B	C	C
	1.0 < x < 1.3	A	B	C
	1.3 ≦ x	A	A	B

5.4.2 Priority Ranking for the Candidate Hydropower Potential Sites

Through the above-mentioned priority ranking procedure, the nine candidate hydropower projects are ranked as shown in Table 5.4.2-1.

Table 5.4.2-1 Ranking Evaluation of the Candidate Hydropower Projects

No.	Site	Type	P (kW)	Q (m^3/s)	He (m)	Annual Generated Energy (MWh)	Project Cost per Annual Energy Production (US$/kWh)	B/C	(1)Primary Evaluation Scores of Social/ Natural Environmental	(2)Priority of Hydropower Development Area	(3)Priority Rank
Viti Levu											
7	Nabiaurua	Run-of-river	1,400	0.85	216.9	8,197	1.17	1.2	1.2	1	**AA**
8	Mba1U/S	Run-of-river	9,200	15.0	74.7	24,836	1.15	1.2	1.2	1	**AA**
14	Naboubuco	Run-of-river	2,700	3.53	96.9	15,308	0.97	1.4	1.4	2	**A**
24	Nakavika	Run-of-river	2,600	7.17	45.7	14,205	1.45	0.9	1.9	1	**C**
26	Wainavadu	Run-of-river	2,500	3.23	97.04	13,749	1.28	1.1	1.8	1	**A**
28	Waisoi	Run-of-river	2,100	1.39	190.9	11,322	1.14	1.2	1.5	1	**A**
29	Wairokodra	Run-of-river	2,600	1.45	226.0	15,046	0.81	1.6	1.5	1	**AA**
Vanua Levu											
31	Saquru	Run-of-river	2,000	1.01	254.1	10,660	1.36	1.0	1.1	1	**A**
35	Wailevu	Run-of-river	2,000	3.23	76.1	10,563	1.14	1.2	1.5	1	**AA**

(1)Primary Evaluation Scores of Social/ Natural Environmental

Natural Environmental			Social Environmental			Average Score
Protected Area	Flora	Fauna Fish	Resettlement	Cultural Heritage	Others	
Notes: Expected negative impacts:			Major			3
			Unknown or can be mitigated			2
			No significant impacts			1

(2)Prioritization of Power Supply Reliability

Area		Score
Viti Levu	South	1
	West	1
	Other	2
Vanua Levu	Whole	1

(3) Priority Rank

Priority Rank	Criterion
AA	It is economically superior, there are no significant social / natural environmental impacts expected and priority power development area is high in Fiji.
A	It is economically superior and there are social / natural environmental impacts expected.
B	It is economically feasible and there are social / natural environmental impacts or technical problems expected.
C	It is uneconomical or there are significant social / natural environmental impacts or technical problems expected.

5.4.3 Selection of the Prospective Hydropower Potential Sites for Preliminary Design

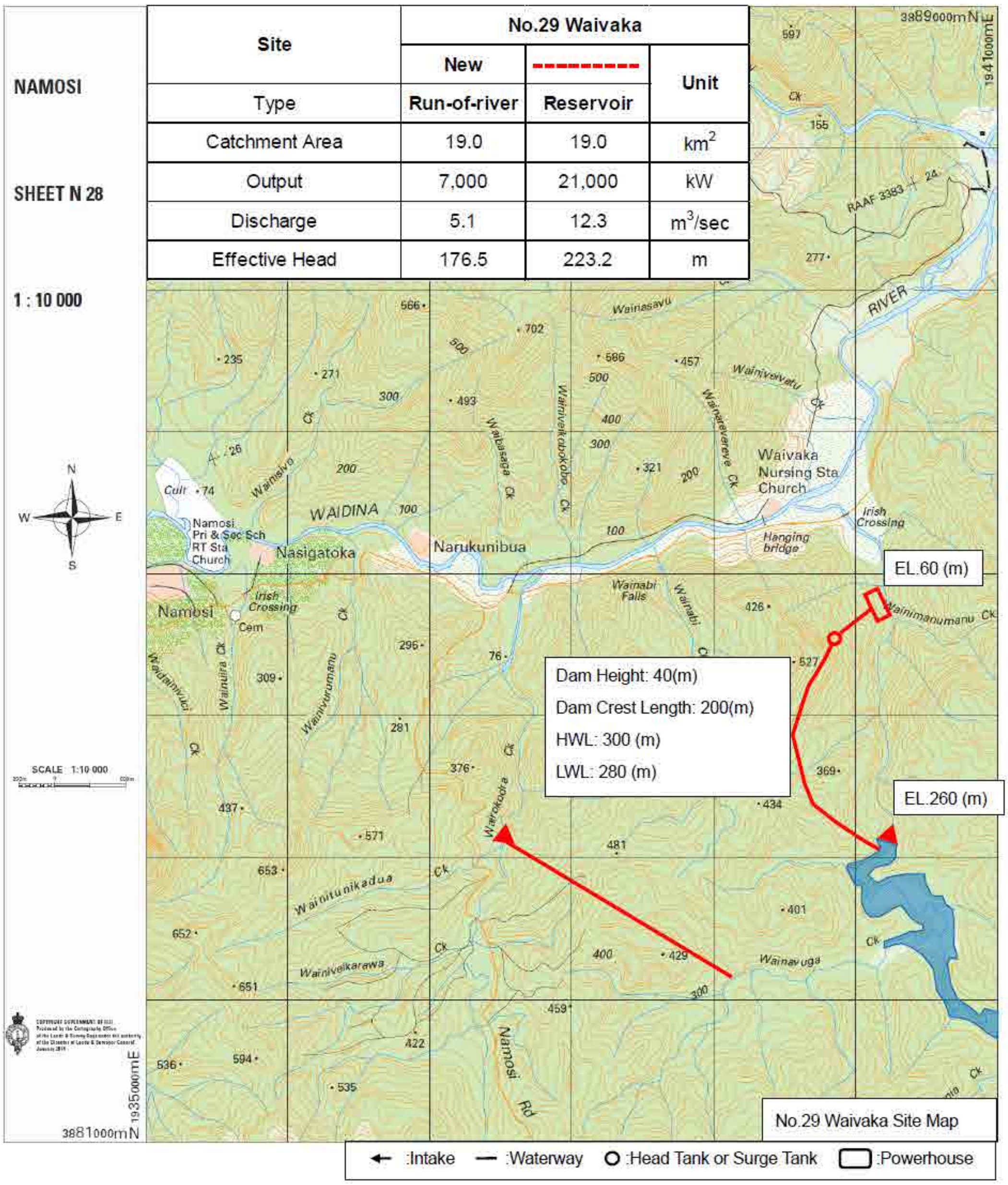
Considering the results of the ranking evaluation on the candidate hydropower projects as shown in Table 5.4.2-1, the selection of three prospective hydropower potential sites for preliminary design were discussed with FEA, DoE, and related organization at the 2nd Stake Holder Meeting. In conclusion, the three hydropower potential sites with a priority rank of "AA", as shown in Table 5.4.3-1, were selected as the prospective hydropower potential sites to be studied for preliminary design.

Table 5.4.3-1 Selection of the Prospective Hydropower Potential Sites

Project Site	Location	Maximum Output P(kW)	Maximum Discharge $Q(m^3/sec)$	Effective Head He (m)	Annual Electricity Generation GE (MWh)	evaluation indicators			Priority Rank	Targeted site for Preliminary Design
		P(kW)	$Q(m^3/sec)$	He (m)	(MWh)	B/C	primary evaluation environment	power supply reliability		
No.8 Mba 1 U/S	**West, Viti Levu**	**9,200**	**15.0**	**74.7**	**24,836**	**1.2**	**1.2**	**1**	**AA**	✓
No.29 Waivaka	**South, Viti Levu**	**7,400**	**5.12**	**176.5**	**15,046**	**1.6**	**1.5**	**1**	**AA**	✓
No.35 Wailevu	**South, Vanua Levu**	**2,000**	**3.23**	**76.1**	**10,563**	**1.2**	**1.5**	**1**	**AA**	✓
No.7 Nabiaurua	West, Viti Levu	1,400	0.85	216.9	8,197	1.2	1.2	1	AA	
No.14 Naboubuco	Central, Viti Levu	2,700	3.53	96.9	15,308	1.4	1.4	2	A	
No.24 Nakavika	South, Viti Levu	2,600	7.17	45.7	14,205	0.9	1.9	1	C	
No.26 Wainavadu	South, Viti Levu	2,500	3.23	97.04	13,749	1.1	1.8	1	A	
No.28 Waisoi	South, Viti Levu	2,100	1.39	190.9	11,322	1.2	1.5	1	A	
No.31 Saquru	East, Vanua Levu	2,000	1.01	254.1	10,660	1.0	1.1	1	A	

※) At first, DoE and FEA selected the No.29 Wairokodra Hydropower Scheme located in the Wairokodra river basin as the prospective hydropower potential site for to be studied for preliminary design. However, the JICA Project Team proposed that this should be changed to an alternative site for the No.29 site in order to increase the maximum capacity of the scheme. The maximum capacity is expected to be around 7 MW in the run-of-river type, while in the case of designing this plan as a reservoir type, the maximum capacity is expected to be over 20 MW. DoE and FEA agreed to the alternative plan for the No.29 site, which will be studied at preliminary design level.

The layout of alternative plan of No.29 is shown in Figure 5.4.3-1.



Site	No.29 Waivaka		Unit
	New	----------	
Type	Run-of-river	Reservoir	
Catchment Area	19.0	19.0	km^2
Output	7,000	21,000	kW
Discharge	5.1	12.3	m^3/sec
Effective Head	176.5	223.2	m

Figure 5.4.3-1 Layout of the Alternative Plan of the No.29 Site – Waivaka

Chapter 6 Preliminary Design of the Prospective Hydropower Potential Sites

6.1 Detailed Site Survey for the Preliminary Design of the No.8 Mba 1 U/S Hydropower Scheme

The No.8 Hydropower Scheme as a run-of-river type that was selected as a prospective hydropower potential site has a maximum output of 9.2 MW and annual generated energy of 24,836 MWh.

The scheme proposes intake water from the Ba River as the main river through the Savatu River in the west. Also the scheme plans to increase the power output and maximum discharge of the Nadarivatu Hydropower Station by using the river flow of both the Ba River and the Savatu River.

On the other hand, in consideration of demand from the Fijian side (such as for 90% renewable energy), the development of the future electricity demand situation and a large-scale hydroelectric power scheme, a detailed site survey for the preliminary design was carried out to confirm whether a reservoir type was possible with certain design conditions, such as the dam type, waterway route, and waterway type.

From the results of detailed site survey, the scheme plan was changed to a reservoir type. Basically, if the dam height was considered to be around 40m, it is assumed that there will be enough bedrock from geological and topographical conditions. A general layout plan is shown in Figure 6.1-1.

Figure 6.1-1 General Layout of the No.8 Hydropower Scheme (Reservoir Type)

6.2 Optimum Power Generation Plan for the No.8 Hydropower Scheme

The optimum power generation plan was prepared in line with the following steps.

Step 1: Hydrological and Meteorological Analysis

The design specifications for the scheme features such as the maximum discharge, duration curve, design flood, and sediment capacity for the reservoir type were determined based on collected hydrological and meteorological data. The hydrological and meteorological data were reviewed based on the results of the site reconnaissance.

Step 2: Setting the Development Scale

The development scale for the reservoir type was determined after the selection of the dam site, headrace route, and power station, which were considered in line with the geological and environmental conditions acquired from the results of the site reconnaissance and through using a 1/10,000 scale topographical map.

Step 3: Selection of Optimum Development Plan

The optimum development scale was determined from an economic point of view such as the benefit-cost ratio (B/C), net present value (B-C), and the index expressed as a construction cost per unit energy (USD/kWh).

6.2.1 Hydrological and Geological Analysis

(a). Hydrological and Meteorological Analysis

(1) **Collected Daily Discharge Data**

A hydrological gauging station is located on the Ba River between the Koro Gauging Station at the Kolo village and the Navala Gauging Station. The Koro Gauging Station, located near the No.8 Hydropower Scheme has reliable data only for 1990. On the other hand, the Navala Gauging Station has nine years of daily discharge data from 1983 to 1991. The analysis of the daily discharge data at the Koro Gauging Station was carried out by correlation analysis to restore the operation of the Navala Gauging Station. The hydrological data and location of the gauging stations on the Ba River are shown in Table 6.2.1-1 and Figure 6.2.1-1.

Table 6.2.1-1 River Discharge Data for the Ba river

Gauging Station	River	Period for Data Collection	CA(km^2)
1. Koro	Ba	1990	62
2. Navala	Ba	1983 - 1991	323

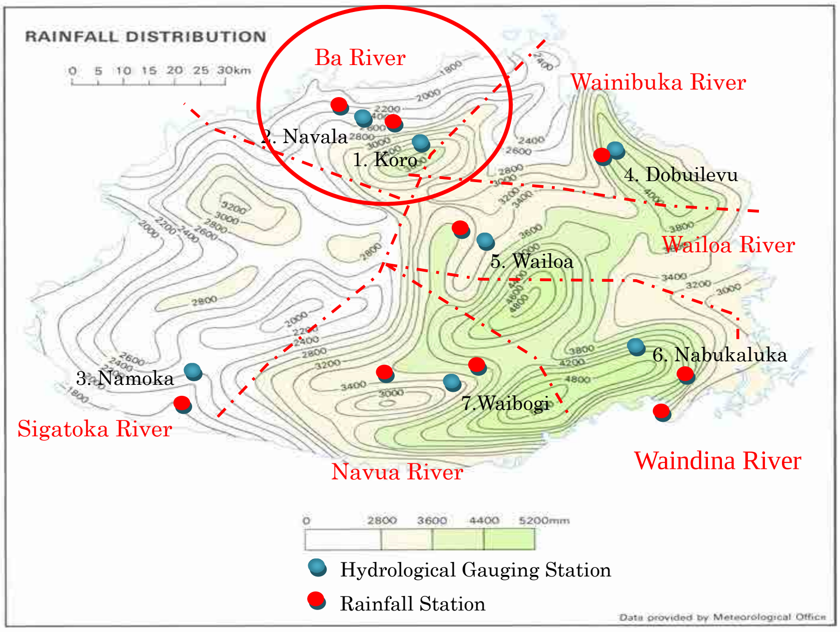


Figure 6.2.1-1 Main Metrological and Hydrological Gauging Stations in Viti Levu

(2) **Correlation Analysis**

The daily discharge data at the Koro Gauging Station during the said nine years (1983 - 1991) was estimated by correlation analysis using the hydrological data from the Koro and Navala stations to plot a duration curve for the No.1 Intake Weir and No.2 Dam Site. The results of the correlation analysis are shown in Figure 6.2.1-2. According to these results, the correlation was R^2=0.63 and R=0.79. The cause of the low correlation is considered to be due to the fact that there was a period of 47 loss days or period used one year only. The average daily discharge for the Koro Gauging Station during the said nine year period was estimated by correlation analysis and is shown in Table 6.2.1-2.

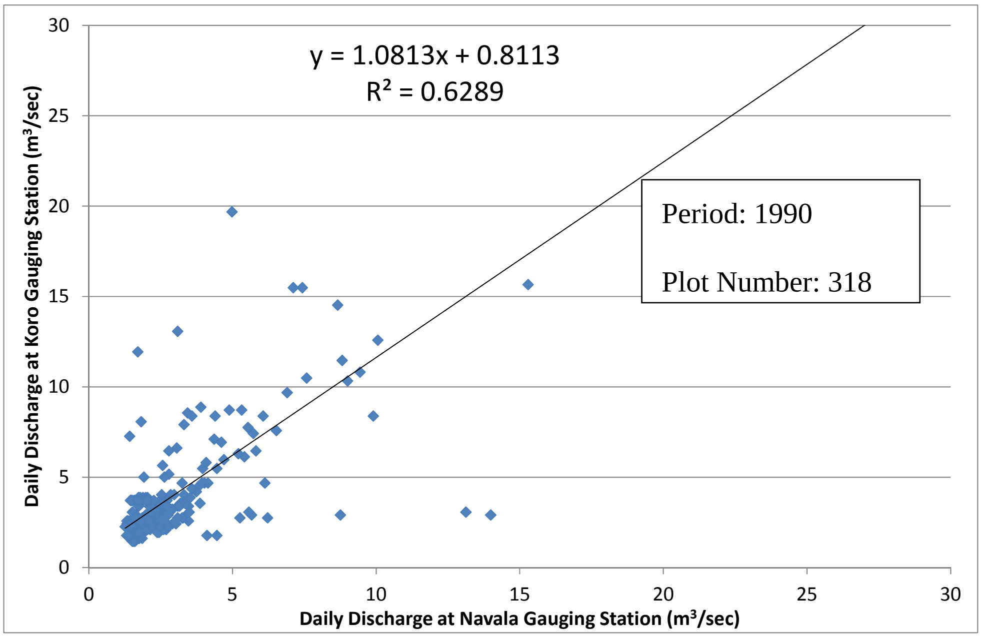


Figure 6.2.1-2 Results of the Correlation Analysis between Koro and Navala

Table 6.2.1-2 Average Daily Discharge Data for the Koro Gauging Station (1983 - 1991)

Mean Daily Discharge — Station No. HA062 — Station Name: Koro
CA : 62 km² — Ba River

Year: 1983-1991 — Unit: m³/sec

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	7.67	20.12	81.18	19.27	3.51	4.22	3.34	2.98	3.13	2.29	4.52	10.25
2	10.99	16.81	71.31	41.18	4.61	6.44	3.33	2.93	2.67	3.02	4.78	7.84
3	12.94	13.82	27.26	33.62	5.81	5.05	4.01	2.86	2.55	2.60	4.05	6.47
4	9.42	11.83	39.21	22.41	5.46	4.67	3.68	2.82	2.47	2.58	6.75	8.18
5	7.80	11.63	62.25	18.24	5.19	4.26	3.49	2.83	2.40	3.34	4.75	17.50
6	6.04	13.77	100.87	12.41	4.77	4.22	3.34	2.87	2.40	4.14	3.49	9.60
7	4.53	10.97	44.94	19.58	4.94	4.51	3.22	2.87	2.96	3.34	3.33	12.74
8	4.85	10.68	36.19	12.76	4.71	4.90	3.11	2.76	3.33	3.30	3.24	11.10
9	17.47	18.40	31.39	12.07	4.75	7.13	3.06	2.74	4.61	2.86	2.93	6.63
10	52.01	21.96	24.30	10.18	4.43	6.19	3.04	2.70	3.27	2.99	3.02	5.80
11	13.35	15.91	19.62	12.62	4.26	4.54	3.02	2.72	2.76	2.64	2.89	5.62
12	12.77	48.29	15.24	16.79	4.13	4.01	2.97	2.74	4.18	3.03	2.59	4.94
13	10.48	36.56	12.21	15.20	4.21	3.75	2.94	2.68	3.13	2.89	2.61	5.08
14	22.14	30.14	11.66	12.37	4.38	3.61	2.96	2.62	11.54	2.67	2.48	5.07
15	15.13	22.48	12.19	12.03	4.91	3.52	2.95	2.61	7.52	2.55	5.05	5.88
16	8.80	17.09	16.21	9.56	4.76	4.34	4.84	2.65	2.51	3.04	4.83	5.17
17	19.74	17.35	56.68	7.09	4.69	11.50	4.09	2.65	3.53	2.81	4.43	5.84
18	26.43	30.08	65.67	6.39	4.19	15.85	3.16	2.63	3.49	3.34	5.00	6.45
19	34.94	21.29	30.15	5.90	4.06	6.91	2.99	2.61	3.58	3.36	4.99	8.52
20	21.63	22.29	20.74	5.60	3.88	4.85	2.93	3.17	3.21	4.31	5.30	7.18
21	10.82	24.87	23.75	5.77	4.02	4.18	2.92	2.94	2.79	3.52	5.64	6.70
22	9.82	28.60	25.37	5.50	3.88	4.70	2.85	2.84	2.66	2.93	5.40	5.42
23	10.37	19.94	45.09	5.23	13.84	5.30	2.82	2.79	2.59	2.96	5.34	5.39
24	8.40	13.71	12.87	5.02	6.19	4.18	2.82	4.16	2.66	2.94	5.02	5.88
25	7.13	18.78	11.22	5.57	4.78	3.98	2.76	4.10	2.61	2.58	4.20	4.89
26	5.86	23.24	14.97	12.53	4.16	3.59	3.88	3.50	2.45	2.55	4.57	5.95
27	5.37	19.13	12.82	5.24	4.61	3.45	3.75	2.90	2.38	4.00	4.60	4.99
28	8.63	35.48	9.81	6.97	5.32	3.38	3.20	2.82	2.46	3.96	3.49	5.15
29	9.98	8.95	8.62	6.84	4.88	3.30	3.00	3.66	2.41	2.96	6.76	4.63
30	14.84		11.93	6.26	4.90	3.24	2.92	3.39	2.32	2.82	7.69	4.43
31	10.30		13.41		4.42		2.81	2.93		3.99		7.26
Min	4.53	8.95	8.62	5.02	3.51	3.24	2.76	2.61	2.32	2.29	2.48	4.43
Mean	13.57	20.83	31.26	12.34	4.92	5.13	3.23	2.95	3.35	3.11	4.46	6.99
Max	52.01	48.29	100.87	41.18	13.84	15.85	4.84	4.16	11.54	4.31	7.69	17.50

(3) Daily Discharge of the Existing Nadarivatu Hydropower Plant (HPP)

a. Collection Period for the Operation Data

The operation data of the Nadarivatu HPP, including daily output and power generation from May 2012 to 8 July 2014 was collected by FEA. The data collection periods is shown in Table 6.2.1-3.

Table 6.2.1-3 Data Collection Period for the Operation Data

Hydropower Station	Organization	Collection Period	Collected Data
Nadarivatu HPP	FEA	2012 - 2014	Power Output (MW) Power Generation (MWh)

b. Daily Discharge from the Existing Nadarivatu HPP

Regarding the daily discharge from the existing Nadarivatu H.P.P, this is estimated by a proportional conversion based on the relationship of the maximum output (42 MW) and maximum discharge (15 m^3/sec). The example calculation of the daily outflow is shown below.

(Calculation Formula)	(Example of Calculation)
Q=Qm x T / 24	Qm=15.0
T= Gm / Pm	(Qm=0.3571 x 44 = 15.0)
Where,	T=880/42=21 hr
Q: Estimated daily discharge	Gm=880 MWh
Qm: Discharge during operation	Pm=42 MW
(Qm= 0.3571 x Pm)	※Q=15 x 21/24=13.1 m^3/sec
T: Operation time	
Gm: Power Generation	
Pm: Power Output	

c. Results

From utilizing the above methods, the average daily discharge during a three year period (2012 - 2014) is shown in Table 6.2.1-4 .

Table 6.2.1-4 Average Daily Outflow from the Existing Nadarivatu Hydropower Plant (2012-2014)

Mean Daily Discharge   Station No.   Station Name Hydropower Scheme
CA : km^2 Ba River
Year: 2012-2014   Unit: m^3/sec

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	5.57	8.28	9.87	8.73	6.57	4.75	0.89	0.77	0.00	1.43	1.05	0.71
2	3.75	5.92	5.28	5.88	6.07	5.35	2.11	0.19	0.85	0.71	0.64	1.86
3	3.60	7.73	7.15	4.15	1.55	5.18	2.66	0.13	0.48	1.90	0.07	1.43
4	3.00	9.36	8.80	3.61	1.62	4.34	2.21	0.15	1.67	0.24	1.04	1.18
5	5.64	6.51	9.11	1.94	2.72	2.92	0.68	0.93	0.71	0.73	1.12	1.76
6	6.62	9.41	9.36	2.66	3.22	2.06	0.42	0.99	0.00	0.83	1.67	1.76
7	8.24	9.08	8.94	3.02	2.41	1.96	0.51	0.85	0.01	1.23	3.01	2.08
8	14.54	9.77	7.90	3.86	2.89	1.09	1.18	1.47	0.26	1.10	1.76	1.86
9	11.74	7.23	7.94	2.91	2.70	3.16	0.68	0.96	0.45	0.24	1.65	1.39
10	5.91	10.34	10.38	4.84	0.96	2.43	1.57	0.40	0.54	0.01	2.52	3.80
11	3.57	11.13	9.14	3.51	0.34	1.81	1.29	0.00	0.30	0.25	1.42	4.53
12	3.60	9.19	8.96	1.22	2.19	1.55	1.23	0.81	0.65	0.24	1.59	4.90
13	4.72	9.42	10.12	1.25	2.14	2.89	0.38	0.72	0.15	0.16	2.55	3.94
14	5.39	8.99	10.63	2.41	2.07	6.95	0.30	0.63	0.25	0.33	1.03	2.77
15	7.59	9.07	14.15	2.82	1.09	4.55	1.05	0.53	1.41	0.31	1.25	0.85
16	5.89	8.67	14.12	3.31	1.34	3.13	0.98	0.00	0.43	0.89	0.04	2.26
17	7.88	8.71	13.66	2.57	4.56	2.67	0.40	0.56	1.43	1.69	0.31	3.17
18	7.05	8.71	10.74	1.41	4.82	2.43	0.97	0.00	0.62	4.95	2.55	2.09
19	3.56	10.53	11.20	2.09	3.23	2.10	0.35	0.65	1.15	2.16	3.82	4.04
20	5.29	14.10	8.57	0.00	2.92	2.27	0.51	0.61	0.46	1.99	1.74	8.50
21	4.91	10.23	5.88	0.00	2.55	2.29	0.58	1.12	0.04	3.53	1.58	9.18
22	2.80	14.24	5.83	3.21	3.06	0.93	0.98	1.03	0.01	2.34	1.16	8.08
23	2.75	9.90	4.89	2.58	2.91	0.72	1.06	0.27	0.96	1.47	1.50	4.71
24	1.71	11.63	7.96	2.07	0.99	2.44	0.53	0.42	1.01	1.57	1.21	4.52
25	2.66	12.51	6.59	1.86	0.00	0.97	0.81	0.09	0.29	1.22	1.94	1.81
26	2.27	13.62	5.47	0.81	1.10	1.77	0.51	0.43	3.11	1.07	2.00	2.19
27	2.26	12.47	7.01	0.91	3.11	1.66	0.00	0.54	2.58	3.91	1.46	2.64
28	1.92	11.88	6.16	1.75	4.68	1.29	0.32	0.45	0.64	1.65	1.54	2.36
29	5.98	0.00	4.49	2.14	1.96	0.96	0.72	0.52	0.76	1.13	0.96	2.42
30	8.38		6.88	2.74	2.51	1.44	0.38	0.68	0.29	1.01	1.08	2.23
31	8.76		8.99		4.25		1.04	0.10		1.31		1.26
Min	1.71	0.00	4.49	0.00	0.00	0.72	0.00	0.00	0.00	0.01	0.04	0.71
Mean	5.41	9.61	8.59	2.68	2.66	2.60	0.88	0.55	0.72	1.34	1.51	3.11
Max	14.54	14.24	14.15	8.73	6.57	6.95	2.66	1.47	3.11	4.95	3.82	9.18

(4) **The Inflow Duration Curves at the No.1 IntakeWeir and the No.2 Dam Site.**

The inflow duration curve of the average daily discharge plotted between the restored Koro Gauging Station and the existing Nadarivatu Hydropower Plant was prepared using a basin conversion for the catchment area of 50.9 km^2 at the No.1 Intake Weir and 33km^2 at the No.2 Dam Site. The inflow duration curves at the No.1 Intake Weir (red Curve) and the No.2 Dam Site (blue Curve) are shown in Figure 6.2.1-3.

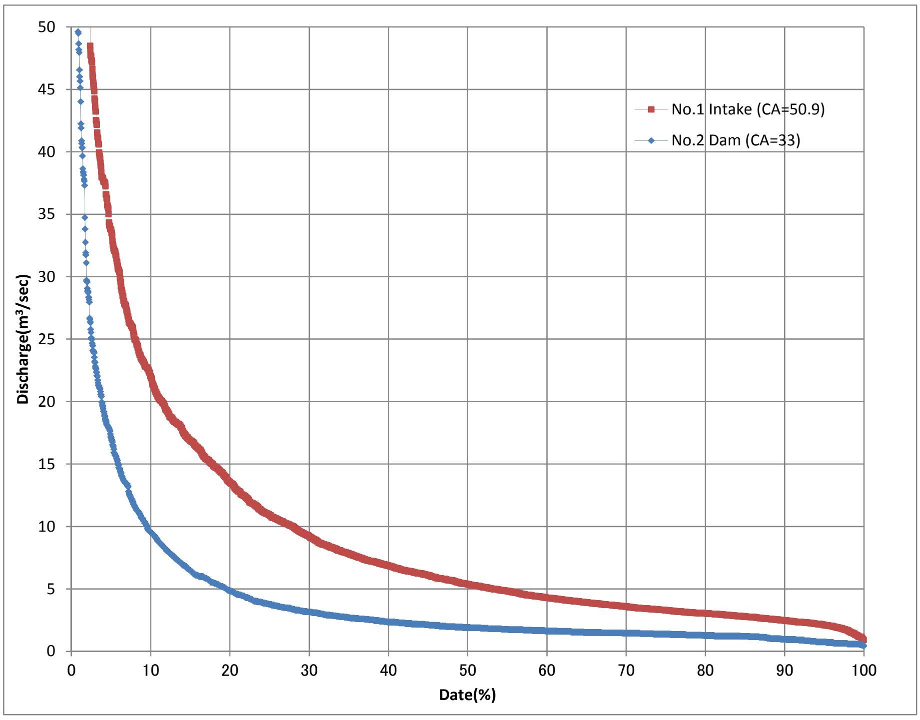


Figure 6.2.1-3 Inflow Duration Curves at the No.1 Intake Weir and the No.2 Dam Site

(5) **Flood Analysis**

The flood analysis was estimated using the logarithmic normal distribution method. The flood discharge data was collected from 1983 until 1991 using hydrological data. The maximum discharge from 1983 to 1991 is shown in Table 6.2.1-5.

Table 6.2.1-5 Maximum Discharge from the No.8 Hydropower Scheme at the No.2 Dam Site from 1983 to 1991

Year	Month	Day	Q	Log Q
1983	3	2	232.83	2.3670
1984	3	18	228.87	2.3596
1985	3	6	370.39	2.5687
1986	3	8	94.27	1.9744
1987	3	19	58.30	1.7657
1988	3	4	125.17	2.0975
1989	2	12	141.34	2.1503
1990	3	23	159.21	2.2020
1991	1	10	199.54	2.3000
			Average u	2.1983
			Standard Deviation σ	0.2376

Through using a normal distribution to indicate floods (below), the following flood probabilities were calculated statistically.

u+3.09σ=0.1% (1000 year probability)
u+2.88σ=0.2% (500 year probability)
u+2.58σ=1% (200 year probability)
u+2.32σ=1% (100 year probability)
u+2.05σ=2% (50 year probability)
Where, u=2.1983 σ=0.2376

The probability of a 1,000 year flood was calculated as follows.

$u+3.09\sigma=2.1983+3.09*0.2376=2.9324$, $10^{2.9324}=856m^3/s$

The results of the flood probability analyss at the No.1 Intake Weir and No.2 Dam are shown in Table 6.2.1-6.

Table 6.2.1-6 Results of the Flood Probability Analysis at the No.1 Intake Weir and the No.2 Dam

	CA (km^2)	1000 year	500year	200year	100 year	50 year
No.1 Intake Weir	140.3	1,405	1,254	1,036	887	754
No.2 Dam	33.0	856	772	648	562	485

(6) **Estimation of the Sedimentation Capacity**

By using the calculation formula below, the 100 year sedimentation capacity of the dam site was estimated to be $825,000m^3$. Therefore, the sedimentation level was determined as El.170 m.

(Calculation Formula)

Vs = qs x CA x 100
Where,
Vs: The 100 year sedimentation capacity (m^3)
qs: 0.25 mm/year(: Proceeding of the Fiji Symposium, June 1990, Erosion and sedimentation in Fiji – An overview)
CA: Catchment area at dam site (33.0 km^2)

(b). Geological Condition

The detailed general geological and engineering geological data for the main structures such as the intake, dam, connection tunnel, headrace tunnel, penstock and powerhouse, are shown in Appendix 6-1-1 (No.8 Mba 1 U/S Hydropower Scheme in the VoL. III APPENDIX).

6.2.2 Conditions for the Calculation of the Power Generation

(1) **No.1 Intake Discharge**

The No.1 Intake Weir that is located downstream of the Nadarivatu Hydropower Plant should be planned so as not to affect the height of the tail water level EL.191.4 m of the existing Nadarivatu Hydropower Station. Among the conditions, the maximum discharge was calculated to be 18m3/sec. The discharge range of the No.1 Intake Weir is shown in Figure 6.2.2-1.

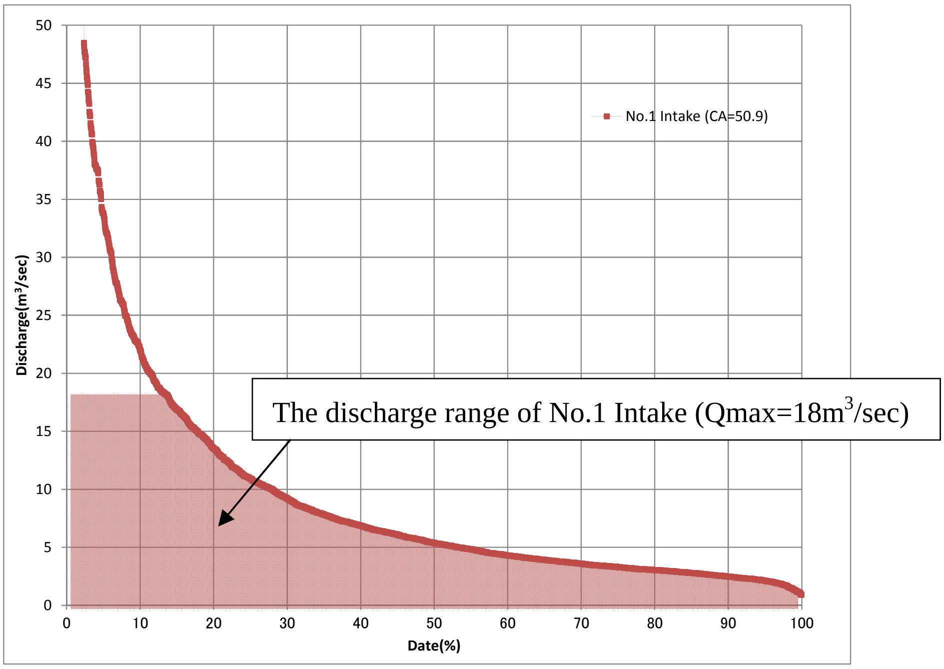


Figure 6.2.2-1 Discharge Range of the No.1 Intake Weir

(2) **The Inflow Duration Curve at Dam Site (Total Inflow)**

The duration curve was prepared for a catchment area of 83.9 km^2 at the dam and intake site. The average discharge at the dam site was assumed to 12.68 m^3/sec. The duration curve is shown in Figure 6.2.2-2. Average daily discharge (1983 - 1991) is shown in Table 6.2.2-1.

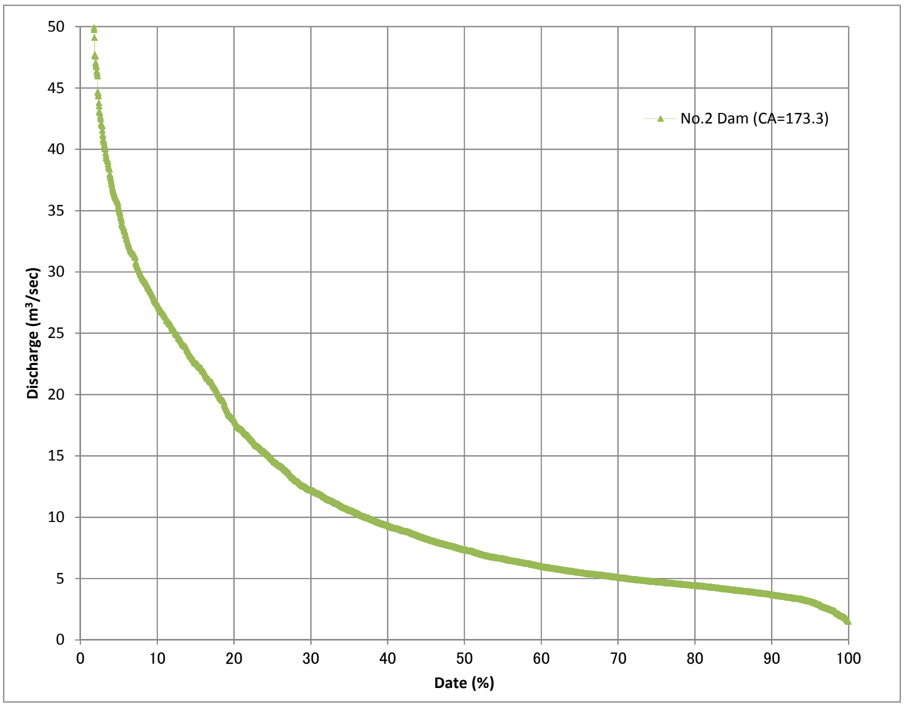


Figure 6.2.2-2 Duration Curve at the No.8 Mba US1 Hydropower Scheme (1983 - 1991)

Table 6.2.2-1 Average Daily Discharge at the No.8 Mba US1 Hydropower Scheme (1983 - 1991)

Mean Daily Discharge Station No. Station Name: No.2 Dam
CA : 83.9 km^2 Ba River
Year: 1983-1991 Unit: m^3/sec

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	15.94	26.81	59.28	26.89	11.32	10.46	5.42	4.80	4.24	4.53	7.17	13.42
2	16.70	24.72	52.41	36.69	12.31	12.95	6.61	4.16	4.46	4.79	7.11	12.46
3	18.53	23.09	29.70	31.76	9.41	11.92	8.08	4.00	3.93	5.42	5.55	10.18
4	15.47	21.59	36.75	26.14	9.01	10.67	7.19	3.97	5.02	3.74	9.02	12.19
5	15.63	19.33	49.42	23.05	9.74	8.68	5.39	4.77	3.96	5.25	7.55	20.44
6	14.55	22.57	70.18	18.99	9.68	7.77	4.95	4.87	3.25	6.43	6.40	13.56
7	14.37	20.55	40.22	22.29	9.09	8.06	4.87	4.73	4.02	5.75	7.52	16.47
8	20.21	21.53	35.61	18.04	9.26	7.72	5.39	5.21	4.77	5.56	6.15	14.09
9	24.87	25.06	32.87	16.11	9.12	11.95	4.82	4.67	6.69	4.11	5.62	10.35
10	38.02	28.08	30.06	16.36	6.96	10.59	5.68	4.06	4.97	4.06	6.60	11.65
11	16.04	25.81	26.79	17.78	6.10	7.95	5.38	3.69	4.04	3.82	5.33	12.14
12	16.72	42.45	24.22	18.41	7.77	6.97	5.25	4.52	6.30	4.34	5.09	11.58
13	15.75	36.34	23.40	18.58	7.83	7.96	4.35	4.34	4.39	4.07	6.08	10.81
14	23.29	32.22	23.03	18.62	8.00	11.84	4.30	4.18	10.95	3.94	4.38	9.63
15	20.92	28.45	24.20	17.88	7.74	9.32	5.04	4.06	9.72	3.75	7.94	8.81
16	15.47	25.65	26.32	15.23	7.77	9.01	7.53	3.58	3.83	5.00	6.57	9.25
17	24.48	25.91	47.81	12.17	10.91	13.55	5.93	4.14	6.20	5.49	6.31	11.07
18	27.90	32.41	51.63	10.05	9.89	16.86	5.25	3.56	5.35	9.48	9.32	10.82
19	30.43	27.90	32.94	10.07	8.32	11.13	4.39	4.18	5.99	6.70	10.57	13.58
20	24.14	29.49	27.44	7.58	7.81	8.83	4.48	4.89	4.80	7.82	8.91	16.95
21	18.06	29.82	27.97	7.81	7.66	7.94	4.54	5.10	3.82	8.29	9.22	17.37
22	15.06	32.94	29.02	10.66	7.92	7.29	4.83	4.87	3.61	6.30	8.47	15.41
23	14.34	27.46	38.53	9.66	14.29	7.88	4.88	4.05	4.47	5.47	8.73	12.01
24	12.09	24.35	22.61	8.86	8.76	8.10	4.35	6.05	4.61	5.55	8.01	12.48
25	12.29	27.53	20.75	9.40	6.47	6.36	4.54	5.63	3.82	4.71	7.62	8.42
26	10.20	30.35	22.53	13.87	6.73	6.63	5.76	5.16	6.42	4.52	8.20	10.24
27	9.53	27.78	21.63	8.00	9.36	6.33	5.07	4.46	5.80	9.32	7.68	9.40
28	13.44	35.92	18.90	11.07	11.50	5.87	4.65	4.27	3.97	7.02	6.27	9.33
29	18.26	12.11	16.15	11.25	8.57	5.42	4.78	5.47	4.01	5.13	10.06	8.69
30	22.54		20.60	11.22	9.14	5.83	4.33	5.27	3.43	4.83	11.38	8.23
31	20.37		22.67		10.23		4.83	4.06		6.71		11.09
Min	9.53	12.11	16.15	7.58	6.10	5.42	4.30	3.56	3.25	3.74	4.38	8.23
Mean	18.57	27.18	32.44	16.15	8.99	9.06	5.25	4.54	5.03	5.55	7.49	12.00
Max	38.02	42.45	70.18	36.69	14.29	16.86	8.08	6.05	10.95	9.48	11.38	20.44

(3) **Reservoir Capacity**

The reservoir capacity was estimated based on the 1/10,000 scale maps and water level. The storage curve is shown in Figure 6.2.2-3.

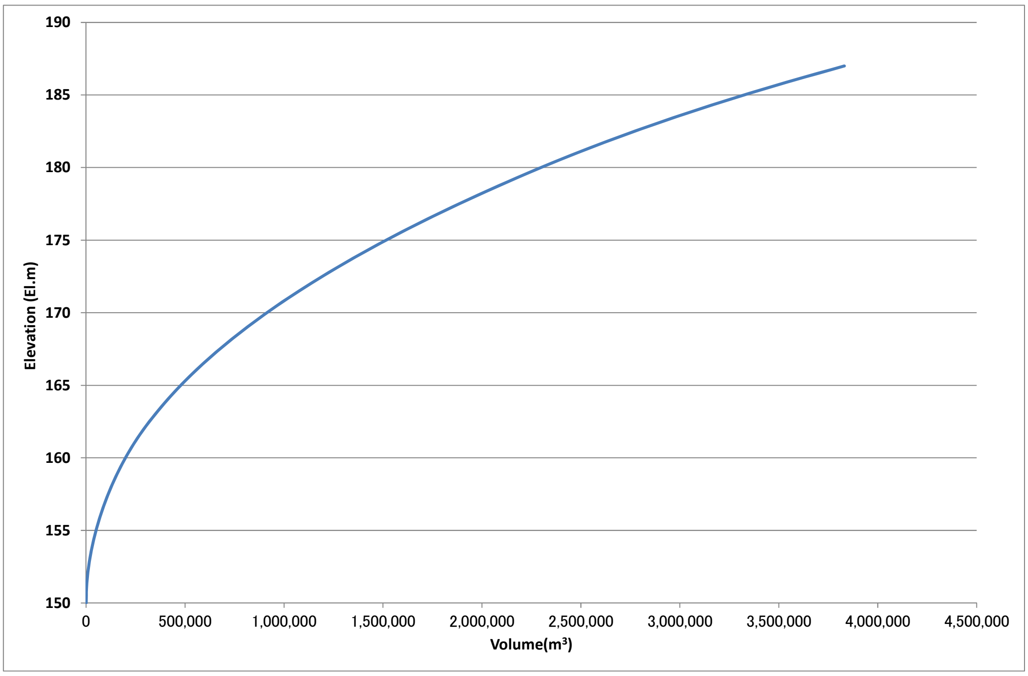


Figure 6.2.2-3 Storage Curve (Scale: 1/10,000)

(4) **Water Level at the Dam Site**

The high water level ("HWL") in consideration of the outlet elevation of the No.1 Waterway was determined as EL.187m.

In order to prevent air from getting inside the tunnel, the minimum water level was determined as EL.175m – this enabled the setting of a position of 1.5 times the length of the pressure tunnel's inner diameter from the sediment level (EL.169 m).

(5) **Optimal Storage Capacity**

The optimal storage capacity was estimated by using the average monthly discharge data from 1983 to 1991 at dam site in order to calculate the available depth of the reservoir. The results of the optimal storage capacity are shown in Table 6.2.2-2 and Figure 6.2.2-4.

The result of the optimal storage capacity was 112,000,000 m^3. However in the case of the No.8 Hydropower Scheme, the storage capacity with dam water level should not affect the tail water level at the existing Nadarivatu Hydropower Plant. In consideration of the above condition, the storage capacity was determined to be around 2,300,000m^3 as shown in the HWL and LWL relationship with the storage curve mentioned above.

Table 6.2.2-2 Results of the Optimal Storage Capacity by Using the Average Annual Discharge

Month	Day	River Discharge Qi	Monthly Storage Capacity	Qi-Qave	Cumulative Storage Capacity ΣQi-Qave
		(m^3/sec)	(m^3)	(m^3/sec)	(m^3)
1	31	18.57	15,755,688	5.88	15,755,688
2	29	27.18	36,312,408	20.38	51,051,600
3	31	32.44	52,905,096	40.13	107,477,496
4	30	16.15	8,974,800	43.59	112,985,280
5	31	8.99	-9,903,384	39.89	106,848,072
6	30	9.06	-9,402,480	36.27	93,998,880
7	31	5.25	-19,920,600	28.83	77,211,576
8	31	4.54	-21,822,264	20.68	55,389,312
9	30	5.03	-19,848,240	13.02	33,754,320
10	31	5.55	-19,117,080	5.89	15,762,384
11	30	7.49	-13,471,920	0.69	1,782,000
12	31	12.00	-1,841,400	-0.00	-0
Average		12.69			

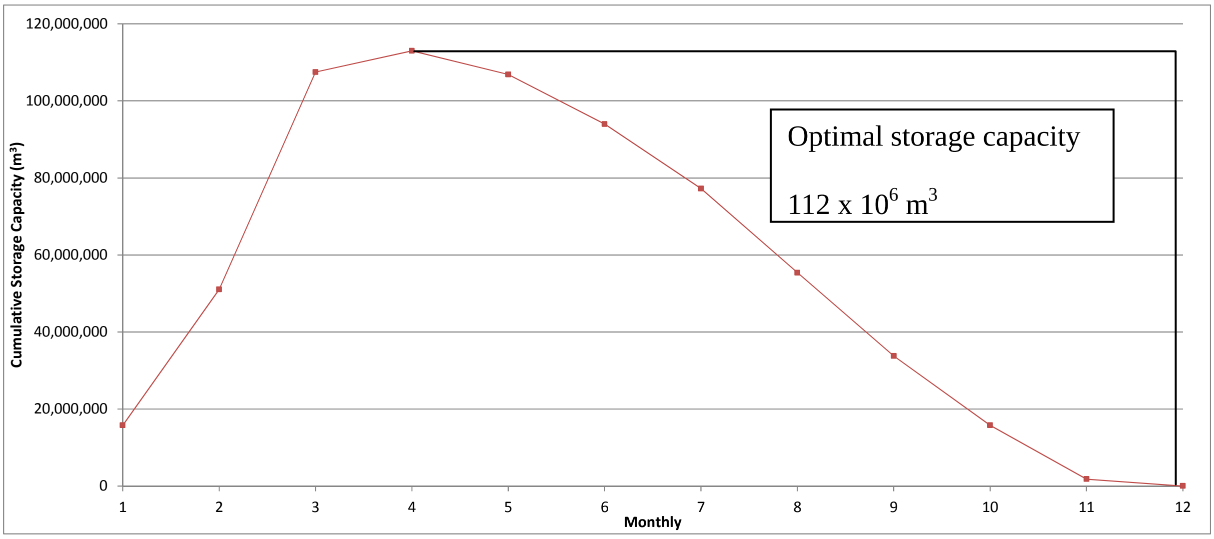


Figure 6.2.2-4 Optimum Storage Capacity Curve

(6) **Combined Efficiency of the Turbine and the Generator**

In this study, the combined efficiency of the turbine and the generator was uniformly 0.85.

(7) **Tail Water Level**

Through using a 1/10,000 scale, the tail water level at the power station site was assumed to be EL.110m.

6.2.3 Calculation of the Power Generation

The No.8 Hydropower Scheme is available for operation during peak times using storage capacity. The maximum plant discharge can be increased to a few times higher than the firm discharge by setting the storage capacity appropriately. In this study, the firm discharge was set as the average discharge of the dry season in consideration of the difference 27.9m^3/sec in the discharges between the dry and rainy seasons. The relationship between the firm discharge and operation time is mentioned below.

$Q_p = Q_f$ x 24hour / T_f
Q_p : Maximum plant discharge (m^3/s)
Q_f : Firm discharge during dry season (m^3/s)
T_f : Operation time is 6 hours

The monthly power generation is calculated based on the monthly discharge and the monthly operation time using the following formula. And the annual power generation is calculated as the sum of the relevant monthly power generation figures.

$G_{date} = 9.8 \times Q_p \times He_{date} \times \eta_{date} \times T_{fdate}$
G_{date} : Monthly Generated Energy

Q_p : Maximum plant discharge(m^3/s)
He_{date} : Effective head for monthly operation water level (m)
η_{date} : Combined efficiency of turbine and generator (%)
T_{fdate} : Peak and off peak operation time(6 hour and 18 hours)

6.2.4 Estimated Construction Costs

The construction costs were estimated based on the “Guideline and Manual for Hydropower Development Vol.1 Conventional Hydropower and Pumped Storage Hydropower” (issued by JICA). The unit cost was quoted in terms of the hydropower renewable energy development project in the Wailoa downstream in the Republic of the Fiji Islands and current, similar hydroelectric development projects in Asian countries.

The construction costs were separated into the direct costs and the indirect costs. The direct costs consist of the preparation works and main construction works, such as civil structures, hydro mechanical works, electromechanical equipment, and transmission lines. The indirect costs consist of administration, engineering service fees, and other contingency costs. The indirect costs are calculated by ratio from the direct costs.

6.2.5 Optimum Development Scale

The optimum development scale was determined with economic evaluation by setting the maximum output in five cases. The peak operation time is eight hours on weekdays and one hour on Saturdays and Sundays; the firm discharge is considered to be 5.22 m3/sec – the relationship between the discharge and the gross storage capacity during the dry season from August to September.

Therefore, in consideration of the firm discharge, the maximum output was set from 11MW, 12MW, 13MW, 14MW, 15MW.

The economic evaluation of the optimum development scale was determined by a comprehensive evaluation based on the benefit-cost ratio (B/C), net present value (B-C), and the index expressed as a construction cost per unit energy (USD/kWh). As an economic value, a diesel power plant was selected as an alternative thermal power generation using diesel plants in Fiji. The hydropower capital recovery coefficient and kW and kWh values were confirmed by relative organization and were carried out based on the same conditions of the hydropower renewable energy development project in the Wailoa downstream. The conditions for the B/C calculation are mentioned below.

The conditions for the B/C calculation:
KW Value：175.3USD/kW
KWh Value：0.144USD/kWh
Hydropower capital recovery coefficient：0.11226
KW correction factor：1.21, kWh correction factor：1.03

The optimum development scale for reservoir type is shown in Table 6.2.5-1.

Table 6.2.5-1 Optimum Development Scale of the No.8 Hydropower Scheme

Case	Unit	1	2	3	4	5
Maximum Output	kW	11,000	12,000	13,000	14,000	15,000
Maximum Discharge	m^3/sec	18.81	20.52	22.23	23.94	25.65
Firm Output	kW	9,408	10,263	10,617	10,617	10,617
Annual Power (Peak time)	MWh	53,754 (22,973)	55,232 (25,062)	56,389 (26,664)	57,842 (28,060)	59,367 (29,474)
HWL	EL.m	187				
TWL	EL.m	110				
Gross Head	EL.m	183.6				
Pressure Tunnel	m	2,000				
Penstock	m	380				
Construction Cost	10^3 x USD	62,366	64,206	65,922	67,702	69,747
B/C		1.34	1.35	1.35	1.34	1.33
B-C	10^6 USD	2.39	2.54	2.58	2.59	2.58
Construction Cost per unit Energy	USD/kWh	1.16	1.16	1.17	1.17	1.17

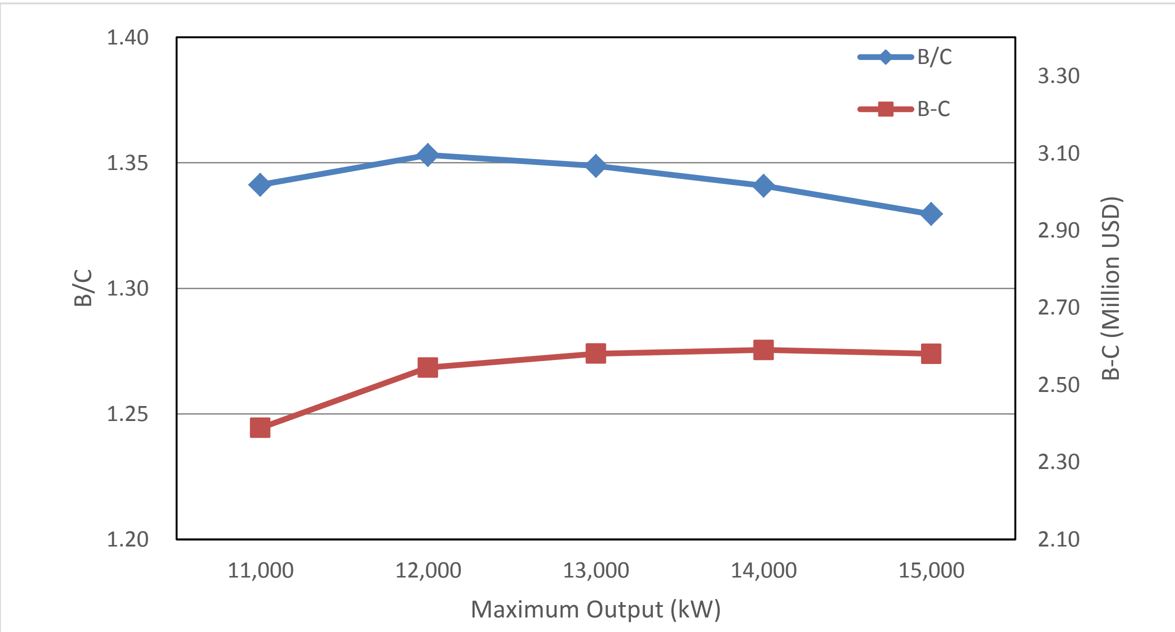


Figure 6.2.5-1 Results of the Economic Evaluation by B/C and B-C

6.2.6 Optimum Development Plan

The optimum development plan was evaluated from an economic point of view, using the benefit-cost ratio (B/C), net present value (B-C), and the index expressed as a construction cost per unit energy (USD/kWh). Following this the most economic maximum output was selected.

From the results of the economic comparison on the case shown in the table, the following considerations were provided.

(1) Case 2 and Case 3 have the highest economic values with a benefit-cost ratio (B/C) of 1.35. Case 4's B/C is almost equivalent to these.

(2) Case 4 has the highest economic value with a net present value (B-C) of 2.59.

(3) All the Cases have a highest economical index of around 1.16 to 1.17USD/kWh.

Therefore, it was assessed that Case 4 was the most advantageous for the project's optimum development plans.

The main features for the optimum development plan are shown in Table 6.2.6-1.

Table 6.2.6-1 Main Features for the Optimum Development Plan

Item	Unit	Features
Catchment Area	km^2	83.9
Type		Reservoir
Maximum Output	kW	14,000
Maximum Discharge	m^3/sec	23.94
Firm Output	kW	10,888
Dam height	m	42.0
High Water Level	EL.m	187
Low Water Level	EL.m	175
Tail Water Level	EL.m	110
Sediment Level	EL.m	170
Foundation Level	EL.m	150
Gross Head	m	77.0
Effective Head	m	72.04
Pressure Tunnel	m	2,000
Penstock	m	380

6.3 Basic Design of the Hydropower Plant (No. 8 Mba 1 U/S site)

6.3.1 Basic Design of the Hydropower Plant (No. 8 Mba 1 U/S site)

Based on the results of the optimum development scale for the No.8 Hydropower Scheme, the preliminary design for a reservoir type was carried out for the main structure using the following characteristics: the Ba River for the No.1 Intake Weir with an operated discharge from the existing Nadarivatu Hydropower Station; and the Savatu River for the No.2 Dam site with a 14MW output.

The main structure's facilities consist of: the No.1 Intake Weir, the sand trap, the waterway for connection to the main scheme, the No.2 Dam, the pressure tunnel, the surge tank, the penstock, and the power station.

The main structure's facilities were designed as follows.

6.3.1-1 No.1 Intake Weir

A natural overflow type for the intake weir was selected, as this is a simple facility with low costs compared with a gate type. The intake weir, located on the existing Nadarivatu Hydropower Station upstream, has a maximum tail water level of EL.191m. Therefore, the NWL shall be considered to be lower than EL.191m. There are good rock conditions around the concrete dam with about a 5m height beside the intake weir. The intake weir was designed to be 4m in height from the foundation, and the NWL was selected, in light of the above conditions, as having EL.190m and a crest length of 60m.

6.3.1-2 No.1 Intake

The intake is located in the right bank to connect the waterway, which has the objective of handling the reservoir's outflow. The standard inflow sill velocity of the intake would be between 0.30m/s to 1.0m/s. The intake of the project site was determined to have a large discharge of 1.0 m/s. The dimensions of the intake were set as being 4.5m wide and 2.0 m high with two gates. The sill level of the intake was determined as El.188m to prevent the inflow of sediment into the intake.

6.3.1-3 Sand Trap

The sand trap is a facility for the precipitation removal of sediment flow. The velocity of the sand trap has to be less than 0.3 m/s to remove the sediment flow by means of the settling basin. The distance of the sand trap would be needed to settle the fine sand in the bottom at end of the basin from intake. The main features of the sand trap are shown below.

Dimension : 17m wide x 22m long x 3.5 m depth
Average velocity : 0.31 m/s
Length of sand trap : 10.6 m

The accumulated sediment in the sand trap would be collected in one place by a slope of gradient 1/22 at the bottom of the basin (i.e. in order to be removed by the sand).

6.3.1-4 Connection Tunnel

For the cross section of the connection tunnel for the non-pressure tunnel to connect to the No.2 Dam site reservoir, a standard horse-shoe type cross section adopted due to its strength with regard to external loading as well as because it is very economical. Also, for economic purposes, the headrace was designed with a gradient of 1/1,000. The length of the connection tunnel is 1,270 m to the outlet; an inner diameter of 3.10m was adopted in consideration of a maximum discharge of 18.0 m^3/sec. The lining thickness was designed to be 30cm, which is about 10% of the inner diameter of the tunnel.

6.3.1-5 No.2 Dam

In consideration of the topographical and geographical conditions of the dam site, a reservoir dam type would provide a concrete dam around 40m high.

A HWL of EL.187m was adopted in relation to the outlet elevation headrace tunnel along with a crest level of El.192m and a crest length of 170m. In light of the geological conditions, the dam foundation level was determined as El. 150m. A natural overflow type spillway was adopted without a gate as this would prove more economical and also avoid complicated gate operation requirements. A river design flood discharge of 648 m3/sec was adopted by taking into account the flood discharge figure for the 200 year flood probability estimated by the logarithmic normal distribution method.

6.3.1-6 Pressure Headrace Tunnel

The length of the pressure headrace tunnel from the No.2 Dam to the surge tank would be 2,000m, with a circular type cross section for the tunnel. In consideration of a maximum discharge of 23.94 m^3/sec, the inner diameter of 2.80m was adopted. The lining thickness was designed at 30cm, which is about 10% of the tunnel’s inner diameter.

6.3.1-7 Surge Tank

The surge tank has the role of preventing/reducing the water hammer pressure that occurs inside the penstock from spreading to the headrace tunnel. Through taking into account the above conditions, the USWL was determined as EL.193.10m and the DSWL as EL.162.70m, with a diameter of 10m being adopted.

6.3.1-8 Penstock

A surface penstock would be adopted in consideration of the topographical and geological conditions, and layout of the facilities related to the surge tank and power station.

The linear distance from the surge tank to the tunnel outlet is 170m and from the tunnel outlet’s open pipe to the powerhouse is 210m. From an economic perspective, a diameter of around 2.40m was selected for the penstock.

6.3.1-9 Powerhouse

The power station is located at the curvature the Mba River’s downstream. An indoor powerhouse was adopted due to the power station being a hydro turbine type. The power station accommodates two unit turbines and two unit generators. In the case of the indoor powerhouse, its assembly and disassembly would be carried out by an overhead traveling crane. In consideration of a predicted flood discharge of 2,169 m3/sec for every 100 year period, the ground level for the powerhouse was determined as El.115.0m. The building’s dimensions would be 14.5m wide x 23.5 m long x 13.1 m high.

6.3.1-10 Power Generating Equipment for the Site No.8

(1) **Type of Hydro Turbine**

The turbine type should be selected by considering the site conditions such as the net head, water discharge, and output. For this study, in light of simple maintainability in Fiji, the turbine selection focused on the typical two turbine types: the Pelton turbine and the Francis turbine.

In general, the Pelton turbine is applied to high head and small discharge conditions. Whereas, the Francis turbine is widely applied to various head and discharge conditions.

Table 6.3.1-1 shows the water discharge, effective head and number of unit in relation to site No.8. Two units should be applied to each power plant, since the water discharge differs between the rainy and dry seasons.

Table 6.3.1-1 Water Discharge and the Net Head

Site	Discharge [m^3/s]	Net head [m]	Number of Unit
No.8	23.94 (11.9/1 unit)	70.2	2

Figure 6.3.1-1 shows the hydro turbine selection chart, which was formulated through giving consideration to the limitations of the turbine characteristics, such as the applicable specific speed and the cavitation factor.

Throughout the site conditions in Table 6.3.1-1, the characteristics of the vertical shaft Francis turbine (“VF”) were applied to the site No.8.

