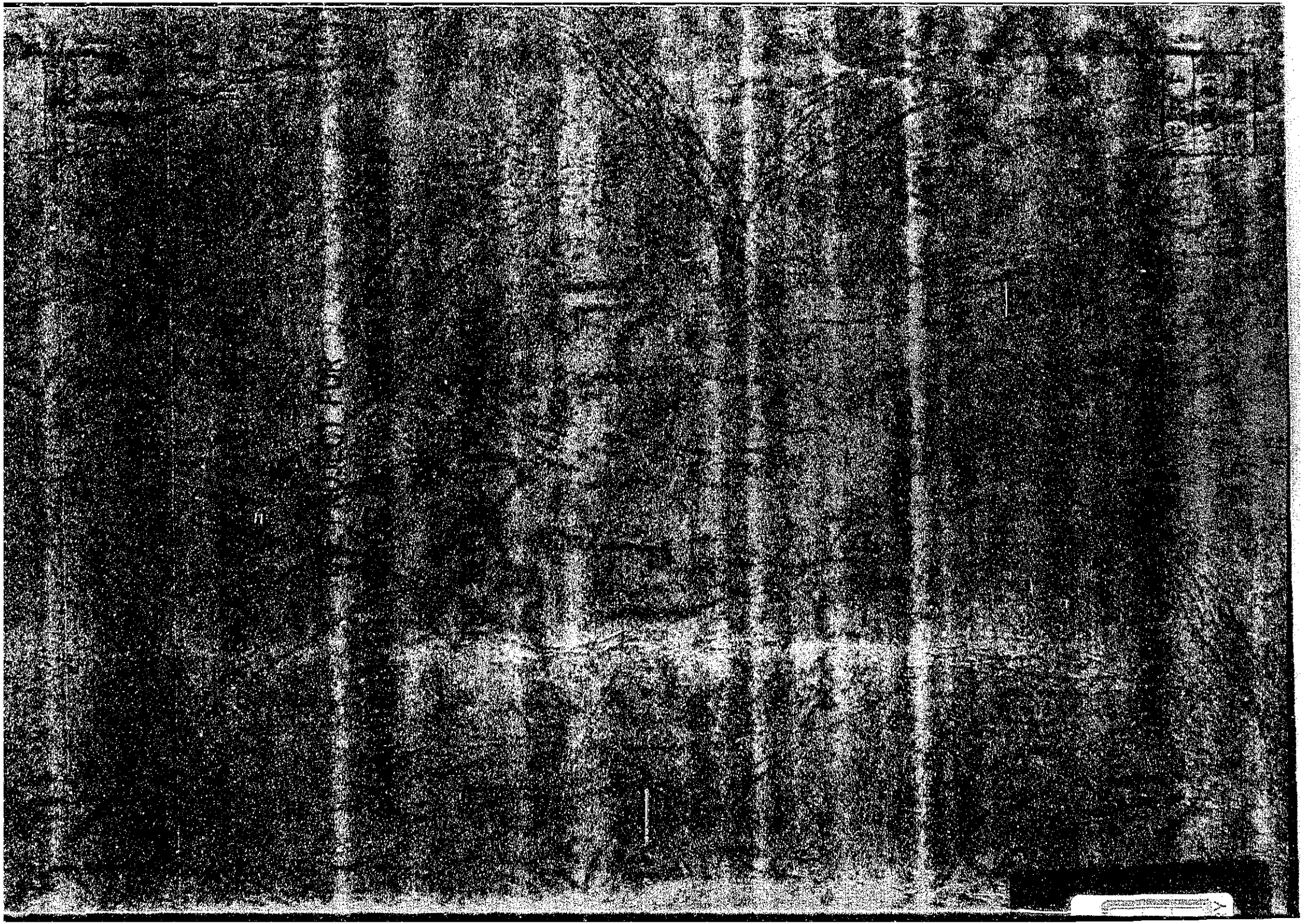


BASIC DESIGN STUDY REPORT
ON
THE PROJECT FOR
SARAKATA RIVER HYDROELECTRIC POWER DEVELOPMENT
IN
THE REPUBLIC OF VANUATU

OCTOBER, 1991

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to a request from the Government of the Republic of Vanuatu, the Government of Japan decided to conduct a basic design study on the Project for Sarakata River Hydroelectric Power Development in the Republic of Vanuatu, and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Vanuatu a study team headed by Mr. Haruo Suzuki Deputy Managing Diretor of Grant Aid Project Management Department, JICA from April 23 to May 20, 1991.

The team held discussion with the officials concerned of the Government of Vanuatu, and conducted field study at the study area.

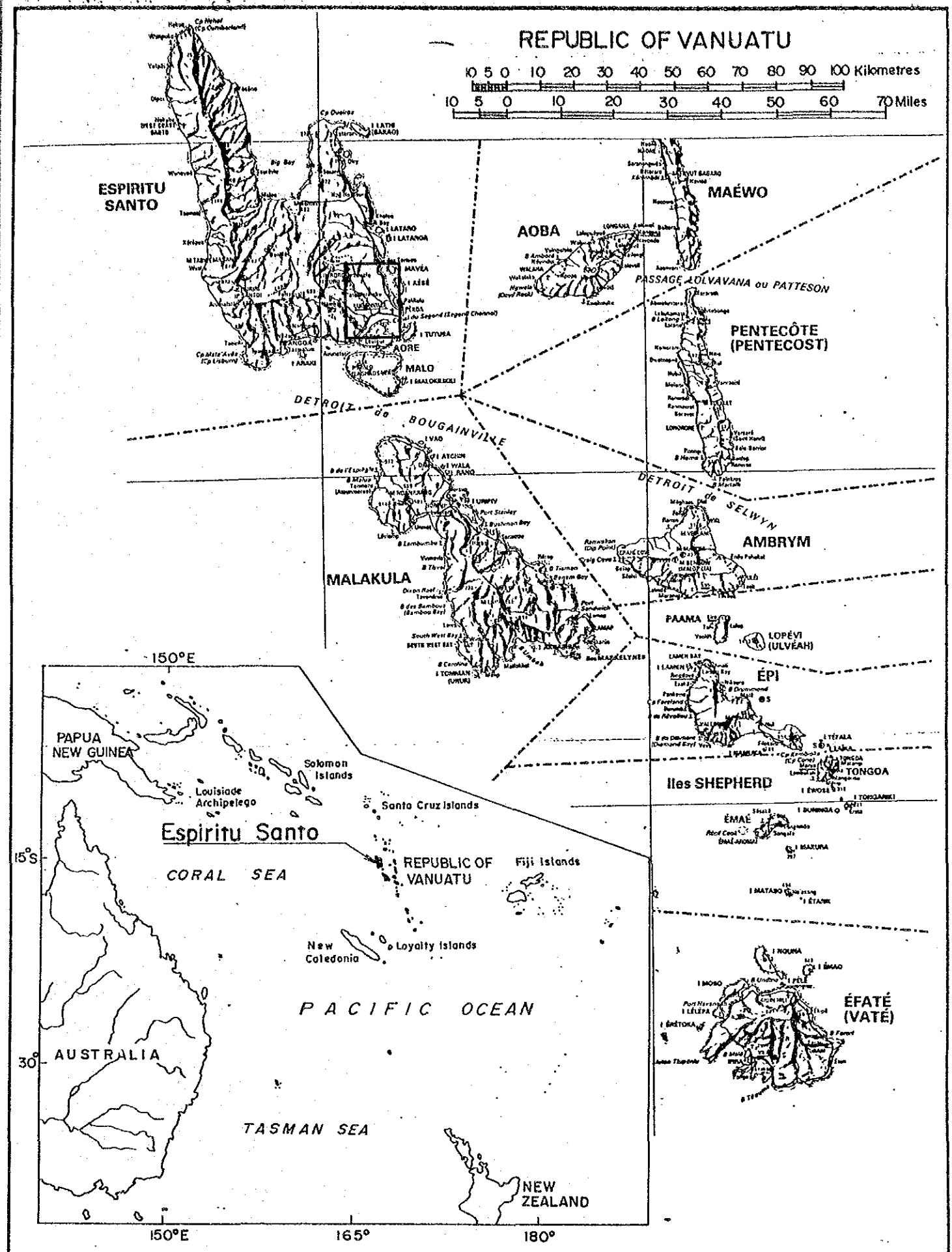
After the team returned to Japan, further studies were made. Then, a mission was sent to Vanuatu in order to discuss a draft report and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to rexpress my sincere appreciation to the officials concerned of the Government of the Republic of Vanuatu for their close cooperation extended to the teams.

October, 1991

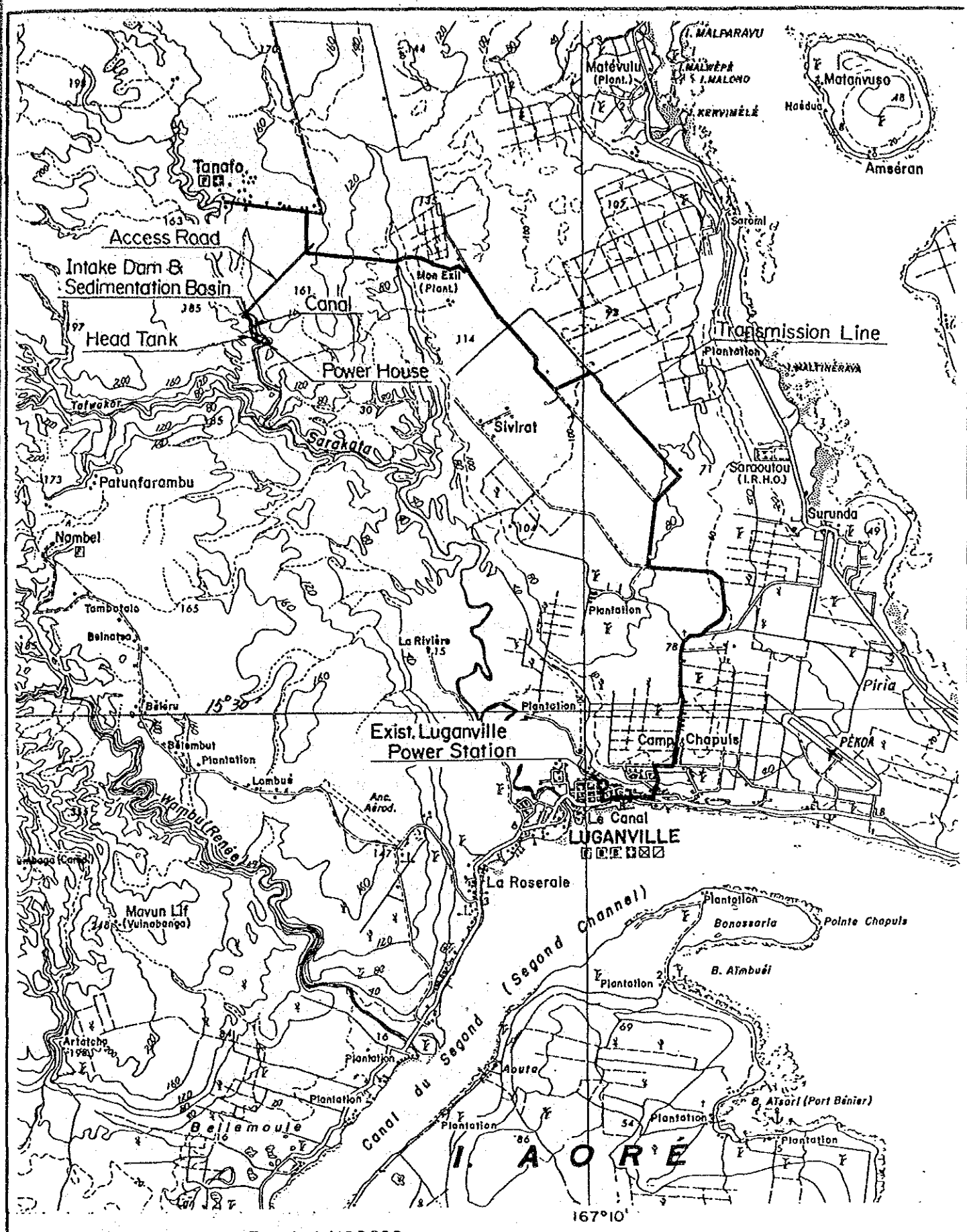
Kensuke Yanagiya
President
Japan International Cooperation Agency



The Project for Sarakata River Hydroelectric Power Development in Espiritu Santo Island

General Map

Fig. 1



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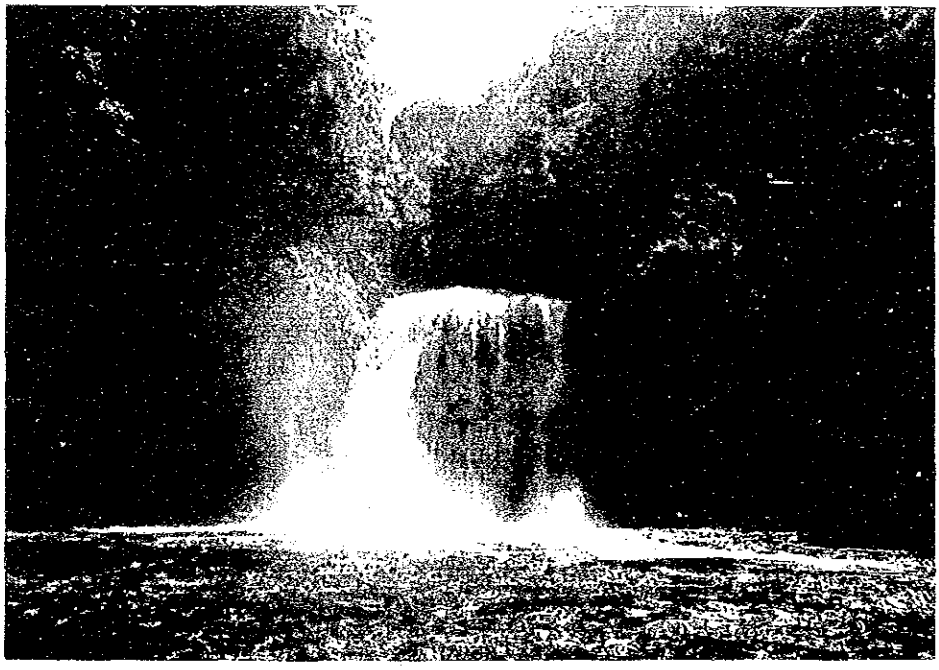
The Project for Sarakata River Hydroelectric Power Development in Espiritu Santo Island

General Layout of the Project

Fig. 2

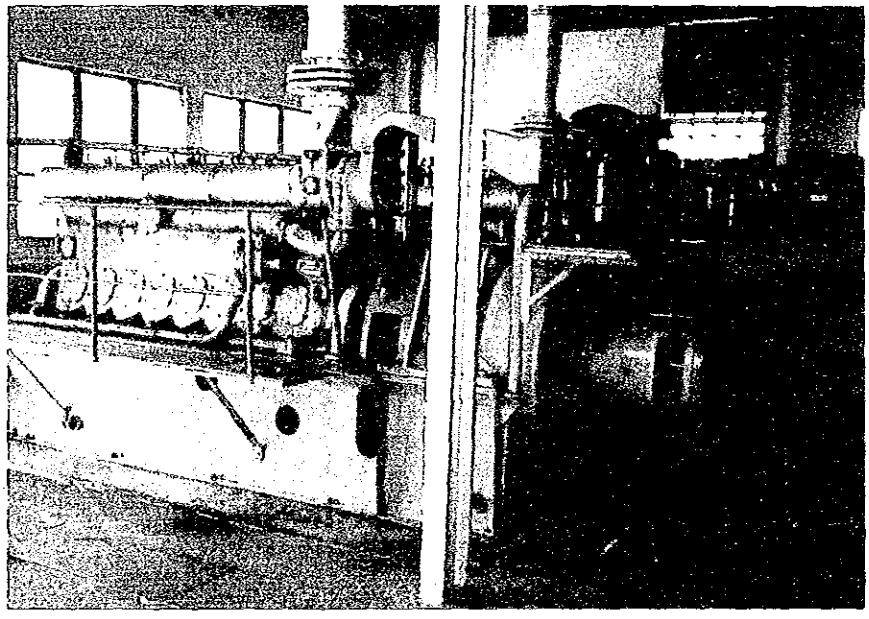
Intake Dam Site (Viewed from Down Stream Side)

