No. 40

THE PEOPLES REPUBLIC OF BANGLADESH
FEASIBILITY STUDY REPORT
FOR
KAPTAI HYDRO-POWER STATION EXTENSION PROJECT

SEPTEMBER 1980

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the People's Republic of Bangladesh, the Japanese Government decided to conduct a survey on the Kaptai Hydroelectric Power Station Extention Project and entrusted the survey with the Japan International Cooperation Agency. The J.I.C.A. sent to Bangladesh a survey team headed by Mr. Mototsune Iwata from March 1 to 29, 1980.

The team exchanged views with the official concerned of the Government of Bangladesh and conducted a field survey (in the Kaptai area, Chittagon). 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 our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the People's Republic of Bangladesh for their close cooperation extended to the team.

September 30, 1980

Keisuke Arita
President
Japan International Cooperation Agency

C O N T E N T S

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1-1 Background and Purpose of Study

This study has been executed as a feasibility study for the Kaptai Hydro-Power Station Extension Project on the Karnafuli River in the People's Republic of Bangladesh.

This is an extension project of the existing Kaptai Hydro-Power Station (Output: 130 MW) by installing further turbine-generator units. The first feasibility study for this project was carried out in 1969 by Overseas Technical Cooperation Agency (OTCA, the present JICA, Japan International Cooperation Agency).

As a result, it was recommended to install 50 MW x two turbine-generator units.

In 1978, the Government of the People's Republic of Bangladesh requested the Government of Japan to newly review this extension project under the present conditions.

This study has been executed on the basis of the above request.

1-2 Scope of Study

This study was carried out in regard to the following subjects based on the data collected through investigations executed on March 1980.

(1) Hydrologic analysis on available reservoir capacity

(2) Power demand forecast

(3) Power supply area from the hydro-power station

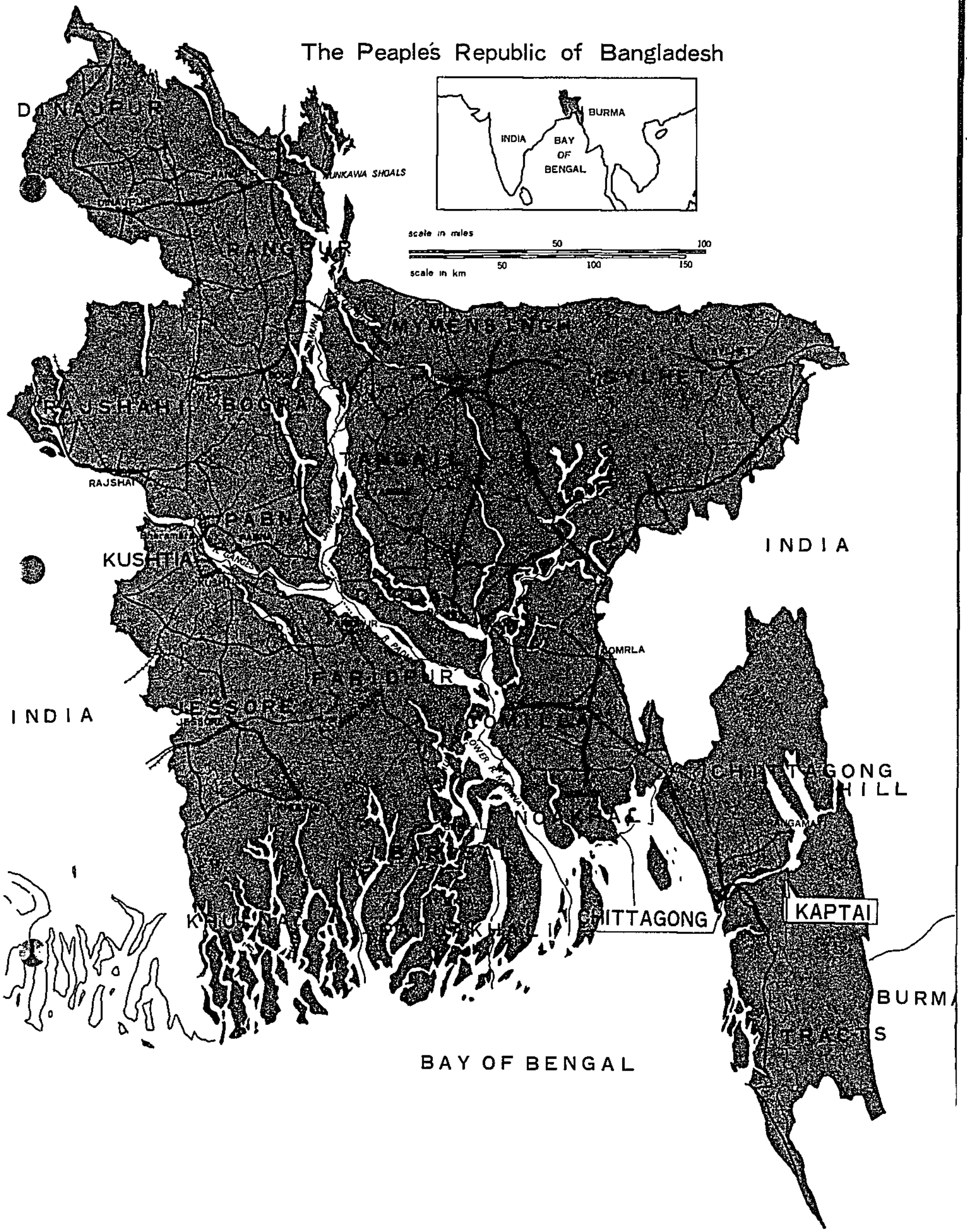
(4) Optimum operation method of the reservoir

(5) Preliminary design of structures

(6) Approximation of construction cost

(7) Outline construction schedule

(8) Economic and financial analysis



The Peaple's Republic of Bangladesh
INDIA
BURMA
BAY OF BENGAL
scale in miles
50
100
scale in km
50
100
150
DINAJPUR
MUNKAWA SHOALS
RANGPUR
MYMENSINGH
SYLHET
RAJSHAHI
BOGRA
TANGAIL
RAJSHAHI
PABNA
KUSHTIA
GANGES
INDIA
COMILLA
FARIDPUR
JESSORE
INDIA
COMILLA
LOWER MEGHNA
NOAKHALI
CHITTAGONG HILL TRACTS
KAPTAI
CHITTAGONG
BURMA
BAY OF BENGAL

1-3 Outline of Study

For this study, local survey including field reconnaissance, data collection, etc. was carried out by the survey team consisting of four members headed by Mototsune Iwata (Tokyo Electric Power Services Co., Ltd.) for twenty-nine days from March 1, 1980. Upon their return to Japan, studies and analysis on the basis of collected data were carried out and the development plan for this project has been worked out.

The survey team again visited the country for ten days from August 18, 1980 and coordinated opinions on the contents of study with the Bangladesh Power Development Board (B.P.D.B.).

1-4 Outline of the Project

Construction of the Kaptai Hydro-Power Station was commenced in 1952, and the Units 1 and 2 were put to operation in 1962. Since then, the power station has been in operation as one of the most important power sources and only one hydro-power station in the People's Republic of Bangladesh (Unit 3 is now under installation).

The power station is located about 65 km upstream on the Karnafuli River from Chittagong, a city of international port and industry in south-eastern part of the country with a population of about 400,000.

The present output of the Kaptai Hydro-Power Station including that of Unit 3 now under installation is 130 MW, and the dimensions of the existing facilities are as follows:

Reservoir:

Catchment area:	11,000 km^2 (2,718.2 x 10^3 acres)
Reservoir area:	750 km^2 (185.2 x 10^3 acres)
Reservoir capacity:	6,470 x 10^6 m^3 (5,235 x 10^3 acre-ft.)
Highest water level:	118 ft.

Dam:

Type:	Uniform earth dam
Height:	About 46 m (150 ft.)
Crest length:	About 670 m (2,200 ft.)

Elevation of crest:	El. 127 ft.
Effective depth:	About 12 m (38 ft.)
Spillway capacity:	16,000 m^3/sec. (562 x 10^3 cu.ft./sec.)

Power plant:

Type:	Kaplan type
Output:	
Unit 1:	40,000 kW
Unit 2:	40,000 kW
Unit 3:	50,000 kW
Total	130,000 kW

This project is intended to extend an additional capacity of 100 MW through effective use of immense water source of the Kaptai Reservoir.

1-5 Organization of Survey Team

The members of the survey team are as follows:

Team Leader	Mototsune Iwata	Tokyo Electric Power Services Co., Ltd. (TEPSCO)
Coordinator	Masaru Tateishi	Japan International Cooperation Agency (JICA)
Civil Engineer	Konomu Nakano	TEPSCO
Economist	Toshiyuki Ouchida	TEPSCO
Electrical Engineer	Takahisa Murata	TEPSCO

Site survey was carried out by the following four members headed by Dr. Iwata according to the assignments in Table 1.1.

Table 1.1 Assignment of Site Survey

Assignment	Nane	Contents of Assignment
Superintendent, Civil Engineering	Mototsune Iwata	Superintendent of survey team: Reconnaissance of reservoir,dam, power station,etc: Survey and study on hydrology, water utilization, flood control, structures, etc.
Civil Engineering	Konomu Nakano	Reconnaissance and tests on reservoir,dam,power station, transmission facilities,etc.: Survey and data collection on hydrology,water utilization, flood control,operation recrds, existing structures, etc.
Economy	Toshiyuki Ouchida	Survey of economic trend such as price, productivity,etc.: Survey on the cost of associated materials and data collection pertaining to forecast in future.
Electrical Engineering	Takahisa Murata	Reconnaissance of transmission and substation facilities.: Survey on the past operation records,electric power damand and supply,transmission and substaion system,and data collection pertaining to forecast in future.

CHAPTER 2

CONCLUSION

CHAPTER 2 CONCLUSION

2-1 Scale and Location of the Project

According to the feasibility study executed by the Overseas Technical Cooperation Agency (OTCA) in 1969, it was clarified feasible to install further two 50 MW units, and this study has been carried out to review the feasibility study of OTCA under the present conditions.

In this study, it has been judged desirable to construct two 50 MW units (100 MW) in scale as indicated in the OTCA's feasibility study report in 1969.

As a result of this study, the place about 150 m upstream from the existing power station is considered suitable in view of execution of the work. The economically optimum type of turbines has been judged to be the Kaplan type in view of head, output and other characteristics.

Incidentally, it has been clarified that the time is not mature to adopt pumped storage units for the extension project judging from the power demand situations in the supply area (For further detail, refer to the attached data).

2-2 Electric Power Demand Forecast

Electric power demand forecast throughout the country and in Chittagong area was carried out on a long term basis from 1980 to 2000.

The nationwide electric power demand forecast was obtained by analyzing the correlation between per capita GNP and electric power demand. The electric power demand forecast in Chittagong area was performed by analyzing the various factors in each sector.

The growth rate of electric power demand in Chittagong area is higher than the nationwide growth rate, and this fact represents that electric power demand in Chittagong area where power is supplied by Kaptai Hydro-Power Station, is vigorous.

Table 2.1 Values of Electric Power Demand Forecast

Years	1986/87		1993/94		1999/2000	
	(MW)	(GWh)	(MW)	(GWh)	(MW)	(GWh)
Nationwide	1,313	6,558	2,553	12,748	4,175	20,849
Chittagong Area	268	1,453	509	2,807	884	4,881

Note: Refer to Fig. 4.2 Nationwide Electric Power Demand Forecast and Fig. 5.1 Maximum Demand and Available Capacity in Chittagong area.

2-3 Supply Area

It is justifiable to supply electric power generated under this project to Chittagong area, the specified industrial development area locating close to the project site.

After this project has been implemented, the existing transmission lines will become insufficient in capacity. In addition, the existing transmission towers fell down at the time of flood. Therefore, two circuits lines are to be constructed along the Hatazalia-Rangamati Road, an entirely different route.

The terminal of the transmission lines is Baraulia.

2-4 Power Station Operation Plan

2-4-1 Operation of Power Station

It is reasonable to operate this power station on the basis of the curves indicated in Fig. 5.2 in view of the daily load curves assumed up to 2000 in the Chittagong area (Refer to Fig. 5.2 Daily Load Curve in Chittagong Area).

2-4-2 Reservoir Operation

(1) Reservoir Capacity

The capacity of the Kaptai Reservoir prepared in 1968 as indicated in the water level and capacity curve in Fig. 5.3, has been analyzed according to the following factors.

(a) Water surface area in LANDSAT photographs

(b) Past operation records of the power station

The reservoir capacity obtained in either case indicated slightly larger values than those in the map of 1968.
The reservoir capacity in the map of 1968 was adopted for this project because of its safety (Refer to Fig. 5.3 Area and Capacity Curve of Kaptai Reservoir and Table 5.1 Comparison of Surface Area).

(2) Rule Curve for Reservoir Operation

The present rule curves for the Kaptai Reservoir are effective only for Units 1 and 2. Therefore, a new rule curve applicable to the extension project has been prepared.

Since the effective discharge is to increase to about three times the present value (Units 1 and 2) after extension, the new rule curve and the rules for reservoir operation have been prepared in order to realize effective utilization of discharge (Refer to Fig. 5.9 Chronological Graph of Water Level Based on New Rule Curve).

(3) Yearly Generated Energy

The yearly generated energy has been studied in respect to the following three cases:

(a) In case the existing power station (three units) is operated on the basis of the present rule curve;

(b) In case the station after extension (five units) is operated on the basis of the new rule curve; and

(c) In case the existing power station (three units) is operated on the basis of the new rule curve.

The yearly generated energy in (b) becomes about 50% and 20% larger than that in (a) and (c), respectively.

[Yearly generated energy]

(a) In case three units are operated according to the present rule curve:

711.1×10^6 kWh

(b) In case five units are operated according to the new rule curve:

$1,088.9 \times 10^6$ kWh

(c) In case three units are operated according to the new rule curve:

878.0×10^6 kWh

2-5 Construction Schedule and Project Execution System

2-5-1 Construction Schedule

In view of the fact that this extension project is required to be completed in 1985 according to the electric power demand forecast, the construction schedule has been prepared in case Units 4 and 5 are to be put to operation on June 1985 and December 1985, respectively.

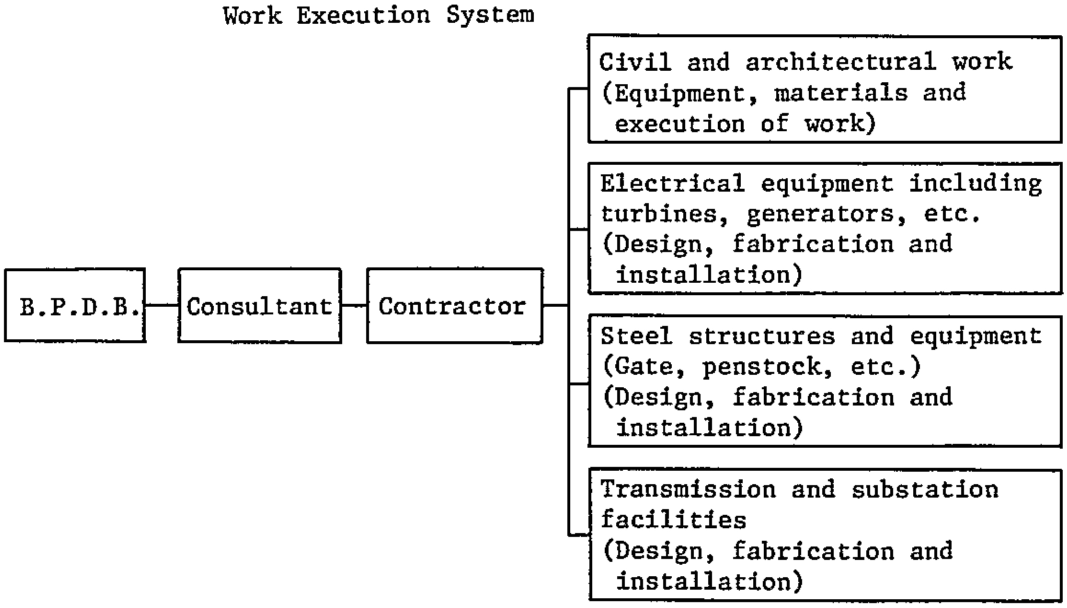
Period from preparation to commencement of construction work:	About 14 months
Period of construction:	About 45 months

(Refer to Fig. 6.6 Tentative Construction Time Schedule.)

2-5-2 Project Execution System

The extension work is to be executed according to the following organization.

Work Execution System



2-6 Required Investment

Table 2.2 Required Investment

(Unit: 10^6)

Items	Foreign currency		Local currency (TK)	Total (TK)
	¥	(TK)		
Direct cost	9,975	(750.0)	282.0	1,032.0
Indirect cost	945	(71.1)	19.0	90.1
Contingency (Escalation)	224	(16.8)	11.0	27.8
Contingency (physical)	1,071	(80.5)	34.5	115.0
Interest during construction period	0	(0)	66.8	66.8
Total	12,215	(918.4)	413.3	1,331.7

(Foreign exchange rate: 1 TK=¥13.3)

〔Conditions for calculation:〕

Import tax:	2.5% of CIF cost
Unloading and warehouse charges and inland transportation cost:	3% of CIF cost
Field establishment:	3% of direct cost in local currency portion
General administration cost:	6% of direct cost in local currency portion
Contingency (escalation)	9% per year after 1984/85
Contingency (physical)	10% of direct cost plus indirect cost
Interest during construction work:	5% per year per 50% of total construction cost

2-7 Economic Evaluation

2-7-1 Comparison with Alternative Plan

As an alternative plan for this project, a 100 MW natural gas firing steam power plant is assumed to be constructed in the outskirts of Chittagong, and comparison with this alternative plan has been made according to the least cost method.

As a result of comparing the cost including running cost of the hydro-power station and the alternative steam power plant up to 2000 by using the least cost method, the following ratio has been obtained:

In case of 10% discount rate:

$$\frac{\text{Cost of alternative steam power plant}}{\text{Cost of Kaptai Hydro-Power Station}} = 1.46$$

In case of 15% discount rate:

$$\frac{\text{Cost of alternative steam power plant}}{\text{Cost of Kaptai Hydro-Power Station}} = 1.29$$

Consequently, it has been made clear that this extension project is advantageous in the respective cases where the discount rate is 10% and 15%.

Other advantages in the hydro-power plant over the steam power plant are:

(a) Troubles occur more frequently in steam power plant than hydro-power plant. Should a steam power plant be shut down, excessive amount of fuel has to be spent to start up the shutdown plant.

(b) Maintenance of a hydro-power plant is easier than that of a steam power plant.

(c) Invaluable escalation of natural gas price in the future results in serious effect upon operation and maintenance of a steam power plant. On the other hand, a hydro-power plant is not so seriously subject to inflation as in the case of a steam power plant.

2-7-2 Financial Analysis

The difference between the energy generated by Units 1 through 5 and Units 1, 2 and 3 according to the new rule curve is the benefit through extension of Units 4 and 5. In this case, the average rate of sold energy is 100 paisa/kWh. When the internal rate of return is calculated on the assumption that the cost is fixed at the 1985/86 level;

$$IRR = 5.37\%$$

The B/C ratio is 0.39 in case of 15% discount rate.

2-7-3 Other Benefits

Other benefits by implementing this project include saving of fossil fuel, stable supply of quality electric power to the Chittagong area.

Moreover, implementation of this project provides opportunity for executing maintenance and inspection of Units 1, 2 and 3 thereby contributing to minimize occurrence of troubles in the entire power station.

2-8 Conclusion

This project has been concluded to be sufficiently feasible technically and economically.

CHAPTER 3

PRESENT ELECTRIC POWER SITUATION

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3-1 Outline

The electric power systems of the People's Republic of Bangladesh are roughly divided into the eastern grid and the western grid by the Brahmaputra-Jamuna River running across the central part of the country in the south-northern direction. At present, the above grids are not interconnected by transmission lines.

The present electric power system of the country consists of 132 kV and 66 kV main trunk line systems, as well as 33 kV and 11 kV distribution line systems.

Speaking of the power sources, the land form throughout the country is entirely flat thereby resulting in poor hydro-electric power source. Kaptai Hydro-Power Station locating on the Chittagong hill tracts is only one hydro-power station in the country. All others are thermal power plants. Although no petroleum is produced in the country, natural gas is fortunately produced in the eastern zone, and this natural gas is used as fuel for almost all steam power and gas turbine power plants in this zone. In contrast, imported oil is used for steam power plants, gas turbine and diesel engine power plants in the western zone.

This difference in energy source situations exerts a direct effect upon the cost of power generation. Namely, the power generation cost per kWh is 58 paisa (1 TK = 100 paisa) in the eastern zone while the cost is as high as 185 paisa in the western zone. However, the B.P.D.B. is adopting uniform energy rate system throughout the country.

When compared to the scale of population of 85 million, electric energy generated annually is extremely as small as 2.1 billion kWh because of less developed industries and low electrification ratio. Therefore, the country has worked out a policy calling for the development of industries and electrification in the rural areas. The electric power demand in the country willing to attain economic independence and welfare of the people is considered to increase rapidly.

On the other hand, skyrocketing price of crude oil and shortage of capital are working as a factor decelerating the investment in the extension of the electric power facilities. Under these situations, the country is directing enormous efforts to increase production of natural gas and discovery of further natural gas deposits. At the same time, the country is earnestly tackling with various problems in order to reduce excessive electric power loss (34%).

3-2 Power Generation Facilities

Table 3.1 shows the present electric power facilities in the People's Republic of Bangladesh. Although the total rated output is 748 MW, the available capacity is 661 MW, a value considerably smaller than the rated output, owing to troubles and superannuation. Particularly in the event of troubles in thermal power stations, the stations have had, in many cases, to be shut down for a long period of time due to shortage of replacement parts.

As is clear from Table 3.1, only diesel engine power plant is the common type of facility to the eastern and western zones in terms of type of driving mechanism and energy source, and any other common factor cannot be observed in the two zones. This difference is largely attributable to the difference of generating cost. At present, the 230 kV transmission line connecting the eastern and western zones is under construction. After its completion in 1981/82, it will become possible to transmit low cost electric power from the eastern zone to the western zone, thereby contributing to reducing the power generation cost as a whole.

One of the most significant features of the eastern zone is that there is a hydro-power station. Therefore, though power output is sometimes depressed in dry season, the power station is continuously in stable operation in other seasons, and it has rarely been shut down of its own failure. However, the generators have frequently been shut down due to the action of frequency relay because of

Table 3.1 Existing Electric Power Facilities in Bangladesh

(Unit: MW)

Items		Hydro-power	Thermal power plants						Total
			Steam power plants		Internal combustion engine power plants				
			Oil	Natural gas	Gas turbines			Diesel engines	
					Gas	Napththa	Diesel oil		
1.Rated output (MW)	Eastern zone	80		318	108			20	526
	Western zone		77			7	70	68	222
	Total	80	77	318	108	7	70	88	748
2.Available output (MW)	Eastern zone	92		312	70			9	483
	Western zone		68			5	70	35	178
	Total	92	68	312	70	5	70	44	661

frequency drop in the entire system at the time of emergency shutdown of thermal power stations. Nevertheless, this hydro-power station is highly evaluated as a stable power source.