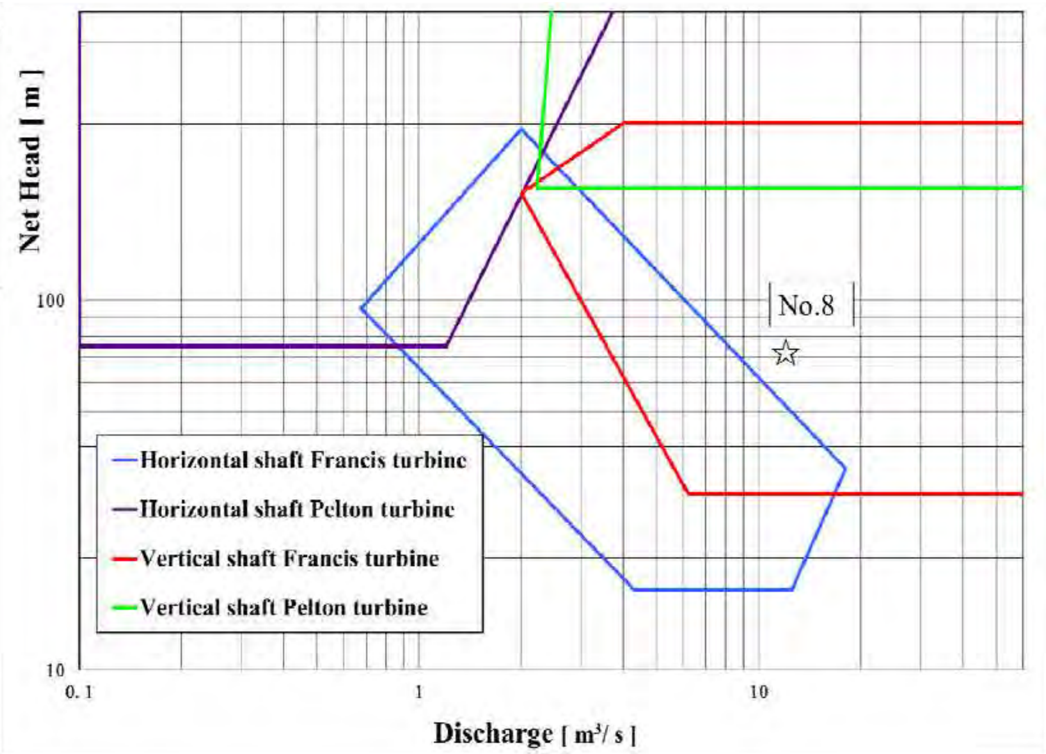


Figure 6.3.1-1 Hydro Turbine Selection Chart

(2) **Selection of the Rated Speed**

The rated speed for hydro turbine depends on the specific speed (Ns). Ns is defined as the following formula.

$$Ns = \frac{N \cdot \sqrt{Pt}}{Ht^{1.25}} \quad \text{(m-kW)}$$

Where,

N	: Rated speed (min^{-1})
Pt	: Rated turbine output (kW)
Ht	: Rated/design net head (m)

From the above formula, the rated speed is calculated as:

$$N = \frac{Ns \cdot Ht^{1.25}}{\sqrt{Pt}} \quad (min^{-1})$$

The formula below from the JEC-4001-2006 (Japanese Electromechanical Committee) was applied to calculate the specific speed for the Francis turbine.

$$Ns \leq \frac{23{,}000}{Ht + 30} + 40 \quad \text{(m-kW)}$$

Pt (kW) is calculated by the using maximum output (Pm) and the generator efficiency(ηg). The rated turbine output is calculated as:

$$Pt = \frac{Pm}{\eta g} \quad (kW)$$

The range of the generator efficiency applied to hydropower plants is commonly accepted between 0.95 and 0.99 for the rated output. In this study, the generator efficiency was determined as 0.97.

In light of the above conditions, the estimation of the rated turbine output, specific speed, and rated speed for each power plant are shown in Table 6.3.1-2. The rated speed for generator would be the same as that of hydro turbine since the connection between the hydro turbine and the generator is a direct coupled type.

Table 6.3.1-2 Estimations for the Specific Speed and Rated Speed

Site	Type of hydro turbine	Rated turbine output [kW] / 1 unit	Specific speed [m-kW]	Rated speed [min-1]
No.8	VF	7,250	251.42	600

(3) **Suction Head (Hs)**

The turbine center elevation was determined in consideration of the cavitation occurring on the hydraulic passage of the turbine. Whereas, the suction head (the elevation difference between the turbine center and minimum tailrace water level) was calculated using the following formula.

$$Hs = Ha - Hv - \sigma p \times Ht \quad (m)$$

where, Hs : Suction head (m)
Ha : Ambient pressure at site (m) at tailrace water level (TWL)
Hv : Vapor pressure at 25 oC (0.32m)
σp : Cavitation coefficient
Ht : Net head (m)

The following formula is one of the guidelines for the cavitation coefficient in Japan.

$$\sigma p = 0.048 \times \left(\frac{Ns}{100} \right)^{1.5}$$

In light of the above conditions and from our experience, the estimations for the suction head, cavitation coefficient, and other conditions for each power plant are shown in Table 6.3.1-3.

Table 6.3.1-3 Estimations for the Suction Head, Cavitation Coefficient, and Other Conditions

Site	Hs[m]	σp	Ha[m]	TWL[m]	Hv[m]	Ht[m]
No.8	-4.0	0.191	10.212	110.00	0.32	70.2

(4) **Generator**

This clause covers the rated voltage, rated power factor, and rated capacity for the generator.

The generator has an important function to supply reactive power to the power system and enhance the voltage stability of the system. The rated power factor, which represents the capabilities of the reactive power supply, was decided in consideration of the capacity of voltage stabilization required by the power system where the generator will be connected, as well as paying attention to the mechanical limitations from the perspective of manufacturing. The range of the rated power factor applied to hydropower plant is commonly 0.8 to 1.0, and in this study the rated power factor was determined at 0.85 although it should be reviewed by taking into consideration the requirements of the power system.

The rated capacity of the generator was calculated using the rated turbine output, rated power factor, and generator efficiency. The calculation is as follows:

$$P_{gu} = \frac{Pt \times \eta g}{p_{fg}} \text{ [MVA]}$$

Where,
Pgu: Rated capacity of generator [MVA]
Pt : Rated turbine output (7.25)[MW]
ηg: Generator efficiency (at rated output:0.97) [%]
p_{fg}: Rated power factor (0.85)

According to a technical report by the IEEJ (The Institute of Electrical Engineers Japan), the terminal voltage was to be determined as shown in Figure 6.3.1-2 (IEEJ Technical Report, Vol. 495, June 1994, “Research and investigation on design for hydropower generation equipment”).

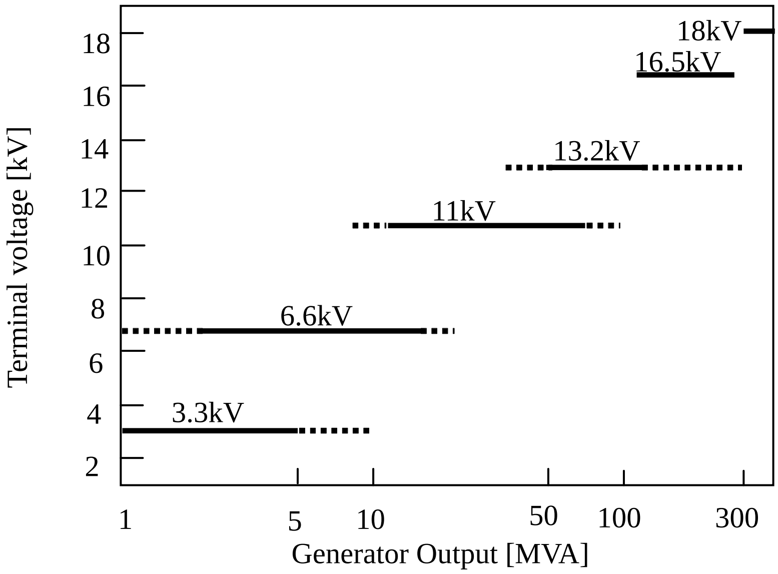


Figure 6.3.1-2 Criterion of the Terminal Voltage Selection for the Hydro Generator

Taking into account the above conditions and our experience, the estimations for the rated voltage, rated power factor, and rated capacity for the generator are shown in Table 6.3.1-4.

Table 6.3.1-4 Estimations for the Rated Voltage, Rated Power Factor, and Rated Capacity for the Generator

Site	Rated voltage [kV]	Rated power factor	Rated capacity [MVA] / 1 unit
No.8	11	0.85	8.3

6.3.2 Rough Cost Estimations

The rough costs, which were estimated by the requisite quantities in the drawings for the main structures required for the hydropower scheme, are given in Table 6.3.2-1.

The drawings for the general layout plan and the general profile are shown in Figure 6.3.2-1 and Figure 6.3.2-2, respectively.

Table 6.3.2-1 Rough Cost Estimations for the No.8 Hydropower Scheme

Item	(USD)	Remarks
1. Preparation and Land Acquisition	1,625,930	
(1) Access Roads	1,056,000	@160USD/ 6,600 m
(2) Camp & Facilities	569,930	3. Civil Works * 2%
2. Environmental Mitigation Cost	854,895	3. Civil Works * 3%
3. Civil Works	28,496,491	
3.1 No.1 Weir	664,999	
3.2 No.1 Intake	268,385	
3.3 No.2 Dam	13,419,770	
3.4 No.2 Power Intake	479,851	
3.5 Sand Trap	810,949	
3.6 No.1 Connection Tunnel	2,968,879	
3.7 No.2 Headrace Tunnel	4,766,521	
3.8 Surge Tank	720,423	
3.9 Penstock	668,873	
3.10 Powerhouse	2,140,407	
3.11 Tailrace Outlet	230,458	
3.12 Miscellaneous	1,356,976	(3.1 to 3.11) * 5%
4. Hydromechanical Works	1,557,800	
5. Electro-Mechanical Equipment	15,692,340	
Direct Cost	48,227,456	
6. Administration and Engineering Service	7,234,118	Direct Cost * 15%
7. Contingency	4,822,746	Direct Cost * 10%
8. Interest during Construction	1,687,961	(Direct Cost + 6. + 7.) *0.4[1]*0.014[2]*Construction period
Total Cost	61,972,281	

[1] 0.4 is a cash flow coefficient which is an empirical value.

[2] 0.014 is interest rate.($i = i_1$*0.4+i_2*0.6 =2%0.4+1%*0.4)

i_1:Interrest rate for local currency, i_2:Interrrest rate for foreign currency

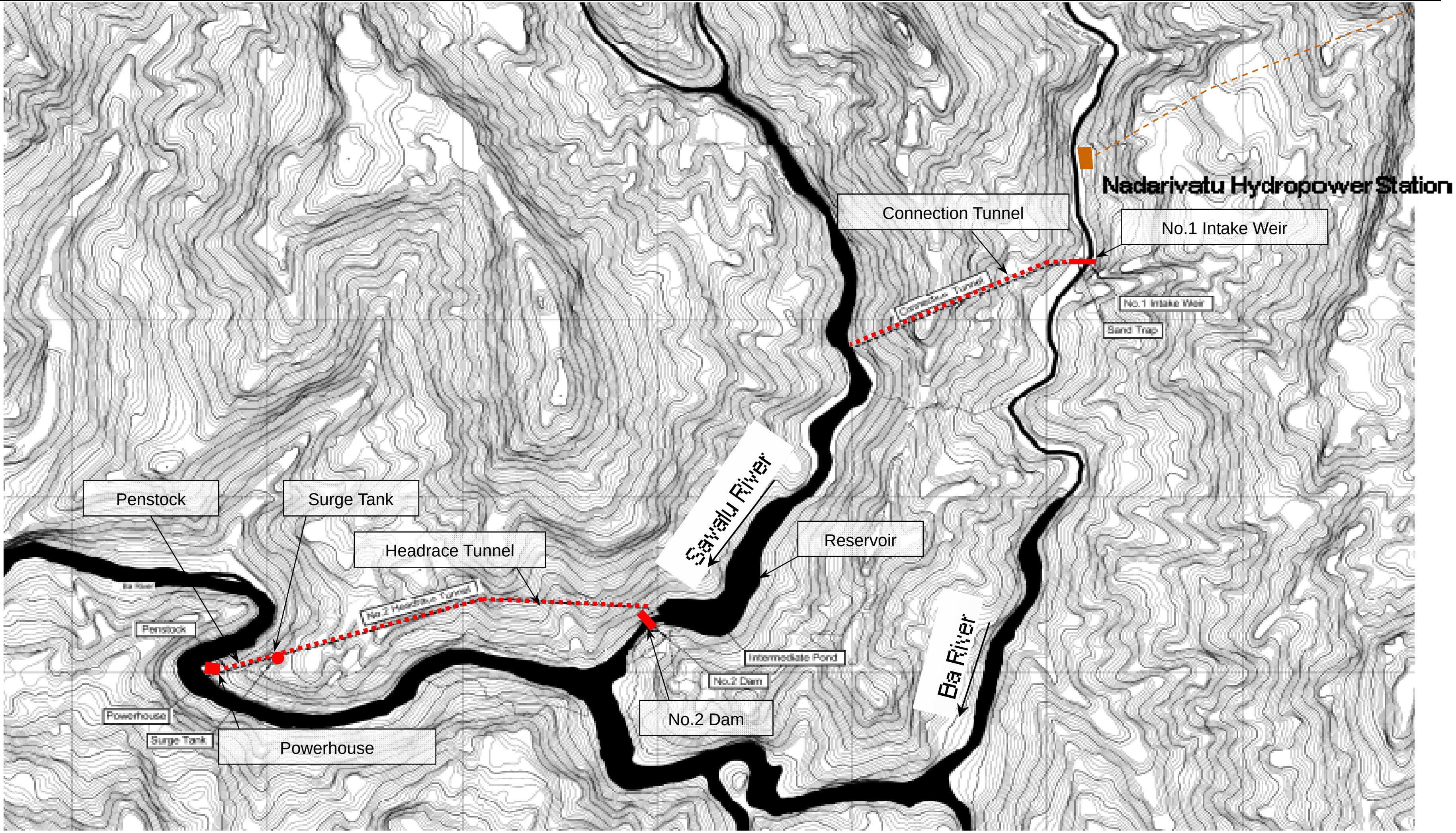


Figure 6.3.2-1 General Layout Plan for the No.8 Mba 1 US Hydropower Scheme

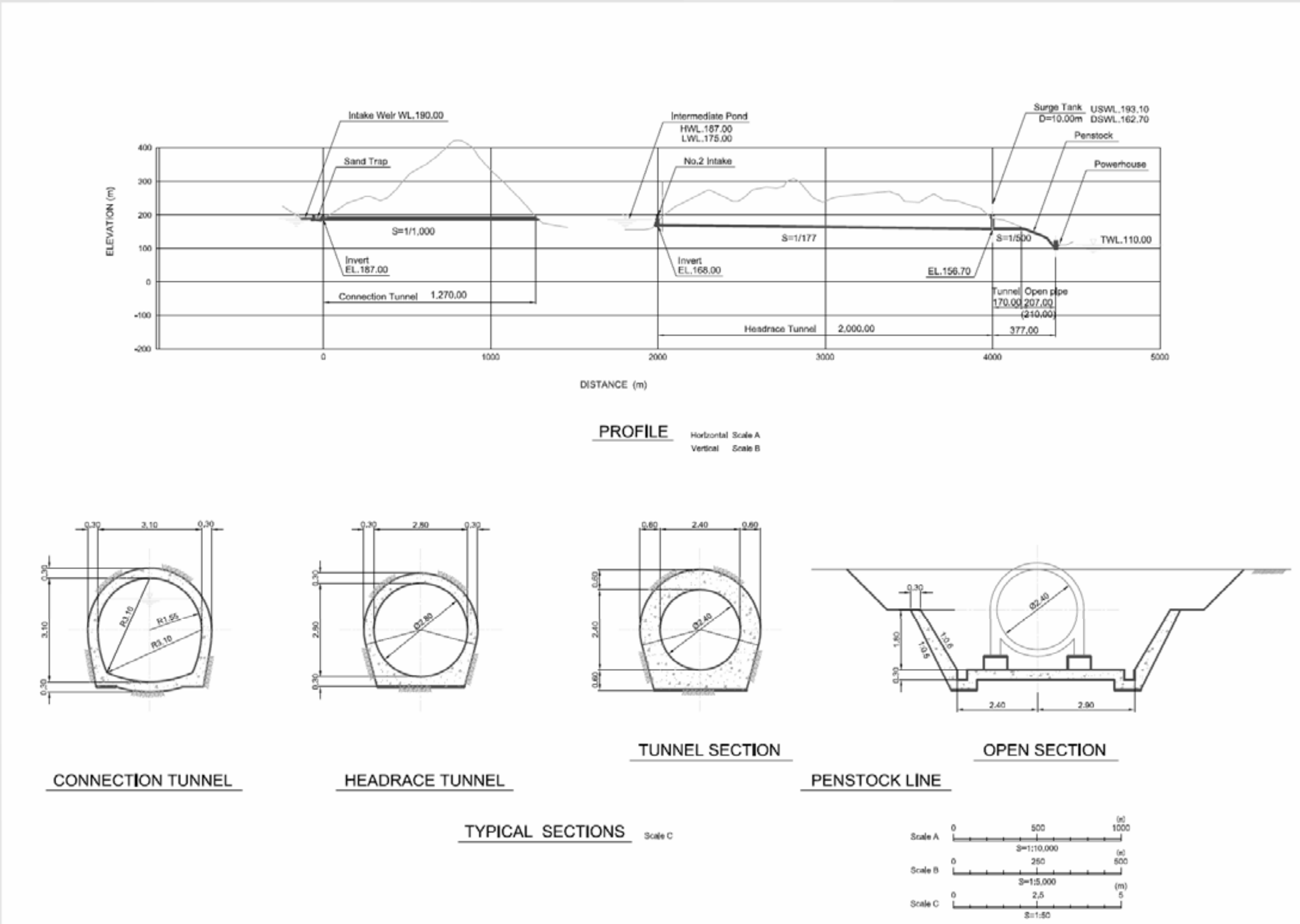


Figure 6.3.2-2 General Profile and Tunnel Sections

6.4 Detailed Site Survey for the Preliminary Design of the No.29 Waivaka Hydropower Scheme

The No.29 Hydropower Scheme as a run-of-river type that was selected as a prospective hydropower potential site has a maximum output of 7.4MW and annual generation energy of 15,046MWh.

The scheme proposes to take water from the Wairokodra River in the west to the Waivaka River in the east. Also the scheme plans to increase the power output and maximum discharge by using the river flows of the Wairokodra River and the Waivaka River.

On the other hand, in consideration of a demand from the Fiji side (such as for 90% renewable energy), the development of the future electricity demand situation and a large-scale hydroelectric power scheme, a detailed site survey for preliminary design was carried out to confirm whether a reservoir type was possible with design conditions, such as the dam type, waterway route and waterway type.

From the results of detailed site survey, the scheme plan was changed to a reservoir type. Basically, if the dam height was around 40m, it is assumed that there will be enough bedrock from the geological and topographical conditions. A general layout plan is shown in Figure 6.4-1.

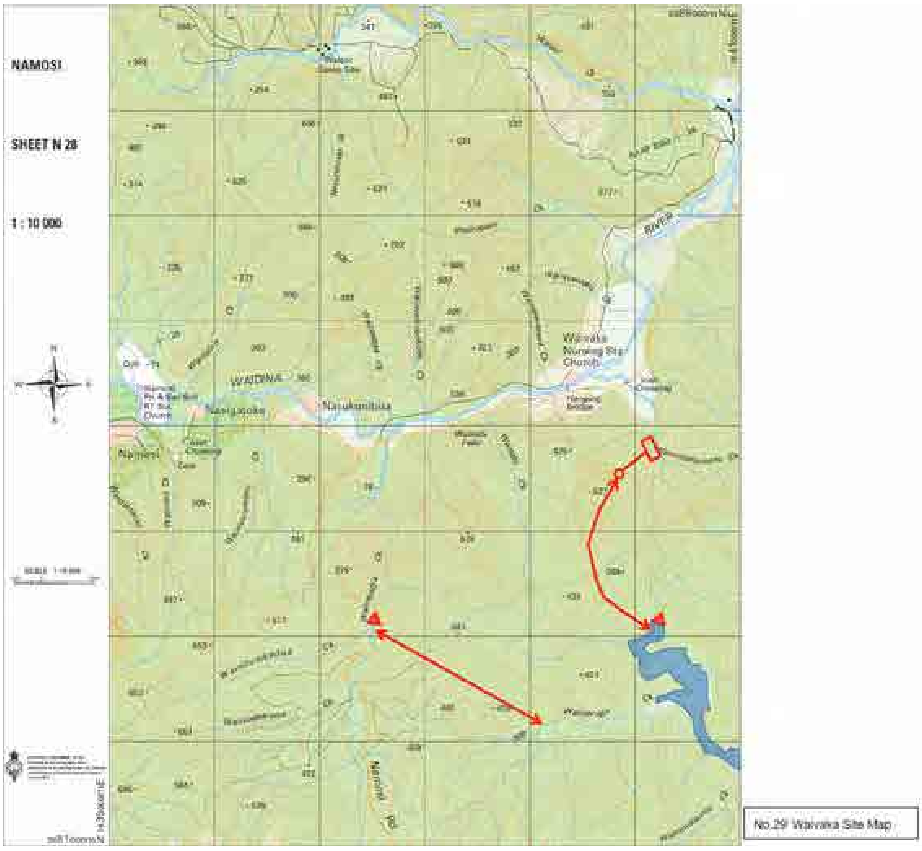


Figure 6.4-1 General Layout of the No.29 Hydropower Scheme (Reservoir Type)

6.5 Optimum Power Generation Plan for the No.29 hydropower Scheme

Step 1: Hydrological and Meteorological Analysis

The design specifications for the scheme features such as the maximum discharge, duration curve, design flood, and sediment capacity for the reservoir type were determined based on collected hydrological and meteorological data. The hydrological and meteorological data were reviewed based on the results of the site reconnaissance.

Step2: Setting the Development Scale

The development scale for a reservoir type was determined under the selected dam site, headrace route, and power station, which were considered in line with the geological and environmental conditions acquired from the relevant 1/10,000 scale topographic map and the results of a site reconnaissance.

Step 3: Selection of the Optimum Development Plan

The high economic evaluation to select optimum development scale were determined the by benefit-cost ratio (B/C), net present value (B-C), and the index expressed as a construction cost per unit energy (USD/kWh).

6.5.1 Hydrological and Geological Analysis

(a). Hydrological and Meteorological Analysis

(1) **Collected Daily Discharge Data**

The Nabukaluka Gauging Station, which only collected data in the basin, is located on the downstream of the Waindina River (a main river); its catchment area is 253 km^2. The hydrological gauging station has 19 years of daily discharge data, with around 60 loss days per year. The hydrological data and location of the gauging station on the Waindina River are shown in Table 6.5.1-1 and Figure 6.5.1-1.

Table 6.5.1-1 River Discharge Data for the Wanidina River

Gauging Station	River	Period for Data Collection	CA(km^2)
6. Nabukaluka	Waindina	1970 – 1991* *(data was not collected in 1987, 1998, and 1990)	253

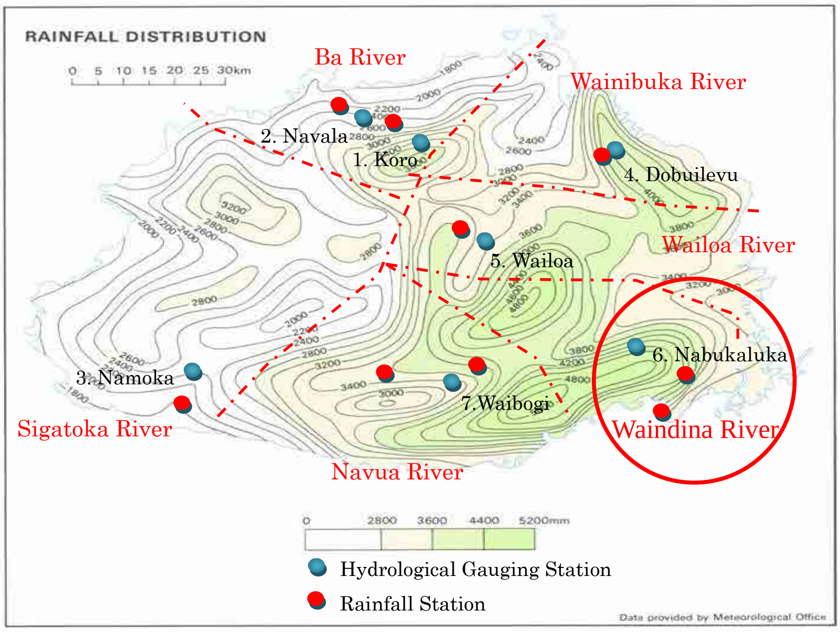


Figure 6.5.1-1 Main Metrological and Hydrological Gauging Stations in Viti Levu

(2) **The Comparison of the Inflow Duration Curve of the M/P Study and Previous Report**

The basin of the dam site is located on the Nakavika Creek near the Nakavika village, upstream of the Waidina Creek. The inflow duration curve at the dam site, which was plotted by the basin conversion using the daily discharge data at the Nabukaluka Gauging Station, is extremely precise in the case of the dam site being located on the main river.

On the other hand, for the dam site located on the tributary should be validated with comparison with the observed river discharge. For validation of the difference of the specific duration curve at the dam site, the specific duration curve plotted from the daily discharge data at the Nabukaluka Gauging Station, was compared with the previous report by the Small Hydro Site Identification in Fiji in 2005 and is shown in Figure 6.5.1-2. The specific duration curve plotted by basin conversion of the normal conditions (indicated in green) was smaller than that of the previous report which observed the river discharge near the dam site. Therefore, the duration curve at the dam site was estimated three times by basin conversion using the existing hydrological gauging station data in comparison with that of the previous report. This curve is shown in Figure 6.5.1-3..

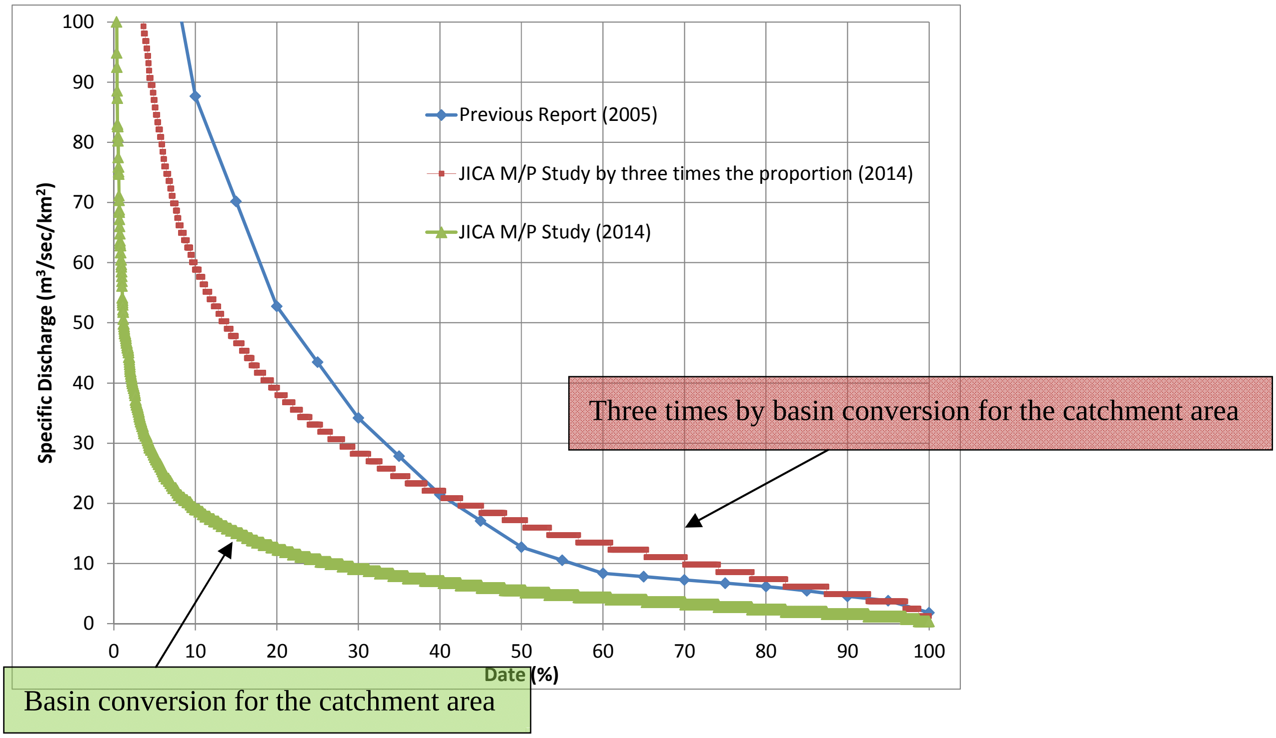


Figure 6.5.1-2 Comparison of the Specific Inflow Duration Curve between the JICA M/P Study and the Previous Report

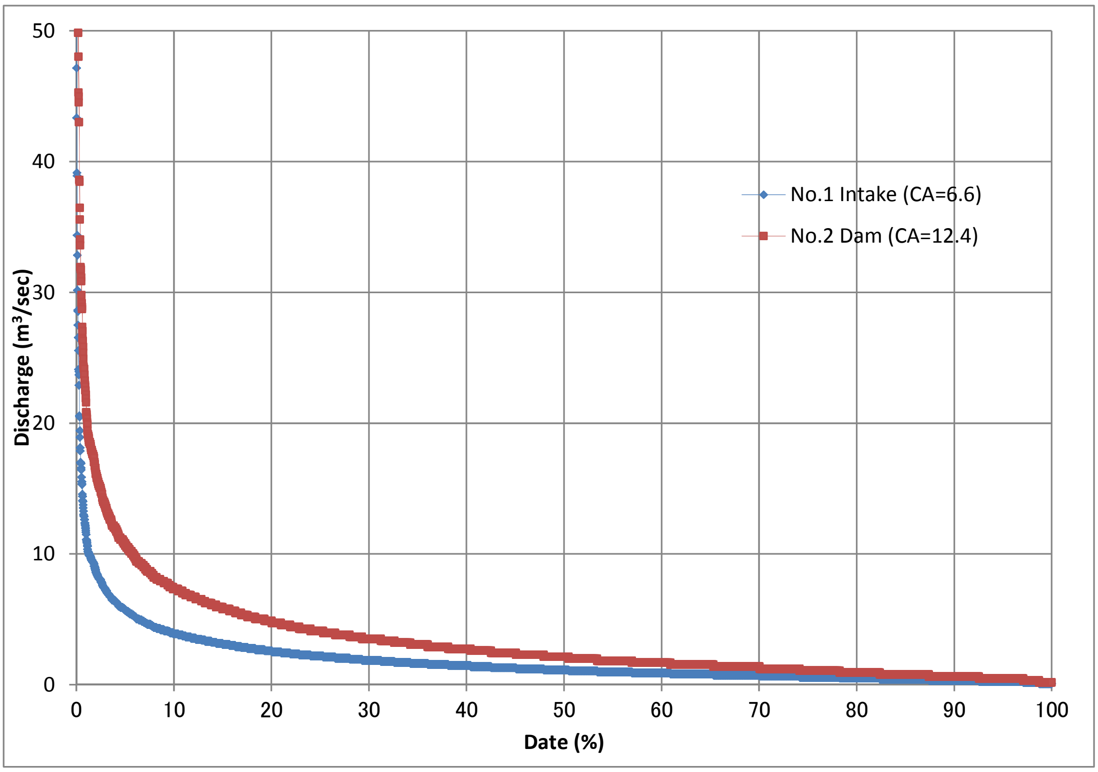


Figure 6.5.1-3 Inflow Duration Curve at the No.1 Intake Weir and the No.2 Dam

(3) **Estimation of Sedimentation Capacity**

The 100 year sedimentation capacity at the dam site was calculated using the following formula to be 310,000m^3. Therefore, the sedimentation level was determined as El.275m.

(Calculation Formula)

Vs = qs x CA x 100

Where,

Vs: The 100 year sedimentation capacity (m^3)

qs: 0.25 mm/year (: Proceeding of the Fiji Symposium, June 1990, Erosion and sedimentation in Fiji – An overview)

CA: Catchment area at dam site (12.4 km^2)

(4) **Flood Analysis**

The flood analysis was estimated by the logarithmic normal distribution method. The flood discharge data was collected from 1970 to 1991 using hydrological data. The maximum discharge from 1970 to 1991 is shown in Table 6.5.1-2.

Table 6.5.1-2 Maximum Discharge from the No.29 Hydropower Scheme from 1970 to 1991

Year	Month	Day	Q	LogQ
1970	12	18	39.55	1.5972
1971	12	25	60.67	1.7830
1972	10	24	92.58	1.9665
1973	3	2	48.52	1.6859
1974	4	26	38.03	1.5802
1975	11	17	49.28	1.6926
1976	9	30	24.36	1.3867
1977	3	15	65.69	1.8175
1978	3	16	48.97	1.6900
1979	3	6	47.00	1.6721
1980	4	4	139.98	2.1461
1981	10	4	22.23	1.3470
1982	4	19	57.63	1.7607
1983	1	3	33.78	1.5287
1984	5	7	23.14	1.3644
1985	11	5	40.46	1.6071
1986	4	19	85.44	1.9317
1989	9	12	19.50	1.2900
1991	2	5	35.75	1.5533
			Average u	1.6527
			Standard Deviatio σ	0.2229

If the flood is indicated in a normal distribution, the following probabilities are calculated statistically.

$u+3.09\sigma=0.1\%$ (1000 year probability)
$u+2.88\sigma=0.2\%$ (500 year probability)
$u+2.58\sigma=0.2\%$ (200 year probability)
$u+2.32\sigma=1\%$ (100 year probability)
$u+2.05\sigma=2\%$ (50 year probability)
Where, $u=1.6527$ $\sigma=0.2229$

A 1,000 year flood probability was calculated as follows.

$u+3.09\sigma=1.6527+3.09*0.2229=2.3415$, $10^{2.3415}=220m^3/s$

The results of the flood probability analysis at the No.1 Intake Weir and the No.2 Dam are shown in Table 6.5.1-3.

Table 6.5.1-3 Results of the Flood Analysis at the No.1 Intake Weir and the No.2 Dam

	CA(km^2)	1000 year	500year	200 year	100 year	50 year
No.1 Intake Weir	6.6	124	111	93	80	69
No.2 Dam	12.4	220	199	169	148	129

(b). Geological Condition

The detailed general geological and engineering geological data for the main structures such as the intake, dam, connection tunnel, headrace tunnel, penstock and powerhouse, are shown in Appendix 6-1-2 (No.29 Waivaka Hydropower Scheme in the Vol. III APPENDIX).

6.5.2 Conditions for the Calculation of the Power Generation

(1) **No.1 Intake Discharge**

From the duration curve at the No.1 Intake Site shown in Figure 6.3.3-1, the maximum discharge was calculated to be 4.0 m3/sec - the equivalent of 36.5 days.

(2) **The Inflow Duration Curve at the Dam Site (Total Inflow)**

The inflow duration curve was prepared for a catchment area of 19.0 km^2 at the dam site and the intake site. The average discharge of the dam site was assumed to be 5.19 m^3/sec. The inflow duration curve is shown in Figure 6.5.2-1. The average discharge (1970-1991) is shown in Table 6.5.2-1.

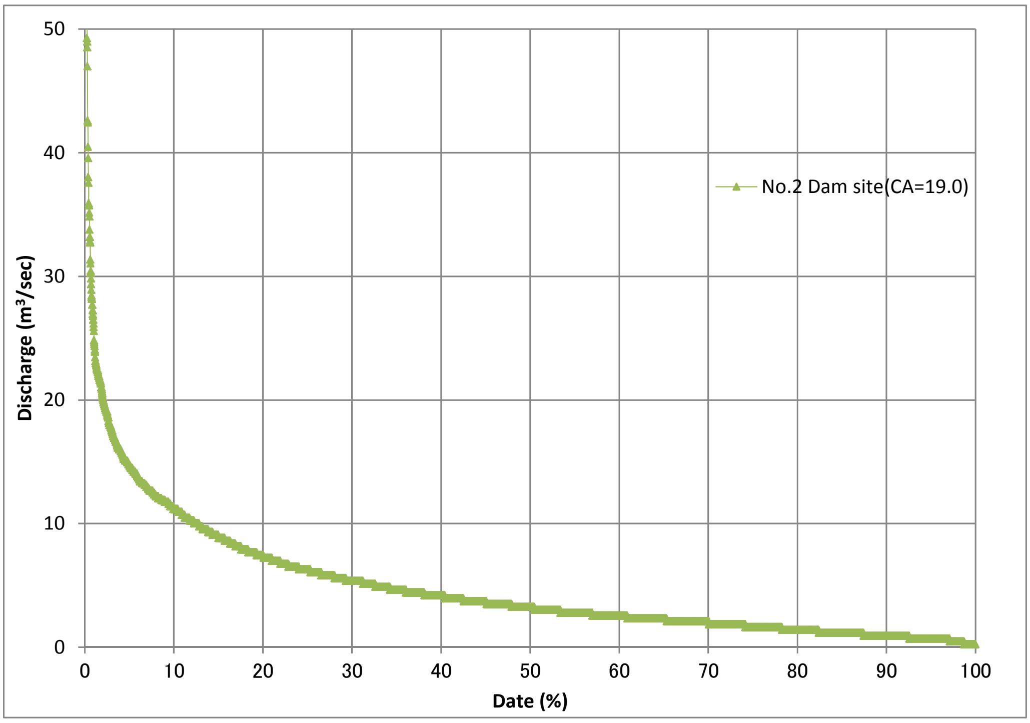


Figure 6.5.2-1 Inflow Duration Curve at the Dam Site

Table 6.5.2-1 Daily Discharge at the Dam Site (1970 - 1991)

Mean Daily Discharge			Station No.				Station Name:		No.2 Dam				
			CA :	19.0 km^2			Waivaka River						
	Year:	1970-1991											Unit: m^3/sec
	Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	1	5.14	8.97	6.75	6.30	4.89	4.58	2.30	1.85	1.79	5.03	6.39	7.99
	2	6.27	9.92	8.82	5.60	5.08	4.95	2.46	2.65	1.75	3.94	5.72	7.41
	3	6.55	7.20	8.59	9.15	5.34	4.17	3.55	3.29	1.68	3.55	5.55	8.33
	4	8.40	7.30	7.58	17.60	4.26	4.10	3.72	3.53	2.23	4.14	4.88	8.58
	5	8.28	9.10	10.23	9.82	3.67	3.97	3.06	3.54	2.18	5.05	7.11	7.62
	6	5.58	7.33	7.63	5.86	7.44	4.45	2.70	2.69	1.92	5.18	5.96	6.45
	7	5.65	7.36	6.83	4.94	5.52	3.39	2.52	2.51	2.01	6.00	5.77	6.34
	8	6.57	6.88	7.21	4.77	4.76	5.04	2.34	3.52	2.01	5.46	4.91	5.55
	9	6.65	7.41	7.77	5.15	3.49	3.77	2.51	2.94	2.02	5.17	4.89	5.78
	10	6.52	8.46	9.32	5.59	4.10	3.29	2.36	3.03	2.04	4.52	5.04	6.35
	11	6.57	7.62	8.98	5.22	4.34	2.74	2.00	3.71	2.47	4.04	5.61	5.04
	12	5.73	6.72	7.44	5.05	4.84	3.29	2.23	3.32	3.48	4.05	5.75	4.46
	13	4.96	7.01	7.89	5.88	4.48	2.51	2.08	2.96	3.29	3.62	6.33	4.38
	14	5.49	7.30	8.92	5.98	3.88	2.23	2.00	2.76	3.18	3.77	5.79	6.04
	15	6.19	8.21	11.15	6.73	4.16	2.45	1.92	2.21	3.14	3.76	4.90	4.98
	16	5.98	8.80	9.24	6.94	4.17	3.02	1.89	2.15	2.53	4.51	5.35	5.29
	17	6.72	8.58	7.30	11.65	4.25	2.51	1.90	2.30	2.85	3.77	7.22	6.21
	18	8.75	8.14	7.26	12.13	3.81	2.56	1.94	1.85	3.55	3.64	8.67	7.50
	19	7.21	6.37	8.79	18.89	3.19	2.36	2.52	2.03	4.44	6.22	6.63	7.59
	20	8.66	6.25	8.40	11.04	2.88	2.11	2.37	2.13	4.80	4.99	5.81	7.39
	21	8.06	5.76	6.41	9.11	3.37	3.24	1.96	2.68	4.87	4.62	5.05	6.94
	22	6.76	5.98	6.18	6.95	4.38	2.48	1.66	3.27	4.51	4.76	4.93	6.26
	23	8.40	6.64	7.11	7.67	3.98	2.28	1.59	3.69	3.48	5.18	5.98	6.02
	24	7.75	6.98	7.14	8.24	4.45	2.03	1.71	2.87	3.21	9.46	7.28	5.96
	25	6.84	5.88	6.26	8.31	4.24	1.96	1.82	2.97	4.04	7.54	8.09	7.84
	26	5.84	5.30	5.02	7.98	3.77	1.77	1.80	3.00	5.07	5.35	9.45	5.77
	27	6.86	5.98	4.99	5.96	3.19	2.27	1.60	2.40	3.43	5.08	7.80	5.52
	28	7.86	6.30	5.47	5.67	2.70	3.68	1.75	2.10	3.00	5.38	7.91	4.92
	29	8.02	4.19	5.63	4.87	3.01	2.63	1.78	2.10	3.05	6.12	8.39	5.39
	30	7.48		5.49	4.71	2.59	2.57	1.97	1.94	5.41	6.11	7.51	5.97
	31	7.94		6.53		2.30		2.03	1.79		6.19		5.44
	Min	4.96	4.19	4.99	4.71	2.30	1.77	1.59	1.79	1.68	3.55	4.88	4.38
	Mean	6.89	7.17	7.50	7.79	4.08	3.08	2.19	2.70	3.11	5.04	6.36	6.30
	Max	8.75	9.92	11.15	18.89	7.44	5.04	3.72	3.71	5.41	9.46	9.45	8.58

(3) **Reservoir capacity**

The reservoir capacity was estimated using the 1/10,000 scale maps and the water level data. The storage curve is shown in Figure 6.5.2-2.

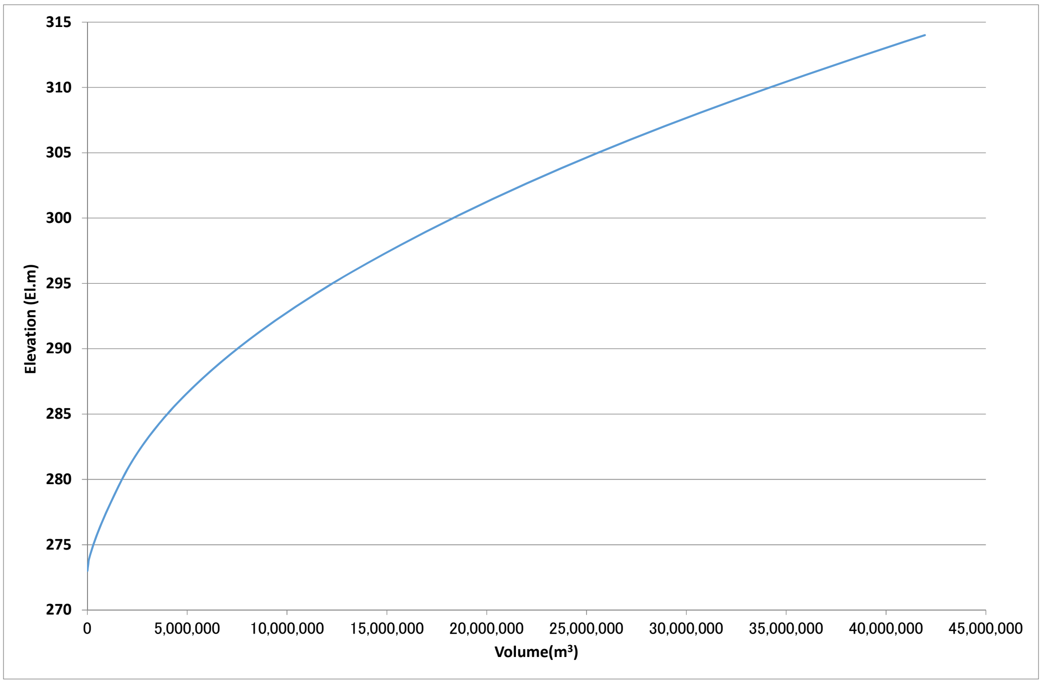


Figure 6.5.2-2 Storage Curve (Scale: 1/10,000)

(4) **Water Level at the Dam Site**

- The HWL was determined as El.309 m . This was because it was expected that a 40m gravity concrete dam would be constructed through taking into account the topographical and geology conditions at dam site and around the reservoir.

In order to prevent air from getting inside the pressure tunnel, the minimum water level was determined as EL.280 m - this enabled the setting of a position of 1.5 times the length of the pressure tunnel's inner diameter from the sediment level (El.275m).

(5) **Optimal Storage Capacity**

The optimal storage capacity is estimated by using the average monthly discharge data from 1970 to 1991 at the dam site in order to calculate the available depth of the reservoir. The results of the optimal storage capacity are shown in Table 6.5.2-2

From the results, the optimal storage capacity was estimated as 29,000,000 m^3 - the same as the storage curve shown in Figure 6.5.2-3. Therefore, it is possible to use the monthly average discharge figure of 5.17m^3/sec.

Table 6.5.2-2 Results of the Optimal Storage Capacity by Using the Average Annual Discharge

Month	Day	Monthly Average Discharge Qi	Monthly Average Storage Capacity	Qi-Qave	Cumulative Storage Capacity ΣQi-Qave
		(m^3/sec)	(m^3)	(m^3/sec)	(m^3)
1	31	6.89	4,568,904	1.71	4,568,904
2	28	7.17	4,975,704	1.99	9,249,840
3	31	7.50	6,202,728	2.32	16,090,488
4	30	7.79	6,754,320	2.61	22,325,760
5	31	4.08	-2,957,400	-1.10	20,112,552
6	30	3.08	-5,454,000	-2.10	14,009,760
7	31	2.19	-8,019,576	-2.99	6,457,176
8	31	2.70	-6,653,592	-2.48	-196,416
9	30	3.11	-5,376,240	-2.07	-5,566,320
10	31	5.04	-386,136	-0.14	-6,138,000
11	30	6.36	3,047,760	1.18	-2,892,240
12	31	6.30	2,988,648	1.12	0
Average		5.17			

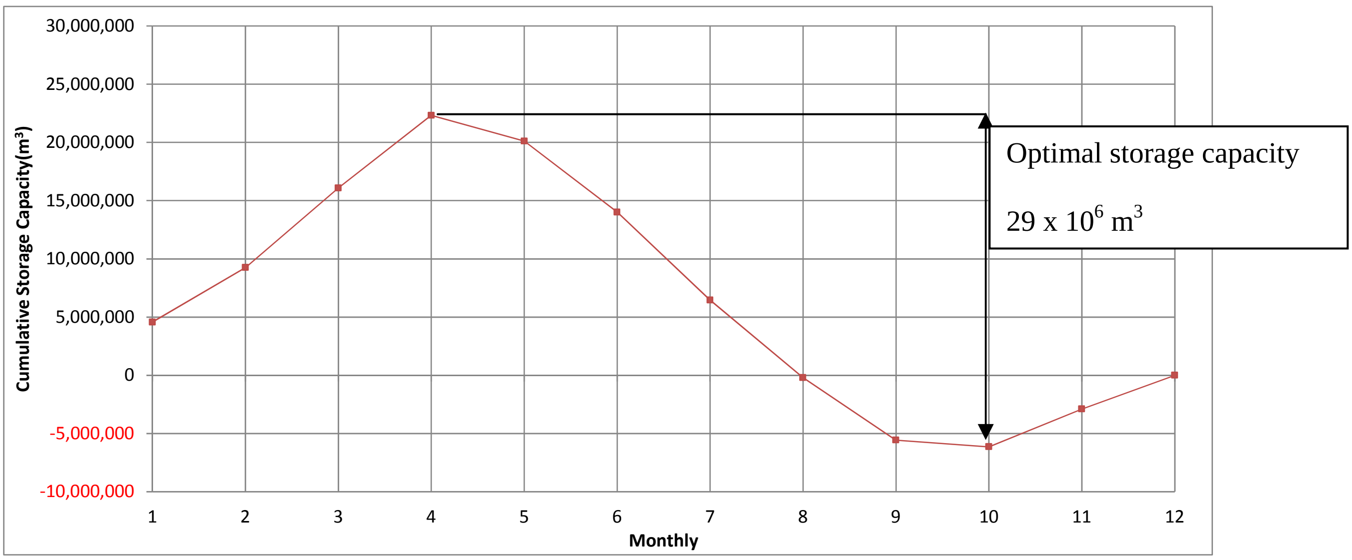


Figure 6.5.2-3 Storage Capacity Curve

(6) **Combined Efficiency of the Turbine and Generator**

In this study, the combined efficiency of the turbine and the generator was uniformly 0.85.

(7) **Tail Water Level**

Through using a 1/10,000 scale, the tail water level at the power station site was assumed to be EL.110m.

6.5.3 Calculation of the Power Generation

The No. 29 Hydropower Scheme is planned as reservoir type for operation during the year. The maximum plant discharge is increased to a few times higher than the firm discharge by setting the storage capacity appropriately. In this study, the firm discharge was set as the average discharge of the dry season in consideration of the difference 5.17 m^3/sec in the discharges between the dry and rainy seasons. The relationship between the firm discharge and operation time is mentioned below.

$Q_p = Q_f$ x 24hour / T_f
Q_p : Maximum plant discharge (m^3/s)
Q_f : Firm discharge during a year (m^3/s)
T_f : Operation time is 6 hours

The monthly power generation is calculated based on the monthly discharge and monthly operation time using the following formula. The annual power generation is calculated as the sum of the monthly power generation figures.

$G_{date} = 9.8 \times Q_p \times He_{date} \times \eta_{date} \times T_{fdate}$
G_{date} : Monthly Generated Energy
Q_p : Maximum plant discharge(m^3/s)
He_{date} : Effective head for monthly operation water level (m)
η_{date} : Combined efficiency of turbine and generator (%)
T_{fdate} : Peak and off peak operation time(6 hour and 18 hours)

6.5.4 Estimated Construction Costs

The construction costs were estimated based on the “Guideline and Manual for Hydropower Development Vol.1 Conventional Hydropower and Pumped Storage Hydropower” (issued by JICA). The unit costs were quoted in terms of the hydropower renewable energy development project in the Wailoa downstream in the Republic of the Fiji islands and current similar hydroelectric development projects in Asian countries.

The construction costs were separated into the direct costs and the indirects cost. The direct costs consist of the preparation works and main construction works such as civil structures, hydro mechanical works, electromechanical equipment, and transmission lines. The indirect costs include administration, engineering service fees, and other contingency costs. And the indirect costs are calculated by ratio from the direct costs.

6.5.5 Optimum Development Scale

The optimum development scale was determined with economic evaluation by setting the maximum output in four cases. The peak operation time is eight hours on weekdays, and one hour on Saturdays and Sundays; the firm discharge was considered to be 5.17 m^3/sec in relation to the monthly average discharge and the effective storage capacity during the year.

Therefore, in consideration of the firm discharge, the maximum output was set from 25MW, 28MW, 32MW, and 35MW.

The economic evaluation of the optimum development scale was determined by a comprehensive evaluation based on the benefit-cost ratio (B/C), net present value (B-C), and the index expressed as a construction cost per unit energy (USD/kWh). As an economic value, a diesel power plant was selected as an alternative thermal power generation using diesel plants in Fiji. The hydropower capital recovery coefficient and kW and kWh values were confirmed by relative organization and were carried out based on the same conditions of the hydropower renewable energy development project in the Wailoa downstream. The conditions for the B/C calculation are mentioned below.

The conditions for the B/C calculation:
KW Value：112USD/kW
KWhValue：18.1US￠/kWh
Hydropower capital recovery coeffcient：0.11226
KW correction factor：1.21, kWh, correction factor：1.03

The optimum development scale for reservoir type is shown in Table 6.5.5-1.

Table 6.5.5-1 Optimum Development Scale of the No.29 Hydropower Scheme

Case	Unit	1	2	3	4
Maximum Output	kW	25,000	28,000	32,000	35,000
Maximum Discharge	m^3/sec	16.06	17.98	20.55	23.76
Firm Output	kW	22,094	24,746	28,281	28,437
Annual Power Generation (Peak time)	MWh	68,012 (52,775)	67,991 (59,108)	67,552 (67,552)	67,929 (67,929)
HWL	EL.m	309			
LWL	EL.m	280			
TWL	EL.m	110			
Gross Head	EL.m	191			
Pressure Tunnel	m	1,590			
Penstocks	m	465			
Construction Cost	10^3 x USD	72,145	75,410	79,944	83,667
B/C		1.69	1.67	1.64	1.57
B-C	Mil. USD	5.57	5.66	5.71	5.38
Construction Cost per unit Energy	USD/kWh	1.06	1.11	1.18	1.23

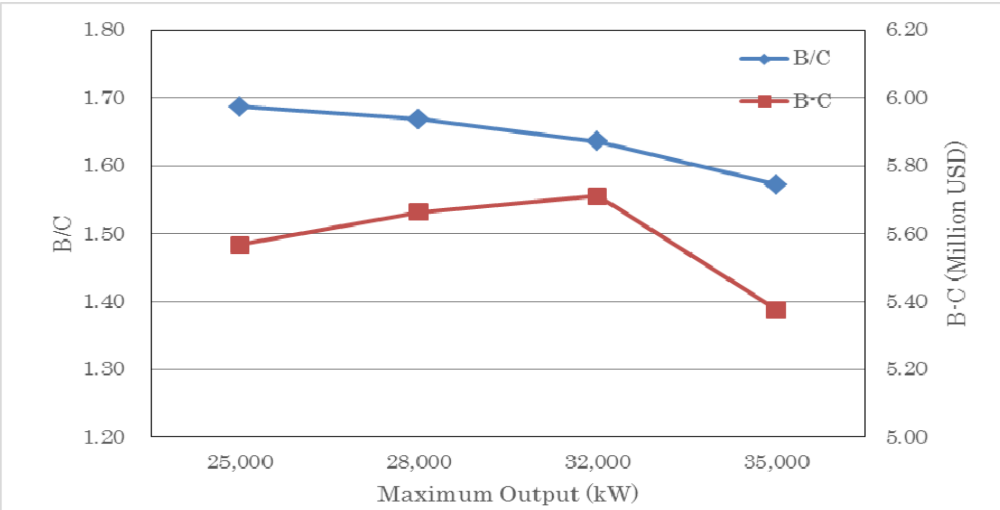


Figure 6.5.5-1 Results of the Economic Evaluation by B/C and B-C

6.5.6 Optimum Development Plan

The optimum development plan was evaluated from an economic point of view, using the benefit-cost ratio (B/C), net present value (B-C), and the index expressed as a construction cost per unit energy (USD/kWh). Following this the most economic maximum output was selected.

From the results of the economic comparison on the case shown in the table, the following considerations were provided.

(1) In comparison with Cases 2 and 3, Case 1 has the highest economic value with a benefit-cost ratio (B/C) of 1.69. However, at around 3% less the B/C values of Cases 2 and 3 are almost equivalent to that of Case 1.

(2) Case 3 has the highest net present value (B-C) with 5.85, which is around 3% higher than Case 1.

(3) Cases 1 and 2 have the lowest economical index of between 1.06 to 1.11USD/kWh.

Therefore, it was assessed that Case 3 was the most advantageous for the project's optimum development plan.

The main features for the optimum development scale are shown in Table 6.5.6 1 below.

Table 6.5.6-1 Main Features for the Optimum Development Scale

Item	Unit	Features
Catchment Area	km^2	19.0
Type		Reservoir
Maximum Output	kW	32,000
Maximum Discharge	m^3/sec	20.55
Firm Output	kW	28,556
Dam height	m	41.0
High Water Level	EL.m	309
Low Water Level	EL.m	280
Tail Water Level	EL.m	110
Sediment Level	EL.m	275
Foundation Level	EL.m	273
Gross Head	m	199
Effective Head	m	194.2
Pressure Tunnel	m	1,590
Penstock	m	465

6.6 Basic Design of Hydropower the Plant (No. 29 Waivaka site)

6.6.1 Basic Design of the Hydropower Plant (No. 29 Waivaka site)

Based on the results of the optimum development scale for the No.29 Hydropower Scheme, the preliminary design for a reservoir type was carried out for the main structure using the following characteristics: the Waikorodra River for the No.1 Intake Weir and the Waivaka River at the No.2 Dam site with a 32 MW output.

The main structure's facilities consist of: the No.1 Intake Weir, the sand trap, the waterway for connection to the main scheme, the No.2 dam, the pressure tunnel, the surge tank, the penstock, and the power station.

The main structure's facilities were designed as follows.

6.6.1-1 No.1 Intake Weir

A natural overflow type for the intake weir was selected, as this is a simple facility with low costs compared with a gate type. There are good rock conditions around the concrete dam with about a 5m height beside the intake weir. The intake weir was designed to be 5m in height from the foundation, and due to the above conditions the NWL was EL.323m with a crest length of 25m.

6.6.1-2 No.1 Intake

The intake is located in the right bank to connect the waterway, which has the objective of handling the reservoir's outflow. The standard inflow sill velocity of the intake would be between 0.30 m/s to 1.0 m/s. The intake of the project site was determined as 0.67 m/s. The dimensions of the intake were set as being 3.0 m wide and 2.0 m high with one gate. The sill level of the intake was determined as El.321.0m to prevent the inflow of sediment into the intake.

6.6.1-3 Sand Trap

The sand trap is a facility for the precipitation remove of sediment flow. The velocity of the sand trap has to be less than 0.3 m/s to remove the sediment flow by means of the settling basin. The distance of the settling basin would be needed to settle the fine sand in the bottom at end of the basin from intake.

Dimension : 5.0 m wide x 17m long x 3.0 m depth
Average velocity : 0.32 m/s
Lenght of sand trap : 8.4 m

The accumulated sediment in the settling basin would be collected in one place by a slope of gradient 1/16 in the bottom of the basin (i.e. in order to be removed by the sand).

6.6.1-4 Connection tunnel

For the cross section of the connection tunnel for the non-pressure tunnel to connect to the No.2 Dam site reservoir, a standard horse-shoe type cross section adopted due to its strength with regard to external loading as well as because it is very economical. Also for economic purposes, the headrace was designed with a gradient of 1/1,000. The length of the connection tunnel is 1,700m to the outlet; an inner diameter of 1.90m was adopted in consideration of a maximum discharge of 4.0 m^3/sec. The lining thickness was designed to be 30cm, which is about 10% of the inner diameter of the tunnel.

6.6.1-5 No.2 Dam

In consideration of the topographical and geographical conditions of the dam site, a reservoir dam type would provide a concrete dam of around 40m high.

A HWL of EL.309m was adopted in relation to the outlet elevation headrace tunnel along with a crest level of El.314m and a crest length of 377 m. In light of the geological conditions, the dam foundation level was determined as El.273m. A natural overflow type spillway was adopted without a gate as this would prove more economical and also avoid potentially complicated gate operation requirements. A river design flood discharge of 169 m^3/sec would be adopted by taking account the flood discharge figure for the 200 year flood probability estimated by the logarithmic normal distribution method.

6.6.1-6 Pressure Headrace Tunnel

The tunnel length of the pressure headrace tunnel from the No.2 Dam to the surge tank would be 1,590 m, with a circular type cross section for the tunnel. In consideration of a maximum discharge of 20.55 m^3/sec, the inner diameter of 2.70m was adopted. The lining thickness was designed at 30 cm, which is about 10% of the tunnel's inner diameter.

6.6.1-7 Surge Tank

The surge tank has the role of preventing/reducing water hammer pressure that occurs inside the penstock from spreading to the headrace tunnel. Through taking into account the above conditions, the USWL was determined as EL.314.10m and the DSWL was determined as EL. 270.50m, with a diameter of 10m being adopted.

6.6.1-8 Penstock

A surface penstock would be adopted in consideration of the topographical and geological conditions, and layout of the facilities related to the surge tank and power station. The linear distance from the surge tank to the tunnel outlet was 73m and from the tunnel outlet's open pipe to the powerhouse was 392m. From an economic perspective, a diameter of around 2.30m was selected for the penstock.

6.6.1-9 Powerhouse

The power station is located on the Waivaka River about 1.5 km downstream from the No.2 Dam site. An indoor powerhouse was adopted due to the power station being a hydro turbine type. The power station accommodates two unit turbines and two unit generators. In the case of the indoor powerhouse, the assembly and disassembly would be carried out by an overhead traveling crane. In consideration of a predicted flood discharge of 174m^3/sec for every 100 year period, the ground level for the powerhouse was determined as El.110.0m. The building's dimensions would be 14.8 m wide x 24.2 m long x 10.6 m high.

6.6.1-10 Power Generating Equipment for site No.29

(1) **Type of Hydro Turbine**

Table 6.6.1-1 shows water the discharge, effective head and number of unit for the site No.29.

Table 6.6.1-1 Water Discharge and the Effective Head at Each Site

Site	Discharge [m^3/s]	Net head [m]	Number of Unit
No.29	20.55 (10.275/1 unit)	186.9	2

Figure 6.6.1-1 shows the hydro turbine selection chart. The selection of a vertical shaft Francis turbine is appropriate for the site No.29.