Water Fall Upstream Side

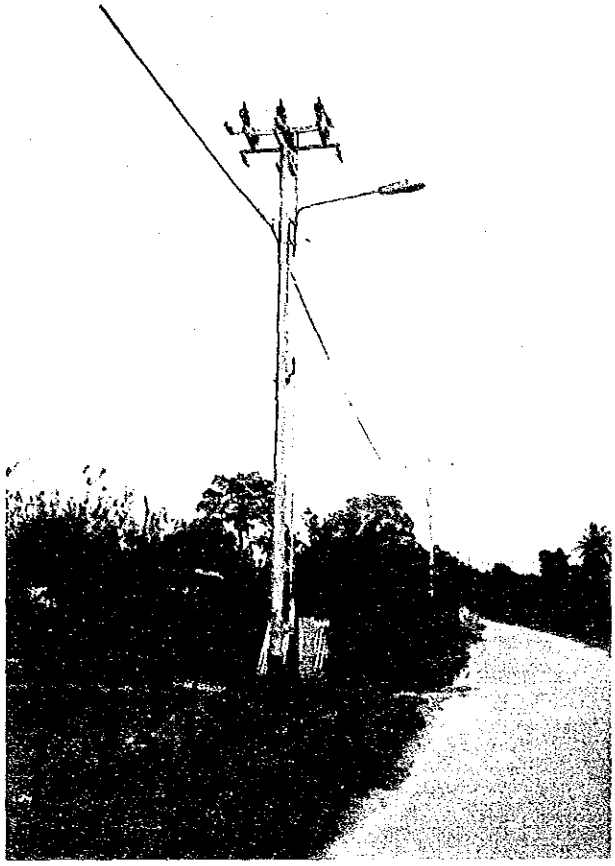


Overall View of Sarakata Water Fall

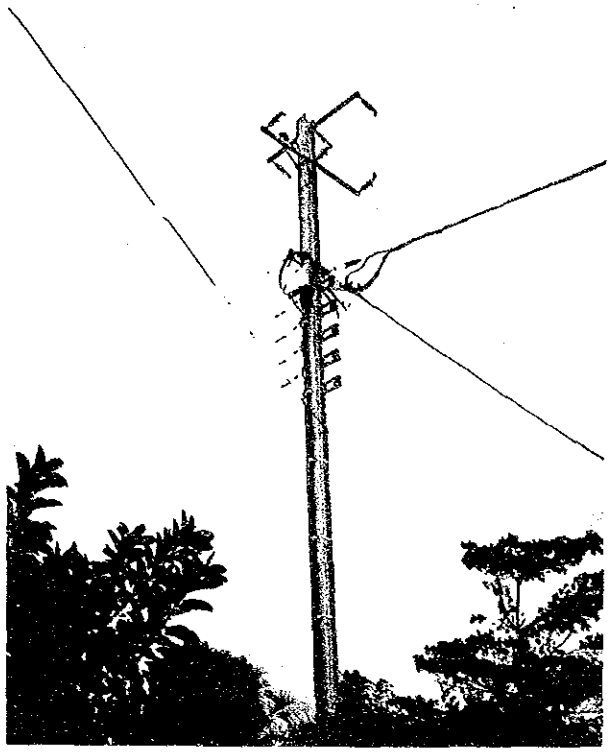
General View of UNELCO Luganville Power Station



352kVA Generator



UNELCO 5.5kV Transmission Line Pole with Section Switch



UNELCO 5.5kV Angle Pole

Proposed 15.0kV Transmission Line Route

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SUMMARY

The Republic of Vanuatu is situated to the southeast of Solomon Islands and 2,500 km to the east of Sydney. The Republic is composed of approximately 80 islands, with a total land area of 12,190 km^2 (approximately 67% of Shikoku Island of Japan), and a total population of 143,000. In recent years, the trend is the concentration of population to the capital city of Port Vila, where 13.5% of the total population (19,300 persons) are living. On the other hand, the present population of the second largest city of Luganville is 4.9% (approximately 7,000 persons) of the total.

The economy of the Republic mainly relies on agriculture (copra and palm oil), animal husbandry, fishery and tourist industries. In recent years, the decline of prices of primary agricultural products and stagnation of tourist industry are the two major causes that impedes the development of the Republic.

Currently, electric power is supplied in the Republic only to the capital city of Port Vila (Efate Island) and the second largest city of Luganville (Espiritu Santo Island which is the largest island of the Republic), and their surrounding zones. As all electric power supplied in this country is generated by diesel power stations that consume expensive imported oil, the price of electricity is high, and the use of electric power by the general public is limited.

The electric utility business is conducted by Union Electrique du Vanuatu Limited (generally called UNELCO), which has been granted a concession by the Government for the operation of generation facilities, transmission and distribution systems and substations. The Government holds 20% of the capital of UNELCO, and there is an agreement between the Government and this company to increase this share to 30% in the future. The remaining 80% of the shares is held by Union Financiere Pour L'Industrie et L'Energie, a French enterprise.

The Government of the Republic of Vanuatu is currently promoting a policy of achieving a self-supporting economy under the Second National Development Plan (1987 - 1991), and upgrading and expansion of the energy sector is one of the important items of this plan. Concerning electric

power supply, in particular, it is intended to reduce the Republic's dependence on imported oil, and the development of hydroelectric power utilizing indigenous water resources is one of the pillar of this plan.

Under the circumstances as described above, the Government of the Republic of Vanuatu intends to industrialize the areas around Luganville City which is located on the largest island of the Republic with the objectives of mitigating the concentration of population to the capital city and encouraging regional development through construction of infrastructures such as harbor and roads are expedited. Concerning the expansion of electric power supply facilities, the Government has focused attention on developing the hydroelectric potential of Sarakata River which flows in the vicinity of Luganville City, and places the top priority on the implementation of the Project.

Luganville City is currently supplied with electric power generated by existing diesel power station (with rated output of 1,080 kW and guaranteed output of 830 kW) of UNELCO, but the price of electricity is high as this is a diesel power station using high cost fuel. In addition, customers are charged 80% of the cost of electric supply connection. For these reasons, 840 homes which is 60% of the total homes in this city are currently not supplied with electric power. The utility's supply area is currently limited to urban areas, and factories, hotels, schools, etc. that are located away from the urban center are forced to relay on expensive captive power generation. The power consumers in the city that have captive generation facilities area not able to receive economic power from the grid.

However, because of insufficient number of indigenous engineers, and unfavorable international balance of trade and fiscal constraints, it is difficult to realize this hydroelectric power development project with the Government's own budget. It was for these reasons that the Government of the Republic of Vanuatu has requested Grant Aid Cooperation of the Government of Japan for the implementation of Sarakata River Hydroelectric Power Generation Project which is a top priority project.

The Government of Japan, after examining this request, decided to conduct preliminary studies to confirm the justification of the Project and whether or not it would be eligible for cooperation. In accordance with

the decision of the Government, the Japan International Cooperation Agency (JICA) dispatched to Vanuatu a preliminary study team from 9 December, 1990 to 23 December of the same year. Based on the finding of the preli-minary study team, the Government of Japan decided to conduct basic design studies for the purpose of re-confirming the justification of the Project and opti-mum nature and scope of facilities, equip-ment and materials that are required for the implementation of the Project.

For this purpose, JICA dispatched to Vanuatu a Basic Design Study Team from 22 April, 1991 to 23 May of the same year. The Basic Design Study Team surveyed the Project Site, the power transmission route, and relevant places in the area around Luganville City where the power generated by this Project is to be consumed. At the same time, the Team collected basic data which are required for the basic design of the Project structures, and discussed with representatives of the Government of the Republic of Vanuatu and UNELCO the current status of power demand and supply, electricity tariff system and other relevant matters.

Upon returning to Japan, the Team conducted analytical studies based on the information obtained by the site investigations, and formulated an optimal scheme for the hydroelectric power generation facility to be con-structed at the Project Site. The Team was again dispatched to Vanuatu from 25 August, 1991 to 8 September of the same year to explain to the authorities of Vanuatu the contents of the draft Final Report. In the preparation of the development plan were given to the following matters.

(1) Based on the assumption that the hydroelectric power station will be commissioned in the year 1994, the output of the hydroelectric power station has been determined so that the peak load can be met by the total of guaranteed output of this hydroelectric power station plus the existing diesel power station of UNELCO.

(2) The structures of hydroelectric power station will be such that it is safe and can be easily operated and maintained.

(3) Considerations were given to minimize the impact of the construction of this hydroelectric power station on the surrounding environment.

(4) This hydroelectric power station will be jointly operated with the existing power generation facilities owned by UNELCO. The

transmission line to be newly constructed for this Project will be connected to the existing transmission line network at the diesel power station of UNELCO.

The optimum scheme of development of this Project is a run-of-river type hydroelectric plant. The installed capacity will be 600 kW (300 kW x 2 units) with provision to increase the plant capacity by another 600 kW in the future.

The pertinent features and main facilities of the Project are summarized below.

Pertinent Data

Name of river	: Sarakata River
Catchment area	: 91 Km^2
Average daily runoff	
Maximum	: 9.65 m^3/sec
Minimum	: 2.84 m^3/sec
Effective head	: 27.8 m
Turbine maximum discharge	: 3.0 m^3/sec
Installed capacity	: 600 kW
Annual energy generation	: 5.16 x 10^6 kWh

Main Facilities

1. Intake dam; concrete gravity type: crest length; 43.0 m, height; 9.5 m
2. Sedimentation pond: Natural sedimentation type; width; 6.0 m, length; 15.0 m, depth; 4.0 m
3. Headrace: concrete open channel; width; 2.5 m, length; 840.0 m, depth; 2.0 m
4. Head Tank: Concrete; width; 4.0 - 6.0 m, length; 22.0 m, depth; 5.5 m
5. Penstock: Steel pipe; diamater; 1.2 m, shell thickness; 6 mm, length; 69.5 m
6. Power Station Building: Concrete building, 2 story, floor space; 143.0 m^2

7. Access Road: Gravel paved; width; 3.00 m (effective), length; 1.4 km

8. Power Generation Equipment

Water Turbine	Output: 340 kW x 2 units
	Type: horizontal shaft, Francis type
Generator	Output: 375 kVA x 2 units
	Type: Brush-less, synchronous generator
	Speed: 750 rpm
	Frequency: 50 Hz
Step-Up Transformer	Output: 750 kVA x 1 unit
	Voltage: 3.3 kV/15 kV
	Type: Outdoor, oil filled, 3-phase

9. Transmission line

Voltage	15 kV
Length	28 km
Step-Down Transformer	Output: 750 kVA x 1
	Voltage: 15 kV/5.5 kV
	Type: Outdoor, oil filled, 3-phase

In the event that this Project is implemented under the Grant Aid Cooperation by the Government of Japan, the major works to be carried out at the expense of the Republic of Vanuatu shall be the acquisition of land needed for construction of facilities, clearing of necessary areas and construction of access road for transportation of materials and equipments (from the existing main road to the dam site).

The works to be performed by the Japanese side shall be implemented in two phases, considering the size and schedule of the Project. In Phase-1, the major civil structures, the transmission line, and 1 unit of water turbine-generator with its control equipment are estimated to be completed in about 12 months after signing of construction contract, and in Phase-2, the remaining water turbine-generator and its control equipment and miscellaneous works are estimated to be completed in about 11.5 months after signing of construction contract in the second year.

The direct and indirect benefits to be created by implementation of the Project are estimated to be as follows.

(1) By commissioning this hydroelectric plant, the operating hours of the existing diesel power plant can be reduced, and it will become possible to save consumption of imported fuel oil (about 45 million VT in 1994 base), thereby contributing to improvement of foreign exchange position.

(2) Electrification of 840 homes in and near the city of Luganville will become possible. At present there are about 500 families (about 2,500 people) living in Tanafo Village which is close to the dam site. In the future, when it becomes possible for these people to burden the cost of electricity, electrification of this village and adjacent areas will also become possible.

(3) The present electricity tariff of 31.58 VT/kWh may be reduced by about 25%, and it should be possible to maintain this tariff for over 10 years.

In order to mitigate the concentration of population in the city of Port Vila, the Government of Vanuatu is now promoting a policy to develop the city of Luganville. By the introduction of this hydroelectric project, the electricity tariff in the city of Luganville can be reduced and maintained at that level over a long time which will be in line with the policy of the Government.

(4) The electric utility industry in the Republic of Vanuatu is being operated by UNELCO in which the Government holds only 20% of the shares. By the introduction of this hydroelectric project it will be possible to increase the participating share of the Government.

(5) By reducing the electricity tariff and expanding the electrification program, schools, hospital and small business which relied on captive power generation will be able to receive electricity service from the public supply system, and this will contribute to enhancing and improving the education and medical service of the inhabitants, and activating the economy of the region.

As stated before, the population which will benefit from the implementation of the Project, will be directly the about 7,000 peoples now living in the city of Luganville and adjoining districts, but with the promotion of electrification of Tanafo Village and implementation of expanding the

urban district which the city of Luganville is now promoting and by attracting industries into the district in the future, it is assumed that the population in the city of Luganville and adjacent districts will grow thereby increasing the population that will receive benefits of this Project to about 15,000 in the year 2010.

In consideration of the above factors, the implementation of the Project will have significant impact to the national development program of the Republic of Vanuatu, and it is judged that the Project is justified for Grant Aid Cooperation of the Government of Japan.

In the implementation of the Project, acquisition of land, improvement of access road for hauling equipment and materials, documentation and other procedures for importation of equipment and materials, and budgetary allocation for these purposes which must be undertaken by the Government of Vanuatu must be expediously handled.

It would be desirable to entrust the operation and maintenance of the Project to UNELCO until the year 2010 when the present contract with them expires.

As this will be the first hydroelectric power plant in Vanuatu, in order to properly manage and operate the plant, the training and education of Vanuatu nationals in the operation, maintenance and management of electric utility is essential. Therefore, in the implementation of this Project, it is judged that Technical Cooperation of the Government of Japan in receiving trainees and assigning experts is necessary.

CONTENTS

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

In the Republic of Vanuatu, electric power service is available only in Port Vila City in Efate Island and Luganville City in Espiritu Santo Island which is the largest island of the Republic.

In these two cities, the Government of Vanuatu has delegated the generation and supply of electricity to an electric utility company known as UNELCO in which the Government of Vanuatu holds 20% of the capital.

However, electricity price in these two cities has risen to a level that impedes the sound development of industry and improvement of the livelihood of the citizens, because both Port Vila Power Plant (installed capacity of 8,450 kW) and Luganville Power Plant (installed capacity of 1,080 kW) use expensive diesel oil, and the facilities of these power plants are aged.

It was for this reason that the Government of Vanuatu focused attention on the development of hydroelectric power, which does not entail fuel cost. For the development of hydroelectric power plant on Efate Island, the Government, UNELCO and a French consulting firm, SEDEP, have formed a consortium. However, up to the present time technical studies only are being conducted with no definite schedule for the implementation of this Project.

In Santo Island, the development of Sarakata River has been regarded as a promising possibility for a long time, and EDF, the French national electric utility corporation, and ENEX, a New Zealand consultant, have conducted pre-feasibility studies.

Should a Grant Aid be given for the development of a hydroelectric power project on the Sarakata River, no capital cost will have to be included in the power generating cost, and it would become possible to supply inexpensive electric power to Luganville City and its surrounding area, thereby promoting development of local industries and improving the livelihood of the inhabitants of this island.

In view of such possibility, the Government of Vanuatu has requested the Government of Japan for Grant Aid so that the hydroelectric power

development of Sarakata River mentioned above can be realized. The Japan International Cooperation Agency (JICA) dispatched a preliminary study team, in response to the request of the Government of Vanuatu, to confirm the contents of the request. Based on the report of this preliminary study team, JICA dispatched the Basic Design Study Team, headed by Mr. Haruo Suzuki, Deputy Managing Director of the Grant Aid Project Department, to the Republic of Vanuatu from April 22, 1991 to May 23 of the same year.

The Basic Design Study Team consulted with the Government of the Republic of Vanuatu, UNELCO and other relevant organizations, and conducted on-site investigations which included a topographic survey conducted by clearing virgin forest of the proposed project site.

The major tasks performed by this Study Team during its stay in Vanuatu were confirmation of the contents of the request of the Government of the Republic of Vanuatu, study of power supply conditions and power demand in Luganville City, topographic survey of proposed site, study of construction conditions, and the capability of Republic of Vanuatu in the operation and maintenance of the power facilities.

The basic agreements reached between the Government of the Republic of Vanuatu and the Study Team have been recorded in a minute which both parties signed on May 3, 1991.

Upon returning to Japan, the Study Team developed a design of hydroelectric power plant having the optimal scale based on the results of on-site investigations and topographic map prepared by the on-site surveys, and selected the required equipments and materials, calculated the approximate project cost and developed an implementation schedule.

At the same time, the Study Team developed a detail operation and maintenance program for the hydroelectric power generation facility and power transmission facility. The Study Team also prepared a recommendation on how the current electricity tariff could be reduced should this Project be constructed on a Grant Aid basis.

JICA prepared a draft Final Report incorporating the results of the studies, and dispatched to Vanuatu a mission headed by Mr. Kazuhisa Matsuoka, Director of Basic Design Investigation 1st Section of Grant Aid Project Department from 25 August, 1991 to 8 September of the same year to explain and discuss the contents of the Report.

The Report has been prepared to describe the optimal plan for the implementation of the Project. The members of the Basic Design Study Team, the itinerary of the Team, the representatives of the Government Agencies of the Republic of Vanuatu with whom the Team interviewed, the minutes of discussions, and data and documents collected in Vanuatu, are compiled in a separate volume which is attached to the Report.

CHAPTER 2

BACKGROUND OF THE PROJECT

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2.1 GENERAL DESCRIPTION OF THE REPUBLIC OF VANUATU

(1) Geography and climate

Until the independence in July, 1980, the Republic of Vanuatu has been governed jointly by Britain and France. This country consists of a Y-shaped long strip of archipelago located from 18 to 28° latitude south, 166 to 172° longitude east.