3-3 Transmission and Distribution Facilities

The electric power system of the People's Republic of Bangladesh is as shown in Fig. 3.1.

The distance and number of circuits of the transmission lines are as follows:

Voltage (kV)	No. of circuits	Route Distance (km)
132	2	485
132	1	852
66	1	165
33		4,650

In addition, 11 kV and 0.4 kV distribution lines extend over a distance of 12,700 km.

There are thirty 132 kV class substations and about two-hundred and ten 33 kV substations throughout the country.

3-4 Power Demand and Loss

Electric power consumption throughout the country was 1,381 x 10^6 kWh in 1978/79, about 70% of which was consumed in three cities of Dacca, Chittagong and Khulna. At present, the distribution facilities in the three cities are under overload condition. Therefore, these cities have been subject to many times of power cut every evening. Practically, the distribution networks have not been replenished systematically since the independence. Thus, consumers have encountered a number of damages due to power failure and cut.

Now, replenishment projects for the distribution networks are under way by overseas assistance in the three cities, behind earnest desires of consumers for completion scheduled in 1982 through 1984.

The number of consumers throughout the country is as small as 450,000 and per capita electric power consumption is also as low as 12.4 kWh a year largely due to high rate of non-electrified areas.

Power loss of as high as 34% as above-mentioned is considered to arise mainly due to the following reasons:

- Uneconomical operation under low load factor
- Theft
- Inaccurate wattmeters
- Free supply to B.P.D.B.'s employees
- Overload in distribution networks
- Long distance power transmission to farming areas.

The B.P.D.B. is directing its utmost efforts to reduce power loss to 20% in 1988 - 1989.

3-5 Power Rate

Because of serious management conditions, raising of energy charge has been a pending matter for the B.P.D.B. for the past several years. However, the B.P.D.B. refrained from raising the rate in consideration of the industrial development and improvement of welfare of the people, a national policy of the country. However, in view of the fact that the B.P.D.B. experienced a deficit of 320 million TK in 1977/78, the government accepted the application for raising the rate and unavoidably approved the new rate to some extent on September 1979, provided that the B.P.D.B. will make efforts to reduce the power loss. Under these circumstances, the B.P.D.B. seems to be worrying about whether it is possible or not to secure sufficient profit for investment for the future development because of raise of labor cost and market prices including oil price. Thus, further about 50% increase of power rates is expected to be realized.

3-6 Load Dispatching Facilities

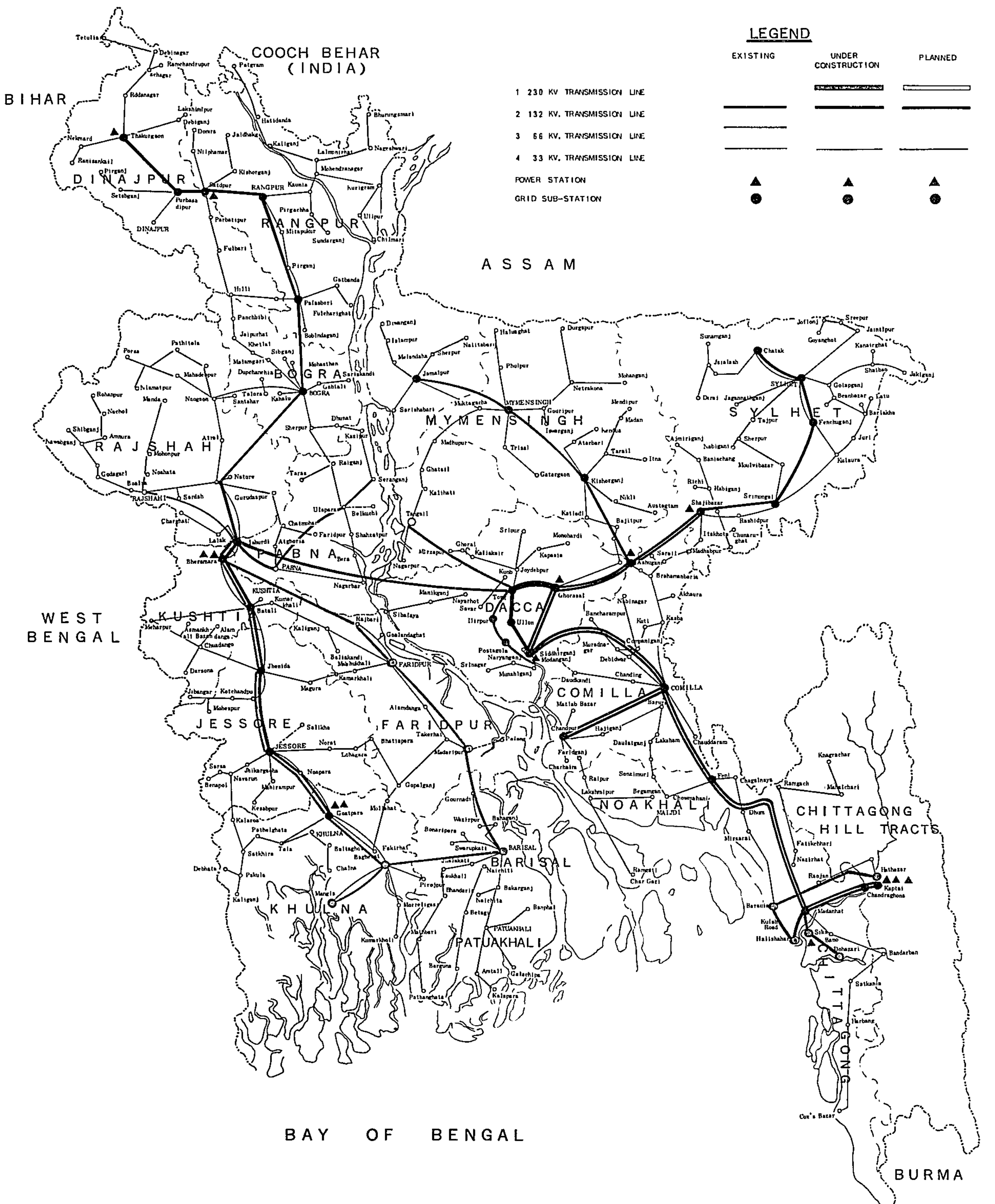
As described previously, the electric power systems of the country are divided into the eastern grid and the western grid, and the load dispatching facilities are also operated independently in both zones.

The load dispatching center for the eastern grid locating in the premise of the Siddhirganji Power Station about 40 km east from Dacca is furnished with simple system boards. The load dispatching center is not furnished with supervisory devices for indicating switching operation of circuit breakers from the respective power stations and telemeters for indicating measurement. The center is entirely operated only by means of power line carrier telephone system.

The load dispatching center for the western grid is located in the premise of Goalpara Power Station and is operated similarly as in the case of the center for the eastern grid.

An overall load dispatching center for controlling the nationwide power systems including the eastern and western grids is now under construction in the premise of the Siddhirganji Power Station adjacent to the existing load dispatching center scheduled for completion in late 1981 under economic assistance from Canada.

Fig.3.1 POWER PROJECTS OF POWER DEVELOPMENT BOARD BANGLADESH



CHAPTER 4

ELECTRIC POWER DEMAND FORECAST

CHAPTER 4 ELECTRIC POWER DEMAND FORECAST

4-1 Demand Forecast throughout the Country

4-1-1 Past Record of Electric Power Demand

The maximum electric power supplied throughout the country, in the eastern and western zones from 1970 are as shown in Table 4.1. The annual average growth rate of electric power demand for the recent six years is as high as 12% throughout the country, and 11.2% in the eastern zone. However, growth in 1978/79 ended in a growth rate of 10% to the previous year.

This is attributable to the fact that the supply did not meet by far the enormous demand of electric power and any positive sales were not promoted while restricting new demand and controlling the load.

Table 4.1 Maximum Electric Power Demand throughout the Country, in Eastern and Western Zones

Year	Maximum electric power supplied (MW)		
	Eastern zone	Western zone	Nationwide
1970/71	171.668	53.002	224.690
1971/72	140.589	42.172	182.761
1972/73	174.395	47.179	221.574
1973/74	184.845	65.262	250.107
1974/75	198.762	67.257	266.019
1975/76	219.917	81.417	301.334
1976/77	253.995	88.303	341.998
1977/78	284.561	108.638	395.961
1978/79	331.318	105.210	436.528
Annual average growth rate for eight years	8.5%	9.0%	8.6%
Annual average growth rate for recent six years	11.2%	14.3%	12.0%

Source: Annual Report for 1977-78 issued by B.P.D.B.

4-1-2 Short-term Demand Forecast by Bangladesh Authorities

The B.P.D.B. is executing power demand forecast together with the Planning Commission while placing emphasis on preferential execution of electrification in rural areas as well as sufficient power supply to industrial and city areas. Though any conclusion of this study has not been obtained, the B.P.D.B. and the Planning Commission are adopting the values described in Table 4.2 as preliminary data.

According to the above data, the B.P.D.B. estimates the annual average growth rate of 21% throughout the country while the Planning Commission estimates the nationwide annual average growth rate of 15%. In any case, there is unmistakably very high rate of potential growth.

4-1-3 Demand Forecast by the Survey Team

The survey team executed electric power demand forecast up to 2000 on the basis of long term outlook. In this case, a so-called Aoki Method where the values of demand are assumed according to per capita GNP is adopted. GNP, population, per capita GNP and the maximum electric power supplied,peak load from 1972/73 to 1978/79 are as shown in Table 4.3.

Table 4.3 Maximum Electric Power Supplied and Per Capita GNP

Years	72/73	73/74	74/75	75/76	76/77	77/78	78/79
GNP (1 million TK)	44,417	49,225	51,657	54,734	56,477	61,188	64,073
Population (1 million)	74.3	76.4	78.0	79.9	81.8	83.7	85.6
Per Capita GNP (TK)	598	644	662	695	690	731	748
Maximum electric power supplied (MW)	222	250	266	301	342	396	437

When per capita GNP is given on the abscissa axis and the maximum electric power supplied, on the axis of ordinate, a linear correlation, though it is uneven to some extent, can be obtained as shown in Fig. 4.1

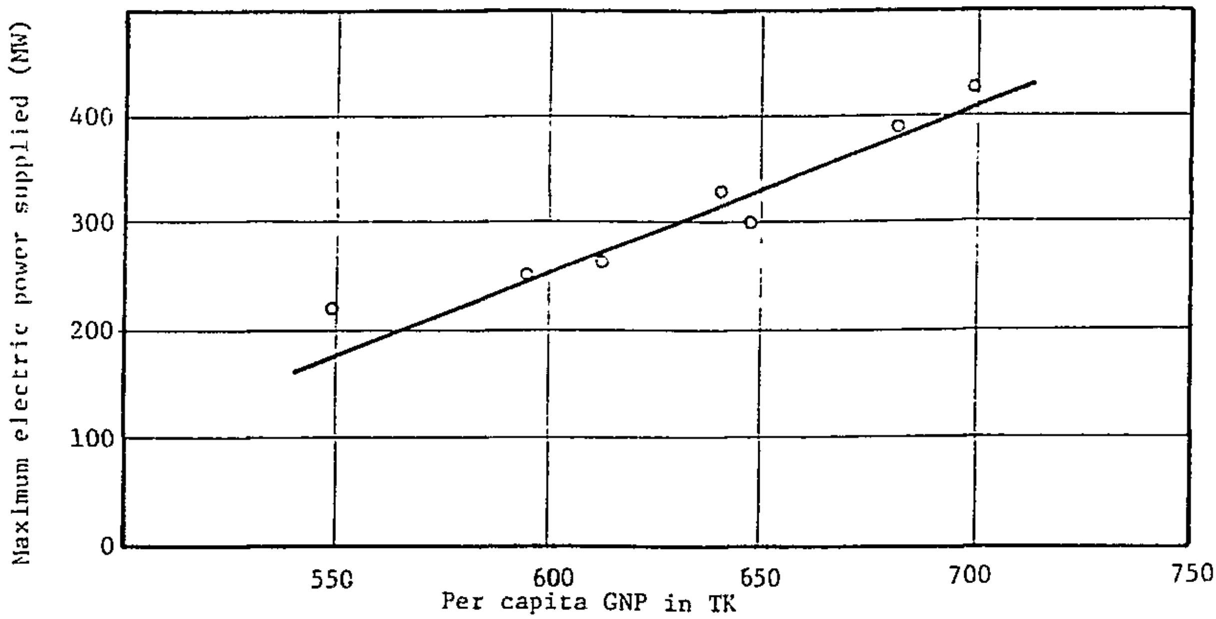
Table 4.2 Preliminary Demand Forecast by Bangladesh Authorities

* Demand forecast by B.P.D.B.					Year	** Demand forecast by Planning Commission				
System classification			Under control of			System classification			Under control of	
Eastern zone	Western zone	Nation-wide	B.P.D.B.	REB		Eastern zone	Western zone	Nation-wide	B.P.D.B.	REB
287	111	398	-	-	1977-78					
319	129	448	426	22	1978-79	331	105	436	436	-
354	150	504	479	25	1979-80	359	127	486	477	9
395	189	584	539	45	1980-81	392	150	542	525	17
450	229	679	606	73	1981-82	438	181	619	588	31
529	291	820	682	138	1982-83	493	225	718	658	60
691	438	1,129	769	360	1983-84	564	285	849	737	112
875	607	1,482	868	614	1984-85	663	372	1,035	825	210
		1,712	953	759	1985-86	742	417	1,159		
		1,909	1,048	861	1986-87	831	467	1,298		
		2,093	1,153	940	1987-88	931	523	1,454		
		2,285	1,268	1,017	1988-89					
		2,485	1,395	1,095	1989-90					

Sources: * "Second Five Year Plan" issued by B.P.D.B.

** "The Second Five Year Plan 1980-1985" issued by the Planning Commission.

Fig. 4.1 Relation between per Capita GNP and Maximum Electric Power Supplied (peak demand)



In this way, the survey team assumed the maximum demand in the future based upon the per capita GNP. The demand forecast has been performed by calculating the per capita GNP on the basis of estimated population according to "Monthly Statistical Bulletin of Bangladesh, October 1979" and on the assumption that the annual average growth rate of GNP up to 2000 is 5.6%, 6.8% and 8%. The maximum power demand obtained according to this demand forecast is as shown in Table 4.4. The power demand calculated on the basis of 57% power factor is also indicated in Table 4.4. In Fig. 4.2, the values estimated both by the Bangladesh authorities and the survey team are plotted. As is clear from Table 4.4 and Fig. 4.2, the values estimated by the Planning Commission and the survey team on the basis of annual GNP growth rate of 8% coincide roughly with each other.

The average annual growth rate of GNP for the past seven years is 6.5%. This growth rate was achieved under somewhat instable conditions right after independence. The government is earnestly willing to attain rapid economic development. Therefore, the government drastically changed the policy of a socialistic economic system into a policy for encouraging private capital, thereby aiming at establishing an economic structure to encourage investment in the private sector. Thus, the government plans to realize reconstruction of its economy by improving the capability for procuring domestic capital in addition to economic assistance from foreign countries.

As can be observed in many cases in developing countries, it is reasonable to expect an economic growth rate of 8% judging from the past rate of 6.5%. Therefore, the growth rate of the country is preferably 8%.

Consequently, the maximum power demand calculated on the basis of an annual GNP growth rate of 8% has been adopted in this study report.

4-2 Demand Forecast in Chittagong Area

4-2-1 Introduction

The Chittagong area is only one hill area in the People's Republic of Bangladesh. At the mouth of the Karnafuli River, there is the Chittagong Port, the largest port in the country. In the adjacent areas, there are steel mills, cement plants, petroleum refinery and other industrial plants. The government intends to make it to be a further larger industrial zone in the country by expanding the existing industrial plants and newly constructing free trade zone, dry dock, electrical appliance assembly plants and others. In addition, the government is planning to establish a light industrial zone mainly for jute and textile along the national road to Dacca. At present, about 80% of electric power is consumed by various industries in this are, and this trend is considered to be kept in the future.

Therefore, sufficient and stable supply of electric power to this area will largely contribute to the economic development of the country.

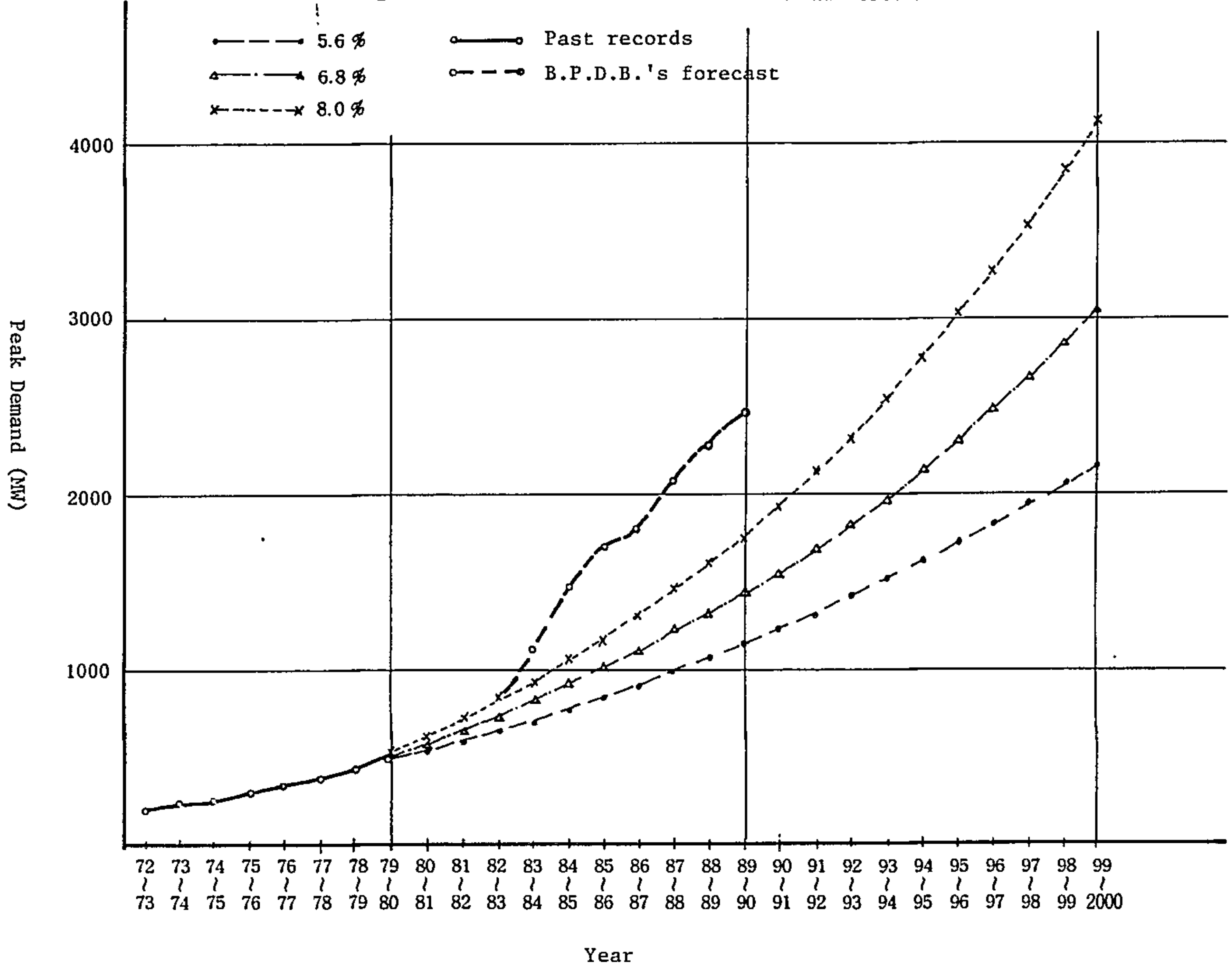
In addition, there is an irrigation project extending to 32,000 acres making use of the Halda River, a tributary of the Karnafuli River, through the assistance of the World Bank. For this project, electric power will also play a significant role.

The B.P.D.B. is steadily implementing establishment of a transmission loop around the city to replenish and extend the distribution network in the area under "Greater Chittagong Distribution Project."

Table 4.4 Nationwide Electric Power Demand Forecast

Years	Population (10^6)	GNP(10^9 TK)			Per capita GNP(TK)			Peak demand(MW)			Energy Demand (GWh)		
		5.6 %	6.8 %	8.0 %	5.6%	6.8%	8.0%	5.6%	6.8%	8.0%	5.6 %	6.8 %	8.0 %
79 - 80	88.6	67.7	68.4	69.2	764	772	781	491	507	526	2450	2534	2628
80 - 81	90.6	71.5	73.1	74.7	789	807	825	543	581	619	2712	2901	3089
81 - 82	92.6	75.5	78.1	80.7	815	843	871	598	656	715	2984	3278	3571
82 - 83	94.6	79.7	83.4	87.2	842	882	922	654	738	822	3267	3687	4106
83 - 84	96.7	84.1	89.0	94.1	870	920	973	713	818	929	3561	4085	4640
84 - 85	98.1	88.9	95.1	101.7	906	969	1037	789	921	1064	3938	4598	5311
85 - 86	100.6	93.8	101.5	109.8	932	1009	1091	843	1005	1177	4211	5018	5877
86 - 87	102.6	99.1	108.5	118.6	966	1058	1156	914	1107	1313	4366	5526	6558
87 - 88	104.5	104.6	115.8	128.1	1001	1108	1226	988	1213	1460	4933	6057	7290
88 - 89	106.5	110.5	123.7	138.3	1038	1162	1299	1065	1325	1613	5317	6616	8053
89 - 90	108.5	116.7	132.1	149.4	1076	1218	1377	1145	1443	1777	5715	7203	8874
90 - 91	110.5	123.2	141.1	161.3	1115	1277	1460	1227	1567	1951	6129	7826	9742
91 - 92	112.4	130.1	150.7	174.2	1157	1341	1550	1317	1701	2140	6574	8495	10686
92 - 93	114.4	137.4	160.9	188.2	1201	1406	1645	1408	1839	2340	7030	9183	11684
93 - 94	116.4	145.1	171.9	203.3	1247	1477	1747	1504	1987	2553	7507	9921	12748
94 - 95	118.3	153.2	183.6	219.5	1295	1552	1855	1605	2145	2782	8015	10709	13889
95 - 96	120.2	161.8	196.1	237.1	1346	1631	1973	1712	2311	3027	8551	11541	15116
96 - 97	122.0	170.9	209.4	256.0	1401	1716	2098	1827	2490	3291	9124	12432	16435
97 - 98	124.0	180.4	223.6	276.5	1455	1803	2230	1941	2672	2567	9690	13342	17813
98 - 99	126.0	190.5	238.8	298.6	1512	1895	2370	2060	2865	3861	10288	14306	19280
99 -2000	128.0	201.2	255.1	322.5	1572	1993	2520	2186	3070	4175	10917	15330	20849

Fig 4.2 Nationwide Electric Power Demand Forecast



4-2-2 Industrial and Bulky Load

About 80% of the electric energy in the Chittagong area is consumed by the industrial consumers. Therefore, the demand forecast has been carried out by focusing attention to the industrial consumers since these consumers constitute a decisive factor in establishing the demand forecast. As summarized in Table 4.5, B.P.D.B. gathered information of power demand up to 2000 from bulk industrial consumers by questionnaire method in connection with the Greater Chittagong Distribution Project. Bulky consumers other than industrial consumers are commercial and public facilities. Total consumption of industrial and bulky consumers increased from 186 GWh in 1977/78 by nearly 24% to 232 GWh in 1978/79. However, since the annual average growth rate in the past two years is slightly less than 21%, the survey team has established the annual growth rate for each year as shown in Table 4.6. Though the values of demand forecast made by the team become increasingly different year by year from those of B.P.D.B., the team intends to adopt the annual growth rate prepared by the team from an overall point of view taking into account the fact that there were some consumers who did not answer to the questionnaire and there will be those who will establish industrial plants newly in the area.

