BASIC DESIGN STUDY REPORT

ON

ESTABLISHMENT PROJECT

FOR

MICRO HYDRO POWER FACILITIES

IN

THE KINGDOM OF BHUTAN

JULY 1985

JAPAN INTERNATIONAL COOPERATION AGENCY

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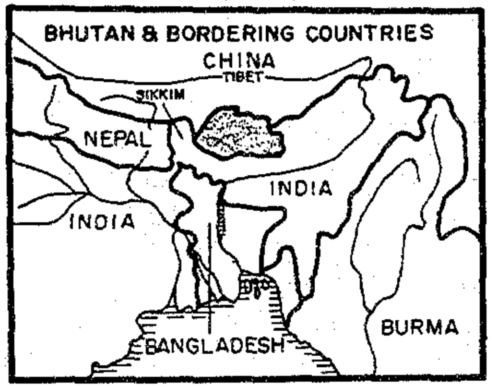
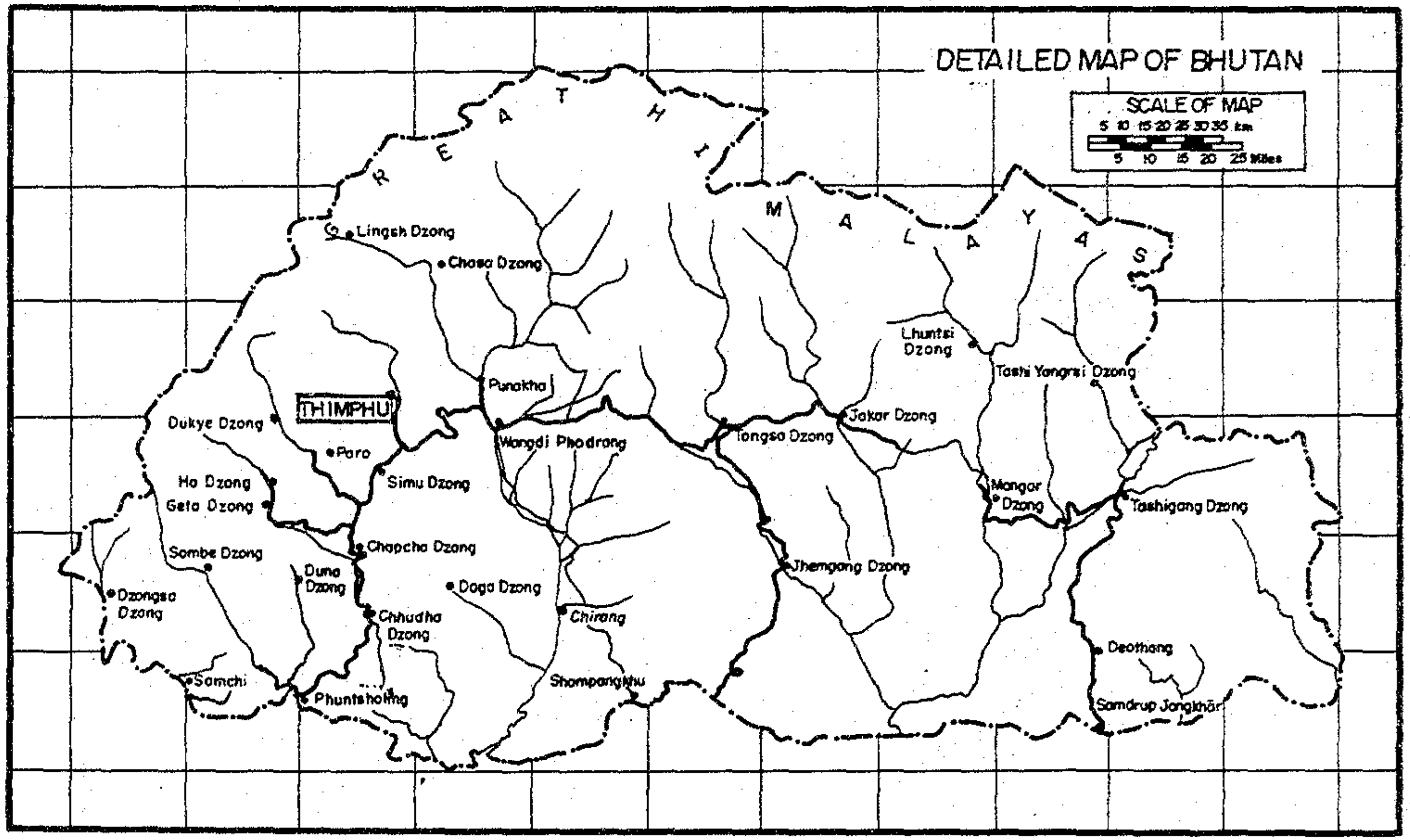
LOCATION OF BHUTAN

Area: 18,000 square miles
Position: Approximately between 26'45" and 28'10" north latitude and 88'45" and 92'10" east longitude
Population: 1,200,000
Capital: Thimphu



PAVED ROADS
UNPAVED ROADS
RIVERS
BOUNDARIES/INTERNATIONAL



PREFACE

In response to the request of the Government of the Kingdom of Bhutan, the Government of Japan decided to conduct a Basic Design Study on the Establishment Project for Micro Hydro Power Facilities and entrusted the study to the Japan International Cooperation Agency (JICA). The JICA sent to Bhutan a study team headed by Mr. Tetsuo Nishimura, Grant Aid Division, Economic Cooperation Bureau, Ministry of Foreign Affairs from April 7th to May 5th, 1985.

The team had discussions with the officials concerned of the Government of the Kingdom of Bhutan and conducted a field survey in Thimphu and the project sites. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the project and contribute to the promotion of friendly relations between the two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Kingdom of Bhutan for their close cooperation extended to the team.

July, 1985

Keisuke Arita
President
Japan International Cooperation Agency

SUMMARY

The Kingdom of Bhutan, (hereinafter called "Bhutan") lying north of India, is a mountainous country whose territory is at the sourthern part of the Himalaya Range. Bhutan with an area of some 437,000 hectres is surrounded by neighbouring countries on all sides and has a population of approximately one million two hundred thousand inhabitants.

Most of the population dwells in the so-called "Intermediate Zone" between areas at an elevation of 3,000 metres and the boundary with India.

Bhutan is rich in her natural environment; agriculture, forestry and animal husbandry are the major industries in Bhutan. There is no remarkable disparity in the living standards of the people. They lead a serene life.

However, Bhutan is one of the countries of which the national income belongs to the low income class in the world. Bhutan's industrial foundation is fragile and relies upon assistance from the Government of India for more than 50% of the national budget.

In order to improve the above-mentioned circumstances, the Government of Bhutan has been implementing the fifth Five-Year National Economic Development Plan; thereby striving to reinforce the industrial foundation and improve the livelihood of the people.

The said Plan takes up an improvement in the daily life of inhabitants as one of the important objectives. The Government of Bhutan has designated the towns and villages which are expected to play an important role in each district in respect to the expanding and reinforcing of the educational facilities, medical services and communication facilities and to the improvement of sanitary conditions including the ensuring of a potable water supply. Thus, the Government of Bhutan is in the course of expanding and reinforcing public institutions in the said towns and villages. Electrification of these towns and villages, which is indispensable for the promotion of the Plan, has just gotten under way. This slow process has proven to be a great hindrance to the attainment of the goals contained in the Plan.

Bhutan is estimated to have hydraulic potentials of 6,000 MW. Of these potentials, hydro power plants with a total installed capacity of 3.46 MW were constructed in seven places. This output is even less than a 0.1% of the hydraulic potentials.

At present, development of the Chukha Hydro Power Project is going on with the assistance of the Government of India. The installed capacity thereof is 336 MW, which is 18 times as large as that of all existing power plants (about 19 MW) including diesel power plants in Bhutan. Places which will be in a position to receive electric power from the Chukha Power Plant are Thimphu, the capital of Bhutan and other cities in the western part of the country. After the completion of this project, surplus power is expected to be exported to India. Accordingly, rural areas other than those mentioned above will not be supplied with electric power from the said power plant. The reason is that since an enormous amount of funds will be needed for the construction of transmission lines and relevant facilities, it is, in fact, impossible to supply electric power to these remote rural areas under the present situation.

Therefore, it is believed that development of small scale hydro power development projects by exploitation of small rivers, streams and irrigation canals scattered in each area will be most effective and proper for the purpose of supplying electric power which is indispensable for promoting the reinforcement of the towns and villages. The Department of Power has worked out a development plan of 150 small scale hydro power plants throughout the country. Because of a shortage of the number of technical personnel and due to the insufficiency of domestic funds alloted for the development, this plan seems difficult to be implemented.

Because of the background mentioned above, the Government of Bhutan has requested the Government of Japan to render its grant aid to procurement of materials and equipment for construction of ten (10) micro hydro power plants as part of the development plan mentioned hereinabove.

In response to this request, the Government of Japan decided to conduct a basic design study on this Project and sent a basic design study team (hereinafter called the "Team") to Bhutan for a period of twenty-nine (29) days from April 7 to May 5, 1985.

The aims of this basic design study are to examine the background, contents and appropriateness of the said request and to conduct studies necessary to determine the optimal scale of the Project.

The Team also had a series of discussions with officials concerned of the Government of Bhutan. In addition to the ten (10) sites for which the request had been made, the Team examined the appropriateness of several other sites on which data were relatively available and to which access was possible for the Team to conduct field surveys. As a result of their considerations, it was mutually agreed upon between the Team and the Government of Bhutan that ten (10) sites which have a high urgency priority should be incorporated into the scope of the basic design study of Project. These ten (10) sites are situated in seven (7) districts of Wangdiphodrang, Bumthang, Tongsa, Shemgang, Gaylegphug, Mongar and Punakha. The Team conducted field surveys on the proposed Project sites in the central mountainous and other areas.

In connection with the construction of micro hydro power plants at the ten (10) sites, the Government of Bhutan newly requested that the Government of Japan provide its grant aid for the construction cost of such power plants on the ground that there will be a difficulty in raising funds for the construction of the said power plants at the ten (10) sites.

After its return to Tokyo, the Team conducted a series of studies based on the results of the surveys performed in Bhutan. According to the results of such work, the Team conducted the basic design study on the procurement of materials and equipment for and the construction of the micro hydro power plants for the electrification of 10 villages in the central mountainous districts and neighbouring areas.

The production amount of the agriculture, forestry and animal husbandry accounts for 63% of the Gross National Product (GDP) of Bhutan while those of the services and industry constitute a 31% and 6%, respectively.

Under the aforementioned circumstances, electric power demand arising from public institutions and domestic consumers occupies almost all of the total power demand in Bhutan. At the end of March 1984 there were only 23 towns, 93 villages and about 9,300 households in terms of the number of consumers which shared in the benefits of "electricity". The total supply of the existing power facilities is recorded at almost 19,000 kW in the whole of Bhutan whereas that of the facilities owned by the Department of Power, in other words, power supply to its general consumers is somewhat 7,900 kW, accounting for approximately 41%. In addition, there exist captive generating power plants owned by organizations other than the Department of Power such as Penden Cement (2,500 kW), Gedu Wood Manufactaring Corp. (550 kW), power generating facility (6,600 kW) for construction owned by Chukha Hydro Power Project Authority.

The maximum power demand of general consumers in Bhutan is recorded at 5,341 kW of which 2,867 kW is supplied by the Department of Power. The balance of power demand is made up by import of electric power from India.

As stated above, the reason why the actual quantity of power supply (2,867 kW) in Bhutan is small, compared with the installed capacity (7,900 kW) of the existing facilities, is that there exist hardly any interconnection systems among districts or areas and there are different reasons depending upon respective power plants. Some power plants are defunct whereas there is a shortage of water although no problem is raised with machinery and devices of power plants. In some cases the installed capacity of a power plant is excessively large compared with demand arising from its consumers.

There is no doubt that interconnection of power systems will be effective for the full use of power plants. Nevertheless, in a country like Bhutan where consumers are scattered throughout the country and their numbers are small, such interconnection of independent and isolated power systems would prove a poor investment efficiency and it is not realistic.

However, potential demand for power is quite strong. Among others, the following categories of facilities activate a demand for power.

(1) Lighting for dormitories of schools in towns and villages

(2) Electric power for clinics and dispensaries in districts

(3) Electric power and electricity for ordinary households

(4) Electric power for rice, flour and timber mills

In order to satisfy the power demands shown hereinabove, development of large scale hydro power plants and construction of transmission and distribution lines will not be economical or practical. It is, therefore, considered that hydro power development by utilization of small and medium scale rivers, streams and irrigation canals at the Project sites and adjacent areas will be quite effective and proper for promotion of the electrification scheme which the Government of Bhutan is considering accomplishing.

Taking into account the background of and the necessity for the Project, the Team has worked out the plan for development of the micro hydro power plants and hereby proposes that the facilities be furnished on a grant aid basis with careful attention to the points listed below.

(1) The power generating facilities to be constructed will have sufficient capacity to supply electric power to public institutions. If there is surplus electric power, it will be supplied to households for their lighting.

(2) Selection will be made of rivers and streams to correspond to the scale of power demand. The power plants will be built in places adjacent to load centres.

(3) In this case, it has been arranged that installation of the micro hydro power plants has shown that there will be no obstacle to the existing irrigation facilities and future irrigation schemes.

(4) Since this Project aims at electrification of towns and villages where no electrcity is available, equipment and machinery of which operation is quite safe and of which maintenance can be made with ease have been selected and designed.

(5) All possible standardization of the design of the equipment and machinery of the power generating facilities has been made to rationalize construction works and operation and maintenance of the facilities.

Outline of Facilities to be Constructed by Grant Aid

No.	Project Sites		Scale of Hydro Power Plant					No. of Conceivable Consumers		
	Site No.	Name of Site	Max. Installed Capacity (kW)	Max. Discharge (m^3/s)	Effective Head (m)	Length of Transmission Line(km)	Length of Distribution Line(km)	No. of Public Institution	No. of House	Population
							*-1	*-2	*-3	*-4
1	3	Rukubji	40	0.17	40	0.4	0.6	0 (7)	45(65)	600
2	4	Ura	50	0.42	20	3.0	1.6	8 (8)	50(104)	500
3	5	Tangsibi	30	0.13	40	0.5	0.8	1 (6)	70(130)	620
4	6	Bubja	30	0.10	50	1.1	1.0	5 (7)	48	130
5	7	Surey	70	0.24	50	2.4	1.2	4 (6)	240	2000
6	8	Yadi	30	0.10	50	3.7	1.8	7 (7)	115(540)	300
7	101	Punakha	30	0.13	40	2.9	1.6	7 (7)	32(54)	180
8	102	Tongsa	50	0.21	40	0.5	0.8	13(13)	100	1600
9	103	Tamjhing	30	0.10	50	0.2	0.8	0 (6)	35(70)	350
10	104	Kekhar	20	0.11	30	2.2	0.8	0 (6)	27	260
		Total	380	—	—	16.9	11.0	—	—	—

Note : * - 1 : The distribution line is only for public institutions.

* - 2 : The figure shown in parenthesis shows the number of public institutio including the number of such proposed institutions.

* - 3 : The figure shown in parenthesis shows the number of houses at the Project site and adjacent places.

* - 4 : The approximate number of persons which was briefed by the heads of villages.

The above-mentioned facilities will include ten (10) micro hydro power plants with a total installed capacity of 380 kW. Each of these power plants is to be of a run-of-river-type. Since the effective heads range from 20 metres to 50 metres, turbines of cross-flow type most suitable for the heads are to be adopted. Standardized specifications are commonly applied to the structures of the respective power plants thereby simplifying the operation and maintenance of these power plants.

The work to be done by the Japanese side on a grant aid basis will include procurement of materials and equipment for the above-mentioned facilities and the construction of the power generating facilities.

The work to be done by the Government of Bhutan will include acquisition of lands for the construction of the facilities, construction and/or reinforcement of access roads for transportation of materials and equipment and operation and maintenance of the facilities after completion thereof.

The amount of the expenses to be borne by the Government of Bhutan comprises ninety-eight thousand ngultrums (Nu. 98,000) (2 million yen) for construction and reinforcement of access roads, one million eight hundred and fifty-four thousand ngultrums (Nu. 1,854,000) (38 million yen) for acquisition of lands, totalling one million nine hundred and fifty-two thousand ngultrums (Nu. 1,952,000) equivalent to forty (40) million yen.

In addition, the annual operation and maintenance cost of the hydro power plants at the 10 sites is estimated at approximately four hundred and eight thousand ngultrums (Nu. 408,000) equivalent to about eight million four hundred thousand yen (8.4 million yen).

The construction period of these facilities will take around seventeen (17) months when counted from the signing of the Exchange of Notes (E/N).

The implementing agency of this Project will be the Department of Power belonging to the Ministry of Trade, Industry and Power of Bhutan. The daily operation and maintenance of the facilities are to be performed by the inhabitants of the respective sites whereas technical personnel from the Department of Power are to patrol such facilities for the periodical operation and maintenance thereof. It will be possible for the Department of Power to appropriate expenses to be incurred in the operation and maintenance of these power plants out of their energy sales revenues.

It is anticipated that the following benefits will be brought about through a power supply following the completion of this Project.

(1) Improvement of the levels of education and medical services in local communities.

(2) Encouragement of local industries and promotion of economic activities.

(3) Lighting, cooking and saving of labour for gathering firewood thereby improving the livelihood of inhabitants.

(4) Protection of timber resources that will result in forestry conservancy and flood control as a propagation effect of the benefit as stated in (3).

Besides the benefits enumerated above, technology transfer will be made possible through the provision of Japanese Grant Aid. This will also serve for nurturing technical personnel of the Department of Power and improving their expertise.

If professional persons in the field of operation and maintenance work are trained in this way, it can be further expected that such man-power will be of great help in raising the technical level in connection with the implementation of this Project.

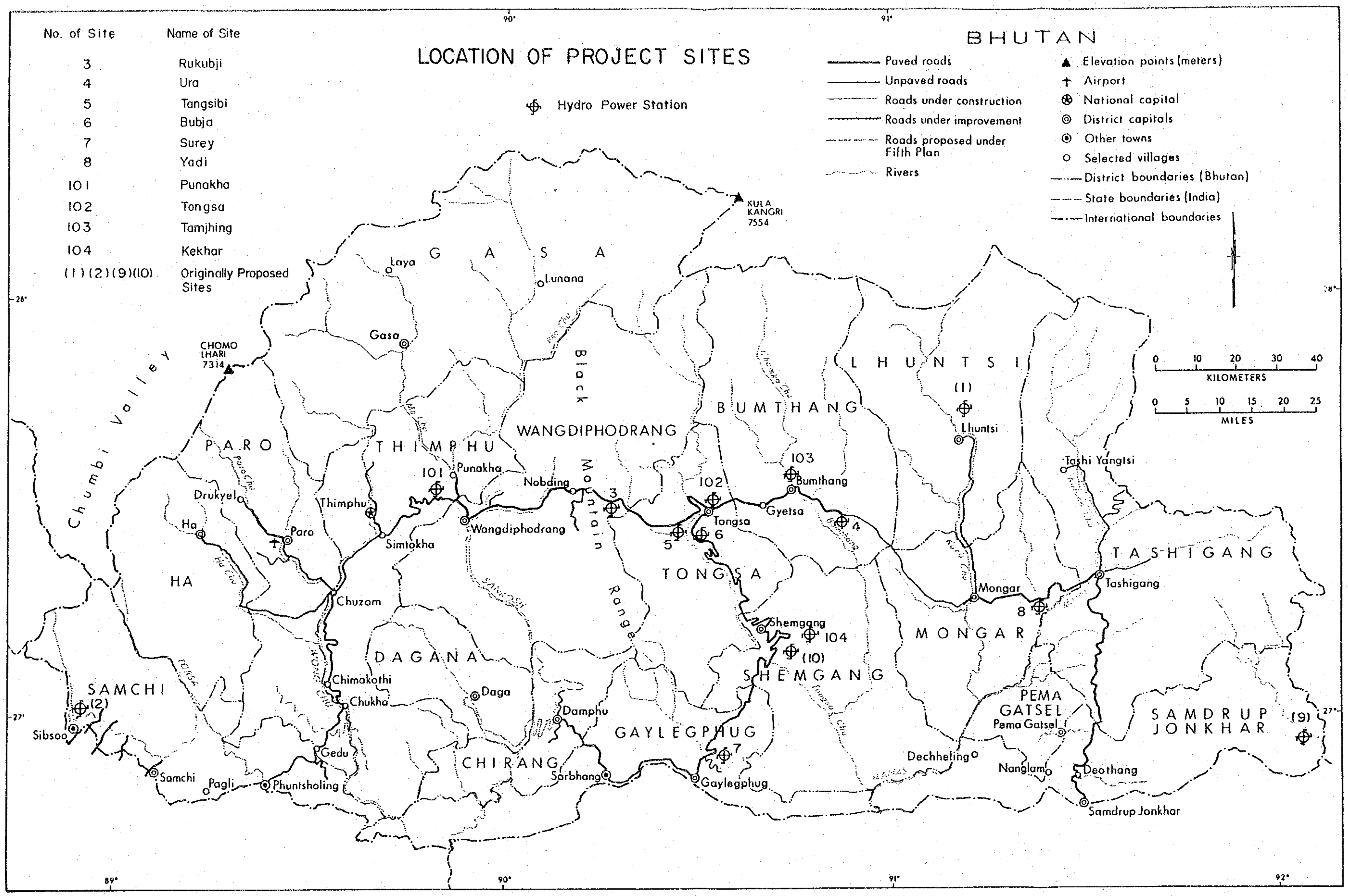
If the above-mentioned benefits and effects are fully taken into account, this Project is judged to be meaningful and worthy of being implemented.