The total land area of the nation is approximately 12,190km^2. Port Vila, the capital city, is on Efate Island, which is located near the geographical center of the archipelago and has an area of 887km^2. The islands have a wide topographical variation ranging from high mountains to coral reefs.

The climate is tropical in the northern areas and subtropical in the southern areas. Average annual rainfall in Port Vila is 2,360mm/year. The variation of temperature is relatively mild and remains between 30°C and 17°C. Periodical attacks by cyclones cause damages all over the country. The largest damage in the history was caused by the cyclone in February, 1987, which divastated Port Vila and southern islands. In addition, three large cyclones destroyed crops and houses in a period of half a year from November, 1987 to April, 1988.

The Project is planned in Luganville, the second largest city of Vanuatu on Santo Island, which is approximately 310km north-west of Efate Island.

(2) Population

The national population is 142,944 (1989) and the average rate of increase over the last 10 years is 2.8% per year. (The average over 14 neighbouring countries is 2.5%.)

The population is considerably centralized, with 26,294 persons (18.4%) living in Port Vila and Luganville. The land area and population of principal islands are shown in Table 2-1-1.

Table 2-1-1 Summary of Data on Principal Island

Name of Island	No. of Inhabitants	%	Area (km^2)	%	No. of Houses	%
Espiritu SANTO	25,581	17.9	4,248	34.8	4,952	17.5
Malakula	19,298	13.5	2,052	16.8	3,654	13.6
Pentecost	11,341	7.9	499	4.1	2,275	8.1
Ambrym	7,191	5.0	660	5.4	1,440	5.1
Epi	3,628	2.5	446	3.7	760	2.7
Efate	30,868	21.6	923	7.6	6,113	21.6
Others	45,037	31.6	3,362	27.6	8,858	31.3
Total	142,944	100%	12,190	100%	28,252	100%

Source: Statistics Office of NPSO

(3) Economy

The economy of Vanuatu has been chiefly based on agriculture of copra and coconut oil, stock raising, fishery and tourist industry. The recent depression of agricultural primary product has severely affected the acquisition of foreign currencies.

On the other hand, the exportation of beef and timber has been increasing gradually in recent years. Tourism has become an important source of foreign money and is encouraged by governmental efforts.

Vanuatu has a chronic deficit in the balance of exportation and importation. As of 1990, exportation was 20.2 million US$, importation was 103.8 million US$, and the deficit was 83.6 million US$.

The total GDP is 150.5 million US$ (1 US$ = 108.75 VT) as of 1990. The breakdown among industries is: fishery 29.0 million US$ (19.2%), manufacturing 19.1 million US$ (12.7%), and commercial and service industries 102.4 million US$ (68.1%). The

economy of Vanuatu is chiefly supported by commercial and service industries. The total GNP in 1990 (based on prices in 1983) is 107.5 million US$, i.e., 752 US$ per capita.

(4) Relations with Japan

Since diplomatic relations between Vanuatu and Japan were opened on January 8, 1981, visits of VIPs has been relatively active including Prime Minister Lini visiting Japan in 1984, Japanese then Foreign Minister Kuranari visitig Vanuatu in 1987, and Mr. and Mrs. President Timakata visiting Japan in 1989 (attending the Rites of Imperial Funeral). Trade relationship has been becoming closer including increasing importation of beef.

Japan has so far provided Grant Aid Fund and Technical Cooperation to the Republic of Vanuatu, mostly for its primary industries. The bilateral ODA assistance in '89 was 3.74 million dollars, and Japan is the fourth contributor to Vanuatu.

In the area of Grant Aid Cooperation, Japan is contributing to the development of agriculture and fishery which directly promote the economic development and also the development of economic infrastructures. Since independence, the assistance by Japan is steadily growing. (The cumulative amount of Grant Aid Cooperation up to fiscal 1990 was 2,979 million yen in terms of assistance provided by Exchange of Notes.)

As of the end of December, 1990, the following Grant Aid Cooperation have been provided to the Republic of Vanuatu.

Grant Aid (Based on Exchange of Notes)
(as of end of December, 1990)

(in 1 million yen)

Date of Agreement	Project Name	Amount
	(General Grant Aid)	
Apr. 9, 1985	Regional Commercial Center Construction Project	270
Oct. 7, 1986	Regional Commercial Center Construction Project	396
July 27, 1987	Regional Commercial Center Construction Project	414
Apr. 19, 1988	Regional Commercial Center Construction Project	150
July 26, 1989	Bauerfield International Airport Terminal Building Construction Project	1,115
	(Fishery Grant Aid)	
Apr. 23, 1982	Fishery Development Project	210
Mar. 17, 1986	Village Fishery Equipment Upgrading Project	393

In the area of Technical Cooperation, emphasis has been placed in human resource development such as education and training, since the population of Vanuatu is relatively large as compared to neighboring nations, and around half of the population belong to the young generation. (The total Technical Cooperation provided up to fiscal 1990 was 597 million yen.) The system of providing technical cooperation is steadily being developed, for example, the agreement for dispatch of "Japan Overseas Cooperation Volunteers" was concluded in July, 1987.

Technical Assistance
(Acceptance of Trainees, Dispatching Japanese experts)

(Unit: in number of persons)

	Sponsoring Organization	FY1988	FY1989	FY1990	Total	
Accepting Trainees	JICA	36	7	10	53	Administration, communication, broadcasting.
Dispatching Expert	JICA Expert	9	-	-	9	Communication, broadcasting, health & hygiene, transportation and traffic.
	JICA Study Team	51	4	9	64	Fishery, commerce, trade, forestry, transportation and traffic.
	JICA, Japan Overseas Cooperation Volunteers	7	1	5	13	Communication and broadcasting

2.2 NATIONAL DEVELOPMENT PLAN

Since the independence in 1980, Vanuatu has formulated national development plan aimed at economic development and the improvement of the living standards of the people. After the First 5-year Plan (1982-1986), the Second 5-year Plan (1987-1991) is ongoing at present.

The purposes of this plan are:

1. Achievement of economic independence through the development of domestic resources;

2. Expansion of the responsibility of the Vanuatu people in the areas of policy making and administration through the training of able Vanuatu people;

3. Expansion of trade through the expansion of the facilities to process and produce domestic resources with more value added;

4. Correction of economic disparity between urban and rural areas;

5. Enhancement of the contribution of the private sector to the national economy through the expansion of the economic activities;

6. Avoidance of the possible damage to the environment and cultural legacies due to the expansion of economic activities; and

7. Establishment of a stable political environment based on parliamentary democracy.

In order to achieve the above objectives, budgetary measures for each sector have been planned and published in "Second National Development Plan 1987-1991". As apparent from Table 2-1-2, more than 90% of the governmental financing is supported by assistance from foreign countries.

In the field of energy industries, the following objectives are pursued to achieve the aims of the Second 5-year Plan:

- Secure provision of energy at affordable prices, with reliability, and in sufficient quantities;

- Acceleration of energy's efficient utilization

- Development of low-cost, long-term national resources; and

- Reduction of expenditure for oil importation

In the field of electric industries, plan to achieve the above energy objectives include the efficient utilization of biomass, geothermal, and hydraulic energy.

Table 2-1-2 TOTAL DEVELOPMENT BUDGETARY REQUIREMENTS BY FUNCTIONAL AND ECONOMIC CLASSIFICATION, 1987-91, (IN THOUSANDS OF VATU)

FUNCTIONAL CLASSIFICATION / ECONOMIC CLASSIFICATION	— 1987 —			— 1988 —			— 1989 —			— 1990 —			— 1991 —			— TOTAL —		
	DONOR	GOVT	TOTAL	DONOR	GOVT	TOTAL	DONOR	GOVT	TOTAL	DONOR	GOVT	TOTAL	DONOR	GOVT	TOTAL	DONOR	GOVT	TOTAL
A. BY FUNCTIONAL CLASSIFICATION																		
1. Plan Implementation and Monitoring	30414	1540	31954	50780	4302	55082	47830	4202	52032	47830	4202	52032	42730	4252	46982	219584	18498	238082
2. Population, Employment and Manpower Development	537985	0	537985	795241	8096	803337	778177	18041	796218	693588	22462	71650	691098	24914	716012	3496089	73513	3569602
3. Land Tenure & Development	30525	400	30925	80762	20143	100905	28943	22076	51019	16705	21627	38332	7600	21333	28933	164535	85579	250114
4. Regional Growth & Devt.	107633	80000	187633	176168	22200	198368	170905	0	170905	185980	0	185980	217436	0	217436	858122	102200	960322
5. Agriculture and Livestock	626628	2300	628929	821018	3240	824258	829108	3242	832350	4509985	4262	455247	415991	4365	420356	3143730	17409	3161139
6. Forestry	37877	948	38825	74733	2715	77448	93590	1720	95310	72580	1810	74390	186504	1760	188264	465284	8953	474237
7. Fisheries	428276	650	428926	239175	2017	241192	123361	2018	125378	96378	4155	100533	63629	3495	67124	950819	12334	963153
8. Minerals Development	26798	1664	28462	37324	3342	40666	49300	3838	53138	35924	3052	38976	19500	1467	20967	168846	13363	182209
9. Industry and Trade	5120	50	5170	9793	550	10343	139140	33934	173074	4904	100	5004	37504	9350	46854	196461	43984	240445
10. Cooperative and Rural Business Development	156105	17297	173402	136054	16222	152276	119659	18599	138258	120635	19957	140592	105620	7865	113485	638073	79940	718013
11. Tourism	8750	2500	11250	31500	5000	36500	24500	5000	29500	8250	2292	10542	0	0	0	7300	14792	87792
12. Money, Banking & Finance	149605	103000	252605	391830	0	391830	335015	0	335015	57620	0	57620	44600	0	44600	978670	103000	1081670
13. Social Welfare and Community Development	10850	1300	12150	4900	1300	6200	4650	1300	5950	2380	1300	3680	2050	1350	3400	24830	6550	31380
14. Health Services	329802	0	329802	295896	0	295896	197415	0	197415	121748	0	121748	162588	0	162588	1107449	0	1107449
15. Education and Training	497783	12685	510468	1353838	30005	1383843	1096202	34500	113072	651232	9360	660592	489967	6520	496487	4089022	93070	4182092
16. Culture	2350	50	2300	16650	6290	22940	5900	3280	9180	1450	90	1540	76500	100	76600	102750	9810	112560
17. Public Order and Safety	201700	1500	203200	239450	0	239450	239200	0	239260	230200	0	230200	230200	0	230200	1140750	1500	1142250
18. Marine Transportation	435922	0	435922	1170800	2776	1173467	236500	3317	239817	72500	3317	75817	196500	3317	199817	2112222	12618	2124840
19. Air Transportation	236677	150	236827	751052	5545	756597	103700	10345	114045	165550	10345	175895	108800	22945	131745	1365779	49330	1415109
20. Land Transportation	74000	0	74000	341600	8087	349687	263865	18927	282792	266000	29962	295962	239500	43962	283462	1184965	100938	1285903
21. Posts & Telecommunications	3733	4530	42263	357261	7004	364265	385475	116369	401844	226771	23534	250305	155311	31808	187119	1162551	83245	1245796
22. Energy	15450	0	15450	88220	1700	89920	36595	2460	39055	23980	3790	27770	12100	2995	15095	176345	10945	187290
23. Water Supply & Sanitation	104023	11994	116017	219249	23182	242431	499208	26343	52551	504774	30978	535752	353664	25958	379622	1680918	118455	1799373
24. Housing	1000	0	1000	24200	8700	32900	83200	6400	89600	258200	6600	264800	328200	7100	335300	694800	28800	723600
25. Environment & Conservation	9046	0	9046	19762	260	20022	4105	260	4365	0	260	260	0	260	260	32913	1040	33953
26. Other Government Services	174368	4277	178645	473553	35539	509092	656301	56852	713153	257030	59911	316941	179645	129708	309353	1740897	286287	2027184
TOTAL — FUNCATIONAL	4276320	246835	4523155	8200809	218106	8418915	6551844	293022	6844866	4573194	263366	4836560	4367237	354824	4722061	27969404	1376153	29345557
B. BY ECONOMIC CLASSIFICATION																		
1. Operational Costs	53065	38091	573156	4890996	139391	628487	459721	196461	656182	410269	226851	637120	342760	315774	658534	2236911	916568	3153479
2. Technical Assistance	1455160	1540	1456700	2257662	9527	2267189	1860218	11688	1871906	1624169	11688	1635857	1436602	10988	1447590	8633811	45431	8967942
3. Training Scholarships	421775	1822	423597	494375	1902	496277	510480	1852	512332	494678	3940	498618	470098	3518	473616	2391406	13034	240440
4. Equipment	592038	10750	602788	1126593	13405	1139998	112464	1955	1126219	614939	980	615919	517921	2250	520171	3975755	29340	4005095
5. Capital Costs	1272282	194632	1466914	3833083	53881	3888694	2597161	81066	2678227	1429139	19907	1449046	1599856	22294	1622150	10731521	371780	11103301
TOTAL — ECONOMIC	4276320	246835	4523155	8200809	218106	8418915	6551844	293022	6844866	4573194	263366	4836560	4367237	354824	4722061	27969041	376153	29345557

Source: NPSO

2.3 ELECTRIC POWER STATUS

2.3.1 Features of Electric Utility Industry

Diesel generators provide electricity on a 24-hour basis in the capital city Port Vila (100% electrified) and Luganville (40% electrified). Other areas have no supply of electricity, except that few villages have small diesel generators providing electricity only during night hours.

In Port Vila and Luganville, the supply of electricity is operated by UNELCO, a government-invested utility company, to which the Republic of Vanuatu has transferred the right to generate and distribute electricity.

Table 2.3.1 shows the conditions in which electricity is supplied in these two cities.

The average retail price of electricity is 24.15VT/kWh (30.2 yen/kWh) in Port Vila and 28.9 VT/kWh (36.1 yen/kWh) in Luganville. A household using three 100W light bulbs would pay about 10% of the monthly income for electricity, which is considered costly. The principal reason for this rather high price is the fact that expensive imported oil is used in diesel power generation.

Table 2.3.1 Supply of Electricity in Port Vila and Luganville

(as of December, 1990)

	Port Vila	Luganville
Installed capacity (kW)	8,540	1,080
Maximum demand (kW)	5,318	600
Annual generation of electricity (MWh)	30,122	2,736
Annual consumption of electricity (MWh)	28,120	2,465
Consumption of fuel oil (kl)	6,728.0	886.8
Average retail price (VT/kWh)	24.150	28.900
Installed capacity per capita (kW/person)	0.442	0.155
Consumption of electricity per capita (kWh/year)	1.457	0.353
Fuel cost in retail price (VT/kWh)	12.820	19.280

Source: Energy Unit, UNELCO

2.3.2 Current Tariff System

The current tariff system has been defined based on "Convention relating to the Concession for the generation and Public Supply of Electric Power in Luganville" and "Specifications relating to the Concession for the Generation and Public Supply of Electric Power in Luganville" dated August 15, 1986. That is, it has been decided to apply the same tariff system to both Port Vila and Luganville.

Table 2.3.2 Electricity Tariff System

Category	Fixed charge	Meter charge
Residential	(VT/Month)	(VT/kWh)
- 60 kWh	-	0.65P : 20.53
61 kWh - 120 kWh	-	1.0 P : 31.58
120 kWh -	-	1.70P : 53.69
Low Voltage Supply		
Non reisdential	19P : 600.02	1.0 P : 31.58
Special use	20P : 631.60	0.90P : 28.42
Official Use	-	0.80P : 25.26
High Voltage Supply	25P : 789.50	0.67P : 21.16

The following equation is applied to variable "P" (equivalent to unit price of average electricity tariff) which is the basis of electricity tariff system.

$$P = P_0 \left\{0.09 + 0.35 \frac{G}{G_0} + \left(0.03 \frac{I}{I_0} + 0.33 \frac{M}{M_0} + 0.20 \frac{K}{K_0}\right) \times \left(0.05 + 0.05 \frac{V_0}{V}\right)\right\}$$

The applicable basic rate from July 1, 1991 is as follows.

The coefficients in this equation are defined in detail in the agreement, but they generally have the following meanings.

P_0 : The standard kWh unit price applied from August 1, 1986 (22.22 VT/kWh).

G_0 : The price of 1 liter of diesel oil as of August 1, 1986 delivered at the wharf of Port Vila, that is, 22.14 VT/l.

I_0 : The total of business tax, direct tax and indirect tax paid by UNELCO during 1986.

I_o' = 10,000,000 VT (Paid at Port Vila by UNELCO)
I_o'' = 1,525,313 VT (Paid at Luganville by UNELCO)

I_o = 11,525,313 VT (Total payment by UNELCO)

M_o : The average daily wage which a bachelor laborer in Port Vila earned in the second quarter of 1988 (without payment of boarding cost and food cost), that is; M_o = 804 VT/day

K_o : The price indices of intermediate goods as released by INSEE (French National Economics Research Institute), which is, according to the release of the second quarter of 1986; K_o = 149.7

V_o : The energy sale of UNELCO in fiscal 1985 (starting on July 1, 1985 and ending on June 30, 1986).