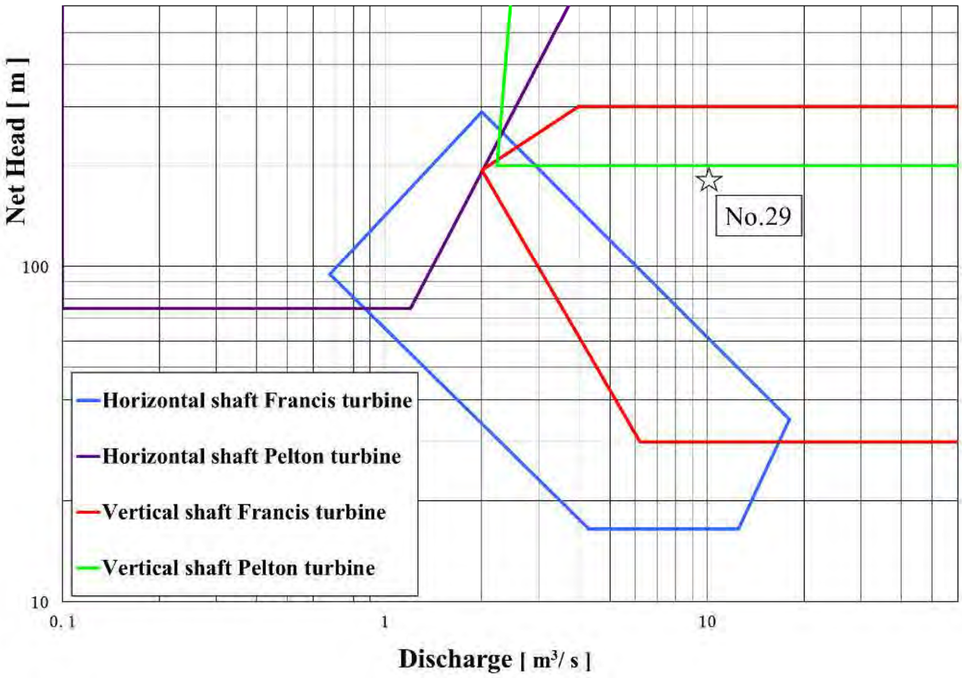


Figure 6.6.1-1 Hydro Turbine Selection Chart

The estimations for the rated turbine output, specific speed, and rated speed for each power plant are shown in Table 6.6.1-2.

Table 6.6.1-2 Estimations for the Specific Speed and Rated Speed

Site	Type of hydroturbine	Rated turbine output [kW] / 1 unit	Specific speed [m-kW]	Rated speed [min-1]
No.29	VF	16,500	139.41	750

The estimations for the suction head, cavitation coefficient, and other conditions for each power plant are shown in Table 6.6.1-3.

Table 6.6.1-3 Estimations for the Suction Head, Cavitation Coefficient, and Other Conditions

Site	Hs[m]	σp	Ha[m]	TWL[m]	Hv[m]	Ht[m]
No.29	-5.0	0.079	10.212	110.00	0.32	186.9

(2) **Generator**

The estimations for the rated voltage, rated power factor, and rated capacity for generator for each power plant are shown in Table 6.6.1-4.

Table 6.6.1-4 Estimations for the Rated Voltage, Rated Power Factor, and Rated Capacity for the Generator

Site	Rated voltage [kV]	Rated power factor	Rated capacity [kVA] / 1 unit
No.29	11	0.85	18,900

6.6.2 Rough Cost Estimations

The rough costs which were estimated by the requisite quantities in the drawings for the main structures required for the hydropower scheme is given in Table 6.6.2-1.

The drawings for the general layout plan and the general profile are shown in Figure 6.6.2-1 and Figure 6.6.2-2, respectively.

Table 6.6.2-1 Rough Cost Estimations for the No.29 Hydropower Scheme

Item	(USD)	Remarks
1. Preparation and Land Acquisition	1,974,443	
(1) Access Roads	1,200,000	@160USD/ 7,500 m
(2) Camp & Facilities	774,443	3. Civil Works * 2%
2. Environmental Mitigation Cost	1,161,664	3. Civil Works * 3%
3. Civil Works	38,722,144	
3.1 No.1 Weir	602,480	
3.2 No.1 Intake	72,636	
3.3 No.2 Dam	25,899,023	
3.4 No.2 Power Intake	715,711	
3.5 Sand Trap	268,007	
3.6 No.1 Connection Tunnel	2,188,811	
3.7 No.2 Headrace Tunnel	3,619,538	
3.8 Surge Tank	974,144	
3.9 Penstock	700,063	
3.10 Powerhouse	1,638,416	
3.11 Tailrace Outlet	199,403	
3.12 Miscellaneous	1,843,912	(3.1 to 3.11) * 5%
4. Hydromechanical Works	2,799,115	
5. Electro-Mechanical Equipment	19,521,948	
Direct Cost	64,179,314	
6. Administration and Engineering	9,626,897	Direct Cost * 15%
7. Contingency	6,417,931	Direct Cost * 10%
8. Interest during Construction	2,246,276	(Direct Cost + 6. + 7.) *0.4[1]*0.014[2]*Constriction period
Total Cost	82,470,418	

---

[1] 0.4 is a cash flow coefficient which is an empirical value.

[2] 0.014 is interest rate.($i = i_1*0.4+i_2*0.6 =2\%0.4+1\%*0.4$)

i_1:Interrest rate for local currency, i_2:Interrrest rate for foreign currency

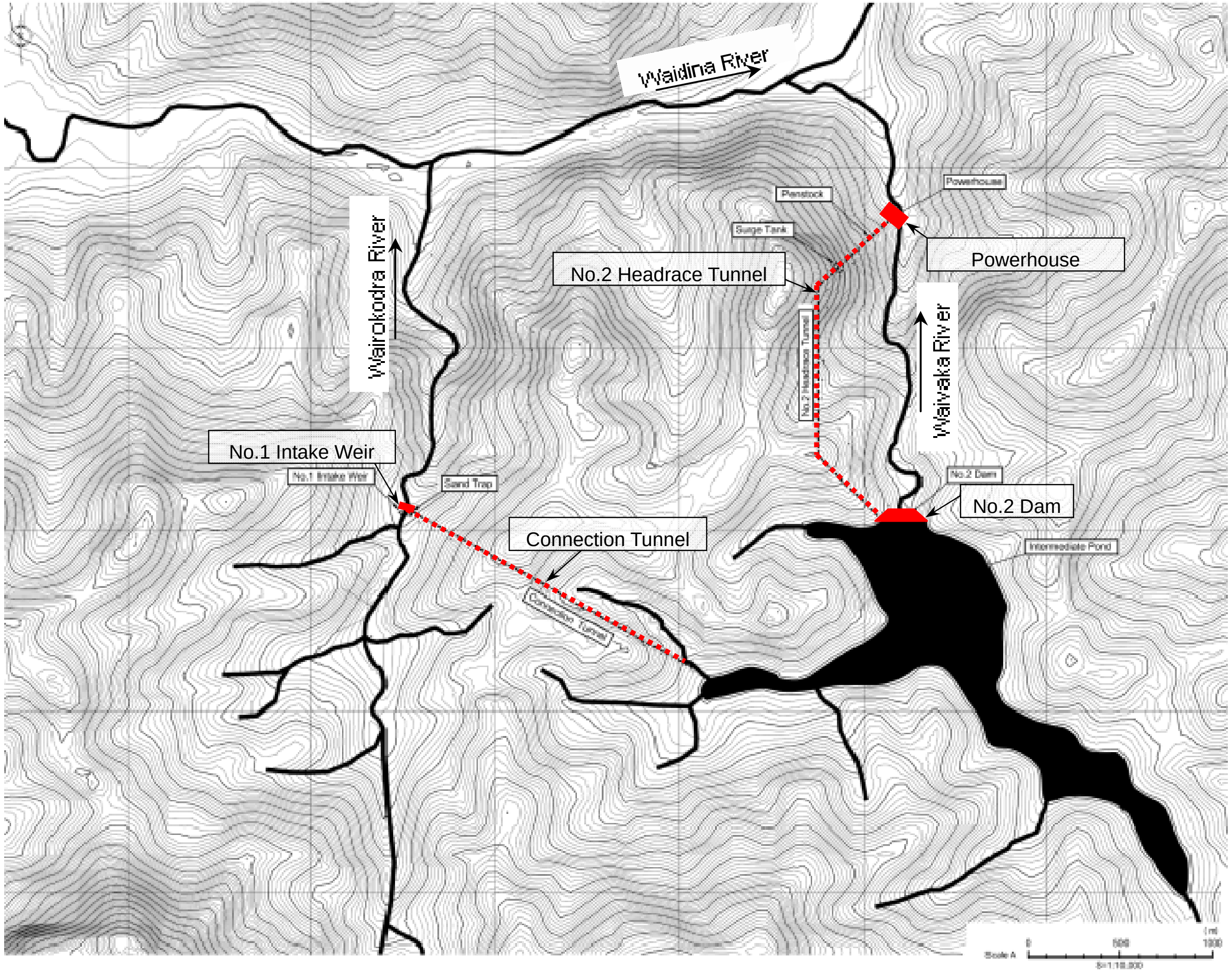


Figure 6.6.2-1 General Layout Plan for the No.29 Waivaka Hydropower Scheme

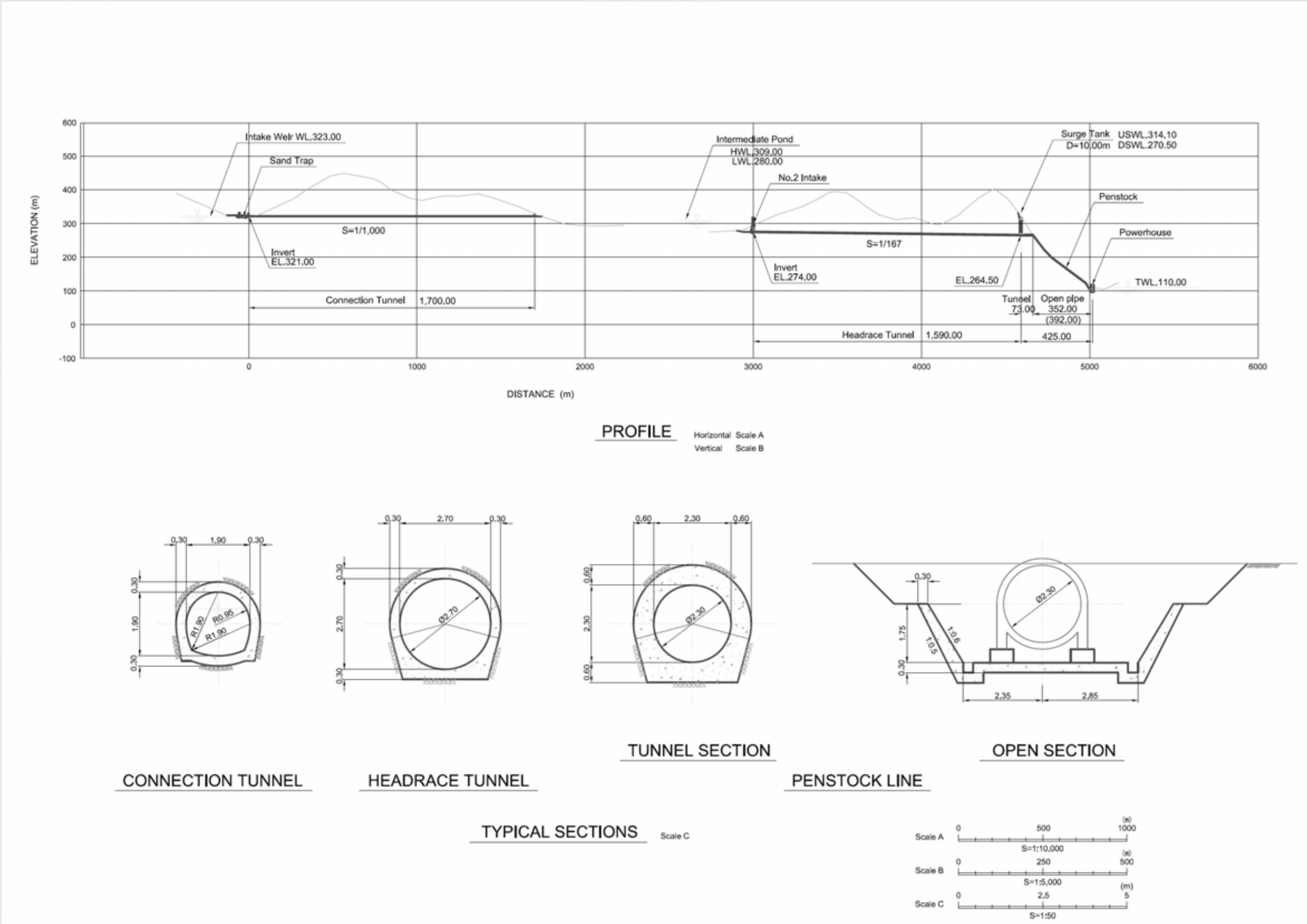


Figure 6.6.2-2 General Profile and Tunnel Sections

6.7 Detailed Site Survey for the Preliminary Design of the No.35 Wailevu Hydropower Scheme

The No.35 Hydropower Scheme as a run-of-river type that was selected as a prospective hydropower potential site has a maximum output of 2.0 MW and annual generated energy of 10,563 MWh.

The scheme proposes to use approximately gross head of 100m from the intake weir to the powerhouse with planning a short headrace route and obtained the big power output.

The upstream from the intake weir site is a gentle slope. When the intake weir site is changed to the upstream in order to get a large head, this becomes uneconomical due to the length of the headrace being too long. However, the basin, as a reservoir, was confirmed by topographical map approximately 2km upstream from the planned intake weir site; as well as this the scheme suggests that the power output and plant discharge can be increased by using the basin of the upper site. This means that a power output of more than four times could be expected from an alternative run-of-river type scheme.

Therefore, a detailed site survey for preliminary design was carried out to confirm whether the reservoir type was possible with design conditions, such as the dam type, waterway route, and waterway type.

From the results of detailed site survey, the scheme plan was changed to a reservoir type. Basically, if the dam height is less than 40m, it is assumed that there will be enough bedrock from the geological and topographic conditions. A general layout plan is shown in Figure 6.7-1.

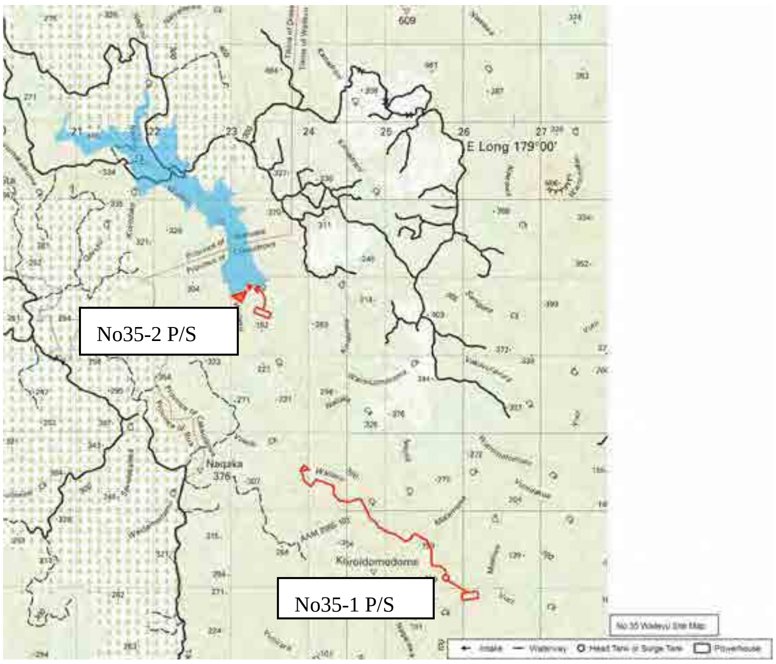


Figure 6.7-1 General Layout of the No.35 Hydropower Scheme (Reservoir Type)

6.8 Optimum Power Generation Plan for the No.35 Hydropower Scheme

Step 1: Hydrological and Meteorological Analysis

The design specifications for the scheme features such as the maximum discharge, duration curve, design flood, and sediment capacity for the reservoir type were determined based on collected hydrological and meteorological data. The hydrological and meteorological data were reviewed based on the results of the site reconnaissance.

Step2: Setting the Development Scale

The development scale for a reservoir type was determined under the selected dam site, headrace route and power station, which were considered in line with the geological and environmental conditions acquired from the relevant 1/10,000 scale topographical map and the results of the site reconnaissance.

Step 3: Selection of the Optimum Development Plan

The optimum development scale was determined from economic points of view such as the benefit-cost ratio (B/C), net present value (B-C), and the index expressed as a construction cost per unit energy (USD/kWh).

6.8.1 Hydrological and Geological Analysis

(a). Hydrological and Meteorological Analysis

(1) **Collected Daily Rainfall Data**

In this study for Vanua Levu, the daily discharge data for the hydrological data were estimated by using the rainfall data collected from FMS. The rainfall data was from the Nabouwalu station located on the southwest and the Savusavu Airfield located on the southeast. The No.35 Hydropower Scheme, which is in the region with the most annual rainfall, determined to use the rainfall data from the Nabouwalu station. The rainfall data and location of meteorological stations are shown in Table 6.8.1-1 and Figure 6.8.1-1.

Table 6.8.1-1 Daily Rainfall Data for Vanua Levu

Meteorological Station	Location	Period for Data Collection	Average Annual Rainfall (mm)
1. Nabouwal	Nabouwal at Southwest	1980 - 2013	2,393
2. Savusavu	Savusavu at Southeast	1980 - 2013	2,107

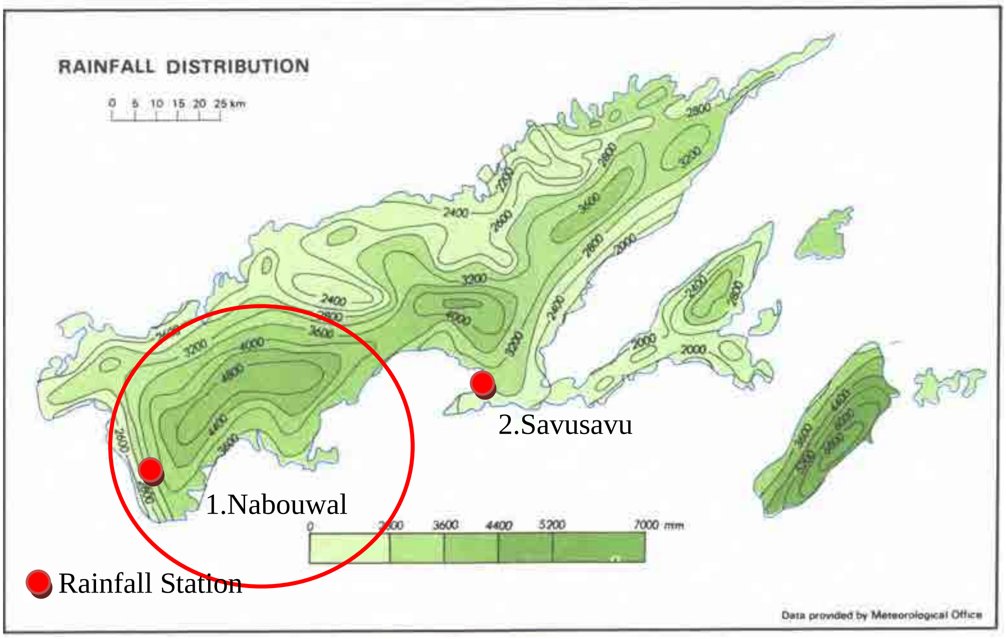


Figure 6.8.1-1 Main Metrological Stations in Vanua Levu

(2) **Run-off-Analysis Method**

As the review of the run-off analysis using rainfall data, the monthly discharge at the dam site and the intake weir site were estimated using the run-off coefficient and base flow considered by the M/P study. The conditions of the river discharge at the planning site were reviewed at the duration curve estimated from rainfall data based on the result of site reconnaissance are shown in the following.

・Run-off coefficient

Run-off coefficient from the amount of precipitation of the day is 0.73.
Run-off coefficient from the amount of precipitation for one day ago is 0.70.
Run-off coefficient from the amount of precipitation for two days ago is 0.50.
Run-off coefficient from the amount of precipitation for three days ago is 0.35.

The total run-off coefficient was determined at 2.28 for the following reasons.

- The rainfall distribution for the No.35 Hydropower Scheme located on the Wailevu basin was about 4,800mm higher than at the Nabouwalu station.
- The average annual rainfall for the Nabouwalu station was 2,393mm. On the other hand, the annual average rainfall of the No.35 Hydropower Scheme was assumed to be around 4,800 – 5,000mm.
- The run-off took into account the underground water as well as the daily rainfall amounts.

a. The Run-off Analysis for No.35-2 the Wailevu Hydropower Station

The average monthly discharge data for the No.35-2 Wailevu Hydropower Station estimated to calculate the optimum storage capacity and annual generated energy are shown in Table 6.8.1-2. The lowest of average monthly discharge was about 2.00 m^3/sec in July. This was almost equivalent to the discharge value that was confirmed by site reconnaissance.

Table 6.8.1-2 Average Monthly Discharge (CA=19.5 km^2)

Mean Daily Discharge			Station No.				Station Name:	No.2 Dam site					
			CA :	19.5	km^2		Wailevu River						
	Year:	1980-2013											Unit: m^3/sec
	Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	1	4.27	5.03	5.55	5.91	4.90	3.42	2.39	2.48	2.36	2.19	3.09	5.09
	2	4.68	5.68	5.64	5.77	6.12	2.89	2.63	2.84	2.31	2.09	2.71	4.33
	3	4.96	5.46	4.84	5.82	5.70	3.22	2.46	2.93	2.13	1.98	2.87	3.43
	4	5.28	5.72	4.86	5.72	6.58	3.36	2.55	2.43	1.76	3.76	3.43	3.77
	5	5.23	5.03	5.65	5.60	5.78	4.09	2.36	1.98	1.54	4.06	3.54	4.15
	6	5.98	5.14	6.25	5.63	4.73	3.75	2.00	1.81	1.44	4.20	3.21	4.48
	7	5.57	4.96	6.34	6.29	4.01	3.22	1.80	2.48	1.47	4.04	3.21	4.50
	8	5.55	5.14	6.18	6.00	3.17	2.66	1.46	2.79	1.69	2.83	3.30	4.33
	9	6.09	5.48	5.65	5.74	2.78	2.27	1.26	2.67	1.75	2.50	3.40	4.57
	10	5.98	5.09	6.06	5.91	2.63	2.37	1.26	2.37	1.78	2.78	3.72	5.15
	11	5.92	6.27	6.47	6.20	2.43	2.22	1.82	2.15	1.90	4.09	3.20	5.36
	12	6.52	6.03	6.90	6.65	1.92	2.65	2.39	2.03	2.68	3.75	2.47	4.60
	13	7.89	5.50	6.12	5.77	3.15	2.52	2.16	1.79	3.54	3.57	2.62	4.85
	14	8.10	4.93	5.61	4.65	3.61	2.33	2.31	1.72	3.48	3.28	3.61	4.60
	15	7.75	5.38	6.14	3.70	3.64	2.28	1.94	2.02	2.90	2.59	4.67	3.89
	16	8.27	5.43	5.79	4.33	3.57	2.70	1.56	2.29	2.57	2.36	5.19	4.41
	17	7.05	5.96	6.23	4.72	3.11	2.88	1.53	2.35	2.58	2.86	4.52	5.00
	18	5.89	6.35	6.53	6.64	2.76	2.92	1.52	2.21	2.25	2.70	3.83	4.83
	19	5.38	5.51	6.97	7.22	2.50	2.77	1.49	2.12	2.52	4.28	3.28	5.42
	20	4.73	5.65	7.34	6.93	2.51	2.23	1.56	2.14	2.27	5.16	2.85	5.25
	21	4.61	4.87	7.08	6.78	2.39	2.12	1.53	2.14	2.25	4.68	2.60	5.13
	22	4.46	5.42	5.96	5.60	2.48	1.99	1.56	2.34	3.09	3.85	3.41	6.20
	23	5.20	5.85	5.86	4.78	3.28	1.92	2.03	2.23	3.19	2.67	3.80	6.12
	24	5.94	6.35	5.91	4.48	3.69	2.13	2.31	2.29	3.00	2.67	4.05	6.31
	25	6.22	6.07	5.57	4.12	3.91	2.14	2.53	2.12	3.01	2.54	4.86	5.60
	26	5.90	5.29	5.33	4.14	3.21	1.98	2.28	1.72	2.86	2.64	4.85	4.86
	27	6.02	6.05	5.42	4.94	2.21	1.90	2.08	1.68	2.55	2.86	4.66	4.63
	28	6.60	5.80	5.64	4.77	1.97	1.75	1.82	1.49	2.62	3.62	4.46	4.60
	29	6.77	4.18	5.86	4.71	2.35	1.72	1.91	1.88	2.52	4.11	5.02	4.29
	30	6.51		6.10	4.68	3.33	1.99	1.90	1.85	2.42	4.01	4.92	4.81
	31	5.41		5.88		3.48		2.27	2.35		3.37		4.43
	Min	4.27	4.18	4.84	3.70	1.92	1.72	1.26	1.49	1.44	1.98	2.47	3.43
	Mean	5.96	5.50	5.99	5.47	3.48	2.55	1.96	2.18	2.41	3.29	3.71	4.81
	Max	8.27	6.35	7.34	7.22	6.58	4.09	2.63	2.93	3.54	5.16	5.19	6.31

b. The Run-off Analysis for No.35-1 Wailevu Hydropower Station

The No.1 Wailevu Hydropower Station for a run-of-river type with a catchment area of 34.7 km^2 was generated by using the outflow of the No.35-2 Hydropower Station with a catchment area of 19.5 km^2. This left a remaining catchment area of 15.2 km^2 for the basin at the No.35-1 site. The discharge date for this remaining area was estimated in the same way based on calculating of the average monthly discharge for the No.35-2 Wailevu Hydropower Station. The average monthly discharge is shown in Table 6.8.1-3.

Table 6.8.1-3 Average Monthly Discharge (CA=15.2 km^2)

Mean Daily Discharge		Station No.				Station Name:	No.1 Intake weir					
		CA :	15.2	km^2		Waivaka River						
Year:	1980-2013											Unit: m^3/sec
Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3.33	3.92	4.33	4.60	3.82	2.67	1.87	1.93	1.84	1.70	2.41	3.97
2	3.65	4.43	4.40	4.50	4.77	2.25	2.05	2.22	1.80	1.63	2.11	3.37
3	3.87	4.26	3.77	4.54	4.45	2.51	1.92	2.29	1.66	1.54	2.23	2.68
4	4.12	4.46	3.79	4.46	5.13	2.62	1.99	1.89	1.37	2.93	2.68	2.94
5	4.08	3.92	4.40	4.36	4.51	3.19	1.84	1.54	1.20	3.17	2.76	3.23
6	4.66	4.01	4.87	4.39	3.69	2.93	1.56	1.41	1.12	3.27	2.50	3.49
7	4.34	3.87	4.94	4.90	3.13	2.51	1.40	1.93	1.14	3.15	2.51	3.51
8	4.32	4.01	4.82	4.68	2.47	2.08	1.14	2.17	1.32	2.21	2.57	3.37
9	4.74	4.27	4.41	4.47	2.16	1.77	0.98	2.08	1.36	1.95	2.65	3.56
10	4.66	3.97	4.72	4.60	2.05	1.85	0.98	1.85	1.38	2.16	2.90	4.01
11	4.61	4.89	5.05	4.84	1.89	1.73	1.42	1.68	1.48	3.19	2.49	4.18
12	5.08	4.70	5.37	5.18	1.50	2.06	1.86	1.58	2.09	2.92	1.93	3.59
13	6.15	4.28	4.77	4.50	2.45	1.96	1.69	1.39	2.76	2.78	2.05	3.78
14	6.31	3.84	4.37	3.63	2.82	1.81	1.80	1.34	2.71	2.56	2.81	3.59
15	6.04	4.19	4.79	2.89	2.83	1.78	1.51	1.57	2.26	2.02	3.64	3.03
16	6.45	4.23	4.52	3.37	2.78	2.11	1.22	1.79	2.01	1.84	4.04	3.44
17	5.49	4.65	4.85	3.68	2.43	2.25	1.19	1.83	2.01	2.23	3.52	3.89
18	4.59	4.95	5.09	5.17	2.15	2.27	1.19	1.72	1.76	2.11	2.99	3.76
19	4.19	4.29	5.43	5.63	1.95	2.16	1.16	1.65	1.96	3.33	2.56	4.22
20	3.69	4.40	5.72	5.40	1.95	1.74	1.21	1.67	1.77	4.02	2.22	4.09
21	3.59	3.80	5.52	5.29	1.86	1.65	1.20	1.67	1.76	3.65	2.02	4.00
22	3.48	4.23	4.64	4.37	1.94	1.55	1.22	1.82	2.41	3.00	2.66	4.84
23	4.05	4.56	4.57	3.73	2.55	1.50	1.58	1.74	2.49	2.08	2.96	4.77
24	4.63	4.95	4.61	3.49	2.88	1.66	1.80	1.79	2.34	2.08	3.15	4.92
25	4.85	4.74	4.34	3.21	3.05	1.67	1.97	1.65	2.34	1.98	3.79	4.37
26	4.60	4.12	4.15	3.23	2.50	1.54	1.77	1.34	2.23	2.06	3.78	3.79
27	4.69	4.71	4.23	3.85	1.72	1.48	1.62	1.31	1.99	2.23	3.63	3.61
28	5.14	4.52	4.39	3.72	1.54	1.36	1.42	1.16	2.04	2.82	3.48	3.59
29	5.28	3.25	4.57	3.67	1.83	1.34	1.49	1.46	1.96	3.20	3.91	3.34
30	5.08		4.76	3.65	2.60	1.55	1.48	1.44	1.88	3.12	3.84	3.75
31	4.21		4.58		2.71		1.77	1.83		2.62		3.45
Min	3.33	3.25	3.77	2.89	1.50	1.34	0.98	1.16	1.12	1.54	1.93	2.68
Mean	4.64	4.29	4.67	4.27	2.71	1.99	1.53	1.70	1.88	2.57	2.89	3.75
Max	6.45	4.95	5.72	5.63	5.13	3.19	2.05	2.29	2.76	4.02	4.04	4.92

(3) **Flood Analysis**

The hydrological data including flood discharge in Wailevu Basin were not collected from WAF. Thus, the flood analysis was estimated by using the Creager curve of Japan based on the results of the flood analysis from the logarithmic normal distribution method for the No.29 Hydropower Scheme (which illustrated a similar pattern for the annual rainfall compared to the distribution rainfall). The calculation formula for the Creager curve is shown below.

$$q = C \times A^{(A^{-0.05}-1)}$$

Where,
q: Largest regional specific flood discharge (m^3/sec/km^2)
C: Regional coefficient
A: Catchment area (km^2)

To estimate the largest regional specific flood discharge with various probabilities – 50 year, 100 year, 200 year, 500year, and 1,000 year - the regional coefficients estimated by using the results of the flood analysis for the No.2 Dam site of the No.29 Hydropower Scheme from the relationship of rainfall distribution are shown in Table 6.8.1-4.

Table 6.8.1-4 Regional Coefficients for the Dam Site of the No.29 Waivaka Hydropower Scheme

Location / Return period	Unit	CA (km^2)	1000 year	500 year	200 year	100 year	50 year
No.29 at No.2 Dam site	m3/sec	12.4	220 (C=24)	199 (C=22)	169 (C=18)	148 (C=16)	129 (C=14)

Calculation method of the regional coefficient (1000 year) was calculated using the following formula.

1000 year: q=Q/CA= 220/12.4=17.7

:C = q/CA^(CA^(-0.05)-1)=17.7/12.4^(12.4^(-0.05)-1)≒24

Flood probabilities – for 50 year, 100 year, 500 year, and 1,000 year periods - were estimated using the above Creager curve method with the relevant regional coefficients. The results of this are shown in Table 6.8.1-5.

Table 6.8.1-5 Results of the Flood Analysis for the No.35-1 Intake Weir and the No.35-2 Dam

	CA (km^2)	1000 year	500year	200 year	100 year	50 year
No.35-2 Dam	19.5	311	285	233	207	181
No.35-1 Intake Weir	34.7	468	429	351	312	273

For reference, the largest regional specific flood discharges using the relevant regional coefficients are shown in Table 6.8.1-6. The largest regional specific flood discharges were about 30% greater when compared to the dam site for the No.29 Hydropower Scheme.

Table 6.8.1-6 Relationship of the Largest Specific Regional Flood Discharges Between No.35 and No.29

Location / Return period	Unit	CA (km^2)	1000 year (C=24)	500year (C=22)	200 year (C=18)	100 year (C=16)	50 year (C=14)
No.35 -2 Dam site	$m^3/sec/km^2$	19.5	15.93	14.60	11.95	10.62	9.29
No.35-1 Intake Weir site	$m^3/sec/km^2$	34.7	13.49	12.36	10.11	8.99	7.87
No.29 at No.2 Dam site	$m^3/sec/km^2$	12.4	17.74	16.05	13.63	11.94	10.40

(4) **Estimation of Sediment Capacity**

The 100 year sedimentation capacity at dam site was calculated using the following formula to be487,500 m^3. Therefore, the sedimentation level was determined as El.199m.

(Calculation Formula)

Vs = qs x CA x 100
Where,
Vs: The 100 year sedimentation capacity(m^3)
qs: 0.25 mm/year (: Proceeding of the Fiji Symposium, June 1990, Erosion and sedimentation in Fiji – An overview)
CA: Catchment area at dam site (19.5 km^2)

(b). Geological Condition

The detailed general geological and engineering geological data for the main structures such as the intake, dam, headrace, penstock and powerhouse, are shown in Appendix are shown in Appendix 6-1-3 (No.35 Wailevu Hydropower Scheme in the Vol. III APPENDIX).

6.8.2 Conditions for the Calculation of the Power Generation

a. No.35-2 Wailevu Hydropower Scheme of Reservoir Type

(1) **The Inflow Duration Curve at the No.35-2 Dam Site**

The inflow duration curve was prepared for a catchment area of 19.5 km^2 at the No. 35-2 dam site. The average discharge was assumed as 3.94 m^3/sec. The inflow duration curve for this is shown in Figure 6.8.2-1.

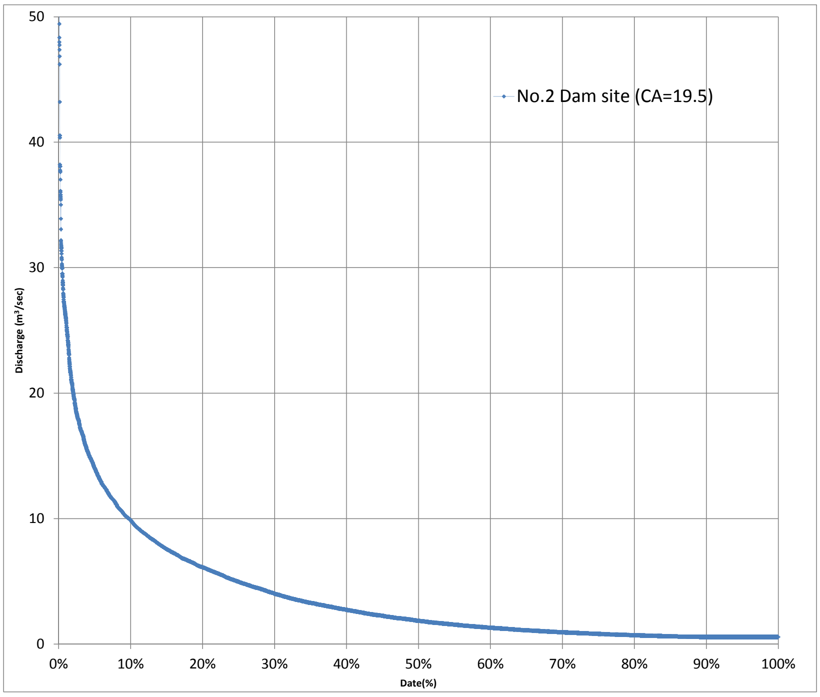


Figure 6.8.2-1 Inflow Duration Curve at the No.35-2 Dam Site (1980 - 2013)

(2) **Reservoir capacity**

The reservoir capacity was estimated using the 1/10,000 scale maps and the water level data. The storage curve is shown in Figure 6.8.2-2.

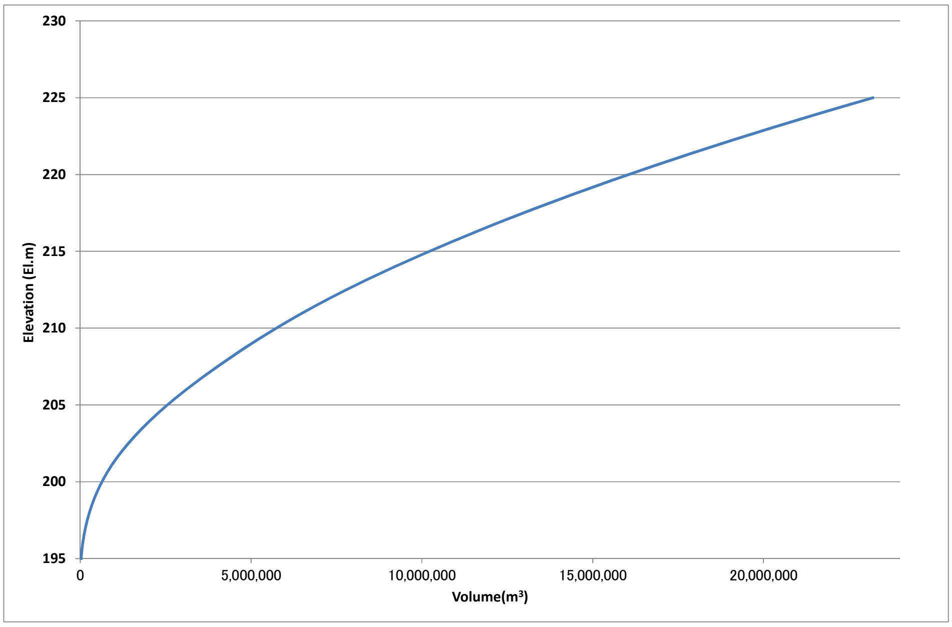


Figure 6.8.2-2 Storage Curve (Scale: 1/10,000)

(3) **Water Level at the Dam Site**

The HWL was determined as EL.221m.

In order to prevent air from getting inside the pressure tunnel, the minimum water level was determined as EL.204m - this enabled the setting of a position of 1.5 times the length of the pressure tunnel's inner diameter from the sediment level (EL.199 m).

(4) **Optimal Storage Capacity**

The optimal storage capacity is estimated by using the average monthly discharge data from 1980 to 2013 at the dam site in order to calculate the available depth of the reservoir. The results of the optimal storage capacity are shown in Table 6.8.2-1 and Figure 6.8.2-3.

From the results, the optimal storage capacity was estimated as 20,000,000 m^3. On the other hand, in relation to the geological conditions around the site, the dam's height should be lower than 40m. Therefore, the storage capacity was determined to be around 15,000,000 m^3 as shown in the HWL and LWL relationship with the storage curve mentioned above.

Table 6.8.2-1 Results of the Optimal Storage Capacity by Using the Average Annual Discharge

Month	Day	River Discharge Qi	Monthly Storage Capacity	Qi-Qave	Cumulative Storage Capacity ΣQi-Qave
		(m^3/sec)	(m^3)	(m^3/sec)	(m^3)
1	31	5.96	5,403,672	2.02	5,403,672
2	29	5.50	3,902,472	1.56	8,957,520
3	31	5.99	5,484,024	2.05	15,059,304
4	30	5.47	3,959,280	1.53	18,532,800
5	31	3.48	-1,238,760	-0.46	17,911,800
6	30	2.55	-3,609,360	-1.39	13,724,640
7	31	1.96	-5,309,928	-1.98	8,872,200
8	31	2.18	-4,720,680	-1.76	4,151,520
9	30	2.41	-3,972,240	-1.53	45,360
10	31	3.29	-1,747,656	-0.65	-1,700,784
11	30	3.71	-602,640	-0.23	-2,248,560
12	31	4.81	2,323,512	0.87	-0
		3.94			

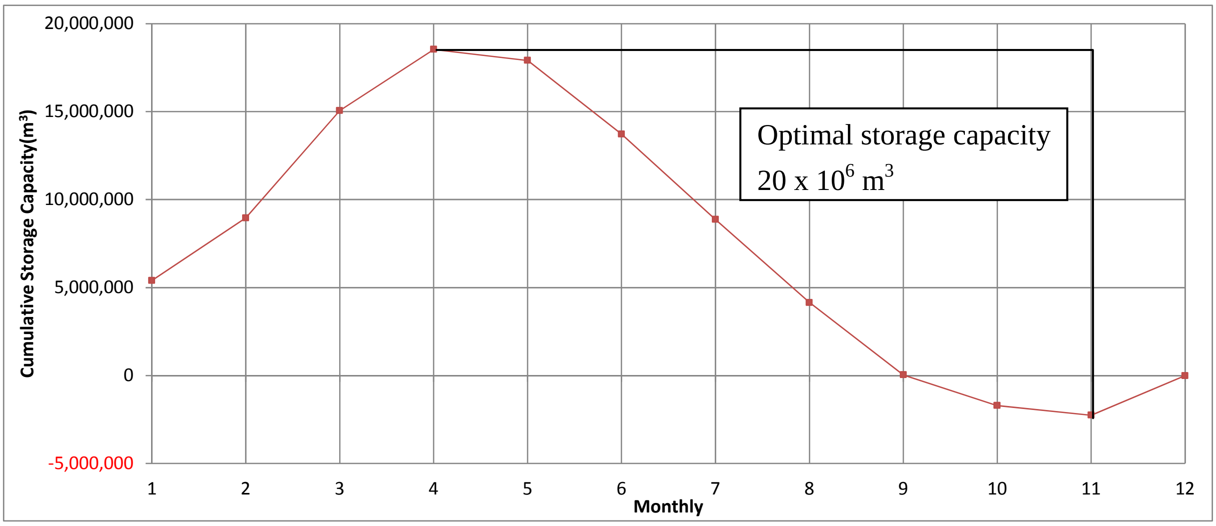


Figure 6.8.2-3 Optimum Storage Capacity Curve (Scale: 1:10,000)

(5) **Combined Efficiency of Turbine and Generator**

In this study, the combined efficiency of the turbine and the generator was 0.85 uniformly.

(6) **Tail Water Level**

The tail water level was assumed to be EL.180m at the No.2 power station site.

b. No.35-1 Wailevu Hydropower Scheme of Run-of-River type

(1) **The Inflow Duration Curve at the No.35-1 Intake Weir Site**

The inflow duration curve was prepared for a catchment area of 34.7 km^2 at the No.35-2 intake site. The average discharge was assumed to be 7.02 m^3/sec. The inflow duration curve is shown in Figure 6.8.2-4.

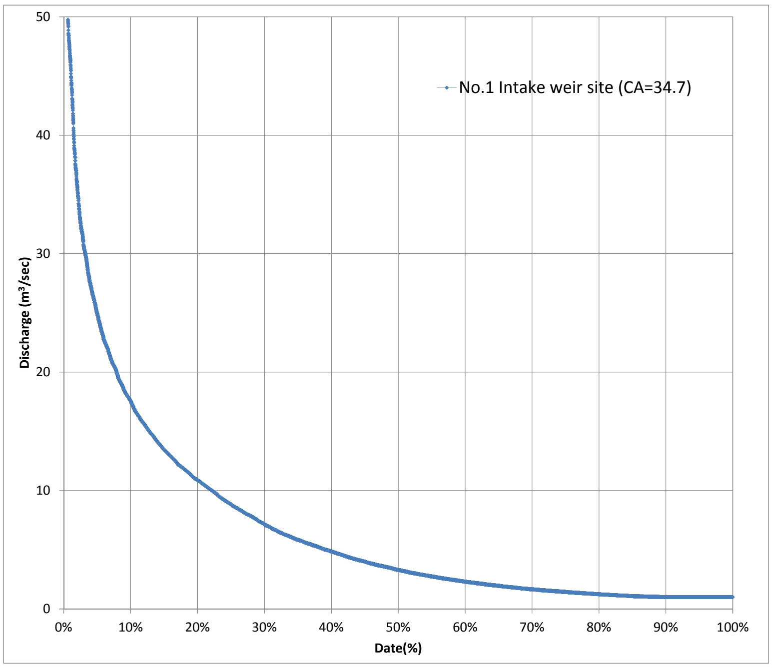


Figure 6.8.2-4 Inflow Duration Curve at the No.35-2 Intake Weir Site (1980 - 2013)

(2) **Water Level**

The intake water level of the No.1 Hydropower Scheme was assumed to be EL.140m

(3) **Combined Efficiency of Turbine and Generator**

In this study, the combined efficiency of the turbine and the generator was 0.85 uniformly.

(4) **Tail Water Level**

Through using a 1/10,000 scale, the tail water level was assumed to be EL.35m.

6.8.3 Calculation of the Power Generation

a. No.35-2 Wailevu Hydropower Scheme for Reservoir type

The No. 35-2 Hydropower scheme is available for operation during peak time using storage capacity. The maximum plant discharge can be increased to a few times higher than the firm discharge by setting the storage capacity appropriately. In this study, the firm discharge was set as the annual average discharge of 3.94 m^3/sec in relation to the storage capacity. The relation between the firm discharge and operation time is mentioned below.

$Q_p = Q_f$ x 24hour / T_f
Q_p : Maximum plant discharge (m^3/s)
Q_f : Firm discharge during a year (m^3/s)

T_f : Operation time is 6 hours

The monthly power generation is calculated based on the monthly discharge and the daily operation time using the following formula. And the annual power generation is calculated as the sum of the relevant monthly power generation figures.

$G_{date} = 9.8 \times Q_p \times He_{date} \times \eta_{date} \times T_{fdate}$

G_{date} : Monthly Generated Energy

Q_p : Maximum plant discharge(m^3/s)

He_{date} : Effective head for monthly operation water level (m)

η_{date} : Combined efficiency of turbine and generator (%)

T_{fdate} : Peak operation time

b. No.35-1 Wailevu Hydropower Scheme for Run-of-River type

The monthly operation discharge was estimated by the above average monthly discharge for the basin remaining at the catchment area of 15.2 km^2 and the outflow of the No.35-2 Wailevu Hydropower Station estimated using the above calculation formula.

$G_{date} = 9.8 \times Q_p \times He_{date} \times \eta_{date} \times T_{pdate}$

G_{pdate} : Peak Monthly Generated Energy (kWh)

Q_p : Peak Operation discharge(m^3/s)

$Q_p = Q_{No.2} + Q_{No.1}$

$Q_{No.2}$: Discharge from outflow of No.2 Wailevu hydropower station

$Q_{No.1}$: Discharge of the basin remaining at catchment area of 15.2 km^2

He_{date} : Effective head for daily operation water level (m)

η_{date} : Combined efficiency of turbine and generator (%)

T_{pdate} : Peak operation time

$G_{date} = 9.8 \times Q_{op} \times He_{date} \times \eta_{date} \times T_{opdate}$

G_{opdate} : Off-Peak Monthly Generated Energy (kWh)

Q_{op} : Daily operation discharge at catchment area of 15.2 km^2(m^3/s)

He_{date} : Effective head for daily water level (m)

η_{date} : Combined efficiency of turbine and generator (%)

T_{opdate} : Off-Peak operation time

$\Sigma G_{date} = G_{pdate} + G_{opdate}$

ΣG_{date} : Monthly Generated Energy (kWh)

6.8.4 Estimated Construction Costs

The construction costs were estimated based on the “Guideline and Manual for Hydropower Development Vol.1 Conventional Hydropower and Pumped Storage Hydropower”. The unit cost was quoted in terms of the hydropower renewable energy development project in the Wailoa downstream in the Republic of the Fiji Islands and current, similar hydroelectric development projects in Asian countries.

The construction costs were separated into the direct costs and indirect costs. The direct costs consist of the preparation works and main construction works such as civil structures, hydro mechanical works, electromechanical, equipment and transmission lines. The indirect costs consist of administration, engineering service fees, and other contingency costs. The indirect costs were calculated by ratio from the direct costs.

6.8.5 Optimum Development Scale

The optimum development scale was determined with economic evaluation by setting the maximum output in 20 cases, which were selected for each of the development plans from the project features of the No.2 Hydropower Scheme and No.1 Hydropower Scheme. The peak operation time was eight hours on weekdays and one hour on Saturdays and Sundays; the relationship between the firm discharge and the effective storage capacity was considered to be 3.6 m^3/sec during the dry season and 4.4 m^3/sec the during rainy season.

The economic evaluation of the optimum development plan was determined by a comprehensive evaluation based on the benefit-cost ratio (B/C), a net present value (B-C), and the index expressed as a construction cost per unit energy (USD/kWh). As an economic value, a diesel power plant was selected as an alternative thermal power generation using diesel plants in Fiji. The hydropower capital recovery coefficient and kW and kWh values were confirmed by relative organization and were carried out based on same conditions of the hydropower renewable energy development project in the Wailoa downstream. The conditions for the B/C calculation are mentioned below.

The conditions for the B/C calculation:
KW Value：175.3USD/kW
KWhValue：0.144USD/kWh
Hydropower capital recovery coefficient：0.11226
KW correction factor：1.21, kWh correction factor：1.03

The optimum development scale for the reservoir type is shown in Table 6.8.5-1, and for the run-of-river type is shown in Table 6.8.5-2.

The results of the economic evaluation for the optimum development scales are shown in Table 6.8.5-3.

Table 6.8.5-1 Optimum Development Scales for the No.35-2 Hydropower Scheme

Case	Unit	A-1	A-2	A-3	A-4
Maximum Output	kW	4,000	4,500	5,000	6,000
Maximum Discharge	m^3/sec	13.43	15.10	16.78	17.52
Firm Output	kW	2,498	2,685	2,685	2,685
Annual Power Generation (Peak time)	MWh	8,783	8,755	8,740	8,733
HWL	EL. m	221			
LWL	EL. m	204			
TWL	EL. m	180			
Gross Head	m	41			
Pressure Penstock	m	291			
Construction Cost	10^3 x USD	35,740	36,932	38,075	39,963

Table 6.8.5-2 Optimum Development Scales for the No.35-1 Hydropower Scheme

Case	Unit	B-1	B-2	B-3	B-4	B-5	The output of No.35-2 Wailevu Hydropower Project
Maximum Output	kW	12,000	13,000	14,000	15,000	16,000	
Maximum Discharge	m³/sec	14,35	15.54	16.74	17.93	19.13	
Firm Output	kW	14,998	14,640				Case A-1 (4,000 kW)
		14,685	15,662				Case A-2 (4,500 kW)
		14,685	15,662				Case A-3 (5,000 kW)
		14,685	15,662				Case A-4 (6,000 kW)
Annual Power Generation	MWh	56,102	58,079	58,984	60,038	60,085	Case A-1 (4,000 kW)
		53,667	55,854	57,712	58,913	59,775	Case A-2 (4,500 kW)
		52,417	54,602	56,426	57,609	58,514	Case A-3 (5,000 kW)
		51,850	54,040	55,864	57,072	57,944	Case A-4 (6,000 kW)
HWL	EL.m	140					
TWL	EL.m	35					
Gross Head	EL.m	105					
Headrace Tunnel	m	2,540					
Penstocks	m	387					
Construction Cost	10^3 x USD	39,303	40,966	43,020	44,978	46,389	

Table 6.8.5-3 Results of the Economic Evaluation for the Optimum Development Scales

Comparison(s) for the Optimum Development Plan		No.2 Wailevu Hydropower Scheme (CA= 19.5 km^2)				
		Case A-1 (4MW)	Case A-2 (4.5MW)	Case A-3 (5MW)	Case A-4 (6MW)	
No.1 Wailevu Hydropower Scheme (CA= 34.7km^2)	Case B-1 (12MW)	1.26	1.22	1.18	1.15	B/C
		2,221	1,916	1,607	1,314	B-C
		1.34	1.42	1.48	1.53	USD/kWh
		75,043	76,235	77,378	79,266	Constriction cost x 10^3 USD
	Case B-2 (13MW)	1.27	1.23	1.20	1.16	B/C
		2,319	2,044	1,735	1,443	B-C
		1.32	1.39	1.45	1.50	USD/kWh
		76,706	77,898	79,041	80,929	Constriction cost x 10^3 USD
	Case B-3 (14MW)	1.25	1.23	1.19	1.16	B/C
		2,219	2,081	1,768	1,475	B-C
		1.33	1.39	1.44	1.49	USD/kWh
		78,460	79,952	81,095	82,983	Constriction cost x 10^3 USD
	Case B-4 (15MW)	1.24	1.23	1.20	1.16	B/C
		2.158	2,158	1,848	1,554	B-C
		1.34	1.39	1.44	1.49	USD/kWh
		80,718	81,910	83,053	84,941	Constriction cost x 10^3 USD
	Case B-5 (16MW)	1.22	1.21	1,18	1.14	B/C
		1,999	2,000	1,690	1,396	B-C
		1.37	1.39	1.44	1.49	USD/kWh
		82,129	83,321	84,464	86,352	Constriction cost x 10^3 USD

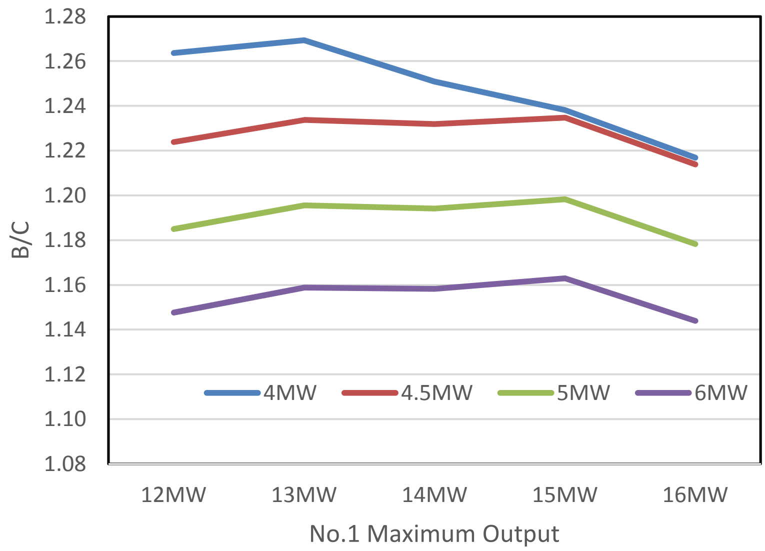


Figure 6.8.5-1 Results of the Economic Evaluation by B/C

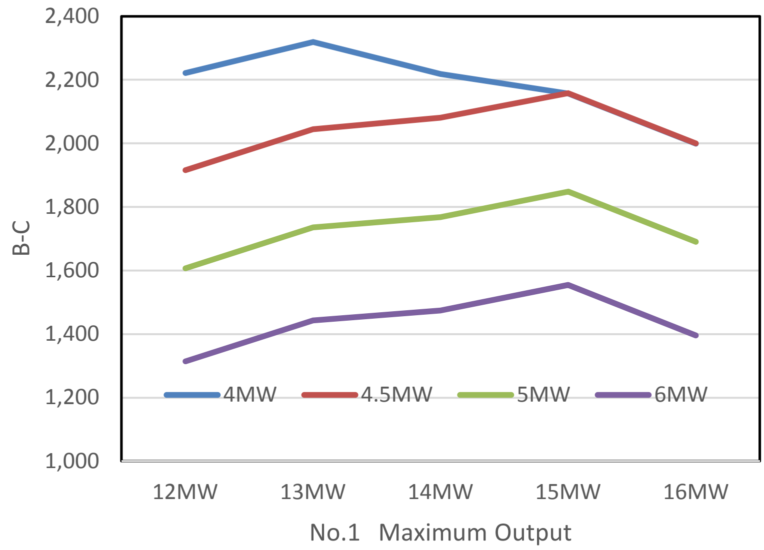


Figure 6.8.5-2 Results of the Economic Evaluation by B-C

6.8.6 Optimum Development Plan

The optimum development plan was evaluated from an economic point of view, using the benefit-cost ratio (B/C), net present value (B-C), and the index expressed as a construction cost per unit energy (USD/kWh). Following this the most economic maximum output was selected. From the results of the economical comparison on the case shown in the table, the following considerations were provided.

(1) CaseA-1-B-1and Case A-1-B-2 (with 17 MW of total capacity) had the highest economic value with a benefit- cost ratio (B/C) of 1.27.

(2) CaseA-1-B-2 (with 17 MW of total capacity) had the highest economic value with a net present value (B-C) of 2,319.

(3) Case A-1-B-2 (with 17 MW of total capacity) had the highest economical index of 1.32 USD/kWh.

Therefore, it was assessed that Case A-1-B-2 (with 17 MW of total capacity) was the most advantageous for the project’s optimum development plans.

The main features for the optimum development plan shown in Table 6.8.5-1.

Table 6.8.5-1 Main Features of the Optimum Development Plan

Item	Unit	Features
No.35-2 Wailevu Hydropower Scheme		
Catchment Area	km^2	19.5
Type		Reservoir
Maximum Output	kW	4,000
Maximum Discharge	m^3/sec	13.43
Firm Output	kW	2,632
Dam height	m	32
High Water Level	EL.m	221
Low Water Level	EL.m	204
Tail Water Level	EL.m	180
Sediment Level	EL.m	199
Foundation Level	EL.m	193
Gross Head	m	41
Effective Head	m	39.3
Pressure Penstock	m	291
No.35-1 Wailevu Hydropower Scheme		
Catchment Area	km^2	34.7
Type		Run-of-River
Maximum Output	kW	13,000
Maximum Discharge	m^3/sec	15.54
Firm Output	kW	12,154
Dam height	m	5
Intake Water Level	EL.m	140
Tail Water Level	EL.m	35
Gross Head	m	105
Effective Head	m	100.3
Headrace	m	2,540
Penstock	m	387

6.9 Basic Design of the Hydropower Plant (No.35 Wailevu site)

6.9.1 Basic Design of the Hydropower Plant (No.35 Wailevu site)

Based on the results of the optimum development scale for the No.35 Hydropower Scheme, the preliminary designs of (1) the reservoir type for the No.35-2 Wailevu Hydropower Scheme (with 4 MW output located on upper stream of the Wailevu River) and (2) the run-of-river type for the No.35-1 Wailevu Hydropower Scheme (with 13 MW located on downstream Wailevu River) were carried out for the main structure(s). The No.35 Hydropower Scheme is a cascade type with a total power generation of 17 MW.

For the No.35-2 Wailevu Hydropower Scheme, the main structure’s facilities consist of: the dam, intake, pressure headrace, and power station. For the No.35-1 Wailevu Hydropower Scheme the main structure’s facilities consist of: the intake weir, sand trap, open channel, head tank, penstock and power station.

The main structure facilities were designed as follows.

a. No.35-2 Wailevu hydropower scheme

6.9.1-1 No.35-2 Dam

In consideration of the topographical and geographical conditions of the dam site, a reservoir dam type would be able to provide a concrete dam of less than 40m in height. A HWL of EL.221m was adopted in relation to the outlet elevation headrace tunnel along with a crest level of El. 225m and a crest length of 520m. A natural overflow type spillway was adopted without a gate as this would prove more economical and also avoid complicated gate operation requirements. A river design flood discharge of 233m^3/sec was adopted by taking account the flood discharge figure for the 200 year flood probability estimated by the logarithmic normal distribution method.

6.9.1-2 Penstock

The length of the penstock is 291m from the dam to the power station. A tunnel cross section was adopted for the pressure type circle tunnel. Due to economic considerations a rough diameter for the penstock was selected as 2.00m.

6.9.1-3 Powerhouse

The power station is located at the Wailevu River about 300 m downstream from the No.2 Dam site. An indoor powerhouse was adopted due to the power station being a hydro turbine type. The power station accommodates two unit turbines and two unit generators. In the case of the indoor powerhouse, its assembly and disassembly would be carried out by an overhead traveling crane. In consideration of a predicted flood discharge of 210 m^3/sec for every 100 year period, the ground level of the powerhouse was determined as El.184.5m considering. The building’s dimension would be 13.0m wide x 30.0 m long x 9.50 m high.

6.9.1-4 Power Generating Equipment for the Site No.35-2

(1) Type of hydro turbine

Table 6.9.1-1 shows the water discharge, effective head, and number of units for theSite No.35-2.

Table 6.9.1-1 Water Discharge and the Effective Head at Each Site

Site	Discharge [m^3/s]	Net head [m]	Number of Unit
No.35-2	15.54 (7.77/1 unit)	100.4	2

Figure 6.9.1-1 shows the hydro turbine selection chart. A vertical shafts and a horizontal shaft Francis turbine are appropriate for this site.

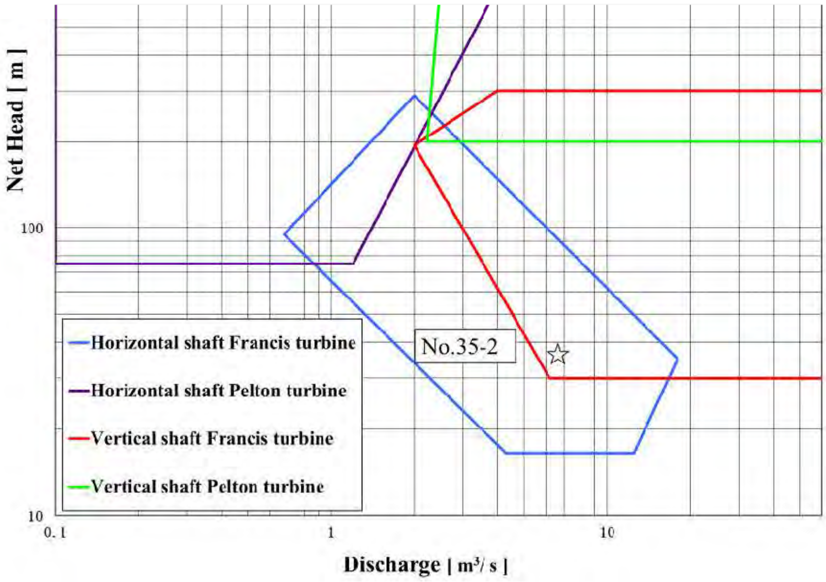


Figure 6.9.1-1 Hydro Turbine Selection Chart (No.35-2)

Table 6.9.1-2 Comparison Between the Vertical Shaft and the Horizontal Francis Turbineshows the comparison between the vertical shaft and the horizontal Francis turbine.

The vertical shaft requires excavation for installation space. The horizontal shaft is a planar structure.

Large Francis machines are usually vertical shafts. In the case of small machines, in terms of ease of installation and maintenance of the generating unit, horizontal shaft machines are preferable. Therefore a horizontal shaft Francis turbine is appropriate for site No.35-2.

Table 6.9.1-2 Comparison Between the Vertical Shaft and the Horizontal Francis Turbine

	Vertical shaft	Horizontal shaft
Space	Smaller than horizontal but excavation is required	Planar structure
Capacity	Approximately 1MW ～	Approximately 0.5MW ～10MW
Maintenance	Difficult	Easy

The estimations for the rated turbine output, specific speed, and rated speed for each power plant are shown in Table 6.9.1-3.

Table 6.9.1-3 The estimations for the Specific Speed and Rated Speed

Site	Type of hydro turbine	Rated turbine output [kW] / 1 unit	Specific speed [m-kW]	Rated speed [min-1]
No.35-2	HF	2,100	313.98	500

The estimations for the suction head, cavitation coefficient, and other conditions for each power plant are shown in Table 6.9.1-4.