It is believed justifiable for the Government of Japan to extend its grant aid for the implementation of this Project.

In implementing this Project, it is desired that the Government of Bhutan ensure the acquisition of lands for construction of the facilities; construction and reinforcement of access roads for transport of materials and equipment; performance of procedures for the import of these materials and equipment; and the allotment of budgets for expenses to be incurred in the work performed by the said Government.

The matters of urgency for the time being will be the collection and sorting of hydraulic data, the preparation and compilation of topographical maps and the training of personnel to be engaged in the operation and maintenance work of the micro hydro power plants for the purpose of implementing the Project effectively.

CONTENTS


LOCATION OF PROJECT SITES
BHUTAN
No. of Site
Name of Site
3 Rukubji
4 Ura
5 Tangsibi
6 Bubja
7 Surey
8 Yadi
101 Punakha
102 Tongsa
103 Tamjhing
104 Kekhar
(1)(2)(9)(10) Originally Proposed Sites
Hydro Power Station
Paved roads
Unpaved roads
Roads under construction
Roads under improvement
Roads proposed under Fifth Plan
Rivers
Elevation points (meters)
Airport
National capital
District capitals
Other towns
Selected villages
District boundaries (Bhutan)
State boundaries (India)
International boundaries
0 10 20 30 40
KILOMETERS
0 5 10 15 20 25
MILES
90°
91°
89°
92°
28°
27°
KULA KANGRI 7554
CHOMO LHARI 7314
Chumbi Valley
G A S A
Laya
Lunana
Gasa
Black Mountain Range
L H U N T S I
B U M T H A N G
WANGDIPHODRANG
P A R O
T H I M P H U
T O N G S A
T A S H I G A N G
H A
D A G A N A
S A M C H I
M O N G A R
S H E M G A N G
PEMA GATSEL
S A M D R U P J O N K H A R
G A Y L E G P H U G
C H I R A N G
Lhuntsi
Tashi Yangtsi
Punakha
Nobding
Bumthang
Drukyel
Thimphu
Gyetsa
Tongsa
Ha
Paro
Wangdiphodrang
Simtokha
Tashigang
Mongar
Chuzom
Shemgang
Chimakothi
Chukha
Daga
Damphu
Pema Gatsel
Sibsoo
Gedu
Dechheling
Nanglam
Deothang
Samchi
Pagli
Phuntsholing
Sarbhang
Gaylegphug
Samdrup Jonkhar

CHAPTER 1 INTRODUCTION

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The Government of the Kingdom of Bhutan (hereinafter called the "Government of Bhutan") has been undertaking the 5th National Economic Development Plan covering six years from 1981 through 1987.

One of the specific objectives of the said Plan is enhancing the quality of life, for which the Government of Bhutan has been endeavouring to improve education, health and medical standards, to secure water for villagers and to alleviate social and economic imbalance.

However, most of towns and villages scattered in the country are still not served with electricity. This provides a great hindrance to the improvement of school education, public health, veterinary sanitation, communication and so on.

In order to overcome these problems, the Government of Bhutan has formulated a plan to develop small scale hydro power plants utilizing rivers in each district which will help to improve the quality of life in the rural and mountainous areas.

According to this plan the Government of Bhutan has selected 150 sites, out of which 10 sites have been chosen to install micro hydro power plants at first. Thus, the Government of Bhutan has requested the Government of Japan to render its grant aid to procure materials and equipment necessary for the realization of the Project.

The Government of Japan has decided to conduct a basic design study on the Project after examination of the request.

In pursuance of the decision, Japan International Cooperation Agency (hereinafter called "JICA") has sent to Bhutan the basic design study team (hereinafter called the "Team") headed by Mr. Tetsuo Nishimura, Grant Aid Division, Economic Cooperation Bureau, the Ministry of Foreign Affairs for a period of 29 days from April 7 to May 5, 1985.

The Team discussed with officials concerned of the Government of Bhutan details of the request. During the course of the discussions, the Team examined the appropriateness of several sites, on which data are available, other than the ten (10) sites for which the request had been made. As a result of their assessment, it was agreed upon between the Government of Bhutan and the Team that ten (10) sites having a high priority of urgency for development be taken up anew for this basic design study. On that occasion, an additional request was also made by the said Government to assist them to construct generating facilities at the proposed 10 sites on a grant aid basis. The Team conducted field surveys on the rivers involved and transmission line routes, held hearings on electric power supply of the country and collected pertinent data and information. The basic agreements resulted from the discussions with the officials concerned of the Government of Bhutan were summarized in the form of the "Minutes of Discussions", which was signed by the representatives of both parties on April 23, 1985.

The member list of the Team, itinerary of the site surveys, parties and officials visited, Minutes of Discussions, list of data collected and so forth are attached to the end of this Report as Annex.

This Report has been prepared and compiled after conducting a series of studies after the return to Tokyo of the Team, based on the results of the field surveys performed in Bhutan.

The Report incorporates the selection of materials and equipment, basic design of the generating facilities, estimates of the Project cost, operation and maintenance plan and the most suitable plan for the implementation of the Project which were prepared upon examination of the appropriateness of this Project.

CHAPTER 2 BACKGROUND OF THE PROJECT

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2-1 National Economic Development Plan

2-1-1 Background

The Five-Year National Economic Development Plan commenced in 1961 was already launched into its fifth Plan, bearing various fruitful outcomes.

The prime objectives are socio-economic development and economic self-reliance. Priorities were placed on such specific targets as roads, communications, education, health and medical facilities, with major part of the state budget being spent on these targets resulting in, by October 1979, completion of: roads 1,900 km, electrified villages 98, hospitals and clinics 81, schools 155, agriculture and animal husbandry facilities 89.

Major sources of funds to implement the Plans from the 1st through 4th Plans were proceeds from grant aid by the Government of India while assistance from UNDP and other international organizations increased from some 3% of the 3rd Plan to 18% of the 4th Plan.

In 1971 while the 3rd Plan was being implemented the Planning Commission was established. The Commission is responsible to determine priorities among projects. An attempt was made under the 4th Plan to involve more directly the populace in development by establishing District Development and Planning Committee (DDPC) in each district to enable the representatives of the people to meet with public officials and express their own development priorities. The projects thus proposed by each district are to be submitted to the joint committee of ministries concerned and the National Planning Commission for consideration and subsequent decision.

2-1-2 The 5th National Economic Development Plan (1981 - 1987)

The 5th National Economic Development Plan has been established to cover the six years from 1981 through 1987 with a view to achieving the following objectives:

- to rectify socio-economic imbalance,
- to improve the quality of life in education, health, medical care, and water supply for daily life,
- to create administrative infrastructures to cope with socio-economic development,
- to improve productivity in agriculture, inter alia,
- to create the sources of budgetary funds through exploitation of natural resources,
- to establish the nation's fiscal systems,
- to develop human resources, etc.

As shown in Table 2-1, the appropriation of the budget for the Plan among respective sectors places priorities upon;

- agriculture (including irrigation and animal husbandry)
- education
- electric power
- public works
- iron and steel industry
- forestry, and
- tourism.

The second largest amount of the budget after the Industry and Mining is alloted to the electric power sector. The budget shared by the electric power sector constitutes an approximately 22% of the total budget amount of Bhutan. The Government of Bhutan aims at electrification of 40% of towns and villages in the whole of the country during the period of the fifth Five-Year Plan.

Table 2 - 1 Record of Implementation of Development plan

Nu Million
(Percentage : %)

	First 1961 - 66		Second 1966 - 71		Third 1971 - 76		Fourth 1976 - 81		Fifth 1981 - 87	
Agriculture	1.9	1.8	21.6	10.7	58.3	12.3	259.0	23.5	421.6	13.3
Animal Husbandry	1.5	1.4	5.8	2.7	24.2	5.1	61.5	5.6	55.4	1.7
Forestry	3.2	3.0	6.9	3.4	28.4	6.0	110.3	10.0	237.8	7.5
Power	1.5	1.4	9.2	4.5	30.1	6.4	50.5	15.8	699.0	22.0
Industry and Mining	1.1	1.0	1.0	0.5	25.2	5.3	175.0	5.3	721.0	22.7
Public Services	62.9	58.7	70.5	34.9	84.6	17.8	128.3	11.6	499.9	14.2
Transportation	7.5	7.0	11.9	5.9	9.5	2.0	…	…	94.4	3.0
Post & Telegram	0.5	0.5	5.9	2.9	11.4	2.4	16.9	1.5	5.8	0.2
Communication	…	…	…	…	14.8	3.1	37.3	3.3	35.8	1.1
Tourism	…	…	…	…	14.1	3.0	12.5	1.1	31.1	1.0
Education	9.4	8.8	35.7	17.7	90.0	19.0	134.6	12.1	130.8	4.1
Health Preservation	3.1	2.9	16.7	8.2	38.1	8.0	54.6	4.9	74.6	2.3
Public Relations	…	…	1.3	0.7	4.0	0.8	11.0	1.0	9.5	0.3
Government Offices	3.5	3.3	8.8	4.3	16.3	3.4	34.3	3.1	181.8	5.7
Preservation of Historical Remanents	…	…	0.6	0.3	2.1	0.4	…	…	…	…
Others	10.9	10.1	6.2	3.1	24.0	5.0	20.3	1.9	27.6	0.9
Total	107.2	100.0	202.2	100.0	475.2	100.0	1,106.2	100.0	3,176.1	100.0

Source : 5th Development Plan

Table 2 - 2 CAPACITY OF GENERATING STATION AS OF 31. 3. 1984

TYPE	Installed capacity (kW)
HYDRO	
1. Department of Power	3,450
2. Chukha Project	–
3. Penden Cement	–
4. Other Non-utilities	10
Total	3,460
DIESEL	
1. Department of Power	4,442
2. Chukha Project Authority (6 x 248 + 6 x 400 + 6 x 248 + 4 x 126.7) + (2 x 55.6 + 1 x 7.2)	6,001.2
3. Penden Cement Authority (3 x 850)	2,550
4. Gedu Wood Manufacturing Corporation	550
5. Other Non-utilities :	
i) P'ling : 1,022.0	
ii) Thimphu : 723.5	
iii) G'Phug : 68.5	
iv) Paro : 250.0	
v) P & T Jabjekha : 48.0	2,112
Total	15,655.2
Total Capacity of the Country	19,115.2

2-2 Power Supply Facilities

2-2-1 Governmental body in charge of electric power

The Department of Power of Ministry for Trade, Industry and Power is solely responsible for power generation, transmission and distribution over the whole territory of Bhutan, and there exists no electricity supply board nor electricity public corporation. Besides the Department of Power, power generating facilities are operated by Chukha Hydro Power Project Authority, Penden Cement, Gedu Wood Manufacturing Corp., etc.

2-2-2 *Share of the Department of Power in power supply*

Tables 2-2 through 2-4 show the installed capacity, actual records of power generation and consumption of electric power.

As shown in Table 2-2, as of March 1984 the total installed capacity of generating facilities throughout Bhutan is 19,115.2 kW comprising the installed capacity of hydro and diesel generating facilities.

Of this figure, 7,892 kW equivalent to 41% of the above total installed capacity is shared by the Department of Power. In addition to the Department of Power, there are other organizations which have their own diesel power generating sets as follows:

Chukha Hydro Power Project Authority: 6,001.2 kW (for construction)
Penden Cement Factory : 2,550 kW

As shown in Tables 2-3 and 2-4, annual power consumption for the fiscal 1983/84 ending in March 1984 was 45,132 x 10^6 kWH, approx. one third of which, 14,812 x 10^6 kWH (approx. 33%), was supplied by the Department of Power. Approx. 30% of the above, 4,895 x 10^6 kWH, however, was imported from India.

2-2-3 Power plants and power supplying district

All the power plants in Bhutan are as shown in Table 2-5. In 1985, the capacity of 7 hydro power plants is 3,460 kW and that of 16 diesel power plants 15,655.2 kW, totalling 19,115.2 kW. The said total capacity of all the power plants in Bhutan includes the capacity of

Table 2 - 3 DETAILS OF GENERATION AND ENERGY AVAILABILITY, 83 - 84

Particulars	Gross Generation in GWH	Consumption of Power House in GWH	Import in GWH	Export in GWH	Energy available in GWH
1. Dept. of Power	10.272	0.350	4.895	—	14.812
2. Chukha Project Authority **	5.00	0.28	10.27	—	14.99
3. Penden Cement Authority **	6.36	—	7.98	—	14.34
4. Gedu Wood Manufacturing Corpn.	0.99	N.A.	N.A.	N.A.	0.99
5. Other Non-utilities	—	—	—	—	—
TOTAL	22.622	0.63	23.145	—	45.132

** Data supplied by C.P.A. & Penden Cement Authority

Table 2 - 4 DETAILS OF ENERGY CONSUMPTION & LOSSES

Particulars	Energy availability (GWH)	Energy consumption in GWH	Loss in GWH	% of Loss
1. Dept. of Power	14.812	10.75	4.062	27.4
2. Chukha Project Authority	14.99	11.41	3.58	23.88
3. Penden Cement Authority	14.34	14.34	—	—
4. Gedu Wood Manufacturing Corpn.	0.99	0.99	—	—
5. Other Non-utilities	—	—	—	—
TOTAL	45.132	37.49	7.642	16.9

Table 2 - 5 Power Generating Capacity

Generating Station	No. of Units x Capacity	Installed Capacity	Commissioning Year
Department of Power			
Hydroelectric Generating			
Thimphu	4 x 90kW	360kW	1967
Gidakom	5 x 250kW	1,250kW	1973
Wangdiphodrang	3 x 100kW	300kW	1972
Tashigang	3 x 250kW	750kW	1972
Mongar	3 x 130kW	390kW	1976
Paro	4 x 100kW	400kW	1970
Other Non-Utilities	10kW	10kW	——
Sub-total		3,460kW (18%)	
Diesel Generating			
Phuntsholing	2 x 128kW 2 x 248kW	256kW 496kW	1966 1979
Samchi	1 x 135kW	135kW	1982
Paro	1 x 90kW 1 x 60kW	150kW	1969 1977
Thimphu	2 x 248kW 1 x 500kW 2x 254.5kW 2 x 150kW 1 x 400kW 1 x 950kW	3,155kW	1977 1978 1980 1982 1983 1984
Damphu	1 x 70kW	70kW	1969
Tongsa	1 x 60kW	60kW	1976
Shemgang	1 x 80kW	80kW	1983
Dagana	1 x 40kW	40kW	1983
Sub-Total		4,442kW (23%)	
Total		7,902kW (41%)	
Others			
Penden Cement	3 x 850kW	2,550kW	
Gedu Wood Manufacturing Corp.	2 x 275kW	550kW	
Chukha Hydro-Power Project Authority	6 x 248kW 6 x 400kW 6 x 248kW 4x 126.7kW 2 x 55.6kW 1 x 7.2kW	6,001.2kW	
Other Non-utilities		2,112kW	
Total		11,213.2kW (59%)	
Grand-Total		19,115.2kW (100%)	

11,213.2 kW of captive power plants for the use of enterprises and for construction purposes which are under the ownership of organizations other than the Department of Power.

As shown in Fig. 2-1, these power facilities are not interconnected except for those in southern Bhutan and are isolated and independent.

As for imported power from India, the system in southern Bhutan is linked to that in east-northern India.

Bhutan's Gaylegphug District and Samdrup-Jonkhar District are importing electric power from India through the Assam State Electricity Supply Board's substations and 33 kV lines, while the Districts of Sibsoo, Phuntsholing, Pagli and Samchi are likewise buying electricity from the West Bengal State Electricity Supply Board.

The existing transmission lines comprise 66 kV line from Birpar of India to Thimphu via Phuntsholing and Chukha and 33 kV and 11 kV lines. The above transmission lines are not reliable, especially in the districts supplied by India where power black-outs take place frequently due to insufficient maintenance of the facilities.

Most of the existing power plants have been constructed and operated with the assistnace of India, and some of the facilities are so obsolete and inappropriately maintained that their plant factor is undesirably low.

All of Bhutan's hydro power plants are of a run-of-river-type. Actual conditions of operations are not clear due to a lack of comprehensive operation records and a basic plan of power plants having not been clarified. Judging from the demand/supply position of power, however, it is presumed that during summer when rivers flow in abundance power generation can satisfy the demand while in winter when power demand reaches its peak, the available supply barely covers as little as about one half of the peak load making frequent power cuts inevitable.

Except for Thimphu-Paro area and southern Bhutan which are the main power consuming area of the country, most of the power supply in the country is localized (isolated) and is not interchanged, which is the most remarkable characteristics.

Accordingly, statistics of the Department of Power as of the end of March 1984 enumerates that electrified localities are 23 towns and 93 villages.

The electrified areas account for about 3% of all towns and villages in number. Data furnished by the Department of Power shows that per capita consumption of electric power in Bhutan is 8.74 kWH.

Breakdown thereof in each district is as shown in Table 2-6.

2-2-4 Substation

The outline of substations belonging to the Department of Power is as per Table 2-7.

The main substations in Bhutan are situated at ten locations all over the country. The total number of step-up and step-down transformers installed in the main substations is 31 units and their aggregated capacity is 11,005 kVA.

In addition 138 distribution transformers with their aggregated capacity of 17,091 kVA are installed in 126 distribution substations.

All of the above-mentioned transformers are made in India, being operated and maintained under supervision by Indian engineers.

2-2-5 Transmission and distribution lines

The preceding Fig. 2-1 shows the outline of the transmission lines.

Table 2-8 shows the lengths of transmission lines and distribution lines separately listed for each owner. The highest voltage is 66 kV line, a majority of which is owned by Chukha Hydro Power Project Authority.

Among the power systems of Bhutan, only the western region is being linked into a grid and strengthened to be fed by the Chukha Hydro

Power Project upon completion thereof, while the central and eastern regions are served by a localized independent system of each power station and the southern region is served by the system interconnected with the Indian power authorities.

The distribution line serving consumers is operated at 400/230 V with three phase four-wire system.