V_o' = 16,949,774 kWH (Supplied to Port Vila by UNELCO)
V_o'' = 2,223,520 kWH (Supplied to Luganville by UNELCO)

V_o = 19,173,294 kWH (Total supply by UNELCO)

G, M, I, K and V are defined as below.

G: The average purchase price of 1 liter of diesel oil by UNELCO, which is calculated by the following equation:

$$G = \frac{G' \times L' + G'' \times L''}{L' + L''} \quad (VT/\ell)$$

Here, G', G", 1' and L" are defined as below.

G' = The average purchase price of 1 liter of diesel oil delivered at wharf of Port Vila.

G" = The average purchase price of 1 liter of diesel oil delivered at wharf of Luganville.

L' = The amount of diesel oil consumed at Port Vila Thermal Power Station during the first 3 months in the 6 months before re-adjustment (in liter).

L" = The amount of diesel oil consumed at Luganville Thermal Power Station during the first 3 months in the 6 months before re-adjustment (in liter).

M: The average daily wage (excluding boarding cost and food cost) which a bachelor laborer at Port Villa received from Burns Philp and Ballande-Vanuatu in the first 3 months in the 6 months before re-adjustment.

When a certain wage system or agreement of collective bargaining is introduced to Vanuatu, the consignor and the consignee shall confer to modify the definition of M based on such rule.

The new index shall be applied in such a manner that neither profit nor loss is created.

I: All business taxes, direct taxes and indirect taxes which have been borne by the consignee at Port Vila and Luganville.

K: The price indices of intermediate goods in terms of French Franc, as released by INSEE (National Statistics and Economics Research Instutute). The value is for the quarter in the one-half year preceding re-adjustment.

As the indices are given in French Franc, the indices must be multiplied by 0.069/C when the exchange rate of Vatu (1 VT = 0.69 French Franc as of June 30, 1986 according to the secretariat of French Embassy, and to reviewed on August 1, 1988) changes to "C".

V: Energy sales (kWh) to consumers from Port Vila and Luganville in the first 12 months in the 15 months preceding the day of re-adjustment.

The variable "P", which is the basis of electricity tariff as adjusted by the above rules for applying it in the 3rd quarter of fiscal year 1991, is given as follows.

P ＝31.58VT/kWh となる。

$$\left.\begin{array}{l} G' = 42.38 \\ G'' = 59.63 \\ L' = 1,796,560 \\ L'' = 228,800 \end{array}\right\} \quad G = \frac{42.38 \times 1,796,560 + 59.63 \times 228,800}{1,796,560 + 228,800} = 44.35 (VT/\ell)$$

M ＝ 916

$$\left.\begin{array}{l} I' = 17,500,000 \\ I'' = 2,310,000 \end{array}\right\} \quad I = 17,500,000 + 2,310,000 = 19,810,000 (VT)$$

$$\left.\begin{array}{l} K' = 165.6 \\ C = 0.054 \end{array}\right\} \quad K = 165.6 \times \frac{0.069}{0.054} = 211.6$$

V ＝26,039,877 (kWh)

$$\therefore P = 22.22 \left\{ 0.09 + 0.35 \cdot \frac{44.35}{22.14} + \left(0.03 \cdot \frac{19,810,000}{11,525,313} + 0.33 \cdot \frac{916}{804} + 0.20 \cdot \frac{211.6}{149.7}\right)\left(0.05 + 0.05 \frac{19,173,294}{26,039,877}\right) \right\}$$

＝31.27VT/kWh

with a margin of 1%

"P" = 31.27 x (1 + 0.01) = 31.58 (VT/kWh)

2.3.3 Electricity Development Plans

According to the Second 5-year Plan, future development of electricity will be directed to the maximum utilization of domestic energy resources by means of the methods of power generation listed below. Of the 187.3 million VT financial requirement in the field of energy until 1991, as much as 94% (176.3 million VT) depends on the assitance from foreign countries.

(1) Power sources for urban areas (output 2-3kW)

1. Hydroelectric generation: Construction is planned in two rivers discussed below.

2. Charcoal generation: A feasibility study was conducted on Efate Island in 1984.

3. Geothermal generation: A boring survey is planned in the northern part of Efate Island.

4. Diesel generation: One generator is planned to be added to Port Vila Power Station.

(2) Power sources for rural areas (output 5-50kW)

1. Wood-fueled steam power generation
2. Micro-hydro power generation
3. Solar power generation

The following two power generation development plans are ongoing at present:

(1) Construction of Sarakata River Hydroelectric Power Plant on Santo Island (planned in this report)

(2) Hydroelectric Development of Teouma River on Efate Island

Hydroelectric power generation in Teouma River will be developed by HYDRO POWER DEVELOPMENT Limited which will be established by the joint investment of the following three parties:

- Government of Vanuatu 40% (share of investment)
- UNELCO 30% (share of investment)
- SEDEP (SOCIETE D'ETUDES ET DE DEVELOPMENT ELECTRO-TECHNIQUE POLYNESIENNE) 30% (share of investment)

While a stockholders' agreement was signed by the above three parties on January 23, 1990, no specific plans have been announced so far.

2.4 BACKGROUND AND CONTENT OF THE REQUEST FOR ASSISTANCE

2.4.1 Background of the Request for Assistance

While the Republic of Vanuatu consists of 12 principal islands, the distribution of electricity is limited to the capital Port Vila (Efate Island), the second largest city Luganville (Santo Island, the largest island of the country), and neighbouring areas. The supply of electricity to these two cities is operated by UNELCO, a government-financed utility company, to which the Government has transferred the right to generate and publicly supply electricity. Because of the supply is depending on diesel power generation using expensive imported oil, the retail price of electricity is considerably high and the usage by general inhabitants is limited. In addition, the dependence on imported oil is pressing the entire economy of the country. At present, the Republic of Vanuatu is promoting the Second National Development Plan (1987-1991), in which a principal stress is placed on the improvement and expansion of energy industries.

In particular, the supply of electricity is envisioned to get out of the dependence on oil and to shift to hydroelectric power generation utilizing rivers in the country. At present, plans in Teouma River on Efate Island and Sarakata River on Santo Island are identified as promising projects.

On the other hand, the Government of Vanuatu is envisioning the industrial development in the areas surrounding Luganville, which is the second largest city in the country and has a potential for future development. One of the aims is to moderate the recent centralization of population to the capital, as well as to promote the development of local areas. The Government is making the best of its way in the development of infrastructure including ports and roads.

As for power generation facilities, hydroelectric power generation has been planned in Sarakata River located in the suburbs of Luganville. Surveys starting from the early half of the 1980's identified this river as one of the best sites for such development, as follows:

(1) 1956 - SEE (Societe D'Etude et Enterprise) proposed the development of hydroelectric power generation in Sarakata River.

(2) 1964 - Electricite de France, International conducted a survey on the water resources on Efate, Malakula, and Santo Islands and made a proposal.

(3) 1985 - OSTROM (France) conducted a survey for the development of water resources of Efate and Santo Islands.

(4) 1986 - ENEX, TONKIN & TAILOR LTD. (New Zealand) conducted a survey on the water resources of Teouma River on Efate Island and Sarakata River on Espirito Santo Island and made a proposal.

At present, the distribution of electricity in Luganville is limited to the central area of the city. Among the 7,000 people living in and around the city, 2,800 (approx. 40%) are receiving electricity. The electrification of ordinary households is retarded because of the high price of electricity, as well as the need for newly contracting rate payers to pay 80% of the costs of distribution and lead-in lines. Factories consuming a large amount of electricity and facilities located distantly from existing power distribution network are forced to install private generators. Some of such consumers are supplementing the supply of commercial electricity with private generators, because of the insufficient capacity of reliability of commercial electricity.

In order to find a way out of this situation, the Government of the Republic of Vanuatu planned the construction of a power station utilizing Sarakata River in order to provide affordable electricity to the inhabitants of Luganville, as well as to reduce the expenditure of foreign money and to improve the international balance of payments through the reduction of fuel importation. For this reason, the Government of Vanuatu requested to the Government of Japan for gratuitous financial assistance.

In response to this request, the Japanese government decided to conduct a preliminary study to confirm the validity of the plan and to

determine the possibility of cooperation. The Japan International Cooperation Agency, based on this decision, conducted a preliminary study from December 9 to December 23, 1990. As the result, the Japanese Government decided to conduct a basic design study which is intended to re-confirm the justification of the Project and to identify the most appropriate types and scales of facilities and equipment to be provided in this assistance, and to examine the contents of the assistance.

2.4.2 Contents of the Request for Assistance

The following are the contents of the request for assistance concerning the Project which was confirmed by the preliminary study conducted by JICA in December, 1990.

In this plan, a water intake facility will be constructed near Tanfo in the middle reaches of Sarakata River on Santo Island, a 1,000kW power station will be constructed about 800m downstream of the intake facility, and the electric power will be distributed through existing Luganville power distribution network.

The outline of the facilities specified in the request is as follows:

a.	Water intake facility	Dam: 5.0m (H) x 20.0m (L) Intake port: 2.0m (B) x 1.7m (D)
b.	Desiltation pond	4.0m (B) x 22.0m (L)
c.	Headrace canal	2.0m (B) x 2.0m (H) x 800.0m (L)
d.	Head tank	$700m^3$
e.	Penstock	1,600mm (D) x 60.0m (L)
f.	Powerhouse	22m (W) x 11m(L) = $242m^2$
g.	Access road	4.0m (W) x 4.0km (L)
h.	Turbine generator	500kW x 2 units
i.	Transformer	625kVA x 2 units
j.	Transmission line	20kV, 15km (L)

Note: L: length, H: height, D: depth, B: breadth, W: width

In addition to the above facilities, a request was made for the dispatchment of experts and the acceptance of trainees as follows:

1. Experts : Management of electric utilities 1 person

2. Trainees: Hydropower engineering 1 person
Mechanical engineering 1 person

As the result of the consultation with the Government of Vanuatu, the request concerning the dispatchment of experts and the acceptance of trainees was changed by the Basic Design Study Team as follows, while no changes were made in the request concerning principal facilities:

1. Experts : Management of electric utilities
2 persons (short-term)

Guidance of operation of hydroelectric power station 1 person (long-term)

2. Trainees: Hydropower engineering 4 persons
Civil engineering 1 person

CHAPTER 3

GENERAL DESCRIPTION OF PROJECT AREA

CHAPTER 3 GENERAL DESCRIPTION OF PROJECT AREA

3.1 OUTLINE OF DAM AND POWER STATION SITE

The Project site will be located in the middle reaches of the Sarakata River (about 15 kilometers from the river mouth), northwest of Luganville.

Undeveloped virgin forest land occupies the right bank of the river, while the left bank is a plateau about 120 meters above sea level dotted with meadowlands. There are no communities to be found in the vicinity of the Project Site, but about three kilometers upstream from the Site is Tanafo, a village of about 500 households. This non-electrified community is totally self-sufficient. There are one French elementary school affiliated with the Catholic church and one dispensary for the public facilities in the village as public facilities. There are no paved roads covering the 30 kilometer-distance from Luganville to Tanafo, but a road has been completed which is capable of accommodating heavy-duty automobile and truck traffic. This road is fully capable of being used for transport of construction equipment and materials for the power plant.

An intake dam about 19 meters high will be constructed on a site 180 meters upstream from the falls, and the power plant at a site about 700 meters downstream from the falls. (Refer to the appended map, "General Layout")

The southeastern portion of Santo Island, which includes the Project area, consists of elevated coral limestone dating from the Pleistocene epoch of the Quaternary period which occurred approximately two million years ago. In the Sarakata River basin, only a very alight amount of igneous breccia and sandstone can be found, the rest of the land is entirely covered by elevated coral limestone, and there are no significant faults at all. (Refer to geological map)

Due to the above-mentioned geological features and the process by which they were created, the topography of the Project area consists of flat land with gentle rolling hills. The Sarakata River erodes the flat land as it flows downstream, and forms a V-shaped channel and

falls in the Project area. Results of the seven test pits dug in the Project area as part of the on-site survey show that the surface soil covering is from 0.8 - 1.40 meters deep, and the soil consists of clay light brown to brown in color.

The rainfall records from 1982 to 1985 as recorded by the rain gauge station set up in Tanafo are shown in Table 3.1.1.

As can be seen from the table, there is a great deal of rainfall at the Project Site. Even though the period from May to September is referred to as the dry season, there is over 500 mm of rainfall, as records for May and June of 1984 indicate, and this will influence to a great extent the progress of construction work on the Project.

GENERAL GEOLOGICAL MAP

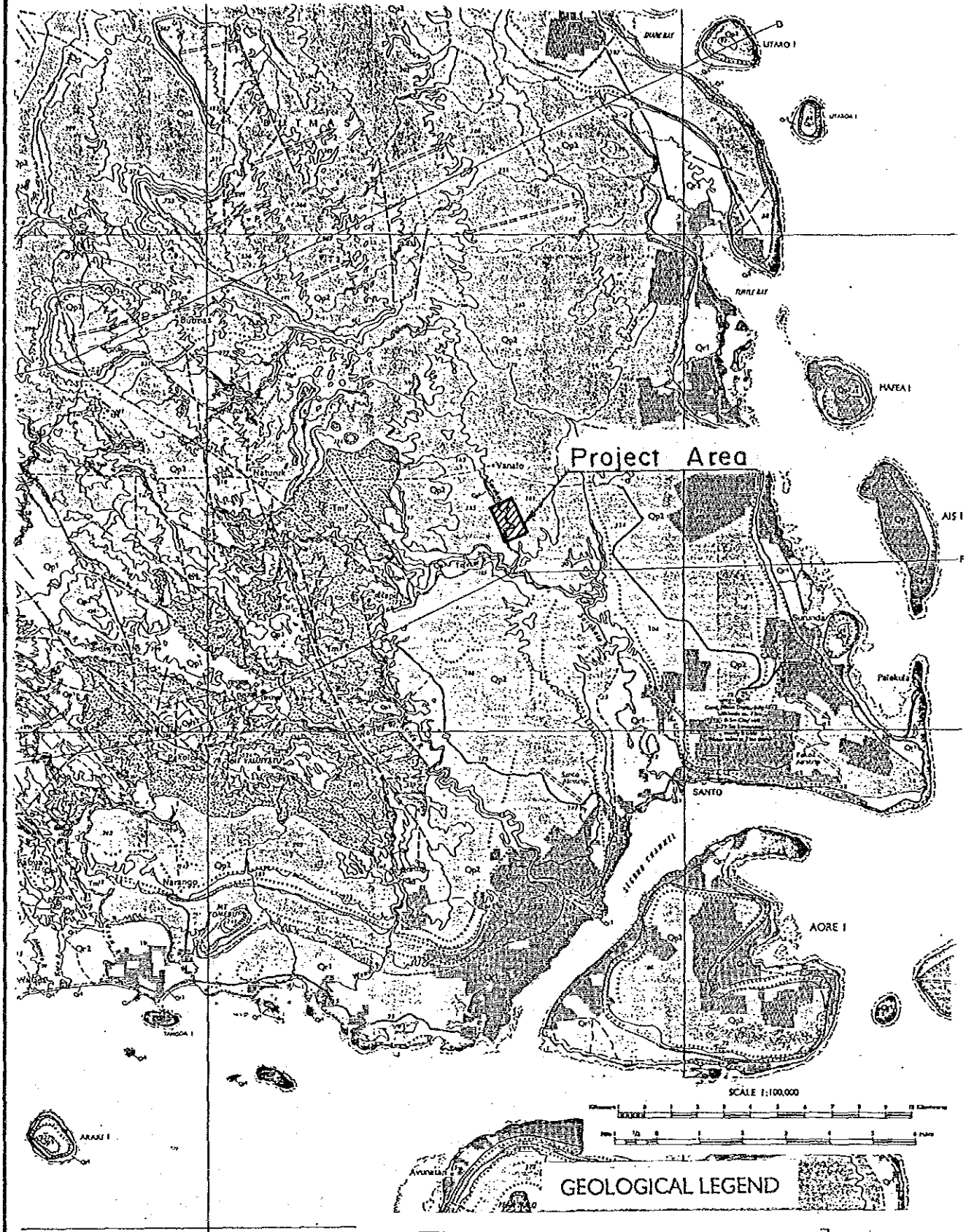


Table 3.1.1 The Tanafo Rain Gauge Station Rainfall Records

Month	Year / Item	1982	1983	1984	1985	Total	Average
January	Rainfall Amount (mm)	440.4	470.3	815.4	477.5	2,163.6	540.9
	Number of Days of rainfall (Days)	-	22	30	16	68	22.7
February	Rainfall Amount (mm)	281.1	188.6	293.1	116.5	879.3	219.8
	Number of Days of rainfall (Days)	22	20	19	21	82	20.5
March	Rainfall Amount (mm)	607.4	201.9	358.8	237	1,405.1	351.3
	Number of Days of rainfall (Days)	24	23	23	-	70	23.3
April	Rainfall Amount (mm)	538.9	310.3	329.1	-	1,178.3	392.8
	Number of Days of rainfall (Days)	22	27	22	-	71	23.7
May	Rainfall Amount (mm)	267.6	87.9	572.2	-	927.8	309.3
	Number of Days of rainfall (Days)	17	23	24	-	64	21.3
June	Rainfall Amount (mm)	138	171	500.6	-	809.6	269.9
	Number of Days of rainfall (Days)	10	16	29	-	55	18.3
July	Rainfall Amount (mm)	300.2	50.6	93.2	-	444	148.0
	Number of Days of rainfall (Days)	19	20	20	-	59	19.7
August	Rainfall Amount (mm)	225.7	93.3	131.7	-	450.7	150.2
	Number of Days of rainfall (Days)	27	22	12	-	61	20.3
Sep-tember	Rainfall Amount (mm)	29.2	94.5	96.2	-	219.9	73.3
	Number of Days of rainfall (Days)	18	18	14	-	50	16.7
October	Rainfall Amount (mm)	130.2	353.8	427	-	911	303.7
	Number of Days of rainfall (Days)	18	24	25	-	67	22.3
November	Rainfall Amount (mm)	746.7	389.3	509	-	1,645	548.3
	Number of Days of rainfall (Days)	19	29	-	-	48	24.0
December	Rainfall Amount (mm)	151.4	288.1	207	-	646.5	215.5
	Number of Days of rainfall (Days)	17	27	20	-	64	21.3
Total	Rainfall Amount (mm)	3,816.8	2,699.6	4,333.4	831	1,680.8	3,522.9
	Number of Days of rainfall (Days)	213	271	238	37	759	

3.2 OUTLINE OF LUGANVILLE

The hydroelectric power station which is to be built will be linked by a 15 kV transmission line with the existing diesel power plant, and all of the power generated will be consumed in the city of Luganville. This city grew up at the mouth of the Sarakata River, and is the largest city in the country after the capital, Port Vila. Luganville

is the political and economic center of the Santo-Male region, an administrative division. The city's population as of 1989 was 7,000, comprising about 1,400 families whose livelihood is centered on commerce and the service industry. Statistics for the working population aged 15 and older by industry are as follows:

	Working Population (People)	Ratio (%)
Agriculture, Forestry, and Maritime Industry	305	14.8
Manufacturing, Mining and Construction Industry	387	18.7
Commerce and Service Industry	1,115	54
Transportation and Communications Industry	257	12.5
Total	2,064	100

Of the total number of 1,400 households within the city, 1050 live in the city's central district, and the remaining 350 live in the surrounding areas. However, only 560 households in the central district have been electrified, while the remaining 840 do not have access to electrical service.