4-2-3 Agricultural Load

According to the irrigation project by making use of the Halda River, 450 sets of 15 to 20 kW pumps are scheduled to be installed. Assuming that these pumps are put into operation from 1982/83, demand forecast in the agricultural sector for each year has been made as shown in Table 4.6.

4-2-4 Small Lot Consumers

Small lot consumers include domestic, commercial and light industries, and street lighting. The power demand in this area where is developing at a high tempo showed a growth rate of 17% in 1978/79 over the previous year. Although the average growth rate of power demand before 1978/79 was 20%, the team has established the yearly growth rate as shown in Table 4.6. Though the growth rate is very high, the rate can be appropriate for Chittagong area, being in the course of development.

Table 4.5 Maximum Power Demand for Bulk Industrial Consumers in Chittagong Area

(Unit: kVA)

Industries	1979	1980	1985	1990	2000
Jute	8,300	8,400	8,500	8,700	12,400
Textile	15,250	15,295	15,470	15,470	15,520
Chemical	9,645	10,125	10,775	10,995	11,475
Steel	22,740	24,710	47,200	48,300	53,900
Cement	3,125	3,125	3,125	3,125	3,125
Machinery and Shipbuilding	2,150	5,750	16,500	21,000	23,200
Public Service	3,200	3,900	5,500	32,000	94,000
Other Industries	23,316	45,389	26,490	27,776	24,678
Total	87,726	95,669	133,560	164,241	238,248

Electrification of rural areas constitutes one of the most important policy for the country, and more than half the rural area around Chittagong has not yet been electrified. The electric power demand in the rural area was forecast by multiplying the total power demand in rural areas in the country by the ratio of the number of tanas in Chittagong area to the number of those throughout the country. As shown in Table 4.6, the demand in this area is assumed to grow at an annual rate of 4% after 1990.

Table 4.6 Electric Power Demand Forecast in Chittagong Area

Year	Small consumers		REB		Irrigation		Bulk consumers		* Total		
	Ratio to previous year	Electric energy (GWh)	Electric power (MW)	Electric energy (GWh)	Electric power (MW)	Electric energy (GWh)	Ratio to previous year	Electric energy (GWh)	Ratio to previous year	Maximum demand (MW)	Electric energy (GWh)
1977-78		49						186		60	313
1978-79	1.17	57					1.24	232	1.21	72	378
1979-80	1.20	68					1.20	278	1.10	85	447
1980-81	1.20	82	1.5	4			1.19	331	1.20	101	538
1981-82	1.20	98	3.2	8			1.18	391	1.17	118	632
1982-83	1.17	115	10.2	26	8	42	1.17	457	1.29	152	813
1983-84	1.17	135	26.6	68	8	42	1.16	531	1.21	183	980
1984-85	1.17	157	45.4	131	9	47	1.15	610	1.20	221	1,180
1985-86	1.17	184	56.3	163	9	47	1.14	696	1.14	247	1,342
1986-87	1.17	216	63.8	184	10	47	1.13	786	1.08	268	1,453
1987-88	1.14	246	69.6	201	10	53	1.12	880	1.12	299	1,625
1988-89	1.14	280	75.4	218	10	53	1.11	977	1.11	331	1,799
1989-90	1.14	319	81.1	234	10	53	1.10	1,075	1.10	364	1,979
1990-91	1.14	364	84.3	244	10	53	1.09	1,172	1.09	391	2,158
1991-92	1.14	415	87.8	254	10	53	1.09	1,277	1.09	426	2,353
1992-93	1.14	473	91.2	264	10	53	1.09	1,392	1.09	466	2,570
1993-94	1.14	539	94.9	274	10	53	1.09	1,517	1.09	509	2,807
1994-95	1.14	615	98.7	285	10	53	1.09	1,654	1.09	557	3,072
1995-96	1.14	701	102.6	297	10	53	1.09	1,803	1.10	610	3,364
1996-97	1.14	799	106.7	308	10	53	1.09	1,965	1.10	668	3,686
1997-98	1.14	911	111.0	321	10	53	1.09	2,142	1.10	733	4,045
1998-99	1.14	1,038	115.4	334	10	53	1.09	2,335	1.10	805	4,441
1999-2000	1.14	1,184	120.0	347	10	53	1.09	2,545	1.10	884	4,881

* Including 20% loss

4-2-5 Summary

The overall demand forecast mentioned in 4-2-1∿4-2-4 is summarized as shown in Table 4.6. When compared with the growth rate throughout the country in 4-1, the growth rate in Chittagong area is higher. However, this rate will be appropriate when taking into account the fact that there are the largest industrial zone and the largest port in the country in this area.

4-3 Measures for Increasing Demand

Though various measures can be taken to cope with increasing demand in Chittagong area, it will be the best way to cope with the demand by extending Units 4 and 5 at Kaptai Hydro-Power Station for the time being.

In order to transmit 230 MW power generated at the Kaptai Hydro-Power Station after extension, it is required to construct two circuits of 132 kV transmission lines since the capacity of the existing transmission lines is only 200 MW.

CHAPTER 5

OPERATION OF HYDRO-POWER STATION

CHAPTER 5 OPERATION OF HYDRO-POWER STATION

5-1 Present Condition of Power in the Project Area

As has been described in the previous chapter, the replenishment and extension project of electric power networks has been executed in Chittagong area. . However, B.P.D.B. actually controls power supply to cover short supply in peak hours.

As a result of study of the data issued by B.P.D.B. and power demand forecast throughout the country prepared by the team, etc., the values of power demand forecast in Chittagong area have been obtained. (Refer to Fig. 5.1).

Actually, the values of electric power demand are depressed due to shortage of power supply and the area is subject to tight power situation. Thus, the project is required to be completed in 1985.

5-2 Operation of Kaptai Hydro-Power Station

The operation method of Kaptai Hydro-Power Station has been analyzed according to the daily load curve in the Chittagong area shown in Fig. 5.2 by classifying the operation period of the power station into the following three periods:

First period (around 1985 when the extension project is to be completed)

Second period (around 1994)

Third period (around 2000)

As a result, the following operation patterns have been obtained:

In the first period, it is considered advantageous to continuously operate the power station on a twenty-four hour basis (in other words, base load operation).

In the second period, though the power station should be preferably operated on a 24-hour basis, it will be economical to operate partially for peak hour power supply.

In the third period, however, the power station should preferably be operated for peak hour supply. When taking into account the response against load fluctuation, the hydro-power plant is more advantageous than thermal power plant.

Fig. 5.2 shows the daily load curves.

5-3 Transmitting Method

There is an idea to transmit the power generated in Kaptai Hydro-Power Station to the Chittagong area by using the existing transmission lines. However, as described in Chapter 6, two circuit 132 kV transmission line (two circuit tower) is recommended to be constructed along an entirely different route from Kaptai Hydro-Power Station to Baraulia Substation to realize improvement of power supply reliability.

Fig. 5 1 Maximum Demand and Available Power Capacity in Chittagong Area

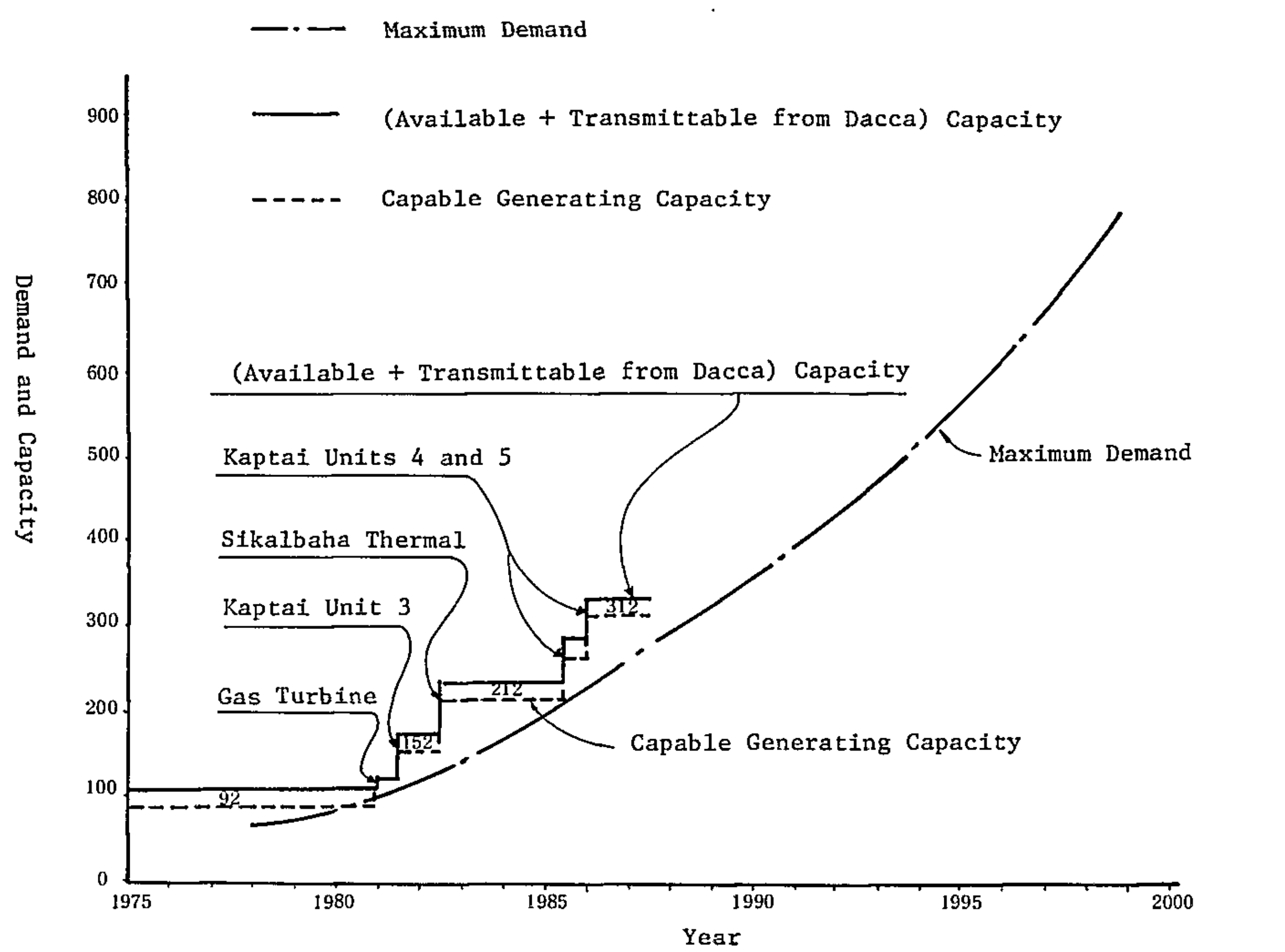
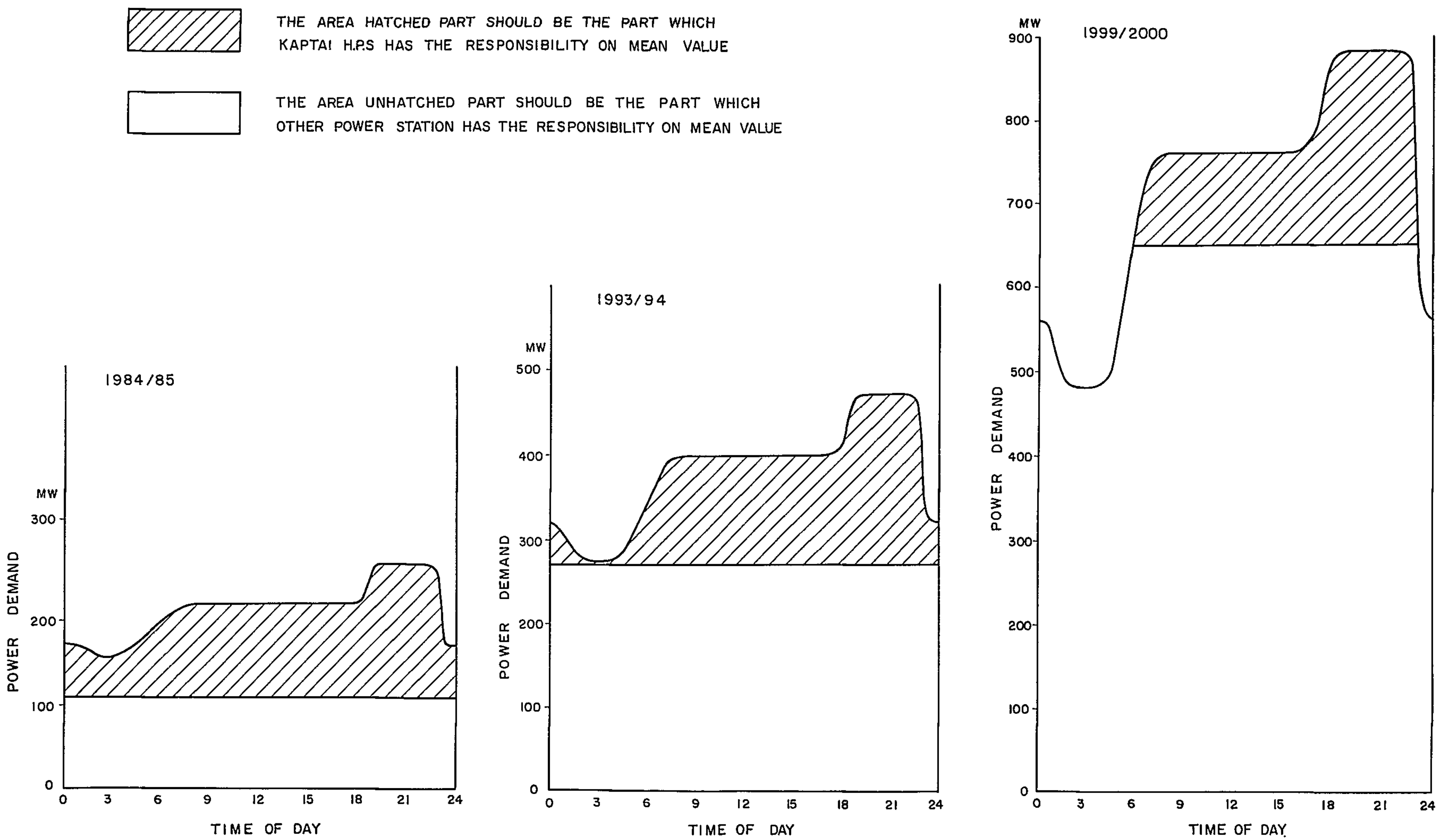


Fig. 5.2 DAILY LOAD CURVE IN CHITTAGONG AREA



5-4 Power Station Operation Plan

As described previously, the Kaptai Hydro-Power Station Extension Project is very important to meet the electric power demand increasing rapidly in the Chittagong area. Therefore, it can be said to be one of the most important tasks for the survey team to establish a plan for reasonable and effective operation of this hydro-power station and the Kaptai Reservoir.

Operation plan of the power station was studied in regard to capacity and operation of the reservoir, and generated electric energy.

5-4-1 Reservoir Capacity

As shown in Fig. 5.3, the area and capacity curve of the Kaptai Reservoir was established in 1968. The reservoir capacity was studied this time according to the following factors:

(1) Reservoir area according to LANDSAT Photographs

As illustrated in Fig. 5.3, the reservoir area according to LANDSAT photographs indicates a slightly larger area than that in the map of 1968.

(2) Operation records of the power station

By selecting the data on fine days from the operation records of the power station, the reservoir area was calculated in respect to El. 100 ft. and 109 ft. which are available comparatively in large quantity.
Table 5.1 shows the results of calculation.
As a result, the reservoir area obtained according to the operation records showed a slightly larger value than the area according to the map of 1968, and a value roughly equal to the area according to the LANDSAT photographs.

(3) Sedimentation in reservoir

As described in the above, the effective capacity of Kaptai Reservoir has made almost no remarkable change since 1968. This fact proves that mud deposits do not exert any influence upon the effective capacity of the reservoir, namely, the reservoir level above the lowest water level (L.W.L.).

Though it is impossible to clarify the present conditions of mud deposits below the lowest water level unless sounding is executed, it can generally be said that the effective capacity of the Kaptai Reservoir can sufficiently be secured in the future due to the following reasons:

(a) The slope of the Karnafuli River is very gentle as much as around 1/10,000, and the flow velocity is also very low. Therefore, the river bed and banks are hardly subject to scour, or erosion by the action of flowing water.

(b) Almost all river basin is gentle in slope and covered by thick forests, and there is no remarkably high mountain along the river. Thus, the river basin area assumes a stable land form.

Since this area is in the typical monsoon zone, the area has been transformed naturally with the lapse of time into the present form capable of withstanding the strict climatic conditions. Therefore, mud deposits will not exert any effect upon power generation for the time being.

Based on the result of the above comparative study shown in Table 5.1, it has been clarified that the values in the map of 1968 are smaller than the values in (1) and (2) in the above. Therefore, the values in the map of 1968 have been adopted for the power station operation plan in consideration of safety.

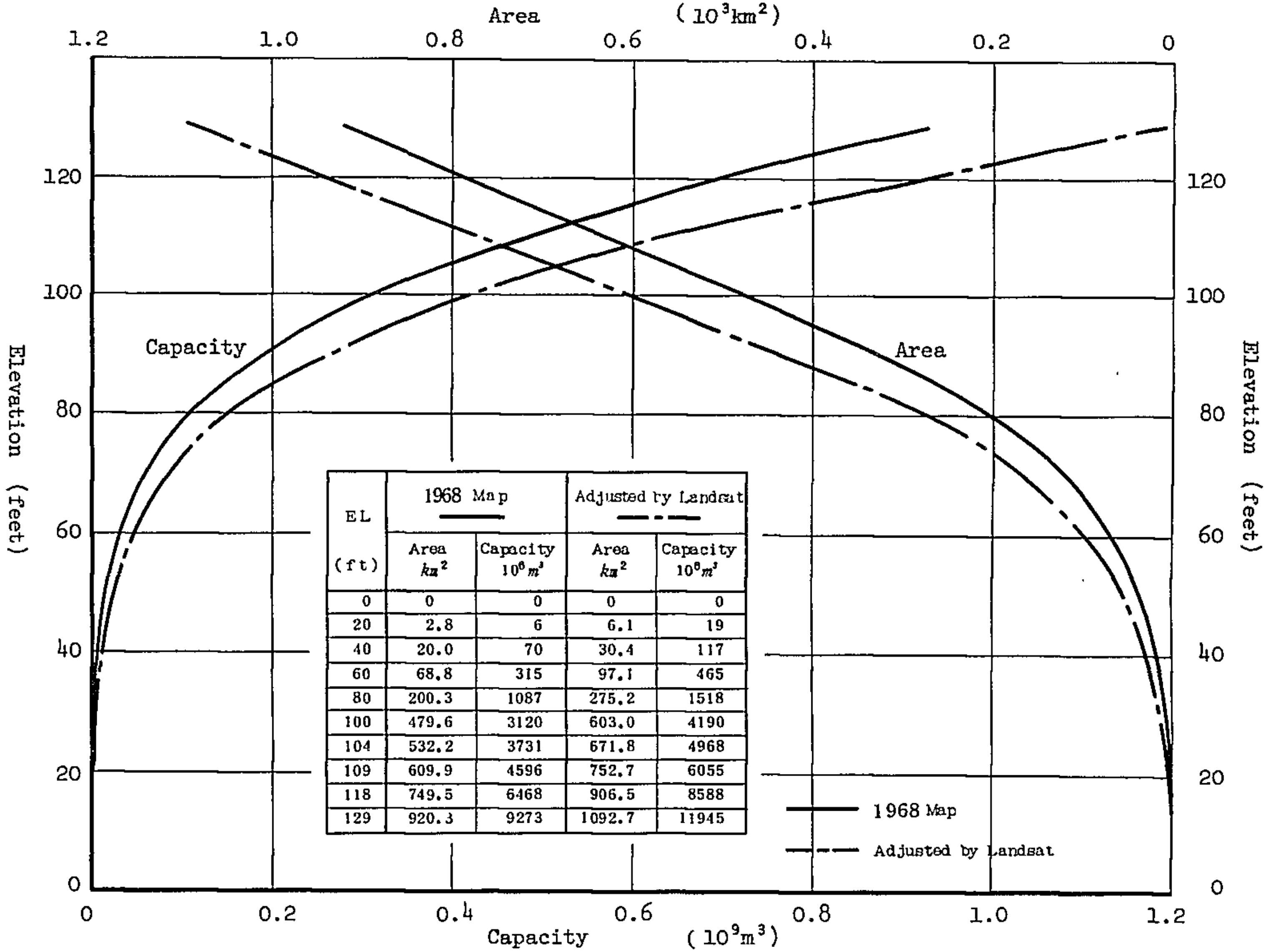
Table 5.1 Comparison of water surface area

(Unit: km^2)

Elevation (ft.) / Data sources	80	100	104	109	
1968 map	200.3	479.6	532.2	609.9	(981.3)
LANDSAT photographs	275.3	603.0	671.8	752.7	(1,211.1)
Operation records	-	605.5	-	737.6	(1,186.8)

Note: Values in parentheses show the surface area in miles.

Fig. 5.3 Area and Capacity Curve of Kaptai Reservoir



EL (ft)	1968 Map Area km^2	1968 Map Capacity $10^6 m^3$	Adjusted by Landsat Area km^2	Adjusted by Landsat Capacity $10^6 m^3$
0	0	0	0	0
20	2.8	6	6.1	19
40	20.0	70	30.4	117
60	68.8	315	97.1	465
80	200.3	1087	275.2	1518
100	479.6	3120	603.0	4190
104	532.2	3731	671.8	4968
109	609.9	4596	752.7	6055
118	749.5	6468	906.5	8588
129	920.3	9273	1092.7	11945

5-4-2 Reservoir Operation

The reservoir has been in operation according to the rule curve established in 1970 and corrected in 1978. This curve was established only for operation of Units 1 and 2. Therefore, the effective discharge from the reservoir through two unit machines is only about 350 m^3/sec.

As a result of study of this time for the extension project, it has been made clear that effective discharge can be increased to 1,017 m^3/sec. corresponding to three times the present value.

Consequently, it has naturally become necessary to establish a new rule curve. This new rule curve was made to attain further efficient and flexible operation of the reservoir in compliance with the changing river discharge. Moreover, the rules for reservoir operation have been established in view of the safety of dam and utilization of water. The non-restricted discharge and non-compensation discharge from the dam are decided to be 1,704 m^3/sec. (60 x 10^3 cu.ft./sec.) and 5,680 m^3/sec. (200 x 10^2 cu.ft./sec.), respectively based on the past records.