Fig. 2-1 MAP OF BHUTAN ELECTRIC POWER SYSTEM

SCALE 1 / 500,000

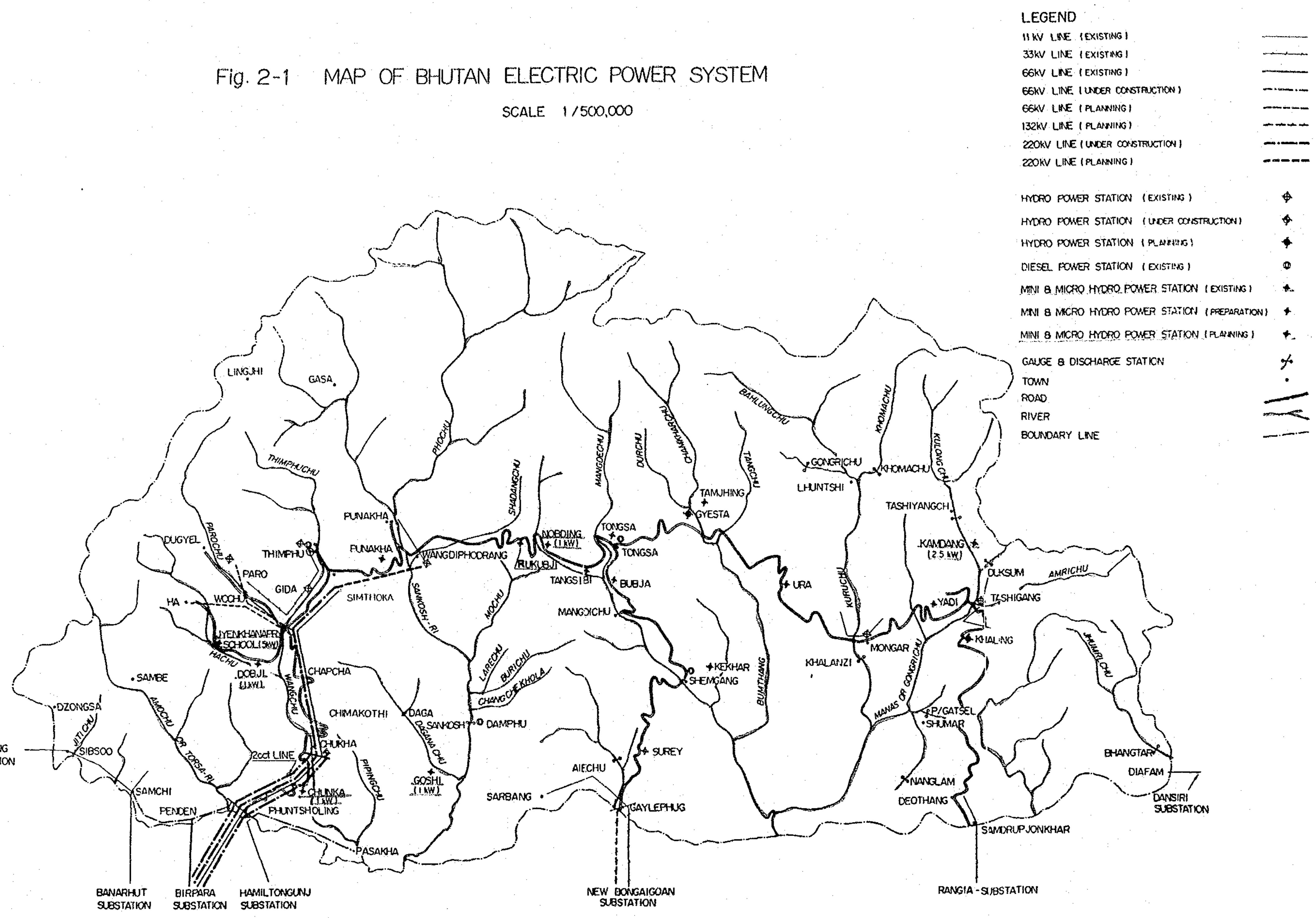


Table 2 - 6 NUMBER OF VILLAGES AND TOWNS ELECTRIFIED AS OF 31-3-1984 (DEPARTMENT OF POWER)

Name of District	Total Number of villages	Total Number of Towns
1. Thimphu	18	3
2. Paro	26	1
3. Wangdiphodrang	16	1
4. Ha	–	—
5. Samchi	12	5
6. Chirang	–	1
7. Dagana	–	—
8. Tongsa	–	1
9. Bumthang	–	—
10. Shemgang	–	1
11. Samdrup Jonkhar	1	3
12. Pema Gatsel	–	—
13. Tashigang	11	4
14. Mongar	5	1
15. Lhuntshi	–	—
16. Gaylegphug	4	2
17. Gasa	–	—
Total	93	23

Table 2 - 7 NUMBER OF SUB-STATIONS, TRANSFORMERS AND THEIR AGGREGATE CAPACITY AS OF 31-3-1984 (DEPARTMENT OF POWER)

(in KVA)

Area	Step-up or Step-down Main Sub-station			Distribution Sub-station		
	No.	Transformer size	Total capacity of transformers	No.	Transformer size	Total capacity of transformers
Thimphu	3	2 x 800 7 x 315 3 x 125 1 x 200 1 x 800	5,180	41	6 x 500 5 x 25 6 x 50 6 x 63 10 x 100 2 x 125 9 x 250 2 x 315 1 x 10	7,943
Paro	1	4 x 125	500	21	10 x 50 1 x 250 4 x 63 2 x 25 1 x 100 3 x 125	1,527
Wangdiphodrang	1	2 x 125	250	6	2 x 100 4 x 50 5 x 25	525
P/ling	2	2 x 315	630	10	1 x 500 1 x 315 6 x 250 1 x 125 1 x 63 1 x 50	2,553
Samchi	1	1 x 315	315	4	1 x 250 2 x 125 1 x 50 1 x 63	613
Sibsoo	—	—	—	3	1 x 125 1 x 63 1 x 25	213
G/phug	1	2 x 1,500	3,000	19	1 x 500 1 x 250 8 x 100 4 x 63 2 x 50 2 x 25	1,952
Damphu	Nil				Nil	Nil
Tongsa	Nil				Nil	Nil
Shemgang	Nil				Nil	Nil
S/Jonkhar	1	1 x 250	250	8	1 x 125 4 x 100 1 x 200 1 x 25 1 x 63	813
Diafam Tashigang	1 1	1 x 50 2 x 315	50 630	10	1 x 250 1 x 125 2 x 63 6 x 25	651
Mongar	1	2 x 100	200	4	1 x 125 2 x 63 1 x 50	301
Total	13	31	11,005	126	138	17,091

Table 2 - 8 Outline of Transmission & Distribution Lines

(km)

	66kV	33kV	11kV	L.T
1. Department of Power		33.5	282.104	342.68
2. Chukha Project Authority			37.5	40.7
a. Birpara Chukha	76			
b. Chukha Sintokha	57.6			
3. Penden Cement Authority Birpara to Penden	18		9	14
Total	151.6	33.5	328.604	397.38

2-6 Tariff and sales revenue

The Schedule of Tariff of the Department of Power is as per Table 2-9.

The current Tariff Schedule revised in 1982 is classified into seven categories and varies according to districts in a range of 0.45 - 1.00 Nu/kWH (9 - 20 yen/kWH). The minimum charges are applicable up to a certain usage.

Table 2-10 shows Sales Revenue of the Department of Power in 1979 - 1984. The annual increase is 15 - 33% over the previous year. The lower growth rates of the electric energy sales revenue in 1983/84 and 1984/85 are probably attributable to the reason that potential demands could not be met due to the delay in the construction of the Chukha Hydro Power Project.

Table 2 - 9 Schedule of Tariff (1982)

	Category	Tariff (Nu/kWh) 1 Nu≈20yen				
		Thimphu, Paro	Phuntsholing, Samchi, Sibsoo, Chargharay	Tashigang, Khanglung, Mongar, Wangdiphodrang, Punakha	SamdrupJonkhar, Deothang, Gaylegphug, Sarbhang	Character of Supply
1	Domestic	0.70	0.60 upto 50kWh 0.80 above 50kWh	0.65	0.75 upto 50kWh 0.80 above 50kWh	AC, 50Hz, 1 φ, 230V upto 5kW AC, 50Hz, 3 φ, 400V above 5kW
2	Commercial	0.80	1.00	—	0.90	Same as above
3	Govt. Offices, Hospital, School, Campus, etc.	0.80	0.80	—	0.80	— ditto —
4	Public Lighting	0.70	0.80	—	0.80	— ditto —
5	Industrial	0.70	0.90	0.45	0.75	L.T upto 5kW, 1 φ, 230V L.T 50~20kW, 3 φ, 400V H.T above 20kW, 3 φ, 11kW
6	Bulk Supply	0.60 and Demand Charge 20.0Nu/kVA	0.90	—	0.75	11/33kW, 3 φ
7	Unmetered Supply	5.00/Lighting Point 20.00/Heating Point 10.00/Connected Load H.P	4.00/Lighting and Fan Point 15.00/Heating, Cooling, Pumping, etc. 20.00/Connected Load H.P	Same as Left	Same as Left	—

Table 2-10 Electric Energy Sales Revenue

Description \ F.Y.	1970/1980	1980/1981	1981/1982	1982/1983	1983/1984	1984/1985
Sold Energy (kWh)						
(1) Domestic	3,200,000	3,827,000	4,014,000	3,840,299	4,157,454.5	——
(2) Commercial	1,244,000	1,430,000	1,494,000	2,624,674	3,274,304	——
(3) Industrial	2,407,000	2,447,000	2,753,000	1,140,136	1,307,613.5	——
(4) Public	203,000	200,000	210,000	41,679	59,915	——
(5) Others	——	——	——	1,741,447	1,954,536	——
Total	7,054,000	7,904,000	8,471,000	9,388,235	10,753,823	——
Energy Sales Revenue (10^3Nu)	3,010	3,918	4,900	6,516	7,512	8,800
Increase Rate Over Previous Year (%)	——	30	25	33	15	17

2-3 Present Situation of Power Demand and Supply

Table 2-11 gives the actual situation of power demand and supply throughout Bhutan as of the end of March 1984. As may be seen from the table, the peak loads in the whole of Bhutan total 12.331 MW, of which the peak load arising mostly from general demands belonging to the Department of Power is 5.341 MW, accounting for around 43% of the total of the peak loads. 2.552 MW equivalent to approximately 48% of the said peak load of the Department of Power is imported from India.

On the other hand, the net available energy totals 45.13 GWH in Bhutan, of which the net available energy under the responsibility of the Department of Power is recorded at 14.81 GWH, occupying around 33% of the total of the net energy availability.

Table 2-12 shows details of power demand and supply of the power facilities under the jurisdiction of the Department of Power in 1983/84, dividing the whole service areas into four (4) regions.

As mentioned before, the quantity of electric energy imported from India occupies a high percentage of the supply, while the domestic generating facilities show low plant factors. This clearly shows that the maximum dependable capacity of 2,867 kW is about 36% against the total installed capacity of 7,902 kW owned by the Department of Power.

Table 2 - 11 Power Demand and Supply as of End of 1984
※-1

System	Gross Generation inGWH	Auxiliary Consumption inGWH	Import if any inGWH	Peak Load in MW	Net Energy Available in GWH	Load Factor %
1. Dept. of Power	2.867	0.078	2.552	5.341	14.81	32
2. Chukha Project** Authority	3.44	0.20	—	3.24	14.99	52.8
3. Penden Cement ** Authority	1.8*	—	1.7	3.5	14.34	47
4. Gedu Wood Manufacturing Corpn.	0.275	0.025	—	0.250	0.99	45
5. Other Non-utilities	—	—	—	—	—	—
TOTAL	8.382	0.303	4.252	12.331	45.13	42

* SELF GENERATION IS STAND BY.
** DATA SUPPLIED BY C.P.A & PENDEN CEMENT AUTHORITY:
※-1 Net Energy Available(GWh)
$= \text{Peak Load (MW)} \times 365\ \text{Days} \times 24\text{Hours} \times \text{Load Factor} \times \frac{1}{1000}$

Table 2－12 DETAILS OF SYSTEM PERFORMANCE (DEPARTMENT OF POWER)
1983－84

System	Generation in MW *	Auxiliary consumption in MW	Export in MW	Import in MW	Peak Load in MW	Net energy available in GWH	Load factor in % **
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
UPPER WESTERN REGION							
Thimphu	1.975	0.054	0.150	0.850	2.621	8.437	36.85
Paro	0.271	0.005	–	0.150	0.416	0.869	23.85
Wangdiphodrang	0.236	0.012	–	–	0.224	0.578	29.45
Sub-total	2.482	0.071	0.150	1.00	3.261	9.884	34.70
LOWER WESTERN REGION							
Phuntsholing	–	–	–	0.70	0.70	1.78	29.20
Samchi	–	–	–	0.17	0.17	0.308	21.0
Sibsoo	–	–	–	0.072	0.072	0.049	7.8
Sub-total	–	–	–	0.942	0.942	2.137	26.00
CENTRAL AND SOUTH CENTRAL REGION							
Gaylegphug	–	–	–	0.51	0.51	1.153	25.81
Damphu	0.036	–	–	–	0.036	0.043	12.7
Tongsa	0.037	0.001	–	–	0.036	0.06	19.0
Shemgang	0.045	0.001	–	–	0.044	0.029	7.5
Sub-total	0.118	0.002	–	0.51	0.626	1.285	23.4
EASTERN REGION							
Sumdrup Jongkhar	–	–	–	0.20	0.20	0.705	40.2
Diafam	–	–	–	0.05	0.05	0.017	3.9
Tashigang	0.175	0.002	–	–	0.173	0.573	37.8
Mongar	0.092	0.003	–	–	0.089	0.209	27
Sub-total	0.267	0.005	–	0.25	0.512	1.504	36.8
Total	2.867	0.078	0.150	2.702	5.341	14.810	32

* Generation and import figures correspond to the date and time of occurrence of individual system peak

$$** \text{ Load factor } (\%) = \frac{\text{Energy available in KWH}}{8,760 \times \text{Peak Load in kW}} \times 100$$

This is partly attributed to the fact that power plants are not linked into a grid, partly because of some inoperative power plants and partly due to lowering in the generating capacity of diesel generators and because of its failures and/or troubles.

Table 2-13 shows details of the operation records of each station owned by the Department of Power in 1983/84.

The total electric power is about 4,500 kW while the total electric energy generated is about 10,300 x 10^3 kWH.

Table 2-14 gives details of purchase of electric power and energy imported from India by the Department of Power in 1983/84. According to the table, the total electric power is about 2,700 kW and the total electric energy 4,900 x 10^3 kWH.

Table 2-15 shows energy sales by the Department of Power in 1983/84 with breakdown for each category while Table 2-16 gives further breakdown area-wise and region-wise.

According to Table 2-15, the total energy sold is 10,700 x 10^3 kWH, out of which 38.7% was domestic, 30.4% commercial and governmental, 12.2% industrial, etc.

Table 2-16 gives that consumption of Upper Western Region which includes Thimphu, the capital of Bhutan, occupies about 60% of energy used in the whole of Bhutan of about 10,700 x 10^3 kWH. Thimphu itself consumed almost 48% of the nation's electric energy.

Table 2-17 shows Area-wise Generation, Import, Availability, Loss, etc. under the operation of the Department of Power during 1983/84, which reveals that the country's total loss aggregated to as much as 4.06 x 10^6 kWH, about 27.4% against a total energy available of 14.81 x 10^6 kWH.

Table 2-18 is a summary of Supply and Demand of Electric Energy under the control of the Department of Power during 1982/83 and 1983/84.

Table 2 - 13 DETAILS OF GENERATION (1983 - 84)

Name of Generating Station	Max. Generation (kW)	Energy Generated (kWh)	Auxiliaries (kWh)	Fuel Consumption (Ltr.)	Fuel Per kWh (Ltr.)
HYDRO					
1. Gidakom	1.200	4,866,170	66,690	-	-
2. Thimphu	220	839,407	47,520	-	-
3. Wangdiphodrang	236	635,515	57,599	-	-
4. Paro	220	722,430	6,873	-	-
5. Tashigang	175	603,320	30,275	-	-
6. Mongar	92	299,460	19,321	-	-
Sub-Total	2,143.00	7,966,302	228,278	-	-
DIESEL					
1. Phuntsholing	360	470,887	46,480	181,742	0.386
2. Samchi	100	60,409	2,765	21,501	0.356
3. Paro	77	7,405	58	-	-
4. Thimphu	1,660	1,648,710	61,470	642,393	0.39
5. Damphu	36	42,623.5	3,888	-	-
6. Tongsa	37.30	66,427.9	5,917.3	-	-
7. Shemgang	45.25	29,963	1,505	-	-
Sub-Total	2,315.55	2,326,425.4	122,083.3	845,636	0.36
Grand Total	4,458.55	10,292,727.4	350,361.3		

Table 2 - 14 DETAILS OF PURCHASE OF ENERGY (1983 - 84)

Purchased Form	Receiving point	Maximum Demand in kW	Energy Purchased in kWh
1. WBSEB at 11 kV	Phuntsholing	360 (700*)	1,363,860
	Samchi	168	251,208
	Sibsoo	72	49,277
2. W.B.S.E.B. (Through CHP) at 66 kV	Simtokha	1,300	1,354,880
Sub-total		1,900	3,019,225
3. A.S.E.B. at 33 kV	Gaylegphug	510	1,153,150
4. A.S.E.B. at 11 kV	S/Jonkhar	200**	705,416
	Diafam	50	17,358
Sub-total		760	1,875,924
GRAND TOTAL		2,660	4,895,149

* Meter defective, calculated value only.

** Estimated, not recorded.

Table 2 - 15 DETAILS OF ENERGY SALES (1983 - 84)

Category of Energy Sold	Energy Sold (kWh)	Percentage of Total Sales(%)
1. Domestic	4,152,344.5	38.7
2. Commercial and Government Office	3,267,068	30.4
3. Industrial	1,307,613.5	12.2
4. Bulk Supply	1,954,536	18.2
5. Public Lighting	56,284	0.5
TOTAL SALES OF THE DEPARTMENT	10,737,846	100

Table 2 - 16 AREA-WISE AND REGION-WISE SALES OF ENERGY DURING' 83-84
(in kWh)

Area	Domestic	Commercial Government Office	Industrial	Bulk Supply	Public Lighting	Total
UPPER WESTERN REGION						
Thimphu (% of Total)	1,679,217 (31.4)	1,665,470 (31.2)	281,509.5 (5.3)	1,698,692 (31.8)	15,514 (0.3)	5,340,402.5 (100)
Paro (% of Total)	172,518.5 (31.6)	281,161 (51.6)	88,191 (16.2)	- (-)	3,542 (0.6)	545,412.5 (100)
W/Phodrang (% of Total)	70,720 (15.2)	349,529 (75.2)	43,476 (9.4)	- -	888 (0.20)	464,613 (100)
Total (% of Total)	1,922,455.5 (30.3)	2,296,160 (36.2)	413,176.5 (6.5)	1,698,692 (26.7)	19,944 (0.3)	6,350,428 (100)
LOWER WESTERN REGION						
Phuntsholing (% of Total)	1,067,424 (59.6)	406,543 (22.7)	316,757 (17.7)	- -	- -	1,790,724 (100)
Samchi (% of Total)	175,099 (76.4)	13,233 (5.8)	40,867 (17.8)	- -	- -	229,199 (100)
Sibsoo (% of Total)	21,978 (58.5)	13,358 (35.5)	2,255 (6.0)	- -	- -	37,591 (100)
Total (% of Total)	1,264,501 (61.5)	433,134 (21.0)	359,879 (17.5)	- -	- -	2,057,514 (100)
CENTRAL & SOUTH CENTRAL REGION						
Gaylegphug (% of Total)	256,953 (26.2)	240,908 (24.6)	474,121 (48.4)	- -	7,536 (0.8)	979,518 (100)
Damphu (% of Total)	41,625 (97.7)	998 (2.3)	- -	- -	- -	42,623 (100)
Tongsa (% of Total)	50,380 (100)	-	-	-	-	50,380 (100)
Shemgang (% of Total)	24,595.0 (100)	-	-	-	-	24,595 (100)
Total Region (% of Total)	373,553 (34.0)	241,906 (22.0)	474,121 (43.3)	- -	7,536 (0.7)	1,097,116 (100)
EASTERN REGION						
S/Jonkhar (% of Total)	432,262 (67)	153,852 (24)	48,995 (7.6)	- -	9,448 (1.40)	644,557 (100)
Diafam (% of Total)	5,110 (31.0)	7,236 (45.3)	- -	- -	3,631 (22.7)	15,977 (100)
Tashigang (% of Total)	89,641 (20.7)	75,358 (17.4)	2,901 (0.70)	255,844 (59.20)	8,652 (2.0)	432,396 (100)
Mongar (% of Total)	69,932 (45.0)	66,658 (43.0)	8,541 (5.5)	- -	10,664 (6.5)	155,795 (100)
Total Region (% of Total)	596,945 (47.8)	303,104 (24.3)	60,437 (4.8)	255,844 (20.5)	32,435 (2.6)	1,248,765 (100)
GRAND TOTAL (% of Total)	4,157,454.5 (38.7)	3,274,304 (30.4)	1,307,613.5 (12.2)	1,954,536 (18.2)	59,915 (0.5)	10,753,823 (100)