The public facilities in the city, including the city hall, police station, hospital, three schools, the telephone office, and the airport, have been electrified. However, the Sarakata St. Domingo elementary and junior high school, which has 105 pupils and conducts classes in two shifts, has not yet been electrified even though it is in the city, because the 5.5 kV main distribution line has not been constructed. It is hoped that the school will be electrified at an early date.

A quay capable of receiving ships of 15,000-ton class has been built in the eastern outskirts of the city, and the construction equipment and materials for the power plant can be unloaded here.

CHAPTER 4

DESCRIPTION OF THE PROJECT

CHAPTER 4 DESCRIPTION OF THE PROJECT

4.1 THE OBJECT OF THE PROJECT

The primary objects of the Project are the following

- Promotion of electrifiction of low income population and reduction of tariff

- Stable supply of electricity

(1) Promotion of electrification of low income population and reduction of tariff

The preferential use of low operating cost hydroelectric power will contribute to saving of expensive imported diesel oil, and by using the saving in fuel cost to the promotion of electrification and reduction in tariff, electric power can be distributed to regional residents, particularly to the lower income level population, thereby raising the living standard of the people.

(2) Stable supply of electricity

The coordinated operation of the hydroelectric power plant and the existing diesel power plant will reduce the number of long term power outages which heretofore have frequently occurred over the entire city. It will also enable the supply of stable power to domestic consumers, public facilities and factories and increase employment opportunities through the stabilization of the people's livelihood and the promotion of industrialization.

4.2 STUDY OF NATURE OF THE REQUEST FOR COOPERATION

4.2.1 Necessity and Appropriateness of the Project

The future role of the Project in the national developmental plan of Luganville and its surrounding areas, as well as the current situation of the region, has been described in the preceding chapters.

In order to promote the future development of Santo Island focused on Luganville, improvements to the infrastructure are necessary for the daily livelihood of the people and economic activity. Among these improvements, the expansion of electric facilities to supply low cost and stable electric power is indispensable. The implementation of the Project is both appropriate and essential for the achievement of the goals outlined in the previous section.

4.2.2 Implementing Methods for Operation of Power Facilities

The following three methods can be considered for operation of the hydroelectric plant after its completion:

(a) Directly operated by government
(b) Delegate operation to UNELCO
(c) Operation by a joint venture enterprise

Following is a comparative examination of the three methods listed above in regard to such factors as the necessity for revision of the power supply agreement, the method of administration, procedures for implementing repairs, recruiting the required personnel for operation and maintenance, the action to be taken when UNELCO relinquishes to the Government the rights and interests for electric power supply to Luganville in the year 2010, and administrative costs.

(1) Need, if any, of revision of the power supply agreement

(a) Directly operated by the Government: revision required

The current power supply agreement was prepared bearing in mind power supply from the UNELCO Luganville power plant only. Consequently, when the hydroelectric power plant is completed, it will be necessary to reexamine the tariff structure taking into account the nature of grant aid, and revise the agreement incorporating the items listed below:

- Revision of the tariff structure for the Luganville district accompanying the commissioning of the hydroelectric power plant.

- Metering procedure of energy supplied by the hydroelectric power plant.

- Determination of the share of revenue from power sales to be received by the Government.

- Procedures for shutting down the power plant and measures during failure.

- Delegate to UNELCO the maintenance of the transmission line to be newly installed between the hydroelectric power plant and the UNELCO Luganville power plant.

(b) Delegate operation to UNELCO:
revision unnecessary, but supplementary provisions must be appended.

It will not be necessary to revise the power supply agreement, but it will be necessary to append supplementary provisions.

The current power supply agreement was prepared bearing in mind supply of power from the UNELCO Luganville power plant only. After the hydroelectric power plant is completed, it will be necessary to append to the existing agreement supplementary provisions regarding Government leadership in such areas as a tariff structure which takes into account the nature of Grant Aid.

The contents of the supplementary provision which should be appended to the agreement are identical with the contents of clause (1) (a) of the previous item. With this method, UNELCO can operate both the hydroelectric power plant and the Luganville power plant under its own responsibility in regard to power plant shutdown procedures and measures during power plant failure, and can take prompt, sure measures without having to consult with the Government.

(c) Operation by joint venture enterprise: revision of current agreement necessary

The joint venture enterprise method is a system adopted for sharing unexpected losses during construction. However, in order to reduce administrative costs, this system is usually not adopted if the Project is completed and the plant has begun normal operation.

If the Sarakata hydroelectric power plant is operated by a joint venture enterprise by the Government and UNELCO, then revision of the contents described in item (1) (a) above will be necessary.

(2) Administration Methods

The composition of the personnel directly involved in the operation of the power plant is shown in Table 4.3.1. Direct personnel costs required for this purpose and direct repair costs for operation and maintenance are described in detail in Chapter 6.

We will consider the administration method for power plant operation from the standpoint of operations and policy, including such matters as negotiations with UNELCO and establishment of yearly budget.

(a) Administration through direct Government operation

Direct operation by the Government will enable a large reduction in the Government administrative structure required for power plant operation through transfer of a great amount of authority to the power plant manager. These administrative duties can be performed by holding positions concurrently at the existing energy unit.

Based on these considerations, administration costs are not estimated in Chapter 6 for the achievement of the goal of electicity tariff reduction. However, if administrative costs are computed from the concurrent

holding of positions, the yearly amount of administration costs will be as indicated below:

Personnel costs for administrators (corresponding to P20)	1,365,000 VT
Office staff (one person in addition to secretary) (corresponding to P3 x 2)	700,000
Subtotal	2,065,000
General expenses (50% of the above amount)	1,000,000
Total	3,065,000 VT

The fact that it will not be necessary to take the above costs into account is a big advantage for the direct operation method.

(b) Assignment to UNELCO

In the event that operation of the hydroelectric plant is assigned to UNELCO, the direct personnel costs and operation and maintenance costs described in Chapter 6 will be transferred to UNELCO as consignment costs. If UNELCO does not demand administrative costs in addition to these, then there will be no accompanying effect on electricity rates by the increase in administration costs.

It is believed that if the Sarakata hydroelectric power plant manager and the assistant manager (electrical) serve concurrently as UNELCO's Luganville power plant manager and assistant manager, it will serve both to simplify the hydroelectric power plant operation and reduce costs for UNELCO.

At present, administrative duties for UNELCO's Port Villa and Luganville thermal power plants are carried out at UNELCO's headquarters. It is believed that even in the

event the hydroelectric power plant operation is assigned to them by the Government, it will not be necessary to establish a new administration structure.

(c) Joint venture enterprise

If the joint venture enterprise method is adopted, then full time administrators will be appointed by both the Government and UNELCO. For this reason, compared to the direct government management method and the method of consignment to UNELCO, this method is more complicated than the other two because both parties must make decisions in consultation regarding activities such as disbursement of the budget and shutdown procedures. There is an additional concern that it will become difficult to transfer great authority to the power plant manager.

In the case of direct Government operation and assignment to UNELCO, no money is appropriated for annual administration costs because it is possible for administrators to serve concurrently in another position. However, in the joint venture enterprise method, a separate office is necessary resulting in rental cost. In addition, it will be necessity to set up a separate budget for personnel costs of administrators. Therefore, this will result in an increase in administration costs stated in (2)(a). The amount of annual administration costs calculated on 1990 cost base is indicated in the table below.

Unit: VT

Personnel costs for administrators (corresponding to P20) One person each from the Government and UNELCO	1,365,000 x 2 = 2,730,000
Office personnel (corresponding to P3) Two persons each from the Government and UNELCO	350,000 x 4 = 1,400,000
Office rent	2,400,000
Subtotal	6,530,000
General Expenses (30% of above)	1,960,000
Total	8,489,000

This will result in a large increase of cost in comparison to the amount stated in item (2)(a). This amount would be incorporated as costs if the joint venture enterprise method is adopted, and would result in an increase in electricity rate.

(3) Procedures for implementing repairs

(a) Direct Government operation

In the direct Government operation, the decision for implementing repairs can be transferred to the power plant manager, enabling appropriate measures to be taken as the circumstances arise. Apart from overhaul which is necessary once every 7 or 8 years, not much time is taken in the maintenance and repair of power generation facility. On the other hand, consideration is required

for civil and hydraulic structures because they are exposed to the danger of nature, and there will be many occasions requiring emergency repairs. For this reason, an administration system as simple as possible would be desirable. The direct operation by the Government would most simple to accommodate these demands.

(b) Assignment to UNELCO

As explained in the foregoing item (1), the simpler and clearer the procedures for implementing repairs, the better. If repairs are also left to the discretion of UNELCO, the implementation procedures should not be particularly complicated.

However, compared to direct government operation, it is possible that situations will occur in which reconciliation of opinions between the government and UNELCO in regard to repair will be necessary.

(c) Operation by joint venture enterprise

As already explained, consultation between administrators of both parties regarding procedures for the implementation of repairs will be necessary in the joint venture enterprise, and these procedures will become complicated. For this reason repairs may be delayed, and it is conceivable there would be cases in which this would cause more extensive damage.

(4) Recruiting personnel for operation and maintenance

(a) Direct Government operation

At present, there is no hope of recruiting personnel experienced in the operation of hydroelectric power plants inside the Government and also in UNELCO. Therefore, it will be necessary for the Government to seek the assistance of UNELCO because it will be difficult for the Government itself to recruit personnel for operation and maintenance.

(b) Assignment to UNELCO

Under present conditions, it will not be possible to find experienced personnel in hydroelectric power plant operation and maintenance in either Port Villa or Luganville.

However, the personnel experienced in the operation of the diesel power plant in Luganville already have thorough knowledge of the composition of the power system in the Luganville district, and it is thought that they have sufficient knowledge that are common to hydroelectric and thermal power station operation such as synchronized parallel operation of the generators, excitation and voltage control, and phase control.

Consequently, if these personnel are taught the basic knowledge for hydroelectric power plant operation, then operation of the plant will be possible.

Iyonnaise Des Eaux, UNELCO's source of supply of manpower, is undertaking the supply of power over a large area in the southern Pacific, so it is believed that it will be possible to recruit through them experienced operators.

Therefore, it will be easier to recruit personnel for operation and maintenance by the assignment method to UNELCO compared to the direct Government operation method.

(c) Joint venture enterprise method

It will be a simple approach to request UNELCO to supply the required personnel for operation and maintenance. However, the Luganville power plant manager being concurrently the hydroelectric plant manager, as explained in item (2)(b) cannot be considered, so in the event that the joint venture enterprise method is adopted, it will be necessary to recruit the required hydroelectric power plant personnel described in item (2).

(5) Measures to be taken when UNELCO relinquishes the power supply rights

(a) Direct Government operation

If the hydroelectric power plant is operated a directly by the Government, it will be simple for the Government to take over the operation and maintenance of facilities and supply of electricity to consumers when the rights are relinguished by UNELCO in the year 2010.

(b) Assignment to UNELCO

Before the rights of electric power supply is completely relinquished to the Government in 2010, the Government should prepare to be ready to operate the power supply industry and set up an electric utility organization by establishing a qualified staffed organization and recruiting the required number of personnel.

As a mean to overcome this problem, the Government through the collection from UNELCO of its share of revenues from the sales of hydroelectric power as described in Chapter 6, and by planning and implementing electrification program should accumulate experience and knowledge in the management of electric utility industry so that it will be prepared to take over the operation and management of the industry when UNELCO relinquishes its rights to the Government.

(c) Joint venture enterprise method

In the event the joint venture enterprise method is implemented, then the above considerations will be necessary for the Government.

(6) Administration costs of the hydroelectric power plant

There would be no change in such costs as personnel and maintenance costs for the operation of the hydroelectric power plant whether the plant be directly operated by the Government, assigned to UNELCO or by joint venture enterprise.

However, it is necessary to examine for each of these three methods the policy relative to administrative costs for power plant operation.

(a) Direct Government operation

A reduction is possible in the administrative costs of 3,065,000 VT (annual amount based on 1990 prices) estimated in item (2)(a) through the method in which administrative personnel would also serve concurrently as Energy Unit employees.

(b) Assignment to UNELCO

Administration of the hydroelectric power plant can be added to the administrative structure of both the Port Villa and Luganville thermal power plants established in UNELCO headquarters, and for this reason it is believed that there would be no increase in administration costs.

Therefore, the total amount of administration costs estimated in the preceding section can be saved.

(c) Joint venture enterprise method

In either case of direct operation by the Government or assignment to UNELCO, the 3,065,000 VT corresponding to the administration costs described in item (2)(a) can be absorbed by both the Government and UNELCO through concurrent service of the administrators. In the joint venture enterprise method, however, 8,489,000 VT must be included in the tariff. These costs will have to be recovered, resulting in a tariff increase.

(7) Comparison of the three methods

Comparison of the above is shown in Table 4.2.1.

Table 4.2.1 Comparison of Advantages and Disadvantages by Operational Pattern

	Direct Government Operation	Assignment to UNELCO	Government-UNELCO Joint Venture Enterprise
Revision of current agreement	A large scale revision is necessary which fully incorporates measures for reduction of tariff and fuel oil consumption, and is not possible until 2010.	Revision of the current agreement will not be necessary. However, the government and UNELCO will have to prepare and sign through consultation supplementary agreement which fully incorporate measures for reduction of tariff and fuel oil consumption.	In this method, as with the direct governmental management method, large scale revision is necessary, and it will not be possible by 2010.
Simplification of the administration system	The transfer of authority to the power plant manager will enable administrators to concurrently hold another office.	The same as the left column.	Administrators will place an office and office staff provided by both the government and UNELCO.
Procedures for implementing repairs	Most of this work can be disposed through the authority of the plant manager.	The same as the left column.	Consultation will be necessary on all such occasions.
Recruiting required personnel for operation and maintenance	Extremely difficult if the government acts independently. It will be necessary to request the assistance of UNELCO. However, it will be necessary to train the required personnel by 1994.	It will be comparatively easy to convert thermal power personnel to hydroelectric personnel. However, it will be necessary to assign Vanuatuans to supervisory positions to prepare for the transfer of rights of power supply in 2010.	The same as the clause on the left.
Measures to be taken when rights for power supply is reverted to the government	Measures can easily be taken as the government has acquired power supply experience.	Measures will be very difficult to take because the government will not be directly involved in supply of power. However, it will be necessary to train the required personnel by 2010.	Response will be easy because a government organization will be a party of the joint venture enterprise and will take part in operation duties.
Administration costs	Low costs (About 3.1 million VT/year)	Low costs (About 3.1 million VT/year)	As the administration method will be complicated, administration costs will be high in comparison to the other two methods.
Overall evaluation	2	1	3

Results of study of the 3 alternatives are summarized below:

(a) If the present electric supply agreement between the Government and UNELCO for Luganville and the surrounding districts are can be revised without difficulties, direct Government operation can be adoopted. However, as it is difficult to recruit the required number of operators and maintenance personnel for the hydroelectric power plant, UNELCO's cooperation is indispensable.