(1) Rules for Reservoir Operation

The Kaptai Reservoir shall be operated in accordance with the following rules:

(a) Control of reservoir water level

The reservoir water level shall be controlled as set forth in the following:

① Lower limit of water level

The lower limit water level of the reservoir shall be El. 85 ft.

② Upper limit of water level

②-1. The upper limit of water level in dry season from October to May shall be controlled to the following level:

Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Water level (ft.)	116	118	118	118	118	118	118	118

②-2. The upper limit of water level in rainy season from June to September shall be El. 113 ft.

(b) Discharge volume

Reservoir water shall be discharged to downstream in compliance with the following procedures:

① In case the reservoir water level has reached the upper limit.
The runoff equivalent to the inflow shall, in principle, be discharged through the power station and spillway.

② In case the reservoir water level does not reach the upper limit.

②-1. Dry season from October to May

In this season, the water level may not be controlled particularly by discharge unless the water level reaches the upper limit.

②-2 Rainy season from June to September

In case the inflow is larger than 1,017 m^3/sec. (equivalent to turbine discharge through five turbine units), at least 1,017 m^3/sec. shall be discharged up to the upper limit water level. In this case, spillway shall be used if the total turbine discharge is less than 1,017 m^3/sec. (The inflow shall be judged according to Fig. 5.4). However, when the reservoir water level is lower than the water level given in the rule curve, it is not necessary to discharge water.

(2) Description of the Rules for Reservoir Operation

The rules for reservoir operation have been established to ensure the safety of the dam and fishing on the Kaptai Reservoir.

(a) Data adopted in working out the rules, and estimation of maximum flood flow

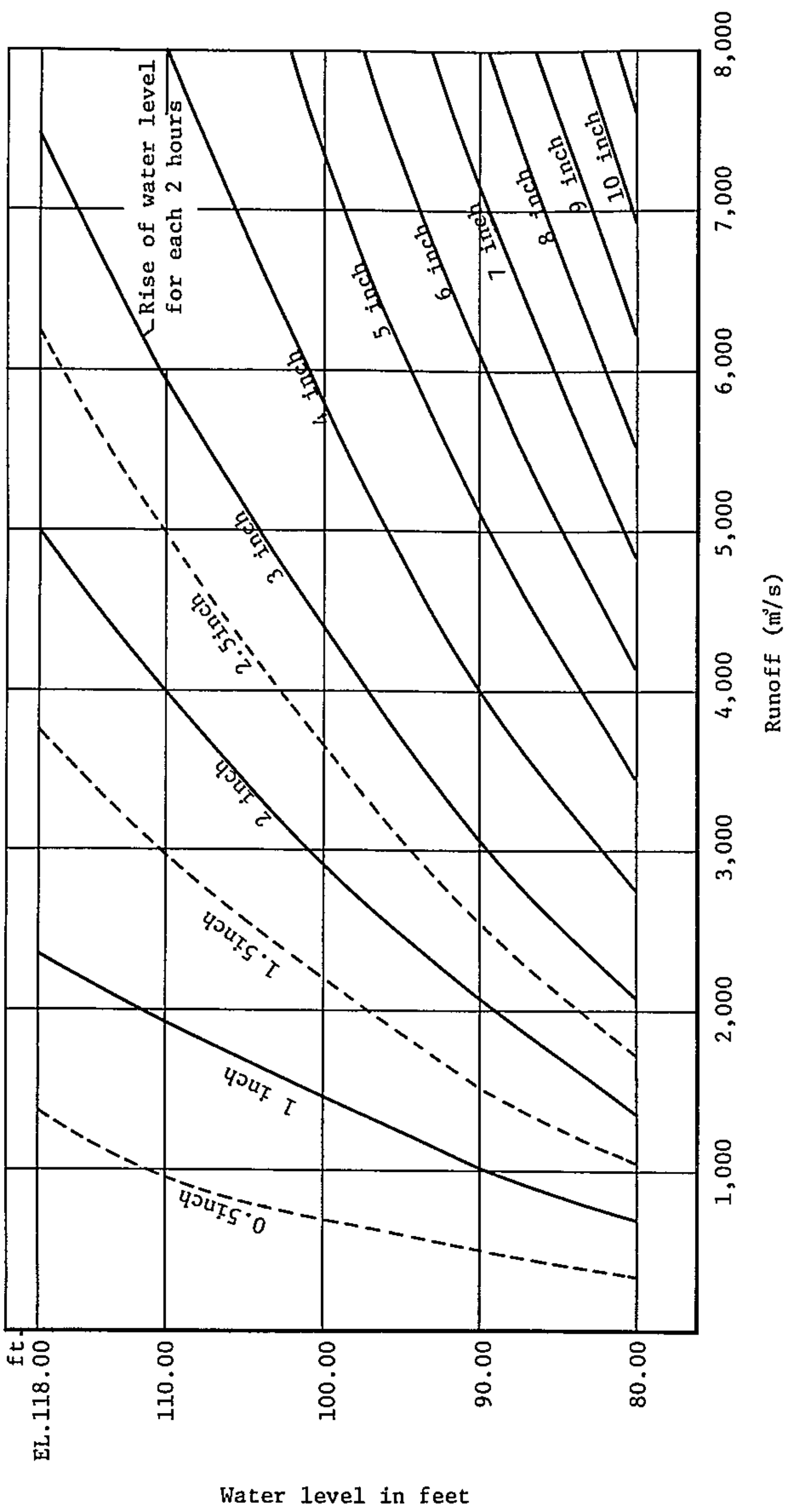


Fig. 5.4 Rise of Water Level - Runoff Curve

① Hydrological and meteorological data adopted

The hydrological and meteorological data adopted as basic data in working out these rules are:

(i) The data in IECO Design Report for 18 years from 1936 through 1953

(ii) The data in OTCA's feasibility study report for 13 years from 1954 through 1966

(iii) Records for the recent 13 years from 1967 through 1979.

② Maximum flood

The capacity of spillway for the Kaptai Reservoir is 16,000 m^3/sec. (563,400 cu.ft./sec.). The spillway capacity of 16,000 m^3/sec. is equivalent to 200-year flood when the probable flood is calculated according to the above hydrological and meteorological data (Refer to Fig. 5.5).

*Iwai method is adopted. This is a method used widely in Japan in calculating the flood probability by using a probability paper. As shown in Fig. 5.5, the horizontal axis refers to annual flood and the vertical axis, return period.

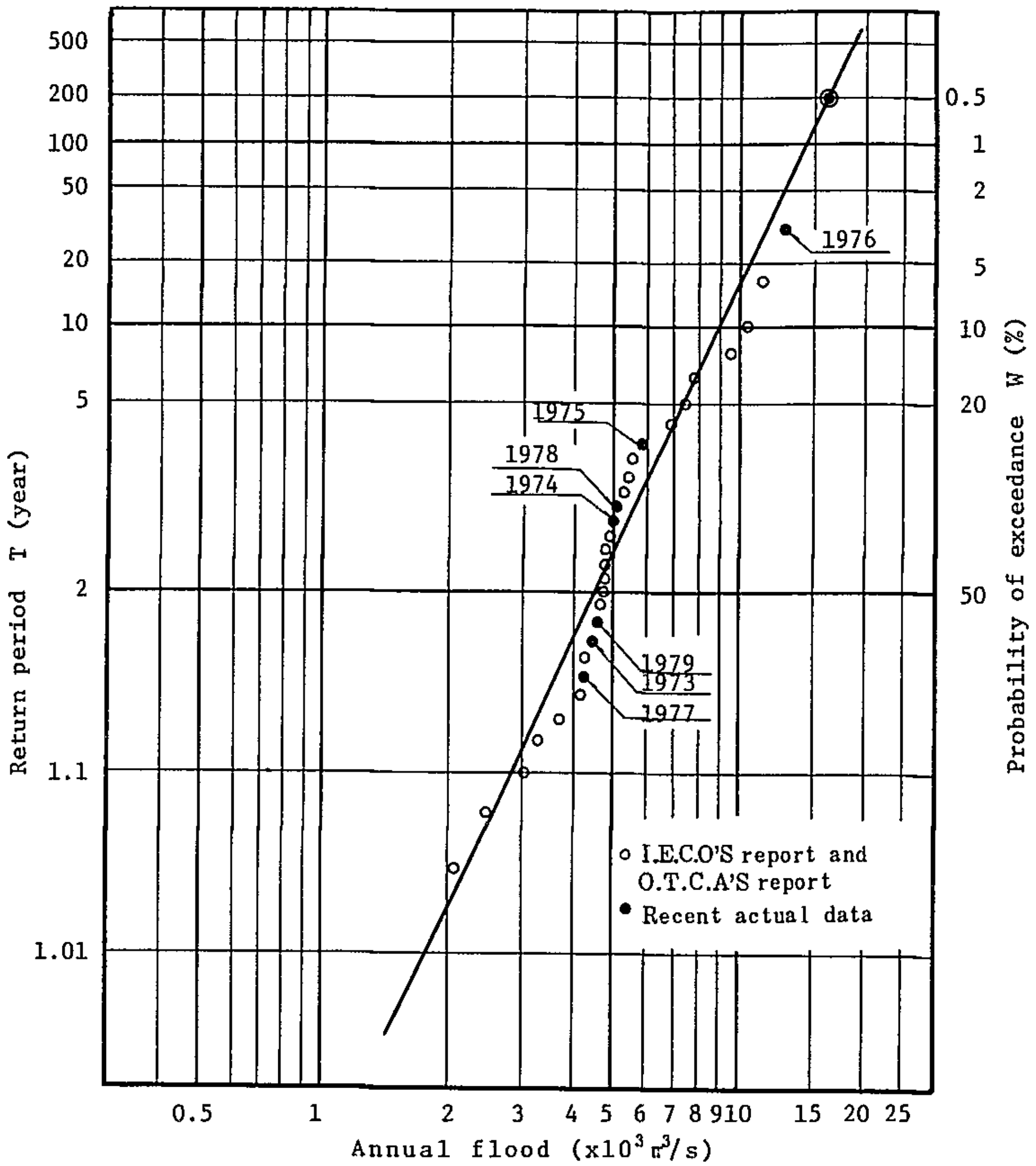
Since the spillway capacity corresponds to the 200-year flood, the yearly and daily maximum, and monthly average flood in the rules for reservoir operation have been established on the basis of the 200-year probability.

The values of monthly probable maximum flood and average flood are as shown in Table 5.2.

* Shigehisa Iwai and Masayoshi Ishiguro :

Applied Hydrologic Statistics on Page 73 – 83, Morikita Publishing.

Fig. 5.5 Flood Frequency Curve



Probability exceedance is calculated according to the following formula;
$W = \frac{n}{N+1} \times 100$ (%) [n; order in size; N: number of probable variables (yearly maximum runoff)] Here, probable variable is yearly maximum runoff, one variable per year.

Therefore, occurrence period (T) is;
$T = \frac{100}{W}$ (year)

Table 5.2 Monthly Probable Flood (200-year return period)

(Unit: m^3/sec.)

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Monthly maximum	523	534	306	2,943	4,362	* 15,992	* 15,992	13,321	7,365	6,163	5,225	4,286
Monthly average	240	175	300	469	1,347	4,608	4,480	3,041	2,417	1,791	804	352

Note: The values with *mark show yearly flood (200-year return period).

* Non-restricted discharge: 1,704 m^3/sec. (60 x 10^3 cu.ft./sec.)
* Non-compensation discharge: 5,680 m^3/sec. (200 x 10^3 cu.ft./sec.)

Here, the 100-year probable flood at the Kaptai site is 14,280 m^3/sec. (503 x 10^3 cu.ft./sec.).

As is well known, the probability of flood and rainfall is in close relation, and the 100-year probable rainfall and the 200-year probable rainfall are 26 inch/day and 31 inch/day, respectively.

(b) Control of reservoir water level

① Lower limit water level of the reservoir

On the Kaptai Reservoir, fishing and barge navigation are carried out by utilizing the lake water. Thus, if the reservoir level is excessively reduced to a lower level, it will become impossible to utilize the lake water surface for fishing and barge navigation. Therefore, the lower limit water level has been established.

② Upper limit water level of the reservoir

②-1. Upper limit of reservoir water level in dry season

The 200-year daily flood from January through March is less than the non-restricted discharge, but it exceeds the non-restricted discharge within the level of non-compensation discharge in the four months of April, May, November and December.

However, since the 200-year daily flood exceeds the non-compensation discharge on October, the volume of water corresponding to the non-compensation discharge is decided to be stored in the reservoir.

In other words, the most critical situation is to be brought about if the 200-year daily flood of 6,163 ton/sec. (217×10^3 cu.ft./sec.) should continue for nine days on October as calculated in the following:

$$\frac{(Q_F 200 \text{ mean M}) \times 30 \text{ days}}{(Q_F 200 \text{ max D})} = \frac{1,791 \times 30}{6,163}$$

$$\fallingdotseq 9 \text{ days}$$

Therefore, the volume of water to be stored on this month is:

$$[Q_F 200 \text{ max day}) - Q_1] \times 9 \text{ days} \times 24 \text{ hrs} \times 3,600 \text{ sec} = (6,163-5,680) \times 9 \times 24 \times 3,600 \fallingdotseq 379 \times 10^6 \text{ m}^3$$

Where,

$Q_F 200$ mean M: 200-year monthly average flood

$Q_F 200$ max. D: 200-year daily maximum flood

Q_1: Non-compensation discharge

The value of 379×10^6 m^3 in Fig. 5.3 corresponds to the storage capacity of H.W.L. 118 ft. - 1.7 ft. Consequently, if the upper limit water level on October is El. 116 ft., it is possible to keep the H.W.L. at 118 ft. only by non-compensation discharge even in the event of 200-year flood.

②-2. Upper limit water level in rainy season

The 200-year flood in rainy season is $Q_F 200$ max. $D < Q_1$, and it is impossible to keep the highest water level within 118 ft. during the period from June through September (Refer to Table 5.2).

In the case of 200-year daily maximum flood (16,000 m^3/sec.) the corresponding amount is to be discharged from the spillway gate. Thereby, sufficient surplus time is required to fully open the spillway gate.

Judging from the above requirements, the upper limit water level has been decided to be El. 113 ft. by giving a surplus water depth of 5 ft. as in the case of OTCA's feasibility study report.
The reservoir capacity corresponding to the surplus water depth of 5 ft. is about 11 x 10^8 m^3 equivalent to about 19 hours' portion of the 200-year probable flood (16,000 m^3/sec.). Thus, the surplus water depth is sufficiently safe in view of operation of the spillway.

(c) Discharge volume

① In case the reservoir water level has reached the upper limit

In case the reservoir water level has reached the upper limit level, the total inflow shall be discharged to downstream without storing the inflow in the reservoir. This countermeasure against flooding has been established in view of the safety of the reservoir operation.

② In case the reservoir water level does not reach the upper limit

②-1 Dry season from October to May

The monthly average river runoff is extremely smaller than that in rainy season. Thus, it is not particularly necessary to control the discharge volume in view of reservoir operation (Table 5.2).

②-2 Rainy season from June to September

In many cases, the river runoff exceeds the maximum turbine discharge of the power station (1,017 m^3/sec.). The new rule curve is established in compliance with the turbine discharge of five units (1,017 m^3/sec.).

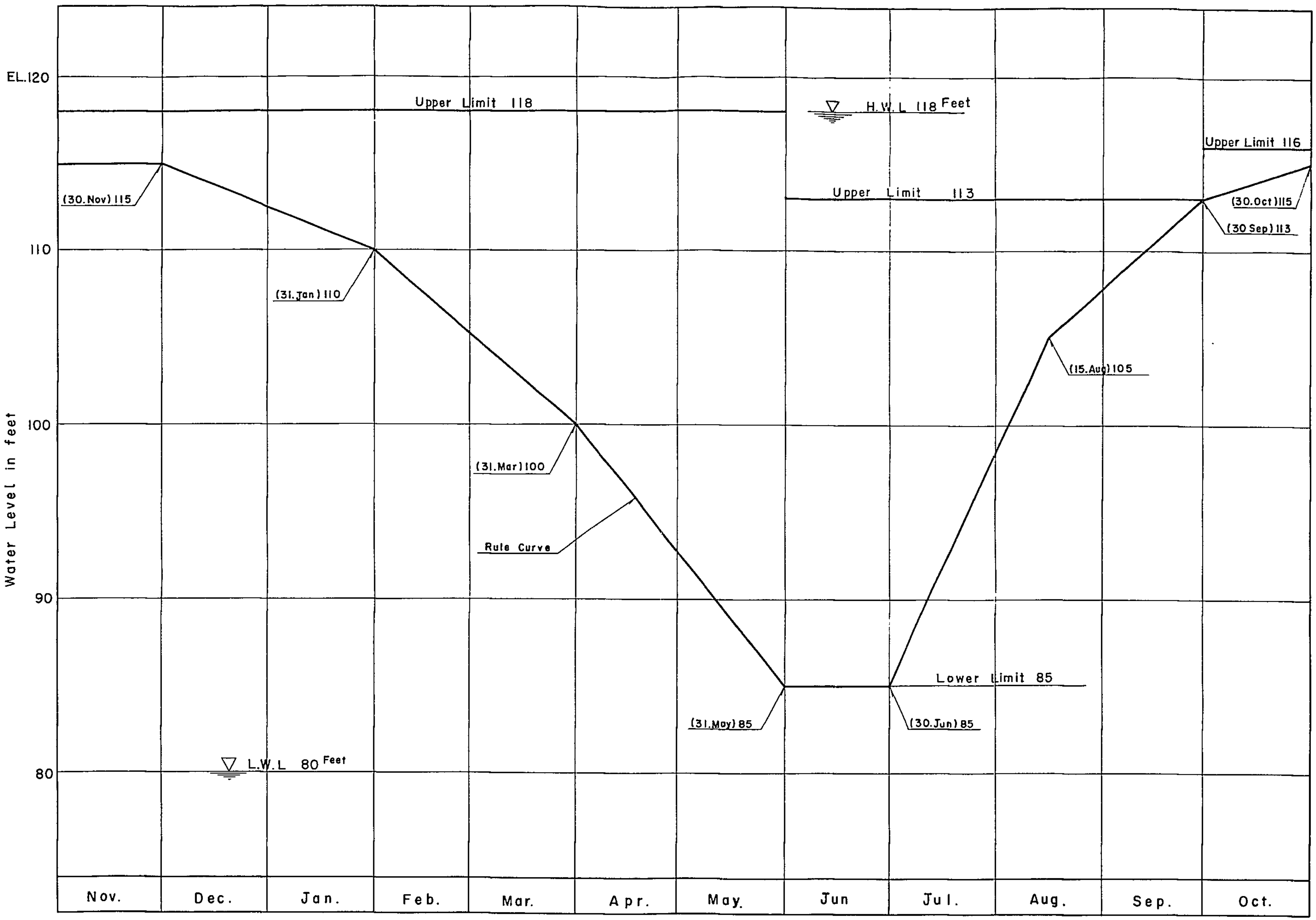
Therefore, should any one of five turbine units be shut down in such flood season, the turbine discharge becomes less than 1,017 m^3/sec.

In such a case, it is not favorable for the safety of the dam, if excessive inflow is stored in the reservoir.

Consequently, if the power station is shut down and the inflow exceeds 1,017 m^3/sec., the equivalent inflow of at least 1,017 m^3/sec. shall be discharged by using the spillway (Refer to Fig. 5.4).

Excessively reducing the reservoir water level to lower than the rule curve results in various troubles in the operation of reservoir thereafter. Therefore, the reservoir water level should not be reduced excessively as far as possible. In case the reservoir water level is lower than the rule curve, it is preferable not to discharge water through other than turbines unless unavoidable.

Fig.5.5 RULE CURVE



(3) Verification on Operation of Reservoir according to New Rule Curve

(a) Hydrological data

The hydrological data used for this study are indicated in Table 5.3, the daily data of which are available.

Table 5.3 Rainfall and runoff patterns in selected years

Year	Basic patterns		Total amount of rainfall
1973	(Normal rainfall year)	Comparatively large runoff was maintained from Oct. through Dec.	2,840 mm
1974	(Normal rainfall year)	A typical pattern, and runoff was concentrated from June through Aug.	2,657 mm
1975	(Normal rainfall year)	Runoff was concentrated in July, and comparatively constant from Aug. through Oct.	2,589 mm
1976	(Wet year)	Runoff was concentrated extremely from June through Aug.	3,593 mm
1977	(Normal rainfall year)	Runoff was comparatively large from April through May. This can be called "an advance rainfall" pattern.	2,631 mm
1978	(Normal rainfall year)	Runoff was comparatively constant from May through Oct.	2,748 mm
1979	(Dry year)	Runoff was extremely small from May through June. A typical pattern of dry year.	2,246 mm

(b) River runoff

The daily river runoff in the records for the recent seven years is used for river discharge. Table 5.4 shows the monthly average runoff in the records for these seven years.

The river runoff calculated according to the storage functional method by using the rainfall data in this area is well in conformity with the past records (Refer to APPENDIX 2).