Table 2-17 AREA-WISE GENERATION, ENERGY AVAILABLE SALES AND LOSSES DURING'83-84

Area	Gross generation (GWH)	Auxiliary consumption (GWH)	Export if any (GWH)	Import if any (GWH)	Net Energy avaiable (GWH) 2-3-4+5	Total Energy Sold (GWH)	Loss (6-7) (GWH)	% of Loss on avail-ability 8÷6×100
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
UPPER WESTERN REGION								
Thimphu	7.354	0.176	0.096	1.355	8.437	5.340	3.097	36.71
Paro	0.780	0.007	-	0.096	0.869	0.545	0.324	37.28
W/Phodrang	0.635	0.057	-	-	0.578	0.465	0.113	9.55
Total	8.769	0.24	0.096	1.451	9.884	6.35	3.534	35.75
LOWER WESTERN REGION								
Phuntsholing	0.47	0.05	-	1.36	1.78	1.78	-	
Samchi	0.060	0.003	-	0.251	0.308	0.229	0.079	25.654
Sibsoo	-		-	0.049	0.049	0.037	0.012	26.53
Total	0.530	0.053	-	1.660	2.137	2.046	0.091	4.2
CENTRAL and SOUTH CENTRAL REGION								
Gaylegphug	-	-	-	1.153	1.153	0.979	0.174	15.1
Damphu	0.043	-	-	-	0.043	0.043	-	-
Tongsa	0.066	0.006	-	-	0.060	0.050	0.01	16.70
Shemgang	0.030	0.001	-	-	0.029	0.024	0.005	17.24
Total	0.139	0.007	-	1.153	1.285	1.096	0.189	14.7
EASTERN REGION								
S/Jonkhar	-	-	-	0.705	0.705	0.644	0.061	8.68
Diafam	-	-	-	0.017	0.017	0.016	0.001	5.88
Tashigang	0.603	0.030	-	-	0.573	0.432	0.141	24.6
Mongar	0.229	0.020	-	-	0.209	0.156	0.053	25.7
Total	0.832	0.050	-	0.722	1.504	1.248	0.256	10.43
GRAND TOTAL	10.27	0.350	0.096	4.986	14.81	10.740	4.070	27.4

Table 2 - 18 STATISTICS FOR 82-83 & 83-84

Item	82-83	83-84	% (+, -) over Previous yr.
1. Installed Capacity (in MW)			
(a) Hydro	3.45	3.45	0
(b) Diesel	3.052	4.442	(+) 45.54
Total :	6.502	7.892	(+) 21.38
2. Generation of Energy (in GWH)			
(a) Hydro	8.283	7.946	(-) 4.10
(b) Diesel	1.587	2.326	(+) 46.57
Total :	9.870	10.272	(+) 4.10
3. Purchase of Energy (in GWH)			
(a) From Assam	1.86	1.875	(+) 0.81
(b) From West Bengal	2.65	3.020	(+) 13.96
Total :	4.51	4.895	(+) 8.54
4. Auxiliary Consumption (in GWH)	0.318	0.350	(+) 10.63
5. Energy Requirement (in GWH)	14.062	14.812	(+) 5.33
6. Sale of Energy (in GWH)	9.389	10.750	(+) 14.50
(a) Loss of Energy (in GWH)	4.674	4.062	(-) 13.10
(b) Loss in percentage of requirement	34.50	27.40	(-) 20.58
7. Peak Load in MW	4.56	5.341	(+) 17.13
8. Load Factor	35.20	32.0	(-) 9.10
9. Number of consumers	8,695	9,262	(+) 6.52
10. Per Capita Consumption	7.62	8.74	(+) 14.70
11. Number of Village Electrification	92	93	(+) 1.10
12. Number of Town Electrification	22	23	(+) 4.55
13. Length of H.T. Lines (in KM)	313.72	315.604	(+) 0.60
14. Length of L.T. Lines (in KM)	318.03	342.68	(+) 7.75
15. Revenue earned (in Million Nu.)	6.432	7.835	(+) 21.81

2-4 Electric Power Development Plan

2-4-1 Power demand forecast

The Department of Power has made a forecast of electric power and energy, dividing the country into the following five regions based on the development plan of each sector up to 1991 - 92 when the 6th Five-year National Economic Development Plan ends.

(1)	Upper Western Region :	Thimphu, Paro, Ha, Wangdiphodrang, Punakha
(2)	Lower Western Region :	Phuntsholing, Penden, Samchi, Pana, Gedu
(3)	South Central Region :	Gaylegphug, Chirang, Dagans, Shemgang
(4)	Central Region :	Tongsa, Bumthang
(5)	Eastern region :	Tashigang, Mongar, Samdrup-Jonkhar

Energy requirements of the above Regions were estimated for the following each sector of the respective Regions, by actually making calculations of the energy requirements.

(1)	Domestic	(Household, Commercial, Governmental Office, School, Hospital, and other public facilities)
(2)	Industries	(Existing and planned factories of large and small scale)
(3)	Tourism	(Tourism Department owned facilities and all other hotels)
(4)	Agriculture	(Irrigation pumps, etc.)
(5)	Others	(All others)

Demand forecast is based on the following premises.

(1) In the category of the domestic sector, there has been only insignificant consumption of electricity due to the constraint of the supply. Therefore as and when the low cost electricity is made available, consumption of electricity for cooking and

heating at ordinary houses will be increased, which will result in increase in power demand.

The Government has been planning to induce the people to change the domestic fuel from traditional firewood to low cost electricity and intends to achieve electrification up to 40% of the country's households by the time the 6th Development Plan is completed.

(2) Industries

As for small scale industries, the requirements of power and energy are estimated on the assumption that adequate supply of electric power for the industries is to be made through the connection of distribution lines.

In the category of large scale industries, principal power-oriented industries will be calcium-carbide factories, cement plants, caustic soda plants, etc. Their use is estimated according to their yearly plans.

Demand in the industrial sector is assessed somewhat on the conservative side in consideration of the situation of some portions being implemented under the 5th Development Plan and those of the projects to be executed in the early part of the 6th Plan.

Table 2-19 summarizes the long term assessment of electricity requirements based on the premises as above mentioned. According to the table, taking 1982 - 83 as the denominator, the peak load in 1992 - 93 will be 9.9 times or 165.5 MW and energy requirement 13.4 times or 738.34 x 10^3 kWH, with an average annual growth rate of 10% and 13.4%, respectively.

2-4-2 Construction and reinforcement of generating power facilities

The geography and abundant precipitation in Bhutan offer an ample possibility of hydro-electric power exploitation and the overall hydraulic potentials are reported to be 6,000 MW.

Table 2 - 19 PEAK LOAD IN KW AND ENERGY REQUIREMENT IN MILLION KWH

Peak Load in MW

Region	82 - 83	83 - 84	84 - 85	86 - 86	86 - 87	87 - 88	88 - 89	89 - 90	91 - 92	92 - 93
1 . Upper Western Region	8.6	9.6	12.8	20.5	30.0	38.0	44.5	50.0	60.0	70.0
2 . Lower Western Region	5.0	6.0	9.0	12.0	18.0	27.0	35.0	43.0	51.0	55.0
3 . South Central Region	1.8	2.5	5.5	6.0	8.0	14.0	26.0	30.0	35.0	40.5
4 . Central Region	0.4					BEING ASSESSED				
5 . Eastern Region	1.0									
Total No-coincident Peak load	16.8	18.1	27.3	38.5	56.0	79.0	105.5	123.0	146.0	165.5
Energy Requirement in Million KWH										
1 . Upper Western Region	27.7	32.77	46.56	76.38	123.10	165.40	198.30	222.20	271.30	327.34
2 . Lower Western Region	19.2	23.60	34.40	46.40	72.20	115.50	150.60	188.00	228.00	251.50
3 . South Central Region	4.43	7.60	15.50	20.00	26.00	49.50	96.00	118.50	136.00	159.50
4 . Central Region	0.70					BEING ASSESSED				
5 . Eastern Region	3.00									
Total Energy Requirement	55.03	63.97	96.46	142.78	221.3	330.40	444.90	528.7	635.3	738.34

As shown in Table 2-5, hydro-electric power has so far been developed at 7 locations with an aggregated capacity of 3.46 MW, less than 0.1% of the potentials.

Upon completion of Chukha Hydro-electric Power Station with a total installed capacity of 336 MW being constructed with the assistance of India, the capacity will be increased to about 18 times as big as the existing one. It is not economically viable, however, to distribute all of the power inside Bhutan as respective power demands remain at a low level and small scale consumers are dotted around among the mountainous terrains. Therefore, power supply through interconnected systems will be limited to Phuntsholing, Thimpu and other western region and the surplus power is planned to be exported to India via Phuntsholing.

The following two sites are being progressed into a specific study stage as the small and medium scale hydro-electric power projects with the assistance of the Government of India.

(1) Gyesta Hydel Project; 1,500 kW
(2) Khaling Hydel Project; 390 kW

The small scale hydro power project being currently studied is expected to be one of effective means to improve the quality of life of the people in the respective districts to proceed with the plan for development of 150 small scale hydro power plants including the first ten (10) power plants presently under the study as part of the 5th National Economic Development Plan.

A project to build up the transmission and distribution systems for the key regions is being implemented by the Department of Power as shown in Table 2-20.

As of the end of March 1984, 80% of the total generating capacity is diesel generation as shown in Table 2-2, of which fuel is all imported from overseas, placing a heavy burden upon Bhutan's economy. To make the matter worse, superannuated diesel generators and their insufficient maintenance can hardly cope with the demand and the gap is obliged to be filled up by importation of electric power from India.

Table 2 - 20 POWER DEVELOPMENT PROJECTS
1983 - 84

Generation under implementation			
Name of the Project	Capacity	Estimated cost	Anticipated date of completion
1 . Micro-Hydro Project	150sites (50kW/site)	Not estimated yet	1986 - 90
2 . Gyesta Hydel Project	1,500kW	Nu. 32.8 Million	1986 - 87
3 . Khaling Hydel Project	390kW	Nu. 10.6	1986 - 87
Total	9,390kW	Nu. 33.4 Million	

E.H.V Transmission lines and sub-station under implementation				
Name of the Project	Approx. Route length in KM	Sub-station capacity in MVA	Estimated cost in Nu. Million	Anticipated date of completion
1 . 66 KV S/C line from Phuntsholing to Pasakha	20 KM	2 x 10 MVA	13.00	1985 - 86
2 . 220 KV S/C line from switching station (Gedue-Tala/Gaikhori) to Pasakha	20 KM	2 x 20 MVA	36.866	1986 - 87
3 . 66 KV S/C line from Phuntsholing to Penden	24 KM	-	13.00	1986 - 87
4 . 66 KV D/C line from Confluence to Wochu	23 KM	-		
5 . 66 KV S/C line from Wochu to Paro	3.5 KM	2 x 5 MVA	43.071	1986 - 87
6 . 66 KV S/C line from Wochu to Ha	16 KM	3 x 5 MVA		
7 . 220 KV S/C line from Thimphu Wangdi-phodrang	33 KM	2 x 5 MVA	41.229	1987 - 88
8 . 66 KV S/C line from Gaylegphug to Bongaigoan	24 KM	2 x 5 MVA	24.0	1986 - 87
Total	153.5 KM	105 MVA	171.166	

The Government of Bhutan intends to enhance and enlarge power plants which are most important for the implementation of the National Economic Development Plan and to achieve this objective, and priority is placed upon hydro-electric power development in particular.

The estimated power demand in the whole of Bhutan for the end of 1992 is to be 738,340 kW, as given in Table 2-19. The aggregated installed capacity of the planned small scale hydro power plants to be located at 150 sites are estimated at approximately 7,500 kW. Accordingly, the latter is equivalent to only one percent of the former in terms of the scale (installed capacity).

Therefore, the above-mentioned project is deemed very benefitial to the towns and villages, but it can hardly be expected that the 150 small scale hydro power plants upon completion thereof will satisfy power demand to arise from the whole of Bhutan.

2-5 Contents of Request

2-5-1 Background of request

As mentioned in introduction, the Government of Bhutan has been implementing the 5th Five-year National Economic Development Plan.

One of the specific objectives of the said Plan is to improve the quality of life.

In order to achieve the goal it is planned to install and to enlarge public facilities for education, medical treatment, communication, etc. in rural towns and villages situated all over the country so that they may play an important role in the respective localties.

A majority of the said rural towns and villages are not served with electricity and the supply of power is indispensable to accomplish the Plan.

In particular, power supply is considered to be prerequisites for such facilities as school dormitories, medical examination equipment and refrigirators for keeping sera in hospitals and refrigirators for storing breeding spermatozoa in veterinary clinics.

It is not economical to meet the said needs by means of developing large scale hydro-electric power plants and constructing transmission and distribution net-works due to the topographical conditions of Bhutan and taking into account the agriculture-oriented industrial structure of the country.

Under the above-mentioned circumstances it has been being planned to serve the purpose by installing a small scale hydro power station on each site by utilizing nearby small to medium rivers and 150 sites have been chosen.

The request made by the Government of Bhutan to the Government of Japan is in regard to the procurement of materials and equipment for the construction of ten (10) micro hydro power plants on a grant aid basis out of the planned 150 power plants.

2-5-2 Outline of sites surveyed and grant aid request

The Team had a series of discussions with responsible officials of the Government of Bhutan in connection with details of the request already made by the Government of Bhutan.

In addition to the ten (10) sites for which the request had been made, the Team examined the appropriateness of several candidate sites on which data were relatively available. As a result of their examination, it was agreed upon between the Government of Bhutan and the Team that the newly enumerated ten (10) sites be contained in the Project from the standpoints of accessibility for the performance of field surveys and a high priority of urgency for development.

Consequently, the following candidate sites were excluded from the ten (10) sites for which the request had been made.

Buli Site (No. 10)	It requires several days to make a round trip for visiting this site, which was hardly possible in view of the itinerary.
Lhuntsi Site (No. 1)	Construction of the power plant is under planning by the hands of the Government of Bhutan.

Lamitar Site (No. 2) and Samrang (No. 9)	It is impossible to reach these sites without going through the restricted area in India.

Subsequently, the following four sites were selected as the alternatives: Punakha (No. 101), Tongsa (No. 102), Tamjhing (No. 103), Kekhar (No. 104).

Therefore, the ten (10) sites listed below were taken up as the sites for which the basic design study would be conducted.

The location of each site is shown in the preceding "Location of Project Sites".

Name of Site		No. of Public Institution *1	No. of House *2	Population *3
Rukubji	(No. 3)	0 (7)	45 (65)	600
Ura	(No. 4)	8 (8)	50 (104)	500
Tangsibi	(No. 5)	1 (6)	70 (130)	620
Bubja	(No. 6)	5 (7)	48	130
Surey	(No. 7)	4 (6)	240	2,000
Yadi	(No. 8)	7 (7)	115 (540)	300
Punakha	(No. 101)	7 (7)	32 (54)	180
Tongsa	(No. 102)	13 (13)	100	1,600
Tamjhing	(No. 103)	0 (6)	35 (70)	350
Kekhar	(No. 104)	0 (6)	27	260

Note: *1: The figure shown in parenthesis shows the number of public institutions including the number of such proposed institutions.

*2: The figure shown in parenthesis shows the number of houses at the Project site and adjacent places.

*3: The approximate number of persons which was briefed by the heads of villages.

Furthermore, during the discussions, an additional request was newly made to the Team for the assistance of construction besides the procurement of materials and equipment for construction of the ten (10) power plants shown above.

CHAPTER 3 OUTLINE OF PROPOSED SITES

CHAPTER 3 OUTLINE OF PROPOSED SITES

3-1 Location and Topography

The area of this Project is located in mountainous terrains of central Bhutan at an elevation of 1,000 m through 3,000 m spreading over seven districts of Wangdiphodrang, Tongsa, Punakha, Shemgang, Bumthang, Mongar and Gaylegphug. The main road connecting these districts is one lane road with light pavement, along which the Project sites are situated in a range of about 200 km from east to west and about 100 km from south to north.

The area in question comprises forest, 70% of the total land area, farming land 9% and grassland, the remainder, having steep topography overall, mostly mountainous except for some portions in Bumthang and Gaylegphug.

The population of the above-mentioned seven districts in the area is about 340,000 in total, 27% of the country's population. Most of the people in the area live in relatively gentle slopes in the mountainous terrains and earn their livelihood by farming in the vicinity of their dwellings.

3-2 Outline of Proposed Sites

The proposed sites for the basic design study are all unelectrified areas except for Tongsa Site (No. 102).

The respective sites are situated in major towns and villages of the areas. They have and are scheduled to have public institutions such as schools, veterinary hospitals, dispensaries and post offices. The inhabitants of all proposed sites are desirous of being supplied with electricity. Tongsa Site, which is electrified, is a major town in Tongsa district. In the area of this site, there are public institutions including a hospital, veterinary hospital and school. The diesel-engine generating units with a capacity of 60 kVA installed there supply electric power. However, the stable supply of electric power is not made as the maintenance of the facilities is insufficient and the generating units are superannuated.

The outline of the proposed sites and adjacent towns and villages is as shown in Table 3-1.

Table 3-1 General Information of Each Site

Item \ Name of projects		③ Rukubji	④ Ura	⑤ Tangsibi	⑥ Bubja	⑦ Surey	⑧ Yadi	(101) Punakha	(102) Tongsa	(103) Tamjhing	(104) Kekhar	Remarks
1. Name of District		Wangdi-phodrang	Bumthang	Tongsa	Tongsa	Gaylegphug	Mongar	Punakha	Tongsa	Bumthang	Shemgang	
2. Name of Village		Rukubji	Ura (+ Sondrang + Pangkhar + Gayden)	Tangsibi (+ Chankka)	Bubja (Changra)	Surey	Yadi (+ Chaskar + Ngatshang)	Thrinlaygang (+ Jalnug + Toaha)	Tongsa	Tamjhing (+ Tamji Chu)	Kekhar	
3. Name of Stream		Gir Chu	Lirigang Chu	Nagani Chu	Ishgong Chu (Bubja Irrigation Channel)	Rang Chu	Gudri Chu	Lamja Chu	Ⓐ Tergang Chu Ⓑ Thipangi Chu	Tanji Chu	Kekhar Chu	
4. No. of Household	(Nos.)	45 (65)	50 (104)	70 (130)	48	240	115 (540)	32 (54)	100	35 (70)	27	
5. Institutions	(Nos.)	0 (7)	8 (8)	1 (6)	5 (7)	4 (6)	7 (7)	7 (7)	13 (13)	0 (6)	0 (6)	
6. Average Elevation	(m)	2,800	3,000	2,300	1,830	900	1,500	1,900	2,100	2,600	2,100	
7. Max. Air Temperature	(°C)	N.I	N.I	37	N.I	N.I	N.I	N.I	N.I	N.I	N.I	N.I: No Information
8. Min. Air Temperature	(°C)	N.I	N.I	(-)6	N.I	N.I	N.I	N.I	N.I	N.I	N.I	" "
9. Catchment Area of Proposed Intake	(km^2)	42.7	42.9	8.38	27.6	87.8	21.3	17.8	Ⓐ 43.9 Ⓑ 14.5	11.9	8.9	
10. Annual Precipitation in Basin	(m/m)	N.I	N.I	1,287	1,500	N.I	N.I	N.I	N.I	N.I	N.I	
11. Max. Precipitation in Basin	(m/m)	SNOW 3" RAIN N.I	SNOW 2" RAIN N.I	N.I	N.I	1,400	N.I	N.I	N.I	N.I	N.I	
12. Discharge at Proposed Intake Site When Visited	(m^3/s)	0.38	0.56	0.14	0.12	4.7	0.09	0.10	A 0.77 B 0.15	0.13	0.42	
13. Population		450 (600)	500 (1,200)	600 (1,200)	240	3,500	300 (3,700)	200 (300)	1,000	350	260	
14. Number of Potential Energy Consumers												
1) Households	(Nos.)	45 (65)	50 (104)	70 (130)	48	240	115 (540)	32 (54)	100	35 (70)	27	
2) Commercial	(")	-	-	-	-	9	-	-	-	-	-	

Item \ Name of projects	③ Rukubji	④ Ura	⑤ Tangsibi	⑥ Bubja	⑦ Surey	⑧ Yadi	(101) Punakha	(102) Tongsa	(103) Tamjhing	(104) Kekhar	Remarks
3) Industrial (Nos.)	-	-	-	-	-	-	-	-	-	-	
4) Others (")	8	8	(4)	-	-	4 (6)	5 (6)	15	- (1)	-	
15. Economic Activities											
1) Livestock (No. of Heads)	1,050	6,480	150	150	800	600	800	N.I	N.I	N.I	N.I: No Information
2) Agriculture	Potato, Wheat	Wheat	Wheat, Paddy	Wheat, Paddy	Maze, Paddy	Paddy	Paddy, Wheat	Wheat	Maze Wheat	Wheat, Maze, Paddy, Orange	
3) Mining (Type of Minerals)	-	-	-	-	-	-	-	-	-	-	
4) Agro-industry (Type and production capacities)	-	-	-	-	-	-	-	-	-	-	
5) Other Industries and Handicrafts	Rice Mill	Back Wheat Mill	Rice Mill x 2	-	-	Rice Mill x 3 Saw Mill x 1	Rice Mill x 4	-	-	-	
16. Existing Public Welfare Facilities											
1) Health											
Hospitals (No.)	-	(1)	-	-	-	-	- (1)	1	-	-	
Dispensaries (No.)	- (1)	1	-	-	1	1	1	-	-	-	
Basic Health Units (No.)	-	-	-	1	-	-	-	-	-	-	
Leprosy Mission Centre (No.)	-	-	-	-	-	-	-	-	-	-	
Malaria Eradication Center (No.)	-	-	-	-	-	-	-	-	-	-	
Indigenous Health Units (No.)	-	-	-	-	-	-	-	-	-	-	
2) Animal Husbandry											
Vet. Hospitals	-	1	-	-	-	-	-	-	-	-	
Vet. Dispensary & Vet. Sub-dispensary	- (VD1)	-	-	1	1	1	1	1	-	-	
Livestock Farms	-	-	-	-	-	-	-	-	-	-	
Diagnostic labs	-	-	-	-	-	-	-	-	-	-	
3) Communication											
Telephone Exchange Wireless Station	- (W1)	-	-	-	-	- (W1)	-	W1, T1	-	-	

Item \ Name of projects	③ Rukubji	④ Ura	⑤ Tangsibi	⑥ Bubja	⑦ Surey	⑧ Yadi	(101) Punakha	(102) Tongsa	(103) Tamjhing	(104) Kekhar	Remarks
4) Education											
Central School	-	-	-	-	-	-	-	-	-	-	
Junior High School	- (1)	-	-	-	-	-	-	1	-	-	
Primary School	-	1	- (1)	1	1	1	1	-	-	-	
Technical School	-	-	-	1	-	-	-	-	-	-	
Junior College	-	-	-	-	-	-	-	-	-	-	
Teacher Training Institute	-	-	-	-	-	-	-	-	-	-	
C.C.T. Institute	-	-	-	-	-	-	-	-	-	-	
F.C.B.	- (1)	1	-	-	-	- (1)	(1)	-	-	-	
Post Office, Branch P.O.	- (1)	B1	-	1	1	B1		1	-	-	
Agriculture Sub-centre	-	1	-	-	-	-	1	1	-	-	

CHAPTER 4 BASIC DESIGN

CHAPTER 4 BASIC DESIGN

4-1 Basic Design Concept and Design Conditions

4-1-1 Basic design concept

The design of this Project has been conducted in accordance with the following principle.