(b) If the operation and maintenance of the hydroelectric power plant are entrusted to UNELCO, no revision of the agreement is needed. It is necessary, however, to stipulate in a supplementary agreement that this hydroelectric power plant has been completed by the Grant Aid of the Japanese Government, and to indicate the range of reduction in the tariff.

(c) If a joint venture enterprise system is adopted, the agreement needs to be revised.

Administration costs will increase, making no contribution to reduction of tariff.

Taking the above matters into consideration, it is judged that under the present situation, it would be best to entrust the operation and maintenance of the Sarakata Hydroelectric Power Plant to UNELCO for the time being. In this case, it is necessary for the Government of the Republic of Vanuatu to nourish the basis of electric power administration by collecting the Government share of hydroelectric power revenues and fuel cost saving corresponding to fluctuation in the volume of hydroelectric power supply, as well as reducing the burden of connection charges to new electric power consumers, in order to enable the smooth transfer of electric supply rights from UNELCO to the Government in 2010.

4.2.3 Facilities, Machinery and Materials

(1) Development system

Judging from the topography of the Project Site, it is thought that a reservoir or regulating pond scheme would not be economical because of poor water storage efficiency. The geology of the Site is coral limestone, and has a strong potential of leakage, and therefore the Site is not suitable for construction of a reservoir. The request for construction of run-of-river hydroelectric plant is judged to be appropriate.

(2) Scale for development

The scale for development proposed by Vanuatu Government is 1,000 kW. As a result of investigation of the topography and geology of the Project Site, the river runoff and the present and future demand for electric power in Luganville, it has been judged that the optimum scale of development would be initially 600 kW (300 kW x 2 units), with provision to increase the output by 600 kW in the future. However, in order to minimize difficulty in the future extension work and the period of shutdown of the hydroelectric power plant already in operation, it would be appropriate to construct the intake structure, headrace canal and head tank having the capacity for the ultimate plant capacity. The power demand forecast and optimum development scale are discussed below.

(a) Power demand forecast

The actual demand and projected demand until 2010 in Luganville are described below:

i) Actual demand

Actual electricity generation and energy sold from 1984 to 1990 are shown in Table 4.2.2.
In recent years, energy sale is growing constantly, and in the 4 years from 1987 to 1990 the average growth rate was 6.4%. In the year 1990, the growth rate was 11.9%.

ii) Demand forecast

There is a close correlation between income levels of consumers, generally expressed by GDP, and the growth of electric power demand. Demand for electric power was calculated by the simple regression method using the correlation between GDP and demand. The past GDP from 1987 to 1990 and the actual electric energy sold are shown in Table 4.2.3, in which the electric energy sold corresponds to changes in the GDP. GDP growth was 2.2% on the average for 5 years, and the annual growth from 1988 to 1989 was 4.5%. Assuming GDP growth rates of 2%, 4%, and 4.5%, the estimated growth in electric energy sales are shown in Table 4.2.4 and Figure 4.2.1.

The result indicate that energy sale at 4% GDP growth rate and taking into account UNELCO's growth projection of 6% annually, the estimated demand forecast is almost identical to that of UNELCO.

As a result of the above study, it is judged that future GDP growth rate of 4% and the corresponding energy demand growth rate of 6% are appropriate as seen from the GDP and energy sale growth rates in the 4 years from 1987 to 1990.

In the draft report which was explained to the Vanuatu Government, UNELCO's energy sales of 2.465 million kWh in 1990 was taken as the demand in 1991 and a growth of demand for 1 year was overlooked. Therefore, in this Report this error is corrected, and an annual growth rate of 6% was considered to arrive at a projected energy sales in 1994 of 3.112 million kWh.

Based on UNELCO's estimated values, Table 4.2.5, and Figs. 4.2.2 and 4.2.3 show the demand forecast up to 2010. The results indicate that there is ample allowance in energy generation (Fig. 4.2.2), but peak

demand (Fig. 4.2.3), will exceed supply capability in 2005 indicating the capacity addition will be required.

Increase in demand by domestic consumers, public facilities and factories is anticipated by acceleration of electrification schemes and reduction in electric tariff. The results of interviews at each public facility and factory are shown below. Values in parentheses represent the future increases.

(1) Electrification of unelectrified homes in Luganville: 840 houses (250 kW)

(2) Schools (10 kW)

- Electrification of St. Domingo Elementary and Junior High School in the Sarakata District
- Addition of classroom lighting at St. Michel Technical School
- Addition of classroom lighting at one other school

(3) City Office (50 kW)

- Addition of indoor lighting and installation of air-conditioning equipment

(4) Hospital (80 kW)

- Addition of indoor lighting and installation of air-conditioning equipment, and addition of medical equipment.

(5) Addition of lighting of main city streets (20 kW)

(6) City water Pumping Station (210 kW)

Three pump units installed with 90-HP diesel engines will be replaced by electrically operated pumps.

(7) Tanafo Village electrification scheme (60 kW)

(8) Industrial complexes (3,200 kW)

Industrial complexes are at the planning stage in the east and the west of the city. However, the timing of development is not clear.

(9) Meat processing plant (80 kW)

Extension work for an increase of 80 kW is presently underway.

(10) Lumber and laminated wood factories (620 kW)

- Melcoffee Sawmill Ltd.: Electrification of presently installed diesel power generating facility (200 kW)
- Santo Veneer & Timers: Facility expansion (190 kW)
- One other company: Electrification of presently installed diesel power generating facility (230 kW)

Table 4.2.2 ENERGY SOLD & GENERATION

	1984	1985	1986	1987	1988	1989	1990	AVERAGE ('86-'90)
ENERGY GENERATION								
Energy Gen.(Mwh)	2356	2367	2247	2291	2308	2461	2736	2,409
Peak Output(Kw)								
ENERGY SOLD								
Energy Sold(Mwh)	2160	2125	1925	2046	2063	2202	2465	2,140
Increase(%)	-	(1.6)	(9.4)	6.3	0.8	6.7	11.9	6.4
Peak Demand(Kw)	526	517	469	498	502	536	600	-
LOSS(%)	8.3	10.2	14.3	10.7	10.6	10.5	9.9	10.4

NOTES: Number in parentheses shows minus

Source:UNELCO

Table 4.2.3 ACTUAL GDP Vs Mwh

	1984	1985	1986	1987	1988	1989
GDP	10,235	10,966	10,743	10,789	10,850	11,343
GDP Increase (%)	-	7.1	(2.0)	0.4	0.6	4.5
GDP Increase ('84-'89)(%)	-	-	-	-	-	2.2
Soled Energy (Mwh)	2,160	2,125	1,925	2,046	2,063	2,202

NOTES: Number in parentheses shows minus
Source:GDP: Statistics Office VANUATU
Mwh:UNELCO

Table 4.2.4

ENERGY SELES FORECAST IN RELATION TO GDP

	1991	1992	1993	1994	1995	1996	1997
Mwh at 2% GDP	2,380	2,467	2,556	2,646	2,740	2,833	2,930
Mwh at 4% GDP	2,553	2,734	2,923	3,119	3,322	3,535	3,755
Mwh at 4.5% GDP	2,596	2,802	3,017	3,242	3,477	3,723	3,980
Forecast by UNELCO	2,613	2,769	2,935	3,112	3,298	3,496	3,706

	1998	1999	2000	2001	2002	2003	2004
Mwh at 2% GDP	3,028	3,128	3,230	3,335	3,441	3,550	3,660
Mwh at 4% GDP	3,984	4,223	4,471	4,729	4,997	5,276	5,567
Mwh at 4.5% GDP	4,248	4,528	4,821	5,127	5,447	5,781	6,130
Forecast by UNELCO	3,928	4,163	4,413	4,678	4,959	5,256	5,572

	2005	2006	2007	2008	2009	2010
Mwh at 2% GDP	3,773	3,888	4,006	4,125	4,247	4,371
Mwh at 4% GDP	5,869	6,183	6,509	6,849	7,202	7,569
Mwh at 4.5% GDP	6,495	6,876	7,257	7,691	8,126	8,581
Forecast by UNELCO	5,906	6,260	6,636	7,034	7,456	7,904

Fig. 4.2.1 ENERGY SAILS FORECAST IN RELATION TO GDP

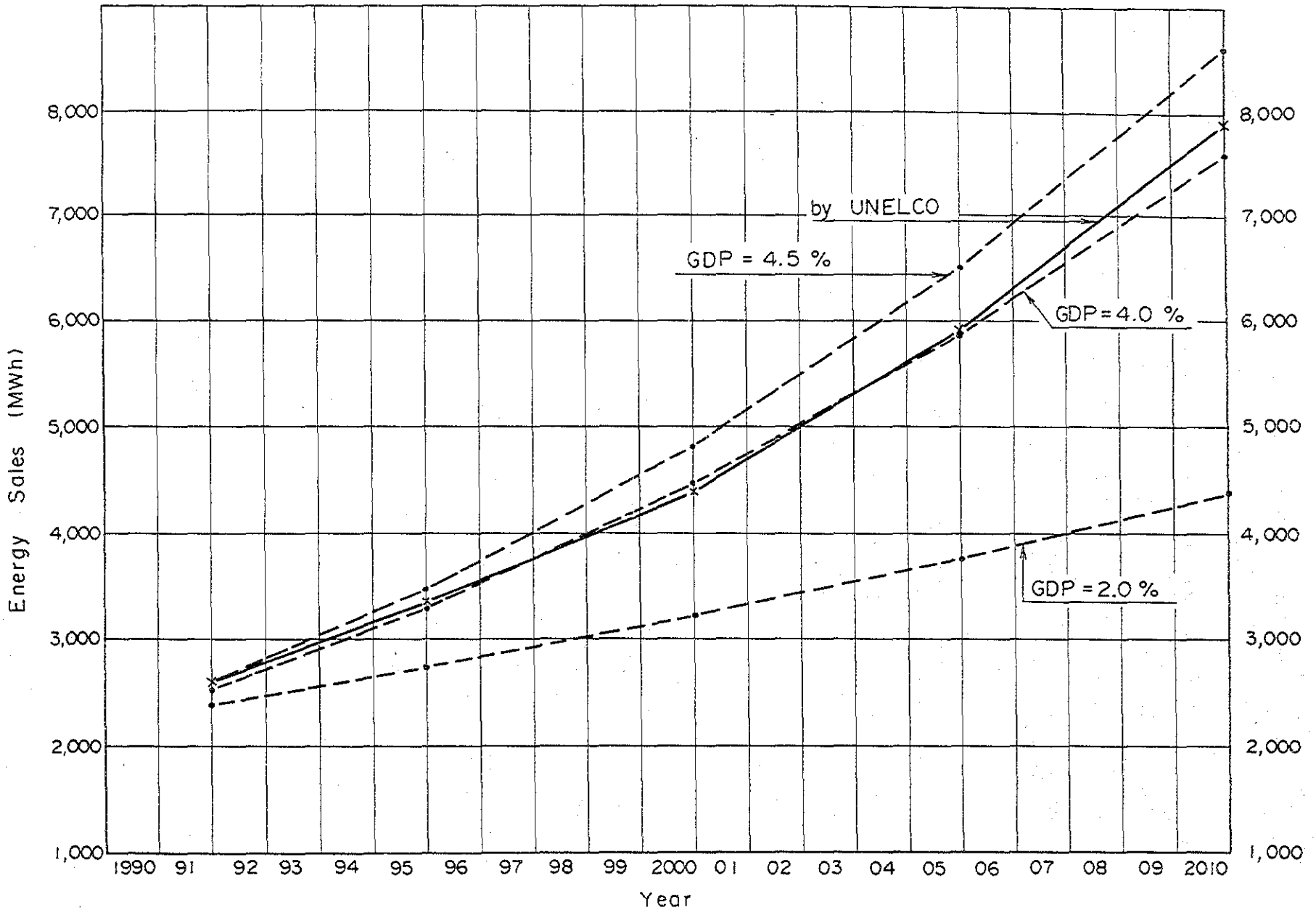


Table 4.2.5 ENERGY FORECAST(Kw & Mwh BALANCE)

Year	SUPPLY							SALES		BALANCE	
	By Diesel (Mwh)	By Hydro (Mwh)	Total (Mwh)	Loss (Mwh)	Dependable Supply(1) (Mwh)	Installed Output (Kw)	Dependable Output(2) (Kw)	Sales (3) (Mwh)	Peak Demand(4) (Kw)	Mwh (1)-(3) (Mwh)	Kw (2)-(4) (Kw)
1991	6,180	-	6,180	618	5,562	1,080	830	2,613	667	2,949	163
1992	6,180	-	6,180	618	5,562	1,080	830	2,769	707	2,793	123
1993	6,180	-	6,180	618	5,562	1,080	830	2,935	750	2,627	80
1994	6,180	2,578	8,758	876	7,882	1,380	1,130	3,112	795	4,770	335
1995	6,180	5,156	11,336	1,134	10,203	1,680	1,430	3,298	842	6,905	588
1996	6,180	5,156	11,336	1,134	10,203	1,680	1,430	3,496	893	6,707	537
1997	6,180	5,156	11,336	1,134	10,203	1,680	1,430	3,706	946	6,497	484
1998	6,180	5,156	11,336	1,134	10,203	1,680	1,430	3,928	1,003	6,275	427
1999	6,180	5,156	11,336	1,134	10,203	1,680	1,430	4,163	1,063	6,040	367
2000	6,180	5,156	11,336	1,134	10,203	1,680	1,430	4,413	1,127	5,790	303
2001	6,180	5,156	11,336	1,134	10,203	1,680	1,430	4,678	1,195	5,525	235
2002	6,180	5,156	11,336	1,134	10,203	1,680	1,430	4,959	1,266	5,244	164
2003	6,180	5,156	11,336	1,134	10,203	1,680	1,430	5,256	1,342	4,947	88
2004	6,180	5,156	11,336	1,134	10,203	1,680	1,430	5,572	1,423	4,631	7
2005	6,180	5,156	11,336	1,134	10,203	1,680	1,430	5,906	1,508	4,297	(78)
2006	6,180	5,156	11,336	1,134	10,203	1,680	1,430	6,260	1,599	3,943	(169)
2007	6,180	5,156	11,336	1,134	10,203	1,680	1,430	6,636	1,695	3,567	(265)
2008	6,180	5,156	11,336	1,134	10,203	1,680	1,430	7,034	1,796	3,169	(366)
2009	6,180	5,156	11,336	1,134	10,203	1,680	1,430	7,456	1,904	2,747	(474)
2010	6,180	5,156	11,336	1,134	10,203	1,680	1,430	7,904	2,019	2,299	(589)

Fig. 4.2.2 ENERGY FORECAST (MWh BALANCE)