Table 6.9.1-4 Estimations for the Suction head, Cavitation Coefficient, and Other Conditions

Site	Hs[m]	σp	Ha[m]	TWL[m]	Hv[m]	Ht[m]
No.35-2	2.5	0.203	10.127	180.00	0.32	100.4

(2) **Generator**

The estimations for the rated voltage, rated power factor, and rated capacity for generator for each power plant are shown in Table 6.9.1-5.

Table 6.9.1-5 Estimations for the Rated Voltage, Rated Power Factor, and Rated Capacity for the Generator

Site	Rated voltage [kV]	Rated power factor	Rated capacity [kVA] / 1 unit
No.35-2	6.6	0.85	2,400

b. No.35-1 Wailevu Hydropower Scheme

6.9.1-5 Intake weir

A natural overflow type for the intake weir was selected, as this is a simple facility with low costs compared with a gate type. There are good rock conditions around the concrete dam with about a 5m height beside the intake weir. The intake weir was designed to be 5m in height from the foundations, and due to the above conditions the HWL was EL.323 m with a crest length of 35m.

6.9.1-6 Intake

The intake is located in the right bank to smoothly guide water into the open channel. The standard inflow sill velocity of the intake would be between 0.30 m/s to 1.0 m/s.

The intake of the project site was determined as 1.04 m/s. The dimensions of the intake were set as being 6.0m wide and 2.5m high with one gate. The sill level of the intake was determined to be El.137.5 m to prevent the inflow of sediment into the intake.

6.9.1-7 Sand Trap

The sand trap is a facility for the precipitation removal of sediment flow. The velocity of the sand trap has to be less than 0.3 m/s to remove the sediment flow by means of the settling basin. The distance of the settling basin would be needed to settle the fine sand in the bottom at end of the basin from intake. The main features of the settling basin are shown below.

Dimension : 15.0 m wide x 21.0 m long x3.50 m depth
Average velocity : 0.296 m/s
Lenght of sand trap : 10.36 m

The accumulated sediment in the settling basin would be collected in one place by a slope of gradient 1/21 in the bottom of the basin (i.e. in order to be removed by the sand).

6.9.1-8 Headrace

A non-pressure type headrace connected to the head tank was selected as an open channel to take advantage of the non-steep terrain. Due to economic considerations the slope of the open channel would be 2,540m in length and set to a gradient of 1/1,000 to the channel slope. The cross section of the headrace was adopted in the rectangle as this would require a relatively small amount of excavation and construction work.

6.9.1-9 Head Tank

The head tank is located at the end of headrace and connected to the penstock. The role of head tank is to remove sediment by screening and preventing damage to the turbine. Therefore, the capacity of the head tank could be safely operated two or three minutes without replenishing the headrace. The downgrade slope to remove the settled sediment was set at at a gradient of 1/25 to the bottom. In terms of dimensions, this is 7m wide and 25m long.

6.9.1-10 Penstock

A surface penstock would be adopted in consideration of the topographical and geological conditions, and layout of the facilities related to the head tank and power station. The linear distance from the head tank to the powerhouse was 387m. From an economic perspective, a diameter of around 2.10m was selected for the penstock.

6.9.1-11 Powerhouse

The power station is located on the Wailevu River about 400m downstream from the confluence of the upper stream of the Wailevu River and the Vuci River. An indoor powerhouse was adopted due to the power station being a hydro turbine type. The power station accommodates two unit turbines and two unit generators. In the case of the indoor powerhouse, the assembly and disassembly would be carried out by an overhead traveling crane. In consideration of a predicted flood discharge of 482 m^3/sec for every 100 year period, the ground level for the powerhouse was determined as El. 39.0m. The building's dimension would be 14.0 m wide x 22.6 m long x 10.7 m high.

6.9.1-12 Power Generating Equipment for the Site No.35-1

(1) **Type of Hydro Turbine**

Table 6.9.1-6 shows the water discharge, effective head, and number of units for the site No.35-1.

Table 6.9.1-6 Water Discharge and the Effective Head at Each Site

Site	Discharge [m^3/s]	Net Head [m]	Number of Units
No.35-1	15.54 (7.77/1 unit)	100.4	2

Figure 6.9.1-2 shows hydro turbine selection chart. The selection of a vertical shaft Francis turbine is appropriate for the site No.35-1.

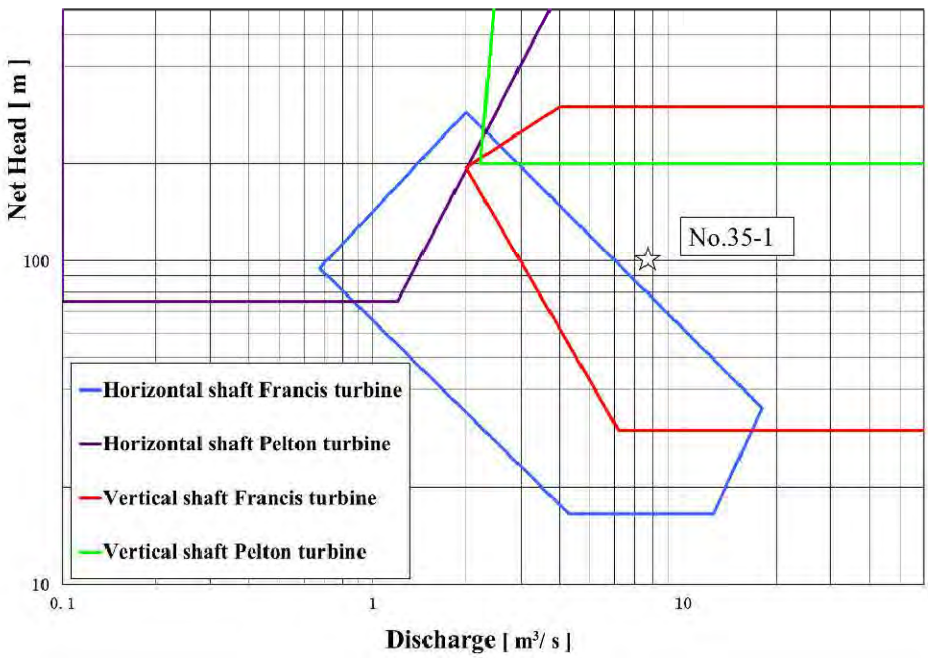


Figure 6.9.1-2 Hydro Turbine Selection Chart (No.35-1)

The estimations for the rated turbine output, specific speed, and rated speed for each power plant are shown in Table 6.9.1-7.

Table 6.9.1-7 Estimations for the Specific Speed and Rated Speed

Site	Type of hydro turbine	Rated turbine output [kW] / 1 unit	Specific speed [m-kW]	Rated speed [min-1]
No.35-1	VF	6,750	193.17	750

The estimations of the suction head, cavitation coefficient, and other conditions for each power plant are shown in Table 6.9.1-8.

Table 6.9.1-8 Estimations for the Suction head, Cavitation Coefficient, and Other Conditions

Site	Hs[m]	σp	Ha[m]	TWL[m]	Hv[m]	Ht[m]
No.35-1	-3.0	0.129	10.303	35.00	0.32	100.4

(2) **Generator**

The estimations for the rated voltage, rated power factor, and rated capacity for generator for each power plant are shown in Table 6.9.1-9.

Table 6.9.1-9 Estimations for the Rated Voltage, Rated Power Factor, and Rated Capacity for the Generator

Site	Rated voltage [kV]	Rated power factor	Rated capacity [kVA] / 1 unit
No.35-1	6.6	0.85	7,700

6.9.2 Rough Cost Estimations

The rough costs which were estimated by the requisite quantities in the drawings for the main structures required for the hydropower scheme are given in Table 6.9.2-1 and Table 6.9.2-2.

The drawings for the general layout plan and the general profile are shown in Figure 6.9.2-1 and Figure 6.9.2-2, respectively.

Table 6.9.2-1 Rough Cost Estimations for the Hydropower Scheme for the No.35-.2 Wailevu Hydropower Scheme

Item/Project	(USD)	Remarks
1. Preparation and Land Acquisition	1,024,762	
(1) Access Roads	592,000	@160USD/ 3,700 m
(2) Camp & Facilities	432,762	3. Civil Works * 2%
2. Environmental Mitigation Cost	649,143	3. Civil Works * 3%
3. Civil Works	21,638,105	
3.1 No.2 Dam	17,429,432	
3.2 No.2 Intake	200,436	
3.3 No.2 Penstock	2,120,634	
3.4 No.2 Powerhouse	754,824	
3.5 Tailrace Outlet	102,393	
3.6 Miscellaneous	1,030,386	(3.1 to 3.5) * 5%
4. Hydromechanical Works	589,902	
5. Electro-Mechanical Equipment	8,672,070	
Direct Cost	32,573,982	
6. Administration and Engineering Service	4,886,097	Direct Cost * 15%
7. Contingency	3,257,398	Direct Cost * 10%
8. Interest during Construction	1,140,089	(Direct Cost + 6. + 7.) *0.4[1]*0.014[2]*Constriction period
Total Cost	41,857,566	

[1] 0.4 is a cash flow coefficient which is an empirical value.

[2] 0.014 is interest rate.($i = i_1*0.4+i_2*0.6$ =2%0.4+1%*0.4)

i_1:Interrest rate for local currency, i_2:Interrrest rate for foreign currency

Table 6.9.2-2 Rough Cost Estimations for the Hydropower Scheme for the No.35-1 Wailevu Hydropower Scheme

Item	(USD)	Remarks
1. Preparation and Land Acquisition	969,659	
(1) Access Roads	800,000	@160USD/ 5,000m
(2) Camp & Facilities	169,659	3. Civil Works * 2%
2. Environmental Mitigation Cost	254,489	3. Civil Works * 3%
3. Civil Works	8,482,967	
3.1 No.1 Weir	523,184	
3.2 No.1 Intake	189,671	
3.3 No.1 Sand Trap	756,602	
3.4 No.1 Headrace	3,661,922	
3.5 No.1 Head Tank	563,115	
3.6 No.1 Penstock & Spillway	831,675	
3.7 No.1 Powerhouse	1,374,843	
3.8 No.1 Tailrace Outlet	178,004	
3.9 Miscellaneous	403,951	(3.1 to 3.8) * 5%
4. Hydromechanical Works	1,862,654	
5. Electro-Mechanical Equipment	13,319,366	
Direct Cost	24,889,135	
6. Administration and Engineering Service	3,733,370	Direct Cost * 15%
7. Contingency	2,488,914	Direct Cost * 10%
8. Interest during Construction	871,120	(Direct Cost + 6. + 7.) *0.4 [1] *0.014 [2] * Constriction
Total Cost	31,982,539	

[1] 0.4 is a cash flow coefficient which is an empirical value.

[2] 0.014 is interest rate.(i = i_1*0.4+i_2*0.6 =2%0.4+1%*0.4)

i_1:Interrest rate for local currency, i_2:Interrrest rate for foreign currency

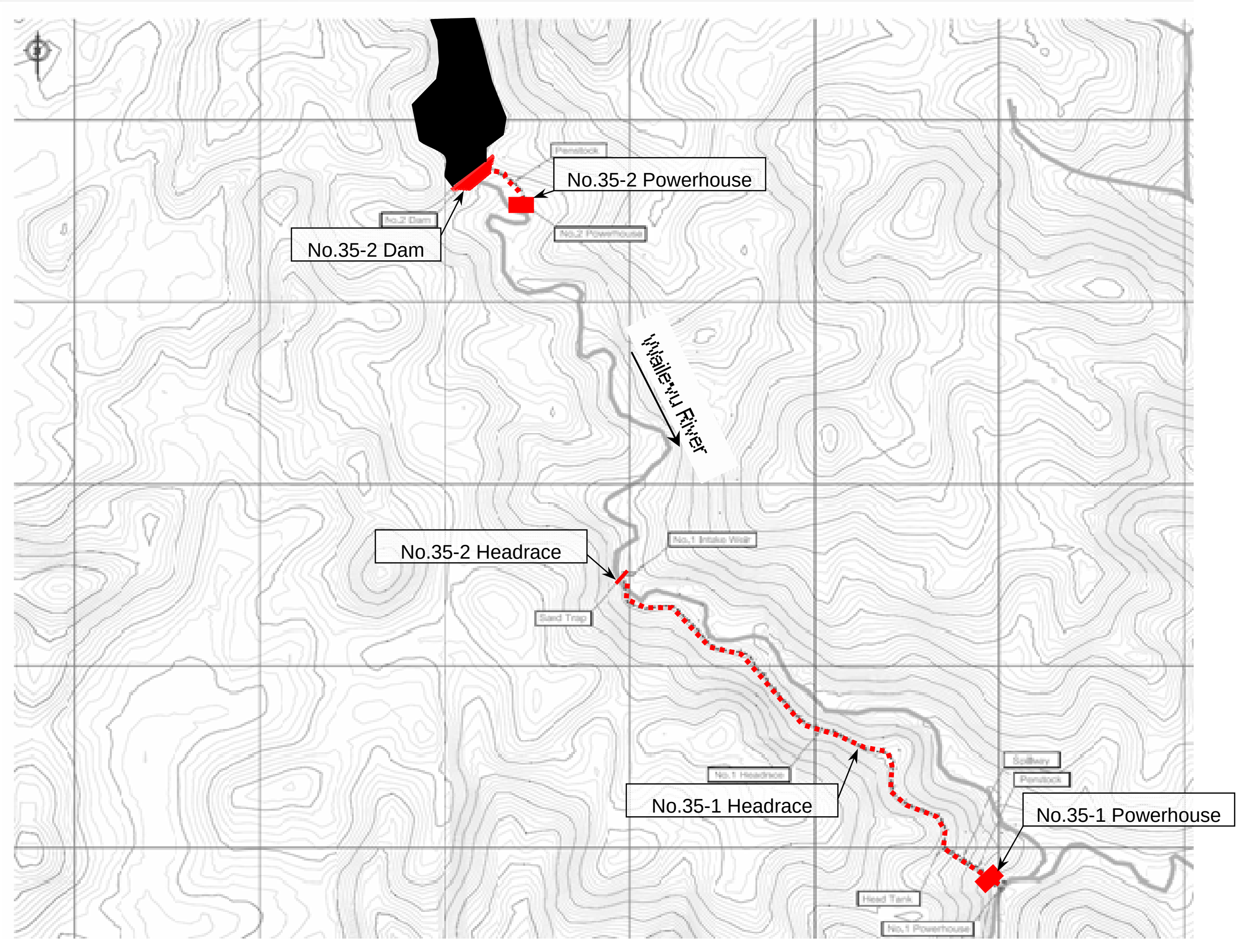


Figure 6.9.2-1 General Layout Plan for the No.35 Wailevu Hydropower Scheme

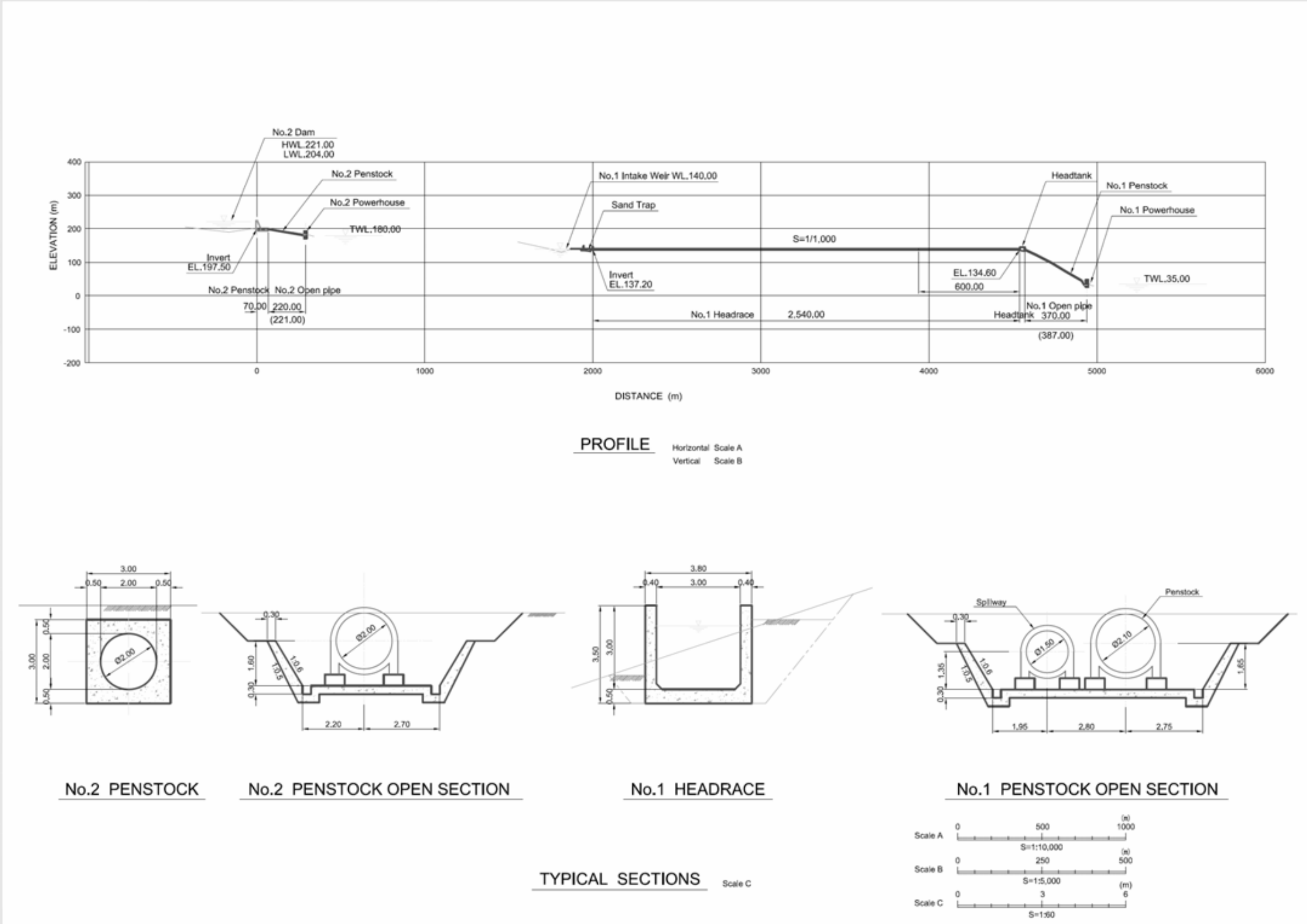


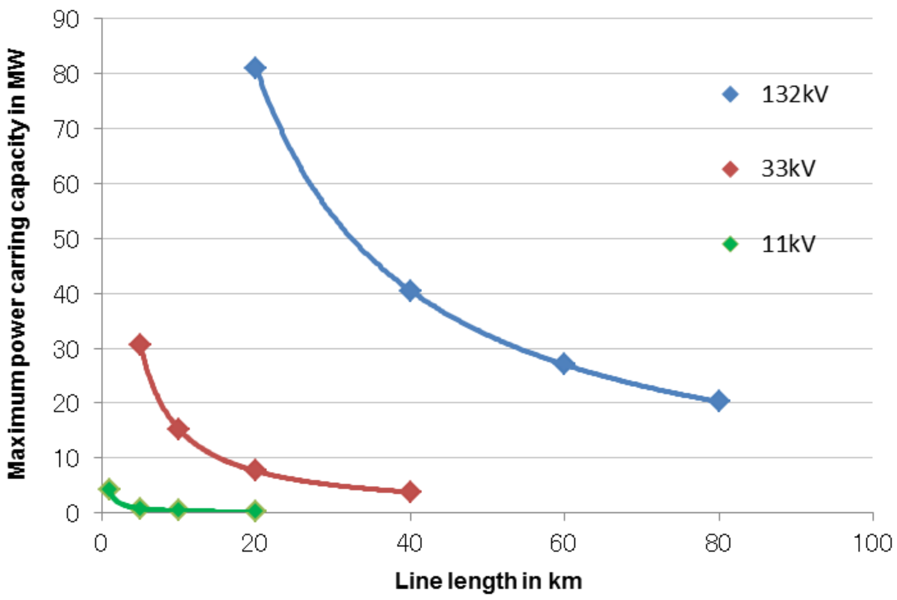
Figure 6.9.2-2 General Profile and Tunnel Sections

6.10 Rough Cost Estimations of the Transmission Facilities

For implementing the proposed transmission schemes, the rough costs of the transmission facilities were estimated. The cost data is based on that of PDP 2011.

6.10.1 Transmission Schemes for the Prospective Hydropower Potential Sites

For the prospective hydropower potential sites, the following transmission schemes were roughly considered for the study based on the transmission system planning for 2020 in PDP 2011. These took into account the maximum power carrying at different voltage levels with different line lengths as shown in Figure 6.10.1-1 and also the surrounding power network system.



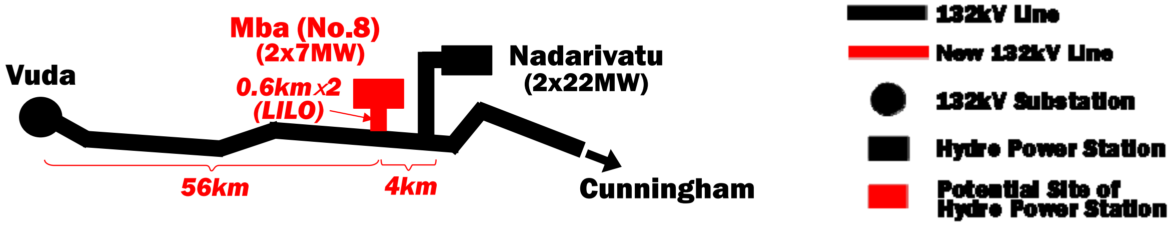
(Source: JICA Project Team based on PDP 2011)

Figure 6.10.1-1 Relationship the Between Maximum Power Carrying in Different Voltage Levels and Line Lengths

Incidentally, it is recommended that detailed power system analyses (including for power flow, short circuiting, and transient stability) should be carried out for various system contingencies in the network based on the revised transmission system plan, generation development plan, and zone substation wise load for the period 2014 to 2025 in PDP 2014. These analyses would take into account for the following prospective hydropower potential sites and their transmission schemes.

➢ Mba (No.8) Potential Site – 2×7 MW

- The location of this potential site is immediately adjacent to the 132kV S/C line from Vuda to Nadarivatu. Therefore, LILO of the 132kV Vuda – Nadarivatu line at this potential site is recommended as shown in Figure 6.10.1-2.



(Source: JICA Project Team)

Figure 6.10.1-2 Transmission Scheme for the Mba (No.8) Potential Site

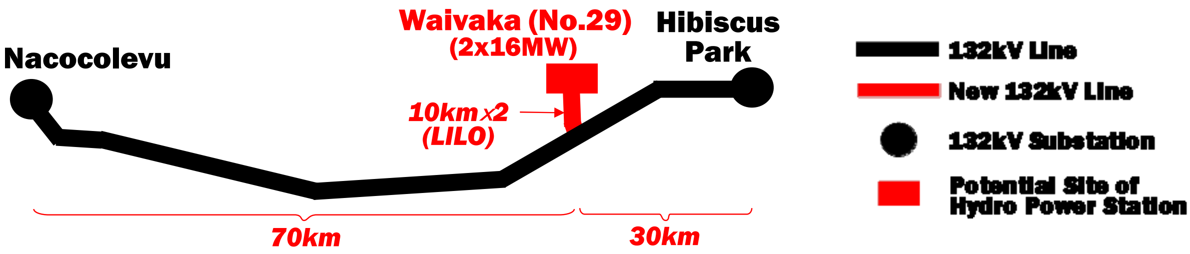
➢ Waivaka (No.29) Potential Site – 2×16 MW

- The nearest 33kV zone substation is Deuva. However, the transmission of power from the Waivaka (No.29) potential site was considered at the 132kV level as it would not be feasible at the 33 kV level, as can be seen from Figure 6.10.1-1. Therefore, connection to the nearest 132 kV Cunningham zone substation through a 132kV S/C line of 30 km was recommended as shown in Figure 6.10.1-3.

(Source: JICA Project Team)

Figure 6.10.1-3 Transmission Scheme for the Waivaka (No.29) Potential Site

- Another option is LILO of the 132kV S/C line from Nacocolevu to Hibiscus Park at the Waivaka (No.29) potential site - this is the same as the Namosi (2×20MW) transmission schemes in PDP 2011 - on the assumption that this line will be constructed based on PDP 2011, as shown in Figure 6.10.1-4.



(Source: JICA Project Team)

Figure 6.10.1-4 Transmission Scheme for the Waivaka (No.29) Potential Site

➢ Wailevu (No.35) Potential Site – 2×6.5 MW+2×2 MW

- As can be seen from Figure 6.10.1-1, connection to the nearest Dreketi 33kV zone substation through a 33kV S/C line of 25 km was recommended as shown in Figure 6.10.1-5.

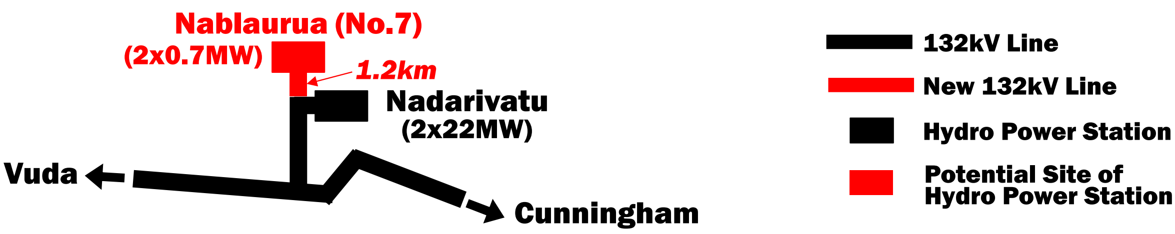
(Source: JICA Project Team)

Figure 6.10.1-5 Transmission Scheme for the Wailevu (No.35) Potential Site

Transmission schemes for other hydropower potential sites were also be considered.

➢ Nablaurua (No.7) Potential Site – 2×0.7 MW

- The location of this potential site is immediately adjacent to the existing Nadaribatu Hydropower Station. Therefore, connection to the Nadarivatu 132kV bus through a 132kV S/C line of 1.2km was recommended as shown in Figure 6.10.1-6.

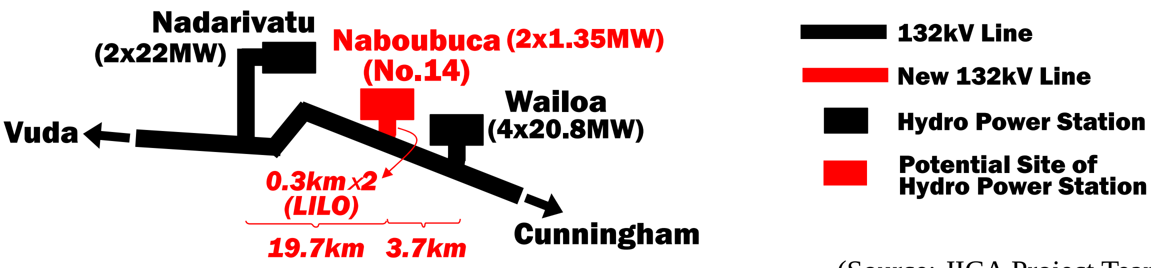


(Source: JICA Project Team)

Figure 6.10.1-6 Transmission Scheme for the Nablaurua (No.7) Potential Site

- Naboubuca (No.14) Potential Site – 2×1.35MW

- The location of this potential site is immediately adjacent to the 132kV S/C line from Nadarivatu to Wailoa. Therefore, LILO for the 132kV line at this potential site was recommended as shown in Figure 6.10.1-7.

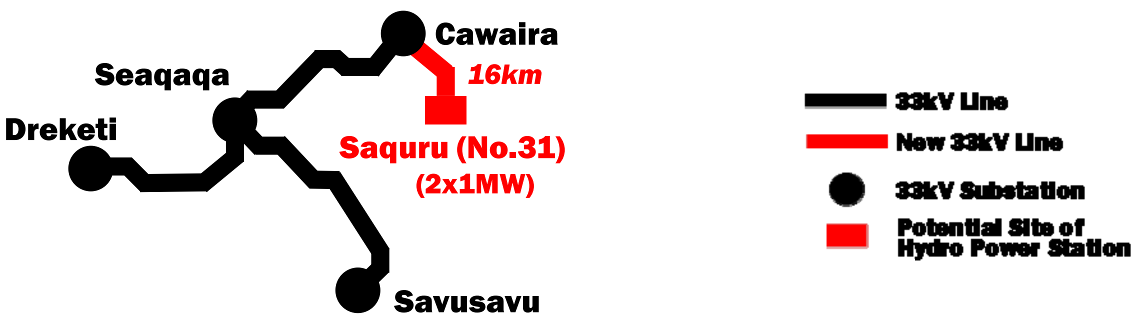


(Source: JICA Project Team)

Figure 6.10.1-7 Transmission Scheme for the Naboubuca (No.14) Potential Site

- Saquru (No.31) Potential Site – 2×1 MW

- As can be seen from Figure 6.10.1-1, connection to the nearest Cawaira 33kV bus through a 33kV S/C line of 16km was recommended as shown in Figure 6.10.1-8.



(Source: JICA Project Team)

Figure 6.10.1-8 Transmission Scheme for the Saquru (No.31) Potential Site

6.10.2 Rough Cost Estimations of the Transmission Schemes

The rough cost estimations required for these transmission schemes are given in Table 6.10.2-1.

Table 6.10.2-1 Rough Cost Estimations for the Transmission Schemes

Transmission line name	Length (km)	Cost/km (FJD) *1	Cost (Million USD)
VLIS			
LILO of 132kV S/C line from Vuda to Nadarivatu at Mba (No.8) potential site	0.6×2	396,000	0.25
132kV S/C line from Waivaka (No.29) potential site to Cunninghum	30	396,000	6.18
132kV S/C line from Nablaurua (No.7) potential site to Nadarivatu	1.2	396,000	0.25
LILO of 132kV S/C line from Nadarivatu to Wailoa at Naboubuca (No.14) potential site	0.3×2	396,000	1.24
Total cost in VLIS			7.91
Vanua Levu			
33kV S/C line from Wailevu (No.35) potential site to Dreketi	25	90,000	1.17
33kV S/C line from Saquru (No.31) potential site to Cawaira	16	90,000	0.75
Total cost is Vanua Levu			1.92
Total cost			9.83

Note: *[1]Based on PDP 2011

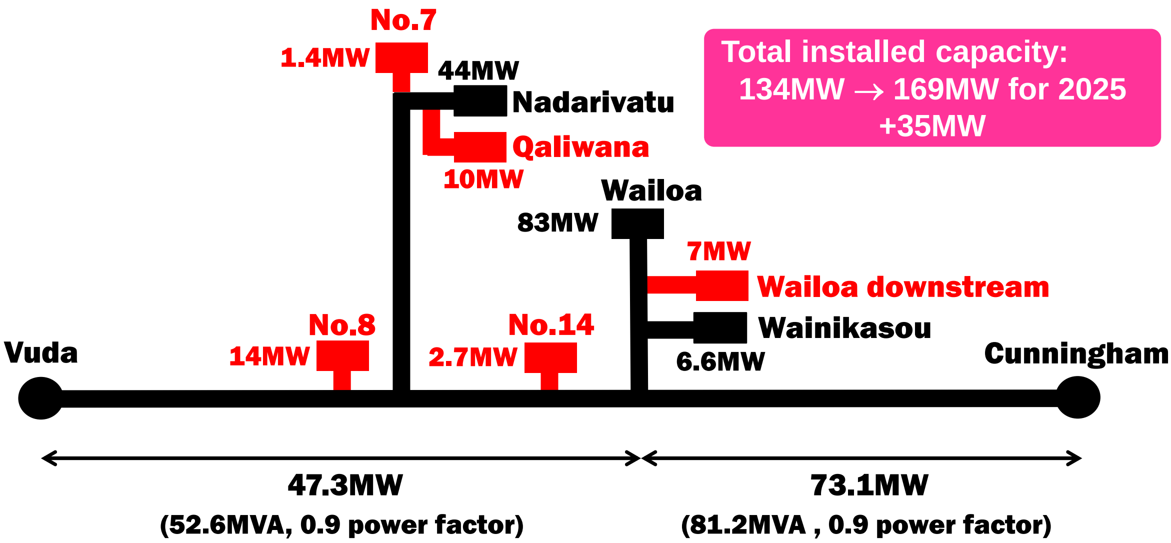
(Exchange rate: 1FJD=0.52USD as of Oct. 9, 2014, Reserve Bank of Fiji)

(Source: JICA Project Team)

6.10.3 Reinforcement of the 132 kV Vuda – Cunningham Line

As mentioned in 6.10.1, the transmission of power from proposed Mba (No.8), Nablaurua (No.7), and Naboubuca (No.14) potential sites - Qaliwana and Wailoa which were committed to by FEA in addition to the existing hydro generations such as Wailoa, Nadarivatu and Wainikasou - was considered through a 132kV S/C transmission line from Vuda to Cunningham.

When these hydro generations are scheduled for maximum output, the 132kV Vuda – Cunningham line and the 132/33kV Vuda transformer is likely to overload in the case of an outage on any sections along the line. The thermal rating capacity of the existing 132kV Vuda – Cunningham line based on PDP 2011 is shown in Figure 6.10.3-1.

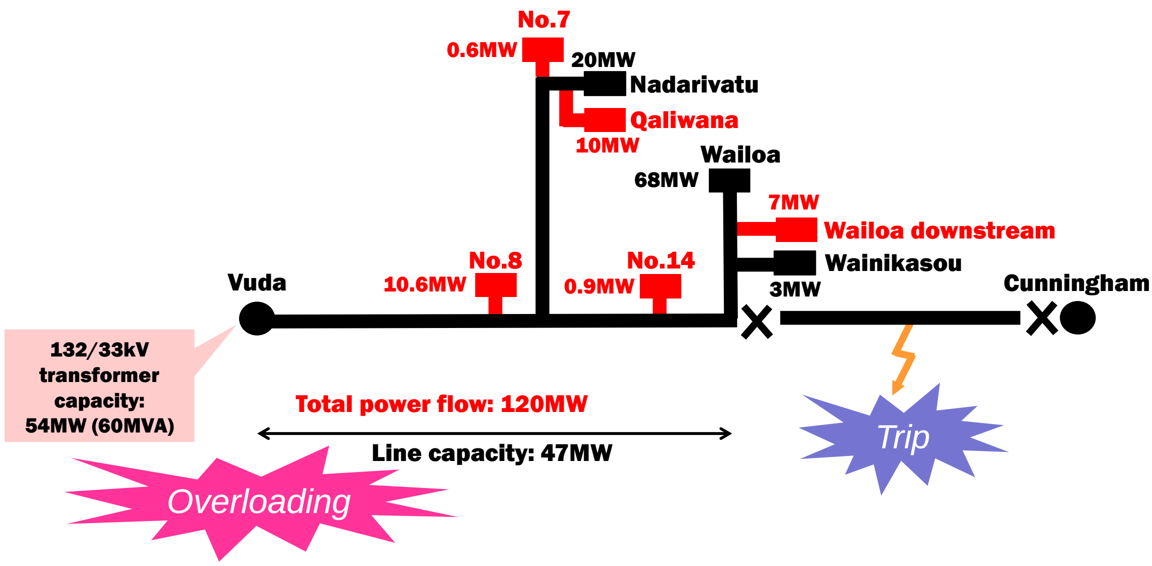


Note: Figures of MW are installed capacity.

(Source: JICA Project Team based on PDP 2011)

Figure 6.10.3-1 Thermal Rating Capacity of the Existing 132 kV Transmission Line

The most severe case of under outage of the 132KV Wailoa-Cunningham line is shown in Figure 6.10.3-2



Note1: Figures of MW for proposed hydro are supply capacity.

Note:2 Figures of MW for other hydro are those from the “high hydro dispatch” of PDP 2011.

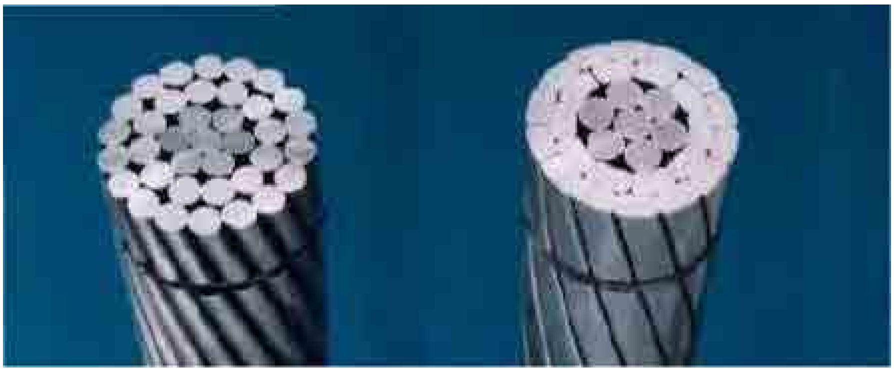
(Source: JICA Project Team based on PDP 2011)

Figure 6.10.3-2 Most Severe Case for the 132KV Vuda-Cunningham Line

On the other hand, the existing 132kV Vuda – Cunningham line is composed of a single circuit and is inadequate to meet the N-1 security criteria. Therefore, this line should be reinforced immediately.

To begin, an additional 132kV Vuda – Cunningham line with increased-capacity conductors (approximately 150MW) will be necessary to satisfy the N-1 security criteria.

In addition, regarding the existing 132kV Vuda – Cunningham line equipped with aluminum conductor steel reinforced (“ACSR”) - with the code name “Lime” - the conductor replacement (“reconductoring”) with low-sag increased-capacity conductors - such as super thermal resistant aluminum alloy conductor invar reinforced (“ZTACIR”) or extra-heat-resistant aluminum alloy conductor invar reinforced (“XTACIR”) - should be carried out as shown in Figure 6.10.3-3.



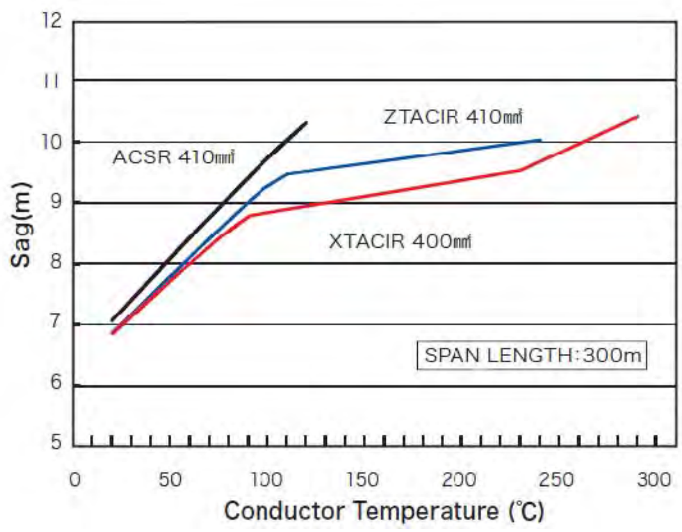
ZTACIR XTACIR

(Source: Website of J-Power Systems)

Figure 6.10.3-3 Invar Conductor

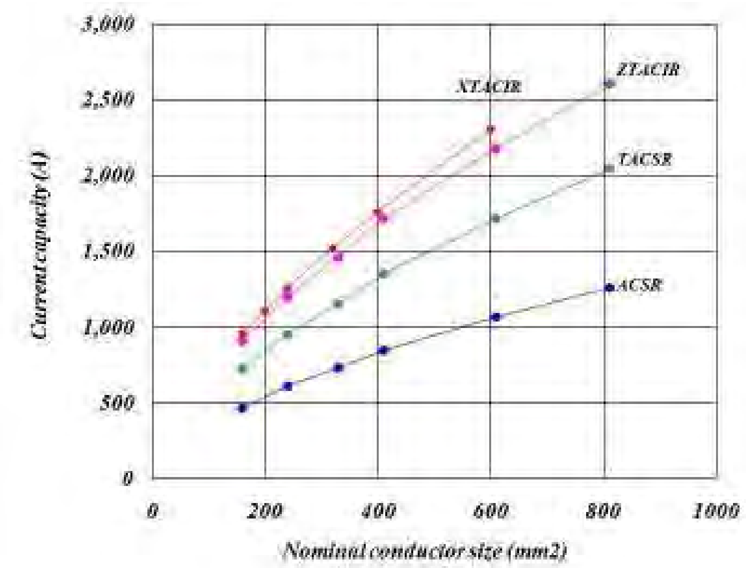
The sag of the ZTACIR/ XTACIR is almost the same as that of the ACSR as shown in Figure 6.10.3-3. Furthermore, the ZTACIR/ XTACIR can double the power transmission capacity without the modifications or reinforcement needed on existing towers, as Figure 6.10.3-

The advantages of reconductoring with low-aag increased-capacity conductors are shown in Figure 6.10.3-; and, from this a resource saving effect can be expected.



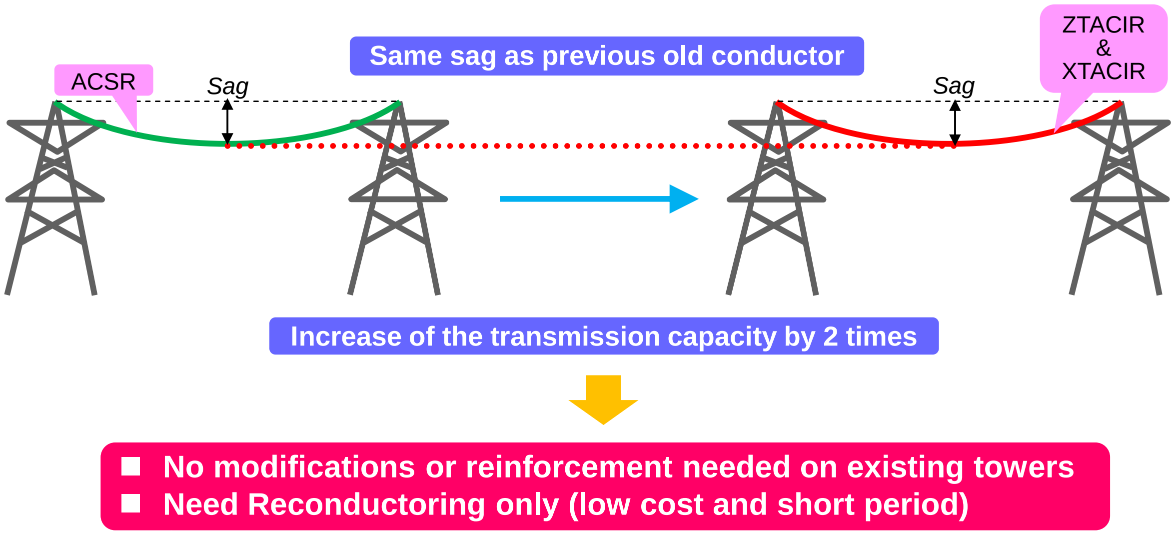
(Source: Website of VISCAS)

Figure 6.10.3-4 Relationship Between the Conductor Temperature and Sag



(Source: Website of Intertech Engineering)

Figure 6.10.3-5 Effect of Reconductoring on the Current Capacity

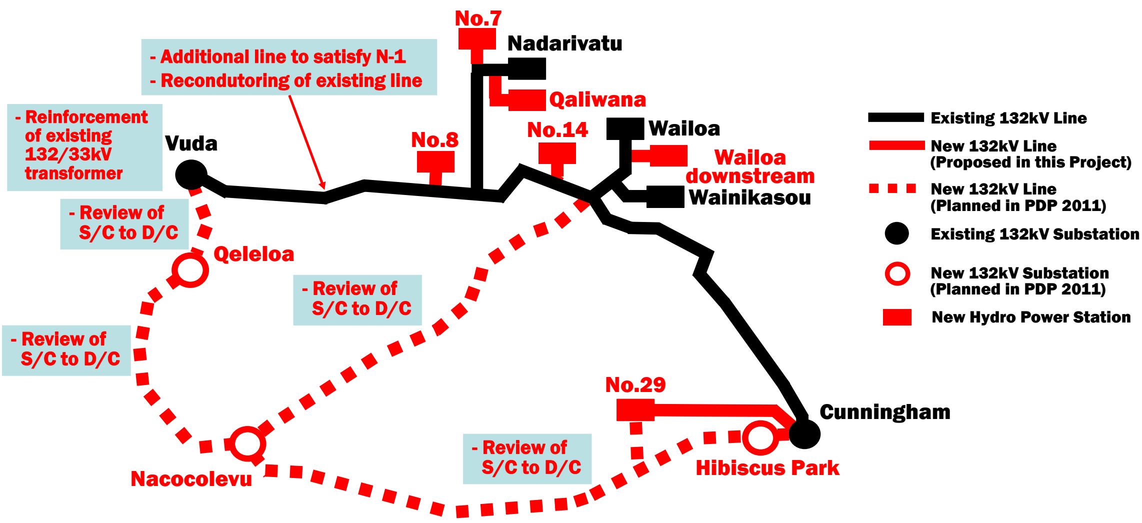


(Source: JICA Project Team)

Figure 6.10.3-6 Advantages of Reconductoring with Low-Sag Increased-Capacity Conductors

6.10.4 High Reliability of the 132 kV system in VLIS for 2025

In order to ensure a higher 132kV system reliability, the new 132kV lines - Wailoa – Nacocolevu , Vuda – Nacocolevu – Hibiscus Park – Cunningham, which were planned in PDP 2011 - should be considered in conjunction with the above-mentioned reinforcement of the existing 132kV Vuda – Cunningham Line and the 132/33KV Vuda transformer. The proposed 132kV transmission system configuration in VLIS for 2025 is shown in Figure 6.10.4-1.



(Source: JICA Project Team based on PDP 2011)

Figure 6.10.4-1 Proposed 132kV System Configuration in VLIS for 2025

These new 132kV lines have to be designed to meet N-1 criteria or to be composed of a double circuit, as shown in Figure 6.10.4-2.

(Source: JICA Project Team)

Figure 6.10.4-2 132kV D/C Designed Tower Near the Cunningham Substation Under S/C Operation

The rough cost estimations for the high reliability 132KV system in VLIS for 2025 are shown in Table 6.10.4-1

Table 6.10.4-1 Rough Cost Estimations for the High Reliability 132KV System in VILIS for 2025

Description	Cost in Million USD	
	Committed by PDP 2011	Proposed by JICA Project Team
Additional 132kV Vuda – Cunningham line	-	30
Recondutoring of 132kV Vuda – Cunningham line	-	15
Reinforcement of existing 132/33kV Vuda transformer	-	8
Extension of 132kV system	91 (S/C)	128 (D/C)
Total	91	173

Note 1: Based on the transmission cost in PDP 2011

Note 2: Costs of reconductoring with low-sag increased-capacity conductors were assumed to be about half that of a new line construction

Note 3: Exchange rate: 1FJD=0.52USD as of Oct.9, 2014, Reserve Bank of Fiji

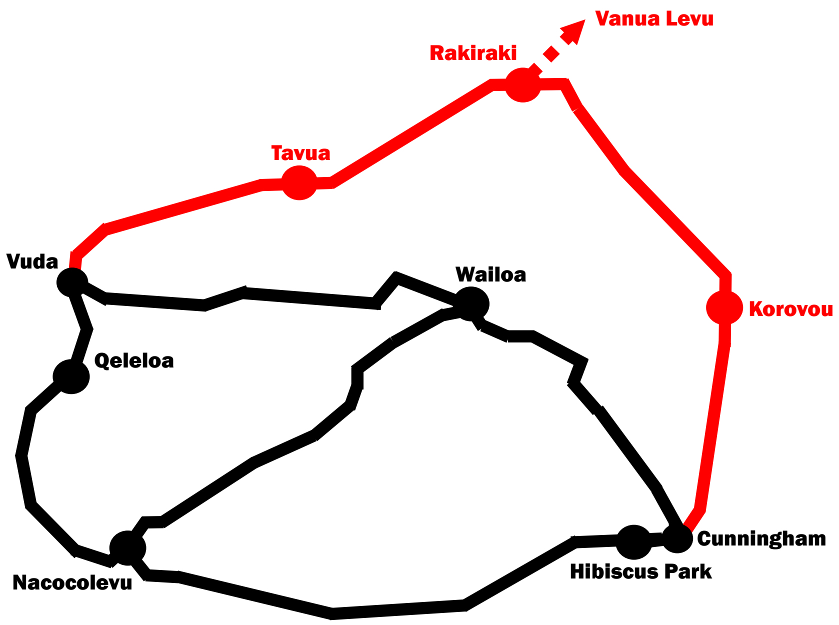
(Source: JICA Project Team)

Incidentally, in order to study an effective 132kV system configuration, it is recommended that detailed power system analyses (including for power flow, short circuiting, and transient stability) should be carried out for various system contingencies in the network based on the revised transmission system plan, generation development plan, and zone substation wise load for the period 2014 to 2025 in PDP 2014. These analyses would take into account the above-mentioned proposed 132kV system configuration in VLIS with prospective hydropower potential sites and their transmission schemes.

6.10.5 Long-term Vision for the 132kV Transmission System in VLIS after 2025

In the long term after 2025, when bulk renewable energy generation is further developed in VLIS and Vanua Levu, a 132kV ring system encircling an island, which will ensure higher system reliability, should be considered in VLIS in order to interconnect with Vanua Levu and also to meet the expected increase in power demand all over the island, as shown in Figure 6.10.5-1.

In addition, the 33kV transmission system with the 33kV zone substation should also be extended along the 132kV transmission system.



(Source: JICA Project Team)

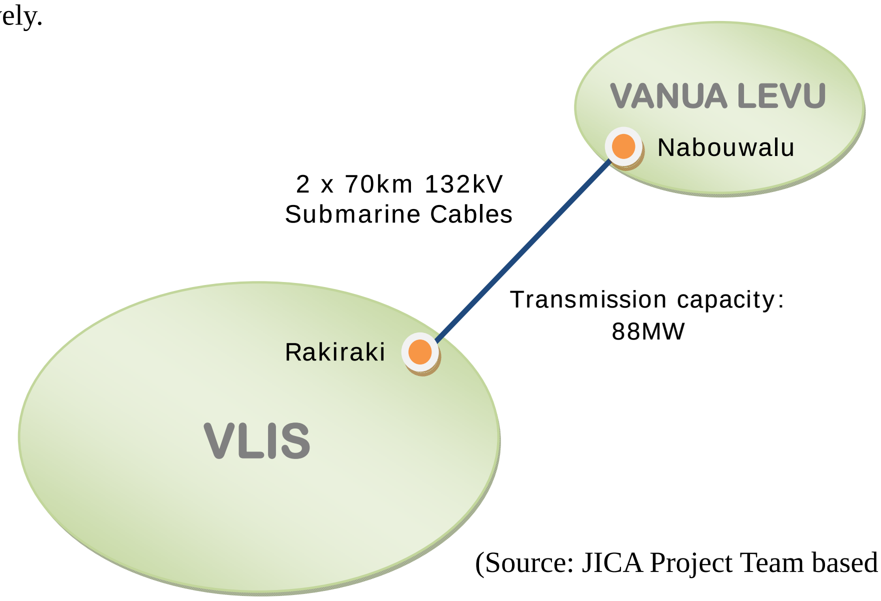
Figure 6.10.5-1 Proposed 132kV Transmission System Configuration in VLIS after 2025

6.10.6 VLIS - Vanua Levu Interconnection Scheme

In the long term after 2025, a VLIS – Vanua Levu interconnection scheme should be considered; for example, when the maximum surplus power generated in Vanua Levu amounts to approximately 90MW which will in effect be utilizing the energy of the prospective hydropower, biomass, and geothermal potential sites. It follows that the interconnection of these two islands will have a large advantage in reducing the necessary reserve margin and increasing the share of generation energy by renewable energy.

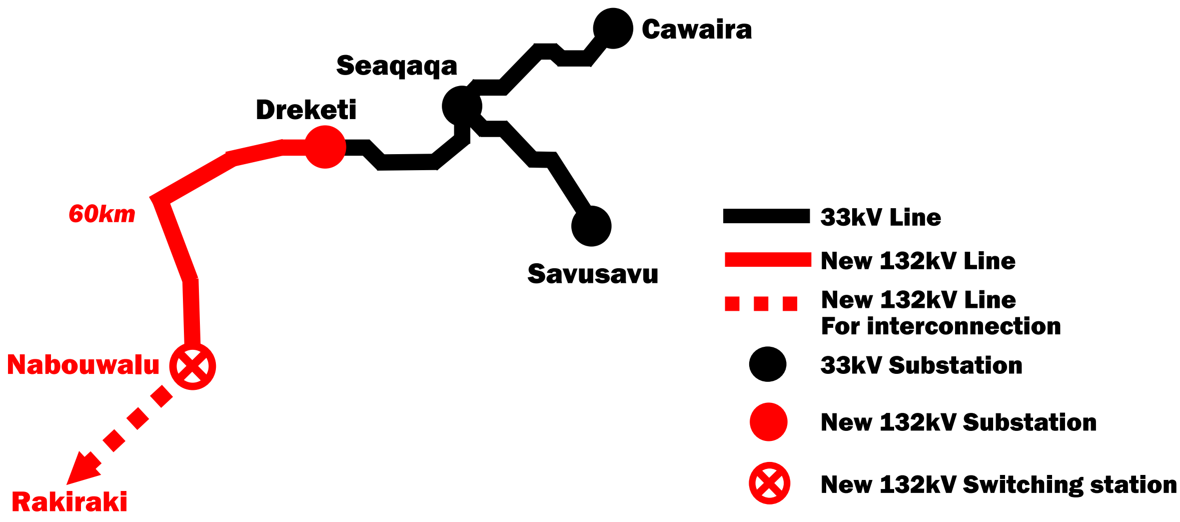
The proposed interconnection scheme is basically the same as that discussed in PDP 2011, as shown in Figure 6.10.6-1.

- When taking into account the maximum transmission capacity and the long distance transmission, the power transmission from Vanua Levu should be considered at the 132 kV level as it would not be feasible at the 33 kV level..
- For transmission, 2×1C×630mm^2 submarine cables are recommended considering the N-1 security criteria. 1C×630mm^2 submarine cables can transfer power to the maximum extent of 88MW at a power factor of 0.9.
- The shortest distance to the Vanua Levu is approximately 70 km from Rakiraki in the Nabouwalu area, as shown in Figure 6.10.6-2.
- In order to transmit the surplus power generated inVanua Levu, a 132kV D/C transmission line of approximately 60km between Nabouwalu and Dreketi will be necessary.
- 132/33kV and 2×60MVA transformers should be installed at Rakiraki and Nabouwalu, respectively.



(Source: JICA Project Team based on PDP 2011)

Figure 6.10.6-1 Proposed VLIS – Vanua Levu Interconnection Scheme



(Source: JICA Project Team

Figure 6.10.6-2 Power System for the Interconnection in Vanua Levu

In order to solve problems such as voltage fluctuations and harmonic resonance of the WER system due to the long distance of the AC cable transmission system, installation of a static VAR compensator ("SVC") will be necessary, as shown in Figure 6.10.6-3.

(Source: Toshiba Review, 2008 Vol.63 No.8)

Figure 6.10.6-3 Overview of SVC

A cable laying vessel is shown in Figure 6.10.6-4, and a 132kV 3-core XLPE submarine cable is shown in Figure 6.10.6-5.

(Source: Website of Viscas)

Figure 6.10.6-4 Cable Laying Vessels

(Source: Website of Viscas)

Figure 6.10.6-5 132kV 3-core XLPE Submarine Cable

The rough cost estimations for the VLIS – Vanua Levu interconnection is given in Table 6.10.6-1.

Table 6.10.6-1 Rough Cost Estimations for the VLIS – Vanua Levu Interconnection

Description	Cost (Million USD)
2×70km 132kV submarine cable (1C×630mm2)	210 *1
SVC with CB at Rakiraki	35 *2
2×60km 132kV transmission line	17 *3
132/33kV, 2×60MVA transformer at Rakiraki 132/33kV, 2×60MVA transformer at Dreketi	17 *3
Total	279

Note: *[1] Based on 100 Per Cent Renewables Study – Electricity Transmission Cost Assumptions, Sep. 2012, AEMP

*[2] Based on Interconnection Feasibility Study – Task 8 Cost Estimate Study,

Aug. 2011, Siemens

*[3] Based on PDP 2011

(Exchange rate: 1FJD=0.52USD as of Oct. 9, 2014, Reserve Bank of Fiji)

(Source: JICA Project Team)

6.11 Economic and Financial Analysis

6.11.1 Conditions for Analysis

Table 6.11.1-1 shows the summary of basic indicators for calculating economic and financial rates of return.

Table 6.11.1-1 Summary of the Basic Indicators for the Hydro Potential Sites

Item	Assumptions		
	No.8 Site	No.29 Site	No.35 Site
a. Power Production			
Capacity:	14,000 kW	32,000 kW	No.1 13,000 kW No.2 4,000 kW
Firm Peak Capacity:	10,617 kW	28,281 kW	14,640 kW
Plant Load Factor:	47.20%	24.10%	No.1 43.30% No.2 25.90%
Annual Generation Energy:	57,842 MWh	67,552 MWh	No.1 49,296 MWh No.2 8,783 MWh
Net Power Production*:	57,611 MWh	67,282 MWh	No.1 49,123 MWh No.2 8,748 MWh
b. Project Cost			
Hydropower Plant Construction Cost	62.0 Million USD	82.5 Million USD	73.9 Million USD
Transmission Cost	0.25 Million USD	6.18 Million USD	1.17 Million USD
c. Construction Period	5 years		
d. Project Life	40 years		
e. Transmission & Distribution Loss	10%		
f.Electricity Tariff**	0.19 USD/kWh		
g. Operation Expenses	1% of Construction Cost		
h. Exchange Rate***	1 FJD = 0.52 USD		

Note
* It is assumed auxiliary comsumption rate is 0.4% of total production.
**Weighted Average in Year 2013
***As of October 9, 2014, Reserve Bank of Fiji

6.11.2 Economic Analysis

(1) **Methodology of Evaluation and Basic Parameters**

The economic analysis measures the effects on the national economy whereas the financial analysis assesses the financial profitability of the project operating entity. The effect of the Project on the national economy is indicated by the Economic Internal Rate of Return ("EIRR"). In particular, a comparison of the "without-project" and "with-project" situations is an essential part of the estimation of the net economic benefits of the Project. In comparing the benefits with the costs, the economic viability of the Project can be measured as the EIRR. In order to calculate the EIRR, it is essential to identify the economic costs and benefits. In the case of the economic costs and benefits of the potential sites for the hydropower projects, the following issues were considered[1]:

- Economic Costs

a) Construction Costs

The economic analysis was based on the construction costs which are used for the financial analysis but exclude taxes and fiscal levies. In Fiji imports of equipment are exempted from custom duties for renewable energy projects.

b) Operation and Maintenance ("O&M") Costs of the Power Plant

The O&M costs for the financial analysis, excluding taxes and fiscal levies, were used for the economic analysis. This was assumed to be around 1% of the construction costs.

- Economic Benefits

This refers to the economic benefits which can be derived by the positive difference between the "with-project" situation and the "without-project" situation.

For the "with-project" situation, the least cost alternative method was utilized for the calculation of the economic benefits in comparison to power generation costs of the alternative Diesel/HFO thermal power plant. In terms of the "without-project" situation, it was assumed that the construction of a thermal power generation plant to produce the same electricity volume was an "avoidable cost". Thus, the economic benefit is the difference between the power generation costs (including the capital and the O&M costs of the Project, as well as the costs for alternative thermal power generation) that would be required in order to create the same volume of power production.

The alternative thermal power plant costs were assumed to be as stated in Table 6.11.2-1.

[1] Standard Convention Factor (SCF) is assumed to be 1.0

Table 6.11.2-1 Summary of the Alternative Diesel Thermal Power Plant Costs

Alternative Diesel Thermal Power Generation Cost		
Construction Cost	845 USD/KW	(including 30% of Installation Fee)
Annual O&M Cost (3% of Construction Cost)	0.326 USD	(Site No.8)
	0.867 USD	(Site No.29)
	2.252 USD	(Site No.35)
Fuel Cost	0.1440 USD/kWh	

(2) **Economic Evaluation**

Through utilizing the basic assumptions in Table 6.11.2-1 and Table 6.11.2-2, the EIRR results - calculated with the relevant economic cash inflows and outflows - are shown in the table below. The net present value ("NPV") and benefit / cost ratio were calculated at a discount rate of 10%.

Table 6.11.2-2 Results of the Economic Internal Rate of Return (EIRR)

Locations	Site No.8	Site No.29	Site No.35
EIRR	13.3%	12.1%	11.7%
Net Present Value (NPV) (B-C)	13.2 Million US$	10.3 Million US$	7.6Million US$
B/C	1.3	1.2	1.1

The estimated EIRR for each site was approximately 11 to 13%.

Generally, the EIRR should be higher than the cost of capital, namely the interest rate of long-term (10 year) Fijian government bonds. Currently these have an interest rate of 5% per annum. Thus, the above results are much higher than this rate.

(3) **Sensitivity Analysis**

The objective of the sensitivity analysis is to assess the effects of the changes on parameters for calculating the EIRR. In the study, the following two variables were selected for the sensitivity analysis: construction costs and fuel costs (for alternative thermal power plant) that can be changed depending on the situation. Table 6.11.2-3 shows the results in case of construction cost changes from – 10% to + 20% from the base case and Table 6.11.2-4 presents the results in case of fuel cost changes from – 50% to +100% from the base case for the alternative diesel power generation project.

Table 6.11.2-3 Results of the Sensitivity Analysis on the Economic Internal Rate of Return (EIRR) in the Case of the Construction Cost Changes

Site	Base Case－10%	Base Case	Base Case+10%	Base Case+20%
Site No.8	14.9%	13.3%	12.0%	10.8%
Site No.29	13.8%	12.1%	10.7%	9.5%
Site No.35	13.2%	11.7%	10.4%	9.3%

Table 6.11.2-4 Results of the Sensitivity Analysis on the Economic Internal Rate of Return (EIRR) in the Case of the Fuel Price Changes for the Alternative Diesel Thermal Power Plant

Site	Base Case－50%	Base Case	Base Case+50%	Base Case+100%
Site No.8	7.8%	13.3%	17.1%	20.0 %
Site No.29	7.9%	12.1%	14.9%	17.0%
Site No.35	6.8%	11.7%	15.0%	17.5%

6.11.3 Financial Analysis

(1) **Methodology of Evaluation and Basic Parameters**

The financial evaluation is based on an analysis of the financial viability of the Project. In other words, the financial evaluation aims to verify the financial sustainability for the entity to operate and maintain the Project at a certain level of financial effectiveness for a certain period.