(1) Study for planning

The 10 proposed sites of this Project are unelectrified areas, except for Tongsa Site.

Therefore, it is required that the capacity of each power plant be determined on the assumption that no electric power is to be supplied from any other power sources.

The capacity of the power plant is to depend upon the volume of the stream discharge as surveyed by the Team at the sites, and the data of gauged discharge, topographical characteristics of each site and possible power demand.

(2) Reliability of facilities

The generating facilities and transmission and distribution lines are expected to be the sole facilities to be installed in each proposed area, and they have been designed with ample strength in full consideration of the importance thereof and of the natural condition.

Attention has also been paid to interchangeability with the existing distribution line at Tongsa Site.

(3) Easy operation and maintenance

The facilities should be of such design that it ensures safety and easy maintenance and is of simple design.

(4) Economical design

In consideration of (2) and (3) mentioned hereinabove, the facilities are to be designed most economically by introduction of Japanese standards and design practices as much as possible.

(5) Interchangeability

Taking account of the Department of Power consuming a number of Indian-made products, full consideration has been given to the interchangeability of the facilities of the Project by the grant aid with such goods made in India.

(6) Standardization

The generating facilities and pole transformers are fully standardized to lower the cost of equipment and rationalize the storage of spare parts required for maintenance.

(7) Limitation of voltage fluctuation rate

The voltage fluctuation should be in principle limited within ±10% at ultimate consumers.

4-1-2 Design conditions

(1) Conditions set by the Team based on available data and in accordance with the results of the surveys conducted by the Team.

(a) Elevation.

Lowest : 300 m
Highest: 3,000 m

(b) Meteorological conditions.

(i) Highest: 40°C
Lowest : -10°C

(ii) Humidity: 100%

(iii) Wind Velocity: 40 m/sec.

(iv) Rainfall: Average 1,400 mm
Max. 7,000 mm

(v) Snowfall: 15 cm to 30 cm

(vi) Number of thunderstorm days a year: 75 days/year.

(2) Conditions applied to the existing facilities owned by the Department of Power.

(a) Condition for earthquake.

(i) Horizontal: 0.1 G
(ii) Vertical : 0.05 G

4-1-3 Applicable standards

The following Japanese standards shall be applied in principle in the design of the equipment for this Project.

Adequate consideration has been given to ensure that the application of the above-mentioned standards will not cause problems with interchangeability with Indian-made products.

JIS - The Japanese Industrial Standards
JEC - Standard of the Institute of Electrical Engineers of Japan
JEM - Standard of Japan Electrical Manufacturers' Association
JCS - Standard of the Japanese Electric Wire and Cable Makers' Association
Other technical standards related to electrical equipment

4-2 Power Demand Forecast for each Proposed Site

4-2-1 Present situation of power demand and supply

The proposed 10 sites are not yet electrified except for Tongsa Site.

There is one 60 kVA diesel power plant in the Tongsa district supplying power to the public institutions, schools and general consumers. The diesel power plant in Tongsa is outlined in Table 4.2-1.

Consumers belonging to the category of "Domestic" in Tongsa are as outlined in Table 4.2-2. The diesel power plant often was stopped while the Team was in Tongsa, and has difficulty in keeping a constant power supply due to the reasons that ample cooling water for the diesel engine is not always available, and that the maintenance of the diesel engine is not satisfactory and that the power supply capability is not sufficient to meet the demand.

As mentioned hereinabove, almost all of the areas where the proposed sites are located are not yet electrified. Even if there is such one diesel power plant, there is still no constant and ample power supply in the area.

On the other hand, in respect to power demand in the areas, there is great expectancy of power supply for lighting of the public institutions like schools and hospitals, of supply of electricity for lighting up houses and power supply for rice-mills, flour-mills and sawmills.

Especially, a power supply is strongly desired for the sake of the said school dormitories, X-ray equipment at hospitals and refrigerators to keep preventive serum and the spermatozoa of domestic animals at veterinary hospitals.

4-2-2 Estimation of power demand

(1) Estimation method of power demand

All the areas where the proposed sites are located, except for Tongsa district, are not yet electrified.

Therefore, the power demand given in the report was estimated by means of adding possible demands based on the existing public institutions, number of households and population, considering the present condition and plan(s) in the near future.

Table 4.2 - 1 Outline of Tongsa Diesel Power Plant

Item	Description
Installed Capacity	60kVA
Dependable Capacity	50kVA
Output Voltage	400V
No. of Phase	3
Commissioning Year	1976
Fuel Oil	Diesel Oil H.S.D
Fuel Consumption	15ℓ / hour
Fuel Cost	3.96Nu / ℓ
Operation Hour	18ᴴ ~22ᴴ

Table 4.2 - 2 List of Consumers of Tongsa Power Plant

No	Name of Consumer	Light Point
1	Dzongkhag Staff Office	43
2	Agriculture Dept Office	8
3	P.W. Dept. Staff Office	8
4	Tourist Lodge	68
5	Tongsa School	112
6	Tongsa Hospital	27
7	Animals Husbandry	8
8	Telephone Exchange Station	26
9	Tongsa Post Office	14
10	Wirelss Station	20
11	Forest Staff Office	22
12	Shop Keeper	131
13	Public Light Point	89
14	Center Jail O.C	24
15	Dept. of Power Staff Office	19
16	R.B.P.D.P.O. Tongsa	88
	Total Light Point	647

Note : Tariff 2.5Nu / Point

(2) Result of power demand forecast

The estimation of power demand was conducted in the following manner.

(a) In order to estimate the power demand in the unelectified areas, reference was fully made to the results of the survey conducted in detail regarding the existing power demand in the Tongsa district already electrified.

(b) The Team heard from the inhabitants of such unelectrified areas about the number of households, population, public facilities, rice-mills, sawmills and so forth and their future program and its information.

(c) By adding all demands which are conceivable, based on the results of the surveys and in consideration of a demand factor and diversity factor of each load, the maximum demand was estimated.

The formula used for the estimation of a maximum demand is as follows:

$$P \geqq \left(\frac{P}{Cos} \times d \times \frac{k^2}{k^1}\right) + \left(\frac{Pm}{\times\ cos} \times d \times \frac{k^2}{k^1}\right) \qquad (kVA)$$

P : Maximum demand

ΣP : Total load of lighting

ΣPm : Total load of power

η : Average efficiency of power load (0.8)

Cos : Average power factor
(Fluorescent lamp 0.8)
(Incandescent lamp 1.0)
(Power 0.8)

d : Demand factor
(Lighting load 0.5)
(Power load 0.75)

k_1 : Diversity factor
(Lighting load 1.2)
(Power load 1.1)

k_2 : Diversity factor to compound load of lighting and power (1.1)

Note : All figures parenthesized are used for this study.

The results of the power demand are shown in Table 4.2-3.

The installed capacity of the power plant at each site has been determined in consideration of the afore-said results of estimation of demand, discharge of each river and possible head, etc.

The example of power demand forecast is as shown in Table 4.2-4, taking up the case of Ura Site.

Annex-7 shows the results of the demand forecast for 9 sites.

The installed capacity of each power plant at the proposed sites has been determined based on the following assumptions.

(1) The "public institutions" are assumed to include hospitals, schools, village offices, agriculture extension centres, veterinary hospitals, forestry centres, cooperative offices, etc.

(2) Fluorescent lamps will be used at hospitals and schools and incandescent lamps be used at public institutions and at ordinary private houses.

(3) The number of electric lights are to be 3 to 5 per room for public institutions and 5 per house in case of private houses.

(4) Refrigerators, heaters, germicidal lamps and so on will be used at hospitals and veterinary hospitals. X-ray equipment will be used in a certain area.

(5) The areas where public institutions are scheduled to be constructed in the future will be indicated by parenthesis, including possible demand to arise from such institutions in the demand required.

Table 4.2 - 3 Results of Power Demand Forecast

No.	Site		Estimated Demand (kVA)		
	No.	Name	Excluding Private Houses	Including Private Houses	Including Private Houses in Neighboring Villages
1	3	Rukubji	22	35	39
2	4	Ura	27	41	51
3	5	Tangsibi	20	46	56
4	6	Bubja	17	38	38
5	7	Surey	15	71	77
6	8	Yadi	24	49	144
7		Punakha	21	47	51
8		Tongsa	81	112	112
9		Tamjhing	15	29	35
10		Kekhar	15	33	33
		Total	257	501	636

Table 4.2 - 4 Demand Forecast of Typical Village at Ura Site

No.	Consumer	Kind of Load (Power Facility)	Unit Capacity (W, VA)	No. of Unit	Installed Capacity (W, VA)
1	Power House	Lamp	60	2	120
2	Village Office	Lamp	60	6	360
		Public Address System	100	1	100
3	Forest Office	Lamp	60	6	360
4	Hospital	Fluorescent Lamp	40	26	1,040
		Room Heater	5,000	3	15,000
		Water Heater	3,600	1	3,600
		Refrigerator	200	1	200
		Germicidal Lamp	20	2	40
		Vacuum Pump	750	1	750
5	Vet. Hospital Sub Center	Lamp	60	16	960
		Water Heater	3,600	1	3,600
		Refrigerator	200	1	200
		Germicidal Lamp	20	2	40
6	Primary School	Lamp	60	43	2,580
		Fluorescent Lamp	40	40	1,600
		Public Address System	100	1	100
7	Food Corporation Office	Lamp	60	6	360
8	Agriculture Extention Center	Lamp	60	6	360
9	Branch Post Office	Lamp	60	6	360
10	Street Lighting	Lamp	60	5	300
11	Private House				
(1)	Including Neighboring Villages	Lamp	60	104 5	31,200
		Radio	10	104	1,040
(2)	Excluding Neighboring Villages	Lamp	60	50×5	15,000
		Radio	10	50	500
12	Buckwheat Milling Plant	Motor	3,700	1	3,700

13	Total				
(1)	Excluding Private House	Lamp Fluorescent Lamp Heater Power			5,760 2,720 22,200 1,350
		Total			32,030
(2)	Including Private House	Lamp Fluorescent Lamp Heater Power			20,760 2,720 22,200 5,550
		Total			51,230
(3)	Including Private House of other Villages	Lamp Fluorescent Lamp Heater Power			36,960 2,720 22,200 6,090
		Total			67,970

Calculation of Maximum Demand Forecast

Case 1 Excluding Private House

$$P \geqq \{ (\frac{5,760}{1.0} + \frac{2,720}{8.0}) \times 0.5 \times \frac{1.1}{1.2} \} + \{ (\frac{22,200}{1.0 \times 1.0} + \frac{1,350}{0.8 \times 0.8}) \times 0.75 \times \frac{1.1}{1.1}$$

$\fallingdotseq$ 4,200 + 18,200 $\fallingdotseq$ 22,400 (VA)

Then, Required Power Plant Output is as follows:,

$P_p \fallingdotseq P \times K \fallingdotseq 22.4 \times 1.2 \fallingdotseq 27$ (kVA)

Where, K is Transmission & Distribution Loss Factor

Case 2 Including Private House

$$P \geqq \{ (\frac{20,760}{1.0} + \frac{2,720}{8.0}) \times 0.5 \times \frac{1.1}{1.2} \} + \{ (\frac{22,200}{1.0 \times 1.0} + \frac{5,550}{0.8 \times 0.8}) \times 0.75 \times \frac{1.1}{1.1}$$

$\fallingdotseq$ 11,100 + 23,200 $\fallingdotseq$ 34,300 (VA)

$P_p \fallingdotseq P \times K \fallingdotseq 34.3 \times 1.2 \fallingdotseq 41$ (kVA)

Case 3 Including Private House of Other Villages

$$P \geqq \{ (\frac{36,960}{1.0} + \frac{2,720}{8.0}) \times 0.5 \times \frac{1.1}{1.2} \} + \{ (\frac{22,200}{1.0 \times 1.0} + \frac{6,090}{0.8 \times 0.8}) \times 0.75 \times \frac{1.1}{1.1}$$

$\fallingdotseq$ 18,500 + 23,800 $\fallingdotseq$ 42,300 (VA)

4-3 Summary of Basic Design for Each Proposed Site

4-3-1 Attention paid during study of plans

The capacity of equipment and distribution systems required by the Government of Bhutan for the proposed sites were studied on the basis of the surveys conducted by the Team and the discussions held with responsible officials of the Government of Bhutan, paying attention to the following points.

(a) Study of maximum discharge

The maximum discharge was studied and decided after confirming if there are any existing irrigation systems or whether there will be any plan to construct new irrigation systems, in order to avoid any possible obstacles.

(b) The design of intake dams, channels, power plants and so forth was studied in order that the standards and sizes could be common as much as possible, and that the total cost could be minimized and also that the operation and maintenance thereof could be easiest.

(c) Much attention was paid to the higher plant factor in an assumption that it is to be impossible to depend on power supply from other areas since each area should have its separate power supply system in this Project.

In other words, the maximum discharge should not be larger than the annual minimum discharge in principle.

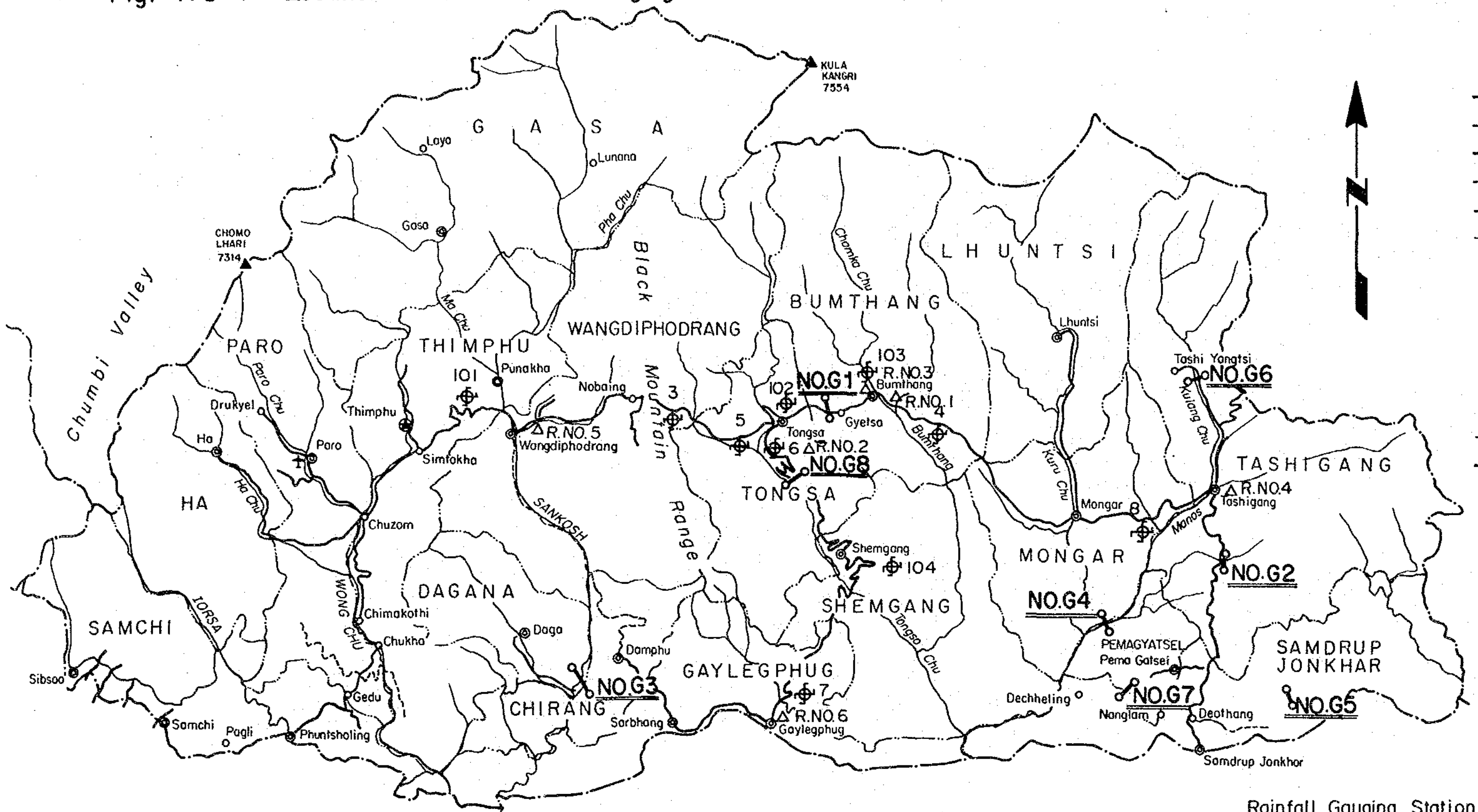
4-3-2 Study of maximum discharge

(1) Basic data

(a) Discharge gauging station

Fig. 4.3-1 shows the data of stream discharge obtained by the Team in Bhutan.

Fig. 4.3-1 Location and Record of Gauging Station



LEGEND

- Paved roads
- Unpaved roads
- Roads under construction
- Roads under improvement
- Roads proposed under Fifth Plan
- Rivers
- Elevation points (meters)
- Airport
- National capital
- District capitals
- Other towns
- Selected villages
- District boundaries (Bhutan)
- International boundaries
- Discharge Gauging Station
- Proposed Site
- Rainfall Gauging Station

No. of Site	Name of Proposed Site
3	Rukubji
4	Ura
5	Tangsibi
6	Bubja
7	Surey
8	Yadi
101	Punakha
102	Tongsa
103	Tamjhing
104	Kekhar

Record of Discharge Gauging Station

Name of Station	Name of River	Catchment Area (Km²)	Year 1982	1983	1984	Remarks
1 Gyetsa G.S.	Khagaxig chu	60				□ Existirg Data ▨ NO. Data
2. Khalhg G.S.	Jiri chu	30				
3. Dobani G.S.	Soxikosh	—				
4. Pemagyatsel G.S.	Uri chu	15				
5. Munsitar G.S.	Baraxpadi	30				
6. Tashi Yangtsi G.S.	Birzam chu	20				
7. Nanglam G.S	Kirang chu	25				
8. Refee G.S	Mangdi chu	3,312				

Rainfall Gauging Station

No. of Station	Name of Station
R. NO. 1	Tamjhing G.S
R. NO. 2	Tongsa G.S
R. NO. 3	Bumthang G.S
R. NO. 4	Tashigang G.S
R. NO. 5	Wangdiphodrang G.S
R. NO. 6	Gaylegphug G.S

0 10 20 30 40 KILOMETERS

0 5 10 15 20 25 MILES

(b) Discharge data

The daily discharge records at the afore-said gauging stations cover three years from 1982 to 1984.