Table 5.4 Monthly Average Runoff for the Past Seven Years

(Unit: m^3/S)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average	Ratio of 1976's Value
1973	84	89	112	106	473	1,248	1,299	1,452	574	577	1,032	264	609	0.69
1974	163	197	198	268	380	1,598	1,874	1,155	1,358	754	249	163	696	0.79
1975	204	149	137	162	243	642	2,153	955	1,029	970	494	168	609	0.69
1976	122	183	120	224	394	3,434	3,027	1,425	813	375	265	152	878	1.00
1977	121	171	46	530	727	1,073	1,071	1,180	799	240	142	51	513	0.58
1978	82	74	71	61	570	1,927	1,137	933	1,414	878	1,202	131	707	0.81
1979	114	107	117	101	123	313	1,655	1,116	1,082	219	141	114	434	0.49
Average	127	139	114	207	416	1,462	1,745	1,174	1,010	573	504	149	635	

Fig. 5.7 Monthly Rainfall

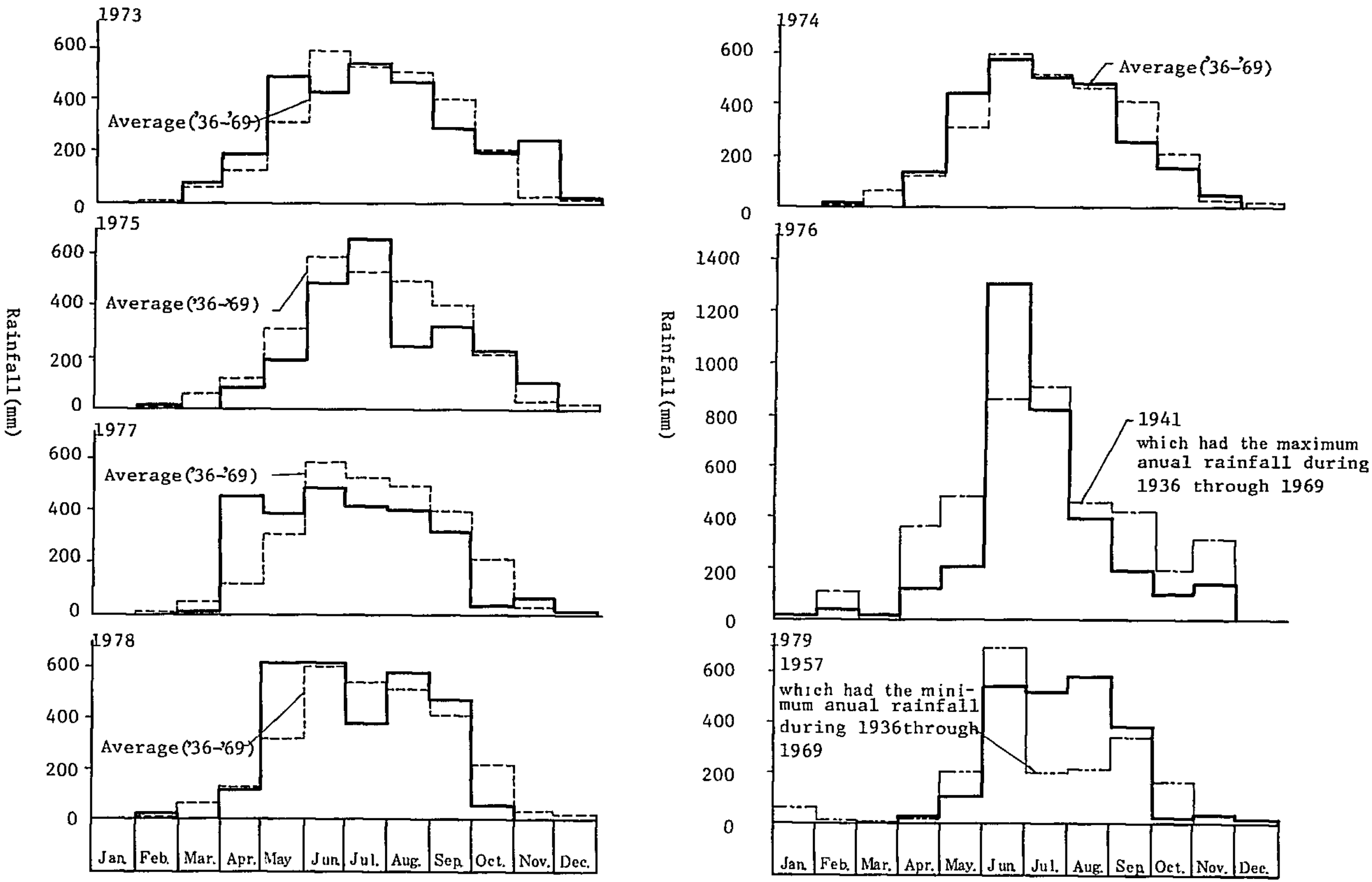
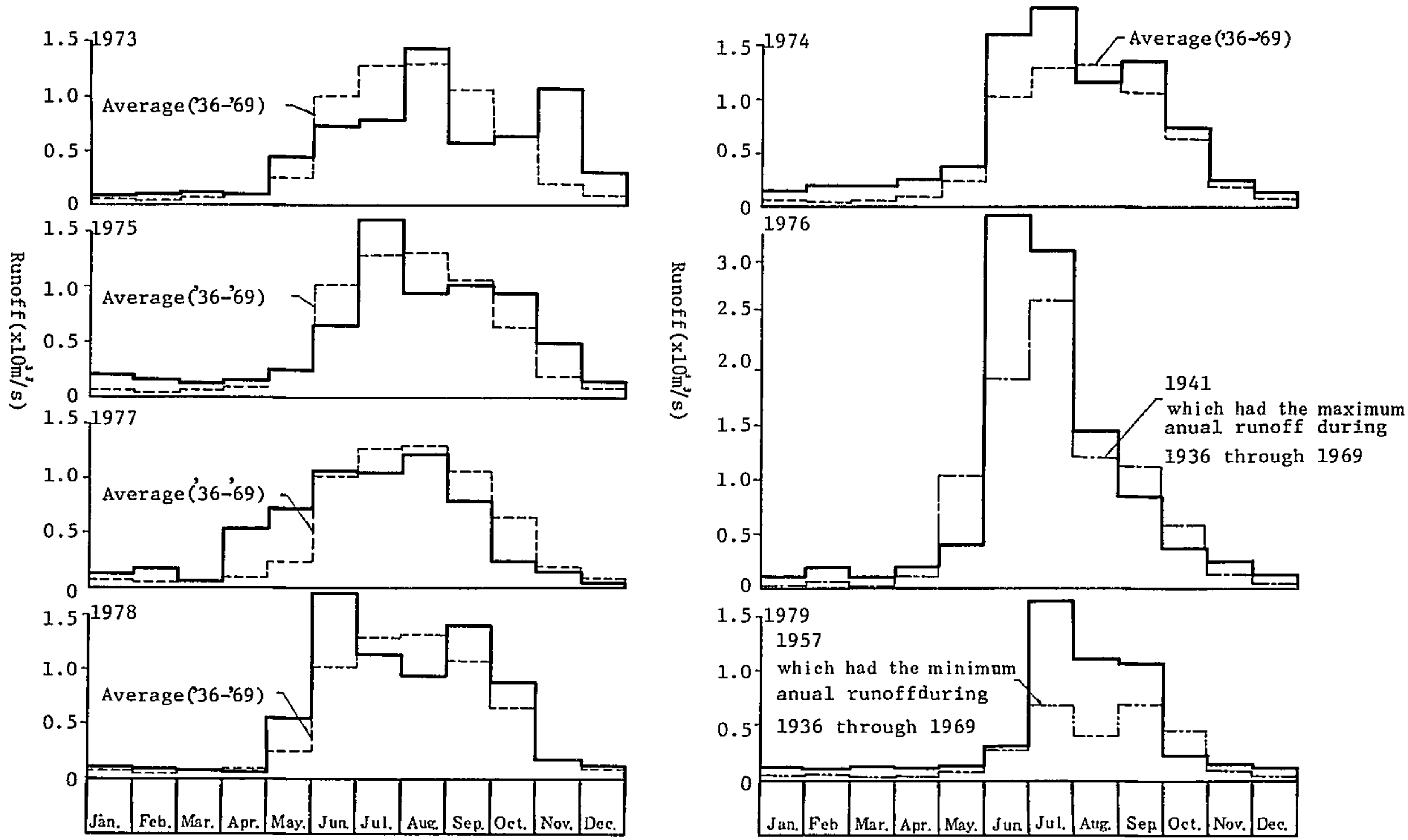


Fig. 5.8 Monthly Mean Runoff



(4) Result of Verification

The new rule curve was verified in respect to the four cases as established in Table 5.5.

Table 5.5 Study of Four Cases

Cases	Generator units	Rule curves
Case 1	3 units (130 MW)	Present rule curve
Case 2	5 units (230 MW)	Present rule curve
Case 3	5 units (230 MW)	New rule curve
Case 4	3 units (130 MW)	New rule curve

Fig. 5.9 shows the history of reservoir water level after extension according to the new rule curve using the daily runoff data described in (3)-(b).

In this case, the history has been prepared in compliance with the rules for reservoir operation described in 6-4-2 (1).

According to the history of reservoir water level, the largest flood of about 13,000 m^3/sec. (458 x 10^3 cu.ft./sec.) occurred on June 1976 when the reservoir level was El. 85.7 ft. However, even if discharge is commenced after the reservoir water level has reached the upper limit water level of 113 ft. in the rainy season, it is possible to keep the water level at lower than H.W.L. 118 ft. if discharge is performed at a rate of less than non-compensation discharge. Namely, in this case, the flood when the upper limit water level reached 113 ft., is about 8,000 m^3/sec. (282 x 10^3 cu.ft./sec.), and there is a surplus depth of 5 ft. up to H.W.L. 118. Therefore, it has been clarified that the reservoir water level does not exceed H.W.L. 118 even if discharge is performed at a rate of less than non-compensation discharge.

In dry season, about 3,000 m^3/sec. (106 x 10^3 cu.ft./sec.) was discharged only for one day at the time of emergency flood on November 1973, but it is possible to maintain the upper water level at H.W.L. 118 by performing discharge within a rate of non-compensation discharge.

Table 5.6 shows the turbine discharge and spillway discharge applicable respectively to the four cases in Table 5.5 using the daily runoff data for the past seven years in the above.

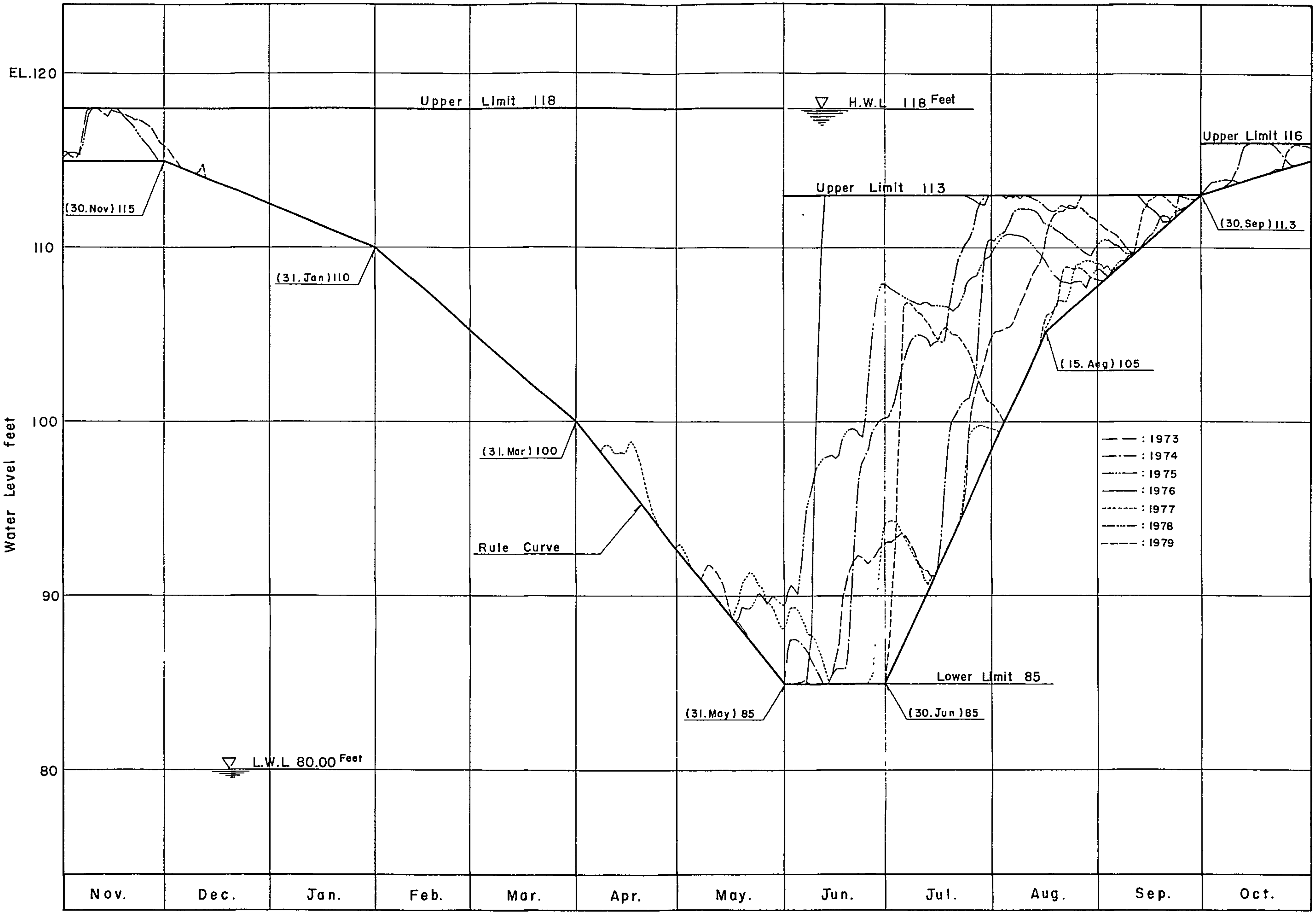
Table 5.6 Monthly Average Turbine Discharge and Spillway Discharge for the Past Seven Years

(Unit: 10^7 m^3)

Month		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Runoff		34.9	33.8	31.3	53.3	111.3	376.4	452.0	318.4	264.1	140.2	120.8	42.9	1,979.4
se 1	Turbine discharge	86.9	116.4	113.6	114.0	135.3	129.0	98.2	97.0	94.3	65.1	73.7	90.3	1,213.8
	Spillway discharge	0	3.4	0.7	14.4	53.2	246.7	218.9	77.1	66.0	34.4	46.4	4.4	765.6
se 2	Turbine discharge	86.9	119.7	114.3	123.8	170.9	194.6	149.6	136.8	128.1	82.0	93.0	92.5	1,492.2
	Spillway discharge	0	0	0	4.4	17.2	181.8	167.8	37.2	32.2	17.5	27.0	2.1	487.2
se 3	Turbine discharge	86.9	119.7	114.3	128.3	177.0	205.6	234.4	237.3	180.7	93.4	112.1	97.8	1,787.5
	Spillway discharge	0	0	0	0	0	40.3	79.7	27.6	33.2	4.0	7.1	0	191.9
se 4	Turbine discharge	86.9	119.0	114.6	118.0	140.3	135.0	149.7	145.4	137.3	78.3	84.4	102.5	1,411.3
	Spillway discharge	0	0	0	0	0	95.2	170.0	138.3	123.2	16.0	25.4	0	568.1

This table indicates that the turbine discharge in Case 3 is about 47% larger than that in Case 1 and about 27% larger than that in Case 4.

Fig.5.9 CHRONOLOGICAL GRAPH of WATER LEVEL BASED on NEW RULE CURVE



(5) Generated Energy

(a) Comparison of Power Station Shutdown Period

Table 5.7 shows the yearly shutdown period of the power station in Case 4 of Table 5.5 using the daily runoff data for the past seven years.

In Cases 1 and 2, the power station is shut down for five to twelve days a year. However, it is hardly shut down in Case 3.

Table 5.7 Yearly Shutdown Period of Power Station

(Unit: day/year)

Year / No. of Case	1973	1974	1975	1976	1977	1978	1979	Average
Case 1	0	6	12	5	11	9	7	7.1
Case 2	0	6	12	5	11	9	8	7.3
Case 3	0	2	0	0	0	0	0	0.3
Case 4	0	2	0	0	0	0	0	0.3

(b) Generated Energy

The yearly generated energy is estimated according to the following basic data in Case 4 in Table 5.5 by using the daily runoff data for the past seven years.

(1) Turbine discharge: Fig. 5.10 H-Q curve
(2) Head loss: Fig. 5.11 Q-He curve
(3) Headrace water level: Fig. 5.12 Q-H curve
(4) Comprehensive turbine-generator efficiency: Fig. 5.13 Q-efficiency curve

Table 5.8 shows the monthly generated energy in the respective cases.

Table 5.8 Monthly Generated Energy

(Unit: 10^6 KWh)

Month / No. of Case	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Case 1	57.9	74.9	68.2	62.2	65.2	57.8	49.4	58.6	61.4	43.4	50.0	62.1	711.1
Case 2	57.9	76.7	68.5	67.6	82.1	87.2	75.2	82.9	83.4	54.9	63.3	63.6	863.3
Case 3	57.9	76.7	68.6	70.2	86.4	104.9	140.4	155.0	120.2	63.4	78.0	67.2	1,088.9
Case 4	57.9	76.6	68.8	65.3	71.2	73.8	89.8	97.6	93.4	53.6	58.6	71.4	878.0

The yearly increase ratio of generated energy in Case 1 to the respective cases is as follow:

Case 1: 1.00
Case 2: 1.21
Case 3: 1.53
Case 4: 1.23

Namely, the generated energy in Case 3 is about 53% larger than that in Case 1 and about 24% larger than that in Case 4 among the respective cases for the new operation plan.

The yearly generated energy in Case 3 is as shown in Table 5.9.

Table 5.9 Yearly Generated Energy in Case 3 (Unit: 10^6 KWh)

Year	1973	1974	1975	1976	1977	1978	1979	Average
Generated energy	1,167.8	1,242.1	1,114.5	1,112.4	931.9	1,226.0	819.2	1,088.9

Fig. 5.14 shows the monthly average water level of reservoir and tailrace in Case 3.

Fig. 5.10 Relation between Effective Head and Maximum Turbine Discharge in Case of High Efficiency

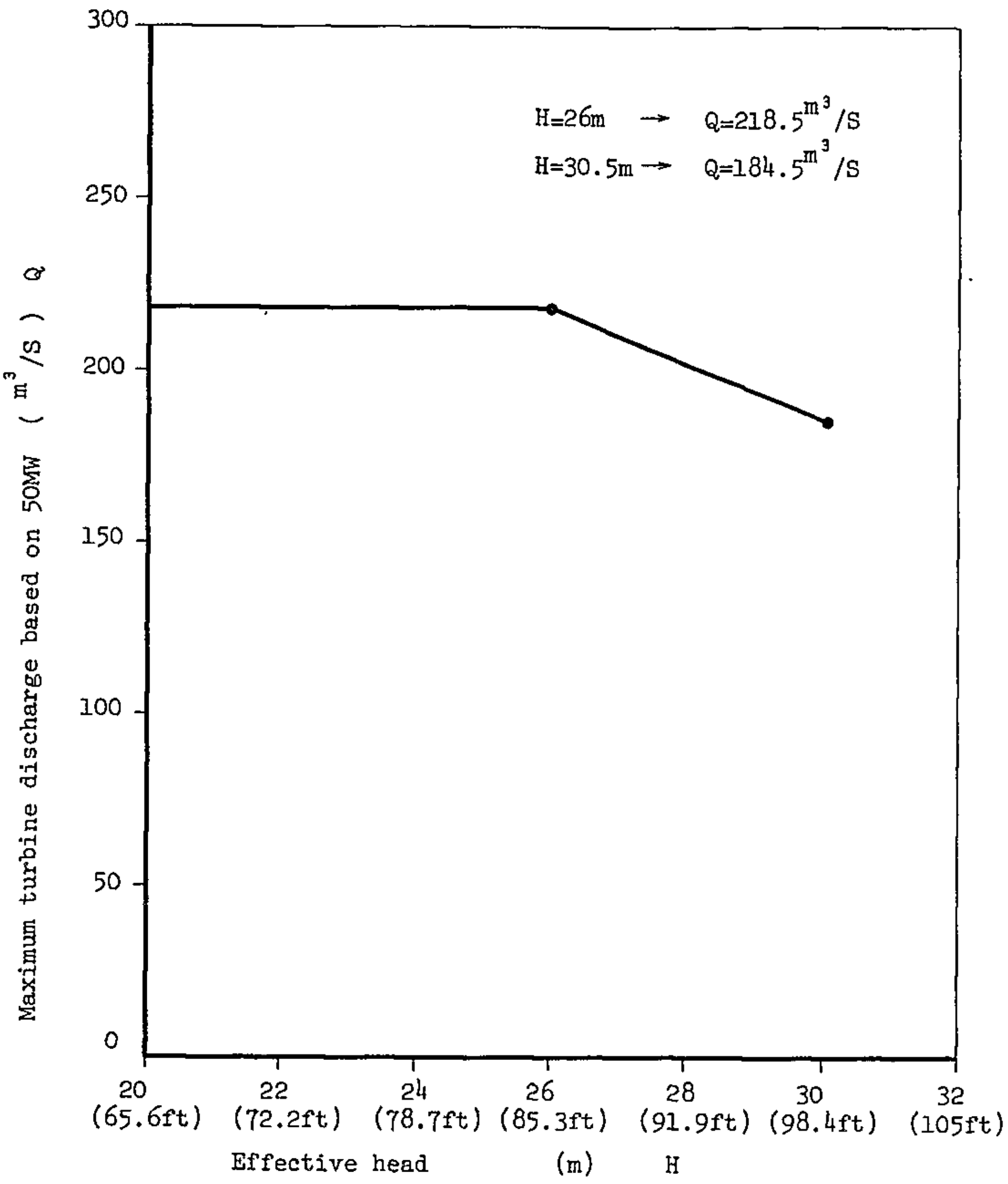


Fig. 5.11 Relation between Turbine Discharge and Head Loss (Units 4 and 5)