In general, financial viability is measured by the financial internal rate of return ("FIRR"), which measures and compares the financial revenue (= financial benefits) with the capital investment on project (= financial cost). A project can be judged as "financially viable" in the case where the calculated FIRR is higher than FEA bond interest rates - currently, 5.90% to 7.19% annum[1].

- Financial Cost

a) Construction Costs

For the financial analysis of the Project, all the estimated costs were constant prices at the year when the construction will start. In Fiji imports of equipment are exempted from custom duties for renewable energy projects.

b) O&M Costs

The O&M costs were assumed to be 1% of the construction costs; this covers O&M for all the facilities to be constructed by the Project, including the initial spare parts, fixed and valuable maintenance costs, and personnel expenses.

c) Income Tax

In Fiji, in the case of renewable energy projects, income tax is exempted for the first five years after commencement of operation.

- Financial Benefits

The financial benefits of the Project are electricity sales revenues.

(2) **Financial Evaluation**

Through utilizing the basic assumptions in Table 6.11.3-1, the FIRR results - calculated with the relevant economic cash inflows and outflows - are shown in the table below. The net present value ("NPV") and Benefit / Cost Ratio were calculated at a discount rate of 10%.

[1] At the of the end of Fiscal Year 2013, the weighted average funding cost of FEA was estimated to be 4.6%. The interest rate of the FEA bonds was the highest among other loans.

Table 6.11.3-1 Results of the Financial Internal Rate of Return (FIRR)

Locations	Site No.8	Site No.29	Site No.35
FIRR	12.9 %	10.5%	10.7 %
Net Present Value (NPV) (B-C)	12.9Million US$	3.0 Million US$	3.7Million US$
B/C	1.3	1.0	1.1

The estimated FIRR for each site was approximately 10 to 13 %, higher than FEA bond interest rate of 7.19%.

(3) **Sensitivity Analysis**

The objective of the sensitivity analysis was to assess the effects of the changes on parameters for calculating the FIRR. In this study, the following two variables were selected for the sensitivity analysis: construction costs and electricity tariff that can be changed depending on the situation. Table 6.11.3-2 shows the results for changes of – 10% to + 20% from the base case in the construction costs. Table 6.11.3-3 presents the results for increases of 10% to 30% from the base case in the electricity tariffs.

Table 6.11.3-2 Results of the Sensitivity Analysis on the Financial Internal Rate of Return (FIRR) in the Case of the Construction Cost Changes

Site	Base Case－10%	Base Case	Base Case+10%	Base Case+20%
Site No.8	14.3%	12.9%	11.7%	10.7%
Site No.29	11.7%	10.5%	9.4%	8.5%
Site No.35	12.0%	10.7%	9.7%	8.7%

Table 6.11.3-3 Results of the Sensitivity Analysis on the Financial Internal Rate of Return (FIRR) in the case of the Electricity Tariff Changes

Site	Base Case	Base Case+10%	Base Case+20%	Base Case+30%
Site No.8	12.9%	14.6%	15.8%	17.0%
Site No.29	10.5%	11.7%	12.8%	13.9%
Site No.35	10.7%	11.9%	13.0%	14.1%

6.11.4 Trial Calculation for the Reduction of Greenhouse Gas (Co_2) Emissions

The Project will contribute to a reduction of fuel consumption for thermal power plants, therefore leading to a reduction in CO_2 emissions. This reduction in CO_2 emissions was roughly estimated as shown in the table Table 6.11.4-1 below.

Table 6.11.4-1 Trial Calculation for the Reduction in CO_2 Emissions

SITE	**Reduction of CO_2 Emission (Ton/CO_2Per Year)**
No.8	**24,406**
No.29	**27,957**
No.35	**23,953**

Note: This was calculated by employing the combined margin emission coefficient indicator of “0.410 ton-CO2/MWh” to the Vitilevu Island power grid in the pilot study by the Japan Bank for International Cooperation (JBIC) in 2008.

6.12 Electricity Operation System

Several groups of hydropower stations could be operated from a control center by a installing centralized remote supervisory control system. The operating signal would be sent to the hydropower stations and substations through tele-control units.

Now almost all of hydro power stations in Fiji are operated through manned controls. If a centralized remote supervisory control system were adopted, all the hydro power stations in Fiji could potentially be effectively operated by the schedule planned in this system. Moreover, this system could be combined with the equipment of the load dispatch center. Thus, overall, this combination could contribute to improving electricity operations in Fiji.

Chapter 7 Environmental and Social Considerations

7.1 Environmental and Social Considerations

JICA promotes sustainable development in developing countries, so environmental and social considerations play an important role. For this, JICA applies a strategic environmental assessment (“SEA”) in its projects - from their early stages through to the monitoring stages – and considers a wide range of environmental and social issues through conducting master plan studies (and other surveys/studies) and encouraging project proponents.

7.2 Scoping and IEE

7.2.1 Scoping and IEE

The first screening study indicated nine selected projects among the projects classified as category B or C under JICA Guidelines for Environmental and Social Considerations (“JICA Guidelines”). An initial environmental examination (“IEE”) for a category B project is required. Basically, JICA categorizes projects according to their environmental hazard potential as shown in Table 7.2.1-1.

Table 7.2.1-1 Three Categories of Project under JICA Guidelines for Environmental and Social Considerations

Category	Definition
A	Likely to have significant adverse impacts on the environment and society
B	Potential adverse impacts on the environment and society, but less adverse than those of category A projects
C	Like to have minimal or little adverse impact on the environment and society

(Source: JICA Guidelines)

After the reconnaissance surveys carried out at the nine hydropower potential sites, the Fiji counterparts and the JICA Project Team proposed at the second stakeholder meeting in Suva that three of the said nine hydropower potential sites should be studied at preliminary design level. The three potential sites have their own environmental characteristics as shown in Table 7.2.1-2. Environmental scoping was conducted based on the results of the reconnaissance surveys. The IEE results are shown in Table 7.2.1-3 and Table 7.2.1-4.

Table 7.2.1-2 Environmental Characteristics of the Three Potential Sites

Site Item	No.8 Upper Ba River	No.29 Waivaka River	No.35 Wailevu River
Protected Area	No encroachment	No encroachment	No encroachment
Vegetation	Anthropogenic Grassland	Pasture and Secondary Forests	Natural lowland rainforest and valuable hardwood plantation
Resettlement	No resettlement	No resettlement	No resettlement
Reservoir Water - reducing section of the river	50 ha Approximately 6km of river	Reservoir over 1.5km in length the – Approximately 2.5km of Wairokodra	Reservoir over 3km in length Approximately 2km of Wailevu

No.8 Upper Ba River		
No.29 Waivaka River		
No.35 Wailevu River		

(Source: The JICA Project Team)

Table 7.2.1-3 Natural Environmental Aspects Covered by the Scoping of the Three Potential Sites

Issue	Stage	No.8 Upper Ba River	No.29 Waivaka River	No.35 Wailevu River
Loss of (or altered) freshwater ecosystems	C/O	B	B	B
Construction of weir , dam and diversion of water		Reduced/minimal flow for the remainder		
Erosion risk and sedimentation	C/O	B	B	B
Sediment discharges from road construction, weir and impoundment earthworks				
Diminished water quality downstream	O	**D/** Tunnel, **C./**Impoundment		D
Sedimentation effects on aquatic ecology				
Diminished freshwater ecosystem	O	C	C	C
Stratification, anaerobic conditions in impoundment				
Loss of terrestrial ecosystem	C/O	D	**B/** Changes in hydrology, **D/** limited native forest	B
Removal of gravel. Earthworks and clearing /changes in hydrology, increased sedimentation				
Contractor's camp problems	C	C	C	C
Establishment of a contractor's camp - issues include water supply; sewage disposal and waste disposal				

Legend of Stage

C: Construction, O: Operation

Legend of Evaluation

A-: Serious impact is expected.

B: High impact is expected.

C: Moderate impact is expected.

D: No or negligible impact is expected. Further examination is unnecessary in EIA study.

Table 7.2.1-4 Social Environmental Aspects Covered by the Scoping of the Three Potential Sites

Issue	Stage	No.8 Upper Ba River	No.29 Waivaka River	No.35 Wailevu River
Loss of (Downstream) fishing areas	O	**C/** below weir and dam respectively **B./** Diversion of water		
Construction of weir; dam and diversion of water; no fishing and a disruption to migratory fish				
Poor water quality entering the reservoir	O	B/C	D	D
Sediment of impoundment				
Downstream uses	O	D	D	D
Pulses of water from the power station				
Visual amenities	O	D	D	D
Buildings, weir, loss of water in river				
Noise, vibration, and dust	C	C	D	D
Vehicle movements, earthworks, stockpiles, excavation, and placement of material				
Traffic impact	C/O	D	D	D
Construction traffic using steep and narrow roads also used by villagers				
Water supply	O	D	D	D
Construction of a tunnel; impact on aquifers and springs that provide potable water				
Relocation of village houses, settlements	C/O	D	D	D
Relocation and compensation issues		Not required	Not required	Not required
Land use issues	C/O	B./ 2-3 farm houses and gardening area	C	C
Sites required for impoundment; construction or access/sites required for weir, tunnel exit, reservoir, construction, or access				
Loss of archaeological or cultural sites	C/O	Unknown	Unknown	Unknown
Not known to occur during IEE work: sites required for construction or access/further examination would be necessary				
Social problems	C/O	C	C	C
Work force dominated by outsiders living at the site				
Contractor’s camp problems	C	C	C	C
Establishment of a contractor’s camp - issues include water supply; sewage disposal and waste disposal				

Legend of Stage

C: Construction, O: Operation

Legend of Evaluation

A-: Serious impact is expected.

B: High impact is expected.

C: Moderate impact is expected.

D: No or negligible impact is expected. Further examination is unnecessary in EIA study.

7.3 Environmental Examination

The outline of the environmental examination in categories B or C is as follows.

(1) Scope of Survey

Based on the results of the environmental scoping, the parameters as evaluated for categories B or C were reviewed in the site.

1) Natural Environment

a. Protected Area

b. Vegetation Classification

c. Flora and Fauna

d. Freshwater Ecosystem

2) Social Environment

a. Socio-Economic Situation/Resettlement

b. Land Ownership/Land Use

c. Water/River Use

d. Historical and Cultural Heritage

(2) Survey Method and Study Area

1) Natural Environment

Based on the information obtained in advance in the field, the survey routes were set up and we basically observed the flora and fauna through the visual survey. In addition interviews were conducted with the local residents in order to achieve a proper flow of information.

2) Social Environment

We visually observed as much as possible of the current state of the land use and water use. Whilst obeying the region's customs, we carried out interviews with village representatives and heard residents' opinions on the project.

7.3.1 Results of Environmental Survey

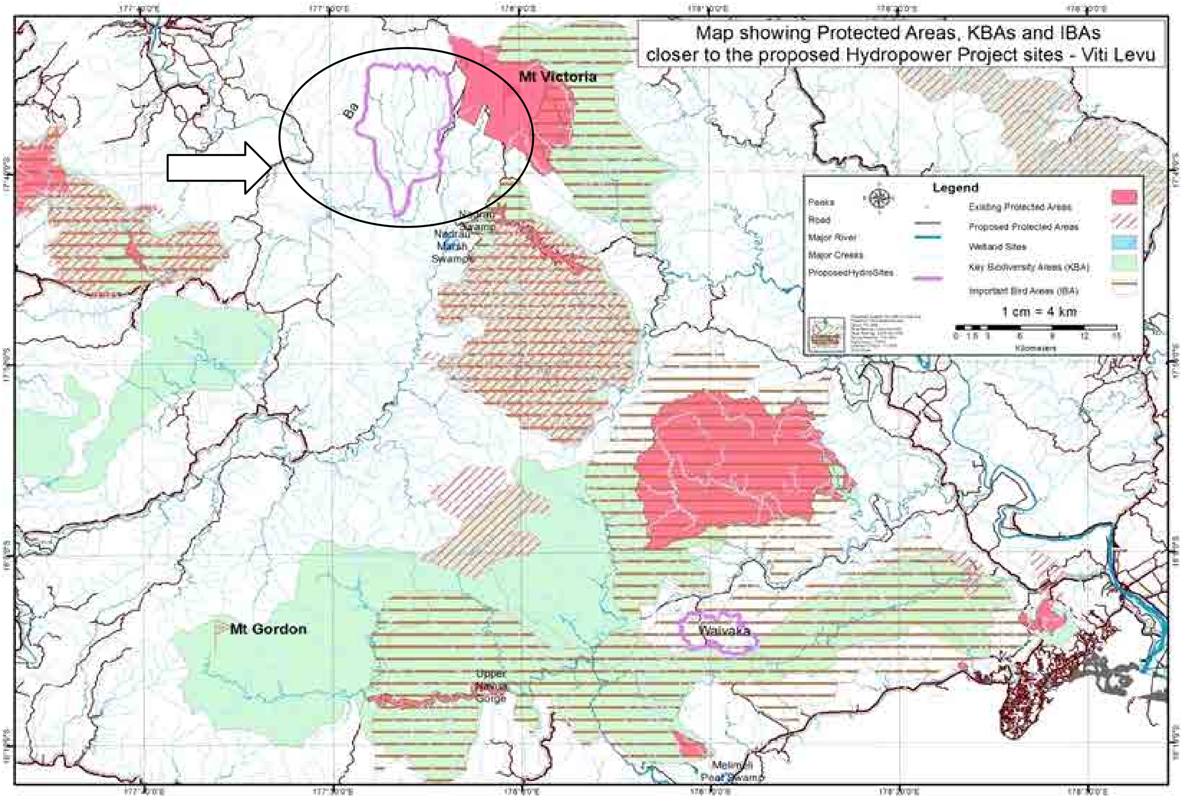
(a) Results of Environmental Survey on the Proposed No.8 Mba 1 U/S Project Scheme

The No.8 Mba 1 U/S Project Scheme is located in the headwaters of the Ba River, adjacent to the Nadarivatu Hydropower Scheme. The region is remote and lightly populated region and it can be accessed by the Nadarivatu and Lewa roads.

(1) Natural Environment

1) Protected Area

The corresponding project site is delineated by a purple line in Figure 7.3.1-1. There are no proposed protected areas (according to the legend, such areas are shaded pink), no key biodiversity areas (according to the legend, such areas are shaded light green), and no important bird areas (according to the legend, such areas are shaded with black horizontal stripes) immediately associated with the Upper Ba River project site or its wider catchment area.



(Source: National Trust for Fiji).

Figure 7.3.1-1 Map of the Protected Areas and Important Biodiversity Areas in Viti Levu (with the Upper Ba River Project Site, delineated with a purple line)

2) Vegetation Type

Figure 7.3.1-2 shows the types of vegetation at the project site and its catchment area.

The existing land covering the project area is predominantly degraded anthropogenic grassland, which continues to deteriorate through annual burning. Narrow widths of riparian vegetation remain in some locations on the banks of the larger rivers, the creeks (which sometimes suddenly extend), and the ephemeral water courses.

There are three distinct types of vegetation in the catchment areas of the Savatu Creek and the Upper Ba River: grass-reed lands in the south, native forest in the central-north east (dark green), and pine plantations north-northwest.

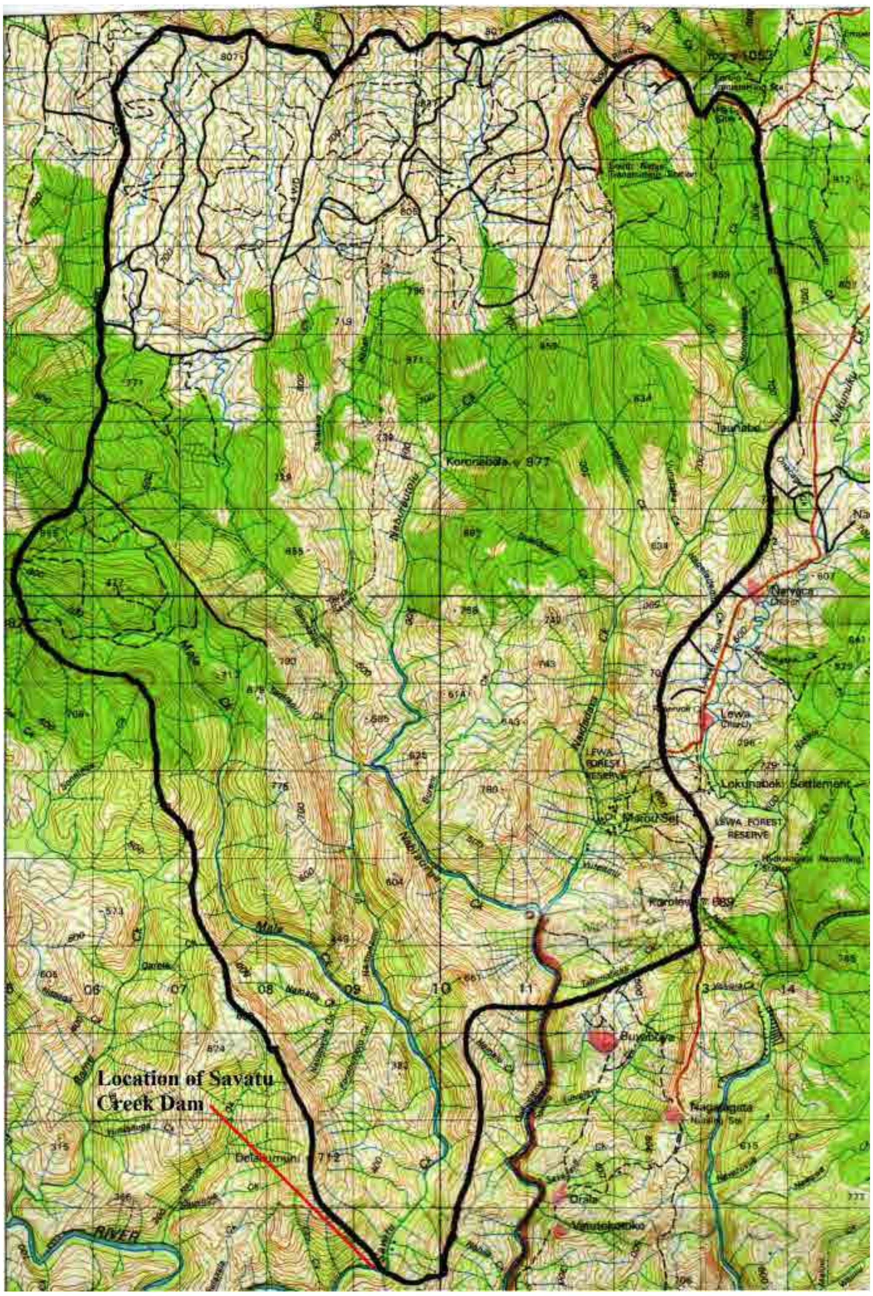


Figure 7.3.1-2 Three Distinct Types of Vegetation in the Savatu Creek and Upper Ba River Catchment Areas: Grass-Reedlands in the South, Native Forest in the Central-North East (dark green) and Pine Plantations North-Northwest

3) Fauna and Flora

There are no known rare or threatened areas of fauna and flora that are affected by the project.

- Table 7.3.1-1 shows the bird list for Viti Levu and those species observed or expected to be resident in the proposed Savatu Reservoir area. None of Fiji's rare or threatened species are expected to be resident in a disturbed, secondary habitat such as the project site.

Table 7.3.1-1 Bird List for Viti Levu and Those Species Observed or Expected to be Resident in the Proposed Savatu Reservoir Area

English name	Scientific name	Observed or likely to be resident in the Savatu Reservoir area	Introduced; endemic; Threat Status	Habitat and distribution
Reef Heron	Egretta sacra	✓v		rivers,streams
White-faced Heron	Ardea novaehollandiae	v		wetland, grass
Pacific Black Duck	Anas superciliosa	✓r		rivers
Fiji Goshawk	Accipiter rufitorques	✓r	e	F
Pacific Harrier	Circus approximans	✓r		F
Peregrine Falcon	Falco peregrinus	v	AR	F
Feral Pigeon	Columba livia		I	T
White-throated Pigeon	Columba vitiensis	r		F/R
Spotted Turtle-dove	Streptopelia chinensis	✓r	I	R
Friendly Ground-dove	Gallicolumba stairii	?	VU	F
Barking Pigeon	Ducula latrans	v	e	F
Many-coloured Fruit-dove	Ptilinopus perousii	v		F
Golden Dove	Ptilinopus luteovirens	✓r	e	F
Collared Lory	Phigys solitarius	v	e	F
Masked Shining Parrot	Prosopeia personata	v	e VU	F
Red Shining Parrot	P. tabuensis/splendens		I	F
Red-throated Lorikeet	Charmosyna amabilis		e CE	F
Fan-tailed Cuckoo	Cacomantis pyrrophanus			F
Long-tailed Cuckoo	Eudynamis taitensis		migrant	F
Barn Owl	Tyto alba	r		F
White-rumped Swiftlet	Aerodramus spodiopygia	✓v		over forest
Pacific Swallow	Hirundo tahitica			A
White-collared Kingfisher	Todiramphus chloris	✓r		F/R
Polynesian Triller	Lalage maculosa	✓r		F
Red-vented Bulbul	Pycnonotus cafer	✓r	I	R
Island Thrush	Turdus poliocephalus			F
Long-legged Warbler	Trichocichla rufa		e **EN**	F
Fiji Warbler	Vitia ruficapilla	✓r	e	F/R
Streaked Fantail	Rhipidura verreauxi			F

Slaty Monarch	Mayrornis lessoni	r	e	F/R
Fiji Shrikebill	Clytorhynchus vitiensis	r		F
Black-faced Shrikebill	Clytorhynchus nigrogularis		e VU	F
Vanikoro Broadbill	Myiagra vanikorensis	✓r		F/R
Blue-crested Broadbill	Myiagra azureocapilla		e	F
Scarlet Robin	Petroica multicolor	r		F
Golden Whistler	Pachycephala pectoralis			F
Fiji White-eye	Zosterops explorator	v	e	F
Silvereye	Zosterops lateralis	✓r		F/R
Orange-breasted Myzomela	Myzomela jugularis	✓r	e	F/R
Wattled Honeyeater	Foulehaio carunculata	✓r		F/R
Giant Forest Honeyeater	Gymnomyza viridis		e **VU**	F
Fiji Parrotfinch	Erythrura pealii	r		F
Pink-billed Parrotfinch	Erythrura kleinschmidti		e **EN**	F
Red Avadavat	Amandava amandava	✓r	I	R
Polynesian Starling	Aplonis tabuensis			F
Common Mynah	Acridotheres tristis			H
Jungle Mynah	Acridotheres fuscus	✓r		H
Fiji Woodswallow	Artamus mentalis	✓r	e	over forest

Key: Shaded – Viti Levu endemic; ✓ – observed; r – resident, v – visitor; e – Fiji endemic; I – introduced. Threat Status – IUCN Red List 2004 – CE – Critically Endangered; EN – Endangered; VU – Vulnerable. AR – At Risk; CC – Conservation Concern (refer Watling 2004). F – Forest; O – Open; H – human associated; A – aerial

4) Freshwater Ecosystem

The proposed reservoir site on the Savatu Creek was surveyed for freshwater fauna on 3 September 2014.

Table 7.3.1-2 presents the aquatic fauna observed and key characteristics of this fauna. Five species were observed, including one fish species, two macro-crustaceans, and two snails. The fish is endemic to Fiji and one of only two known completely freshwater resident species. However, this species appears relatively hardy and is widespread on all the large islands of Fiji.

Table 7.3.1-2 Relative Local Abundance, Life History, Feeding Guilds, Conservation Status and Flow Requirements of Fish, Macro-Crustaceans and Snails Found at the Savatu Creek, Upper Ba Catchment.

			Abundance	Life History	Feeding Guild	Status	IUCN Status	Flow requirements
FISHES								
Family	**Genus**	**Species**						
Gobiidae	*Redigobius*	*leveri*	R	FR	G	END	DD	rheophilic, med-high velocity, cannot surmount barriers
CRUSTACEANS								
Atyidae	*Atyoida*	*pilipes*	R	A	DG	IND	LC	rheophilic, 1-2m/s, can climb waterfalls
Palaemonid	*Macrobrachium*	*grandimanus*	R	A	DG	IND	LC	usually in reduced flow areas, can climb
SNAILS								
Neritidae	*Neritina*	*sp.*	R	A	HG	IND	NA	can climb in high velocity
Thiaridae	*Melanoides*	*sp.*	R	A	HG	IND	NA	can climb in high velocity

(Key: Locally abundant (Ab); moderately abundant (M); rare (R); data not available (NA). Life history classifications, after Elliot et al. (2007), include: freshwater resident (FR); freshwater straggler (FS); estuarine migrant (EM); amphidromy (A); obligate catadromy (COB); and facultative catadromy (FC). Feeding guild classes are: detritivore generalist (DG); planktivore generalist (PlG); herbivore specialist (HS); herbivore generalist (HG); invertivore specialist (IS); invertivore generalist (IG); piscivore generalist (PG); carnivore (C); and omnivore generalist (OG). Status categories are: indigenous (IND); endemic (END); potentially endemic (PEND) and introduced (INT). IUCN categories shown are least concern (LC); near threatened (NT); endangered (EN) and data deficient (DD)).

The hydropower project will have relatively high impacts on the river and project site.

- Issue 1: The mainstream Ba river will have no water, or only residual flow, in the stretch adjacent to Koro-Drala-Vatutokotoko with resultant reduced water quality and removal of all nearby fish resources. The latter will affect upstream communities Buyabuya and Marou, though they will still have water flowing.
- Recommendation 1: Thorough surveys of fish and other aquatic fauna are required to clarify losses and changes which will occur as a result of water diversion.
- Issue 2: To date the construction of dams and weirs across Fijian rivers for hydropower purposes has paid no meaningful attention to impacts on migratory fish and ‘residual or compensatory flow’ requirements.
- Recommendation 2: Fish ladders and ‘minimum ecological flow’ requirements need to be incorporated into the design of the scheme.

(2) Social Environment

1) Socio-Economic Conditions/Resettlement

The land use in and around the project area is primarily for low intensity grazing and subsistence agriculture. The villagers are essentially living traditional Fijian subsistence lifestyles, supplemented by a few opportunities for cash cropping.

2) Location and Access

The No.8 Mba 1 U/S Project Scheme is located approximately 200km from Suva in the highlands of central city of Viti Levu. The project site is close to four villages: Koro, Drala, Vatutokotoko, and Buyabuya. However, the landowners of the major project components reside in Navala village, which is around 10km downstream. Navala village is accessed from the King's road from Ba town. Koro, Drala, Buyabuya, and Vatutokotoko villages are accessible via the unpaved Lewa and Nadarivatu roads which connect to the King's road near Tavua.

- Population

The project area is lightly populated. Unofficial population figures for the three villages closely connected with the project are tabulated in Table 7.3.1-3. There is no requirement to relocate houses or settlements.

Table 7.3.1-3 Population by Ethnicity of the Qaliyalatini and Savatu Districts

EAS	Locality	Population				
		Total	Fijian	Indian	Rotuman	Others
10600230	Navala, Nawani, Volavola, Nakuro, Gunu	626	624	0	1	1
10600240	Koro, Naiyaca, Taunabe, Marou, Buyabuya, Drala, Vatutokotoko, Nakito, Lutu, Lutunabaki	597	595	0	2	0
	Total	1,223	1,219	0	3	1

(Source: Government Bureau of Statistics)

Table 7.3.1-4 shows the population of Koro, Drala, and Navala villages.

Table 7.3.1-4 Population and Number of Households of in the Navala, Koro, and Drala Villages

Village	No. of Households	Population
Navala	127	700
Koro	30	150
Drala	20	60

(Source: Interview Data)

- Land Ownership and Land Use

The landowners of the principal elements of the project (reservoir and power station) reside at Navala village, about 10km downstream from those villages closest to the project (Koro, Drala, Vatutokotoko, and Buyabuya) and they do not use the project area for their own purposes. The Savatu River Reservoir site is an important gardening and cash cropping area for the villagers from Drala and Vatutokotoko,; to signify this there is a traditional agreement basis with the Navala landowners.

The land ownership of No.8 the Mba 1U/S Project Scheme is tabulated in Table 7.3.1-5

Table 7.3.1-5 Land Ownership for the No.8 Mba 1U/S Project Scheme

Mataqali	Village	District	Comment
Votualevu	Buyabuya	Savatu	The proposed weir and intake on the Ba River are located on the *Mataqali* Votualevu land. The tunnel diverting water from the Ba River to the Savatu River runs under the *Mataqali* Koroilagi land until it spills into the reservoir.
Koroilagi	Navala	Qaliyalatini	The weir and its reservoir planned in the Savatu Creek impoundment are on the land owned by the *Mataqali* Koroilagi.
Veivatu	Navala	Qaliyalatini	The water diverted through the tunnel from the Savatu Reservoir to the power station, together with the Power Station will be on land owned by the *Mataqali* Veivatu.
Ekubu	Marou	Savatu	Catchment
Taunasagati		Savatu	Catchment
Navakadevo	Navala	Qaliyalatini	Catchment
Nakorosovivi	Naiyaca	Savatu	Catchment
Vaturavi		Savatu	Catchment
Virara	Nadelei	Tavua	Catchment
Nubunisiga	Nadelei	Tavua	Catchment
Bekasaisai	Naiyaca	Savatu	Catchment
Nayau	Nadelei	Tavua	Catchment
Narata	Navala	Qaliyalatini	Catchment

Issue 1:Between two and four farmhouses and small-scale productive agricultural farm land is likely to be inundated under the reservoir.

A farmhouse on the bank of the Savatu Creek that is likely to be inundated by the project reservoir.

- Recommendation 1: Farmhouses and agricultural land should be surveyed in relation to the inundatation zone
- Issue 2: Some residents near the project area (from Koro and Drala villages and Vatutokotoko settlement) use the Savatu Reservoir site, their most productive agricultural area, with traditional agreements arranged with the landowners from Navala who reside 10km downstream.
- The scheme will result in an imbalance of the negative impacts to be received by the adjacent but non-landowning communities (Koro, Drala, and Vatutokotoko) and the non-resident landowners of Navala (10akm downstream) who do not use the project site, which will receive all the benefits from the scheme.
- Recommendation 2: Resolution of this imbalance in negative impacts and benefits of the scheme is likely to be critical to the acceptance of this scheme by the local communities.

3) Water/River Use

The mainstream of the Ba River will have no water, or only residual flow, in the stretch adjacent to Koro-Drala-Vatutokotoko with a resultant reduction in water quality and the removal of all nearby fish resources. The latter will affect the upstream communities of Buyabuya and Marou, though they will still have flowing water.

- The surveys of fish and other aquatic fauna are required to clarify any potential losses and changes which will occur as a result of the water diversion.
- Pulses of water discharged from the Nadarivatu Hydropower Scheme - as currently experienced by the local communities - will be transferred downstream and may potentially be experienced by Navala villagers. This is likely to be a minor issue as there are other tributaries joining the river and these villagers are 10km downstream from the power station.

4) Historical and Cultural Heritage

According to the Fiji Museum database, there are various sites of cultural or archaeological importance to the *Mataqali* located within the catchment area. More research is required to determine the exact location and potential impact of the hydropower project on Tabunacici.

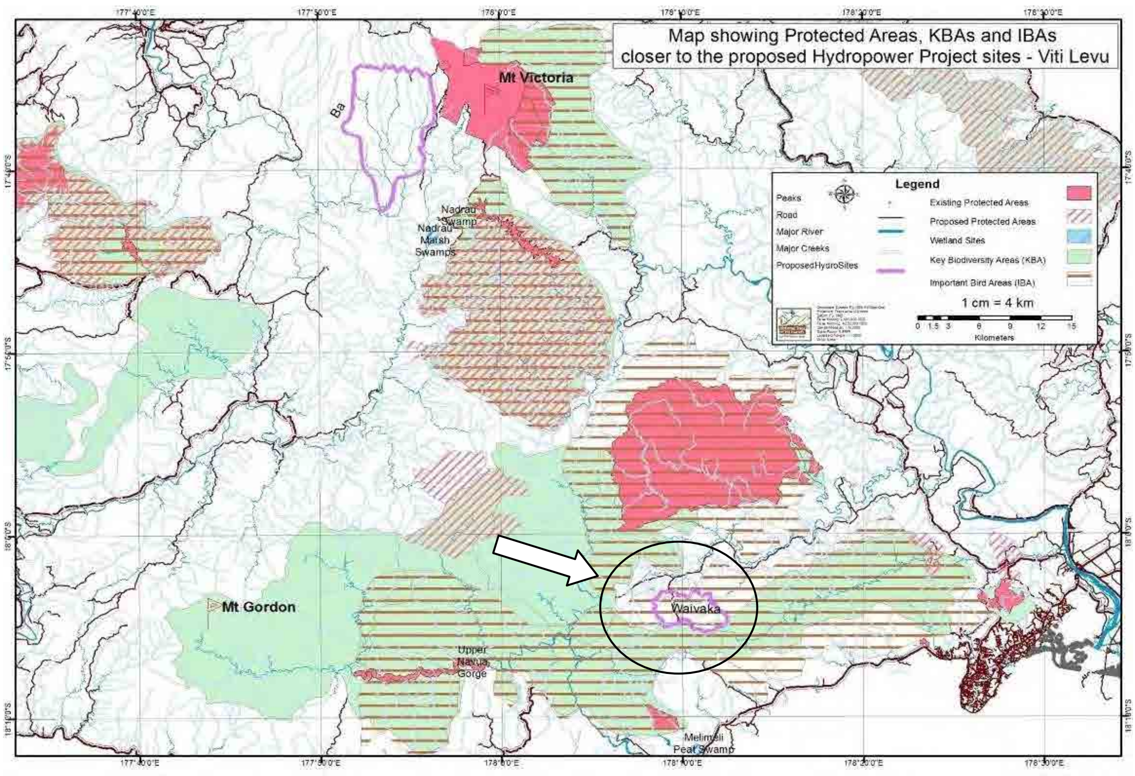
(b) Results of the Environmental Survey in the Proposed No.29 Waivaka Project Scheme

The project is located in the middle reaches of the Waidina River, in central Viti Levu. The area is a remote and lightly populated region accessed by the unsealed Namosi-Nabukavesi road, with two villages in the vicinity of the development – Waivaka and Narukunibua.

(1) Natural Environment

1) Protected Area

The corresponding project site is delineated by a purple line in Figure 7.3.1-3. There are no proposed protected areas (according to the legend, such areas are shaded pink) and no key biodiversity areas (according to the legend, such areas are shaded light green) immediately associated with the Waivaka Hydropower Power project or located in its wider catchment. The project site overlaps with the important bird areas (according to the legend, such areas are shaded with black horizontal stripes), however there are no rare species according to the results of the bird survey.

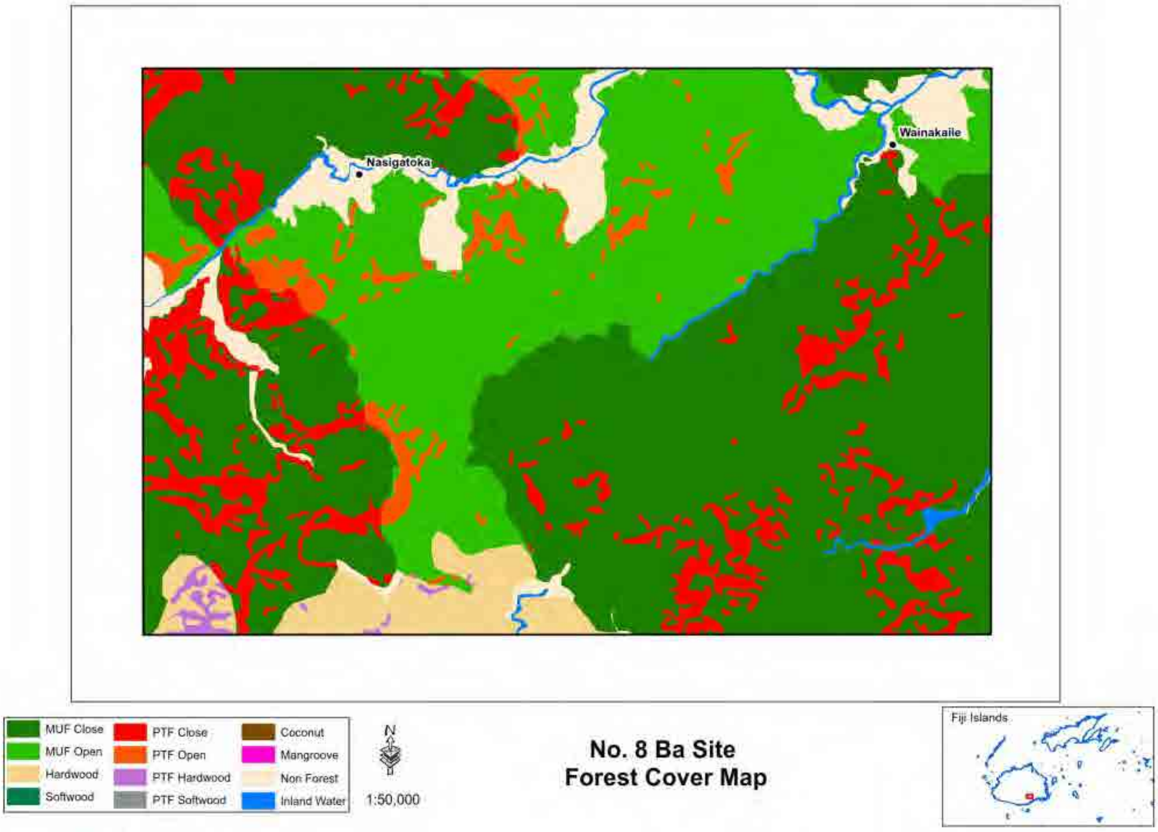


(Source: National Trust for Fiji).

Figure 7.3.1-3 Map of the Protected Areas and Important Biodiversity Areas in Viti Levu (with the Waivaka Hydropower Project Site delineated in purple, pink, central lower)

2) Vegetation Type

Figure 7.3.1-4 shows the types of vegetation types at the project site. The vegetation of the proposed Waivaka reservoir is largely secondary vegetation and mostly open grassland, modified completely from the original habitat and maintained in its present condition by cattle grazing.



(Source: Department of Forests)

Figure 7.3.1-4 Forestry Planning – Forest Function Classifications for the Wairokodra-Waivaka Area

3) Fauna and Flora

There are no known rare or threatened fauna and flora that are affected by the project. The landbirds of Viti Levu and those species observed or likely to be resident in the proposed Waivaka Reservoir area are listed in Table 7.3.1-6. None of Fiji's rarer or threatened species are expected to be resident in the disturbed, secondary habitats found there.

Table 7.3.1-6 Bird List for Viti Levu and Those Species Observed or Expected to be Resident in the Proposed Waivaka Reservoir Area.

English name	Scientific name	Observed or likely to be resident in Waivaka Reservoir area	Introduced endemic Threat Status	Habitat and Distribution
Reef Heron	Egretta sacra	✓v		rivers,streams
Pacific Black Duck	Anas superciliosa	✓r		rivers
White-faced Heron	Ardea novaehollandiae	v		wetland, grass
Fiji Goshawk	Accipiter rufitorques	✓r	e	F
Pacific Harrier	Circus approximans	✓v		F
Peregrine Falcon	Falco peregrinus	v	AR	F
Feral Pigeon	Columba livia		I	T
White-throated Pigeon	Columba vitiensis	✓r		F/R
Spotted Turtle-dove	Streptopelia chinensis	✓r	I	R
Friendly Ground-dove	Gallicolumba stairii	r	VU	F
Barking Pigeon	Ducula latrans	✓r	e	F
Many-coloured Fruit-dove	Ptilinopus perousii	r		F
Golden Dove	Ptilinopus luteovirens	✓r	e	F
Collared Lory	Phigys solitarius	r	e	F
Masked Shining Parrot	Prosopeia personata	v	e **VU**	F
Fan-tailed Cuckoo	Cacomantis pyrrophanus	✓r		F
Long-tailed Cuckoo	Eudynamis taitensis		migrant	F
Barn Owl	Tyto alba	r		F
White-rumped Swiftlet	Aerodramus spodiopygia	✓r		A
Pacific Swallow	Hirundo tahitica			A
White-collared Kingfisher	Todiramphus chloris	✓r		F/O
Polynesian Triller	Lalage maculosa	✓r		F
Red-vented Bulbul	Pycnonotus cafer	✓r	I	R
Island Thrush	Turdus poliocephalus	r		F
Long-legged Warbler	Trichocichla rufa	?	e EN	F
Fiji Warbler	Vitia ruficapilla	r	e	F
Streaked Fantail	Rhipidura verreauxi	✓r		F
Slaty Monarch	Mayrornis lessoni	✓r	e	F
Fiji Shrikebill	Clytorhynchus vitiensis	✓r		F

Black-faced Shrikebill	Clytorhynchus nigrogularis	r	e VU	F
Vanikoro Broadbill	Myiagra vanikorensis	✓r		FO
Blue-crested Broadbill	Myiagra azureocapilla	✓r	e	F
Scarlet Robin	Petroica multicolor	r		F
Golden Whistler	Pachycephala pectoralis	✓r		F
Fiji White-eye	Zosterops explorator	✓r	e	F
Silvereye	Zosterops lateralis	✓r		F/O
Orange-breasted Myzomela	Myzomela jugularis	✓r	e	F/O
Wattled Honeyeater	Foulehaio carunculata	✓r		F/O
Giant Forest Honeyeater	Gymnomyza viridis	✓r	e VU	F
Fiji Parrotfinch	Erythrura pealii	✓r		F/O
Pink-billed Parrotfinch	Erythrura kleinschmidti	✓r	e EN	F
Red Avadavat	Amandava amandava		I	O
Polynesian Starling	Aplonis tabuensis	r		F
Common Mynah	Acridotheres tristis			H
Jungle Mynah	Acridotheres fuscus			H
Fiji Woodswallow	Artamus mentalis	✓r	e	A

1. Source: Environment Consultants Fiji – File Data, ECF (2003)
2. Key: e – Fiji endemic; Viti Levu endemic species - shaded. I – introduced. Threat Status – IUCN Red List 2004 – CE – Critically Endangered; EN – Endangered; VU – Vulnerable. AR – At Risk; CC – Conservation Concern (refer Watling 2004). F – Forest; R – Riparian habitats

4) Freshwater Ecosystem

The Waivaka River and the proposed reservoir site on the Waivaka were surveyed for freshwater fauna in August 2012 (Jenkins, unpublished). (Please note, only the records of this catchment were surveyed.)

Table 7.3.1-7 Relative Local Abundance, Life History, Feeding Guilds, Conservation Status, and Flow Requirements of Fish Found at the Waivaka Creek Catchment

Family	Genus	Species	Abundance	Life History	Feeding Guild	Status	IUCN Status	Flow requirements
Anguillidae	*Anguilla*	*marmorata*	M	FS	G	Ind	LC	Any, can surmount obstacles when land is wet
Gobiidae	*Stiphodon*	*Isabellae (mn)*	M	A	HG	End	NA	clear, oxygen rich water, can climb waterfalls
Gobiidae	*Stiphodon*	*rutilaureus*	R	A	HG	Ind	LC	clear, oxygen rich water, can climb waterfalls
Gobiidae	*Awaous*	*guamensis*	R	A	G	Ind	LC	med-high velocity, can climb small waterfalls
Eleotridae	*Eleotris*	*fusca*	Ab	A	C	Ind	LC	lower, low flow areas, buries in sand
Eleotridae	*Bunaka*	*gyrinoides*	R	A	C	Ind	LC	lower, low flow areas, buries in sand
Kuhliidae	*Kuhlia*	*rupestris*	M	COB	IS	Ind	LC	rheophilic, med-high velocity, cannot surmount barriers
Poecilliidae	*Poecilia*	*reticulata*	M	FS	IG	Int	LC	Low flow areas, low oxygen
Cichlidae	*Oreochromis*	*niloticus*	M	FS	G	Int	LC	Low mid flow areas, low oxygen

(Key: Locally abundant (Ab); moderately abundant (M); rare (R); data not available (NA). Life history classifications, after Elliot et al. (2007), include: freshwater resident (FR); freshwater straggler (FS); estuarine migrant (EM); amphidromy (A); obligate catadromy (COB); and facultative catadromy (FC). Feeding guild classes are: detritivore generalist (DG); planktivore generalist (PlG); herbivore specialist (HS); herbivore generalist (HG); invertivore specialist (IS); invertivore generalist (IG); piscivore generalist (PG); carnivore (C); and omnivore generalist (OG). Status categories are: indigenous (IND); endemic (END); potentially endemic (PEND) and introduced (INT). IUCN categories shown are least concern (LC); near threatened (NT); endangered (EN) and data deficient (DD)).

The fish found at this site are presented in Table 7.3.1-7. Six indigenous species and two introduced species were present. One species is considered endemic but is widespread on all the large islands in Fiji. The freshwater eel, Anguilla marmorata, is a totem of the landowners. Three of the species (Bunaka gyrinoides, Kuhlia rupestris, and Oreochromis niloticus are considered as important food species for the inland villages. The eel can also be eaten, but strictly speaking the totemic relationship here does not allow this.

(2) Social Environment

1) Socio-Economic Condition/Resettlement

The project is located in the middle stream of the Waidina River, in central Viti Levu. The area is a remote and lightly populated region accessed by the unpaved Namosi-Nabukavesi road, with two villages in the vicinity of the development – Waivaka and Narukunibua.

The No.29 Waivaka Project Scheme is located approximately 45km from Suva in the highlands of Namosi, Viti Levu. The project site is close to two villages – Waivaka and Narukunibua, although they are located on the opposite sides of the Waidina River. Two other villages in the vicinity Nasigatoka and Namosi are slightly further away. However, there are no landowners in the latter village. The villages are accessible via the unpaved Namosi-Nabukavesi road which connects to the Queen's road at Nabukavesi.

-Population

Namosi is a sparsely populated village. Unofficial population figures for the three villages closely connected with the project are tabulated in Table 7.3.1-8. The villages are not large with a combined population of 275. It can be assumed that about as many again belong to the villages but currently live elsewhere in Fiji.

Table 7.3.1-8 Population of the Three Villages Associated with the Waivaka Hydropower Project

Village	No of Households	Population
Nasigatoka	14	65
Waivaka	37	110
Narukunibua	24	100

(Source: Turaga ni Koro)

2007 Census figures for the enumeration areas containing these villages are shown in Table 7.3.1-9.

Table 7.3.1-9 Population by Ethnicity of the Namosi District

EAS	Locality	Population/ Households				
		Total	Fijian	Indian	Rotuman	Others
100100000	NamosiVill, NavunibuaVill	555/100	545/99	1/0	0/0	9/1
100100010	NasigatokaVill, NarukunibuaVill, WaivakaVil, Namosi Sec / Pri.Sch	409/81	398/77	8/3	0	3/1

(Source: Government Bureau of Statistics. Key: Population / Households)

The land use in and around the project area is primarily low intensity, for free-range cattle and subsistence agriculture. The villagers are essentially living a traditional Fijian subsistence lifestyle, supplemented by a few opportunities for cash cropping.

- There is no requirement to relocate houses or settlements

2) Land Ownership and Land Use

In Namosi village, a *yavusa* is the smallest official landholding unit. Land ownership of the project is comparatively straightforward, being owned by three *yavusa* – Nabukebuke, Vanuaca, and Dakunibure (please refer to Table 7.3.1-10).

Table 7.3.1-10 Land Ownership for the Waivaka Hydropower Project

Yavusa	Village	District	Comment
Dakunibure	Waivaka	Namosi	The reservoir, dam, water intake, tunnel, head tank, power station, and part of the catchment area islocated on the *yavusa* Dakunibure land.
Vanuaca	Narukunibua	Namosi	A weir, water intake, the majority of the tunnel transporting water from the Wairokodra River to the Wainavuga Creek, and part of the catchment area is located on the *yavusa* Vanuaca land.
Nabukebuke	Nasigatoka	Namosi	A small section of the tunnel transporting water from the Wairokodra River to the Wainavuga Creek, and part of the catchment area is located on the *yavusa* Nabukebuke land.

The reservoir, dam, water intake, tunnel, head tank, and power station are located on the *yavusa* Dakunibure land. The weir, the water intake and the almost of the flowing water through the tunnel from Wairokodra river to the Wainavuga creek are located on the *yavusa* Vanuaca land, (a small section of the tunnel passes through land owned by the *yavusa* Nabukebuke).

Disturbance to the traditional lifestyles of the landowning and adjacent communities as a result of construction and the influx of workers to the area could be significant. There is significant ongoing activity related to the prospect of a large mine in the vicinity of the proposed project, which is evoking great social sensitivity.

Continued meaningful consultation with all affected communities is an important requirement to move forward.

3) Water/River Use

- Fishing – fish, crustaceans, and eels. This is an important subsistence activity which supplies much of the protein available to the villagers.

- Drinking water for livestock and for bathing livestock.

4) Historical and Cultural Heritage

According to the Fiji Museum database, there are no sites of cultural or archaeological importance affected by the project work sites. However two sites are listed in the database without reference to type, and are located by the 'Ridge along Wainavuga Creek'. Consultation with landowners of the project area did not reveal any sites of cultural significance.

(c) Results of the Environmental Survey in the Proposed No.35 Wailevu Project Scheme

The No.35 Wailevu Project Scheme is located in the highlands of west Wailevu, Vanua Levu. The Wailevu catchment area crosses the Macuata and Cakaudrove provincial boundaries as a well as the reservoir, the dam, and two power stations that are in the mid reaches of the catchment area. The area is very sparsely populated and there are no villages near the project area. Access is via unpaved logging or forestry plantation roads from the Nabouwalu-Seaqaqa road at Dreketi.

(1) Natural Environment

1) Protected Area

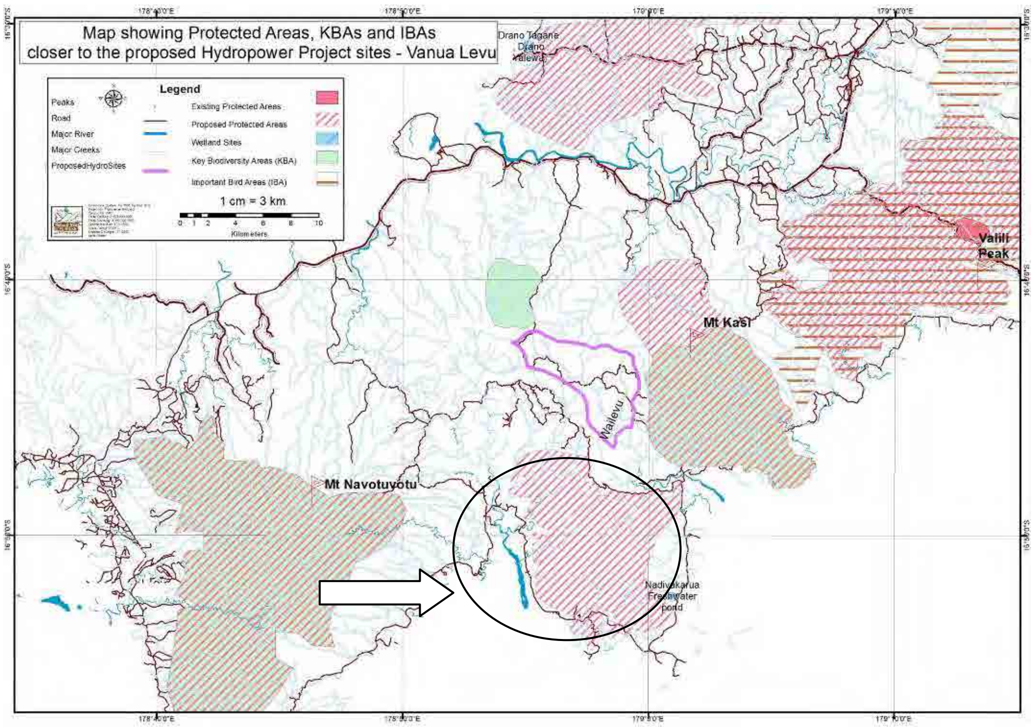
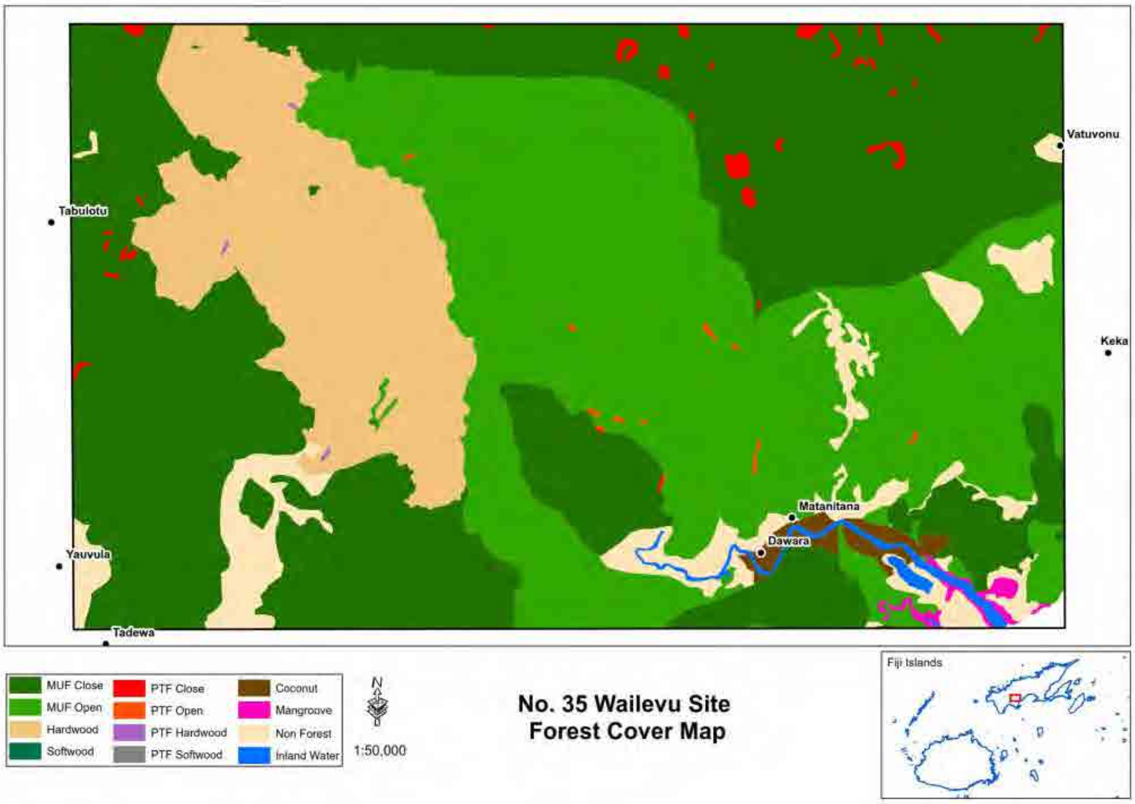


Figure 7.3.1-5 Map of the Protected Areas and Important Biodiversity Areas in Vanua Levu (with the No.35 Wailevu Project Scheme delineated in pink)

The corresponding project site is delineated by a purple line in Figure 7.3.1-5. There are no proposed protected areas (according to the legend, such areas are shaded pink), no key biodiversity area (according to the legend, such areas are shaded light green), and no important bird areas (according to the legend, such areas are shaded with black horizontal stripes) immediately associated with the Wailevu Hydropower project or located in its wider catchment.

2) Vegetation Type

- Figure 7.3.1-6 shows the types of vegetation at the project site.
- The vegetation at the reservoir area is primarily hardwood plantation with an area of native forest around and immediately upstream of the proposed dam. The wider catchment area is similar to the native forest; there are no agriculture and no other land uses in the catchment area. The native forest can be assumed to have high a biodiversity and timber values as it has not been logged.



(Source: Department of Forests)

Figure 7.3.1-6 Forestry Planning – Forest Function Classifications for the West Area of Wailevu, Vanua Levu

3) Fauna and Flora

There will be an inundation of the mature native forest and valuable hardwood plantation.

- There are no known rare or threatened fauna and flora affected by the project, but knowledge for the Vanua Levu forests is sparse. Table 7.3.1-11 shows the bird list for Vanua Levu and those species observed or expected to be resident in the proposed Wailevu Reservoir area.
- <u>Recommendation:</u> Detailed fauna and flora surveys on the native forest areas are needed.

Table 7.3.1-11 Bird List for Vanua Levu and Those Species Observed or Expected to be Resident in the Proposed Wailevu Reservoir Area

English name	Scientific name	Observed or likely to be resident in Wailevu Reservoir area	Introduced endemic Threat Status	Habitat and Distribution
Reef Heron	Egretta sacra	✓v		rivers,streams
Pacific Black Duck	Anas superciliosa	✓r		rivers
White-faced Heron	Ardea novaehollandiae	v		wetland, grass
Fiji Goshawk	Accipiter rufitorques	✓r	e	F
Pacific Harrier	Circus approximans	✓v		F
Peregrine Falcon	Falco peregrinus	v	AR	F
Feral Pigeon	Columba livia		I	T
White-throated Pigeon	Columba vitiensis	✓r		F/R
Spotted Turtle-dove	Streptopelia chinensis	✓r	I	R
Friendly Ground-dove	Gallicolumba stairii	r	VU	F
Barking Pigeon	Ducula latrans	✓r	e	F
Many-coloured Fruit-dove	Ptilinopus perousii	r		F
Orange Dove	Ptilinopus lvictor	✓r	e	F
Collared Lory	Phigys solitarius	r	e	F
Red Shining Parrot	P. tabuensis	✓r	I	F
Fan-tailed Cuckoo	Cacomantis pyrrophanus	✓r		F
Long-tailed Cuckoo	Eudynamis taitensis		migrant	F
Barn Owl	Tyto alba	r		F
White-rumped Swiftlet	Aerodramus spodiopygia	✓r		A
Pacific Swallow	Hirundo tahitica			A
White-collared Kingfisher	Todiramphus chloris	✓r		F/O
Polynesian Triller	Lalage maculosa	✓r		F
Red-vented Bulbul	Pycnonotus cafer	✓r	I	R
Island Thrush	Turdus poliocephalus	r		F
Long-legged Warbler	Trichocichla rufa	?	e EN	F
Fiji Warbler	Vitia ruficapilla	r	e	F
Streaked Fantail	Rhipidura verreauxi	✓r		F
Slaty Monarch	Mayrornis lessoni	✓r	e	F
Fiji Shrikebill	Clytorhynchus vitiensis	✓r		F

Black-faced Shrikebill	Clytorhynchus nigrogularis	r	e VU	F
Vanikoro Broadbill	Myiagra vanikorensis	✓r		FO
Blue-crested Broadbill	Myiagra azureocapilla	✓r	e	F
Scarlet Robin	Petroica multicolor	r		F
Golden Whistler	Pachycephala pectoralis	✓r		F
Fiji White-eye	Zosterops explorator	✓r	e	F
Silvereye	Zosterops lateralis	✓r		F/O
Orange-breasted Myzomela	Myzomela jugularis	✓r	e	F/O
Wattled Honeyeater	Foulehaio carunculata	✓r		F/O
Giant Forest Honeyeater	Gymnomyza viridis	✓r	e **VU**	F
Fiji Parrotfinch	Erythrura pealii	✓r		F/O
Pink-billed Parrotfinch	Erythrura kleinschmidti		e **EN**	F
Red Avadavat	Amandava amandava		I	O
Polynesian Starling	Aplonis tabuensis	r		F
Common Mynah	Acridotheres tristis			H
Jungle Mynah	Acridotheres fuscus			H
Fiji Woodswallow	Artamus mentalis	✓r	e	A

3. (Source: Environment Consultants Fiji – File Data, ECF (2003))

4. Key: ✓ – observed; r – resident, v – visitor; e – Fiji endemic; I – introduced. Threat Status – IUCN Red List 2004 – CE – Critically Endangered; EN – Endangered; VU – Vulnerable. AR – At Risk; CC – Conservation Concern (refer Watling 2004). F – Forest; O – Open; H – human associated; A - aerial

4) Freshwater Ecosystem

Fish, eels, and prawns provide an important protein source for the villagers of the area, especially prawns are also a source of income for the women of Nasigasiga village. The fish surveys found a varied fish fauna with clear indications of good water quality and no barriers to the passage to the sea for the migratory species.

- Two approximately 50 meter sections of the upper Wailevu River (in plantation) were surveyed on 25 August 2014 and another two in the lower stream of the river on 26 Aug 2014.

- Table 7.3.1-12 presents the aquatic fauna that was observed and key characteristics of this fauna. Overall, as observed in the Kilaka Basin, the fauna here is quite diverse, abundant and contains several species of conservation significance.

- No introduced species were observed.

- A key observation here is that the population sizes of fish and crustaceans are generally high.

Table 7.3.1-12 Relative Local Abundance, Life History, Feeding Guilds, Conservation Status and Flow Requirements of Fish Found at the Upper Wailevu River Site

			Abundance Site 1	Abundance Site 2	Life History	Feeding Guild	Status	IUCN Status	Flow requirements
FISHES									
Family	**Genus**	**Species**							
Gobiidae	*Stiphodon*	*lailai (mn)*	Ab		A	HG	End	NA	clear, oxygen rich water, can climb waterfalls
Gobiidae	*Stiphodon*	*Isabellae (mn)*	Ab		A	HG	End	NA	clear, oxygen rich water, can climb waterfalls
Gobiidae	*Sicyopterus*	*lagocephalus*	Ab	Ab	A	HG	Ind	LC	rheophilic, 130 -160 cm/s, can climb waterfalls
Gobiidae	*Sicyopus*	*zosterophorum*	M	Ab	A	IS	Ind	LC	clear, oxygen rich, fast flowing, can climb
Gobiidae	*Glossogobius*	*sp.*	R	R	A	IS	End	NA	shallow, moderate flowing streams
CRUSTACEANS									
Atyidae	*Atyoida*	*pilipes*	Ab		A	DG	Ind	LC	rheophilic, 1-2m/s, can climb waterfalls
Atyidae	*Atyopsis*	*spinipes*	Ab	M	A	DG	Ind	LC	high oxygenated water, can climb waterfalls
Palaemonid	*Macrobrachium*	*australe*	Ab		A	OG	Ind	LC	mainly river banks and areas of reduced flow, can climb
Palaemonid	*Macrobrachium*	*lar*	Ab	M	A	OG	Ind	LC	well oxygenated streams, can climb
SNAILS									
Neritidae	*Neritina*	*sp.*	M	M	A	HG	Ind	NA	can climb in high velocity

(Key: Locally abundant (Ab); moderately abundant (M); rare (R); data not available (NA). Life history classifications, after Elliot et al. (2007), include: freshwater resident (FR); freshwater straggler (FS); estuarine migrant (EM); amphidromy (A); obligate catadromy (COB); and facultative catadromy (FC). Feeding guild classes are: detritivore generalist (DG); planktivore generalist (PlG); herbivore specialist (HS); herbivore generalist (HG); invertivore specialist (IS); invertivore generalist (IG); piscivore generalist (PG); carnivore (C); and omnivore generalist (OG). Status categories are: indigenous (IND); endemic (END); potentially endemic (PEND) and introduced (INT). IUCN categories shown are least concern (LC); near threatened (NT); endangered (EN) and data deficient (DD)).