According to the data the records throughout the year are hardly found. (Refer to Annex-8)

(c) Rainfall observation stations and rainfall data

Only the annual rainfall records were obtained.

Bhutan has 20 rainfall observation stations all over the country, but the records of monthly rainfall are not pigeonholed.

(2) Study of discharge data

(a) An estimation of a monthly minimum discharge

As mentioned hereinbefore, discharge gaugings have not been continuously conducted. No gauging has been conducted in certain periods, especially in July, August and September.

This is probably attributable to the reason that the gauging facilities are poor and also gauging could not be done due to traffic suspension caused by flood during the rainy season.

Therefore, minimum discharge (daily average discharge) of each year and each month was firstly calculated from data available and then the monthly minimum discharge to cover the whole survey period was calculated, as per Table 4.3-1.

The discharge duration curves were prepared as per Figs. 4.3-2-(1) through (8) by means of a computer based on the available discharge data (Refer to Annex-9). For reference, the monthly average discharge has been estimated as follows:

Table 4.3 - 1 Estimation of Monthly Average Discharge

Unit : m³/sec

Name of Gauging Station	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Remarks
No.1 Gyesta G.S CA = 60km²	2.92 4.87	4.20 6.99	2.42 4.03	5.45 9.09	4.69 7.81	—	3.92 6.53	2.79 4.65	1.86 3.09	2.02 3.37	2.04 3.40	1.96 3.27	No.4 Ura No.5 Tangsibi No.6 Bubja No.102 Tongsa No.103 Tamjhing
No.2 Khalhg G.S CA = 30km²	0.33 1.10	0.51 1.70	0.79 2.65	1.17 3.90	0.16 2.03	0.73 2.44	0.70 2.34	0.68 2.27	0.50 1.66	1.13 3.77	0.33 1.08	0.35 1.16	No.8 Yadi
No.3 Dobani G.S													
No.4 Pemagyatsel G.S CA = 15km²	0.30 1.99	0.36 2.38	0.44 2.92	0.82 5.45	1.01 6.74	1.59 10.61	1.39 9.28	1.05 6.98	1.22 8.13	0.39 2.60	1.02 6.80	0.31 2.03	
No.5 Munsitar G.S CA = 30km²	7.94 26.55	10.65 35.46	14.17 47.19			21.13 70.36	20.77 69.16	15.07 50.18	13.90 46.29	13.01 43.32		11.52 38.36	
No.6 Tashi Yangtsi G.S CA = 20km²	0.27 1.34	0.37 1.86	0.29 1.45	0.69 3.47	0.50 2.49	0.70 3.51	0.46 2.31	0.29 1.47	0.25 1.25	0.23 1.16	0.25 1.25	0.24 1.21	
No.7 Nanglam G.S CA = 25km²	1.76 2.06	2.94 11.76	4.31 17.22	10.36 41.44	5.14 20.56	5.25 21.00	4.63 18.52	0.98 3.94	0.89 3.55	2.78 11.12	1.59 6.35	1.59 6.36	No.7 Surey No.104 Kekhar
No.8 Refee G.S CA = 3,312km²	29.46 0.89	40.75 1.23	93.86 2.84	—	98.34 2.97	76.24 2.30	51.20 1.55	32.97 1.00	25.13 0.76	30.2 0.91	25.25 0.76	25.65 0.77	No.3 Rukubji No.101 Punakha

Note ; [ ] Value are Minimum Discharge in year of each station

(b) Estimation of an average monthly discharge

The monthly average discharge was estimated from the aforesaid three-year data of discharge by simply averaging the records.

However, the study has not fully been coducted, and only 4 sites out of 8 sites were analyzed in detail, as shown in Table 4.3-2.

The annual rainfall at Gauging Stations No. 2 and No. 6 (Tashigang Site is located just between the two sites) is approximately 730 mm. If this annual rainfall is considered as the average rainfall, the annual outflow rate at each gauging station will be approximately 23%. Gauging Station No. 4 is located at almost the same elevation as Shemgang. If the annual average rainfall surveyed at Shemgang Rainfall Observation Station (1,180 mm) is assumed to be the average rainfall, the outflow rate will be 32%.

If Gauging Station No. 7 has the same average rainfall (2,126 mm) as Samdrup-Jongkhar Rainfall Observation Station, an outflow rate of 56% can be obtained.

However, the rainfall data of Samdrup-Jongkhar show that the fluctuation rate of the annual rainfall is more than 100% and such data are not very reliable.

Table 4.3 - 2 Estimation of Monthly Average Discharge Adopted for This Study

Unit : m^3/sec

No. & Name of Gauging Station	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Fed	Mar	Ave
No. 2 Khalhg G.S CA = 30km²	0.77 (2.56)	0.91 (3.03)	1.20 (3.98)	2.13 (7.09)	1.71 (5.70)	2.11 (7.03)	1.11 (3.70)	0.87 (2.90)	0.73 (2.43)	1.31 (4.38)	0.76 (2.52)	0.65 (2.15)	1.19 (3.96)
No. 4 Pemagyatsel G.S CA = 15km²	0.65 (4.35)	0.79 (5.24)	1.44 (9.59)	4.46 (29.75)	2.63 (17.55)	4.09 (27.26)	2.39 (15.90)	1.44 (9.61)	1.35 (9.01)	0.82 (5.49)	1.07 (7.14)	0.62 (4.13)	1.81 (12.08)
No. 6 Tashi Yangtsi G.S CA = 20km²	0.45 (2.03)	0.67 (3.36)	0.65 (3.25)	0.99 (4.97)	1.08 (5.38)	1.06 (5.31)	0.75 (3.77)	0.55 (2.74)	0.47 (2.33)	0.36 (1.65)	0.27 (1.33)	0.26 (1.31)	0.63 (3.13)
No. 7 Nanglam G.S CA = 25km²	3.30 (13.19)	17.38 (69.50)	14.09 (56.34)	28.53 (14.11)	11.55 (46.19)	17.55 (70.21)	8.75 (35.01)	4.48 (7.92)	3.03 (12.13)	3.56 (14.23)	2.99 (11.94)	2.86 (11.46)	9.84 (37.52)

Note : ( ) are Value m^3/sec / 100km²

(c) Stream discharge gauging stations applied to proposed power plant sites

The minimum discharge at each site is estimated based on the records available at the following gauging stations.

Description	Stream Discharge Gauging Station Applied	Outline of Proposed Sites					Remarks
Name	G No. 1 Gyesta	Ura (No. 4)	Tangsibi (No. 5)	Bubja (No. 6)	Tongsa (No. 102)	Tamjhing (No. 103)	The five (5) proposed sites are located in the neighbourhood of G No.1 Gyesta Gauging Station, and their elevation and catchment area are almost similar.
Catchment Area (km²)	60	42.9	8.38	27.6	14.5	11.9	
Average Elevation within Catchment Area (m)	2,800	3,000	2,300	1,800	2,100	2,600	
Average Annual Precipitation in Catchment Area (mm)	730 (Bhumthang)	730 (Bhumthang)	730 (Bhumthang)	730 (Ghumthang)	1,239 (Tongsa)	732 (Tamjhing)	
Name	G No. 2 Khalhg	Yadi (No. 8)					Yadi Site (No. 8) is situated closest to Khalhg Gauging Station. Its catchment area and average elevation in the catchment area almost resemble. The rainfall pattern is also assumed to be similar to the said gauging station.
Catchment Area (km²)	30	21.3					
Average Elevation within Catchment Area (m)	1,400	1,500					
Average Annual Precipitation in Catchment Area (mm)	732 (Tashigang)	732 (Tashigang)					
Name	G No. 7 Nanglam	Surey (No. 7)	Kekhar (No. 104)				Surey Site (No. 7) and Kekhar Site (No. 104) are slightly different from the elevation of Nanglam Gauging Station and located far from each other. However, as the said two areas are similar in respect of vegetation, the rainfall pattern is likewise presumed to be almost the same as that of Nanglam Gauging Station.
Catchment Area (km²)	25	87.8	14.5				
Average Elevation within Catchment Area (m)	1,500	900	2,100				
Average Annual Precipitation in Catchment Area (mm)	2,120 (Gaylephug)	2,120 (Gaylephug)	2,120 (Gaylephug)				
Name	G No. 8 Refee	Rukubji (No. 3)	Punakha (No. 101)				Rukubji Site (No. 3) and Punakha Site (No. 101) are located adjacent to Refee Gauging Station. Refee Gauging Station has smaller precipitation than other survey points. The minimum discharge of the two (2) posed sites has been conservatively estimated from the specific discharge of the said gauging station.
Catchment Area (km²)	3,312	42.7	17.8				
Average Elevation within Catchment Area (m)	2,000	2,800	1,900				
Average Annual Precipitation in Catchment Area (mm)	622 (Wangdiphodrang)	622 (Wangdi-phodrang)	622 (Wangdi-phodrang)				

(d) Maximum available stream discharge and annual minimum stream discharge at each proposed site

The maximum stream discharge available at each proposed Site is worked out on the basis of the following formula in consideration of:

(1) The total electric power requirement based on the results of the electric power demand forecast for towns and villages located near the proposed sites,

(2) The head confirmed to be available through the actual survey conducted at the sites,

$$P\ (kW) = \eta \cdot g \cdot Q \cdot H$$

$$Q = \frac{P\ (kW)}{\cdot g \cdot H}$$

P : Electric Power Generated (kW)

η : Efficiency of Turbine and Generator (60%)

g : Gravity Acceleration (9.8 $m/sec.^2$)

Q : Stream Discharge ($m^3/sec.$)

The annual minimum stream discharge estimated at each proposed site on the basis of item (c) mentioned hereinbefore (on the basis of data available) is compared, as per Table 4.3-3, with the maximum discharges of the power plant calculated by the afore-mentioned formula and with the stream discharges actually gauged by the Team at the proposed sites.

The calculated maximum discharges required for almost all proposed sites are found to be smaller than that estimated from the data available and the utilization factors thereof are around 100%.

Therefore, the maximum discharges of the power plant are considered to be considerably reasonable.

Table 4.3-3 Comparison of Estimated Annual Minimum Stream Discharge and Maximum Discharge of Power Plant

Name of Project		Min. Stream Discahrge available (M3/S)	Stream Discharge surveyed at Project Site (M3/s)	Max. Discharge of power plant (M3/S)	Max. electric power output (kW)	Effec-tive head (M)	Remarks
No. 3	Rukubji	0.35	0.38	0.17	40	40	
No. 4	Ura	1.40	0.56	0.42	50	20	
No. 5	Tangsibi	0.27	0.14	0.13	30	40	
No. 6	Bubja	0.90	0.12	0.10	30	50	*
No. 7	Surey	3.12	4.70	0.24	70	50	
No. 8	Yadi	0.16	0.09	0.10	30	50	
No. 101	Punakha	0.14	0.10	0.13	30	40	
No. 102	Tongsa	0.47	0.15	0.21	50	40	
No. 103	Tamjhing	0.39	0.13	0.10	30	50	
No. 104	Kekhar	0.31	0.42	0.11	20	30	

* The stream discharge is limited as some of it is used for irrigation purposes on the way to the proposed site.

4-3-3 Summary of general features of proposed sites

(1) Outline of planning

The results of the study based on the analyses of the data and information collected during the site surveys are as given in Table 4.3-4 and Figs. 4.3-3-(1) to (10) of Annex-10, respectively.

(2) Selection of sites for power plants and intake points

The Department of Power had made rough surveys on the sites from Nos. 3 through 8 and selected the location of the respective facilities.

However, four sites from Nos. 101 through 104 were newly taken up to replace the previously proposed four sites. These four sites had not yet been surveyed. The Team conducted field surveys on the above-mentioned four sites, exerting its utmost to check the availability of previous data, information and findings. In particular, as far as these four sites are concerned, the Team collected data and information for planning and design for the sites and selected the locations of the respective power plants and relevant intake facilities. The reasons for selection of such facilities at the respective sites are as described hereunder.

(a) Rukbuji Site (No. 3)

At the intake point previously selected by the Department of Power sand and gravel are piled and accumulated, and the width of the river is as wide as 30 metres.

Therefore, it was considered that intake facilities be installed about 20 metres further downstream where the width of the river bed is as narrow as 5 metres from the originally selected location.

Table 4.3 - 4 Salient Features of the Project

Item \ Name of Project	③ Rukubji	④ Ura	⑤ Tangsibi	⑥ Bubja	⑦ Surey	⑧ Yadi	101 Punakha	102 Tongsa	103 Tamjhing	104 Kekhar
1. Name of District	Wangdiphodrang	Bunchang	Tongsa	Tongsa	Gaylegphug	Mongar	Punakha	Tongsa	Bumthang	Shemgang
2. Name of Village	Rukubji (Bumblo)	Ura Sondrang Penkhar Gayden	Tangsibi (Chankha)	Bubja (Changra)	Surey	Yadi Chaskar Ngatshang	Thrinlaygang Jalnug Toaha	Tongsa	Tamjhing	Kekhar
3. No. of Houses	45 (65)	50 (104)	70 (130)	48	240	115 (540)	32 (54)	100	35 (70)	27
4. Institution	0 (7)	8 (8)	1 (6)	5 (7)	4 (6)	7 (7)	7 (7)	13 (13)	0 (6)	0 (6)
5. Average Elevation (m)	2,800	3,000	2,300	1,800	900	1,500	1,900	2,100	2,600	2,100
6. Name of Stream	Gir Chu	Lirigang Chu	Nagani Chu	Isagang Chu	Ronggang Chu	Gudari Chu	Lamja Chu	Thipangi Chu	Tamjhing Chu	Chhudagong Chu
7. Catchment Area at the Intake Site (km²)	42.7	42.9	8.38	27.6	87.8	21.3	17.8	14.5	11.9	8.9
8. Stream Discharge at the Intake as of April, '85 (m³/s)	0.38	0.56	0.14	0.12	4.7	0.09	0.10	0.15	0.13	0.15
9. Estimated Maximum Turbine Discharge (m³/s)	0.17	0.42	0.13	0.10	0.24	0.10	0.13	0.21	0.10	0.11
10. Estimated Effective Head (m)	40	20	40	50	50	50	40	40	50	30
11. Estimated Power House Output (kW) (Results of Power Demand Forecast) (Resuls of Power Demand Forecast including Private House)	40 (22) (35)	50 (27) (41)	30 (20) (46)	30 (17) (38)	70 (15) (71)	30 (24) (49)	30 (21) (47)	50 (81) (112)	30 (15) (29)	20 (15) (33)
12. Transmission Length (km)	0.4	3.0	0.5	1.1	2.4	3.7	2.9	0.5	0.2	2.2
13. Accessibility										
1) Road condition	Unpaved	Path & Cliff	Path	Path	Path	Unpaved & Slope	Slope	Unpaved & Path	Unpaved	Path
2) Distance between Main Road and Power House (km)	0.15	0.07	1.0	0.15	0.02	0.11	0.15	0.3	6.0	6.0
14. Investigation Date	4/25	4/19	4/16	4/23	4/26, 27	4/21, 22	4/26, 27	4/17	4/18	4/25

(b) Ura Site (No. 4)

The original plan formulated by the Department of Power was to construct a power plant approximately 50 metres upstream from the bridge crossing the Lirigang River.

This river runs at a river gradient of 1/20, being suitable for construction of a run-of-river-type power plant on it. On the contrary, it is not appropriate to build an intake dam on the river because the originally proposed site is located upstream of the bridge where both banks of the river are too steeply sloped to build such an intake dam. On the said banks there exist a number of huge stones on the river bed where huge quantities of rocks and soil must be excavated and removed for construction of the intake dam. It seemed to be difficult to transport materials and equipment therefor. Thus the selection was made by the Team on the intake place upstream of the bridge where the river bed is stable. Selection was likewise made on the canal route along the gently sloped mountain side on the right side bank of the river. It was decided that the power plant be located near a point where another river flowing from the north join the river.

(c) Tangsibi Site (No. 5)

The original plan worked out by the Department of Power is a generation scheme which will utilize the idle head of the existing irrigation canal. No special problem will be raised.

(d) Bubja Site (No. 6)

There were two alternative sites beside the originally proposed site. Since these alternative sites might affect irrigation facilities, the original plan which will provide no hindrance to irrigation is considered appropriate. The canal to utilize the existing canal will be further extended along the road. In order to construct the new canal as stated hereinabove, a slightly larger quantity of excavation will be needed due to removal of soil becuase the route of the new canal to be extended has topographical undulations.

(e) Surey Site (No. 7)

There exists of small stream flowing from the right side bank approximately 30 metres downstream from the originally proposed intake site. A large quantity of earth and rock are piled due to land sliding at the location approximately 50 metres upstream of the above small stream. Since it is feared that the passage of the canal into the piled earth and rock will be difficult, it has been decided that the intake dam be located about 50 metres downstream from the originally proposed site.

(f) Yadi Site (No. 8)

The original plan was to install generating facilities by utilizing an irrigation canal. At the orignal site, the quantity of water usable for irrigation purposes is small, and it was observed during the site survey that discharge at the said site and adjacent areas was extremely scarce. It was, therefore, judged that the originally proposed site would be inappropriate for generation purposes. It has been planned that a generation plan be worked out on the assumption that a discharge of 0.09 m^3 measured during the site survey is to be taken in from the Gudari River.

This new site is located approximately half-way between Mongar and Tashigang.

It has been decided that an intake dam be constructed immediately downstream of the bridge where the trunk road linking Mongar and Tashigang crosses the Gudari River, and that a canal, about 300 metres long, along the right side bank be constructed thereby obtaining a head of 50 metres.

(g) Punakha Site (No. 101)

Two alternative sites can be raised other than the originally proposed site. Either of these sites has complicated irrigation facilities, and it was found difficult to make adjustments between water for irrigation and water for generation purpose. Therefore, it has been planned that generation be made by means of taking in water from the Lamja River according to the plan. The said river has a river gradient of about 1/12 on the average and a catchment area of about 18 km^2. The intake point is located almost half-way between Wandiphodrang and Thimphu. It has also been planned that an intake dam be constructed immediately downstream of the bridge where the trunk road linking both places cross. A canal, around 470 metres long, will be constructed along the right side bank to obtain a head of 40 metres.

(h) Tongsa Site (No. 102)

The plan originally proposed by the Department of Power included two candidate places to be developed. One is on the Thipangi River which flows into the central part of the town and the other is located on the Tergang River about 3 kilometres far from the town.

It was hardly possible to decide as to which place would be more suitable merely based on the results of the site survey.

Then, the following comparative study of both places was made as per Table 4.3-5.

Table 4.3 - 5 Comparison for Selection of Tongsa Site

No.	Item	Thipangi Chu A	Tergang Chu B	Judgment
1	Intake (m)	L = 7.5, H = 1.8	L = 11.000, H = 2.00	A
2	Water Channel (m)	H B L 0.30× 0.475×440	H B L 0.50× 0.825×310	A
3	Penstock (m)	D L 0.30 112.6	D L 0.60 × 30	A
4	Power House (m)	4 × 4.5 × 3.5	5 × 5 × 4	A
5	Speed Governor	Speed Govornor	Mechanical Governor	A
6	Transmissiom Line (km)	0.5	2.5	A
7	Effective Head (m)	40	20	A
8	Power House Output (kW)	50	80	B
9	Max. Discharge (m^3/s)	0.21	0.67	A
10	Tentatively Estimated Construction Cost(%)	100	200	A
11	Construction Cost/kW (%)	100	130	A

As may be easily seen from the above table, Place "A" excels Place "B" except for the output of a power plant. Place "B" offers only a head as high as 20 metres at the most from the topographical and geological standpoints. It will be necessary to increase the volume of discharge so as to correspond with the demand for electricity. Therefore, a cost of constructing a canal has been increased.

As the Tongsa area is a central place of the district, only public institutes in this area are estimated to require approximately 80 kVA. Details of power demands are as shown in Table 4.2-3. Since the existing diesel power plants in the Tongsa area are obsolete, it has been planned that power from the micro hydro power plant under this Project be supplied to meet the base load while the existing diesel power plant (60 kVA) should supply its power for meeting peak loads in order to make up for a shortage of power.

As a result of the study stated above, it is finally proposed to select Place "A" named Thipangi Chu.

(i) Tamjhing Site (No. 103)

This site has been selected as a generation scheme to utilize the existing irrigation canal which conveys water along the right side bank. The existing intake facilities and head race are considerably superannuated, and there are many leaks in the canal. It is therefore, necessary to completely repair it.

(j) Kekhar Site (No. 104)

This site is located about 6 kilometres by a mountain path, around 1 metre wide, from Dakpai village situated almost in a middle position of the trunk road leading to Gaylegphug from Tongsa.