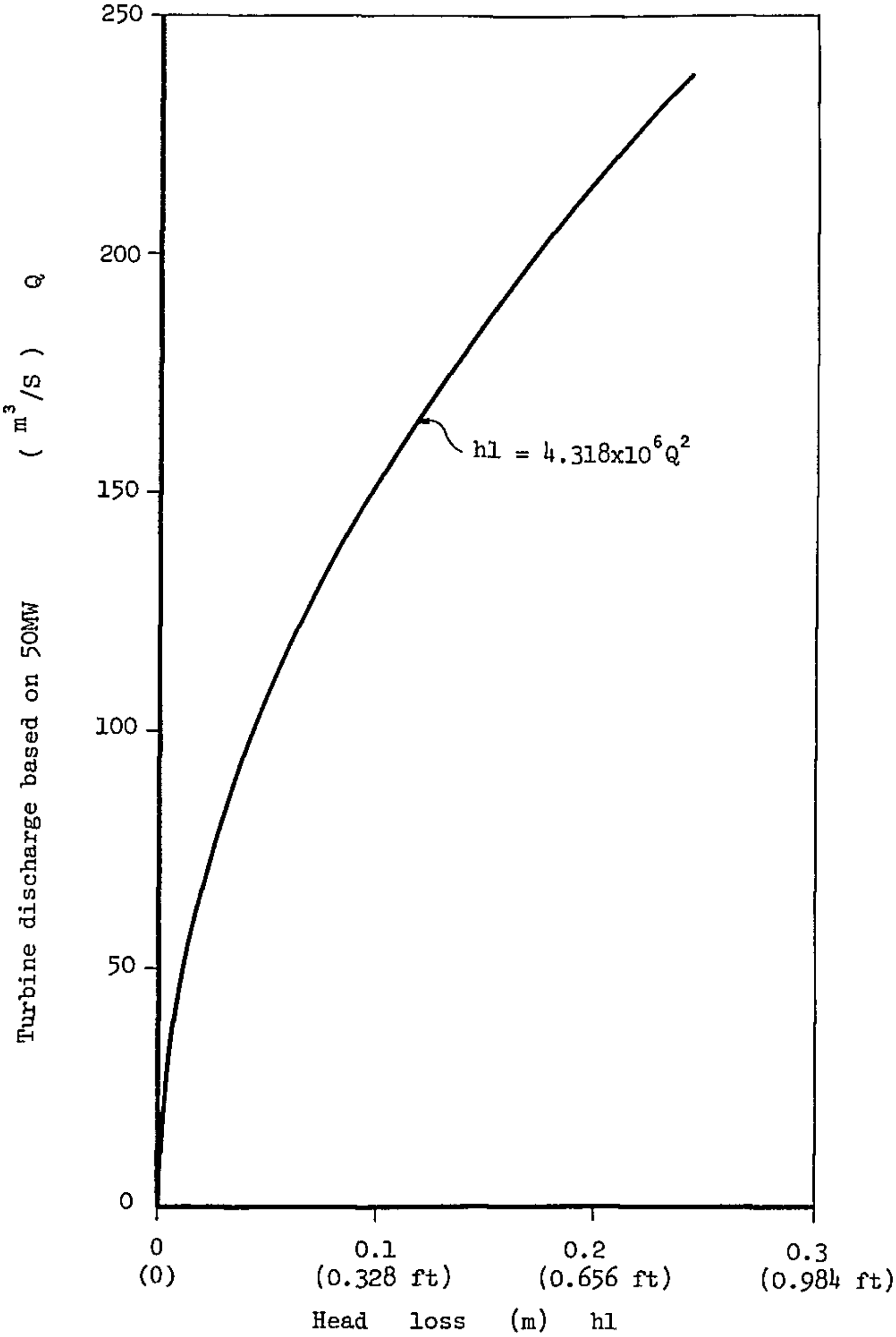


Fig. 5.12 Tailwater Rating Curve

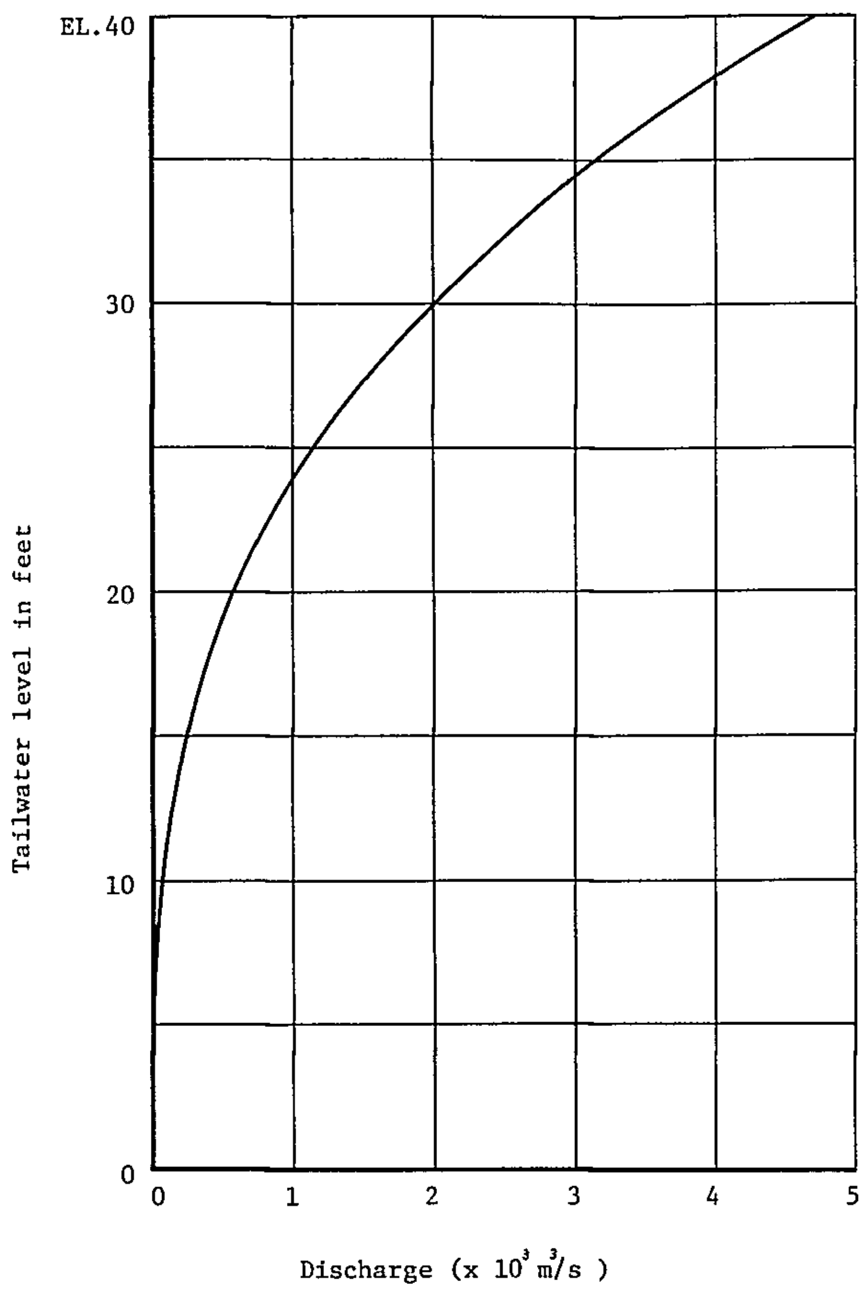


Fig. 5.13 Turbine and Generator Efficiency Curve

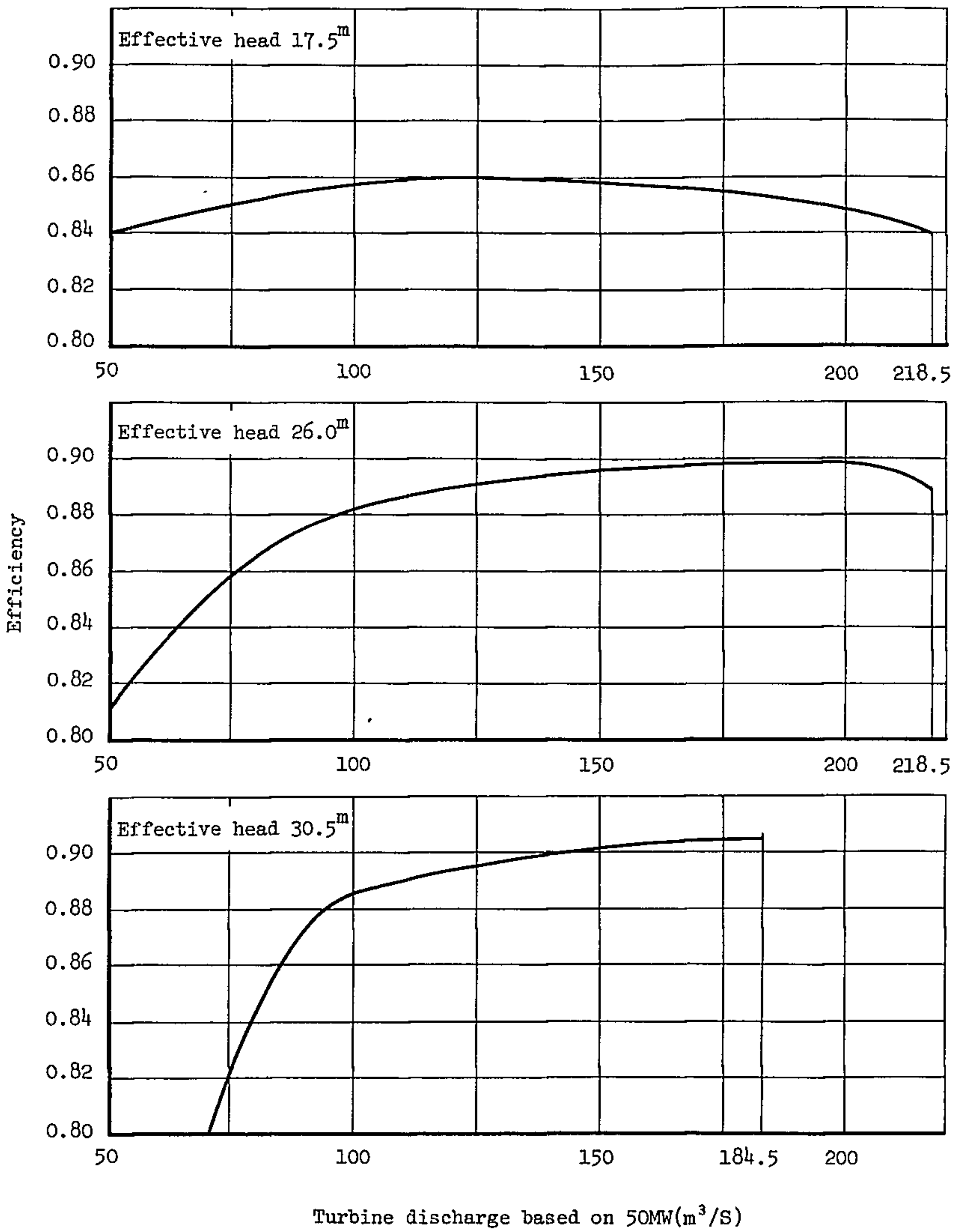
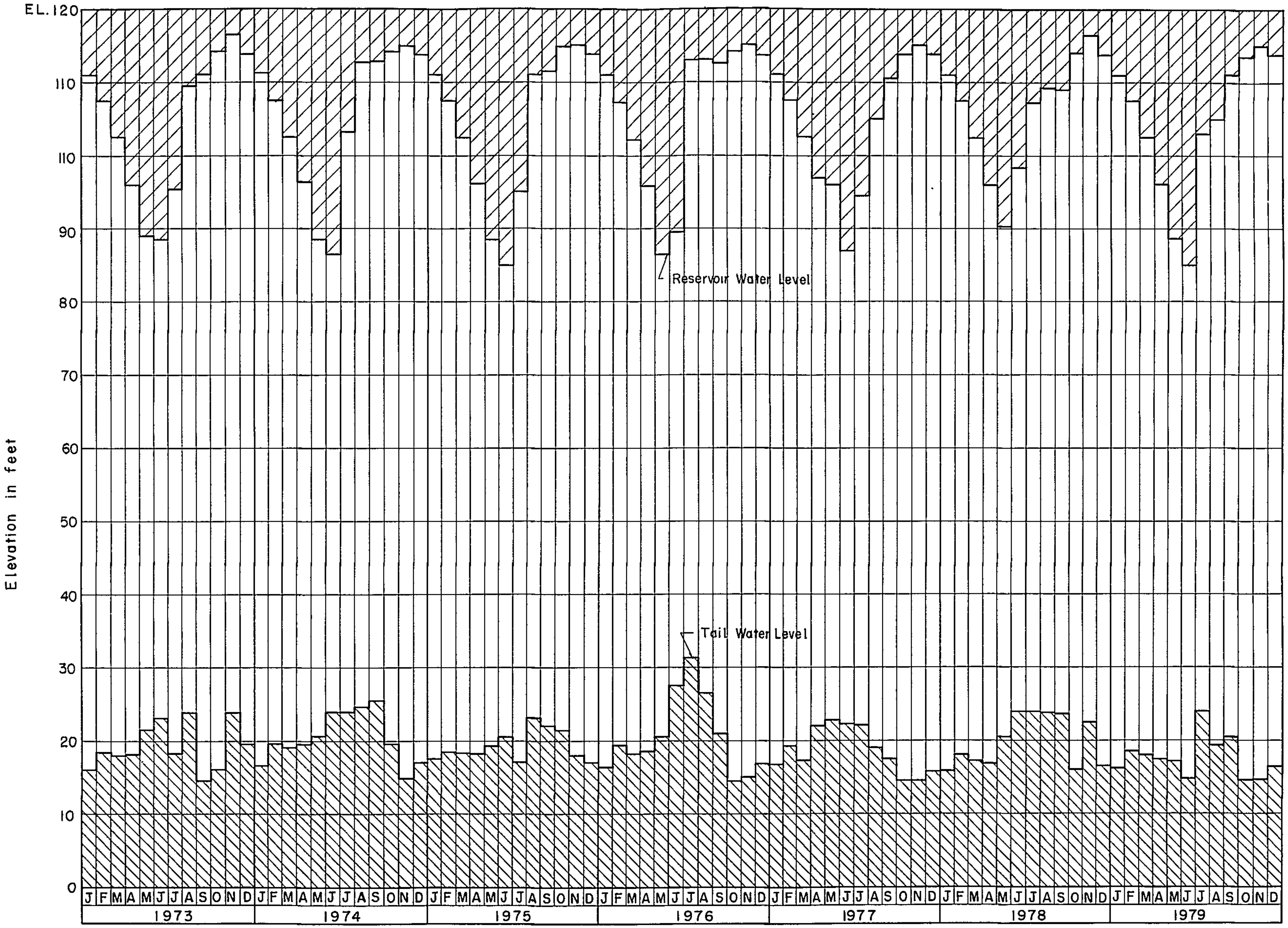


Fig. 5.14 CHRONOLOGICAL GRAPH of MONTHLY WATER LEVEL



CHAPTER 6

CONSTRUCTION OF POWER STATION

CHAPTER 6 CONSTRUCTION OF POWER STATION

6-1 Selection of Site

The four sites indicated in Fig. 6.1 were selected prior to the execution of the local survey, and the survey was carried out in regard to the selected sites.

Site No. 1: The area right upstream from the transfer cargo

Site No. 2: The existing power station site

Site No. 3: The area 150 m upstream from the existing power station

Site No. 4: Intake : The area about 100 m upstream from the existing intake (Same as Site No. 3)

Powerhouse: To be constructed at the existing station site

These four proposed sites have different characteristics in view of arrangement, construction, etc. as indicated in the following table:

Comparison of Four Alternative Sites

Proposed sites	Characteristics of the respective sites
Site No. 1	Though the land form of the water channel matches the structure and is reasonable, construction of by-pass road and other compensation are required since the area is beyond the control of B.P.D.B.
Site No. 2	Though the station is compact and advantageous in view of maintenance, measures for protecting the existing station facilities at the time of construction are required since this is located at the existing station site.
Site No. 3	Though this site is reasonably located in view of design and construction, this site is distant from the existing facilities and slightly inconvenient in view of maintenance and inspection.
Site No. 4	Though the existing cranes can be used commonly for the extended units and this site is convenient for maintenance, the length of water channel is longer than that in the case of Sites No. 2 and 3.

In this basic study, comparative study was carried out in respect to the two proposed sites No. 2 and 3, the ground conditions of which are well known according to the OTCA's report.

Regarding these four proposed sites, it is considered necessary to execute comparative study upon detailed investigations in view of topography and surrounding environmental conditions and select an optimum site at the time of detail design while giving consideration to the space for the extension of the power station by raising the dam height.

Tables 6.1 and 6.2 outline the results of comparative design of Sites No. 2 and 3. As indicated in the above tables, the Site No. 3 is more advantageous in view of construction cost, when compared with that of Site No. 2, and it is possible to allot sufficient space for the extension of the power station in the future.

Table 6.1 Outline of Comparative Design

		Site No. 2 Plan Installation next to the existing power station	Site No. 3 Plan Site 150 m upstream from the existing power station
Intake	Advantage	(1) Compact due to installation next to the existing power station (Advantageous in view of maintenance)	(1) Quantity of work such as excavation, temporary coffering, etc. is smaller. (2) Operation of the existing power station is not interfered with during construction.
	Disadvantage	(1) Volume of excavation is large. (2) It is necessary to protect the existing intake during construction.	(1) Maintenance and inspection is slightly inconvenient since the intake is separated from the existing one.
Headrace, Penstock	Advantage	(1) Channel length is short.	(1) Channel length is slightly shorter.
	Disadvantage		(1) Quantity of work is slightly larger.
Power Station, Tailrace	Advantage	(1) Assembly house and overhead traveling crane of the existing power station can be used.	(1) Operation of the existing power station is not interfered with during construction. (particularly, the tailrace). (2) Accessible to main building.
	Disadvantage	(1) Temporary coffering of tailrace becomes large in scale.	
Comprehensive evaluation		Disadvantageous in view of design and construction (quantity of work, etc.)	Though slightly inconvenient in view of maintenance since the site is separated from the existing facilities, this site is advantageous in view of design and construction.

Table 6.2 Comparison of Major Cost Factors for the Respective Sites

Structures	Work			Site No. 2 (Next to existing station)	Site No. 3 (150 m upstream from existing station)
Intake	Main work	Excavation	(m^3)	224 x 10^3	48.9 x 10^3
		Concrete	(m^3)	24 x 10^3	8.8 x 10^3
		Reinforcing bar	(ton)	1,210	450
	Direct cost (¥10^6)			2,026	933
Headrace and penstock	Main work	Excavation	(m^3)	25 x 10^3	38 x 10^3
		Concrete	(m^3)	7 x 10^3	13 x 10^3
		Reinforcing bar	(ton)	400	255
		Gate	(ton)	500	500
		Penstock	(ton)	1,700	1,500
	Direct cost (¥10^6)			2,380	2,680
Powerhouse and tailrace	Main work	Excavation	(m^3)	115 x 10^3	99 x 10^3
		Concrete	(m^3)	20 x 10^3	19.5 x 10^3
		Reinforcing bar	(ton)	1,000	910
		Gate	(ton)	270	270
		Building	(m^3)	17 x 10^3	17 x 10^3
	Direct cost (¥10^6)			1,896	1,782
Total direct cost (¥10^6)				6,302	5,395

Fig. 6.1 COMPARISON of POWER STATION SITE PLANS

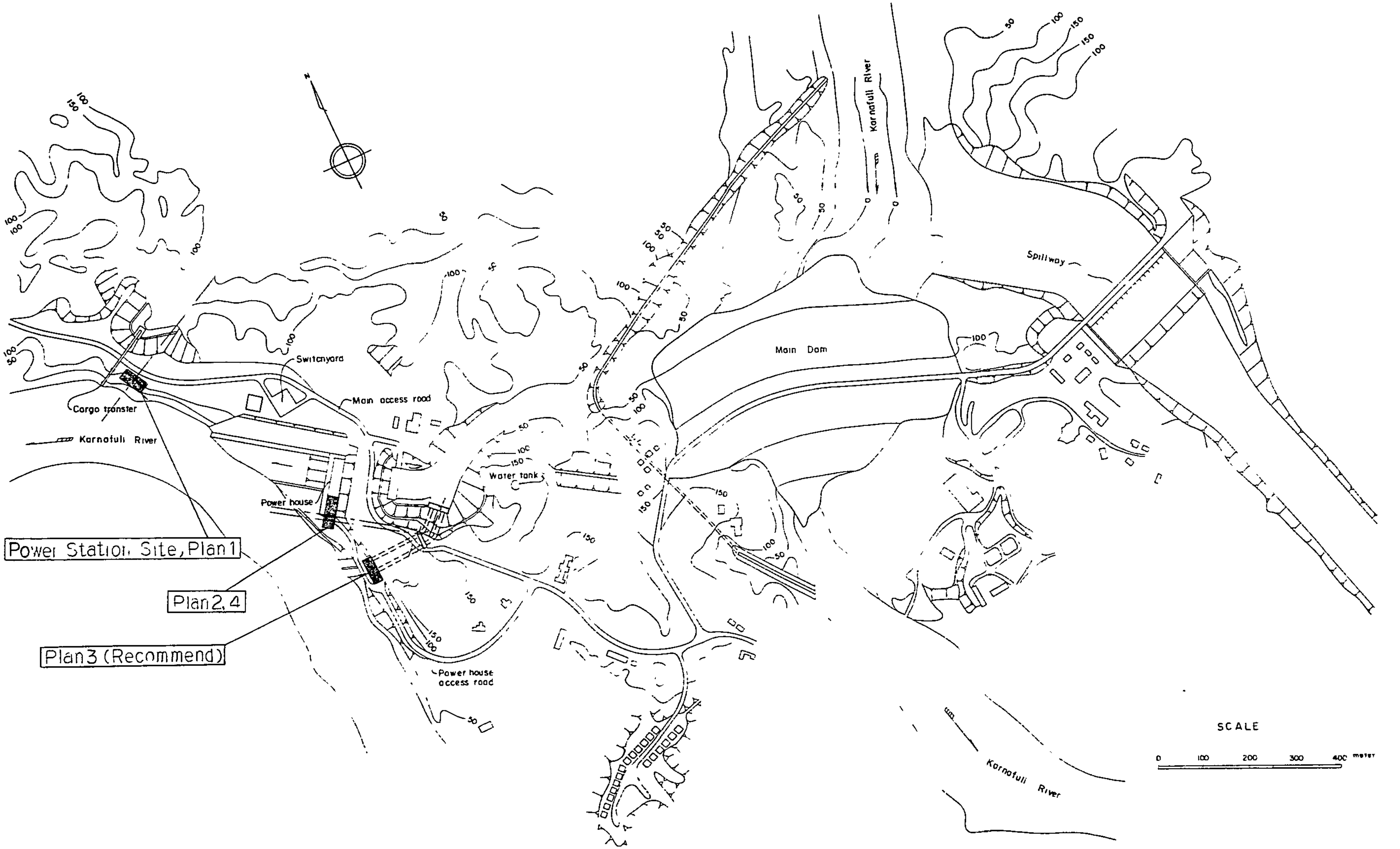
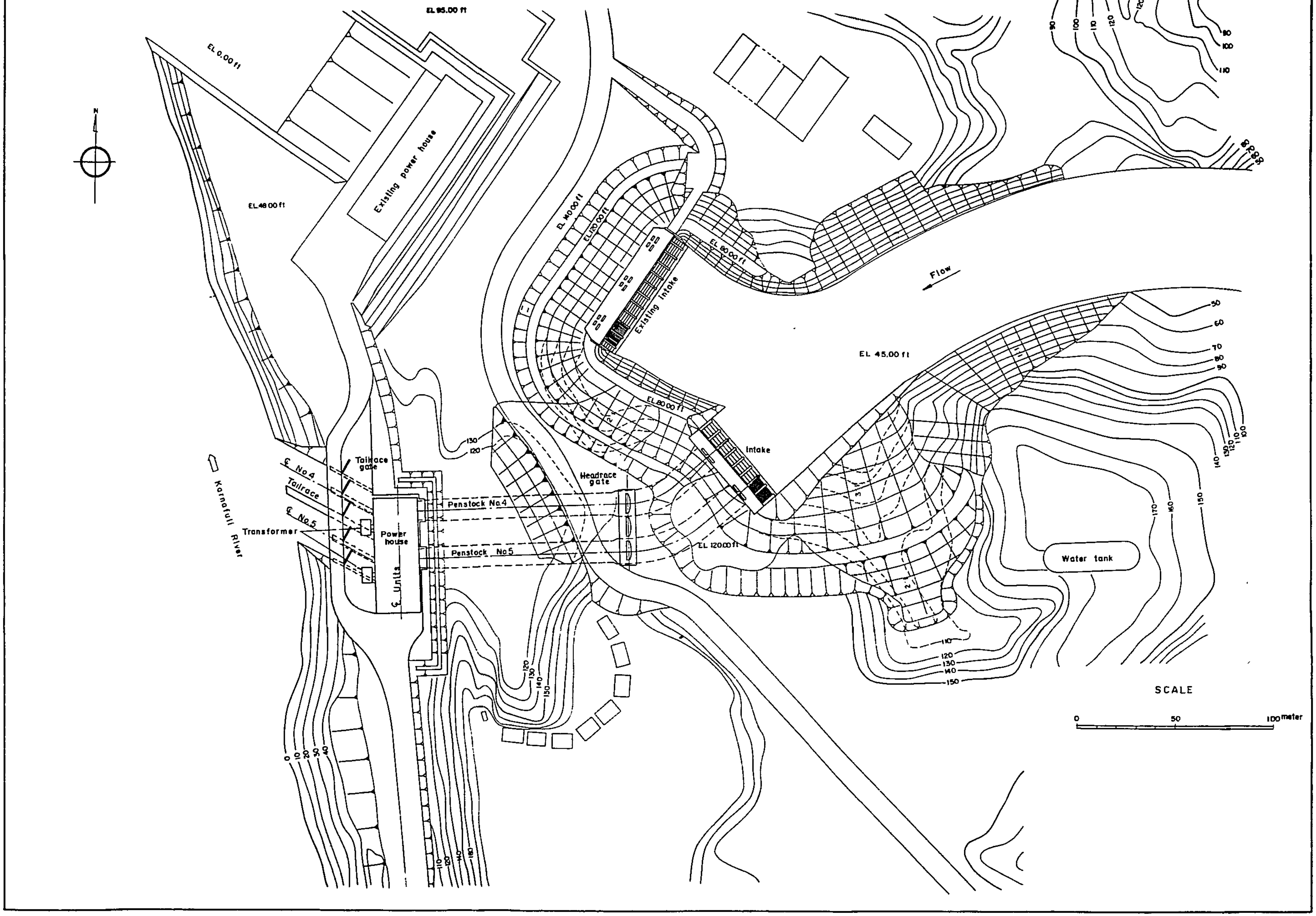


Fig.6.2 GENERAL PLAN of WATERWAY and POWER HOUSE



6-2 Preliminary Design

This preliminary design has been provided in regard to Site No. 3.