Table 7.3.1-13 presents the aquatic fauna observed and key characteristics of this fauna.

- While the higher diversity of the site reflects the site being closer to the sea, the abundance of fish seen relative to the volume of water was very low.

A fish survey was conducted using a medium pole and seine net in the lower reaches of the Wailevu

Examining the results of the fish survey in lower reaches of the Wailevu River

Table 7.3.1-13 Relative Local Abundance, Life History, Feeding Guilds, Conservation Status and Flow Requirements of Fish Found at the Lower Wailevu River Site.

			Abundance	Life History	Feeding Guild	Status	IUCN Status	Flow requirements
FISHES								
Family	**Genus**	**Species**						
Muraenidae	*Gymnothorax*	*polyuranodon*	R	*COB*	*PG*	*Ind*	LC	med-high velocity, prefers pools near boulders
Gobiidae	*Stenogobius*	*sp.*	R	*A*	*PG*	*End*	NA	clear, oxygen rich, fast flowing, can climb
Gobiidae	*Awaous*	*guamensis*	R	*A*	*G*	*Ind*	LC	med-high velocity, can climb small waterfalls
Gobiidae	*Redigobius*	*leveri*	R	*FR*	*G*	*End*	DD	rheophilic, med-high velocity, cannot surmount barriers
Eleotridae	*Eleotris*	*fusca*	R	*A*	*C*	*Ind*	LC	lower, low flow areas, buries in sand
Ambassidae	*Ambassis*	*miops*	Ab	*FS*	*G*	*Ind*	LC	lower, low flow areas, schools mid water
Kuhliidae	*Kuhlia*	*rupestris*	M	*COB*	*IS*	*Ind*	LC	rheophilic, med-high velocity, cannot surmount barriers
Kuhliidae	*Kuhlia*	*marginata*	Ab	*COB*	*IG*	*Ind*	LC	rheophilic, med-high velocity, cannot surmount barriers
Kuhliidae	*Kuhlia*	*munda*	M	*COB*	*IG*	*Ind*	LC	rheophilic, med-high velocity, cannot surmount barriers
Syngnathidae	*Microphis*	*retzii*	R	*FS*	*IS*	*Ind*	NA	lower, low flow areas, cannot surmount barriers
Syngnathidae	*Microphis*	*liaspis*	R	*FS*	*IS*	*Ind*	NA	lower, low flow areas, cannot surmount barriers
CRUSTACEANS								
Atyidae	*Atyoida*	*pilipes*	R	A	DG	Ind	LC	rheophilic, 1-2m/s, can climb waterfalls
Atyidae	*Caridina*	*typus*	M	FR	DG	Ind	LC	mainly lower flow areas
Atyidae	*Caridina*	*weberi*	R	FR	DG	Ind	LC	mainly lower flow areas
Palaemonidae	*Macrobrachium*	*lar*	R	A	OG	Ind	LC	well oxygenated streams, can climb
SNAILS								
Neritidae	*Neritina*	*sp.*	R	A	HG	Ind	NA	can climb in high velocity
Thiaridae	*Melanoides*	*sp.*	R	A	HG	Ind	NA	can climb in high velocity

(Key: Locally abundant (Ab); moderately abundant (M); rare (R); data not available (NA). Life history classifications, after Elliot et al. (2007), include: freshwater resident (FR); freshwater straggler (FS); estuarine migrant (EM); amphidromy (A); obligate catadromy (COB); and facultative catadromy (FC). Feeding guild classes are: detritivore generalist (DG); planktivore generalist (PlG); herbivore specialist (HS); herbivore generalist (HG); invertivore specialist (IS); invertivore generalist (IG); piscivore generalist (PG); carnivore (C); and omnivore generalist (OG). Status categories are: indigenous (IND); endemic (END); potentially endemic (PEND) and introduced (INT). IUCN categories shown are least concern (LC); near threatened (NT); endangered (EN) and data deficient (DD)).

- Issue 1: After the project construction, the mainstream Wailevu River will have no water, perhaps only residual flow in the two consecutive stretches of the river each about 2km long (this first being from the dam to the No.2 Power Station, and the second being from that point to the No.1 Power Station) with a resultant reduction in water quality and removal of all nearby fish resources. This will affect the fish and crustacean of the upper catchment area above the reservoir.
- Recommendation 1: Surveys of fish and other aquatic fauna are required to clarify any potential losses and changes which will occur as a result of the water diversion.
- Issue 2: To date the construction of dams and weirs across Fijian rivers for hydropower purposes has paid no meaningful attention to impacts on migratory fish and crustacea, and 'residual or compensatory flow' requirements.
- Recommendation 2: Fish ladders and 'minimum ecological flow' requirements need to be incorporated into the design of the scheme.

(2) Social Environment

1) Socio-Economic Conditions/Resettlement

The villagers are essentially living traditional Fijian subsistence lifestyles but exploitation of income generating opportunities are available.

- Location and Access

- The Wailevu hydropower project site is located approximately 80km from Savusavu Town in the highlands of west Wailevu, Vanua Levu.
- The Wailevu catchment area crosses the Macuata and Cakaudrove provincial boundaries as well as the reservoir, dam, and two power stations that are in the mid reaches of the catchment area.

- Population

- The project area is very sparsely populated with nobody living close to the project site.
- There is no requirement to relocate the houses or the settlements.

Table 7.3.1-14 Population of the Three Villages Associated with the Wailevu Hydropower Project

Village	No of Households	Population
Nasigasiga	31	169
Nabiti	41	289
Dawara	63	200

（Source: Turaga ni Koro）

Table 7.3.1-15 Population by Ethnicity of the Enumeration Areas in Cakaudrove and Macuata Associated with the Wailevu Hydropower Project

EAS	Locality	Population / Households				
		Total	Fijian	Indian	Rotuman	Others
3070 0000	Cakaudrove: Dawara Vill, Dawara Dist Sch. Matanitaga, Mt Kasi, Drawa Vill, Vatuvonu Vill,Naviavia Vill,St Paul Pri Sch,Keka Vill,Dogoru, Natovatu, Saqasaqa, Vunibuabua, Loganimasi	615/137	455/98	25/7	2/1	133/31
7040 0020	Macuata: Nabiti Vill, Nasigasiga Vill, Maramarua Dist Sch, Dreketi High Sch, Dreketi Govt Station	655/143	440/86	180/47	0	35/10

（Source: Government Bureau of Statistics. Key: Population / Households）

2) Land Ownership and Land Use

The landowners of the upper part of the catchment area live to the north in Nasigasiga and Nabiti villages in Macuata, while the lower catchment landowners live at Dawara close to the main south coast road.

Those landowners living in Macuata are the owners of all the hardwood plantations in the catchment area, but none of the landowners use the project area to any great extent.

A preliminary analysis of land ownership of the Wailevu Hydropower project infrastructure (reservoir, power stations, weirs, roads) indicates that it will be constructed on native tenure land owned by eight *Mataqali*, with a further six *Mataqali* owning land in the catchment area that supplies water to the project (please refer to Table 7.3.1-16). Altogether, 14 *Mataqali* reside in four villages in three districts in two provinces.

Table 7.3.1-16 Land Ownership for the Wailevu Hydropower Project

Mataqali	**Village**	**District**	**Comment**
Nalase	Dawara	Wailevu	The No.2 Power Station is located on the *Mataqali* Nalase land.
Nakicu	Dawara	Wailevu	The dam and the lower part of the reservoir are located on the *Mataqali* Nakicu land (west of the river).
Lutulevu	Dawara	Wailevu	The dam and intake for the No.2 Power Station and the lower part of the reservoir are located on the *Mataqali* Lutulevu land (east of the river).
Navisere	Dawara	Wailevu	A small area of the lower catchment area and the tunnel transporting water to the No.1 Power Station are located on the *Mataqali* Navisere land.
Naveitokaki	Dawara	Wailevu	This is location of a small section of the tunnel, the penstock, and the No.1 Power Station.
Natalau	Nasigasiga	Dreketi	Part of the reservoir and catchment area is located on the *Mataqali* Natalau land, some of which is currently leased for forestry plantation.
Naikorokoro	Nabiti	Dreketi	Part of the reservoir and catchment area is located on the *Mataqali*Naikorokoro land currently leased for forestry plantation.
Tava	Nabiti	Dreketi	Part of the reservoir and catchment area is located on the *Mataqali* Tava land currently leased for forestry plantation.
Tuarewa	Nabiti	Dreketi	A small area of the upper catchment area is located on the *Mataqali* Tuarewa land.
Wasavulu	Nabiti	Dreketi	A small area of the upper catchment area is located on the *Mataqali* Wasavulu land, some of which is currently leased for forestry plantation.
Solourua	Nabiti	Dreketi	Part of the upper catchment area is located on the *Mataqali* Soloura land, some of which overlaps with land leased for forestry plantation.
Tavaira	Nabiti	Dreketi	Part of the upper catchment area is located on the *Mataqali* Tavaira land that is currently leased for forestry plantation.
Tonikula	tbd	Dreketi	A small area of the catchment area is located on the *Mataqali* Tonikula land.
Navunicau	Nabiti	Wailevu	Part of the catchment area is located on the *Mataqali* Navunicau land.

- Issue 1: IIf the Wailevu Hydropower Scheme is to operate efficiently and effectively in the long term, a high standard, low-impact logging plantation management system will be required to ensure a sustained water supply and lower sediment transport to the Wailevu Reservoir.
- To achieve this, consideration must be given to involving the three or four additional landowning groups who stand to receive no benefits from the scheme under current arrangements, and the lessee of the plantations, the Fiji Hardwood Corporation Ltd.

- Recommendation 1: Attention will need to be paid to enabling a high-standard of management through the support of the landowners and the Fiji Hardwood Corporation who are not otherwise beneficiaries of the scheme.
- Issue 2: There will be disturbance to traditional lifestyles in all the landowner village communities as a result of construction and influx of workers to the area. However, the villages are relatively far away from the construction site, so it is likely that any potential disturbance will be indirect.
- Recommendation 2: Continued meaningful consultation with all affected communities is an important requirement going forward.

3) Water/ River Use

- Issue 1: The water quality in the Wailevu River appears to be very good and construction practices and mitigation measures will need to be designed and implemented to a high standard, especially as the rainfall is so high in the area. There are proven mitigation measures already practiced in Fiji for reducing erosion and river sedimentation risk from earthworks associated with dam construction, however, effective implementation is often problematic.
- Recommendation1: A very high standard of erosion and sedimentation control is required to maintain the high water quality of the Wailevu.

4) Historical and Cultural Heritage

Fiji museum has no records of cultural/ archaeological sites from the project area (Elia Nakora, in litt.). Discussions with Dawara villagers recorded the presence of an old village site (*koro makawa*) within the Wailevu catchment but its exact location was not clearly known.

7.3.2 Issues and Recommendations from IEE

Three hydropower potential sites have been examined in detail so far. The recommendations and the issues gained from IEE's survey results are shown in Table 7.3.2-1.

Table 7.3.2-1 Issues and Recommendations from IEE Survey Results

No.8 Mba 1U/S Project Scheme		
Task	Issue	Recommendation
1	Two to four farmhouses and scarce productive agricultural land will be inundated under the reservoir	Farmhouses and agricultural land to be surveyed in relation to the inundated zone.
2	The river flow of the mainstream Ba river in the stretch adjacent to Koro-Drala-Vatutokotoko will decrease and it brings about the possibility of water degradation and decrease of all nearby fish resources. The latter will affect upstream communities Buyabuya and Marou, though they will still have water flowing.	The hydropower scheme needs to minimize the negative impacts on water quality and fish resources by conducting thorough surveys of fish and other aquatic fauna.
3	To date the construction of dams and weirs across Fijian rivers for hydropower purposes has paid no meaningful attention to impacts on migratory fish and 'residual or compensatory flow' requirements.	Fish ladders and 'minimum ecological flow' requirements need to be incorporated into the design of the scheme.
4	The scheme will result in an imbalance of negative impacts to be received by the adjacent but non-landowning communities (Koro, Drala, Vatutokotoko) and the non-resident landowners of Navala (10km downstream) who do not use the project site but will be due all benefits from the scheme.	Resolution of this imbalance in negative impacts and benefits of the scheme is likely to be critical to the acceptance of this scheme by local communities.
5	If the Upper Ba Hydropower Scheme is to operate efficiently and effectively in the long term, improvements in the catchment area management will be required to ensure a more sustained water supply and lower sediment transport to the Savatu Reservoir. To achieve this will involve 10 additional landowning groups who stand to receive no benefits from the scheme under current arrangements.	Attention needs to be paid to enabling improved catchment area management through the support of the landowners who are not otherwise beneficiaries of the scheme.
6	Disturbance to traditional lifestyles in Koro, Drala, Vatutokotoko and Buyabuya communities as a result of construction and influx of workers to the area will be significant. Such disturbance has been experienced previously during the construction of the Nadarivatu Hydropower Scheme.	Continued meaningful consultation with all affected communities is an important requirement going forward.

No.29 Waivaka Project Scheme		
Task	Issue	Recommendation
1	During operation, the primary effects will be related to the 'dewatering' of the lower Wairokodra River and the lower Waivaka River, which will potentially have an impact on the river habitat, sediment transport, water quality, riparian groundwater	Thorough surveys of fish and other aquatic fauna are required to clarify losses and changes which will occur as a result of

	levels, as well as the direct and indirect effects these will potentially have on the users of the water resources at the site.	water diversion.
2	To date the construction of dams and weirs across Fijian rivers for hydropower purposes has paid no meaningful attention to impacts on migratory fish and ‘residual or compensatory flow’ requirements.	Fish ladders and ‘minimum ecological flow’ requirements need to be incorporated into the design of the scheme.
3	Disturbance to traditional lifestyles of the landowning and adjacent communities as a result of construction and influx of workers to the area may be significant. There is significant ongoing activity related to the prospect of a large mine in the vicinity of the proposed project, which is evoking great social sensitivity.	Continued meaningful consultation with all affected communities is an important requirement going forward.

No.35 Wailevu Project Scheme		
Task	Issue	Recommendation
1	There will be inundation of the mature native forest and valuable hardwood plantation. There are no known rare or threatened fauna and flora affected by the project, but knowledge for the Vanua Levu forests is sparse.	Detailed fauna and flora surveys of the native forest areas which will be affected are needed.
2	The mainstream Wailevu River will have no water, perhaps only residual flow in the two consecutive stretches of the river each about 2km long (this first being from the dam to the No.2 Power Station, and the second being from that point to the No.1 Power Station) with a resultant reduction in water quality and removal of all nearby fish resources. This will affect the fish and crustacea of the upper catchment area above the reservoir.	Thorough surveys of fish and other aquatic fauna are required to clarify losses and changes which will occur as a result of water diversion.
3	To date the construction of dams and weirs across Fijian rivers for hydropower purposes has paid no meaningful attention to impacts on migratory fish and crustacea, and ‘residual or compensatory flow’ requirements.	Fish ladders and ‘minimum ecological flow’ requirements need to be incorporated into the design of the scheme.
4	If the Wailevu Hydropower Scheme is to operate efficiently and effectively in the long term, a high standard, low-impact logging plantation management system will be required to ensure a sustained water supply and lower sediment transport to the Wailevu Reservoir.To achieve this, consideration must be given to involving the three or four additional landowning groups who stand to receive no benefits from the scheme under current arrangements, and the lessee of the plantations, the Fiji Hardwood Corporation Ltd.	Attention will need to be paid to enabling high-standard management through the support of the landowners and the Fiji Hardwood Corporation who are not otherwise beneficiaries of the scheme.
5	There will be disturbance to traditional lifestyles in all the landowner village communities as a result of construction and influx of workers to the area. However, the villages are relatively far away from the construction site, so it is likely that any potential disturbance will be indirect.	Continued meaningful consultation with all affected communities is an important requirement going forward.

6	The water quality in the Wailevu River appears to be very good and construction practices and mitigation measures will need to be designed and implemented to a high standard, especially as the rainfall is so high in the area. There are proven mitigation measures already practiced in Fiji for reducing erosion and river sedimentation risk from earthworks associated with dam construction, however, effective implementation is often problematic.	A very high standard of erosion and sedimentation control is required to maintain the high water quality of the Wailevu.

7.3.3 Conclusion of IEE

As an overall result, one can say that for the construction of any of the hydropower plants, there exist *no major environmental concerns*. However, it is likely that *moderate impacts* could occur, so these have to be mitigated. A comprehensive environmental management plan with subsidiary component plans is proposed in this IEE to address issues during the construction and operation phase. If it is implemented satisfactorily, then the adverse environmental effects of the project will be minimized.

Implementation of Stakeholder Meetings

There is a close connection between the enhancement of environmental and social considerations and the implementation of stakeholder meetings in developing countries. Thus, two types meetings are required. The first is meetings in which the development designers in charge participate, and the other is the meetings at the local-level in which landowners and settlers in project areas shall participate. In order to promote development projects in developing countries, it is essential to make use of these two types of meeting.

The native land has been heavily protected in Fiji. The native land accounts for some 83% of the total land area of Fiji and belongs to the native Fijians. The native land is held under the traditional principles and is protected by the Native Lands Act of 1905. The native land is inalienable and is collectively owned by the *Mataqali*, which are clans whose membership is based on patrilineal descent.

These two types of meeting should be promoted substantially depending on the situation. The stakeholder meetings of the central government will be managed by the project's counterparties, while the local stakeholder meetings will, depending on the situation, be managed by the local community and consultants with local socio-economic expertise.

7.4 Development of Environmental Checklists and Monitoring Format

This IEE has enabled conclusions to be drawn up for the detailed design of the project. In particular, through these IEE studies, we have created a sound base for further examinations that will become necessary for the implementation of the Environmental Impact Assessment ("EIA") that is required under Fijian legislation. Further, the consultative process which is needed with the landowners and the other village communities and site users residing close to the project site has already been started. This process has to continue during the EIA examinations. To sum up, going forward the following aspects are considered most important for the environmental checklists and monitoring format:

Basically, there are two kinds of environmental impact according to the hydropower development plan. One kind of impact occurs by diverting water from the river. It is the basic technique of the hydroelectric scheme. In this context, noteworthy impacts would likely occur on the fish and aquatic resources and minimum ecological flow, with resultant social-economic impacts on local communities. The second kind of impact mainly depends on the regional environment.

The most important subjects for the three prospective potential sites are:

① The surveys of fish and other aquatic fauna that are required to clarify any potential losses and changes that will occur as a result of water diversion.

② The fish ladders and 'minimum ecological flow' requirements need to be incorporated into the design of the scheme.

③ Continued meaningful consultation with all stakeholders and affected communities is an important requirement to avoid social impacts.

In addition, consideration should be given to the local social environment of the three corresponding project sites. For instance, in the case of the No.8 Mba 1 U/S Project, we should pay attention to the imbalance between affected communities and those receiving the monetary benefits of leasing land for the power plant operation. This problem has to be addressed.

In the case of the No.29 Waivaka Project Scheme, resource developments in the project are highly sensitive due to the long-standing Namosi mining interests.

And in the case of No.35 Wailevu Project Scheme, skillfully consulting with all stakeholders and preventing any difference of opinions escalating between the Macuata-based and the Cakaudrove-based landowners will be crucial to the scheme's trouble-free progress.

All of these described potential problems and impacts are resolvable, but they have to be further examined by EIA before the project is implemented.

Chapter 8 Biomass Power Potential

8.1 General Potential

The word "Biomass," which consists of the words "Biology" and "Mass," means biological resources for energy usage. Biomass is an organic substance, for which it is deemed that no carbon dioxide is created through combustion ("Carbon Neutral"), therefore the usage of an alternative to fossil fuels leads to a reduction in CO2 emissions.

In Fiji, since early times, biomass energy was used mainly in people's lives, for example, firewood was used for cooking and livestock waste mixed with straw was used as fuel after drying. Major types of biomass in Fiji are (1) bagasse (sugarcane residues), (2) wood residues, and (3) general waste (organic waste from the city). JICA Survey Team focuses on examination of potential for (1) bagasse (sugarcane residues) and (2) wood residues.

8.2 Bagasse potential

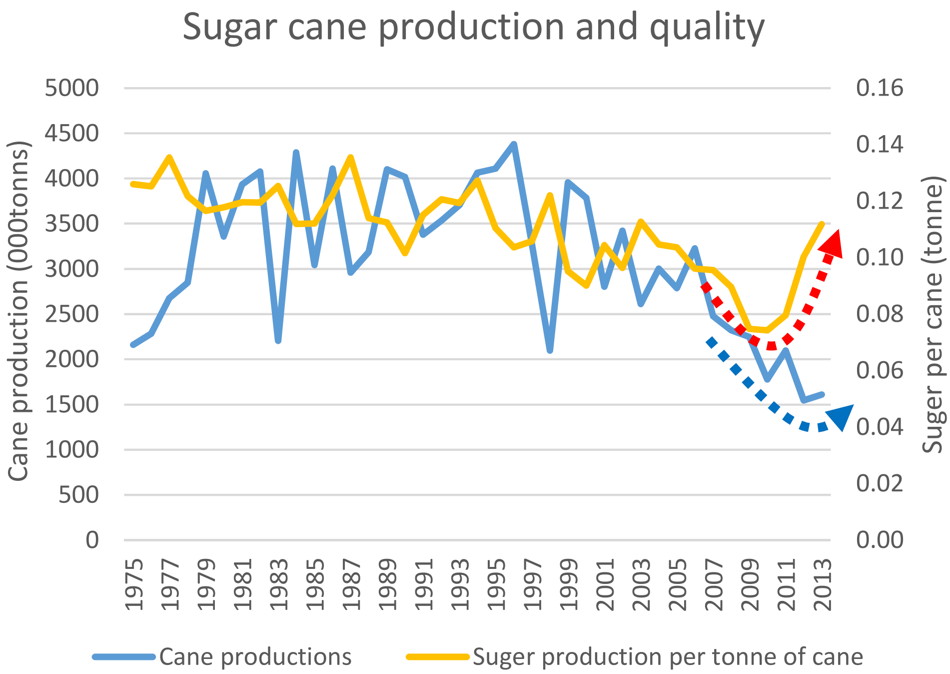
8.2.1 Production

Fiji Sugar Corporation (FSC) is the State Owned Enterprise (SOE) in Fiji having monopoly on production of raw sugar in Fiji.

Sugar cane production has been declined in the past due to reduction of famers as well as reduction of land area for harvest as shown in the following figure.

Sugar cane production is one of the key industries in Fiji. Under such environment, FSC has made every effort to restore productivity of sugar cane by improvement such as contract condition to increase harvest area, and breed improvement to increase density.

Sugar production per ton of cane as quality indicator, describing yellow line in Figure 8.2.1-1, shows an upward tendency from 2010. In addition, even though sugar cane production has been on a declining trend in a long term, the trend would reach a turning point and has been changed to upward in 2012. Those trends coincide with the point of view of what FSC dwell on their challenging on quantity and quality improvement.



(Source: Key statistics, Fiji Bureau of Statistics, 2014)

Figure 8.2.1-1 FSC Sugar Cane Production and Quality

8.2.2 Existing Generation Facility

Fiji Sugar Corporation (FSC) is the State Owned Enterprise (SOE) in Fiji having monopoly on production of raw sugar in Fiji. The Government of Fiji is a major shareholder that owns 68% of shares while statutory bodies, local companies and individuals own the remaining shares. FSC owns and operates four sugar mills located at Lautoka, Ba and Rakiraki on the main island of Viti Levu while Labasa mill is located on the second largest island of Vanua Levu.

The four sugar mills owned by FSC have a collective electricity generating capacity of around 48 MW during the sugar cane crushing season. The boilers in these mills are fuelled by bagasse. FSC has existing generation facilities, utilizing surplus steam by sugar processing, and it also possess future expansion plan as shown in the below.

(1) FSC Lautoka

The FSC Lautoka plant crushed 484,600 tonnes sugar cane in the 2013 season, and have a collective electricity generating capacity of around 12 MW during the sugar cane crushing season. The boiler was established by John Tompson (Australia) in 1994, having 200 t/h capacity. The Lautoka plant also is proposed to have 5MW x 2units bagasse generation in 2017 and 2018. Table 8.2.2-1 shows the outline of generation facilities of FSC Lautoka plant.

Table 8.2.2-1 FSC Generation Facility (Lautoka)

Categocy	Mill	Fuel type	Derated Capacity	COD	Steam Turbine		Generator	Boiler					
			(MW)		Manufacture	type	Manufacture	Manufacture	Capacity (t/h)	Temp. (℃)	Pressure (Mpa)	Type	COD
Existing	FSC Lautoka	Bagasse	3.0	~~1983~~ 2010	~~Shin Nippon Machineray (Japan)~~ Kessek (India)	back pressure	Shinko Electric Ltd. (Japan)	Yoshimine	136				1962
			9.0	2005	Peter brothers (UK)	back pressure	GEC Alstom	John Tompson (Austrana)	200	360	3.3	Fixed bed	1994
		Diesel (stand-by)	0.88×2units	2000	-	-	Cummius power generation Ltd. (Austraria)	-	-				-
New	FSC Lautoka	Bagasse	10.0	2017/ 2018	-		-	-	-				-

(Source: JICA Project Team based on FSC, 2014)

Boiler

Bagasse Stock Silo
(600 tonne capacity)

Bagasse to Burner

Control Room

Bagasse Transport

Sugar Production Process

Discussion

(2) FSC Rarawai

The FSC Rarawai plant crushed 581,000 tonnes sugar cane in the 2013 season, and have a collective electricity generating capacity of around 4 MW during the sugar cane crushing season. The boiler was established by Yoshimine (Japan) in 1977, having 115 t/h capacity. The Rarawai plant also have completed a construction of new 5 MW during 2014, and is proposing a new 40 MW bagasse generation in 2016. Table 8.2.2-2 shows the outline of generation facilities of FSC Rarawai plant.

Table 8.2.2-2 FSC Generation Facility (Rarawai)

Category	Mill	Fuel type	Derated Capacity	COD	Steam Turbine		Generator	Boiler					
			(MW)		Manufacture	type	Manufacture	Manufacture	Capacity (t/h)	Temp. (°C)	Pressure (Mpa)	Type	COD
Existing	FSC Rarawai	Bagasse	4.0	1979	Shin Nippon Machineray (Japan)	back pressure	Shinko Electric Ltd. (Japan)	Yoshimine (Japan)	115	280	1.7	Fixed bed	1977
			5.0	2014	Siemens (India)	Condensate	TDPS (India)	-	-				-
		Diesel (stand-by)	0.88×2units	2008	-	-	Cummius power generation Ltd. (Austraria)	-	-				-
New	FSC Rarawai		40.0	2016	-	Condensate	-	-	-				-

Turbine

Boiler (Yoshimine; Japan)

Generator

New Construction 5MW (2014 commissioning)



Sugar Production Process



Overview

(3) FSC Penang

The FSC Penang plant crushed 180,000 tonnes sugar cane in the 2013 season, and have a collective electricity generating capacity of around 3 MW during the sugar cane crushing season. The boiler was established by Yoshimine (Japan) in 1980, having 115 t/h capacity. The Penang plant also is proposed to have 5 MW bagasse generation in 2018. Table 8.2.2-3 shows the outline of generation facilities of FSC Penang plant.

Table 8.2.2-3 FSC Generation Facility (Penang)

Categocy	Mill	Fuel type	Derated Capacity	COD	Steam Turbine		Generator	Boiler					
			(MW)		Manufacture	type	Manufacture	Manufacture	Capacity (t/h)	Temp. (°C)	Pressure (Mpa)	Type	COD
Existing	FSC Penang	Bagasse	3.0	1982	Shin Nippon Machineray (Japan)	back pressure	Shinko Electric Ltd. (Japan)	Yoshimine (Japan)	115	280	1.7	Fixed bed	1980
		Diesel (stand-by)	0.53×1units 0.88×1units	N/A	N/A	-	N/A	-	-				-
New	FSC Penang	Bagasse	5.0	2018	-	Condensate	-	-	-				-



Boiler (Yoshimine; JAPAN)


Turbine and Generator (SHINKO; JAPAN)



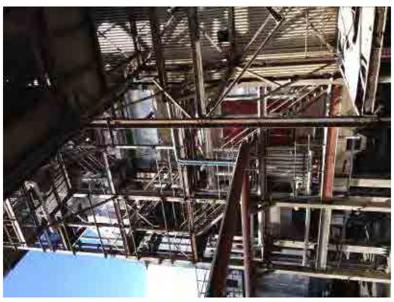
Overview

(4) FSC Labasa

The FSC Labasa plant crushed 612,000 tonnes sugar cane in the 2013 season, and have a collective electricity generating capacity of around 14 MW during the sugar cane crushing season. The boiler was established by John Tompson (Australia) in 1994, having 200 t/h capacity. The Labasa plant also is proposed to have 10 MW bagasse generation in 2017. Table 8.2.2-4 shows the outline of generation facilities of FSC Labasa plant.

Table 8.2.2-4 FSC Generation Facility (Labasa)

Categocy	Mill	Fuel type	Derated Capacity (MW)	COD	Steam Turbine		Generator	Boiler					
					Manufacture	type	Manufacture	Manufacture	Capacity (t/h)	Temp. (℃)	Pressure (Mpa)	Type	COD
Existing	FSC Labasa	Bagasse	4.0	1979	Shin Nippon Machineray (Japan)	back pressure	Shinko Electric Ltd. (Japan)	~~Yoshimine (Japan)~~	~~136~~				~~1982~~
			10.0	1997	Peter brothers (UK)	back pressure	N/A	John Tompson (Austraria)	200	360	3.3	Fixed bed	1996
		Diesel (stand-by)	0.75×2units	1992	N/A		N/A	-	-				-
New	FSC Labasa	Bagasse	10.0	2016	Harbin Turbine (China)	Condensate	TDPS (India)	India	50	N/a	N/A	N/A	2014

Boiler (Yoshimine; JAPAN)



Turbine and Generator (SHINKO; JAPAN)


New construction 10 MW, COD 2014



Overview

8.2.3 Production Projection

FSC sugar cane production in 2013 is 1,857,000 tonne in total, along with 484,600 in Lauoka, 581,000 in Rarawai, 180,000 in Penang, and 612,000 tonne in Labasa. FSC has projected sugar cane production up to 2018 as indicated in Table 8.2.3-1.

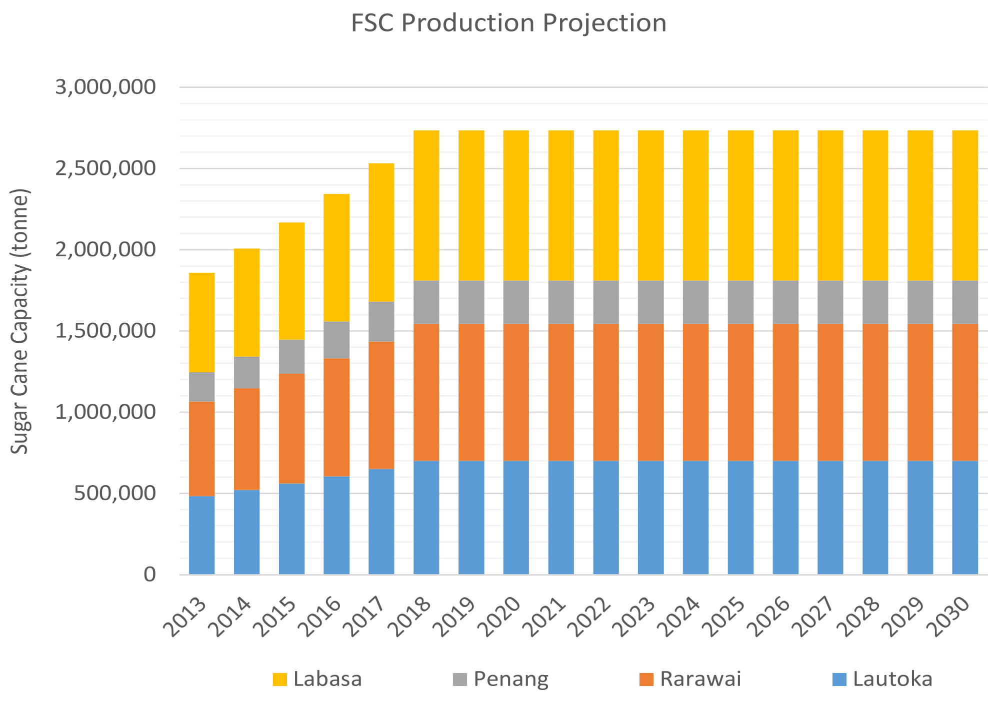
Table 8.2.3-1 FSC Projection of Sugar Cane Projection

[unit: tonne]

FSC mills / FY	2013	2014	2015	2016	2017	2018
Lautoka	484,600	521,604	561,433	604,304	650,449	700,117
Rarawai	581,000	626,052	674,597	726,907	783,272	844,009
Penang	180,000	194,626	210,440	227,539	246,027	266,018
Labasa	612,000	664,642	721,813	783,901	851,330	924,559
Total	1,857,600	2,006,924	2,168,283	2,342,651	2,531,078	2,734,703

(Source: FSC, 2014)

According to the discussion with FSC, it sets a goal of rolling back to production level of 10 years, which represents a 50 percent increase over last year. As discussed in the previous clause, FSC dwell on their challenging on quantity and quality improvement. Therefore, FSC projection up to 2018 has been adopted and it assumed to be a fixed value until 2030 as a base scenario as shown in the figure below.



(Source: JICA Project Team based on FSC data, 2014)

Figure 8.2.3-1 FSC Sugar Cane Production and Quality

8.2.4 Theoretical Generation

In general, almost all required energy is supplied by its in-plant-generation facility for 30 weeks sugar operational season, and extra electricity is sent to the national grid based on the contract. JICA Project Team has examined theoretical generation capacity based on bagasse projection, adopting the following conditions, which are obtained by discussions with FSC headquarter and mills. Then, The JICA project team has confirmed those obtained assumption value has high validity, comparing similar data and project.

- Bagasse ratio on sugar cane = 25%
- Moisture ratio on bagasse = 48%
- Calorific value of dry-bagasse = 17 MJ/ kg (or 4,060 kcal/ kg, 1 cal = 4.187 J)
- Calorific value of wet-bagasse = 9 MJ/ kg (or 2,150 kcal/ kg)
  Existing power plant thermal efficiency = 24%
- Minimum load = 1/3* Economical Continuous Rating (ECR)
- Generation supply only for 30 week during sugar production season

Theoretical generation based on bagasse production is calculated on the following equation;

Theoretical generation (MW) = Calorific value of dry-basis* plant thermal efficiency*sugar cane production volume* bagasse ratio on sugar cane*(1- Moisture ratio on bagasse)/ 860/ (24hours*7 days*30weeks)

The results of mill-wise theoretical generation capacity are summarized in Table 8.2.4-1. For Lautoka, theoretical generation in 2013 is estimated at around 14MW, which is nearly equal to the current capacity of 12MW. In 2018 its capacity goes up to 25MW, which comes near the FSC planning of 22MW (existing 12MW + new 10MW). For Rarawai, theoretical generation in 2013 is estimated at around 17MW, which is far below the current capacity of 4MW. In 2018 its capacity goes up to 40MW, which comes near the FSC planning of 49MW (existing 4MW + new 45MW). According to the discussion with FSC, operation pattern of 49MW will be carefully considered after the completion of all new unit installations by utilizing available bagasse into higher efficiency units, such as stopping lower efficiency units and run higher efficiency units. For Penang, theoretical generation in 2013 is estimated at around 5MW, which is nearly equal to the current capacity of 3MW. In 2018 its capacity goes up to 9MW, which comes near the FSC planning of 8MW (existing 3MW + new 5MW). For Labasa, theoretical generation in 2013 is estimated at around 18MW, which is nearly equal to the current capacity of 14MW. In 2018 its capacity goes up to 32MW, which comes near the FSC planning of 24MW (existing 14MW + new 10MW). Therefore, FSC expansion bagasse generation plan, which is almost same with the theoretical value examined by JICA Project Team, is regard as having high validity.

The optimum generation capacity is estimated as follows, based on theoretical examination and FSC discussion;

- Lautoka and Rarawai: to be (25+40-3=) 62MW, considering additional 3MW internal consumption and mutual bagasse transportation since both mills located in a short distance.
- Penang: to be (9-3=) 6MW, considering additional 3MW internal consumption.
- Viti Levu Grid: to be (62+6=) 68MW.
- Vanua Levu Grid: to be 5MW only, considering grid capacity constraint.
- Therefore, total optimum generation by bagasse is to be 73MW

Table 8.2.4-1 Theoretical Generation Capacity (mill-wise)

FSC sugar mills		Sugarcane production in 2013 ton/year	thermal efficiency η (LHV) %	Calorific value (dry) Bagasse kcal/kg	30 weeks theoretical generation (MW)	Capacity		
						total 2013/2018 (MW)	existing in 2013 (MW)	new plan by 2018 (MW)
Lautoka								
	2013	484,600	24.0	4,060	14	12	12	
	2018	700,117	29.0	4,060	25	22		10
Rarawai								
	2013	581,000	24.0	4,060	17	4	4	
	2018	844,009	38.7	4,060	40	49		45
Penang								
	2013	180,000	24.0	4,060	5	3	3	
	2018	266,018	27.8	4,060	9	8		5
Labasa								
	2013	612,000	24.0	4,060	18	14	14	
	2018	924,559	28.6	4,060	32	24		10
Total								
	2013	1,857,600			54	33	33	
	2018	2,734,703			106	103		70

(Source: JICA Project Team based on FSC, 2014)

8.2.5 Operation patterns

The table below shows the operation patterns on FSC existing generation facilities on the sugar mills. At FSC Lautoka, total generation capacity is 12MW, and 5MW internal usage is taken for the sugar processing facilities, so that the capacity of 7MW is sold to the national gird as a surplus power. At FSC Penang, another capacity of 1MW is sent to the grid. Therefore, the capacity of 8MW in total supplied to the Viti Levu grid system by FSC. On the Vanua Levu grid, a capacity of 8MW is provided by FSC Labasa during sugar production season.

Figure 8.2.5-1 Theoretical Generation Capacity (mill-wise)

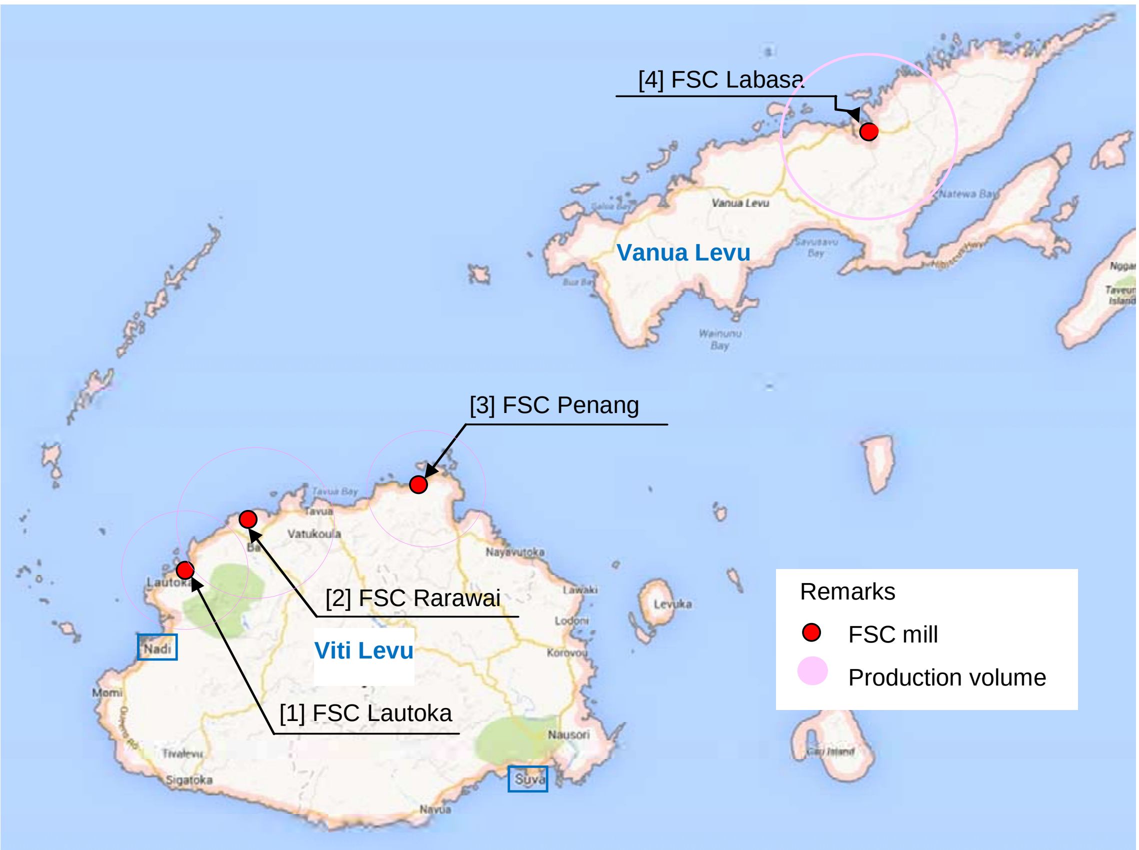
			On season					Off season						
			7	8	9	10	11	12	1	2	3	4	5	6
Viti Leve	Lautoka	Internal (MW)	5	5	5	5	5	1	1	1	1	1	1	1
		External (MW)	7	7	7	7	7	0	0	0	0	0	0	0
		Total (MW)	12	12	12	12	12	1	1	1	1	1	1	1
	Rarawai	Internal (MW)	5	5	5	5	5	1	1	1	1	1	1	1
		External (MW)	0	0	0	0	0	0	0	0	0	0	0	0
		Total (MW)	5	5	5	5	5	1	1	1	1	1	1	1
	Penang	Internal (MW)	2	2	2	2	2	1	1	1	1	1	1	1
		External (MW)	1	1	1	1	1	0	0	0	0	0	0	0
		Total (MW)	3	3	3	3	3	1	1	1	1	1	1	1
		Grid supply	**8**	**8**	**8**	**8**	**8**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Vanua Levu	Labasa	Internal (MW)	5	5	5	5	5	1	1	1	1	1	1	1
		External (MW)	5	5	5	5	5	0	0	0	0	0	0	0
		Total (MW)	10	10	10	10	10	1	1	1	1	1	1	1
		Grid supply	**5**	**5**	**5**	**5**	**5**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

(Source: JICA Project Team based on FSC data, 2014)

8.2.6 Potential Map

The figure below is a bagasse potential map, indicating a location of mills and its production volume. Each red-colored circle indicates the FSC mill location and a size of each pink-colored circle shows the production volume in a relative evaluation.

The potential of bagasse is eccentrically located in the east to north region where FSC mills are located in in Viti Levu, and its potential in Vanua Levu is focused in one place of Labasa area, since FSC Labasa is the sole source in the island.



(Source: JICA Project Team based on FSC data, 2014)

Figure 8.2.6-1 Bagasse Potential Map (mill-production basis)

8.3 Wood Residues Potential

8.3.1 Existing Generating Facility

Tropik Wood Industries Limited (TWIL), one of the biomass waste based IPP's in Fiji, maintains around 46,000 hectares of pine forests and currently process around 300,000 ton/year of logs as part of sawmilling and wood chipping operations. The waste barks and fines (14% of the logs processed) from wood processing operations are currently being used as feedstock for power generation through direct combustion of biomass at the two power plants (3 MW & 9.3 MW). According to TWIL, most of the biomass waste generated currently is being consumed by the existing power plants and no excess or surplus biomass waste is available.

Table 8.3.1-1 Existing Generating Facility (Tropik Wood)

Categocy	Mill	Fuel type	Derated Capacity	COD	Steam Turbine		Generator	Boiler					
			(MW)		Manufacture	type	Manufacture	Manufacture	Capacity (t/h)	Temp. (°C)	Pressure (Mpa)	Type	COD
Existing	Tropik Wood Industries Limited (TWIL)	Saw mill waste	3.0	1987	Peter brothers (UK)	back pressure	Shinko Electric Ltd . (Japan)	Yoshimine (Japan)	27	N/A	N/A	Fixed bed	1986
			9.3	2006	Siemens (India)	back pressure	Siemens (India)	RCR east eel (New Zaland)	35	360	3.3	Fixed bed	1994
		Diesel (stand-by)	0.88×2units	N/A	-	-	-	-	-				-

Boiler (Yoshimine; Japan)

Feeder

Turbine and generator

Boiler

Feeder

Overview

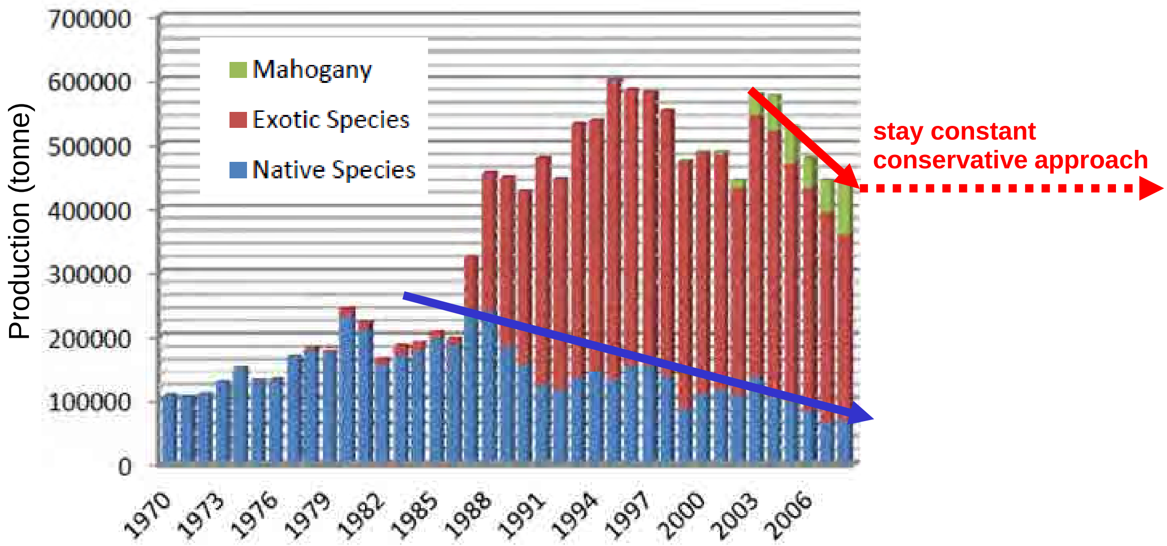
Wood resides

Discussions

8.3.2 Production Projection

Wood industry is also one of the major economic activities in Fiji. According to the Department of Forestry (DOF), major licensed wood mills exist with total production of 312,500 m^3 sawmill and 135,00m^3 plywood as listed in Table 8.3.3-1.

Government of Fiji has made every effort to recover forestry environment by tree-planting program. JICA Project Team recognized difficulty to stand an optimistic point of view of increasing waste wood being increased by planting for biomass usage. Therefore, the current value of total production of 312,500 m^3 sawmill and 135,00m^3 plywood is adopted for a base scenario.



(Source: DOF, 2012)

Figure 8.3.2-1 Wood Production

8.3.3 Theoretical Generation

JICA Project Team has examined theoretical generation capacity based on wood projection, adopting the following conditions, which are obtained by discussions with mill engineers, and has confirmed those obtained assumption value has high validity, comparing similar data and project.

- Wood residues calculation
  - Sawmill 312,500 m3/ year: = 156,000 m3/ year wood chip, waste ratio is 50%
  - Plymill 135,000 m3/ year = 18,900 m3/ year wood chip, waste ratio is 14%
  - Total wood chip = 174,900 m3/ year wood residues

According to the results of the theoretical capacity by wood residues in Table 8.3.3-1, most of the mills have small capacity, ranging mainly from 0.1MW to 0.3MW over a wide range, except Tropik Wood Industries Ltd in Lautoka of 5.1WM, which has now generated nearly 5 to 6 MW.

Table 8.3.3-1 Theoretical Generation Capacity (mill-wise)

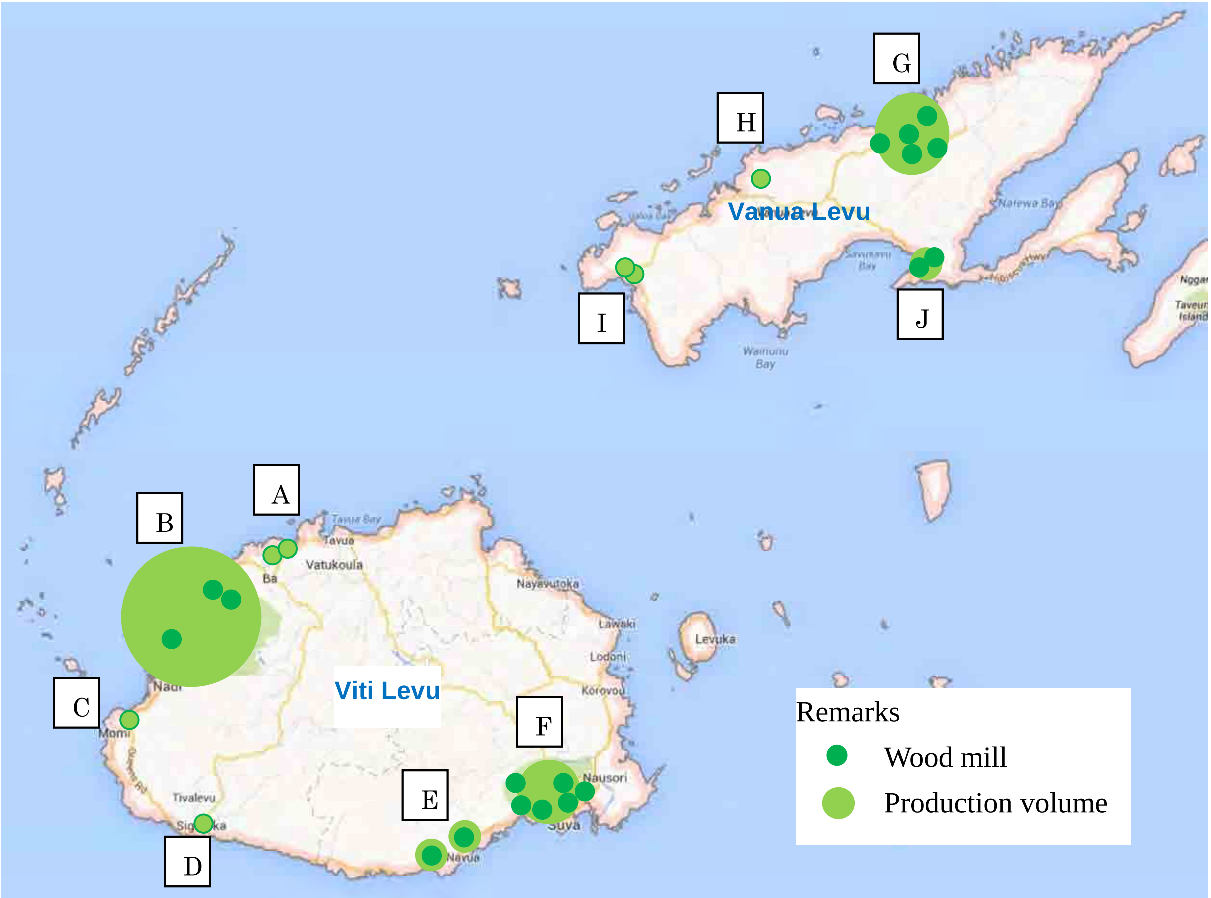
Island	Division			company name	capacity (m3)		Theoritical Output(MW)
					Sawmill	Plywood	
Viti Levu	Western	A	A1	Dayals Sawmill Ltd	7,500		0.3
Viti Levu	Western		A2	Tropik Forest Joint Venture	7,000		0.3
Viti Levu	Western	B	B1	Tropik Wood Industries Ltd	100,000	100,000	5.1
Viti Levu	Western		B2	Lomolomo Sawmill	5,000		0.2
Viti Levu	Western		B3	Best Industries Ltd	7,500		0.3
Viti Levu	Western		B4	Designtech Sawmill	7,000		0.3
Viti Levu	Western	C	C1	K.K.Komove	7,000		0.3
Viti Levu	Western	D	D1	Global Food Import & Export	7,000		0.3
Viti Levu	south	E	E1	Yarawa sawmill	12,000		0.5
Viti Levu	south		E2	Sustainable Mahogany Industries	12,000		0.5
Viti Levu	south	F	F1	Touchwood Investment	17,000		0.7
Viti Levu	south		F2	Timber Utilization Division	3,000		0.1
Viti Levu	south		F3	Southern Forest Wood Product Ltd	17,500		0.7
Viti Levu	south		F4	Vitiana Timbers	7,000		0.3
Viti Levu	south		F5	Newmart	5,000		0.2
Viti Levu	south		F6	Island Tropical Forest	5,000		0.2
Sub-total (Viti Levu)					**226,500**	**100,000**	**10.0**
Vanua Levu	North	G	G1	Fiji Forest Industries Ltd	17,500	17,500	0.9
Vanua Levu	North		G2	Waiqele Sawmill	17,500		0.7
Vanua Levu	North		G3	Sam Civil Service	3,000		0.1
Vanua Levu	North		G4	Valebasoga Tropik Board Ltd	17,500	17,500	0.9
Vanua Levu	North		G5	Vunimoli Sawmill	5,000		0.2
Vanua Levu	North	H	H1	Taiwan Timber Fiji Ltd	7,000		0.3
Vanua Levu	North	I	I1	J/Narayan & RT Sikeli	1,500		0.1
Vanua Levu	North		I2	Raviravi Sawmill	3,000		0.1
Vanua Levu	North	J	J1	Lumber Processor	7,000		0.3
Vanua Levu	North			Long Investment	7,000		0.2
Sub-total (Vanua Leve)					**86,000**	**35,000**	**3.7**
Total					**312,500**	**135,000**	**13.8**

(Source: JICA Project Team based on DOF data, 2014)

8.3.4 Potential Map

The figure below is a potential map, indicating a location of mills and its production volume. Each green-colored circle indicates the mill location and a size of each greenish yellow-colored circle shows the production volume in a relative evaluation

Unlike in the case of bagasse, locations of the wood mills in both Viti Levu and Vanua Levu are scattered over a large area with a small size except Tropik Wood Industries Ltd, or sole large-scale mills in Viti Levu as listed in Table 8.3.1-1.



(Source: JICA Project Team based on DOE data, 2014)

Figure 8.3.4-1 Waste Wood Potential Map (production basis)

Considering such conditions of biomass potentials using wood residue, the optimal development capacity of biomass power plants using wood residue is expected to be only 4 MW, which is generated by the plant of Tropik Wood industries limited.

8.3.5 Difficulty of co-firing with bagasse and wood residues

For Bagasse single designed boiler, co-firing with bagasse and waste wood drastically damaged. Due to different moisture, different calorific value, combustion temperature and speed between bagasse and waste wood or wood residues are different. Bagasse single designed boiler is fixed bed type, for co-firing boiler shall change to fluidized-bed system. For example, FSC Penang purchases wood residues at a price of 120 F$ /tonne form the adjacent wood mills in a total of 2,500tonne/year.

For Bagasse single use designed boiler, co-firing with bagasse and waste wood drastically damaged.

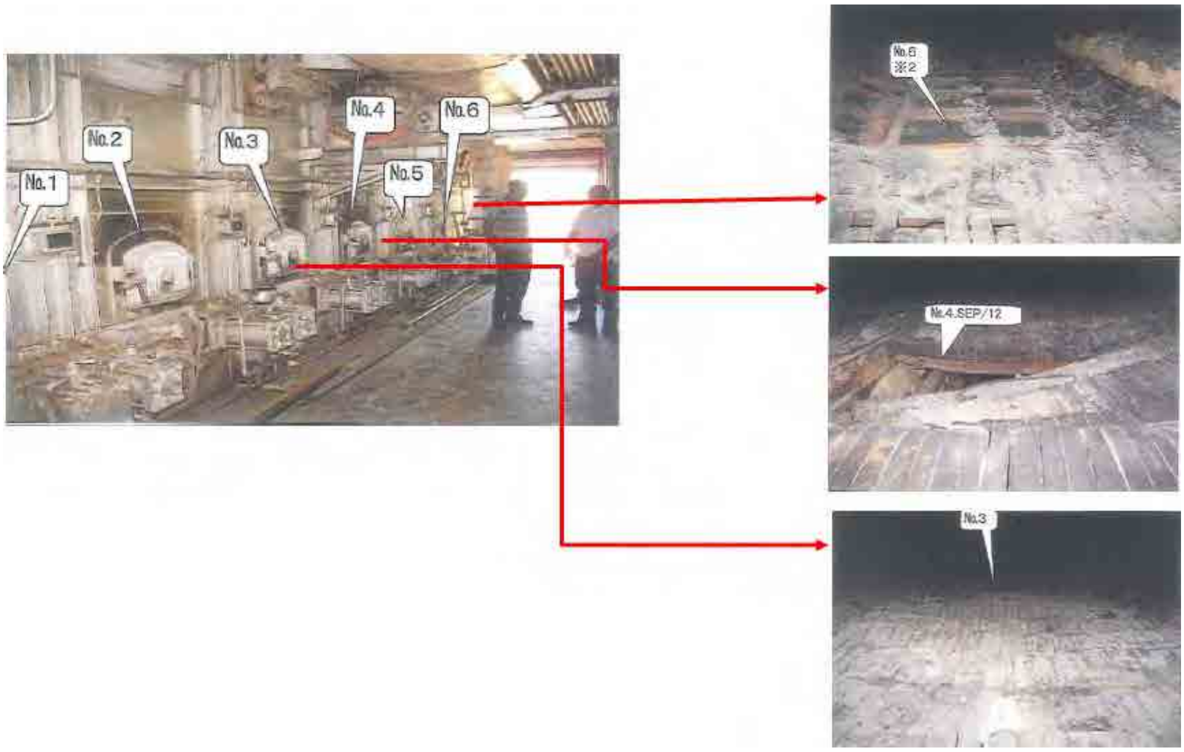


Figure 8.3.5-1 Boiler damage by co-firing with bagasse and wood residues

(Source: Yoshimine Co., LTD)

8.4 Financial Viability of Biomass Power Projects in Power Supply

8.4.1 Outline of Specific Bagasse Project

As shown in the Figure 8.4.1-1, water circulation system ensures the greatest possible hat absorption. Water from the upper drum moves downward (blue lines) and collects in the lower drum and headers before moving up (red lines) and generating a mixture of water and steam. The high heat absorption that results improves the boiler's efficiency for greater overall economy.

Complete combustion in the large combustion chamber produces heat which radiates and is absorbed by the water walls. Gas passing through the slug screen changes direction three times before passing through the preheater. Ash and cinder are separated from the gas and deposited in special pockets as the gas passes. This prevents ash and cinder from accumulating in the tubes and maintains the best possible thermal efficiency even when boiler is used continuously for many hours as illustrated in the Figure 8.4.1-1.

Water circulation | Gas circulation

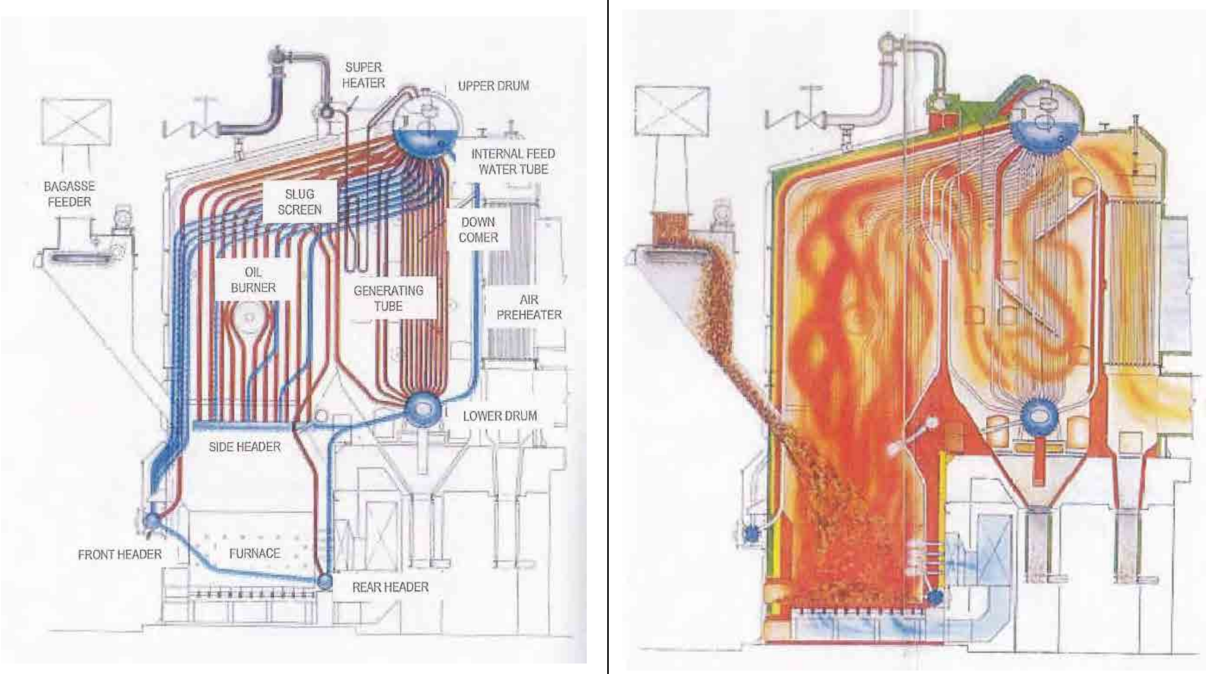


Figure 8.4.1-1 Water and Gas Circulation System in Boiler

(Source: Yoshimine Co., LTD)

8.4.2 Financial Viability

In order to examine financial viability of biomass power projects, economic and financial rate of return are tentatively calculated in case of 5MW, 2.5MW, 1 MW bagasse project cases. The basic assumptions for calculations are described the table in Table 8.4.2-1.