The Kekhar River with a catchment area of about 9 km^2 has a river gradient of 1/5 in the neighbourhood of the intake dam and flows very rapidly. It has been planned that an intake dam be built on this tributary and a canal, 30 metres long, be newly constructed to obtain the head of 30 metres. As for this site, the transportation cost of construction materials and equipment will be rather high as the road is narrow and there are many undulant places on the way to the site.

4-4 Civil Structures

4-4-1 Intake dam and sedimentation basin

1) Intake dams

The proposed dam site was selected at a location of each river with a river bed which is considerably stable, except for Bubja (No. 6) and Tamjhing (No. 103) where the existing irrigation facilities are used, based on the results of the field survey conducted by the Team.

The intake dam is to be of concrete construction. An opening will be installed at the top of the dam in order that water may naturally run down through the said opening from where necessary water can be taken in. A pipe-screen will be installed on the opening so that sand, soil and stone may naturally flow down through the said pipe-screen.

Standardization was made on the structures of the dams in due consideration of later design, construction, operation and maintenance of such dams. In this report, standard sections were applied to all intake dams. The structures of the intake dams are as per 4-6 Basic Design Drawings.

2) Sedimentation basin

During the rainy season, muddy water containing earth and sand is led into canals. Sedimentation basins will be constructed near the intake dams. The sedimentation basin will be of a structure to enable the speed of water to be decreased and to have earth and sand sediment inside the sedimentation basin. Thus, it will be possible to take out earth and sand sedimented at the sand draining device therefrom. The design of the sedimentation basin has also been standardized in the same way as in the case of the intake dam. The length of the sedimentation basin has been determined on the assumption that the mean velocity of stream inside the sedimentation basin is to be 0.2 metres per second and the depth of water 1 m in principle. The structure of the sedimentation basin is as shown on 4-6 Basic Design Drawings. The length of each sedimentation basin has been determined according to the following calculations.

Calculation for Determination
of Length of Sedimentation Basin

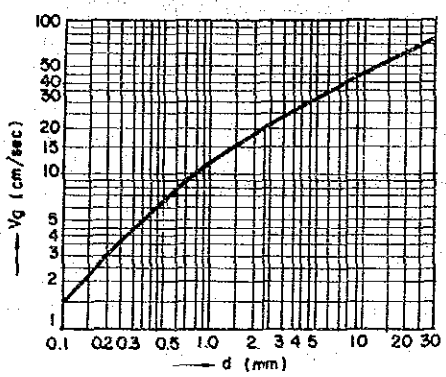
$$L \geqq \frac{h}{V_g} \times V$$

L : Minimum Required Length of Sedimentation Basin (m)

h : Depth of Water in Sedimentation Basin (m)

V : Average Velocity of Flow in Sedimentation Basin (m/sec.)

V_g : Critical Settling Velocity of Fine Sand Particles (m/sec.)



Relations between average diametre of fine sand particles "d" and critical settling velocity "V_g".

The critical settling velocity "V_g" will be approximately 0.07 m/sec., provided, however, that the diametre of fine sand particles ranges from 0.5 m/m to 1.0 m/m.

Therefore, provided that the following parametres are given;

h : 1 m

V : 0.2 m/sec.

V_g : 0.07 m/sec.

the length required can be calculated as follows:

$L \geqq 2.86$ m

Accordingly, L = 3 m has been obtained.

4-4-2 Head race

It has been designed that the head race will be of an open-channel type. Hydraulic calculations of the quantities of water passing through the head race will be made by the formula of "Manning". The most advantageous section which offers the largest hydraulic radius for water conveyance in the same sectional area has been determined.

The maximum mean velocity of the head race has been determined to be less than the allowable velocity which does not erode the interior of the head race. Accordingly, 1 m/sec. has been employed for this Project. The allowable velocity in which the interior of the head race is not eroded is as shown below.

Kind	Stream Velocity/sec.
Sandy soil	0.45
Sandy loam	0.60
Loam	0.70
Clay loam	0.90
Clay	1.00
Clay mixed with sand	1.20
Soft rock	2.00
Intermediate hard rock	2.50
Hard rock	3.00
Thick concrete	3.00
Thin concrete	1.50
Asphalt	1.00
Masonry of cobble stone without cement motar (stay: less than 30 cm)	1.50
Masonry of cobble stone without cement mortar (stay: less than 30 cm)	2.00
Masonry of cobble stone with cement mortar	2.50
Precast concrete	2.50
Pipe	5.00
Steel pipe	5.00

The hydraulically most efficient sectional area and hydraulical characteristics of the open channel are as indicated in Annex 11. Design has been made on the sections of the respective open channels at the sites, based on the results of these calculations. (Refer to 4-6 Basic Design Drawing for details of the standard section drawing.)

The section of each channel at the site is;

Type-A : (1) Inner dimensions of channels:
= 45 cm (bottom width)
x 65 cm (upper width)
x 40 cm (height)

Tangsibi Site (No. 5)
Yadi Site (No. 8)
Punakha Site (No. 101)
Kekhar Site (No. 104)

(2) Structure: Bottom — Concrete lining
Side wall — Masonry with cement mortar

Type-B : (1) Inner dimensions of channels:
= 55 cm x 65 cm x 40 cm

Rukbji Site (No. 3)
Tongsa Site (No. 102)

(2) Structure: Bottom — Concrete lining
Side wall — Masonry with cement mortar

Type-C : (1) Inner dimensions of channels:
= 75 cm x 102.5 cm x 55 cm

Bubja Site (No. 6)
Surey Site (No. 7)

(2) Structure: Concrete lining

Type-D : (1) Inner dimensions of channels: Ura Site (No. 4)
= 80 cm x 110 cm x 55 cm

(2) Structure: Concrete lining

Type-E : (1) Inner dimensions of channels: Tamjhing Site (No. 103)
= 380 cm x 50 cm x 30 cm

(2) Structure: Bottom — Concrete lining
Side wall — Masonry with cement mortar

4-4-3 Head tank

A head tank will be installed at the intake of each penstock. The capacity thereof should be large enough to supply maximum discharge for more than 30 seconds. No gate will be installed at the entrance of the penstock. Instead, an inlet valve will be set at the end of the penstock lying at the side of the power house. Free overflow type outlets will be installed beside the head tank. A gate for draining sand and soil will be installed for purposes of removing sand and soil flowed into the head tank therefrom. A manually operable spindle gate will be employed. The construction of the head tank will be of reinforced concrete structure and is as shown on 4-6 Basic Design Drawing.

4-4-4 Penstock

The penstock will be of ordinary water supply tube with a flange and will be buried under the ground in view of later operation and maintenance of the penstock.

The design velocity of flow inside the penstock will be 3.5 m/sec. at maximum. The diametres of the penstocks have been standardized as much as possible and are divided into three kinds of diametres as listed below.

(1)	Diametre	0.4 m	Ura Site	(No. 4)
			Surey Site	(No. 7)
(2)	Diametre	0.3 m	Rukubji Site	(No. 3)
			Tangsibi Site	(No. 5)
			Tongsa Site	(No. 102)
			Kekha Site	(No. 104)
(3)	Diametre	0.25 m	Bubja Site	(No. 6)
			Yadi Site	(No. 8)
			Punakha Site	(No. 101)
			Tamjhing	(No. 103)

Details of the losses of heads are as shown in Table 4.4-1.

Table 4 - 4 - 1 Calculation of Head Loss

Items	Name of Sites	No.3 Rukubji	No.4 Ura	No.5 Tangsibi	No.6 Bubja	No.7 Surey	No.8 Yadi	No.101 Punakha	No.102 Tongsa	No.103 Tamjhing	No.104 Kekhar
1. Maximum Discharge (m^3/s)		0.17	0.42	0.13	0.10	0.24	0.10	0.13	0.21	0.10	0.11
2. Penstock Diameter (m)		0.3	0.40	0.30	0.25	0.40	0.25	0.25	0.30	0.25	0.30
3. Penstock Length (m)		72.5	58.10	116.40	117.00	130.70	107.10	64.40	119.50	107.90	71.00
Mouth Loss of Penstock	Vo	2.40	3.342	1.839	2.037	1.910	2.037	2.648	2.971	2.037	1.556
	$Vo^2/2g$	0.122	0.171	0.094	0.104	0.097	0.104	0.135	0.45	0.104	0.079
	h_1	0.012	0.017	0.009	0.010	0.010	0.010	0.014	0.045	0.010	0.008
Friction Loss	Vo^2	5.760	11.167	3.382	4.149	3.648	4.149	7.012	8.827	4.149	2.421
	$D^{4/3}$	0.2008	0.2947	0.2008	0.15749	0.2947	0.15749	0.15749	0.2008	0.15749	0.2008
	h_2	1.903	2.025	1.794	2.820	1.480	2.582	2.624	4.807	2.601	0.783
Oters	h_3	0.485	0.458	0.497	0.310	0.210	0.508	0.362	0.303	0.259	0.609
Total	h_4	2.400	2.500	2.300	3.140	1.700	3.100	3.000	5.110	2.870	1.400

Formula

1) $h_1 = fe \dfrac{Vo^2}{2g}$

$fe = 0.1$ (coefficient for Bell mouth)

$Vo = Q/Ao$

$Ao = \pi Do^2/4$

2) $h_2 = \dfrac{124.5n^2}{D^{4/3}} L_1 \dfrac{V_1^2}{2g}$

$= 9.15 \times 10^{-4} \times L_1$

$\times V_1^2 \times D_1^{-4/3}$

$n = 0.012$ (Roughness coefficient)

4-4-5 Power house and outlet

The construction of the power house, outlet and equipment arrangement (layout) is as shown on Basic Design Drawing No. 4-6. The power house will have ample space sufficiently enough to undertake inspection, decomposition, etc. of the equipment. The outlet has been designed to cause no whirl-pool in the water running down from the turbine and to maintain a certain depth of such water. The power house will have a concrete wall in portions 1 metre above its foundation, thereby avoiding an inflow of sand and earth into the power house and possible damage to be inflicted by falling stones upon the power house.

4-5 Electrical Equipment and Facilities

4-5-1 Selectin of electrical systems

In selection of the electrical systems, it will be necessary to take into account the economy of equipment, the capability of Bhutanese personnel to maintain and operate such equipment and coordination thereof with the existing electrical equipment.

The transmission and distribution systems currently employed in Bhutan are as follows:

(i) Transmission voltage

11 kV, 33 kV, 66 kV and 220 kV

(ii) Distribution systems

400/230V, 3-phase, 4 Wire system

(iii) Frequency : 50 Hz

Selection of the kinds of the turbines, generating equipment and transmission/distribution systems for this Project is based on the following requirements:

(a) Selection of type of turbine

Table 4.5-1 gives the types, characteristics and constructions of the turbines. Examples for the selection of the types of the turbines from the standpoint of heads and effective discharge are shown in Fig. 4.5-1. Selection of the type of turbine depends upon effective heads and discharge. As may be easily seen from Table 4.5-1, a Francis type turbine and cross-flow type turbine are considered to be suitable for medium heads.
However, a cost of manufacturing a Francis type turbine is costly because of its small size if discharge is not large. Besides, it is difficult for this kind of turbine to be repaired on account of its size in case cavitation takes place after a power plant is placed into operation. The complexity of this equipment is apt to cause considerably a large amount of expenses.

On the other hand a cross-flow type turbine has a simple constuction usable for medium heads and small discharge. This type of turbine is considered suitable for this Project. Accordingly, the cross-flow type turbine is proposed in this report. The control of this type of turbine is as stated hereunder:

It is common to adjust required discharge and the speed of a turbine so as to meet demands (actual loads) usually by means of a guide vane servomotor. In case of a power plant with a unit capacity of around 50 kW, employment of a servomotor will cause the complexity of mechanism, difficulty in operation of the equipment and increase in the maintenance cost thereof. Accordingly, the following control system of the turbine will be employed.

(i) Control of the quantities of water

The guide vane will be manually controlled from time to time so that necessary demands can be met as much as possible within the limits of the quantities of inflow. Such control is to be made once a day at the most.

Table 4.5-1 Characteristics of Turbines (for small hydroelectric power gnerators)

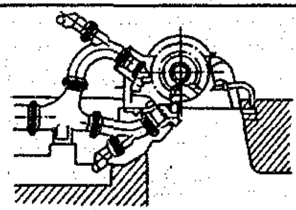
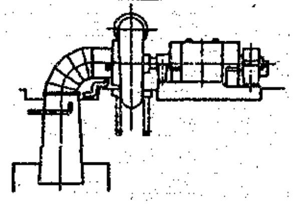
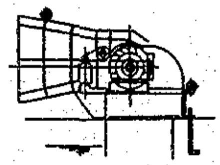
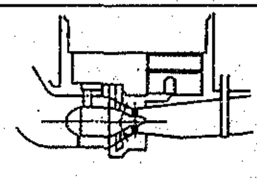
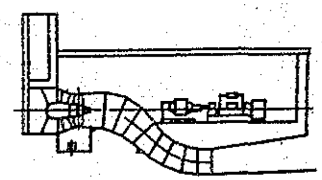
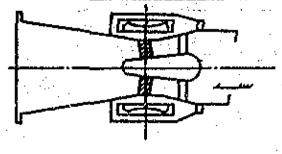
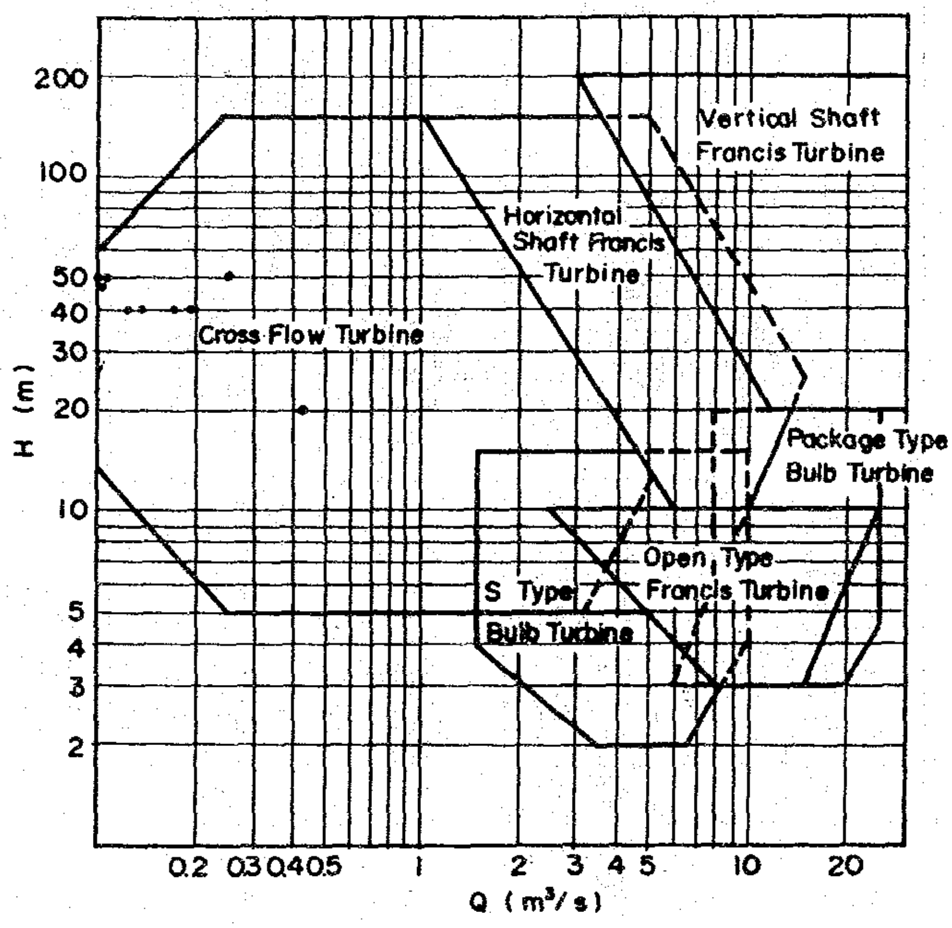
Type of Turbine	Difference in heads	General characteristics	Example of Turbines
Pelton Turbine	for higher head (more than 75 m)	Usable for dams, channels or for discharge water. High efficiency in change of stream volume.	
Francis Turbine	for medium height head (15 m - 200 m)	Most popular ones (for medium capacity) Able to match the change in stream volume by use of partial load runner.	
Cross-Flow Turbine	for medium height head (8 m ~ 100 m)	Suitable for small capacity (1,000 kW) and lowest in cost. Efficiency is not highest but least influence by change in stream water volume.	
Kaplan Turbine Tubular Turbine	for lower head (less than 25 m)	Suitable for channel (low head). Widest operability by use of movable wing runner.	 
Fixed wing propeler turbine (including one piece turbine)	for lower head (less than 18 m)	Smallest equipment with diameter smaller than 1,000 mm. Able to meet changes in stream volume by means of changing number of equipment.	

Fig. 4.5 - 1 Selection Figure of Water Turbine Type (For Example)



• ; Design Point of This Project

(ii) Control of speed

The turbine speed will be controlled by means of pipe-heaters to be installed in the tail race in order to maintain a certain required revolving speed irrespective variation (increase or decrease) in demand.

(iii) Inlet valve

A manually operated sluice valve will be installed whereas no intake gates will be set in the upper head tank.

The servoless governor which will be applied to this Project will be so designed as to be free from mechanical damage even if any trouble and/or failure take place; so-called the "run-away" is reached.

(b) Electrical systems of generating equipment

"No-man control" system will be employed for control of the power plant. Consideration has been given to the design so that daily short visits by maintenance crews to the power plants for inspection thereof will suffice for the operation of the said power plants.

(i) Voltage of generator: AC 400V has been employed in view of the economy.

(ii) Control system:

An intermittent control system will be employed. In other words, "no-man power house" has been considered, and the voltage of the generator will be automatically regulated by means of an automatic voltage regulator (AVR).

(c) Electrical system of transmission lines

The formula of "Still" was used in this report to roughly find the classifications of transmission voltages for the transmission lines. According to the results of the calculation by means of "Still" formula, it is found that the voltages of 4 to 9 kV will be economical for this Project. Therefore, it can be said that 6.6 kV will be appropriate as the standard voltage.

Formula of "Still"

$$V = 5.5 \times \quad 0.6 \times L + \frac{P}{100}$$

where V : Transmission voltage (kV)

L : Transmission line length (km)

P : Transmission power (kW)

The result of the calculation by use of the formula is as per Table 4.5-2 "Transmission line length".

Table 4.5 - 2 Transmission Line Length

No.	Site No.	Name of Site	Installed Capacity (kW)	Line Length (km)	Calculated Economical T/L Voltage (kV)
1	3	Rukubji	40	0.4	4.4
2	4	Ura	50	3.0	8.3
3	5	Tangsibi	30	0.5	4.3
4	6	Bubja	30	1.1	5.4
5	7	Surey	70	2.4	8.1
6	8	Yadi	30	3.7	8.7
7	101	Punakha	30	2.9	7.9
8	102	Tongsa	50	0.5	4.9
9	103	Tamjhing	30	0.2	3.6
10	104	Kekhar	20	2.2	6.8
		Average	38	1.7	6.5

On the other hand if viewed from voltage drops on transmission lines, voltage drops on transmission lines of 400V, 3.3 kV and 6.6 kV are as given in Table 4.5-3 "Voltage Drop".

Table 4.5 - 3 Voltage Drop

Site No.	Site Name	Installed Capacity (kW)	Line Length (kW)	Voltage Drop (V)				
				400V T/L			3.3kV T/L	6.6kV T/L
				$22mm^2$	$38mm^2$	$60mm^2$	5 mm	5 mm
3	Rukubji	40	0.4	49.6	11.6	7.2	2.8	1.4
4	Ura	50	3.0	183.9	108.7	67.8	25.8	12.9
5	Tangsibi	30	0.5	18.4	10.9	6.8	2.6	1.3
6	Bubja	30	1.1	40.4	23.9	14.9	5.8	2.9
7	Surey	70	2.4	205.8	121.7	75.9	28.6	14.3
8	Yadi	30	3.7	136.0	80.4	50.1	19.4	9.7
101	Punakha	30	2.9	106.6	63.0	39.3	15.2	7.6
102	Tongsa	50	0.5	12.3	18.1	11.3	4.2	2.1
103	Tamjhing	30	0.2	7.4	4.3	2.7	1.0	0.5
104	Kekhar	20	2.2	54.0	31.9	19.9	7.4	3.7

According to the results of the above calculations, the voltage drop on a transmission line is 5%, the allowable ranges are 20V, 165V and 330V in cases of a 400V transmission line, 3.3 kV transmission line and 6.6 kV transmission line, respectively.