6-2-1 Topography

As shown in Fig. 6.1, the power station site is located 150 m upstream from the existing power station. There are existing access roads around the intake gate chamber and around the powerhouse, and the land form is entirely flat.

6-2-2 Geology

The ground surface at this site is covered with thin silty sand, and the ground under the silty sand is composed of comparatively dense siltstone. The silty sand which can be called surface soil is a little more thick (about 9 m) on the side of the reservoir (close to the intake site), but its thickness becomes gradually smaller toward the Karnafuli River side (the site for the proposed power station), and the surface soil is not observed at the place around the tailrace.

The siltstone, which is partially intercalated with sandstone, is hard and dense (V_p = 1,000 m/s). The surface soil at the intake and the headrace is thick, and there is considered to be some portion where overburden of rock is thin on the tunnel. Therefore, a method for securing stability of this portion should be necessary during construction.

6-2-3 Outline of Structures

Fig. 6.2 shows a general plan from waterway to powerhouse.

Regarding the general layout of all structures, the intake, powerhouse and tailrace have been completely separated from those of the existing power station in order to avoid any trouble to the existing power station in operation as described in 6.1 in the above.

(1) Intake

The forebay is widened so that the velocity of intake flow is under $\lesssim$ 0.5 m/sec. at L.W.L. Screen and stop log ditch are provided at the inlet of the intake.

The center distance between the intake for Unit 4 and that of Unit 5 is decided to be 24.4 m.

(2) Headrace

The headrace is composed of an intake tunnel and a gate shaft with a slope of 16°. The tunnel length is 50 m and 65 m, for Units 4 and 5, respectively, and the height of gate shaft is about 41 m. The intake tunnel which connects to the intake and the gate is a round-shaped tunnel with an internal diameter of 9.1 m, and it is of a reinforced concrete lining construction.

The gate shaft is of a reinforced concrete construction having a groove for the gate and serves as air hole from El. 140.0 ft.

Gates are provided for the two water channels for Units 4 and 5.

(3) Penstock

The penstock which runs from the gate shaft to the power station, is an internally steel-lined round-shaped horizontal tunnel with an internal diameter of 9.1 m, and the length each for Units 4 and 5 is 108 m.

The penstock should be designed so that it bears internal and external pressure by itself, and the external circumference of the penstock is to be filled with concrete.

(4) Powerhouse

In the powerhouse, two turbine-generator units (50 MW x 2) are to be installed, and an assembly space and a hatch for receiving equipment and materials are to be provided on the up-stream side. As a result, the plan dimensions of the powerhouse are 21.5 m in width and 57.0 m in length. The elevation of main structures in the powerhouse is as follows:

Crane rail:	EL. 94.0 ft.
Assembly room (G.L.):	EL. 49.0 ft.

Generator room:	EL. 36.0 ft.
Turbine room:	EL. 22.5 ft.
Turbine center:	EL. 5.0 ft.

At the height of EL. 49.0 ft. on the tailrace side of the powerhouse, decks for main transformer and gantry crane for handling draft gate are provided.

(5) Tailrace

The tailrace is arranged so that it will join the thalweg of the Karnafuli River at an angle of about 60° in the downstream direction. The tailrace extending to 35 m from the draft outlet is to be concrete-lined.

6-2-4 Electrical Machinery and Equipment

(1) Features

The features in selecting the types of turbines and generator for the Kaptai Hydro-Power Extension Project are as in the following:

Elevation of dam crest:	EL. 127.0 ft.
Highest water level of reservoir:	EL. 118.0 ft.
Lowest water level of reservoir:	EL. 80.0 ft.
Highest water level of tailrace:	EL. 24.0 ft.
Lowest water level of tailrace:	EL. 14.5 ft.

(2) Selection of the number turbine units

Under this extension project, it is feasible to install further 100 MW units in addition to a total output of 130 MW of Units 1, 2 and 3 of the existing power station. And, as a result of study taking into account the following factors, the number of turbine units has been decided to be 50 MW x 2 units as in the OTCA's feasibility study report.

(a) Shutdown due to failure

The unit output is studied by comparing the following two cases of combinations:

Case 1: 50 MW + 50 MW + 50 MW + 40 MW + 40 MW

Case 2: 100 MW + 50 MW + 40 MW + 40 MW

In operating a power station, it is quite natural to give consideration to shutdown of the plant.

Should a 100 MW unit in Case 2 be shut down particularly in rainy season from June through September, the damage to power supply is more serious than when a 50 MW unit is shut down in Case 1.

Even when 50 MW x 2 units in Case 1 are shut down, the extent of damage to power supply is equal. However, the probability of shutdown is higher in Case 2 when compared with simultaneous shutdown of 50 MW x two units in Case 1.

(b) Interchangeability of repair parts

There is much higher interchangeability of repair parts in case of 50 MW x 2 units than in case of 100 MW x 1 unit.

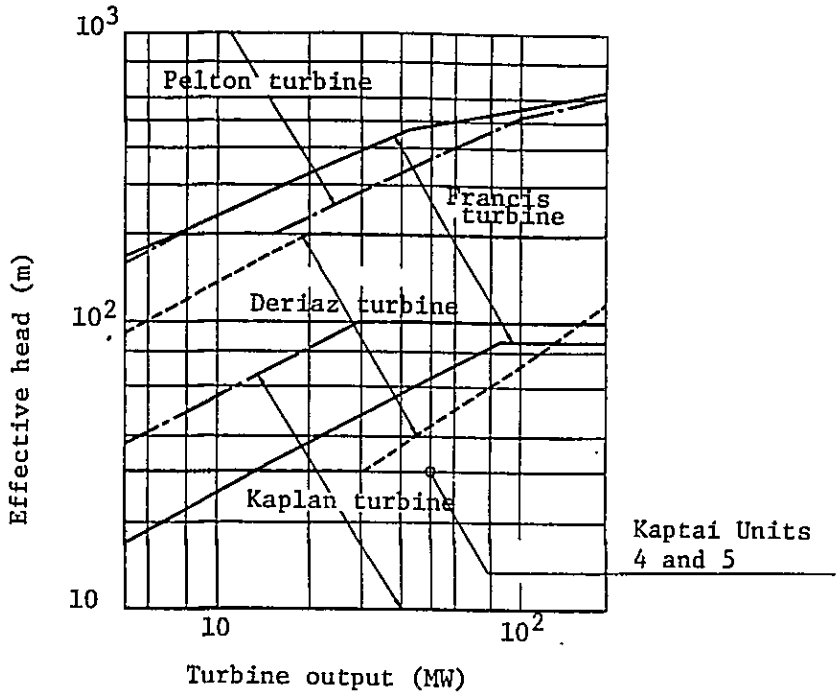
(c) Periodical inspection of turbine units

The periodical inspection of turbine units should naturally be carried out alternatively. When all unit output is the same, power failure is less in case the number of units is larger, but excessive number of units results in increase of construction cost. Therefore, it is considered appropriate to install 50 MW x two units.

(3) Type of Turbine

Since the differential head is about 14 m in contrast to the maximum effective head of 31.5 m, and unit maximum turbine discharge is about 220 m^3/s, the optimum machine applicable to these conditions is the Kaplan turbine as in the case of the existing Units 1 through 3. Therefore, the turbines are to be designed on the basis of this type.

Conditions for selecting the type of turbine



(4) Design Head

Since the effective head changes extensively from 31.5 m (103.3 ft.) to 17.5 m (45.9 ft.) due to fluctuation of the reservoir water level, the design head was decided to be 26.0 m in view of overall efficiency.

(5) Features of Turbine

(a) Trubine revolution

In view of the characteristics of turbine, the most efficient turbine revolution, N = 136.4 rpm was adopted.

(b) Elevation of turbine installation

Judging from the fact that the induction height becomes about -5.2 m (-17.0 ft.) assuming the effective head is 26.0 m and cavitation coefficient is 0.59, and the distance from spiral casing to the center of runner blades is about 2.3 m (7.5 ft.), the installation elevation of turbine is to be

EL. 5.0 ft. This is about 2.9 m (9.5 ft.) below the lowest water level of tailrace, EL. 14.5 ft.

(6) AC Generators

The AC generators to be installed for the extension of the Kaptai Hydro-Power Station are to be vertical shaft revolving field type machines and coupled directly to Kaplan turbines. The ratings of the generators are 136.4 rpm, 48-pole, 62,500 kVA, 11 kV, 11 kW, 3-phase, 50 Hz and a power factor of 0.8.

Because of low speed and large capacity machines, umbrella type generators are adopted. Assembly and disassembly of these generators are to be performed by using the overhead travelling cranes.

(7) Main Transformer

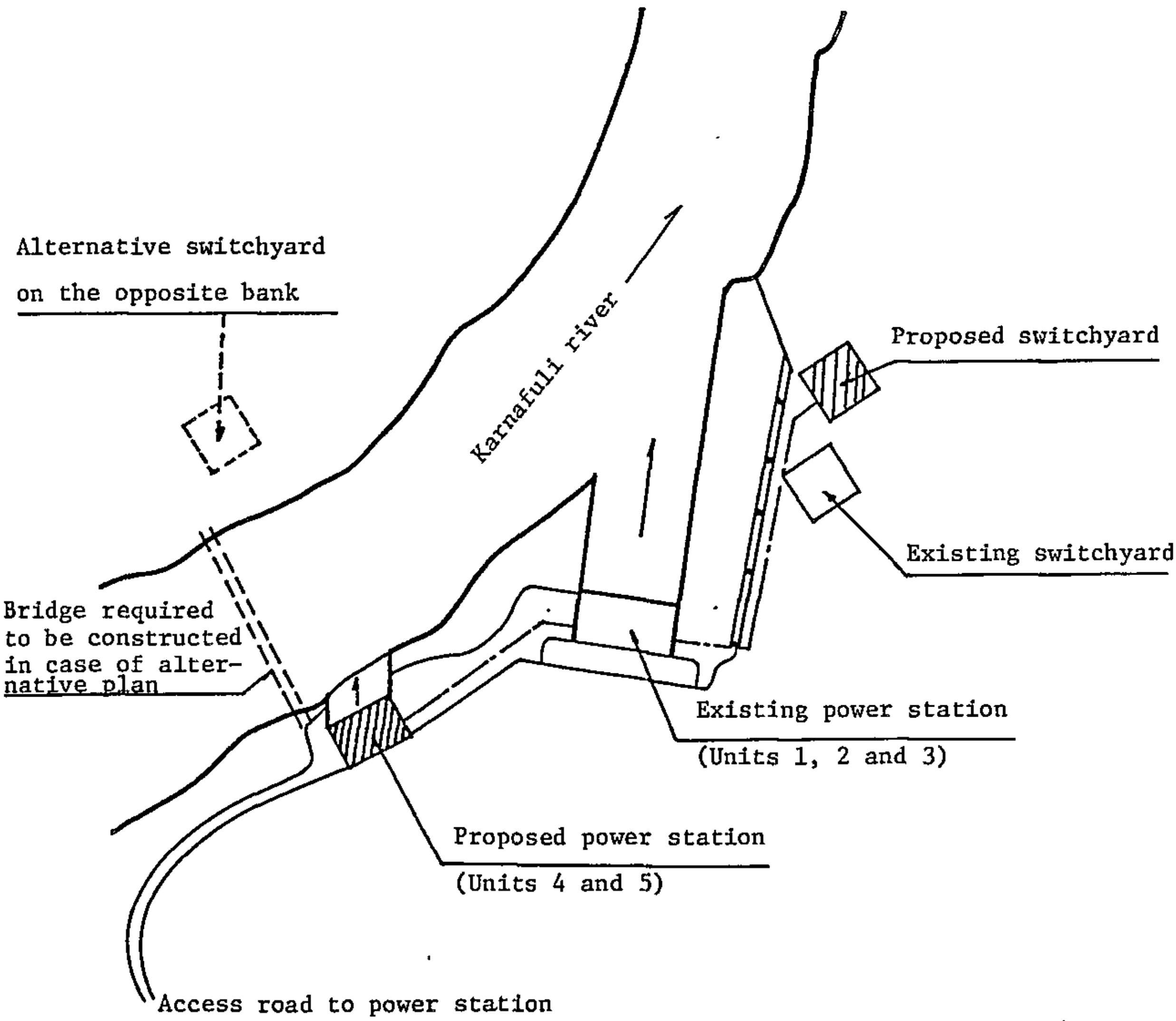
The ratings of the main transformer are 72,000 kVA, 50 Hz, 3-phase, double windings, 11 kV/132 kV, and this transformer is of outdoor, forced oil, air-cooled type.

6-2-5 Switchyard

(1) Location of switchyard

Although a plan to construct the switchyard on the opposite bank of the Karnafuli River was studied, a new bridge must be constructed in this case. Thus, this plan is not advantageous economically and technically. Therefore, the switchyard for Kaptai Hydro-Power Station is to be constructed according to the following diagram.

Since the hydro-power station to be extended and the proposed switchyard can also be interconnected by overhead lines, it is required to provide further study regarding the selection of interconnection system at the time of detail design. The construction cost in this feasibility study is estimated on the basis of cable interconnection system.


Alternative switchyard
on the opposite bank
Karnafuli river
Proposed switchyard
Existing switchyard
Bridge required
to be constructed
in case of alter-
native plan
Existing power station
(Units 1, 2 and 3)
Proposed power station
(Units 4 and 5)
Access road to power station

(2) Scale of Switchyard

The main equipment to be installed in this switchyard is listed below.

° Circuit breakers (6 units)
  132 kV, 800 A, 3,500 MVA, 3-phase, outdoor type with BCT

° Disconnecting switches (18 units)
  132 kV, 800 A, 3-phase, outdoor horizontal break

° Lightning arresters (12 units)
  132 kV, outdoor self-standing type

° Power line carrier equipment (1 unit) with 132 kV CCPD and WT

° Required land area; 0.02 km^2 (5 acres)

(3) Configuration of Bus System for Switchyard

The B.P.D.B. is conducting overall study on bus systems for substations.

So far, single bus system, double bus system, standby bus system and one-and-half circuit breaker system have been adopted in the country.

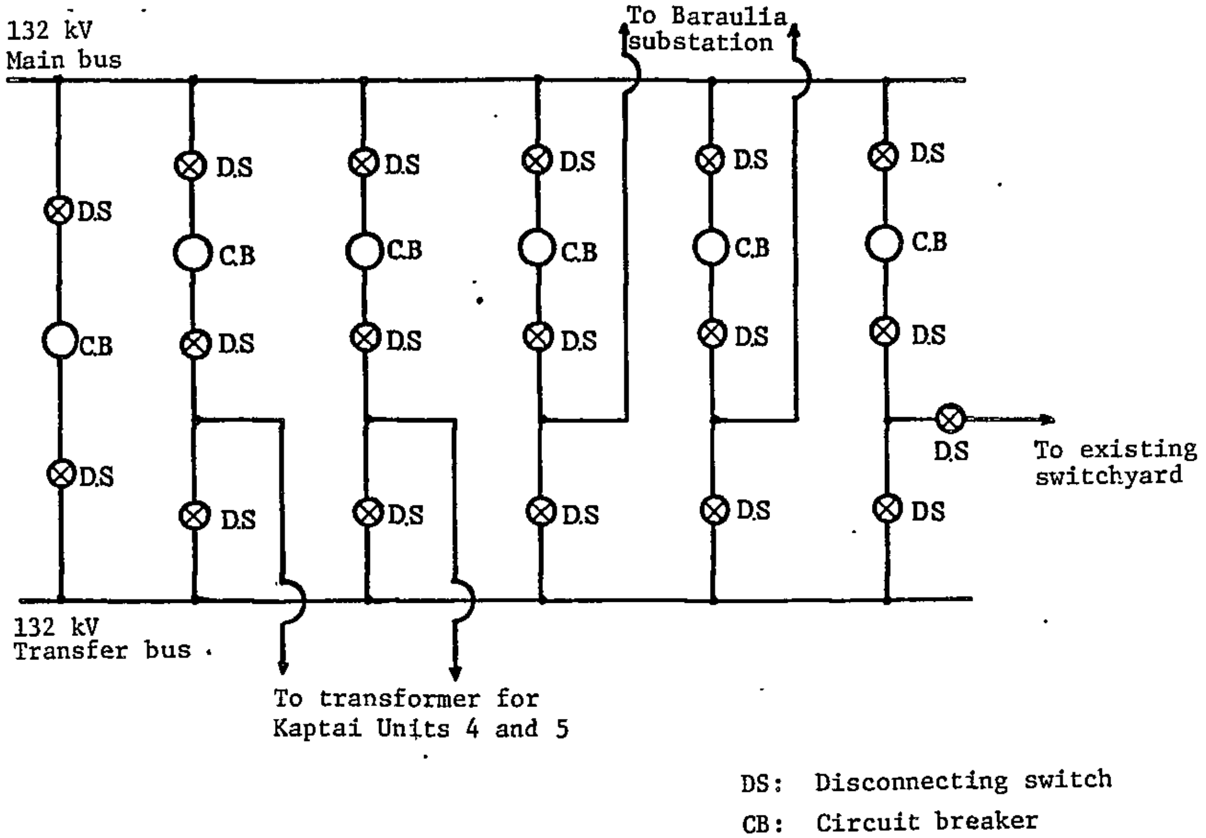
In this study, the standby bus system is adopted taking into account the following requirements:

① The circuit breaker can be inspected while it is in service.

② No serious damage should be caused to power supply in case of troubles in bus system or partial equipment.

③ The system should be operated easily.

The bus system configuration is as indicated in the following diagram:


132 kV
Main bus
To Baraulia
substation
D.S
C.B
DS
132 kV
Transfer bus
To transformer for
Kaptai Units 4 and 5
To existing
switchyard
DS: Disconnecting switch
CB: Circuit breaker

6-2-6 Transmission Line

(1) Transmission Line Route

In selecting the transmission line route between the Kaptai Hydro-Power Station and Baraulia Substation, the team carried out desk study and reconnaissance of the route by jeep.

As a result, the team has selected two transmission line routes which are considered to be optimum. These routes are required to be finally decided upon comparative study at the time of detail design.

The construction cost in this study has been estimated on the basis of Proposed Route 1.

(a) Proposed Route 1

This route is selected over hill tracts from Kaptai to Rangamati Road and along the road from Hatazali to Baraulia. Though this route passes partially through hill tracts from Hatazali to Baraulia, the route was selected over the place where has not been subject to landslide.

(b) Proposed Route 2

This route runs along the existing 132 kV transmission line between Kaptai and Madanhat. It principally runs roughly in a straight line, but it passes partially over hill tracts where are not subject to landslide.

Regarding these proposed transmission line routes, refer to Fig. 6.4.

(2) Scale of transmission line

The scale of 132 kV transmission line proposed in this study is as listed below:

(a) Transmission voltage: 132 kV

(b) Conductor size: ACSR 636 MCM (Code name: Grosbeak)

(c) Transmission capacity: About 100 MW/circuit
Circuit voltage: 126 kV

Power factor: 0.8

Length: about 90 km (56 miles)

(d) No. of circuits: two circuits

At present, the existing two circuits of 132 kV transmission lines are in service between Kaptai and Madanhat. The transmission capacity is about 200 MW. When the Kaptai Hydro-Power Station is extended according to this study, the total capacity of this power station including Units 4 and 5 is to be extended to 230 MW. Since the transmission capacity of the existing lines become insufficient when the extension project is implemented, new transmission lines are required to be constructed.

Moreover, the existing transmission lines were so far subjected to serious damage such as collapse of towers due to heavy rainfall, etc. Therefore, the new 132 kV transmission lines are required to be constructed along an entirely different route from that of the existing lines so as to improve the reliability in power supply from Kaptai Hydro-Power Station.

(3) Design Conditions

(a) Design of towers

(i) Design criteria

Steel tower design conditions are established taking into account the local meteorological conditions, design criteria of B.P.D.B., as well as design conditions of existing transmission lines and under construction.

(ii) Design conditions

° Conductors

The conductor selected for the transmission line is the Aluminum Conductor Steel Reinforced (ACSR) 636 MCM (26/7) conforming to ASTM B232. This conductor is widely used as standard conductor in Bangladesh, and has been selected by taking into consideration the interchangeability of accessories in the case of faults, repairs, etc. For the overhead grounding wire, Galvanized Steel Wire (GSC) of 9.6 mm (7/3.2 mm), conforming to JIS G-3537 and in wide use in Bangladesh has been selected.

° Selection of insulators

The selected insulator is the ball and socket type 250 mm suspension insulator conforming to BS-137. This insulator is widely used in Bangladesh as standard product. The quantity to be used has been determined in accordance with the design guidelines of B.P.D.B., i.e., 10 units of 6,800 kg (15,000 Lb) when used as suspension insulator and 11 units of 11,400 kg (25,000 Lb) when used as tension insulator.

In this project insulators made of porcelain containing alumina will be used because they exhibit excellent arc withstanding characteristics in addition to superior resistance to mechanical shock loads.

° Design of towers

The design guidelines prevailing in Bangladesh and the design conditions of existing transmission lines and those under construction have been adopted as fundamental design conditions such as wind pressure and the safety factor of the towers. However, details other than those mentioned above have been designed according to JEC 127.

[a] Type of tower and number of circuits

The number of circuits is two as described previously.

The following five types have been assumed in designing the towers:

Type A (Up to 3°)
Type B (Up to 15°)
Type C (Up to 30°)
Type D (Up to 60° or anchor) and
Type B' (for crossing)

The type A is of a suspension type while all others are of a tension type.

[b] Wind load

The following wind loads are assumed in consideration of attack of cyclone:

Maximum average wind speed:
44.4 m/sec (100 mph)

Wind pressure:
300 kg/m^2 (61.5 Lb/sq.ft)
125 kg/m^2 (25.6 Lb/sq.ft)

[c] Safety factor

Safety factors are based upon the same criteria adopted for the transmission lines under construction and have the following values.