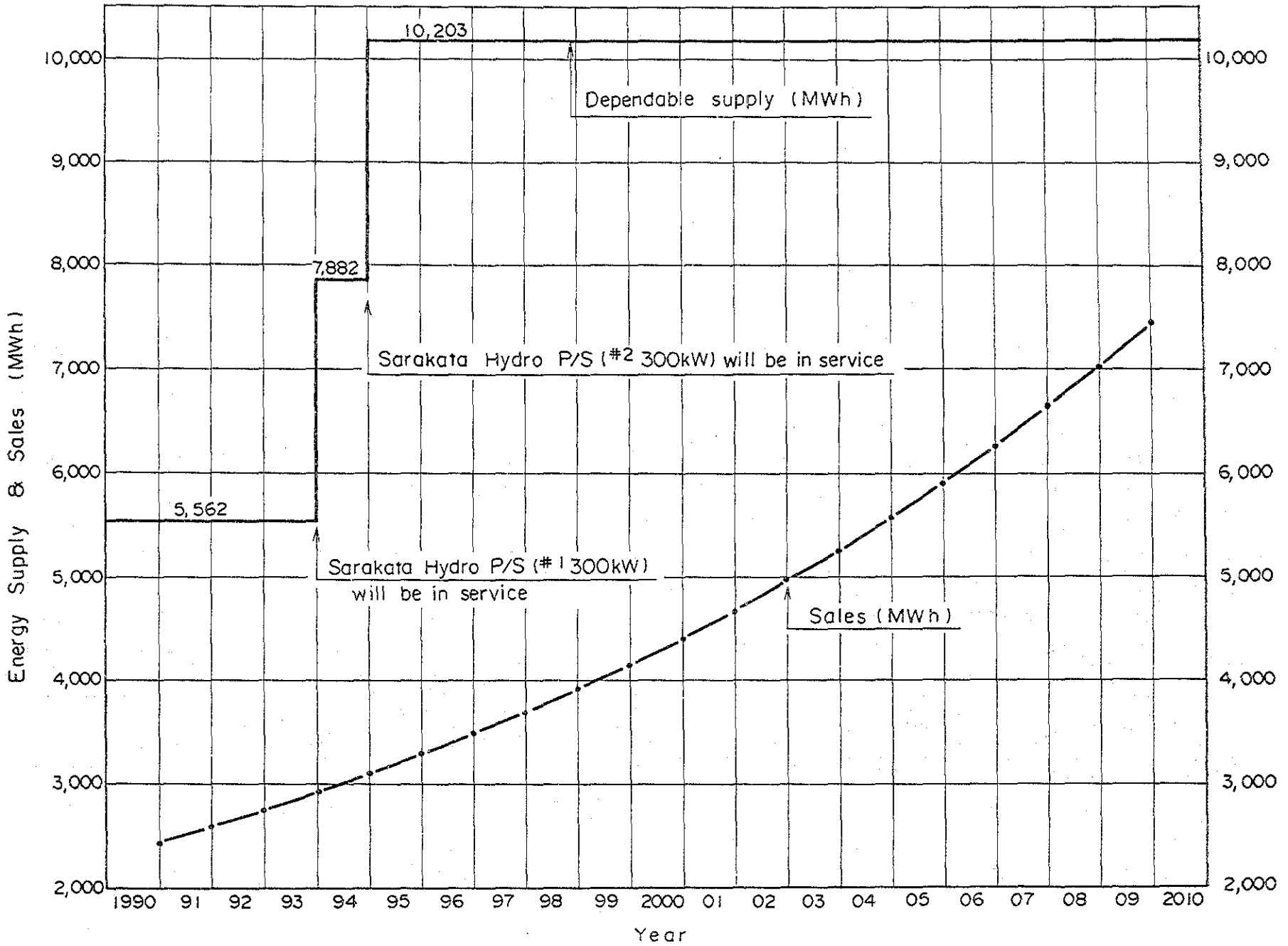
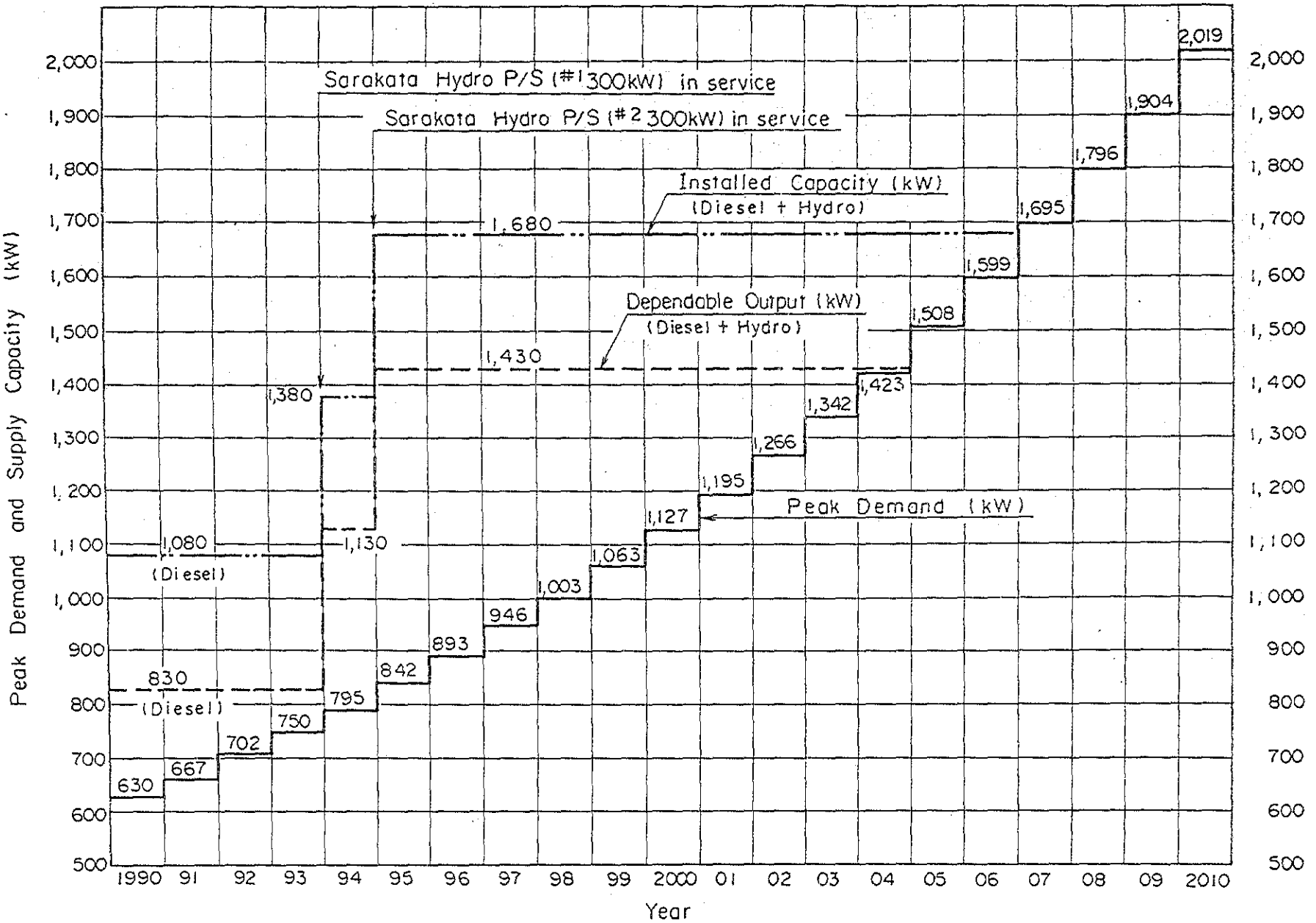


Fig. 4.2.3 ENERGY FORCAST (kW BALANCE)



(b) Optimal development scale

In examining the optimal development scale, the river runoff and plant output are based on the following conditions:

1) River runoff

Name of gaging station: SARAKATA COTE 110
Name of river: SARAKATA RIVER
Altitude: +110 m
Catchment area: 97.1 km^2

Observation of the river runoff started on October 1st, 1981. However, much data are missing because the recording instruments were washed away.

The observation records during the 3-year period from 1982 to 1984 are almost complete and can therefore be used.

Consequently, of the data for the three years, the data employed are those taken during 1984 which record the mean runoff. (Table 4.2.6 shows the daily runoff record and Fig. 4.2.4 shows the duration curve.)

Table 4.2.6 MEAN DAILY DISCHARGE

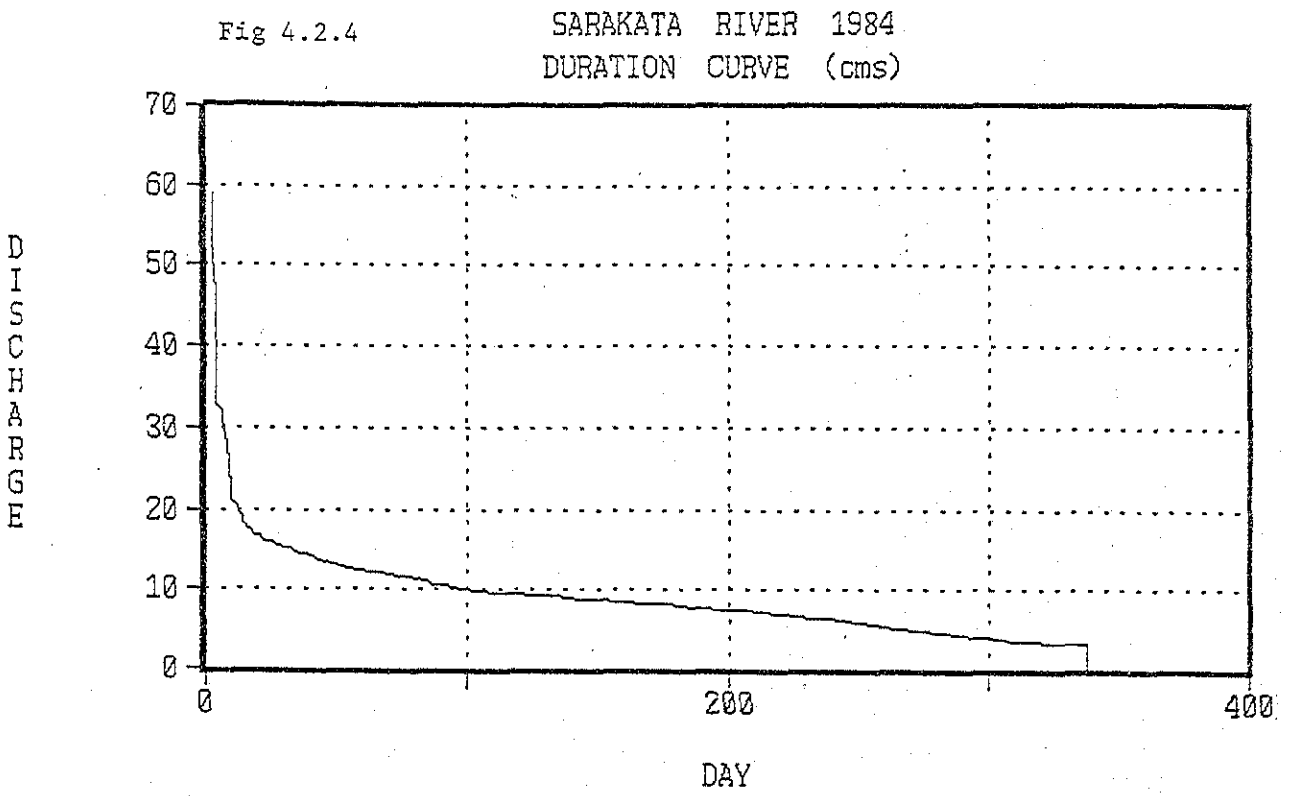
Name of River : SARAKATA

Year : 1984

Catchment Area : 97.1 km2

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	
1	6.91	9.67	6.92	12.50	7.42	13.20	9.56	5.77	4.16	3.53	15.60	8.29	1
2	6.14	9.19	6.66	17.60	10.40	15.30	9.36	5.68	4.13	3.42	12.70	9.29	2
3	6.14	8.41	6.53	14.40	16.00	20.60	9.57	5.57	4.07	3.33	9.53	8.50	3
4	7.12	7.91	7.58	11.30	14.90	15.90	10.00	5.49	3.99	3.26	8.35	7.58	4
5	9.61	7.59	6.56	9.88	10.60	14.30	9.55	5.42	4.03	3.25	7.83	6.88	5
6	9.66	7.39	6.43	9.19	9.32	15.30	9.03	5.35	4.11	3.25	8.42	6.56	6
7	12.20	13.20	6.50	11.50	8.62	14.40	8.75	5.28	4.03	3.25	8.26	6.00	7
8	9.42	15.50	8.19	13.50	12.30	15.20	8.49	5.21	3.97	3.25	7.13	5.96	8
9	8.56	13.70	11.50	10.50	12.20	13.50	8.36	5.10	3.93	4.15	6.33	7.44	9
10	9.48	11.60	10.10	10.00	14.50	12.70	8.37	5.04	3.83	4.53	5.92	7.32	10
11	9.09	10.30	8.29	8.89	12.10	12.10	8.19	5.01	3.72	3.62	6.49	8.68	11
12	8.02	10.90	9.65		16.90	11.70	7.92	4.89	3.68	3.45	12.40	7.37	12
13	8.21	8.95	8.85		12.40	11.40	7.78	4.87	3.68	5.09	9.38	6.70	13
14	8.34	9.32	9.66		10.50	15.80	7.58	4.78	3.61	6.71	8.20	7.47	14
15	12.80	11.20	9.88		9.47	141.00	7.43	4.74	3.54	4.80	16.80	9.26	15
16	32.10	9.20	10.50		8.86	58.90	7.33	4.74	3.54	4.14	16.30	7.87	16
17	30.10	8.71	8.66	7.87	17.40	26.60	7.23	4.74	3.54	3.75	14.30	7.09	17
18	20.90	9.69	7.76		15.90	20.50	7.16	4.76	3.54	3.68	13.70	6.52	18
19	16.80	11.90	8.15		11.80	19.40	7.10	4.81	3.54	4.45	13.10		19
20	14.20	11.50	9.32		10.50	18.10	6.86	7.58	3.47	5.11	10.70		20
21	12.10	9.30	7.67		11.00	15.90	6.71	5.59	3.40	4.83	9.54		21
22	12.30	8.83	8.01		11.40	14.70	6.54	7.91	3.39	4.28	10.00		22
23	12.90	8.24	8.86		11.50	13.80	6.44	6.08	3.36	4.13	9.12		23
24	10.30	8.02	7.56		9.72	12.90	6.36	5.27	3.33	3.81	8.47		24
25	9.42	8.73	8.15		9.12	12.20	6.31	4.90	3.41	4.72	7.72		25
26	10.00	8.50	9.42		8.73	11.50	6.27	4.75	3.29	5.01	7.14		26
27	9.93	7.74	12.70		12.00	11.00	6.18	4.73	3.31	5.42	6.69		27
28	9.85	7.40	12.00	8.54	47.60	10.60	6.03	4.50	3.62	7.08	6.47		28
29	14.50	-	9.66	7.85	32.60	10.10	5.88	4.31	3.42	6.71	8.69		29
30	14.10	-	8.91	7.56	19.20	9.79	5.85	4.28	3.45	49.90	9.48		30
31	11.10	-	12.20	-	15.20	-	5.84	4.27	-	28.40	-		31
Average	12.01	9.74	8.80	10.74	13.88	20.28	7.55	5.21	3.67	6.59	9.83	7.49	9.65
Max.	32.10	15.50	12.70	17.60	47.60	141.00	10.00	7.91	4.16	49.90	16.80	9.29	141.00
Min.	6.14	7.39	6.43	7.56	7.42	9.79	5.84	4.27	3.29	3.25	5.92	5.96	3.25

Fig 4.2.4


SARAKATA RIVER 1984
DURATION CURVE (cms)
DISCHARGE
70
60
50
40
30
20
10
0
0
200
400
DAY

2) Plant capacity

Item \ Output	600 kW	900 kW	1,200 kW	1,500 kW
Total head (m)	28.8	28.8	28.8	28.8
Turbine discharge (m^3/sec)	3.0	4.5	6.0	7.5
Annual energy generation (10^6 kWh)	5.155	7.264	9.018	10.044

Judging from the balance between electric power demand and supply capacity mentioned in the foregoing item 4.2.3 (a), it is not necessary to immediately construct the full output of each plan with output exceeding 900 kW. Therefore, step-by-step development will be examined for these alternatives. Also, with respect to unit capacity given in Table 4.2.7, the output of each alternative and the magnitude of electric power demand at the time of development is taken into consideration.

Table 4.2.7 Staged Development

Scale of Development (kW)	Unit capacity x No. of units	Phase-I		Phase-II (Future)
		Stage-I	Stage-II	
600	300 x 2	300 x 1	300 x 1	---
900	300 x 3	300 x 1	300 x 1	300 x 1
1,200	300 x 2 600 x 1	300 x 1	300 x 1	600 x 1
1,500	300 x 3 600 x 1	300 x 1	300 x 1	300 x 1 600 x 1

As this project is a run-of-river type power plant, and the purpose is to save fuel consumption of the existing diesel power generation equipment, a development scale of the least construction cost per kWh of energy generated is most economical.

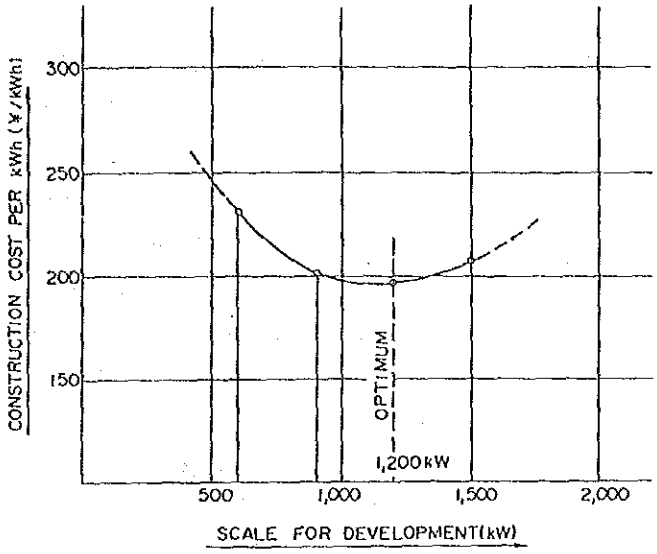
Based upon the above conditions, Table 4.2.8 and Fig. 4.2.5 show the results of examination of the optimal development scale.

Table 4.2.8 Optimum Scale of Development

Basic Assumption for Comparison

Scale of Development (kW)	Unit Capacity No. of Units	Construction Cost (10^6¥)	Annual Energy Generation (10^6kWh)	Construction Cost per kWh (¥/kWh)	Priority
600	300kWx2	1,188	5.155	230.46	4
900	300kWx3	1,463	7.264	201.40	2
1,200	300kWx2 600kWx1	1,775	9.018	196.83	1
1,500	300kWx3 600kWx1	2,079	10.044	206.99	3

Fig. 4.2.5 OPTIMUM SCALE FOR DEVELOPMENT



As evident from these results, the per kWh construction cost for a scale of development of 1,200 kW is the least followed by 900 kW and 1,500 kW. Therefore, the optimum scale of development for this hydroelectric power plant project is 1,200 kW.