As far as the voltage drop is concerned, transmission lines having both voltages of 3.3 and 6.6 kV could be employed.

The merits and demerits of the transmission voltage of 6.6 kV are as follows:

Merits:

(i) Since the voltage of 6.6 kV is becoming most popular among distribution voltage classifications in Japan, it will be possible to procure switches and transformers to correspond to the said voltage considerably with ease and at a fairly low cost.

(ii) Although 6.6 kV is a new standard voltage for Bhutan, it is considered that this voltage will be most appropriate for rural electrification in the country.

(iii) Insulated conductors are used for avoidance of electric shock in case of distribution lines with voltages up to 6.6 kV in Japan. Likewise, insulated conductors will be employed for this Project in view of the safety control because the sites of the Project are located in un-electrified rural areas. If this voltage of 6.6 kV is introduced to Bhutan, it will be more economical than the conventional transmission voltage of 11 kV.

Demerits:

(i) A new class of voltage is to be introduced in Bhutan.

In due consideration of the merits and demerits as indicated above and upon comparative study of them, it is believed appropriate that 6.6 kV be selected as the transmission line voltage for this Project.

(d) Electrical system of distribution line

The voltage of the distribution line is to be the same as the existing ones in consideration of easy maintenance of the facilities, availability of spare holdings/parts thereof and relevant factors in Bhutan. The electrical system as listed below has been employed.

(i) Nominal voltage : 400/230 (V)

(ii) Distribution system: 3-phase, 4-wire system

(iii) Grounding system : Direct grounding neutral system

4-5-2 Power generating plant

The power generating plant is designed in full consideration of estimated power demand at each proposed site area and of stream discharge available in each proposed river.

(1) Outline of equipment design

(a) Turbine

Type : Cross-flow type turbine (Once-through turbine)

Governor : Electronic servoless static type governor, controlling electronically the current of during load to keep certain required rotation.

Inlet valve: Manual sluice valve.

Rating : As per Table 4.5-4

Principal dimensions: As per Basic Design Drawing 4-6.

(b) Generator

Type : Three-phase A.C. blushless synchronous generator

Frequency: 50 Hz

Connection: Star circuit, 3-phase, 4-wire

Rating : As per Table 4.5-4

Principal Dimensions: As per Basic Design Drawing 4-6

(c) Control and protection relay board

Type : Self-standing, front door opening type

Control protection device: Meters, protection relays, AVR and control system for governor, electromagnetic switch, etc.

Principal dimensions: As per Basic Design Drawing 4-6

The turbine generator is to be of a direct-coupling type in order to avoid possible decrease in coupling efficiency in the case of employing a turbine generator of belt type and for avoiding inconvenience for maintenance.

The total efficiency of turbine generator must be 60% at the maximum, while turbine efficiency is to be 71% and generator efficiency be about 85%.

(2) Outline of power house

The generators shall be installed indoors, as mentioned in Item 4-4. Civil Structures, for the following reasons.

(i) Protection against damages possibly caused by rolling stones falling down from higher slopes in the site area and also by domestic animals pasturing in the same area.

(ii) Consideration to be paid to convenience for maintenance in the area where the climatic conditions are severe.

(iii) Storage and control of spare parts.

(iv) Protection against damages possibly caused by ants and bees which are apt to give inconvenience to maintenance by building nests on or under the equipment.

Table 4.5 - 4 Design of Power Plant

No.	Site No.	Site Name	Turbine Design				Generator Design				Normal Power House Output (kW)	Note
			Effective Head (m)	Maximum Discharge (m^3/s)	Maximum Output (kW)	Revolving Speed (r.p.m)	Rated Capacity (kVA)	Rated Voltage (V)	Power Factor (Lag)	Revolving Speed (r.p.m)		
1	3	Rukubji	40	0.17	50	750	50	400	0.8	750	40	
2	4	Ura	20	0.42	61.7	600	60	400	0.8	600	50	
3	5	Tangsibi	40	0.13	38.2	750	40	400	0.8	750	30	
4	6	Bubja	50	0.10	36.8	1,000	40	400	0.8	1,000	30	
5	7	Surey	50	0.24	88.2	1,000	90	400	0.8	1,000	70	
6	8	Yadi	50	0.10	36.8	1,000	40	400	0.8	1,000	30	
7	101	Punakha	40	0.13	38.2	750	40	400	0.8	750	30	
8	102	Tongsa	40	0.21	55.9	750	60	400	0.8	750	50	
9	103	Tamjhing	50	0.10	36.8	1,000	40	400	0.8	1,000	30	
10	104	Kekhar	30	0.11	24.3	750	30	400	0.8	750	20	
11	102	Tongsa (Alternative)	20	0.67	98.5	600	100	400	0.8	600	80	

In consideration of the above mentioned factors, the power house building shall be surrounded by small moats of which side wall is of concrete make and will be of wooden make with ventilation openings covered by worm-proof nets.

The outline of the power house is as per Basic Design Drawing 4-6.

4-5-3 Transmission line

Typical line diagram of the transmission line is shown in Fig. 4.5-2. The scope of the design of the transmission line is to run from the power plant in each town or village to a transformer to be installed in the centre of the said town or village. The scope of the design of the distribution line is to be from the said transformer to each of public institutions and house-wiring therein. However, house-wiring work for private houses is to be conducted on national funds. The basic design is to be made as follows on the above-mentioned assumptions.

(1) Total length and selection of route

The transmission line will be of one circuit from the power house to load centres and shall be installed along the road in principle in consideration of convenience of maintenance. The total line length of all sites is as per Table 4.5-2.

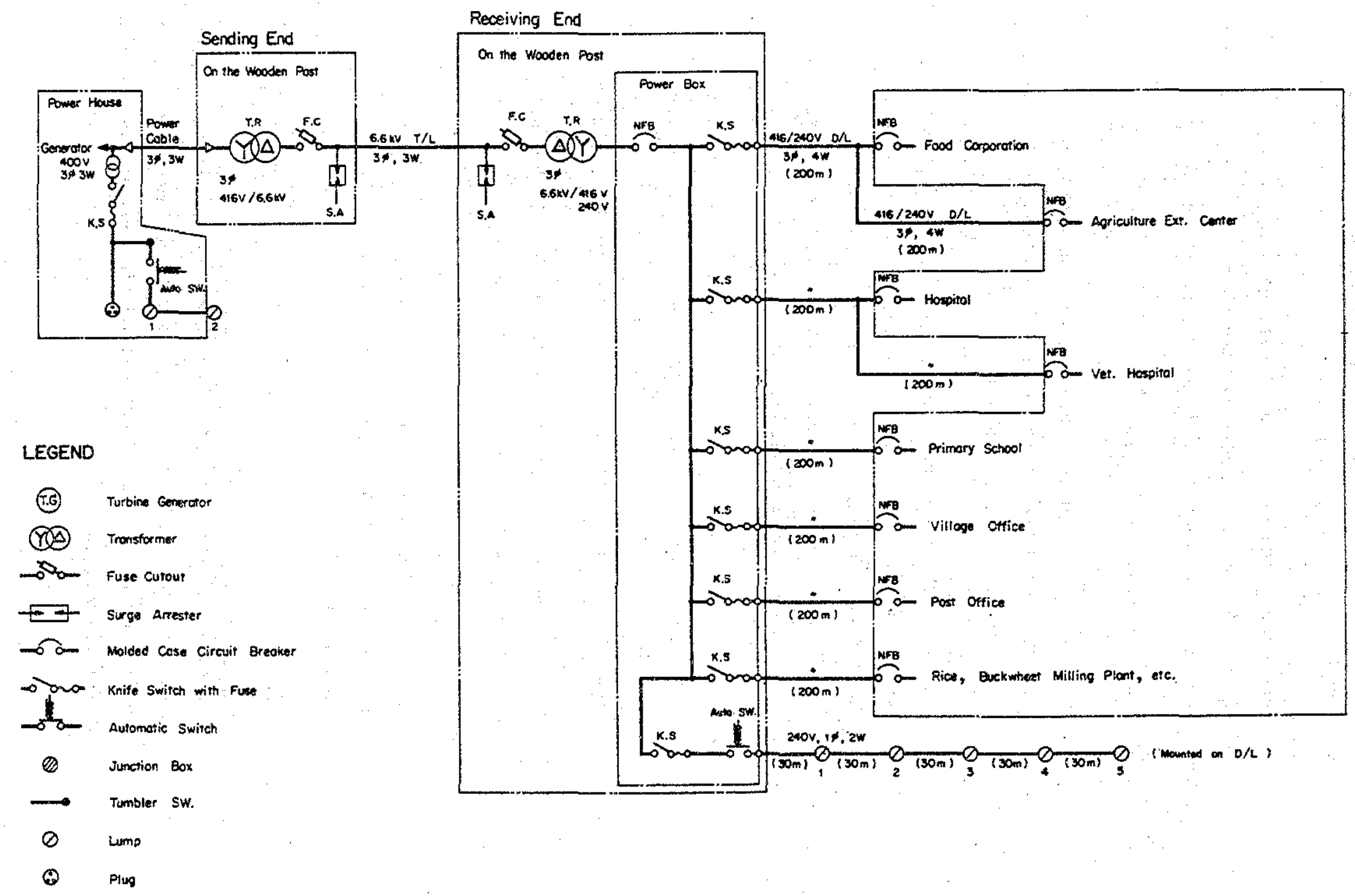
(2) Design of transmission line

(a) Kind of supporting materials

Bhutan is rich in forestry resources, and lumber of cherry trees, pine trees and blue pine trees are widely used for supporting materials.

The lumber of Bhutanese origin has to be dried for 2 or 3 years after being cut in a forest and will undergo antiseptic treatment by use of creosote, etc. Therefore, tubular steel poles are to be used for this Project.

Fig. 4.5-2 TYPICAL SINGLE LINE DIAGRAM FOR T/L & D/L (No.4 URA SITE)



The tubular steel poles will be dismantled into three sections.

Each such piece disconnected will be shorter than 14 feet (around 4.2 metres) in gross length due to the existing traffic requirements of lengthy cargoes in Bhutan.

(b) Types of line conductors

In view of the unelectrified areas, insulated wire is to be used for avoidance of any possible accident which might occur due to electric shocks.

The types of line conductors usable for this Project will be "Aluminium conductor steel reinforced insulated wire", "Hard-drawn aluminium conductor insulated wire", "Aluminium-clad hard-drawn steel stranded conductor" and "Hard-drawn copper stranded conductor".

Contact resistance is rapidly increased in case where the surface of element wire is oxidized, and may possibly cause trouble if it is not coped with properly. Therefore, the hard drawn copper wire is to be used for this Project.

High voltage outdoor polyethylen insulated wire with a cross sectional area of 22 mm^2 will be used for the transmission line.

Low voltage outdoor polyvinyl chloride insulated wire suitable for each different load will be used for the distribution line.

(c) Insulators

The sites of this Project located at an elevation of 3,000 metres at the maximum require certain consideration in the insulation design to adjust dielectric strength becuase of their height.

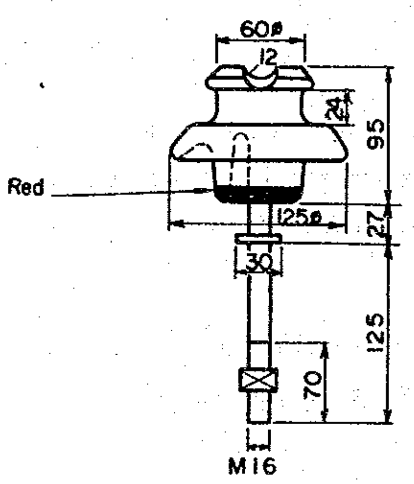
The dielectric strength at a place with an elevation of 3,000 metres is decreased to approximately 80% of what is available at places at an elevation of less than 1,000 metres.

Therefore, the insulating materials usable for this Project should have a dielectric strength of 1.25 times larger than those usable at palces at an elevation of less than 1,000 metres.

The insulators to be used for this Project are as shown in Fig. 4.5-3.

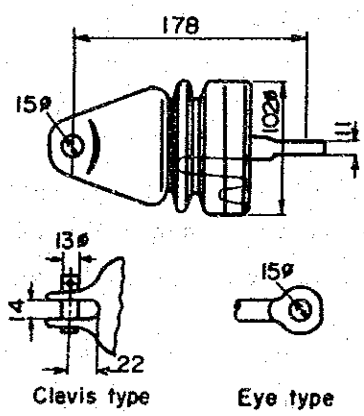
Fig. 4.5-3 Dimension of Insulator (For Example)

Pin Type Insulator (JIS C3821)
System Voltage 6.6kV



JIS C 3821 No.1

Suspension Type Insulator (JIS C 3826)
System Voltage 6.6 kV



JIS C 3826

The parametres and characteristics of the insulators to be used for this Project are shown in Table 4.5-5.

Table 4.5-5 Characteristics of Insulators (For Example)

Name	Pin Type Insulator	Suspension Type Insulator
System Voltage	6.6	6.6
Power-Frequency Withstand Voltage (1 min.) (Wet/kW)	22	24
Impulse Withstand Voltage (kV)	65	75
50% Impulse Flashover Voltage (kV)	80	90
Cantilever Strength (1 min.) (kg)	200	-
Leakage Distance(mm)	140	205
Net Weight (kg)	1.4	2.0
Max. Tensile Strength (kg)	-	1,300

As may be seen from Table 4.5-5 hereinabove, since those insulators have ample tolerance and insulated wires are used, there will be no necessity of using any insulators of special design, or any ones of 11 kV class.

The low voltage pin type insulators and anchor insulators, etc. are to be used for distribution line in this Project.

(3) Design of house wiring

The house wiring of public institutions will be of an open type, and will have junction boxes at branches except those branches for lighting fittings.

The typical examples of indoor wiring are as shown in Figs. 4.5-4 (1) through (4) in Annex-12.

4-6 Basic Design Drawings

Basic design drawings of civil structures and electrical equipment and, facilities designed in accordance with the requirements mentioned hereinbefore in this Chapter 4 are as shown in Annex-12.

(1) Intake dam

As per Fig. 4.6-1-(1) and (2)

(2) Sedimentation basin

As per Fig. 4.6-2

(3) Conduit

As per Fig. 4.6-3

(4) Head tank and outlet

As per Fig. 4.6-4

(5) Penstocks and outlet

As per Fig. 4.6-5-(1) through (10)

(6) Power plant and drain

As per Fig. 4.6-6-(1) through (10)

(7) Post arrangement for transmission line

As per Fig. 4.6-7-(1) and (2)

(8) Post arrangement for distribution line

As per Fig. 4-6-8

4-7 Estimated Project Cost

In implementing this Project, the estimated cost to be borne by the Government of Bhutan are as follows:

(1) Conditions of estimation

(a) Time of estimation: As of April, 1985

(b) Exchange rate: US$1 = ¥250

(c) Construction period: Ten (10) months from the commencement of the construction works

(2) Amount of cost to be borne by the Government of Bhutan

The amount of cost to be borne by the Government of Bhutan is estimated to be 40 million yen.

(a) Acquisition of lands at each proposed site (including compensation for the clearance of interfering and danger trees, etc.) Cost of acquisition of lands: ¥100/m^2 Area of clearance required: 38 km (length) x 10 m (width)	38 million yen
(b) Construction and reinforcement of access roads for the transport of materials and equipment to each site	2 million yen

CHAPTER 5 IMPLEMENTATION PLAN

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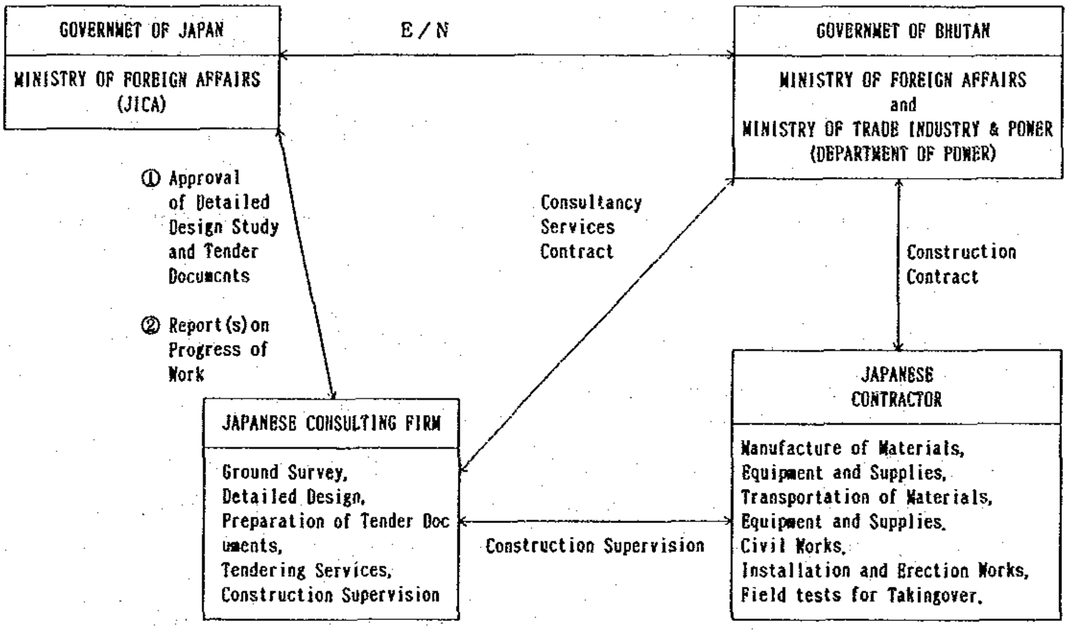
5-1 Implementation Body

(1) Implementing organization

This Project is to be implemented by means of proceeds from Japanese Grant Aid. Fig. 5-1 illustrates the overall relations among the parties concerned with the implementation of the Project.

Fig. 5 – 1 PROJECT IMPLEMENTATION SYSTEMS



(2) Implementing agency of the Government of the Kingdom of Bhutan

In implementing this Project, the Ministry of Foreign Affairs and the Ministry of Trade, Industry and Power will be responsible for liaison with the Government of Japan and taking the necessary procedures. The Ministry of Trade, Industry and Power (the Department of Power) will be held responsible for the detail design and supervisory work of this Project.

5-2 Scope of Work

The scope of work to be performed by the Government of Japan and the Government of Bhutan is as stated hereunder in connection with the implementation of the Project.

(1) Work to be done by the Government of Japan

(a) Supply of materials and equipment as listed in 4-4 and 4-5

(b) Marine and inland transportation to the Project sites of the materials and equipment as stated in (a) above

(c) Civil works (for major facilities) required

(d) Construction of transmission and distribution lines required

(i) Transmission lines up to transformers installed at the receiving ends of load centres

(ii) Distribution lines for public institutions

(e) Installation/erection, field testing and commissioning of generating equipment

(f) Consultancy services related to detailed design, tendering and construction supervision

(2) Work to be done by the Government of Bhutan

(a) Acquisition of land for each proposed site

(b) Compensation for trees and bushes cut and removed in each construction site

(c) Reinforcement (including improvement) of access roads for transport of materials and equipment

The Government of Bhutan is to assume full responsibility for taking the procedures related to customs clearance and tax exemption for import of materials and equipment at the port of disembarkation according to the "Minutes of Discussions".

5-3 Detailed Design and Construction Supervision

The work of the detailed design and construction supervision enumerated below will be performed according to the contract for consultancy services which will be concluded between the Government of Bhutan and a Japanese consulting firm after the approval by the Japanese cabinet of Japanese Grant Aid for the Project following the completion of this basic design study and the signing of the Exchange of Notes (E/N) between both Governments.

5-3-1 Detailed design and tendering

(1) Ground survey

Detailed ground surveys will be conducted on the present condition of the planned places for installation of civil structures and the planned transmission and distribution line routes.

(2) Detailed design and preparation of tender documents

Detailed design will be made in accordance with the results of the ground survey stated in (1) and tender documents in draft form will be prepared for consultation with the Government of Bhutan.

(3) Tender for selection of a contractor and conclusion of a contract

Advertisement for the tendering, receiving of letters for participation in the tender and issuance of the tender documents following the explanations of the tender and tender documents will be performed. After a certain period of time (tender period), evaluation of tender proposals will be made immediately after receipt thereof.

5-3-2 Construction supervision

(1) Supervisory work in Japan

Upon conclusion of a contract with a contractor who is a Japanese juridical person (corporation) the Project implementation is to launch into the stage of construction supervision. The consulting firm will examine and approve manufacture drawings submitted by the contractor for and on behalf of the Department of Power in order to expedite the implementation of the Project. The consulting firm will also attend shop tests of manufactured equipment for and on behalf of the Department of Power.