Table 8.4.2-1 Summary of the Basic Assumptions for Power Projects by Bagasse

Installed Capacity	1) 5 MW class 2) 2.5 MW class 3) 1 MW class
Plant Load Factor	90%
Operating Period	30 Weeks / Year (8 months, excluding rainy season from January to April)
Auxiliary consumption ratio	3.0%
Construction Cost	1) USD 2,500/ kW 2) USD 4,500/ kW 3) USD 8,750/ kW
Project Life	20 years (Construction Period: 2 years)
Operation and Maintenance Cost	3.5% of total gross revenue and 10% of construction cost (for sugar processing)
Purchase Price from IPP	0.1720 USD/ kWh (0.3308 FJD/ kWh)

The results of the calculation of bagasse power plant are shown in Table 8.4.2-2. Economic benefit is calculated as avoidable cost for alternative diesel thermal power plant construction cost. From these results, it should be necessary to have a certain capacity, around 5 MW, in order to have enough revenue from electricity sale to have return on the investment cost more than 10%. It is difficult to be financially viable if the project facilities are 2.5MW and less. In case of 1MW, all cash flow is negative; therefore, IRR cannot be calculated.

Table 8.4.2-2 Result of Financial Viability of Power Plants by Bagasse

Plant Capacity	5 MW	2.5 MW
FIRR	16.5%	1.2%
EIRR	18.3%	-6.6%

In case of the power plant project by wood waste, even more cost is required for transportation cost of the wood waste from dispersedly located saw mills in addition to these projects by bagasse. As a result of IRR based on the assumption of Table 8.4.2-3, cash flows of all cases are negative, thus IRR cannot be calculated. As described previously in the potential on the power plant by wood waste, 2 to 3MW plant appears to be the maximum capacity from collecting the wood waste of existing sawmills which are located. Thus, taking the case of 2.5 MW power plant and examining the sensitivity analysis of transportation cost, if transportation cost can be reduced to 10 USD per ton from 62.4 USD per ton, FIRR become more than 10%. In the sensitivity analysis of electricity tariff, if the electricity tariff is increased to two times more of current tariff, FIRR become more than 10%. As a result, it can infer that the project would be difficult to be financially viable, without large decrease of transportation cost and/or drastic increase of electricity tariff for power purchase.

Table 8.4.2-3 Summary of the Basic Assumptions for Power Plants by Wood Waste

Installed Capacity	1) 5 MW class 2) 2.5 MW class 3) 1 MW class
Plant Load Factor	80%
Operating Period	30 Weeks / Year (8 months, excluding rainy season from January to April)
Auxiliary consumption ratio	3.0%
Construction Cost	1) USD 2,500/ kW 2) USD 4,500/ kW 3) USD 8,750/ kW
Project Life	20 years (Construction Period: 2 years)
Operation and Maintenance Cost	3.5% of total gross revenue
Required wood waste per year	1) 70,000 ton 2) 35,000 ton 3) 14,000 ton
Transportation cost of wood waste	62.40 USD/Ton
Purchase Price from IPP	0.1720 USD/ kWh (0.3308 FJD/ kWh)

Chapter 9 Review of Long-term Supply and Demand Plan

9.1 Current Status and Evaluation of Power Demand Forecast

9.1.1 Demand Forecast

FEA forecasted power demand in Power System Development Plan (2011-2020) under the following preconditions.

1) Electrification rate by 2015 : 100%

2) Population growth rate : 0.8%／year

3) Average number of household residents : 5 people

4) Estimation of the power consumption of each household in 2015 against in 2005

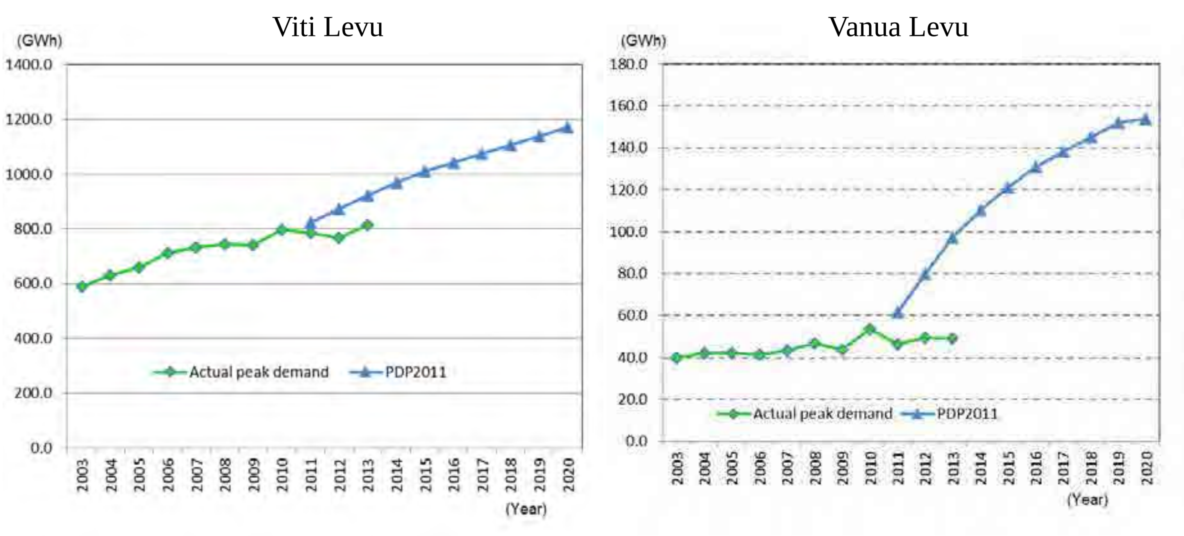
A) Viti Levu Island : 90%

B) Vanua Levu Island : 90%

C) Obalau Island : 25%

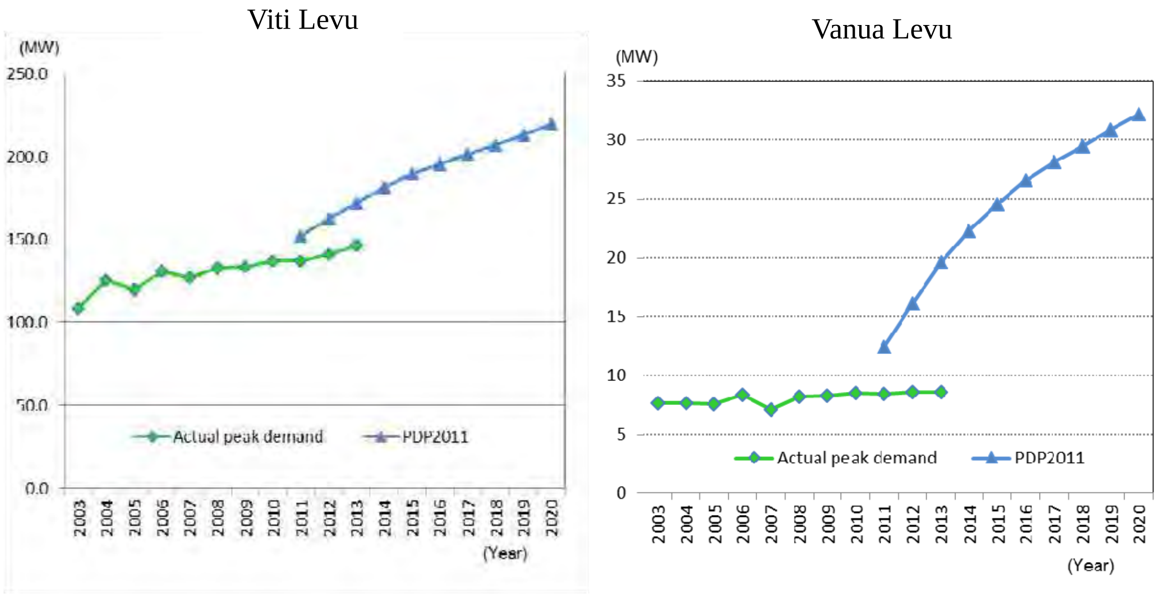
5) Transmission and distribution loss : 10%

A comparison of the actual value from 2003 to 2013 and the forecasted power demand is as shown in Figure 9.1.1-1 in terms of electricity generation and in Figure 9.1.1-2 in terms of peak demand. According to these Figures, the forecasted values in Vanua Levu are far apart from the actual values. A drastic review is strongly required in the Power System Development Plan 2015-2025.



(Source: Key Statistics December 2011, Fiji Bureau of Statistics)

Figure 9.1.1-1 Comparison of Actual Demand and Demand Forecast
(Electricity Generation)



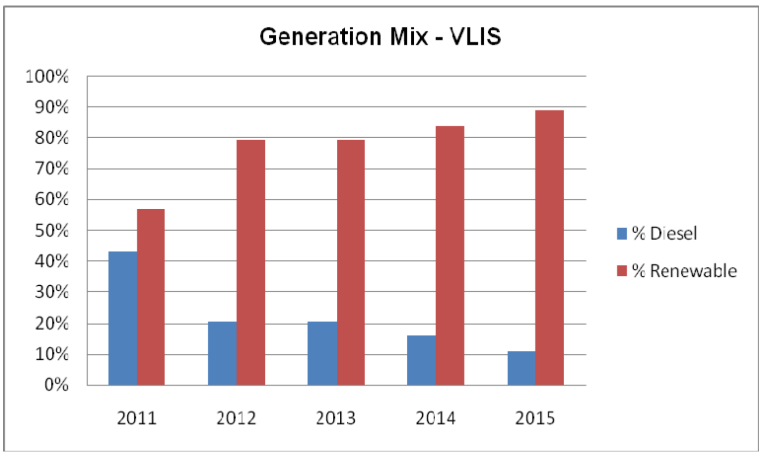
(Source: Power Development Plan (2011-2020))

Figure 9.1.1-2 Comparison of Actual Demand and Demand Forecast (Peak Demand)

9.1.2 Power Development Plan of FEA

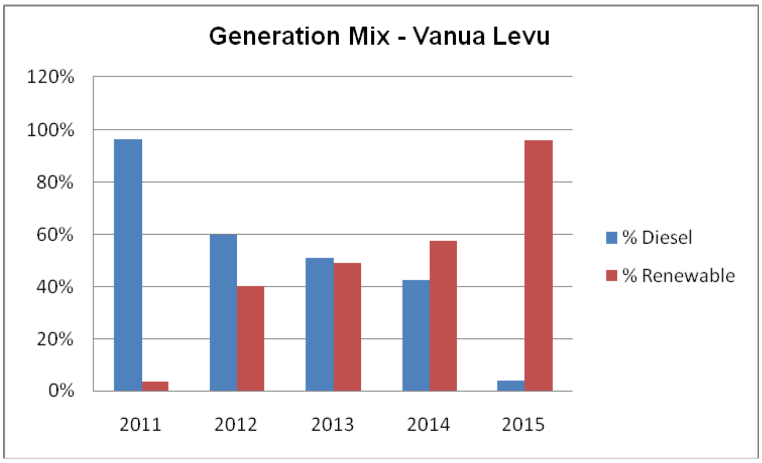
FEA raised a target to generate 90% of total electricity generation by using renewable energy in the light of serious influence on the power sector including FEA due to the recent price hike of fossil fuels. However, this plan has not achieved the target yet.

FEA also raised a target to generate 90% of total electricity generation by renewable energy power sources by 2015 in the Power System Development Plan (2011-2020). Figure 9.1.2-1 and Figure 9.1.2-2 indicate the target ratio of diesel and renewable energy generation to be achieved by 2015 in Viti Levu and Vanua Levu.



(Source: Power Development Plan (2011-2020), FEA)

Figure 9.1.2-1 Targeted Generation Mix in Viti Levu



(Source: Power Development Plan (2011-2020), FEA)

Figure 9.1.2-2 Targeted Generation Mix in Vanua Levu

Power development plan in the Power System Development Plan (2011-2020) is shown in Table 9.1.2-1.

Table 9.1.2-1 Development Plan up to 2020

Company name	Type	Capacity (MW)	Development year	Current status
Viti Levu Island				
Vuda	Biomass	18	2013	Committed by IPP
FSC Lautoka	Biomass	6	2013	Committed by IPP
Wailoa Downstream	Hydro	7	2014	Committed by FEA
Qaliwana	Hydro	10	2014	Committed by FEA
FSC Rarawai	Biomass	20	2015	Proposed by FEA/IPP
Namosi	Hydro	40	2017	Proposed to meet demand by renewable generation
Nausori	Biomass	40	2017	
Vanua Levu Island				
Labasa	Biomass	7.5	2013	Committed by IPP
Wairiki	Biomass	4	2013	Committed by IPP
Savusavu	Geothermal	4	2013	Proposed by FEA/IPP
Savusavu	Geothermal	4	2017	Proposed by FEA/IPP
Labasa	Biomass	7.5	2017	Proposed to meet demand by renewable generation
Saivou	Biomass	7.5	2017	
Ovalau Island				
Nasinu	Biomass	3	2013	Proposed to meet demand by renewable generation
Viro-Stage 1	Biomass	1.8	2013	
Viro-Stage 2	Biomass	0.6	2017	

(Source: Power Development Plan (2011-2020), FEA)

The actual power development in Viti Levu and Vanua Levu is largely differed from the plan as shown in Table 9.1.2-2.

Table 9.1.2-2 Current Power Development Plan

Location	Power Plant Name	Source and Tyoe	Installed Capacity (MW)	Supply Capacity (MW)	Commiss-ioning Year	Current Status
Viti Levu	Kinoya PS Extention	HFO thermal	35	35	2015	Procurement by FEA
	Wailoa Downstream	Hydro	7	1.3	2018	Consultant Selection
	Qaliwana	Hydro	10	1.9	2018	Consultant Selection
	Wainisavulevu weir raising *[1]	Hydro	3	1.8	2015	Under Construction
	Lautoka (FSC)	Biomass	5	4.5	2017	Committed by FEA
	Rarawai (FSC)	Biomass	5	4.5	2015	Committed by FEA
			40	36	2016	Committed by FEA
	Penang	Biomass	5	4.5	2017	Committed by FEA
	Sub-total		110	89.5		
Vanua Levu	Labasa	Biomass	10	9	2016	Committed by FEA
	Sub-total		10	9		
Total			120	98.5		

*1 : One of 2units of Wainikasou HPP under rehabilitation will be restart

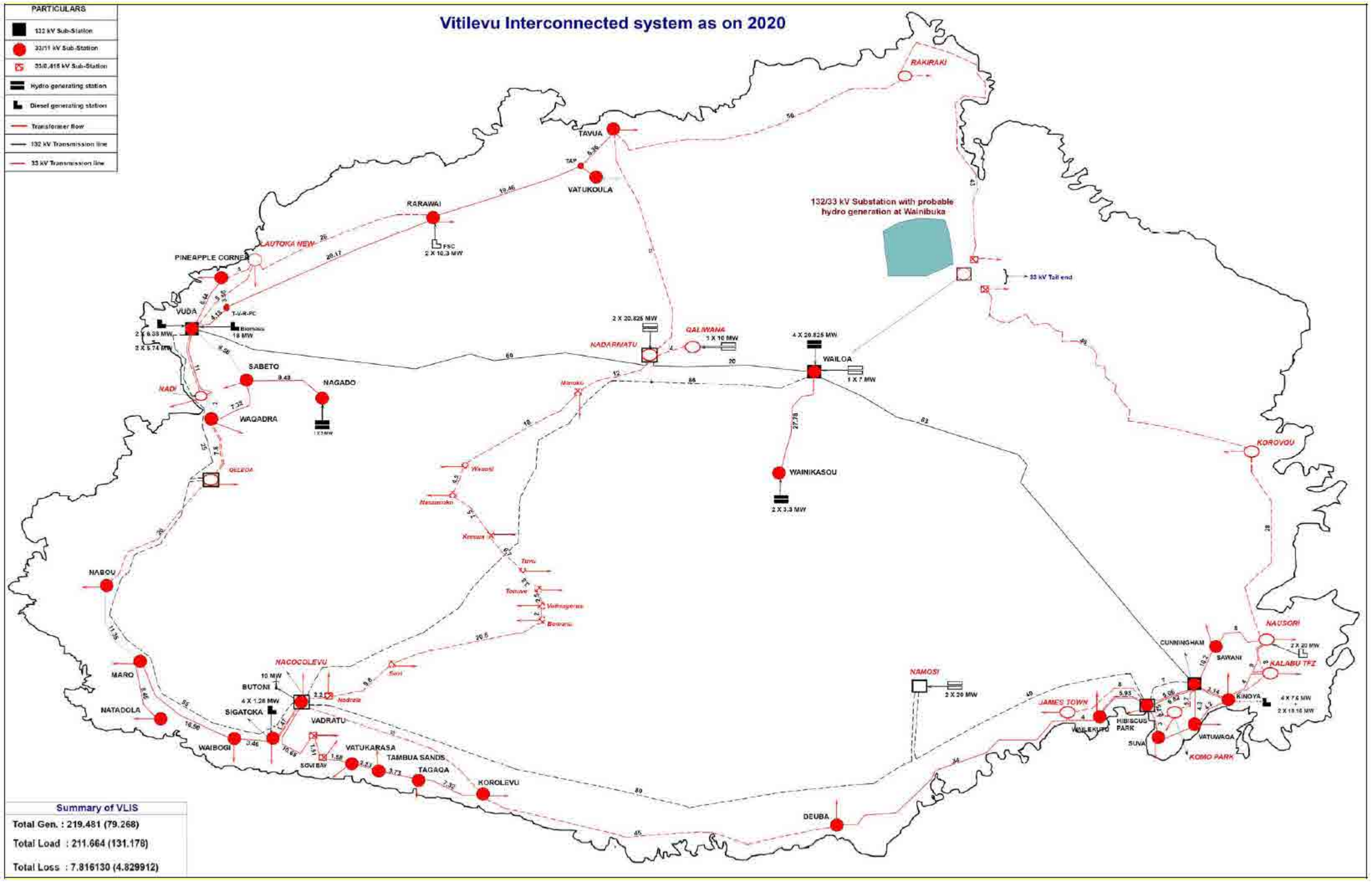
(Source: FEA annual report 2013, JICA Project Team Evaluation)

9.1.3 Power Transmission Development Project

FEA is taking next 3 conditions into consideration for making plan of the Power Transmission Development.

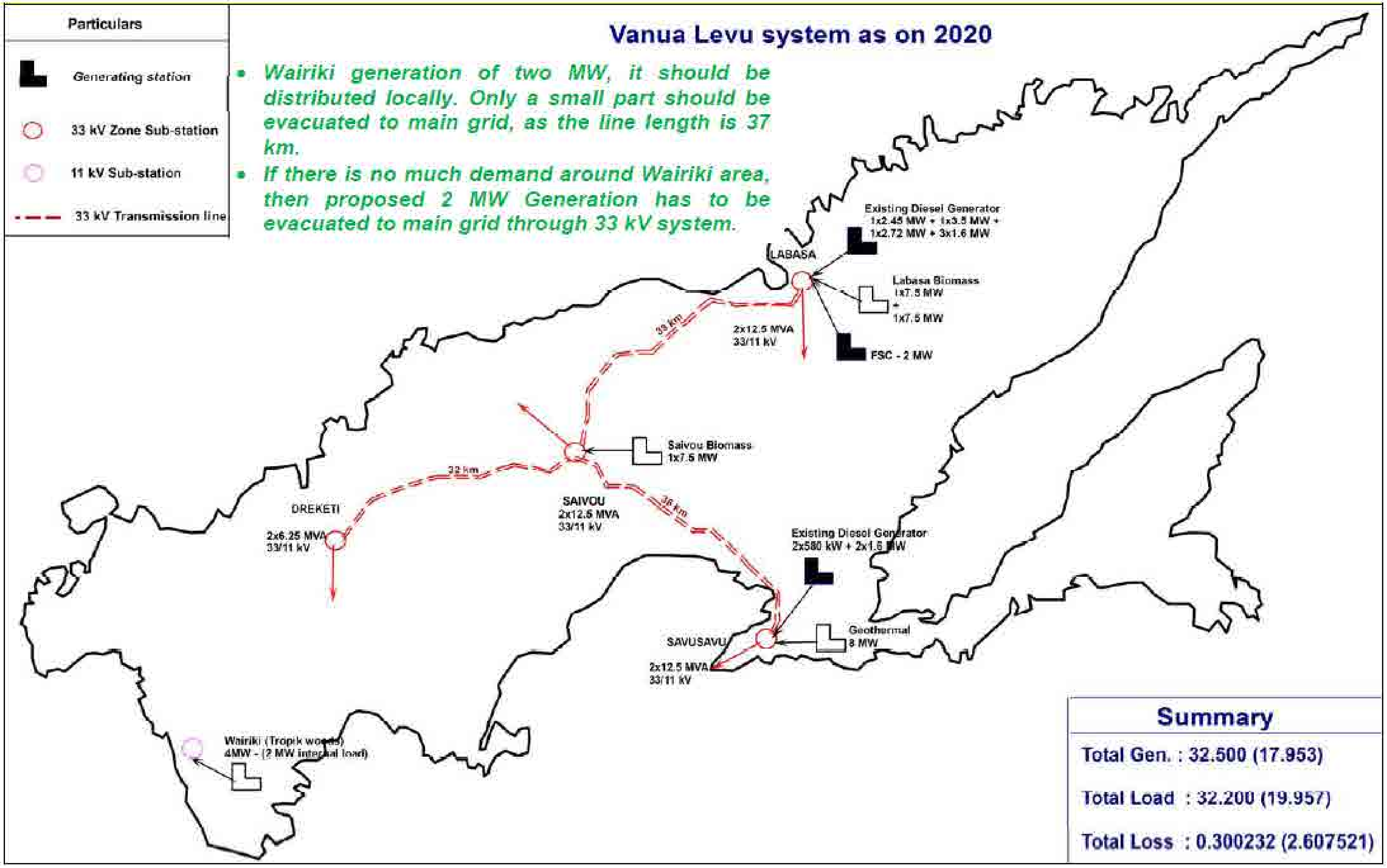
1) Assure system security and reliance
2) Distribute power to every household. Electrification of every village.
   (Applies to the Islands of Viti Levu, Vanua Levu and Ovalau)
3) Coping with a system demand corresponding to renewable energy generation.

FEA is planning to extend and reinforce transmission lines and substations taking into account the above mentioned points. Figure 9.1.3-1 and Figure 9.1.3-2 show a system diagram of Viti Levu and Vanua Levu in year 2020.



(Source：Power Development Plan (2011-2020), FEA)

Figure 9.1.3-1 Power System Plan for Viti Levu (as of 2020)



(Source：Power Development Plan (2011-2020), FEA)

Figure 9.1.3-2 Power System Plan for Vanua Levu (as of 2020)

9.2 Current Status and Evaluation of the Power Development Plan

9.2.1 Method of Power Development Planning

(1) Issues on Power Supply Reliability

Any criteria regarding power supply reliability was not seen in the previous power development plan. Generally, it is necessary to set the target value of LOLP (Loss of Load Probability) or LOLE (Loss of Load Expectation), on a condition that the target value is satisfied, the most economical power supply composition and development pattern should be determined. In Southwest Asian countries (Vietnam, Indonesia, etc.), LOLP =0.27% or LOLE=24hr is set as annual power shortage duration.

Since FEA has set goal to generate 90% of total electricity generation by renewable energy power generation by 2015, it is essential to consider the fluctuation of supply capacity of renewable energy power sources on the basis of statistical probability.

① Hydropower: Fluctuation of high water flow, and drought. Fluctuation of the power supply of wet/dry season.
② Wind : Supply capability shall only be expected to the degree of annual capacity factor.
③ Bagasse : Power supply to the power system is limited to 30 weeks (June - December)

Besides, it is necessary to take into consideration actual error of power demand forecast as described below.

(2) Issues on Power Demand Forecast

As shown in Figure 9.2.1-1, since the power demand forecast in PDP (2011-2020) is far from actual results, it is necessary to reconsider so as to satisfy the target value described in Draft National Energy Policy (NEP) 2014 based on the actual power demand records.

Indicator	Baseline	Targets 2015	2020	2030
Access to modern energy services				
Percentage of population with electricity access	89%[3] (2007)	90%	100%	100%
Percentage of population with primary reliance on wood fuels for cooking	20%[4] (2004)	18%	12%	<1%
Improving energy efficiency[5]				
Energy intensity (consumption of imported fuel per unit of GDP in MJ/FJD)	2.89[6] (2011)	2.89 (0%)	2.86 (-1%)	2.73 (-5.5%)
Energy intensity (power consumption per unit of GDP in kWh/FJD)	0.23 (2011)	0.219 (-4.7%)	0.215 (-6.15%)	0.209 (-9.1%)
Share of renewable energy				
Renewable energy share in electricity generation	60%[7] (2011)	67%	81%	100%
Renewable energy share in total energy consumption	13%[8] (2011)	15%	18%	25%[9]

Figure 9.2.1-1 Target value in National Energy Policy 2014

(Source：SE4All Report)

Chapter 10 Power Development Plan

10.1 Economic Comparison of Various Powers by Screening

By calculating the power cost of each utilization rate from construction costs (fixed cost) and fuel costs (variable costs) of various powers, the optimal power supply of each of base, middle, and peak supply capability shall be examined.

10.1.1 Construction Costs

By referring to Power Development Investment Cost described in P34 of SE4All report, the standard construction cost of each power source was set as shown in Table 10.1.1-1.

Table 10.1.1-1 Construction Cost of Each Power Source

	Construction cost
Hydro（Afflux type）	2000 USD/ kW
Water（Reservoir type）	4000 USD/ kW
Diesel Thermal（IDO）	550 USD/ kW
Diesel Thermal（HFO）	700 – 1000 USD/ kW
Geothermal	3500 USD/ kW

10.1.2 Annual Fixed Cost

Annual fixed cost of each power source is calculated based on the above construction cost. Annual fixed cost generally differs, depending on the methods of depreciation, and hits maximum immediately after commissioning. Table 10.1.2-1 shows costs equalized by lifetime with an interest rate set at 10%. In addition, the lifetime of each power source was set as; 30 years for Geothermal, 15 years for Diesel Thermal, 40 years for Hydropower due to large share of civil engineering structures.

Table 10.1.2-1 Annual Fixed Cost by Power Source

	Construction cost (USD/ kW)	Expense ratio（%）			Annual expense (USD/kW/ year)
		Interest・Redemption	O&M expense	Total	
Hydro（Afflux type）	2000	10.23	1.0	11.23	224.5
Hydro（Reservoir type）	4000	10.23	1.0	11.23	449.2
Existing Diesel Thermal（IDO）	550	13.15	4.0	17.15	94.3
New Diesel Thermal（HFO）	850	13.15	4.0	17.15	145.8
Biomass	2500	11.75	4.0	15.75	393.8
Geothermal	3500	11.61	4.0	15.61	546.4

10.1.3 Fuel Cost

As a fuel price forecast for the future, fuel price prediction up to 2030 which International Energy Agency (IEA) announced in 2009 was referred. Table 10.1.3-1 shows the mentioned forecast.

Table 10.1.3-1 IEA Projection

		2008	2015	2020	2025	2030
Oil (HFO)	USD/ bbl	97.19	86.67	100.00	107.50	115.00
Gas	USD/ Mbtu	10.32	10.46	12.10	13.09	14.02
Coal	USD/ tonne	120.59	91.05	104.16	107.12	109.40

Meanwhile, Table 10.1.3-2 indicates the actual results of Fossil Fuel Supply Cost during 2008-2012.

Table 10.1.3-2 IDO Supply Cost

	Diesel Quantity (M litres)	Value (F$M)	Unit Price F$/litre	Unit Price US$/bbl
2008	248	390	1.573	135
2009	189	218	1.153	99
2010	318	366	1.151	99
2011	276	410	1.486	128
2012	264	402	1.523	131

(Source：SE4All Report)

Based on the above actual results, the assumed price of HFO in year 2020 would be 100USD/ bbl as IDO price remains at 2009-2012 average price of 114 USD/ bbl. The fuel prices at standard thermal power plants are calculated as shown in Table 10.1.3-3.

Table 10.1.3-3 Fuel Cost of Thermal Power

	Assumption (2020)	Calories	Fuel price (Cent/ Mcal)	Efficiency	Fuel cost (Cent/ kWh)
Diesel (IDO)	114.0 USD/bbl	9200 kcal/ℓ	7.8	33%	20.33
Diesel (HFO)	100.0 USD/bbl	9600 kcal/ℓ	6.6	33%	17.20

10.1.4 Unit Generation Cost

Based on the above estimation of construction costs and fuel costs, the unit generation cost of each power source in year 2020 is calculated as follows.

In a field concerning base load supplier (Capacity factor of 70% or more), geothermal power generation is most economical than the other power sources. In a field of middle load supplier (Capacity factor of 30 &- 60%), hydropower (Run- of river type) is the most economical power source.

This was caused by carefully finding and developing the most efficient project site (Capacity factor of 40%-50% with peak generation time of approximately 3500 hours) to make it more economical than other power sources. In addition, Hydro power (Reservoir type) is the most efficient peak power source. This was caused by finding and developing the most efficient project site available (Capacity factor of 15%-30% with peak generation time of approximately 2000 hours) to make it more economical than the other power sources.

The generation costs by power source are summarized in Figure 10.1.4-1.

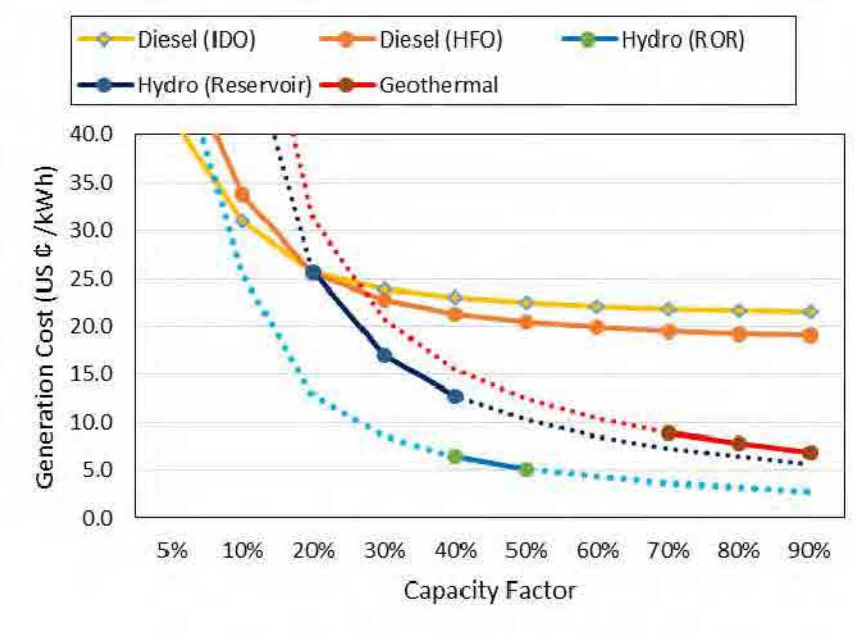


Figure 10.1.4-1 Generation Cost by Power Source

10.2 Creating the Supply and Demand Operation Simulation Data

Input data for PDPAT II (Power Development Plan Assist Tool) program was created in order to execute supply and demand operating simulation by utilizing PDPAT II.

10.2.1 Power Demand Forecast

(1) Electricity Generation Demand Forecast after Year 2015

As the demand forecast under PDP (2011-2020) formulated by FEA is shown inFigure 10.2.1-1, those are far apart from the actual results. Therefore, the Project Team forecasted subject to the below preconditions.

Table 10.2.1-1 GDP Growth Rate (2008-2013)

Year	2008	2009	2010	2011	2012	2013	Average
GDP at current basic prices	4,730.6	4,786.0	5,051.0	5,385.8	5,622.1	6,014.0	-
Growth Rate	-	1.17	5.54	6.63	4.39	6.97	4.92
GDP at constant basic prices	4,730.6	4,665.0	4,802.9	4,932.8	5,023.1	5,255.6	-
Growth Rate	-	-1.39	2.96	2.70	1.83	4.63	2.13

(Source：SE4All Report)

① The actual GDP growth rate for 2008-2013 recorded an average of 2.1% and 3% growth rate in year 2015 was predicted by Outlook of ADB. Therefore, the GDP growth rate is assumed as 3%. Besides, guided from past actual value, the elasticity of generation energy demand growth rate against GDP growth rate is assumed as 1.5.

② Considering the target to increase rural electrification rate from 90% in 2015 to 100% in 2020, it is appropriate to add 0.5% onto the electricity generation growth rate for 2015-2020.

③ The impact which population growth and DSM give to electricity generation demand is assumed to be offset

(2) Peak Demand Forecast after 2015

Since the growth of demand in daytime in the summer is getting larger as dissemination of air conditioners, the annual load factor may fall gradually from 64% to 60% by 2025 (Refer to the Section 10.2.2). From the above preconditions, the demand forecast of electricity generation and peak demand are set as shown in Table 10.2.1-2, Figure 10.2.1-1 and Figure 10.2.1-2. Moreover, High case was assumed in order to avoid shortage of supply capacity since development of hydropower plant takes at least 6 years including Feasibility Study period

Table 10.2.1-2 Demand Forecast from 2015 to 2025

Year	Peak Load (MW)		Load Factor (%)		Generation Energy (GWh)		Growth Rate (%)	
	Viti Levu	Vanua Levu	Viti Levu	Vanua Levu	Viti Levu	Vanua Levu	Viti Levu	Vanua Levu
2010	137.1	8.5	66.3	71.6	796.4	53.4	7.4	22.2
2011	137.2	8.4	65.4	62.9	785.3	46.4	-1.4	-13.1
2012	141.2	8.6	62.1	65.3	768.0	49.2	-2.2	6
2013	146.2	8.6	63.6	64.9	814.4	49.0	6	-0.4
2014	152.5	9.2	64.0	64.0	855.1	51.5	5.0	5.0
2015	160.2	9.6	64.0	64.0	897.9	54.1	5.0	5.0
2016	169.2	10.2	63.6	63.6	942.8	56.8	5.0	5.0
2017	178.8	10.8	63.2	63.2	989.9	59.6	5.0	5.0
2018	188.9	11.4	62.8	62.8	1039.4	62.6	5.0	5.0
2019	199.7	12.0	62.4	62.4	1091.4	65.7	5.0	5.0
2020	211.0	12.7	62.0	62.0	1145.9	69.0	5.0	5.0
2021	221.9	13.4	61.6	61.6	1197.5	72.1	4.5	4.5
2022	233.4	14.1	61.2	61.2	1251.4	75.3	4.5	4.5
2023	245.5	14.8	60.8	60.8	1307.7	78.7	4.5	4.5
2024	258.3	15.5	60.4	60.4	1366.6	82.3	4.5	4.5
2025	271.7	16.4	60.0	60.0	1428.1	86.0	4.5	4.5

(Source: The JICA Project Team)

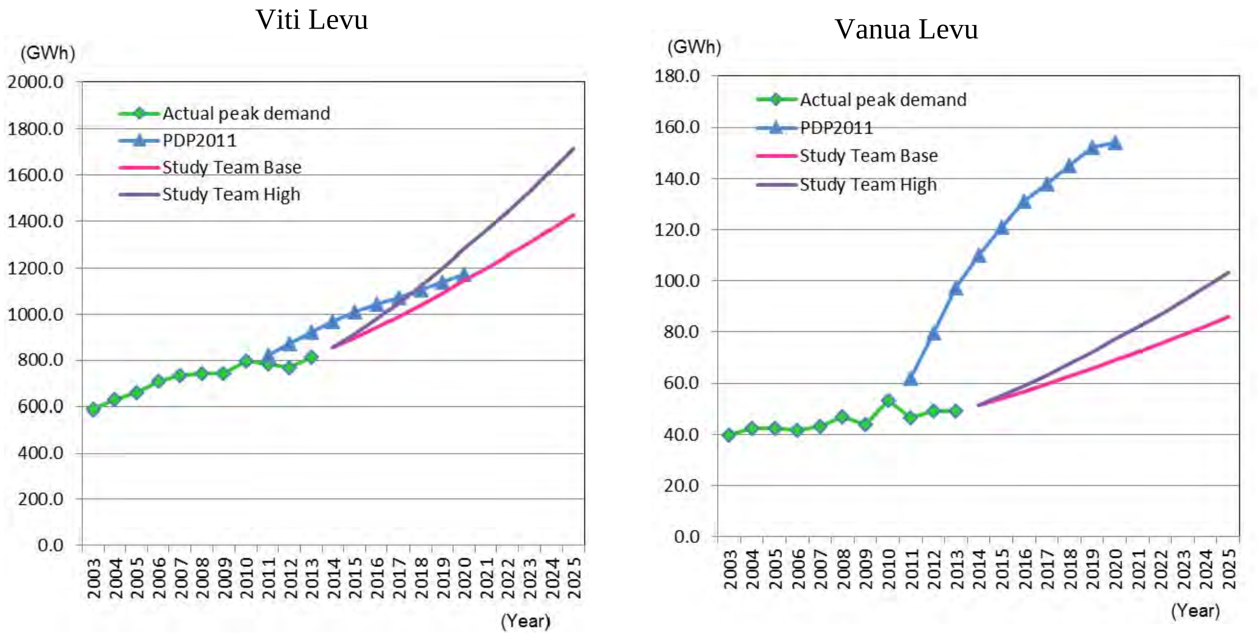


Figure 10.2.1-1 Demand Forecast of Electricity Generation (up to 2025)

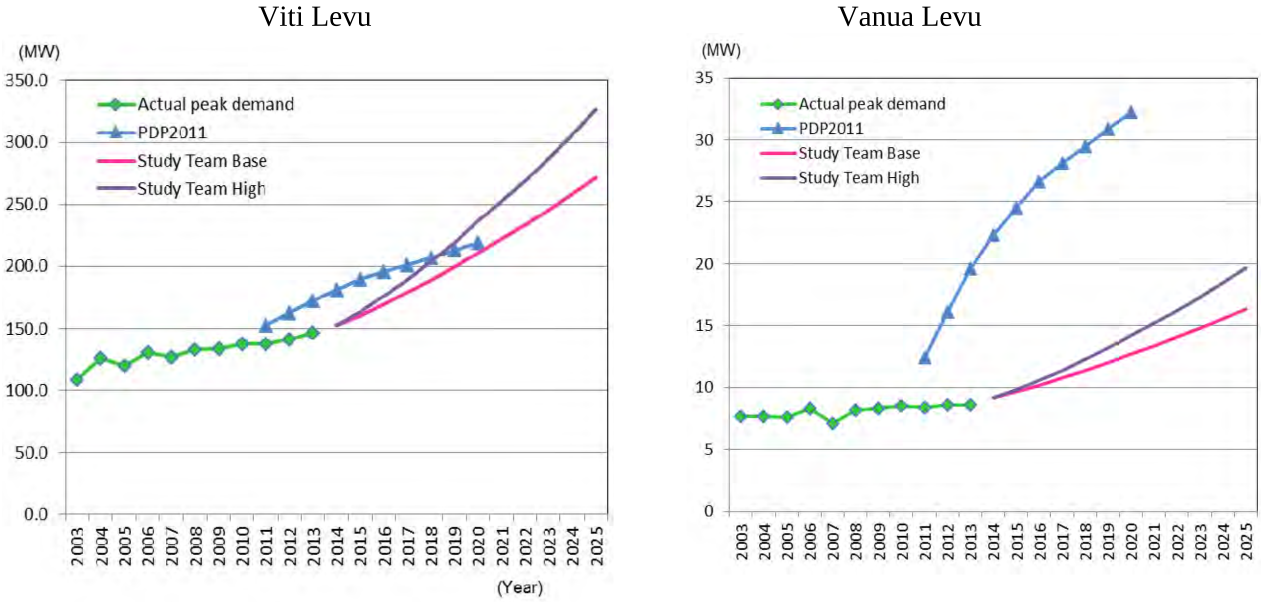


Figure 10.2.1-2 Demand Forecast of Peak Load (up to 2025)

According to the above forecast, the total peak demand of Viti Levu and Vanua Levu together in 2025 was assumed approximately 290 MW for Base case, and 350 MW for High Case. The peak demand in whole Fiji would hit a demand scale of 300 MW by 2025. In the case of High Case, which the growth speed is faster than base case, the examination in 2022 is equivalent to the Base case examination in 2025.

10.2.2 Current Status and Forecast of Peak Demand Shape

As recent trend in developing country, it becomes a common recognition that the growth of demand in daytime in the summer is getting larger as dissemination of air conditioners.

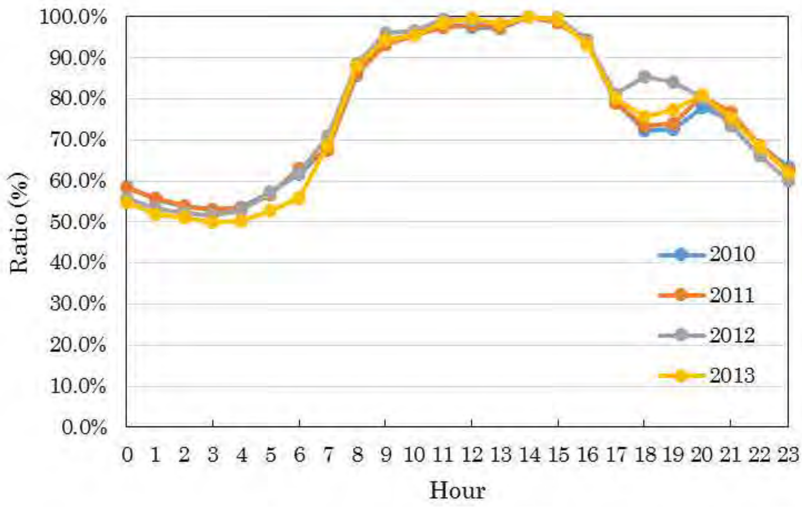
Under the above mentioned status, the forecast of change of the daily load curves was conducted. Meanwhile, since hourly past demand records of Viti Levu were only obtained, the following study was conducted on the power demand of Viti Levu.

(1) Demand Load Curve of Maximum Demand Date in Summer

Figure 10.2.2-1 shows the daily load curve of maximum demand date in summer from 2010 to 2013.

From the figure, the following trends of the daily load curve can be recognized.

- Peak demand has occurred around 14:00.
- Evening peak demand around 20:00, evening lighting peak, has declined.
- Gap (Minimum load / Maximum load) has gradually increased, the growth rate of maximum load is 1.7%, and the growth rate of the minimum load is -0.4%.



(Source: The JICA Project Team prepared based on the FEA data)

Figure 10.2.2-1 Daily Load Curve on Date of the Peak Demand occurred in Summer

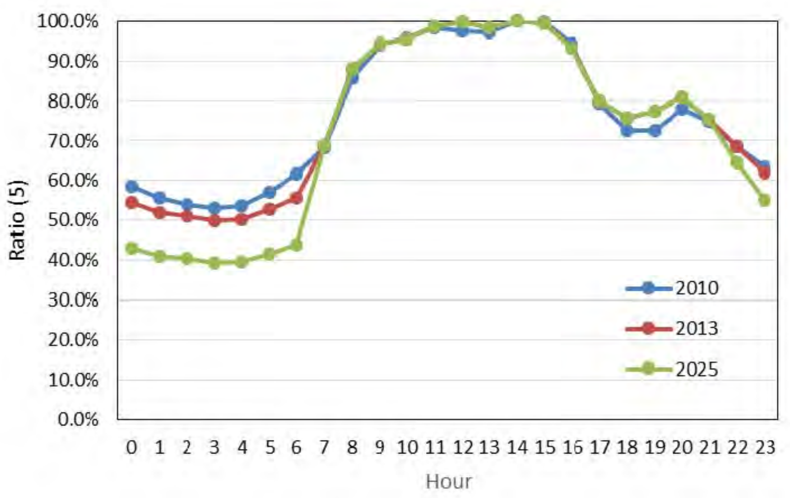
Table 10.2.2-1 shows mean power of the monthly 3days maximum demand at 2 p.m. and minimum demand at 3 a.m. from 2010 to 2013.

Table 10.2.2-1 Trend of Daily Peak Load and Minimum Demand

	2010	2011	2012	2013	Average increase	
					(MW)	(%)
Maximum	135.9	135.0	138.6	143.0	2.3	1.7
Minimum	72.2	71.6	71.7	71.4	-0.2	-0.4

(Source: The JICA Project Team prepared based on the FEA data)

Although, maximum demand has been growing by 2.3 MW per year, minimum load has not been grown. If it is assumed that the trend of every hour-wise growth rate continues up to 2025, the daily load curve in 2025 could be forecasted as shown in Figure 10.2.2-2.

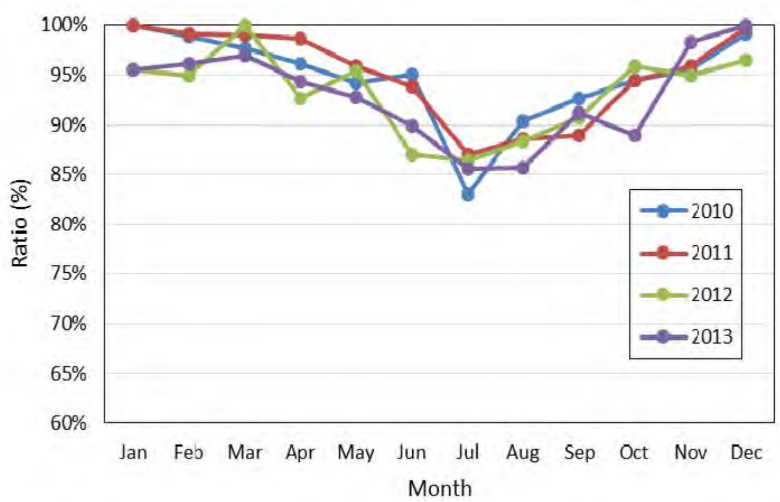


(Source: The JICA Project Team prepared based on the FEA data)

Figure 10.2.2-2 Forecast of Daily Load Curve in 2025（Peak Load Date）

(2) Seasonal Difference

Peak demand of every month from 2010 to 2013 is shown in Figure 10.2.2-3. Peak demand of winter season from Jun. to Sep. is around 90 % of that of summer season from Dec. to Apr. in every year.



(Source: The JICA Project Team prepared based on the FEA data)

Figure 10.2.2-3 Monthly Peak Demand

10.2.3 Data of Power Plant Facilities

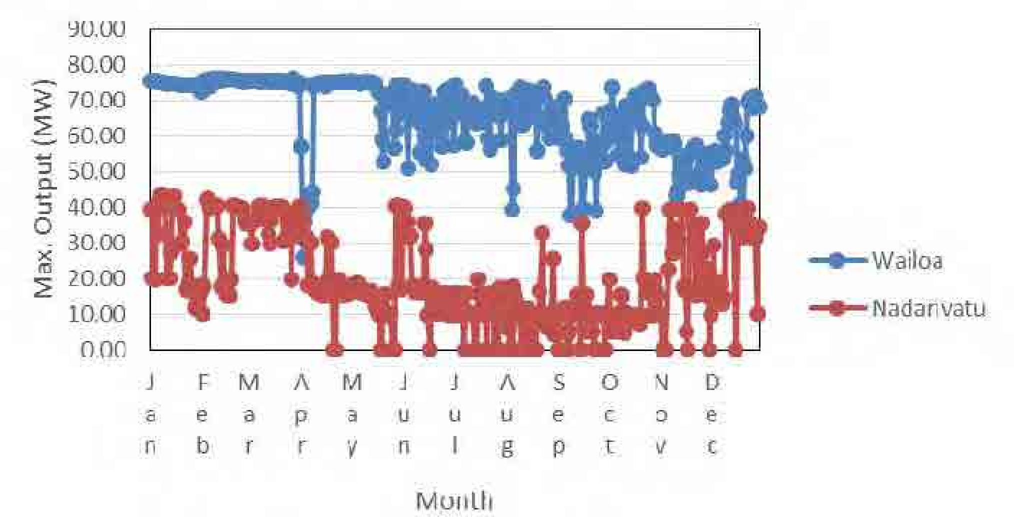
(1) Hydropower Plant Features

Daily maximum output, minimum output and electricity generation by existing power plant are obtained.

(a) Monthly maximum and minimum output

Referring to operation records of daily maximum output of every power plant, monthly maximum output and minimum output are assumed.

Figure 10.2.3-1 shows operation record, daily maximum output of Wailoa hydropower plant of a reservoir type in 2012 and Nadarivatu hydropower plant of a run-of-river type in 2013.



(Source: The JICA Project Team prepared based on the FEA data)

Figure 10.2.3-1 Annual Operation Records of Large Scale Hydropower Plants

Daily maximum outputs of the only one reservoir type hydropower of Wailoa HPS were recorded at around the available capacity of 75MW even in the dry season, while the capacity factor was 72.7%. However, daily maximum outputs of the run-of-river type of Nadarivatu HPS in the dry season from May to October were declined largely to around 1/4 of the available capacity of 40MW, while the capacity factor was 28.0%.

Daily maximum and minimum outputs of the other small scale run-of river type hydropower plants were recorded at around 80% and 50% of the available capacity respectively in the wet season from Nov. to Apr., and at around 30% and 20% of the available capacity respectively in the dry season from May to Oct.

(b) Monthly electricity generation

Monthly mean electricity generation of the each existing hydropower plant was calculated based on the operation records.

As for the hydropower projects which will be commissioned near future, monthly electricity generation described in the F/S report was applied. As for the hydropower projects which F/S report could not be obtained, the monthly electricity generation was calculated in reference to the operation record of the existing hydropower plant which is located in the vicinity river basin.

(c) Forced outage rate

Since the past records of forced outage period could not obtain, the forced outage rate of hydropower was set as 2% in reference to the other countries' hydropower operation records.

(d) Future hydropower development projects

As described in Chapter 6, six prospective hydropower potential sites in Table 10.2.3-1 are nominated from the viewpoints of economic efficiency and environmental & social consideration in the Study.

Table 10.2.3-1 List of the Prospective Hydropower Potential Sites

Location	Power Plant Name	Source and Type	Installed Capacity (MW)	Supply Capacity (MW)	Generation Energy (GWh)
Viti Levu	No.8 Mba	Reservoir	14	10.6	57.8
	No.29 Waivaka	Reservoir	32	28.3	67.6
	No.7 Nablaurua	Run-of-river	1.4	0.6	8.3
	No.14 Naboubuca	Run-of-river	2.7	0.9	20.4
	Sub-total		50.1	40.4	154.7
Vanua Levu	No.35 Wailevu	Reservoir	17	14.6	58.1
	No.31 Saqru	Run-of-river	2	0.2	9.6
	Sub-total		19	14.8	67.7
Total			69.1	55.2	222.4

(2) Thermal Power Plant Features

The thermal power plants which available capacity is more than 3 MW were categorized according to the categorization as shown in Table 10.2.3-2. As for the small scale thermal power plants under 3 MW, the total capacity in one lump by categorized group was inputted.

(a) Categorization of thermal power plants

Thermal power plant features were categorized by such as fuel type, generation type and unit capacity, as follows. Since actual records of outrage rate could not obtained, the forced outage rate of thermal power was set as follows in reference to the other countries' thermal power plant operation records.

Table 10.2.3-2 Categorization of Thermal Power Plants

No.	Fuel type	Other information	Unit capacity (MW)	Efficiency (maximum output)	Minimum output	Forced Outage rate	Corresponding Plants
21	Existing Diesel	IDO	3-5	33.0%	40%	10%	Vuda, Lautoka, Sigatoka, Kinoya PS
24	Existing Diesel	HFO	3-5	33.0%	40%	10%	Kinoya PS
25	New Diesel	HFO	3-5	45.0%	40%	8%	Kiniya PS extention New Plants

Heat efficiency at the maximum output and minimum output were determined in consideration of standard performance of the objective equipment.

(b) Future thermal power development projects

Since Kinoya PS extension project of 35 MW is described as a future thermal power development project in the annual report 2013 of FEA, diesel power generation with HFO is only considered as a future thermal power development project.

(3) Future Power Development Project with Renewable Energy

(a) Biomass power plants

As described in the chapter 6, the following two prospective biomass power potential sites in the following table are nominated from the viewpoints of biomass supply capacity forecasted in the Study.

(b) Geothermal power plants

Geothermal potential sites more than 3 MW among geothermal potential sites described in SE4All report were nominated as development projects as shown in Table 10.2.3-3.

Table 10.2.3-3Table 10.2.3-3 List of Prospective RE Power Development Projects

Location	Power Plant Name	Source and Type	Installed Capacity (MW)	Supply Capacity (MW)	Generation Energy (GWh)
Viti Levu	Lautoka (FSC)	Biomass	5	4.5	16.6
	Tavua	Geothermal	6	6	44.7
	Busa	Geothermal	4	4	29.8
	Sub-total		15	14.5	16.6
Vanua Levu	Labasa	Biomass	10	9	33.3
			3	2.7	10.0
			4	3.6	13.3
	Savusavu	Geothermal	8	8	59.6
	Waiqele	Geothermal	8	8	59.6
	Sub-total		25	23.3	116.1
Total			40	37.8	132.7

10.2.4 Proper Supply Reserve Margin based on the Supply Reliability Criteria

(1) Base Case Study

The relationship between loss of load expectation (LOLE) and the supply reserve margin was obtained, taking into consideration the generation mix forecast around 2020 (with the demand size of approx. 230 MW), and the appropriate supply reserve margin was determined to achieve the targeted supply reliability criteria.

(2) Input Data

(a) Load shape

The maximum demands and the minimum demands in the respective seasons are shown in Table 10.2.4-1.

Table 10.2.4-1 Maximum and Minimum Demands in the Respective Seasons

		Maximum	Minimum	Min/Max
Viti Levu	Nov-April	211	88	42.8%
	May-Oct	190	83	43.7%
Vanua Levu	Nov-April	12.7	5.4	42.8%
	May-Oct	11.4	5.0	43.7%

(Source: The JICA Project Team)

(b) Error in demand forecast

Error in the demand forecast, which is 2% of the forecasted demand, is estimated as the standard deviation.

(c) Generation facility composition and forced outage rate

The generation mix and their forced outage rates are as shown in Table 10.2.4-2.

Table 10.2.4-2 Generation Mix and Forced Outage Rate

	Available Capacity (MW)	Ratio	Max. Unit Capacity	Outage Rate
Hydropower	120.5	52.5%	20 MW	2%
Wind	10.0	4.3%	1 MW	5%
Oil-fired thermal	85.9	37.3%	3-5 MW	8% - 10%
Biomass fired thermal	13.6	5.9%	3-20 MW	10%
Total	230.0	100%		

(Source: The JICA Project Team prepared based on the FEA data)

(d) Output fluctuation probability of hydropower plant

Approximately 6% (7 MW) in wet season and 12% (15 MW) in dry season is estimated respectively as the standard deviation of supply capacity fluctuation possibility of hydropower plant.

(3) Relationship between LOLE and Supply Reserve Margin in 2020

The relationship between LOLE and the supply reserve margin determined based on the inputted data as described above is shown in Figure 10.2.4-1.

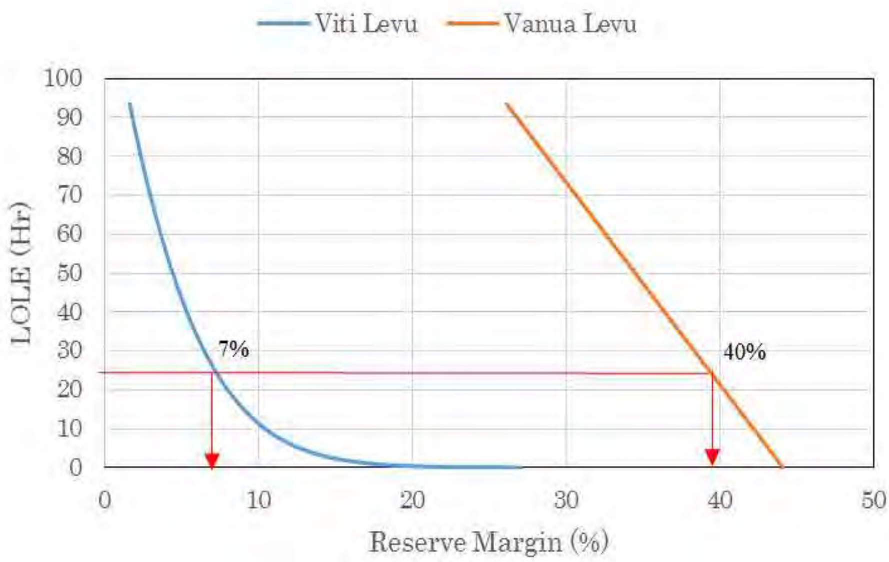


Figure 10.2.4-1 Relationship between LOLE and Supply Reserve Margin

When referring to examples in other countries, 24 hours in LOLE value is targeted as the supply reliability criterion in Thailand and Vietnam as well. Given the economic situation in Fiji at this moment, damage to economic activities because of a power outage that occurs due to insufficient supply capacity would be large and the electricity price when supply capacity is insufficient would become 1 USD/ kWh or more. Accordingly, 24 hours or less should be targeted in the LOLE value.

When the above-described supply reliability criterion is taken into consideration in the case of no interconnection power line, approx.7% in Viti Levu and 40% in Vanua Levu would be needed as the supply reserve margin in 2020.

Consequently, the future study in this investigation should aim at securing the supply reserve margin of 8-10% in Viti Levu and 35-45% in Vanua Levu as the supply reliability level.

(4) Supply Reliability Study in 2025

The results of studying the reserve supply capacity by using demand profile and composition of power plants expected in 2025 is shown in Figure 10.2.4-2.

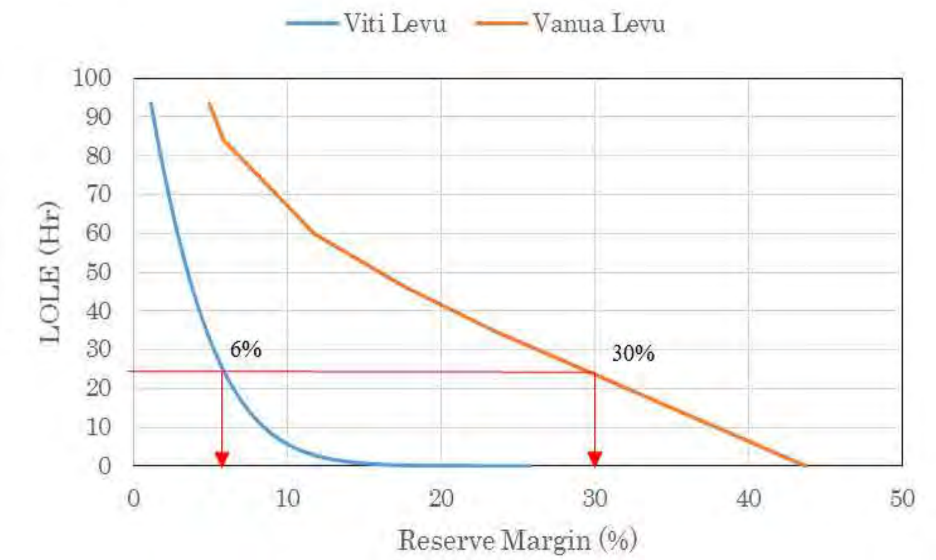


Figure 10.2.4-2 Relationship between LOLE and Supply Reserve Margin in 2025

In the study of the case in 2025, the supply reserve margin required to secure the comparable supply reliability level can be about 1% lower than the result of studying the projected status of 2020 in Viti Levu and about 10% lower than the result of 2020 in Vanua Levu. This seems to be due to the following reasons:

- As the demand profile takes a greater peak, peak hours with high demand will become shorter.
- The ratio of unit capacity of power plant newly developed against its peak demand is getting smaller, especially in the case of Vanua Levu.

For these reasons, it is expected that the supply reserve margin required to secure a comparable supply reliability level will gradually decline from 2020 onward.

In addition, interconnection between Viti Levu and Vanua Levu has large advantage to reduce necessary reserve margin and to increase the share of electricity generation by renewable energy. That is, abundant renewable energy potential in Vanua Levu can be made use of.

(5) Supply Reliability Study in the Case of Interconnection between Viti Levu and Vanua Levu in 2025

The relation between the amount of reduction of reserve capacity and interconnection capacity of Viti Levu and Vanua Levu is analyzed. The amount of reduction of reserve capacity by interconnection in 2025 was calculated by RETICS (Reliability Evaluation Tool for Inter-Connected Systems) as a tool of system reliability analysis. The calculation results are shown in Figure 10.2.4-3.

The amount of reserve capacity reduction is saturated in the case of interconnection capacity of 10 MW. The most economical capacity of interconnection is necessary to be examined considering fuel cost savings by the economic operation through the interconnection with a simulation analysis of the demand and supply balance.

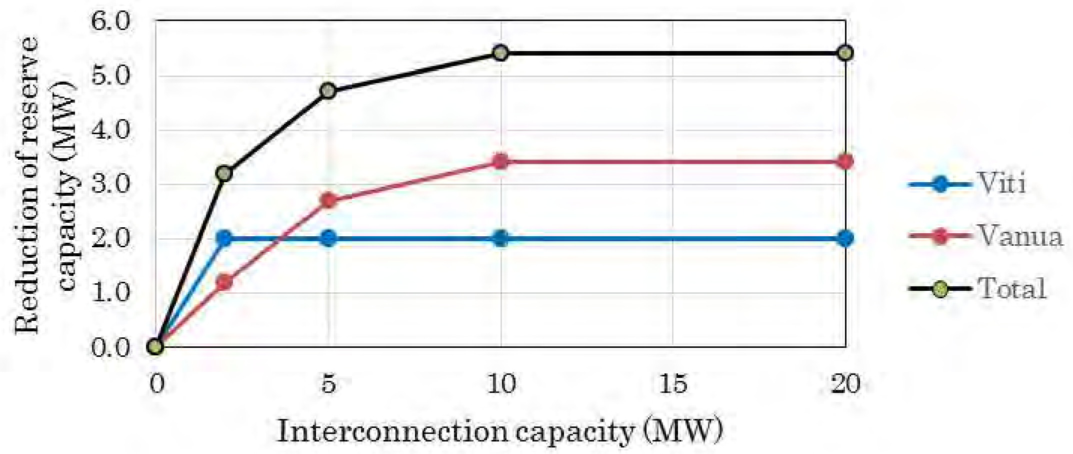


Figure 10.2.4-3 Relationship between Amounts of Reduction Reserve Capacity and Interconnection Capacity in 2025

Besides, the necessary reserve capacity of Viti Levu or Vanua Levu is 14.0 MW (5.1%) or 1.1 MW (6.5%) respectively and that of the total system is 15.1 MW (5.2%), if interconnected with the interconnection capacity of more than 10 MW.