(3) Main facilities

(a) Civil structures

The types and scales of the structures are judged to be appropriate for the purposes of use and turbine discharge. According to the request of the Government of Vanuatu, the headrace is located on the left bank of the river. However, as a result of site investigation by the Team, it has been judged that the headrace should be located on the right bank of the river for the following reasons:

- Although both sides of the river form cliffs, the right bank of the river has more advantages than the left bank when construction of roads and temporary facilities are taken into account and construction cost is the least.
- The topography of the right bank of the river is suited to install steel penstock and to locate the power plant.

(b) Water turbine-generator

According to the request of the Government of Vanuatu, the unit output is specified to be 500 kW. However, this unit output is too large when the present and future magnitude of electric power demand of the Project area and its influence to the power system at the time of fault and shutdown are taken into consideration. It has therefore been judged that 300 kW unit capacity is appropriate for this Project. In addition, taking into consideration the effective head and turbine discharge, Francis turbine, which is highly efficient and has a low failure rate, has been selected.

(c) Transmission line

According to the request of the Government of Vanuatu, the transmission voltage is specified to be 20 kV. However, a transmission voltage of 15 kV is adopted, taking into consideration the results of studies of scale of development described in the preceding item 4.2.3 (2) and the voltage class adopted in the Republic of Vanuatu.

4.2.4 Necessity of Technical Cooperation

As described in the foregoing item 2.4.2, the Government of the Republic of Vanuatu has requested Technical Cooperation of the Government of Japan to dispatch the following engineers to Japan for training and to receive experts from Japan in the implementation and management of this Project:

Experts: Electric utility management: 2 persons (short term)

Operations instructor of hydroelectric power plant
1 person (long term)

Trainees: Electrical and mechanical engineers: 4 persons
Civil engineer: 1 person

If this Project is implemented, it will be Vanuatu's first hydroelectric power plant. After the completion of the power plant, it will be necessary to educate and train engineers who will take over the operation and maintenance of the power plant in order to maintain the plant the performance of the good condition.

As there are no hydroelectric plants in Vanuatu, UNELCO does not have personnel experienced in the operation and maintenance of hydro plant. Therefore, in the case the operation and maintenance of this plant is entrusted to UNELCO, they will have to educate and train the power station staff. At the time the electricity supply business is transferred to the Government by UNELCO, it is probable that government will hire the operation and maintenance staff assigned to the plant at that time.

Moreover, ability to manage electric utility industry will be required because when this Project is commissioned, the Government will have to calculate its share of the revenues produced by the plant to be applied for electrification projects, collect said sum from UNELCO, prepare and implement electrification program, and to revise electricity tariff. Therefore, it will be necessary to educate and train personnel to perform these duties.

As a result of studies of these requirements, Technical Cooperation of Japan is indispensable, and it is judged that the request of the Government of Vanuatu is reasonable.

4.2.5 Principle for Implementation of Cooperation

The foregoing studies have confirmed the benefits, feasibility and capability of implementation by the recipient country of the Project, and the benefits to be created by the Project are in line with the object of Grant Aid, and, therefore, it is judged that this Project is justified for implementation by Grant Aid of Japan. However, the judgement that some of project features given in the request for cooperation has been explained in the study of facilities, equipment and materials given in the said request by the Government of Vanuatu.

4.3 PROJECT SUMMARY

4.3.1 Implementation Organization and Management System

The electric power supply in the Republic of Vanuatu, including Luganville, is managed by UNELCO in accordance with the Electric Power Supply Agreement (effective until 2010) made between the Government and UNELCO. After completion of the Project, it is judged advisable to entrust the operation and maintenance of the plant to UNELCO for the time being for the reasons mentioned below:

(1) The Electric Power Supply Agreement does not need to be revised:

In the case of direct operation by the Government, or joint venture by the Government and UNELCO, drastic revision of the current agreement will be required, which will not be feasible until 2010.

(2) Operators and maintenance personnel can be recruited without much difficulty:

Transfer of the operators and maintenance personnel at the existing thermal power plant to the hydroelectric power plant can be carried out without much difficulty. In the case of direct Government operation, this transfer would be difficult.

(3) Administration is not difficult and administration costs are low:

In the case of direct Government management and joint venture enterprise between the Government and UNELCO, a new administration organization would have to be established to which required personnel would have to be assigned.

In the case the plant operation is assigned to UNELCO, the Vanuatu Government needs to establish an organization to monitor the state of operation and administration of the hydroelectric power plant and the existing diesel power plant, which are the base for calculation of the Government's share of revenues and electricity tariff as well as to manage the promotion of electrification projects. In

addition, it is necessary for the Government to nourish experience and knowledge in electric utility management in order to facilitate transfer of electric power supply right to the Government by UNELCO in 2010.

4.3.2 Project Summary

This Project is to generate hydroelectric power by utilizing a head of approximately 19-m created by a waterfall located about 3 km downstream from the village of Tanafo in the Sarakata River basin, and daily mean discharge of about 9.65 m^3/sec. The Project includes 9.5-m high concrete gravity dam to be built approximately 180 m upstream of the waterfall, and 3.0 m^3/sec. of water taken in from the intake constructed on the right abutment of the dam is to be conveyed through a sand sedimentation basin and a 840-m non-pressure concrete open channel to a head tank. The water introduced to the head tank will be delivered by steel penstock 1.2 meters in diameter, to a surface power plant located on the right bank of the Sarakata River.

The Project is a run-of-river plant with an installed capacity of 600 kW (300 kW x 2), with provision to add 600 kW in the future. The particulars of the Project are as follows:

Particulars of the Project

River name:	Sarakata River
Catchment area:	91 km^2
Daily mean runoff:	(max.) 9.65 m^3/sec.
	(min.) 2.84 m^3/sec.
Effective head:	27.8 m
Maximum turbine discharge:	3.0 m^3/sec.
Installed capacity:	600 kW
Annual energy generation:	5.16 x 10^6 kWh

Electricity produced at this plant is transmitted approximately 25 km through a 15 kV transmission lines which is newly installed as part of the Project, and connected to the existing system at the UNELCO power plant in Luganville City.

4.3.3 Features of Facility

A summary of the main facilities of the Project are as follows:

Main facilities

1. Intake dam	Concrete gravity Height x Crest length; 9.5m x 43.0m
2. Sedimentation basin	Natural sedimentation Width x Height x Depth; 6.0m x 15.0m x 4.0m
3. Conduit	Concrete open channel Width x Height x Depth; 2.5m x 840.0m x 2.0m
4. Head tank	Concrete tank Width x Height x Depth; 4.0-6.0m x 22.0m x 5.5m
5. Steel penstock	Steel conduit Diameter x Pipe thickness x Length; 1.2m x 6mm x 69.5m
6. Power plant building	2-floor concrete building Total floor area; 143.0m^2
7. Access road	Gravel road Width (effective) x length; 3.0m x 1.4km
8. Electromechanical equipment	Water turbine Capacity: 340kW x 2 units Type : Francis-type, horizontal shaft Generator Capacity: 375kVA x 2 units Type : Brushless synchronous generator Rotating Speed: 750 rpm Frequency: 50Hz

Step up transformer

Capacity: 750kVA x 1 unit

Voltage : 3.3kV/15kV

Type: Outdoor, oil-filled 3-phase type

9. Transmission line

Voltage: 15kV

Length : 28km

Step down transformer:

Output : 750kVA x 1 unit

Voltage: 15kV/5.5kV

Type: Outdoor, oil-filled 3-phase type

4.3.4 Operation and Maintenance

For reference, Table 4.3.1 shows the assignment of personnel by UNELCO at both the Port Vila and Luganville diesel power plants.

At present, all responsible positions are held by foreigners. After 2011, when the power supply agreement between the Government of Vanuatu and UNELCO expires, all electric power supply operations must be taken over by the Vanuatu Government.

Table 4.3.1 UNELCO Man Power

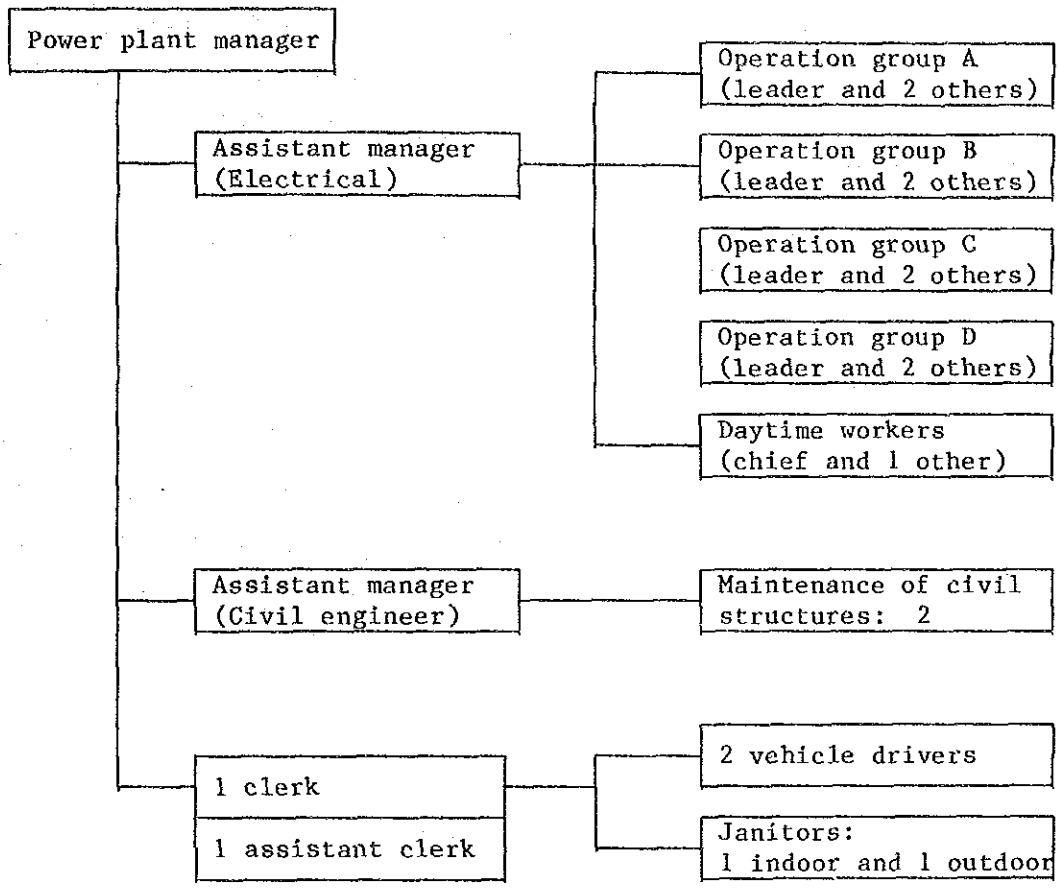
	Port Vila PS.		Luganville PS.	
	Expatriate	Ni-Vanuatu	Expatriate	Ni-Vanuatu
Power Station				
Manager	1		1	
Deputy Manager	2			
Operator		3		4
Maintenance		13		8
Others		2		2
Transmission and Distribution Line Maintenance Section				
Manager	1		1	
Deputy Manager	1	1	1	
Line Man		13		3
Labour		*10		*10
Energy Sales Section				
Manager		1		1
Deputy Manager		1		1
Meter Checker		4		4
Tariff Calculator		4		4
Others		2		1

* shows unfixed employment

Source: UNELCO

Using as reference the present organization of operation and maintenance at UNELCO's power plants in both Port Vila and Luganville, a conceivable management organization of the Sarakata hydroelectric power plant is shown in Table 4.3.2.

Table 4.3.2 Sarakata Hydroelectric Power Plant Management Organization



Transmission line maintenance and tariff collection personnel were not included for the following reasons:

(1) Maintenance of transmission line

When the hydroelectric power plant is commissioned, transmission line from this plant will be connected directly to the UNELCO Luganville power plant without any branch lines, and accordingly there will not be much maintenance work. The transmission line maintenance is to be assigned to UNELCO for the time being.

(2) Tariff collection

All power generated at the hydroelectric power plant will be sold to UNELCO until branch lines are constructed from the power transmission line.

Monthly reading of the integrating KWh meter for sale of electric power installed at the entrance of the UNELCO Luganville power plant will be conducted by a member of the hydroelectric power plant staff, in the presence of a UNELCO staff, and the monthly reading will be reported to the Government staff at Port Vila.

This method will greatly simplify tariff collection for the time being.

4.4 TECHNICAL COOPERATION

It is necessary to educate and train personnel in the operation, and maintenance, and electric utility management after completion of the hydroelectric power plant, for the purpose of achieving the objects and benefits intended. Therefore, Technical Cooperation of the Government of Japan is required for the training of Vanuatu engineers and receiving the assistance of experts in Vanuatu.

1. Operation and maintenance technique hydroelectric power plant

- Training of engineers (in Japan)

Electrical and mechanical engineering	4 persons
Civil engineering	1 person

- Experts to Vanuatu (long term) 1 person

2. Electric utility management

- Experts to Vanuatu (short term) 2 persons

CHAPTER 5

BASIC DESIGN

CHAPTER 5 BASIC DESIGN

5.1 PRINCIPLE OF DESIGN

As the Republic of Vanuatu is comprised of more than 80 islands, its economic and social structure are divided among those islands. The population in Port Vila, the metropolis, is roughly 19,000 and in Luganville, the submetropolis, is approx. 7,000. The scale of every city is small due to such geographic circumstances and therefore the infrastructure which support the function of city is remaining at an elementary stage. In such a situation, the opportunity of construction work is seldom and the scale of such construction work, if it takes place, are comparatively limited. Most of the materials necessary for the construction work are imported from other countries except lumber and aggregate for concrete. In regard to the labor to be used for the construction work, employment of unskilled forces on the spot is possible, however, skilled forces should be procured from the third countries or from Japan. Therefore, all these factors and conditions should be taken into consideration at design stage and must pay attention to the following points.

- As annual rainfall over the Project Site is about 3,500mm and it is concentrated from October to April, therefore careful planning of implementation program is necessary.

- Since the Project area belongs to the volcanic zone, it should be taken into consideration on determination of earthquake coefficient for calculation of stability of the structures.

- As Santo island where the Project Site is located, is on the route of cyclone, it should be taken into consideration on the determination of wind pressure coefficient.

- In order to ease the construction works, maintenance and operation of the plant, the layout and the shape of such structures should be carefully determined.

- As regard to the portion of construction work to be done by the expense of the Republic of Vanuatu Government, the scope of work

should be decided under due consideration of their capability of technology and available fund.

In addition to the above, the concrete principles of design are as follows.

(1) Taking a possible expansion of 600kW to take place in the future into account, the portion of aqueduct between the intake and the head tank is to be constructed to match with the capacity for 1,200kW in this stage.

(2) In principle, the planned hydroelectric power plant and existing diesel electric power plant are to be operated in parallel, but in case either power plant is temporarily interrupted due to inspection and repair, the other plant is to be operated independently. For this reason, a frequency control function is to be equipped in the present hydroelectric power plant.

(3) Between the present hydroelectric power plant and the exiting diesel electric power plant in Luganville are to be linked with a planned 15 kV transmission line, and the available electric power is to be distributed to Luganville through the existing distribution line.

(4) In order to ease the operation and the maintenance of the power plant and transmission line, simplification of those facilities and maintenance free measures should be taken into account and due consideration is to be given on securing of sufficient spare parts to be able to cope with unexpected failures or troubles.

(5) In order to ease the construction work, maintenance and operation and to minimize the clear-cutting of natural forests, the route of transmission line shall be constructed along the existing roads. Although the distribution of electric power to the private houses locating nearby the route of transmission line is not included in this Project, but facility for junction shall be included in the Project in order to ease the distribution of power to those houses in the future.

(6) The intake gate, spillway gate and flashing gate will not be used frequently (only once or twice in a year), therefore, the

operation of such gates is to be made manually.

(7) With a view on the protection of rivers from the eventual pollution of oil leaked from the equipment, oilless mechanism and equipment shall be applied (electric servomotor and oilless metal are to be used).

5.2 CONDITIONS OF DESIGN

Based on the collected data and results of site survey by the Team, the conditions of the design is determined as follows:

(1)	Name of river	Sarakata River
(2)	Catchment area	91km^2
(3)	Daily average flow	9.65m^3/s in 1984 (max.) 2.84m^3/s in 1983 (min.)
(4)	Location of dam	180m upstream of the waterfall
	Elevation (Riverbed)	114m
(5)	Location of power plant	700m downstream of the waterfall
	Elevation (Riverbed)	88m
(6)	Meteorological conditions	
	i) Temperature	40°C (max.) 10°C (min.)
	ii) Wind velocity	50m/s (average for 10 minutes)
	iii) Rainfall	3,500mm/year
(7)	Earthquake coefficient	Kh = 0.15 (horizontal) Kv = 0.10 (vertical)
(8)	Installed capacity	300kW x 2 units = 600kW
(9)	Maximum water discharge	1.5m^3/s x 2 units = 3.0m^3/s