Meanwhile, the construction cost of the interconnection between Viti Levu and Vanua Levu was estimated as shown in Table 10.2.4-3. 132 kV line is to be selected, if interconnected, since it is more economical than 33 kV line in terms of unit cost. And its annual cost is estimated as 30.4 million USD/ annum.

Table 10.2.4-3 Rough Cost Estimate of Interconnection

Voltage	Transmission Capacity	Description	Cost (Million USD)
132 kV	88 MW*1	Submarine × XLPE cable 2 × 70 km	210*2
		SVC	35*3
		4 × 132/ 33 kV transformer	17*1
Tota1			262
33 kV	6.5 MW*1	Submarine × XLPE cable 2 × 70 km	158*2
		SVC	35*3
Tota1			193

*1 Based on PDP 2011 (Exchange rate: 1 FJD＝0.52FJ, as of Oct. 9, 2014, Reserve Bank of Fiji)

*2 Based on Interconnection Feasibility Study - Task 8 Cost Estimate Study, Aug. 2011, Siemens

*3 Based on 100 Per Cent Renewables Study - Electricity Transmission Cost Assumptions, Sep. 2012, AEMP

10.2.5 Study on Optimal Power Supply Configuration in 2025

At the power system which peak demand will get to the scale of 290 MW around 2025, it is precondition that all ongoing hydropower projects and prospective hydropower potential sites found in this Project are to be developed, and the each optimal configuration ratio of biomass and geothermal power plant was studied. Next, the economy comparison study on with or without of interconnection between Viti Levu and Vanua Levu was conducted.

Meanwhile, in the case of High case of which the growth of power demand is larger than expected, the above optimal power supply configuration can be read as the optimal one in 2022.

(1) Optimal configuration rate of Biomass and Geothermal Power Plant

(a) Calculation assumptions

There are two types of biomass power plant, one utilizes Bagasse as fuel and the other utilizes wood waste as fuel. Bagasse biomass power plant is to be operated continuously from June to December (for 30 weeks) without output change and the development potential is limited to 100 MW including existing power plants.

Besides, since wood waste biomass power plant can operate continuously from May to December (for 35 weeks) more longer than bagasse power plant and the economic development potential is limited to only 5 MW, it is to be developed initially.

Meanwhile, geothermal projects of over 3 MW among geothermal potential sites described in SE4ALL Report were considered as a development capacity. The total capacity is 26 MW (10 MW in Viti Levu, 16 MW in Vanua Levu).

All of the above renewable power sources are deemed to be developed by IPP scheme, however, Annual generation expense calculated based on construction cost as shown in Table 10.1.2-1 is applied rather than current PPA price, since FIT will be applied to determine the PPA price in future.

(b) Calculation results by demand supply balance operational simulation

The calculation results of the annual generation expense is shown in Figure 10.2.5-1 in the case that development capacity of bagasse biomass power plants is varied without geothermal power development or with geothermal power development of 10 MW. Here, the base case of development capacity of biomass power plant is set as 72 MW (Bagasse 68MW+Wood residue 4MW) in Viti Levu and 5 MW (only Bagasse) in Vanua Levu.

The annual expense decreases along with the increase of development capacity of biomass power plant in Viti Levu. However, since there is no more development potential more than that of the base case, the cases of increasing development capacity of biomass power plants in Vanua Levu were considered under the condition of interconnection between the two islands, on the contrary, the annual generation expense increased. This is deemed to be caused mainly by little economic power exchange due to power loss of interconnection line.

Besides, the annual generation expense of the cases with geothermal power development of 10 MW is about 5 million USD less than the cases without geothermal power development on the whole.

It is caused that development capacity and electricity generation of diesel power plant decrease largely, since the geothermal power plant can supply power through the year.

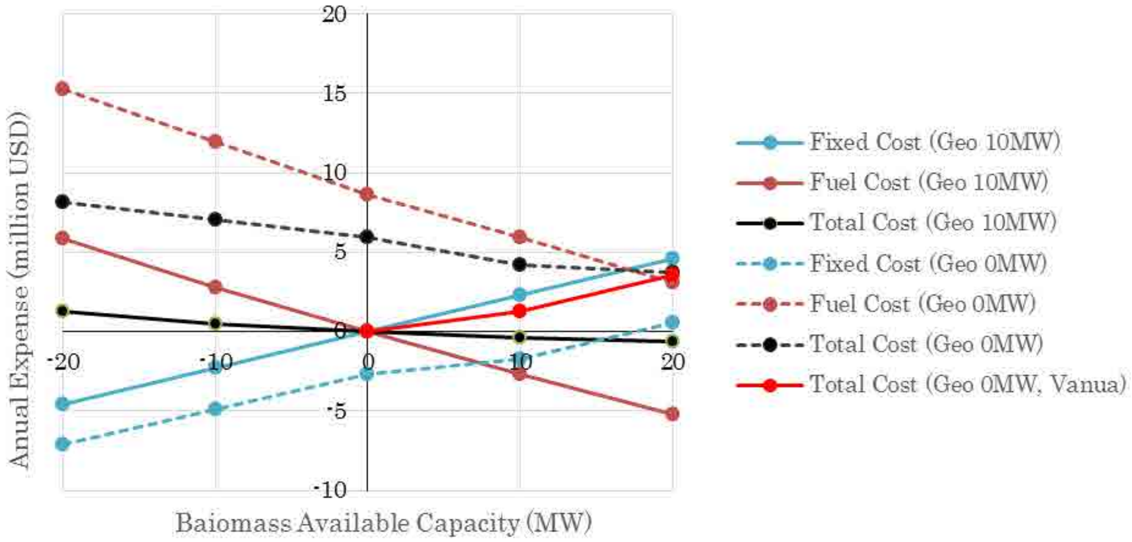


Figure 10.2.5-1 Cost Comparison between Biomass and Diesel (HFO)

On the basis that the above optimal development capacity of biomass power plants of 77 MW and geothermal power plants of 10 MW, the calculation results of the annual generation expense is shown in Figure 10.2.5-2 in the case that development capacity of geothermal power plants is varied.

In the case that geothermal power plants are developed in Viti Levu, the annual generation expense decreases monotonously in line with increase of development capacity. However, since there is no more development potential more than that of the base case, the cases of increasing development capacity of geothermal power plants in Vanua Levu were considered as well. As the results, the annual generation expense in the case of 4 MW decreased a bit and that in the case of 8 MW increased.

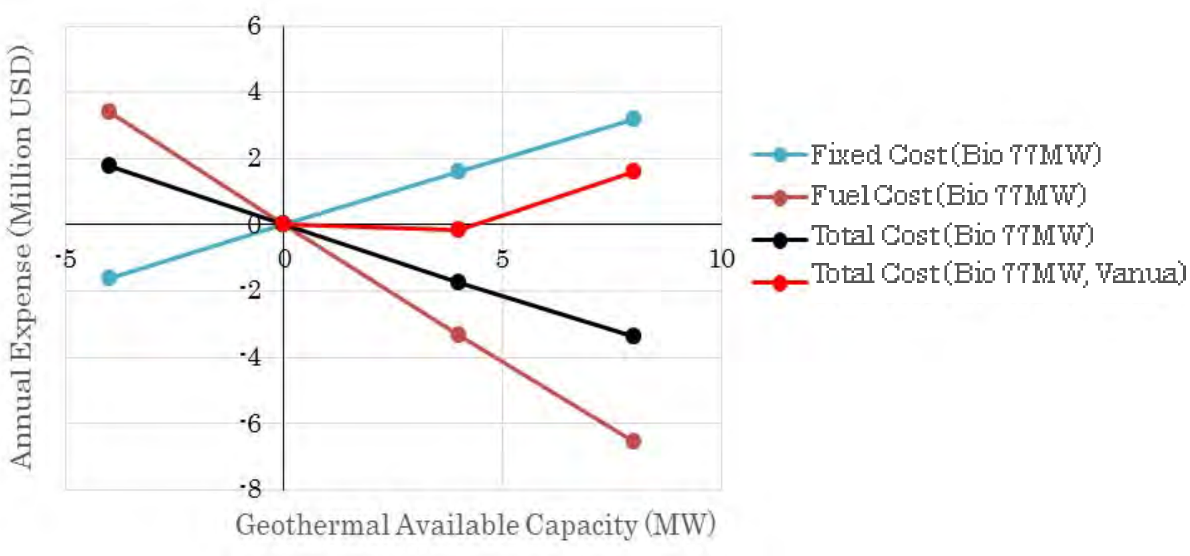


Figure 10.2.5-2 Cost Comparison Between Geothermal and Diesel (HFO)

(2) Economy comparison of with or without of interconnection

The above study was carried out in consideration of the interconnection between Viti Levu and Vanua Levu and the total necessary supply reserve margin is set as 5.2%. As for the case without system interconnection, the required supply reserve margin of Viti Levu and Vanua Levu in 2025 are 6% (12 MW) and 30% (5 MW) respectively. As the results, the reduction advantage of the annual generation expense is as follows.

Fixed Cost:	0.87 million USD/ annum
Fuel Cost:	0.65 million USD/ annum
Total:	1.52 million USD/ annum

On comparing the reduction advantage to the annual expense of 132 kV interconnection line of 30.4 million USD/ annum, it is evident that without case of interconnection line be more economical.

Accordingly, the system interconnection is not considered in the subsequent study on the optimal power supply configuration.

(3) Optimal power supply configuration in 2025

Based on the above study results on the optimal power supply configuration in 2025, kWh balance of Viti Levu and Vanua Levu are as shown in Figure 10.2.5-3 and in Figure 10.2.5-4. The supply demand balance becomes the tightest in April and May and the reserve margin is also minimum through the year.

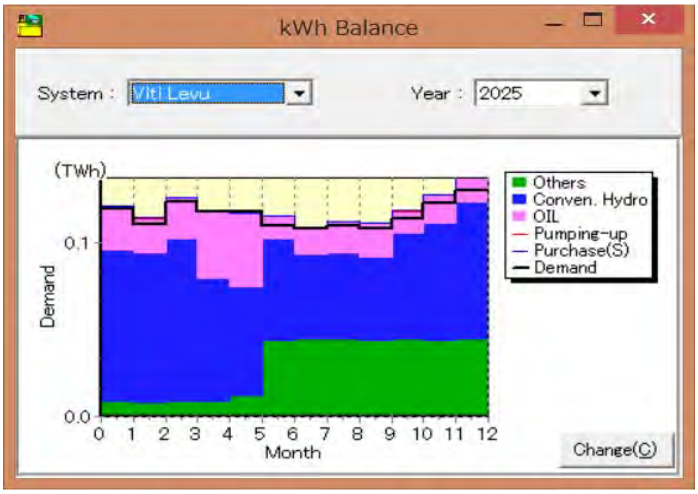


Figure 10.2.5-3 kWh Balance of Viti Levu in 2025

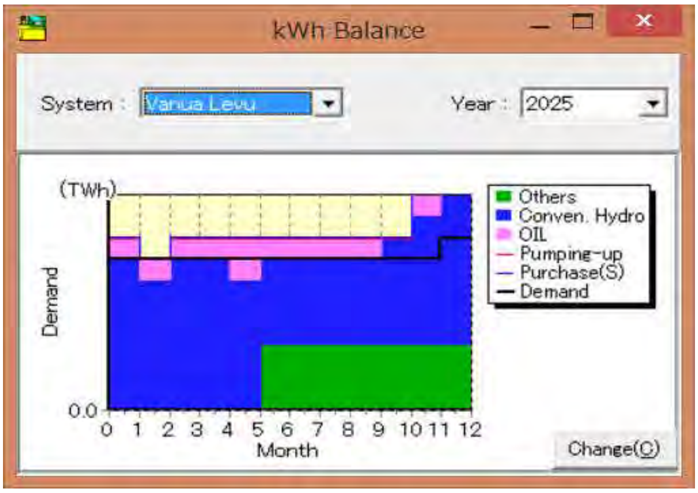


Figure 10.2.5-4 kWh Balance of Vanua Levu in 2025

Besides, simulation results of the weekly operation in summer (Mar.) and in winter (Sep.) in Viti Levu are shown in Figure 10.2.5-5 and Figure 10.2.5-6 respectively.

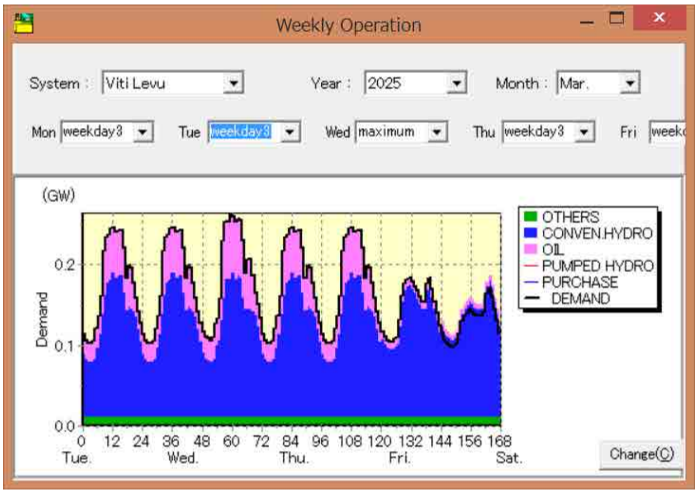


Figure 10.2.5-5 Weekly Operation of Vanua Levu in Winter (Mar.) 2025

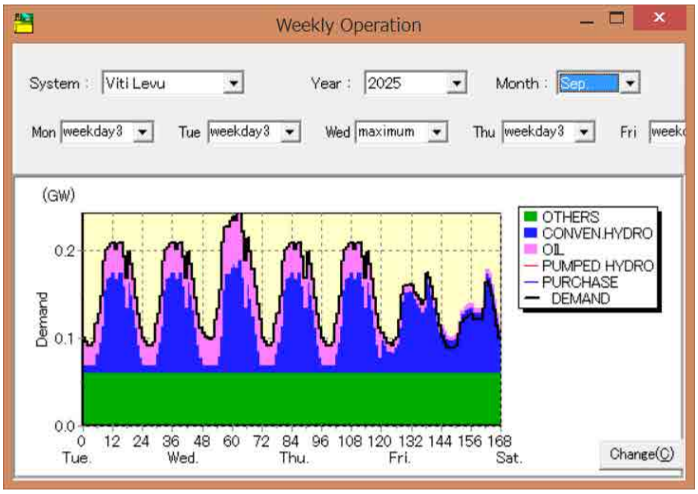


Figure 10.2.5-6 Weekly Operation of Vanua Levu in Summer (Sep.) 2025

Since baiomass power plants stop during summer season and amount of electricity generation and supply capacity of hydropower plants decrease in winter, diesel power plants have to operate on weekdays and monthly maximum days to meet the demand.

Optimal power supply configration in Vili Levu and Vanua Levu in 2025 is shown in Figure 10.2.5-7. Configration ratio of Diesel (HFO) of 27% is optimal. Consequently, electricity generation supplied by renewable energy (incl. hydropower) account for 82 % in 2025 as shown in Figure 10.2.5-8.

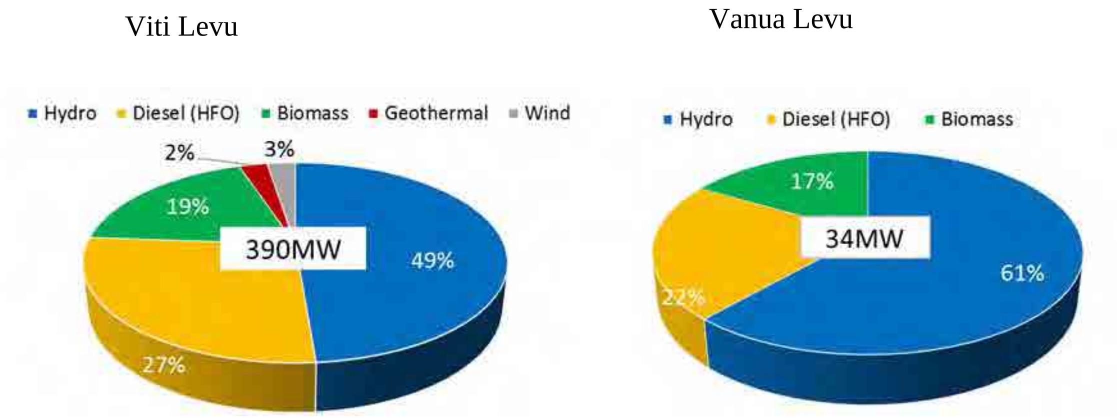


Figure 10.2.5-7 Optimum Generation Mix in 2025 (Available Capacity Base)

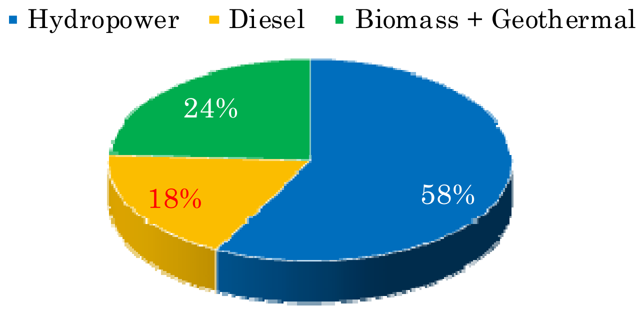


Figure 10.2.5-8 Total Electricity Generation Mix in 2025

10.3 Power Development Plan from 2015 to 2025

10.3.1 Power Development Plan from 2015 to 2025

Based on the above study results, the optimal long term power development plan during decade (2015 – 2025) is proposed targeting minimization of total present value of power supply cost.

(1) Calculation assumptions

Calculation assumptions of power plants are basically the same as those described in Section 10.2.

(2) Power demand forecast

Peak demand forecasts in May of Base case, when demand supply balance is the tightest, are as shown in Table 10.3.1-1.

Table 10.3.1-1 Peak Demand Forecast in May

(MW)

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Viti	140.3	147.4	155.7	164.5	173.8	183.7	194.1	204.2	214.8	225.9	237.7	250.0
Vanua	8.4	8.9	9.4	9.9	10.5	11.1	11.7	12.3	12.9	13.6	14.3	15.1
Total	148.8	156.2	165.1	174.4	184.3	194.8	205.8	216.5	227.7	239.5	252.0	265.1

(3) Supply reliability criterion

LOLE of 24 hr (1 day) is applied as a supply reliability criterion. And necessary supply reserve margin of each year in Viti Levu and Vanua Levu is calculated.

(4) Basic development policy of each power source

(a) Hydropower Plant

In addition to currently developing power projects, based on the potential study on hydropower described in Chapter 5, 6 prospective hydropower potential sites which are judged to be economical and have no major environmental negative impacts are to be developed by 2025. Especially, 3 reservoir type hydropower potential sites are to be developed as early as possible, and other 3 run-of-river type hydropower potential sites are to be incorporated in the development in line with the growth of power demand. Meanwhile, development period of hydropower was set that 1.5 years for FS and 3.5 years for construction are necessary at least, that is, total 5 years is needed at earliest, that is, the commissioning year is to be after 2020.

(b) Biomass power plant

Based on the results of potential study on Biomass power described in Chapter 8 in line with product prediction of bagasse and wood waste, the supply capacity of each mill to the power grid is taken into account.

- As for the wood waste biomass power plant, the only one project planned by Tropic Wood in Lautoka is considered.
- As for the bagasse biomass power plant in Viti Levu, development schedule planned by FSC and FEA is basically considered. If overflow of hydropower is occurred, the commissioning year will be delayed.
- As for the bagasse biomass power plant in Vanua Levu, the existing power plant in Labasa is only considered based on the study results on optimal configuration in 2025.

(c) Geothermal power plant

Geothermal projects of over 3MW in Viti Levu among geothermal potential sites described in SE4ALL Report (total 10MW) are considered as a development capacity within 2015. However, the commissioning year is to be after 2024, since any potential investigation works such as borehole drilling has not progressed.

(d) Decommissioning plan of the existing generation facilities

The existing Diesel power facilities using IDO are to be decommissioned or replaced by modern Diesel power facilities using HFO as early as possible.

(e) Generation facilities of which commissioning year is varied

The commissioning year of the following two kinds of power source was varied.

- ■ New Bagasse Biomass power plants
- ■ Diesel power plants

(5) Least cost power development plan from 2015 to 2025

According to the above development policy, commissioning year of biomass and diesel power is varied securing necessary power supply reserve and total present value as of 2014 of generation expense from 2015 to 2025 is calculated by demand supply balance simulation. As the results, the total present value as of 2014 of the long term power development pattern shown in Figure 10.3.1-1 is minimum. Besides, the overall generation unit cost (LRMC) of the above long term development plan from 2015 to 2025 is shown in Table 10.3.1-2 The overall generation unit cost in 2025 is estimated to be 15% down against the 13.4 US cent/ kWh in 2015.

Table 10.3.1-2 Overall Generation Unit Cost

(US cent/ kWh)

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Unit Cost	13.4	12.3	12.6	12.6	12.0	11.9	11.9	11.6	11.7	11.6	11.5

Available capacity configuration ratio and electricity generation ratio of each power source from 2015 to 2025 are shown in Figure 10.3.1-2. Electricity generation produced by renewable energy power sources including hydropower accounts for 86% in 2022 at the maximum, after that, the share is declined to 82%, since there is not any power development of large scale renewable energy power sources except geothermal power. Accordingly, it is recommended in order to increase the share of electricity generation by hydropower and renewable power sources up to more than 85% that further finding and developing hydropower potential and development of wind farm on which DOE has started potential study is to be progressed.

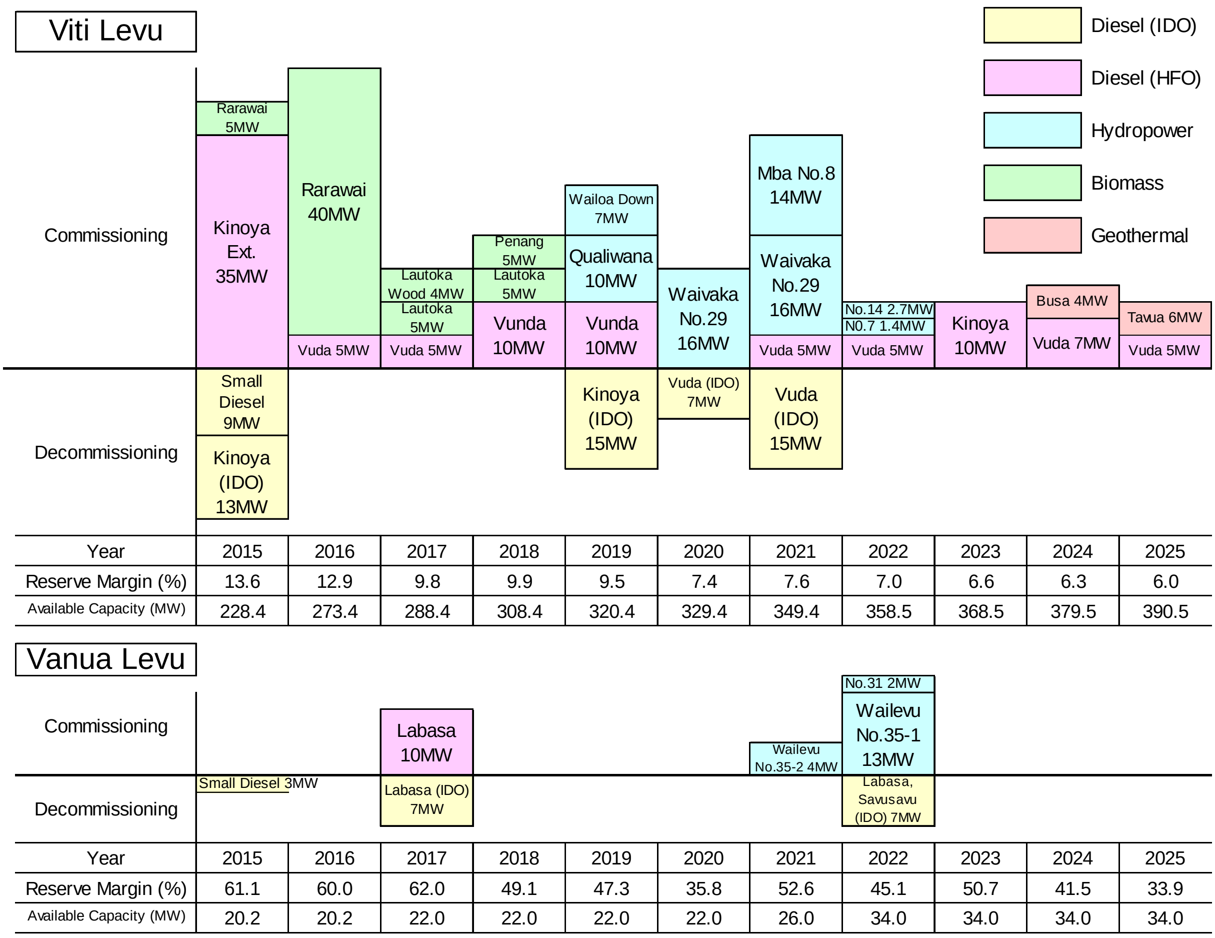


Figure 10.3.1-1 Long Term Power Development Plan (2015-2025)

The power plants corresponding to Figure 10.3.1-1 are listed in Table 10.3.1-3.

Table 10.3.1-3 Long Term Power Development Plan

Location	Power Plant Name	Source and Type	Installed Capacity (MW)	Supply Capacity (MW)	Generation Energy (GWh)	Commiss-ioning Year	Remarks
Viti Levu	Kinoya PS Extension	HFO	35	35	-	2015	Procurement by FEA
	Rarawai (FSC)	Biomass	5	3.3	16.6	2015	Committed by FEA
			40	26.4	97.6	2016	Committed by FEA
	Vuda New#1	HFO	5	5	-	2016	Proposed
	Lautoka (Wood Waste)	Biomass	4	4	23.0	2017	Committed by FEA
	Lautoka (FSC)	Biomass	5	3.3	16.6	2017	Committed by FEA
	Vuda New#2	HFO	5	5	-	2017	Proposed
	Penang	Biomass	5	3.3	16.6	2018	Committed by FEA
	Lautoka (FSC)	Biomass	5	3.3	16.6	2018	Proposed
	Vuda New#3	HFO	10	10	-	2018	Proposed
	Wailoa Downstream	Hydro	7	1.3	33.8	2019	Consultant Selection
	Qaliwana	Hydro	10	1.9	48.2	2019	Consultant Selection
	Vuda New#4	HFO	10	10	-	2019	Proposed
	Waivaka (No.29)	Hydro	16	14.3	34.1	2020	Proposed
	Mba (No.8)	Hydro	14	10.9	59.5	2021	Proposed
	Waivaka (No.29)	Hydro	16	14.3	34.1	2021	Proposed
	Vuda New#5	HFO	5	5	-	2021	Proposed
	Nablaurua(No.7)	Hydro	1.4	0.6	8.3	2022	Proposed
	Naboubuca (No.14)	Hydro	2.7	0.9	20.4	2022	Proposed
	Vuda New#6	HFO	5	5	-	2022	Proposed
	Kinoya New#1	HFO	10	10	-	2023	Proposed
	Vuda New#7	HFO	7	7	-	2024	Proposed
	Busa	Geothermal	4	4	29.8	2024	Proposed
	Vuda New#6	HFO	5	5	-	2025	Proposed
	Tavua	Geothermal	6	6	44.7	2025	Proposed
	Decommission small diesel	IDO	(9)	(9)	-	2015	Proposed
	Decommission Kinoya	IDO	(13)	(13)	-	2015	Proposed
	Decommission Kinoya	IDO	(15)	(15)	-	2019	Proposed
	Decommission Vuda	IDO	(7)	(7)	-	2020	Proposed
	Decommission Vuda	IDO	(15)	(15)	-	2021	Proposed
	Sub-total		197	156.3	396.7		
Vanua Levu	Labasa	Biomass	10	6.6	33.2	2017	Committed by FEA
	Wailevu (No.35-2)	Hydro	4	2.6	9.1	2021	Proposed
	Wailevu (No.35-1)	Hydro	13	12.2	49.3	2022	Proposed
	Saquru (No.31)	Hydro	2	0.2	9.6	2022	Proposed
	Decommission small diesel	IDO	(3)	(3)	-	2015	Proposed
	Decommission Labasa	IDO	(7)	(7)	-	2017	Proposed
	Decommission Labasa+Savusavu	IDO	(7)	(7)	-	2022	Proposed
	Sub-total		10	6.6	33.2		
Total			207	162.9	429.9		

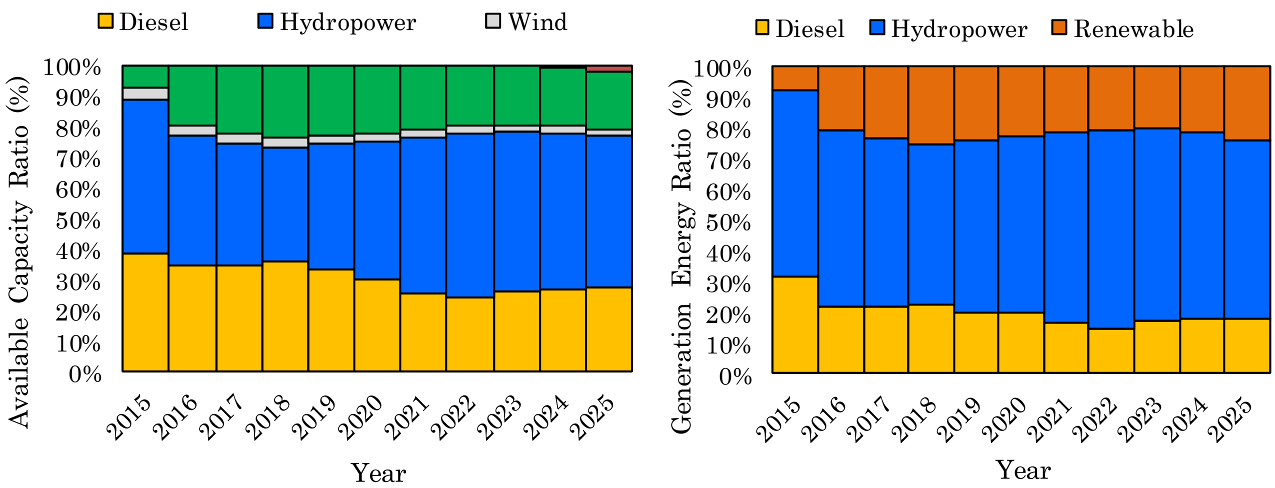


Figure 10.3.1-2 Generation Capacity Mix and Electricity Generation Mix (2015-2025)

10.4 Long Term Investment Plan

10.4.1 Long Term Investment Plan

(1) Calculation Assumptions

Yearly deployment of construction cost of a hydropower or a thermal (diesel) power plant is assumed as shown in Table 10.4.1-1. And interest rate during construction is assumed as 10%.

Table 10.4.1-1 Assumptions of Year Allocation of Construction Cost

Year	5 years ago	4 years ago	3 years ago	2 years ago	1 year ago
Hydropower	15%	20%	20%	30%	15%
Diesel Power			30%	50%	20%

(2) Calculation Results

Long term investment cost by FEA in order to achieve the long term power development plan proposed in Section 10.3 is estimated as shown in Table 10.4.1-2. Meanwhile, considering that a biomass (bagasse / wood waste) power plant is developed by IPP such as FSC / Tropic Woods, those investment costs are excluded.

Since initial investment cost for development of a hydropower plant is far larger than that of a diesel power plant and the construction period of a hydropower plant is also longer, the investment cost more than 50 million USD/annum will be required from 2017 to 2020.

Table 10.4.1-2 Long Term Investment Cost by FEA

(million USD)

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Viti	13.6	16.3	33.0	41.8	42.0	42.8	31.9	14.4	14.4	12.7	5.4	0.0
Vanua	2.1	3.6	3.9	9.2	12.8	15.7	19.6	11.9	0.8	0.0	0.0	0.0
Total	15.7	20.0	36.9	51.1	54.9	58.5	51.5	26.3	15.3	12.7	5.4	0.0

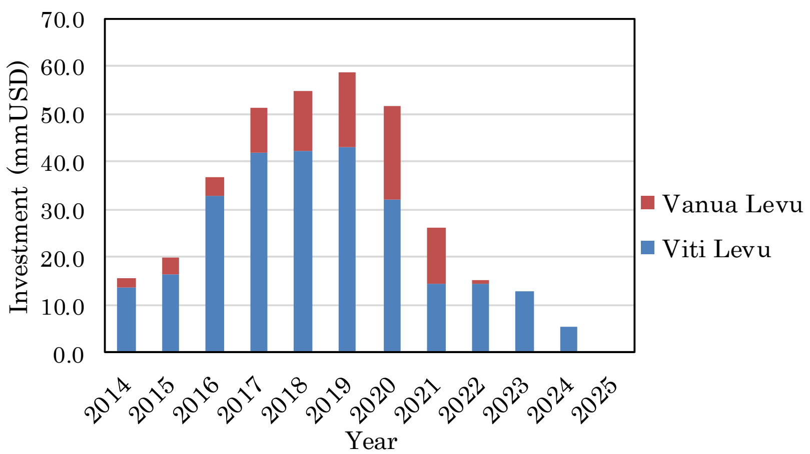


Figure 10.4.1-1 Long Term Investment Cost by FEA

10.5 Issues on Financing Plan for Proposed Hydropower Projects

10.5.1 Issues on Financing Plan for Proposed Hydropower Projects

Out of total investment in Table 10.5.1-1, the investment cost only for hydropower development is nearly 248.9 million USD, which account for approximately 72% of the total investment between 2014 and 2022. Total investment cost for proposed projects in this study has a share of 82% (204 million) to total investment cost during the same period.

Table 10.5.1-1 Long Term Investment Cost by FEA (by Source)

(Million USD)

	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total	**15.7**	**20.0**	**36.9**	**51.1**	**54.9**	**58.5**	**51.5**	**26.3**	**15.3**
Diesel	10.2	9.0	9.4	6.2	3.3	3.2	5.4	6.7	6.2
Hydro	**5.5**	**10.9**	**27.5**	**44.9**	**51.5**	**53.6**	**41.0**	**13.1**	**0.8**
Geothermal	0.0	0.0	0.0	0.0	0.0	1.7	5.1	6.5	8.3
Proposed Hydro Projects in the Study	**0**	**4.9**	**20.9**	**34.0**	**43.0**	**51.8**	**38.6**	**10.7**	**0**

Note: Total Viti Levu and Vanua Levu

For development of proposed hydropower projects in this survey, if all would be financed by IPP, it would be roughly estimated that funding cost might be at least 8.9% (USD 18.58 Million)[1]. For IPP side, it is necessary that electricity sales revenue should cover the investment and O & M cost and also the profit margin; therefore, most probably they require that the conditions on power purchase agreement assure to cover them. Thus, in long-term perspective, this cost may have to be ultimately covered by the Fijian government side. Currently, the electricity tariff for IPP is stipulated to be 0.3308 FJD per kWh as a minimum rate which is less than the weighted average of electricity tariff for consumers 0.3743 FJD/ kWh. Should the IPP require the higher electricity tariff than this minimum rate, financial sustainability of FEA might be risked unless the increase of electricity tariff of consumers or any other means will be implemented.

Given the current financial situation of FEA as described in the Chapter 3, that is, financial cost will increase in the near future and difficulty in increasing dramatically the electricity tariff due to social purpose, the finance by the concessional loans by any foreign international development institutions can be more sound option, considering the merit of the longer repayment period including grace period and the lower interest rate For example, the general lending terms of the Japanese ODA loan for upper middle income country (annual fixed interest rate: 1.7%, repayment period 25 years including grace period 7 years) for the project cost, funding cost is estimated to be 3.0%, that is less than 4.6%

[1] It is assumed to be the finance from all commercial loans, based on the average long-term interest rate of the commercial bank loan during the past 10 years in Fiji. Namely, lending terms are assumed to be annual interest rate of approximately 7.2%, repayment period of 15 years, and semi-annual installment.

of the current weighted average funding cost of FEA. If the preferential terms (annual fixed interest rate: 0.6%, repayment period 40 years including grace period 10 years) can be applied as the project contributing to the climate changes, funding cost would be 1.6%.

Chapter 11 Others

11.1 Stakeholder Meetings

Since the Project is a master plan study, not a feasibility study, there is not always a need to hold stakeholder meeting(s) during the course of the Project. However, in this case, three stakeholder meetings were planned to deepen the stakeholders' understanding of the candidate projects. The outlines of these stakeholder meetings are as follows.

11.1.1 First Stakeholder Meeting

The first stakeholder meeting ("SHM") was held before commencing the preliminary site reconnaissance to the candidate hydropower sites. At this stage, the prospective hydropower project sites to be studied for preliminary design had not yet been identified, but nine candidate sites had just been shortlisted. Therefore, the main purpose of this SHM was to ensure the collection of effective information and data from a wide range of stakeholders prior to conducting the site reconnaissance. The JICA Project Team proposed that the stakeholders for the first SHM should consist of the counterparty agencies (including DOE and FEA), and the relevant central government agencies (including the Department of Environment, the Fiji National Protected Area Committee, the Water Authority of Fiji ("WAF"), and the Ministry of Strategic Planning).

In the first SHM, the methodology for the selection of the targeted areas/sites for the preliminary site reconnaissance, the results of site selection including the outline (e.g. project profiles and locations) of around 10 candidate sites and method for site reconnaissance were explained and discussed with the stakeholders. In addition, the JICA Project Team confirmed the necessary procedures to be taken and the local customs to be noted (and observed) by the team when it entered the areas/sites for the preliminary site reconnaissance.

The outline of the First SHM was as follows:

a. Time and Date : 10:00 – 12:00, on 16th May 2014
b. Venue: Conference room of FEA head office in Suva
c. Participants: 23 people as shown in Table 11.1.1-1:

Table 11.1.1-1 Participants in the First Stakeholder Meeting

Organization	Name	Position
DoE	Mr. Peceli Nakavulevu	Director of Energy
	Mr. Paula Katirewa	Principal Scientific
	Mr. Ravinesh T Nand	Senior Scientific Officer
	Mr. Mikaele Belena	Senior Scientific Officer
	Mr. Vamarasi Kafoa	Project Manager, SEFP
	Mr. Waisale Vulagi	Technical Officer
	Mr. Jeke Pai	Biofuel Engineer
FEA	Mr. Fatiaki Gibson	GM Major Projects
	Mr. Om Dutt Sharma	GM System Planning Control
	Mr. Uate Biutanaseva	Unit Leader Renewable
	Mr. Karunesh Rao	Executive Projects Public Relations Manager
	Mr. Epeli Malo	Unit Leader Thermal
WAF	Mr. Seymour Vimlesh Singh	Business An dust
National Planning	Mr. Sandip Kumar	Economic Planning Offer
	Mr. Hennonn Yuen	Economic Planning Offer
Department of Environment	Mr. Ilaitia Finau	SEO
	Mr. Viliame Momoivalu	EO-EIA
JICA Project Team	Mr. Masahiko Nagai	Team Leader/ Power Development Planning
	Mr. Masayuki Ito	Hydropower Planning
	Mr. Hiroshi WATABE	Electrical Engineering
	Mr. Kiminori Nakamata	Geologist
	Mr. Noboru Matsushima	Environmental & Social Considerations
	Mr. Tadahisa YOSHIARA	Hydrology & Meteorology Analysis

d. Agenda:
   i. Outline of the Project (JICA Project Team)
   ii. Selection of the candidate hydropower potential sites for the first site reconnaissance (JICA Project Team)
   iii. Natural and social environmental considerations for the candidate hydropower potential sites in relation to the first site reconnaissance (JICA Project Team)
   iv. Discussions (Q&A)

   (Note: the JICA Project Team's presentation materials are shown in Appendix-11-2)

e. Major opinions from the stakeholders:
   - The Fiji side desired that at least three sites would be selected for preliminary design, although the JICA Project Team planned to conduct the preliminary design for only two sites (DoE).
   - WAF intended to send someone to participate in the site reconnaissance.
   - In the selection of the prospective sites for preliminary design, the JICA Project Team needed

to take into consideration “Community Development” (National Planning).


First Stakeholder Meeting at FEA Head Office

11.1.2 Second Stakeholder Meeting

The second SHM was held mainly for the final selection of the three prospective hydropower sites for preliminary design through discussions with the stakeholders.

The outline of the second SHM was as follows:

a. Date & Time :10:00 – 12:00, on 4th July, 2014
b. Venue : Board Room of FEA Head Office
c. Participants : 25 people as shown in Table 11.1.2-1

Table 11.1.2-1 Participants of the Second Stakeholder Meeting

Organization	Name	Position
DoE	Mr. Peceli Nakavulevu	Director
	Mr. Inia Saula	Principal Technical Officer
	Mr. Ravinesh Nand	Senior Scientific Officer
	Mr. Mikaele Belena	Senior Scientific Officer
	Mr. Waisale Vulagi	Technical Officer
FEA	Mr. Hasmukh Patel	CEO
	Mr. Karunesh Rao	Executive Projects Public Relations Manager
	Mr. Jitendra Kumar	G.M Network
	Mr. Epeli Malo	Unit Leader Thermal
WAF	Mr. Jone Tubui	Team Leader – Water Resource Limit
Mineral Resource Department	Ms. Venasio Nasara	Assistant Director
	Mr. Raymond Mohammed	Senior Mining Engineer
Ministry of Strategic Planning	Mr. Sandip Kumar	Economic Planning Officer
iTaukei Land Trust Board	Mr. Solomoni Nata	Deputy GM
Ministry of Forestry	Mr. Y Tupua	Forest Officer
National Trust of Fiji	Ms. Elizabeth Erasito	Director
	Mr. Kasaqa Tora	PA Officer
Environment Consultant Fiji	Mr. Dick Waltling	Principal
	Mr. Kolinio Moce	Social scientist
JICA Project Team	Mr. Masahiko Nagai	Team Leader/Power Development Planning
	Mr. Masayuki Ito	Hydropower Planning
	Ms. Mitsue Mishima	Economical and Financial
	Mr. Noboru Matsushima	Environmental & Social Considerations
	Mr. Shinichi Funabashi	Power System Planning
	Mr. Tadahisa Yoshiara	Hydrology & Meteorology Analysis

d. Agenda:

i. Outline of the Project (Mr. Nagai, JICA Project Team)

ii. Selection of the three prospective hydropower potential sites for the second site reconnaissance (Mr. Ito, JICA Project Team)

iii. Initial Environmental Examination (“IEE”) of the three prospective hydropower potential sites for the second site reconnaissance (Dr. Matsushima, JICA Project Team)

iv. Discussions (Q&A)

(Note: the JICA Project Team’s presentation materials are shown in Appendix-11-3)

e. Major questions and answers from the SHM:

1) <u>On the results of reviewing of the nine candidate hydropower potential sites:</u>

- Q: In the southern part of Viti Levu, there are some potential sites which were evaluated as economically viable projects. Do the construction costs for these sites include the costs for transmission lines?

  A: Yes, the total construction costs include the rough costs for the transmission line construction.

- Q: Explain in more detail about the ranking factor - "power security".

  A: In terms of "power security", areas that are relatively near to electricity demand areas, such as a capital city with a large population, are given a higher score than areas without these characteristics. .

- Q: There are as many as nine potential sites which were evaluated as economically viable projects. It is desirable to conduct preliminary designs not just for the three selected sites but also for the remaining sites.

  A: Taking into account the contract with JICA and the Project time schedule, it is impossible to conduct preliminary designs on more than three sites. The remaining sites can perhaps be covered by the Fiji Government or in another assignment.

2) <u>On environmental and social considerations</u>

- Q: Regarding the area around the No.26 site, there are various problems concerning matters such as the mining development plan, the negotiations with the landowners for the land acquisition, and the protected area. The scoring of the No.26 site should be reviewed by taking into account these risks.

  A: The JICA Project Team evaluated the No.26 site on the premise that it was a site based outside the protected area.

f. Three prospective hydropower potential sites to be studied at preliminary design level:

After the SHM, the Fiji side had a discussion on the selection of the three prospective hydropower potential sites to be studied at preliminary design level. DOE reported to the JICA Project Team about the results of the discussion and selected the three following hydropower potential sites:

1) Western Area of Viti Levu : No.8 Mba U/S 1, located in the Ba River Basin
2) Southern Area of Viti Levu :No.26 Wainavadu, located in the Wainavadu River Basin
3) Vanua Levu :No.35 Wailevu, located in the Wailevu River Basin

g. Conclusion:

In relation to the No.26 site, the JICA Project Team carefully checked whether the site area was actually inside the Sovi River Basin Protected Area, because at the SHM it was pointed out that this was the case.

In the end, the team's check, which included obtaining the latest information from and consulting with relevant parties, confirmed that the dam site and its reservoir area were inside the protected area. Upon confirming this fact, the JICA Project Team suggested that the No.26 site should not be selected as a prospective site for preliminary design, because from an earlier Project stage DOE, FEA, and the team mutually agreed that any potential sites which were located in protected areas or proposed protected areas should not be selected. The JICA Project Team then opted not to select the No.26 site and instead suggested the No.29 site from those identified in the southern area of Viti Levu. DOE and FEA accepted this suggestion.

Second Stakeholder Meeting at FEA Head Office

11.1.3 Third Stakeholder Meeting

The third SHM was held mainly in relation to the results of the preliminary designs and the IEE for the three prospective hydropower potential sites. The stakeholders were satisfied with the results of these.

The outline of the third SHM is as follows:

a. Date & Time :10:00 – 13:00, on 11th November, 2014
b. Venue : Conference Room of Tanoa Plaza Hotel, Suva
c. Participants : 30 people as shown in Table 11.1.3-1

Table 11.1.3-1 Participants of the Third Stakeholder Meeting

Organization	Name	Position
DoE	Mr. Peceli Nakavulevu	Director
	Mr. Inia Saula	Principal Technical Officer
	Mr. Ravinesh Nand	Senior Scientific Officer
	Mr. Mikaele Belena	Senior Scientific Officer
	Mr. Waisale Vulagi	Technical Officer
	Mr. Jeke Pai	Biofuel Engineer
	Mr. Paula Katirewa	Assistant Director
	Mr. Jonati Delaimoala	Scientific Officer
	Mr. Ulaiasi Butukoro	Scientific Officer
	Ms. Susana Pulini	Project Manager FREPP
	Mr. Vamarasi Kafoa	Project Manager SEFP
FEA	Mr. Karunesh Rao	Executive Projects Public Relations Manager
	Mr. Epeli Malo	Unit Leader Thermal
Mineral Resource Department	Ms. Agnes Peter-Hansen	Senior Scientific Officer
Ministry of Strategy Planning	Mr. Sandip Kumar	Economic Planning Officer
	Ms. Malvina Singh	Economic Planning Officer
Ministry of iTaukei Affairs	Ms. Salaseini Naiduki	Clerical Officer
Ministry of Forestry	Ms. Anjeshai Narayan	REDD Coordinator
Department of Environment	Ms. Eleni Tokaduadua	Principal Environment Officer
iTaukei Land Trust Board	Ms. Varanisese Veitala	Estate Officer
Investment Fiji	Ms. Malika Kumar	Senior Investment Officer
JICA Fiji Office	Mr. Katsuhiko Ohara	Assistant Resident Representative
	Ms. Seema Chand	Program Office
JICA Project Team	Mr. Masahiko Nagai	Team Leader/Power Development Planning
	Mr. Masayuki Ito	Hydropower Planning
	Dr. Noboru Matsushima	Environmental & Social Considerations
	Mr. Shinichi Funabashi	Power System Planning
	Mr. Yoshiyuki Takahashi	Electrical Engineering
	Mr. Toshiyuki Kobayashi	Renewable Energy (Biomass) A
	Mr. Tadahisa Yoshiara	Hydrology & Meteorology Analysis

d. Agenda:

  i. Introduction (Mr. Nagai, JICA Project Team)
  ii. Results of the preliminary designs for the three prospective hydropower potential sites (Mr. Yoshiara, JICA Project Team)
  iii. IEE for the three prospective hydropower potential sites (Dr. Matsushima, JICA Project Team)
  iv. Biomass energy potentials (Mr. Kobayashi, JICA Project Team)
  v. Power Development Plan until 2025 (Mr. Ito, JICA Project Team)
  vi. Discussions (Q&A).

  (Note: the JICA Project Team’s presentation materials are shown in Appendix 11-5)

e. Major questions and answers from the SHM:

Q: Explain in more detail about the interconnection transmission line between Viti Levu and Vanua Levu mentioned in the “Power Development Plan until 2025”.

A: The details of the interconnection transmission line will be studied and prepared in the draft final report.

SHM with Stakeholders

11.2 Presentation to FEA Management

11.2.1 First Presentation to FEA Management

The first presentation to FEA management, including its CEO and CFO, was held regarding the results of the preliminary designs and the IEE for the three prospective hydropower potential sites. Overall, FEA management favorably evaluated the results for the three sites. However, they showed concern about the No.29 Waivaka site hydropower scheme as a new energy source. In addition, FEA management requested that the "Power Development Plan until 2025" be added in relation to the results of the preliminary design for the three prospective hydropower potential sites.

The presentation schedule and FEA attendees (Table 11.2.1-1) are stated below:

a. Date & Time :9:00 – 10:00, on 12th November, 2014
b. Venue : Board Room of FEA head office
c. Participants : 9 people (FEA management)

Table 11.2.1-1 Participants from FEA (1st)

Organization	Name	Position
FEA	Mr. Nizam-ud-Dean	Board Chairman
	Mr. Hasmukh Patel	CEO
	Mr. Bobby Naimawi	CFO
	Mr. Fatiaki Gibson	General Manager of Major Projects
	Ms. Annabel Ducia	General Manager
	Mr. Krishneel Prasad	Unit Leader System Strategy & Protection
	Mr. Karunesh Rao	Executive Projects Public Relations Manager
	Mr. Jitendra Kumar	G.M Network
	Mr. Epeli Malo	Unit Leader Thermal

Presentation to FEA Managemnt at FEA Head Office

11.2.2 Second Presentation to FEA Management

The purpose of the second presentation was to explain to FEA management about the results of the evaluation in relation to the following items.

- Preliminary designs for the three prospective hydropower potential sites
- Biomass energy potentials
- Power system planning
- "Power Development Plan until 2025"

FEA agreed to the results of the evaluation and were keen for a feasibility study, for the three aforesaid preliminary designs, to be implemented through utilizing Japanese assistance.

The presentation schedule & FEA attendees (Table 11.2.2-1) are described below:

a. Date & Time :14:30 – 15:30, on 7th January, 2015
b. Venue : Board Room of FEA head office
c. Participants : 12 people (FEA management)

Table 11.2.2-1 Participants from FEA (2nd)

Organization	Name	Position
FEA	Mr. Hasmukh Patel	CEO
	Mr. Bobby Naimawi	CFO
	Mr. Fatiaki Gibson	General Manager of Major Projects
	Mr. Jitendra Kumar	General Manager Network
	Mr. Mohammed Khan	Unit Leader of Civil
	Mr. Eparama Tawake	General Manager of Generator
	Mr. Basant Kumar	-
	Mr. Krishneel Prasad	Unit Leader System Strategy & Protection
	Mr. Musheer Khan	-
	Mr. Om Dutt Sharma	General Manager System Planning & Control
	Mr. Karunesh Rao	Executive Projects Public Relations Manager
	Mr. Epeli Malo	Unit Leader Thermal

Presentation to FEA Management at FEA Head Office

11.3 Technology Transfer and Human Resource Development

11.3.1 Plan for Technology Transfer and Human Resource Development

In order to contribute to a technology transfer and human resource development in the area of hydropower development planning, the JICA Project Team pledged to carry out a series of seminars/workshops and training. In particular, these were to focus on the criteria for identifying hydropower potential sites, the methods for shortlisting/selecting candidate sites, as well as providing an insight on how to jointly execute site reconnaissance with the counterparty personnel for the purpose of sharing information with the counterparty agencies.

The JICA Project Team pledged to execute a technology transfer in relation to the following matters.

1) Evaluation of the hydropower potential in Fiji
2) Evaluation of the hydropower planning and design at a pre-F/S level
3) Evaluation of the power system

In order to execute the transfer of these technologies to the relevant personnel of DOE and FEA, the JICA Project Team planned to carry out the seminars/workshops and training as shown in Table 11.3.1-1.

Table 11.3.1-1 Seminars/Workshops and Training for the Technology Transfer

Execution Item	Target Personnel	Specific Content
First workshop/seminar (first works in Fiji)	Counterparty personnel in charge of investigations and planning	Explanation and discussion on the methods of map study for the hydropower potential study
Second workshop/ seminar (second works in Fiji)	All related counterparty personnel	Explanation and discussion on the results of hydropower potential identification and evaluation criteria (for identifying and screening)
First site reconnaissance training (second works in Fiji)	Counterparty personnel in charge of investigations and planning	On-the-job-training (“OJT”) for preliminary site survey methods through the joint implementation of site reconnaissance
Second site reconnaissance training (third works in Fiji)	Counterparty personnel in charge of investigations and planning	OJT for site survey methods for pre-F/S through the joint implementation of site reconnaissance
Third workshop/seminar (fourth works in Fiji)	All related counterparty personnel	Explanation and discussion on the preliminary design of prospective hydropower stations
Fourth workshop/seminar (fifth works in Fiji)	Counterparty personnel in charge of transmission lines and power system planning	Explanation and discussion on the results of power system analysis and transmission line extension plans

11.3.2 Implementation of Technology Transfer and Human Resource Development

(1) First Workshop/Seminar

The first workshop/seminar was held as follows:

a. Time and Date : 14:00 - 15:30, on 7th October, 2013
b. Venue: Conference room of DOE
c. Participants: approximately 20 people
(Main participants)
Mr. Peceli Nakavulevu
Director of Energy, Department of Energy (DOE), MWTPU
Mr. Mikaele Belena
Senior Energy Analyst, DOE, MWTPU
Mr. Epeli Malo
Unit Leader Thermal Generation, FEA
d. Agenda:
1) Presentation on methods of map study for the hydropower potential study by the JICA Project Team
(Note: the JICA Project Team's presentation materials are shown in Appendix 11-7)
2) Q&A

Workshop on Map Study at DOE

(2) Second Workshop/Seminar

The second workshop/seminar itself was not held during the course of the second works in Fiji. However, at the meeting with DOE and FEA prior to the first site reconnaissance and the first SHM, the JICA Project Team explained in detail to the relevant personnel of the counterparties about the results of the hydropower potential identification and the evaluation criteria for identifying and screening.

(3) First Site Reconnaissance Training

As shown by the activity records in Table 11.3.2 1, during the second works in Fiji, the JICA Project Team carried out the first site reconnaissance for the nine candidate hydropower potential sites jointly with officials of DOE, FEA, and WAF. In the course of this site reconnaissance, the JICA Project Team conducted OJT for the Fijian participants in relation to the preliminary site survey methods through the joint implementation of the site reconnaissance.

Table 11.3.2-1 Activity Records for the First Site Reconnaissance

Day		Activities	Participants from the Fijian Side
Mon. 19th May 2014	a.m.	Moved from Suva to **Namosi area**. Surveyed the intake site of the **No.29** site (Wairokodra Creek) and the intake site of **No.24** site (Wainikoroiluva River) in and around Navunikabi Village.	(DoE) Mr. Mikaele Belena Mr. Waisale Valagi Mr. Iliesa Nalawa
	p.m.	Surveyed the sites for the head tank, penstock, and powerhouse of the **No.24** site (Wainikoroiluva River) in and around Nakabika Village, as well as the sites for the headtank, penstock, and powerhouse of the **No.29** site (Wairokodra Creek) near Narukunibua Village. (Stayed in Suva)	
Tue. 20th May 2014	a.m.	Surveyed the confluence of the Wainavadu River and the Waidina River, but no survey on any sites of the **No.26 site** (Wainavadu River) due to the difficult access.	(DoE) Mr. Mikaele Belena Mr. Waisale Valagi Mr. Iliesa Nalawa (WAF) Mr. Jone Tubui Mr. Setauiki Delai
	p.m.	Surveyed the confluence of the Waisoi River and the Waidina River; the sites for the penstock and powerhouse of the **No. 28** (Waisoi River); but no survey on the intake site of the **No. 28** due to a landslide on the way to the intake site. Moved to **Monasuvu area**. (Stay at Monasuvu)	
Wed. 21st May 2014	a.m.	Survey on the sites for the intake, headtank, penstock, and powerhouse of the **No.7** site (Naboubuco River) near Rewasau village.	(DoE) Mr. Mikaele Belena Mr. Waisale Valagi Mr. Iliesa Nalawa (WAF) Mr. Jone Tubui Mr. Setauiki Delai (FEA) Mr. Uate Biutanaseva Mr. Jone Manu
	p.m.	Moved to **Nadarivatu area** (Stayed in Nadaribatu)	
Thu. 22nd May 2014	a.m.	Surveyed the No.1 intake of the **No.8** site(Ba River) near the existing Nadaribatu Power Station.	(DoE) Mr. Mikaele Belena Mr. Waisale Valagi Mr. Iliesa Nalawa (WAF) Mr. Jone Tubui Mr. Setauiki Delai (FEA) Mr. Uate Biutanaseva Mr. Rusiate Faivakibau
	p.m.	Surveyed the sites for the powerhouse and penstock of the **No.7** site (Nabiaurua Creek) near Marou Set village upstream from the existing Nadaribatu Power Station. No survey on the intake site due to steep topographical conditions. (Stayed in Nadarivatu)	

Day		Activities	Participants from the Fijian Side
Fri. 23rd May 2014	a.m.	Moved to Koro village by car. Walked to the downstream of the Ba River. Surveyed the sites for the powerhouse and penstock of the **No.8** site (Ba River)	(DoE) Mr. Mikaele Belena Mr. Waisale Valagi Mr. Iliesa Nalawa (WAF) Mr. Jone Tubui Mr. Setauiki Delai
	p.m.	Surveyed the sites for the No.2 Intake (or regulating dam on the Savatu Creek) of the **No.8** site (Ba River). Returned to Koro village. Moved to Nadi by car. (Stayed in Nadi)	
Sun. 25th May 2014	a.m.	Moved from Nadi to **Vanua Levu area** (Labasa) by plane.	
	p.m.	Moved from Labasa to Savusavu. (Stayed at Savusavu)	
Mon. 26th May 2014	a.m.	Moved from Savusavu to Dawara Village by car. Walked to and surveyed the powerhouse site of the **No.35 site** (Wailevu River).	(DoE) Mr. Mikaele Belena Mr. Waisale Valagi
		Return to Dawara Village Move to Labasa by car. (Stay at Labasa)	
Tue. 27th May 2014	a.m.	Move from Labasa to Saquru River by car. Surveyed the sites for the powerhouse and penstock of the **No.31** site (Saquru River) Moved to Delaikoro (transmitting station for telecoms, etc.) and observed the conditions in the catchment area for the **No.31 site** (Saquru River).	(DoE) Mr. Mikaele Belena Mr. Waisale Valagi Mr. Tomasi Qabalse (WAF) Mr. Peni Bavia Mr. Kolimio Niuinataiwalu Mr. Josese Ratuba
	p.m.	Returned to Labasa. (Stayed at Labasa)	
Wed. 28th May. 2014	a.m.	Internal meeting	
	p.m.	Move from Labasa to Suva by plane	

First Site Reconnaissance

(4) Second Site Reconnaissance Training

As shown by the activity records in Table 11.3.2-2, the JICA Project Team carried out the second site reconnaissance for the three prospective hydropower potential sites jointly with officials of DOE. During the course of this site reconnaissance, the JICA Project Team conducted OJT for the Fijian participants in relation to the detailed site survey methods for pre-F/S through joint implementation of site reconnaissance.

Table 11.3.2-2 Activity Records for the Second Site Reconnaissance

Day		Activities (Site Visit, Meeting, etc.)	Participants from theFijian Side
Tue. 8th Jul. 2014	a.m.	Moved from Stone Bowl Lodge to Vatutokotoko village by car. Surveyed the sites for the No.1 headrace outlet and the No.2 intake weir of the **No.8 site**	Mr. Waisale Vulagi Technical Officer Mr. Jonati Delaimoala Scientific Officer
	p.m.	Surveyed the intake of the regulating dam of on the **No.8 site** (Savatu Creek). Moved from Koro village to Stone Bowl Lodge by car.	
Wed. 9th Jul. 2014	a.m.	Moved from Stone Bowl Lodge to Nadi by car	-
	p.m.	Prepared for the next site survey.	
Thu. 10th. Jul 2014	a.m.	Prepared for the next site survey.	-
	p.m.	Moved from Nadi to Labasa by plane.	
Fri. 11th Jul. 2014	a.m.	Moved from Labasa to Dreketi area by car.	-
	p.m.	Surveyed the upperstream area of the No.2 dam site (reservoir type) of the **No.35 site**.	
Sat. 12th Jul. 2014	a.m.	Moved from Labasa to Dreketi area by car.	Mr. Jonati Delaimoala Scientific Officer
	p.m.	Surveyed 1 km upstream of the No.2 Dam site of the **No.35 site**.	
Sun. 13th Jul. 2014	a.m.	Surveyed the road conditions from Dreketi to Dawara village.	-
	p.m.	Moved from Labasa to Suva by plane.	
Mon. 14th Jul. 2014	a.m.	Moved from Suva to Namosi area. Surveyed the intake site of the **No.29 site** (Wairokodra Creek)	Mr. Mikaele Belena Senior Scientific Officer Mr. Waisale Vulagi Technical Officer Mr. Jonati Delaimoala Scientific Officer
	p.m.	Surveyed the sites for the powerhouse, head tank, and penstock of the **No.29 site** (Wairokodra Creek).	
Mon. 17th Jul. 2014	a.m.	Moved from Suva to Namosi area. Survey on intake site of the **No.29 site** (Waivaka Creek)	Mr. Mikaele Belena Senior Scientific Officer Mr. Waisale Vulagi Technical Officer
	p.m.	Surveyed the sites for the powerhouse, head tank, and penstock of the **No.29 site** (Waivaka Creek).	

Second Site Reconnaissance