Towers:	2.0 - normal conditions
	1.2 - abnormal conditions (rupture of conductor)
Conductors:	2.0
Ground wire:	2.3
Insulaters:	2.3 or more

[d] Aboveground height

According to the design criteria of B.P.D.B., the clearance between conductor and the ground level is to be more than 6.71 m (22 feet, at conductor temperature of 65.6°C) in normal areas.

(4) Material Transportation Method

The railroad and road networks have been more developed in the eastern zone than in the western zone. However, it is considered advantageous to transport heavy objects by means of barges as much as possible. Therefore, the equipment and materials for this project are to be transported by means of barges and trucks.

The port for unloading equipment and materials is to be Chittagong Port, a port for international trade.

The advantages of barges adopted as a means of transportation are as follows:

① It is possible to transport extremely heavy equipment such as transformers, generators, etc. only by means of barges.

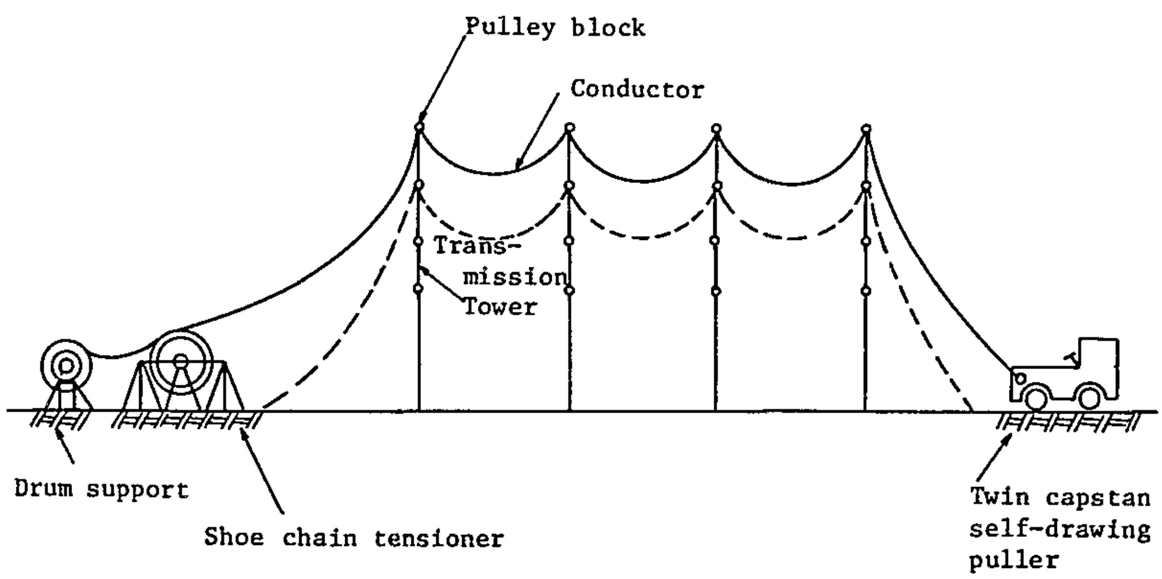
② This transportation system becomes rather advantageous in rainy season.

③ Transportation cost can be reduced substantially.

(5) Stringing Method

Presently B.P.D.B.'s stringing method depends mainly on man power and oxcarts. In view of protection of the conductors, safety, and efficiency of work, the team recommends to adopt the "non-stop stringing" method in the construction of this transmission line.

Stringing Method



6-2-7 Substation

(1) Installation of Substation

Along with the construction of this transmission line, a plan for installing the following substation has been drawn out to cope with the demand increasing in the corresponding areas. At the same time, this substation is to be constructed at optimum site in consideration of 230 kV transmission line between Dacca and Chiggagong to be undertaken in future.

- Baraulia Substation

  This substation is located on the outskirts of Chittagong and located along the route of the 230 kV transmission line between Dacca and Chittagong scheduled to be constructed under the next five year programme. Furthermore 132 kV transmission line is also scheduled to be constructed between Kulshi and Baraulia under the two year programme. Therefore, it is concluded that the 132 kV Baraulia Substation, a terminal substation from Kaptai Hydro-Power Station is to be constructed adjacent to the existing 33 kV/11 kV Baraulia Substation.

(2) Scale of Substation

- Baraulia Substation

  The main equipment to be installed in this substation is listed below.

  ° Circuit breakers (5 units)
    132 kV, 800 A, 3,500 MVA, 3-phase, outdoor type with BCT

  ° Disconnecting switches (14 units)
    132 kV, 800 A, 3-phase, outdoor horizontal break, one unit furnished with earthing switch

  ° Lightning arrester (6 units)
    132 kV, outdoor self-standing type

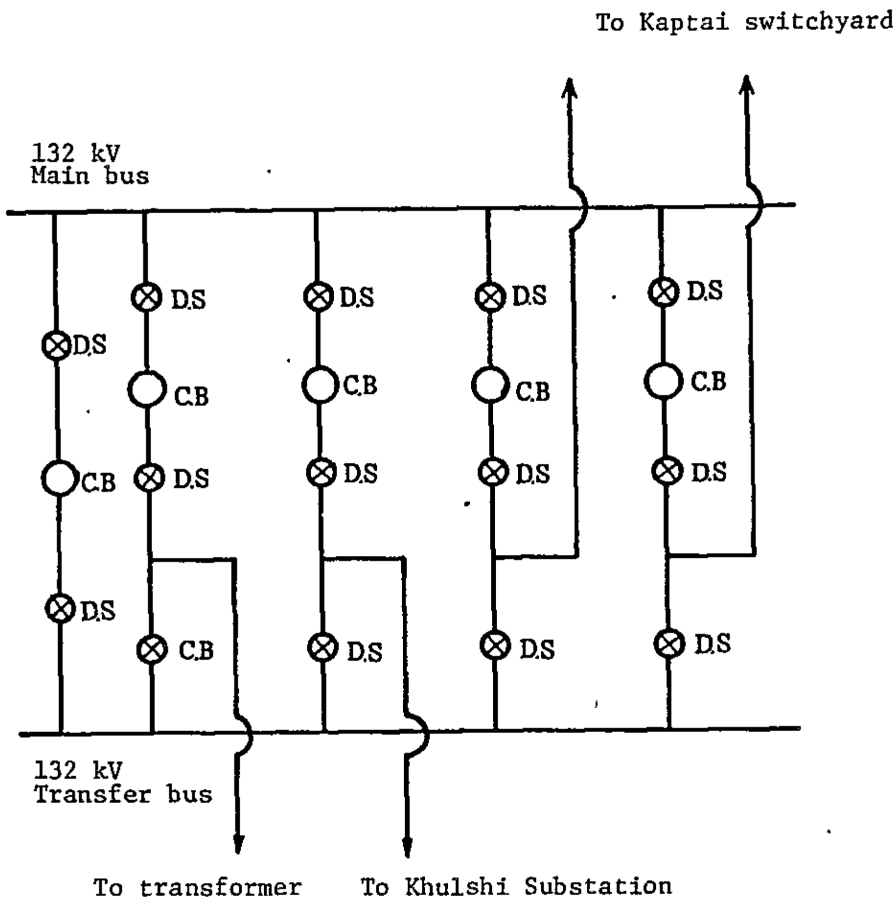
° Power line carrier equipment (1 set)
With 132 kV CCPD and WT

° Control room: 370 m^2 (0.09 acres)

° Office room: 280 m^2 (0.07 acres)

(3) Configuration of Bus System for Substation

The standby bus system is adopted for this substation, although there are some differences from the Kaptai Switchyard.



DS: Disconnecting switch

CB: Circuit breaker

Fig.6.3 KAPTAI H.P.S and SWITCHYARD SINGLE LINE DIAGRAM

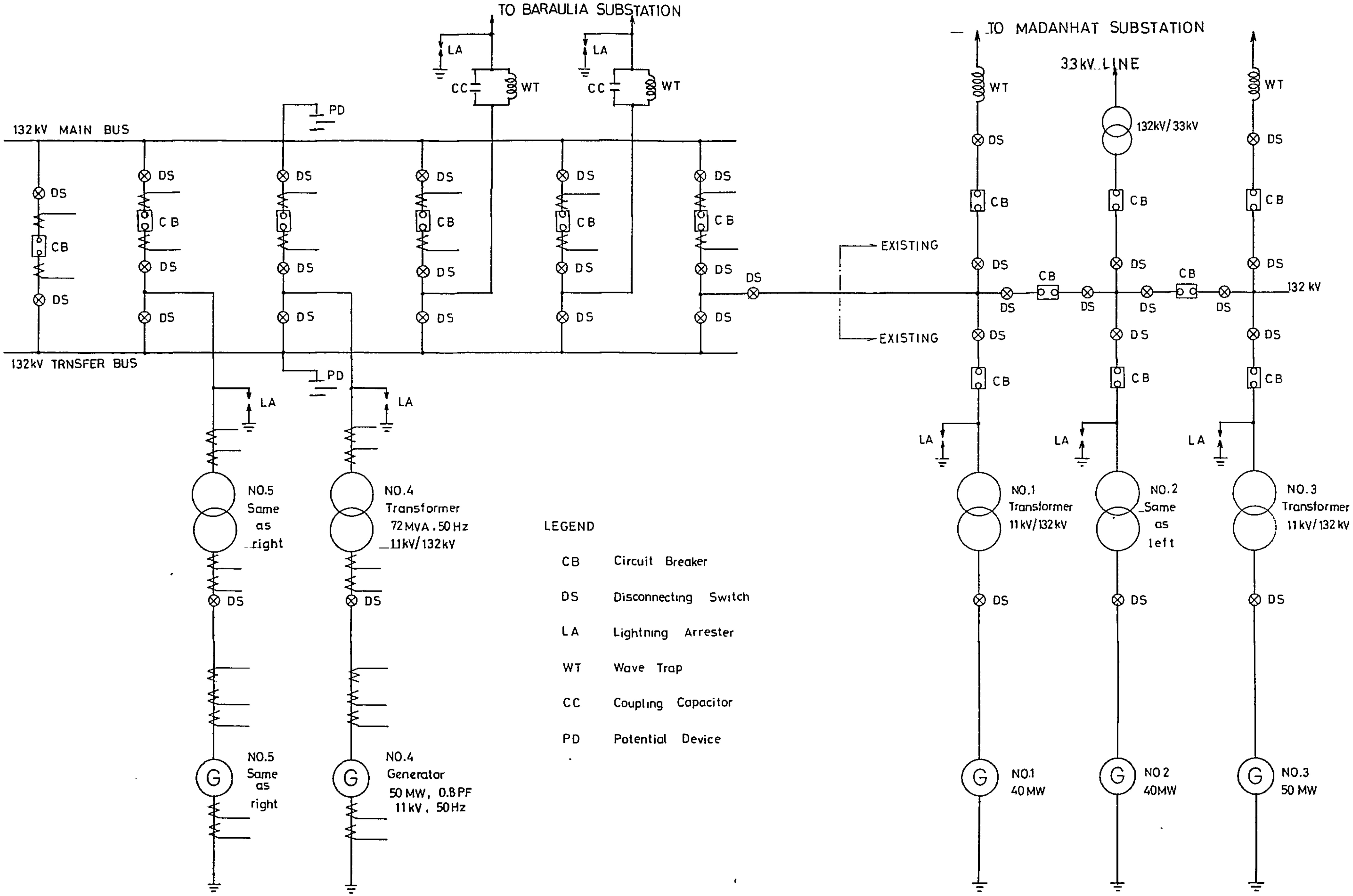


Fig. 6.4 TRANSMISSION LINE ROUTE

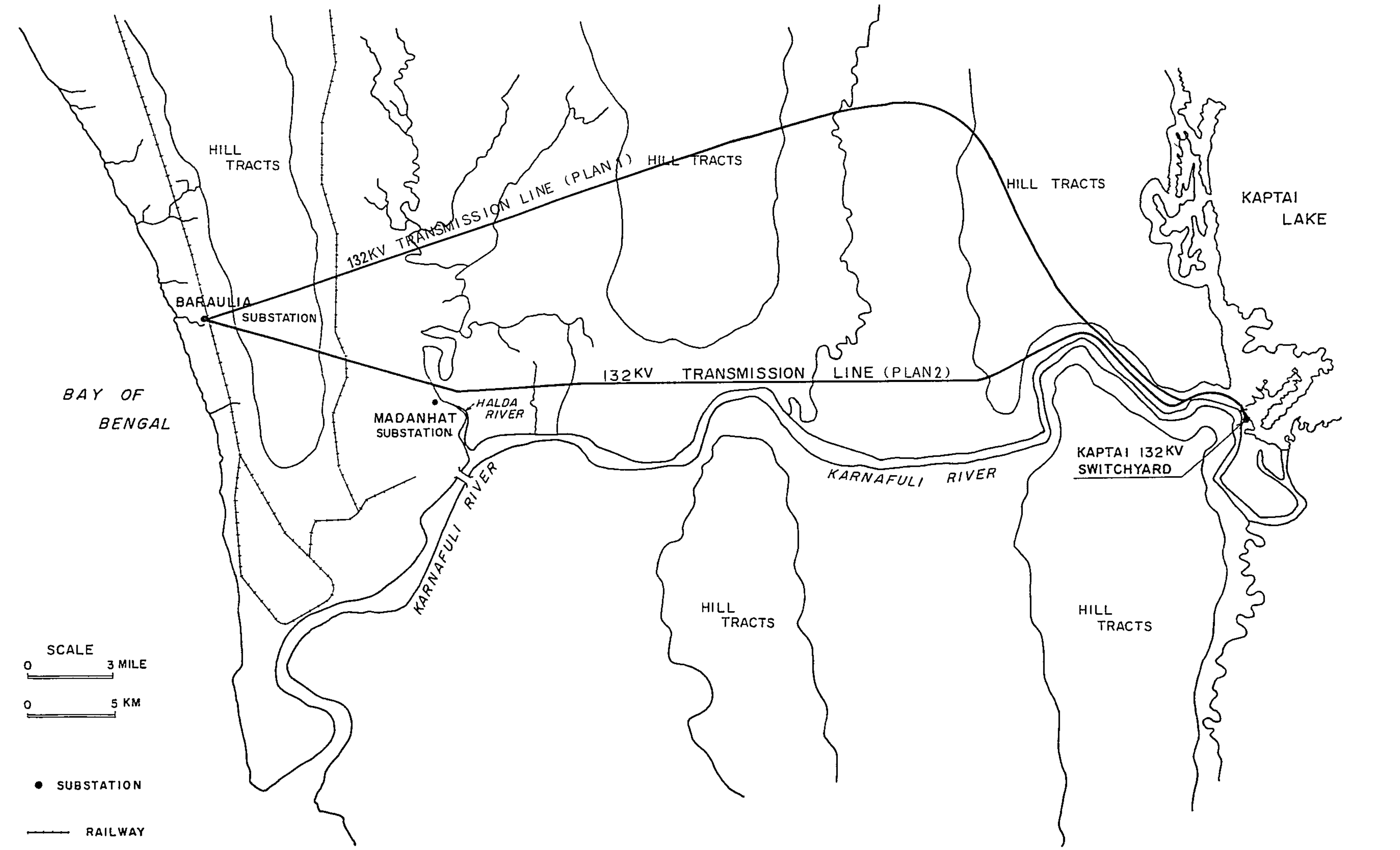
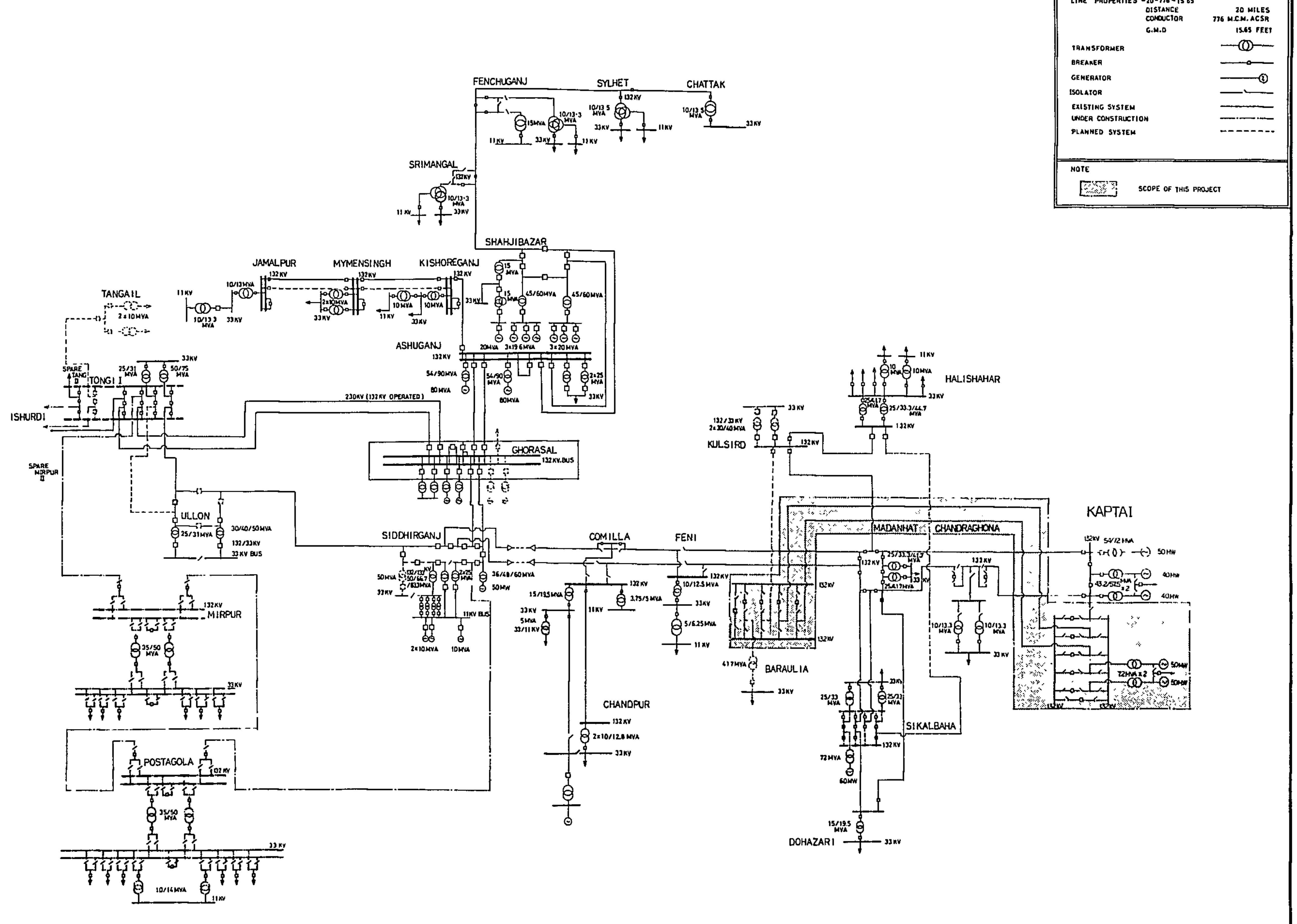


Fig.6.5 TRANSMISSION SYSTEM FOR EASTERN ZONE



6-3 Preliminary Construction Schedule

This project is the extension project of the existing Kaptai Hydro-Power Station, and the structures to be newly constructed are the intake, headrace, power plant, tailrace and other power generating facilities as well as switchyard and transmission lines.

In executing this extension project, it is necessary to give sufficient consideration so as not to cause any trouble to the existing facilities.

The construction site (the sites for material yeard, office, plant and others), the power source and road for the construction work were already prepared when the existing dam was constructed. Consequently, these are available for the extension work.

The period of this extension project required for civil and architectural work, installation and test runs of turbines and generators, is about 4 years.

6-3-1 Volume of Main Work

The volume of main works for water channel, power plant, etc. is as outlined in the following:

Excavation (open):	147,900 m^3	(193,446 yd^3)
Excavation (tunnel):	38,000 m^3	(49,702 yd^3)
Concrete:	41,500 m^3	(54,280 yd^3)
Grouting		
Mortar:	700 m^3	(916 yd^3)
Cement:	1,300 m^3	(1,700 yd^3)
Reinforcement work:	1,615 t	(359 x 10^4 ℓb)

6-3-2 Main Construction Materials

The main construction materials to be used for this extension work are as outlined in the following:

Cement :	11,000 t (2,444 x 10^4 ℓb)	(Procured locally)
Reinforcing bars:	1,615 t (359 x 10^4 ℓb)	(Procured mainly from other country)
Aggregates :	75,000 t (16,670 x 10^4 ℓb)	(Procured locally)

Steel materials	:	3,800 t (844 x 10^4 ℓb)	(Procured from other country)
Wood	:	2,000 m^3 (2,616 yd^3)	(Procured locally)
Fuel	:	2,400 kℓ (527,940 gal.)	(Procured locally)

6-3-3 Method for the Execution of Work

Hereunder is the outline of the method for the execution of the work:

General

° For material yard, concrete plant and place for soil disposal, the space on the downstream side from the dam is to be used.

° For storage of equipment and materials, such as turbines, generators and others to be imported from other country and transported to the work site, a stock yard of about 5,000 m^2 (53,750 $ft.^2$) is to be established.

° Prior to the commencement of the work for intake and power plant, a road for bypassing the work site is to be established for general traffic.

° Heavy equipment and materials, and aggregates are, in principle, to be transported by barges from the Chittagong Port, while others are to be land-transported.

Intake

° Temporary coffering of the intake is to be provided by driving sheet piles into the bedrock, and the cofferdam should be reinforced when necessary so that it can bear the external hydraulic pressure.

° Since the space to be coffered is also used as yard for penstock work, this space must be as wide as possible, and such work should be executed under dry condition.

° Excavation for enlargement of the forebay outside the cofferdam should be performed by underwater excavation.

Headrace tunnel

° The upper half section of the tunnel should preferably be excavated in advance.

° All excavation muck is to be transported to the upstream side by dump trucks.

° When necessary during excavation, the tunnel should be protected by support, roof bolts or gunite shooting, and the final concrete lining should be performed after the penstock has been set in place.

° After completion of concrete lining, consolidation grouting is to be performed around the tunnel.

Penstock tunnel

° The upper half section of the tunnel is to be excavated in advance from the power plant side, and excavation muck should be transported to the power plant side by dump trucks.

° Penstock pipes are to be transported from the intake side and installed in order from the power plant side. Then, concrete is to be filled around the penstock.

Power plant and tailrace

° Fill-type dam is to be used for temporary coffering of the tailrace, and the crest serves as the access road to the downstream area.

° When necessary, the excavation slope face is to be reinforced by rock bolts or by gunite shooting.

6-3-4 Construction Schedule and Execution System

(1) Construction schedule

The Units 4 and 5 are to be put into operation on June 1985 and December 1985, respectively in the light of electric power demand and B.P.D.B.'s intention.

The construction schedule for this extension project is as shown in Fig. 6.6 Tentative Construction Time Schedule. The period required for preparatory works and execution of other works is as described in the following:

The fundamental requirement particularly in executing this project is that commencement of work, procurement and transportation of equipment to the site should be carried out in strict conformity with the respective schedules, not to mention the selection of excellent contractors and manufacturers.

Period from preparation to commencement of work:
About 14 months

Period of construction work:
About 45 months

Breakdown:

Civil and architectural work:
About 34 months

Design and fabrication of electrical equipment:
About 18 months

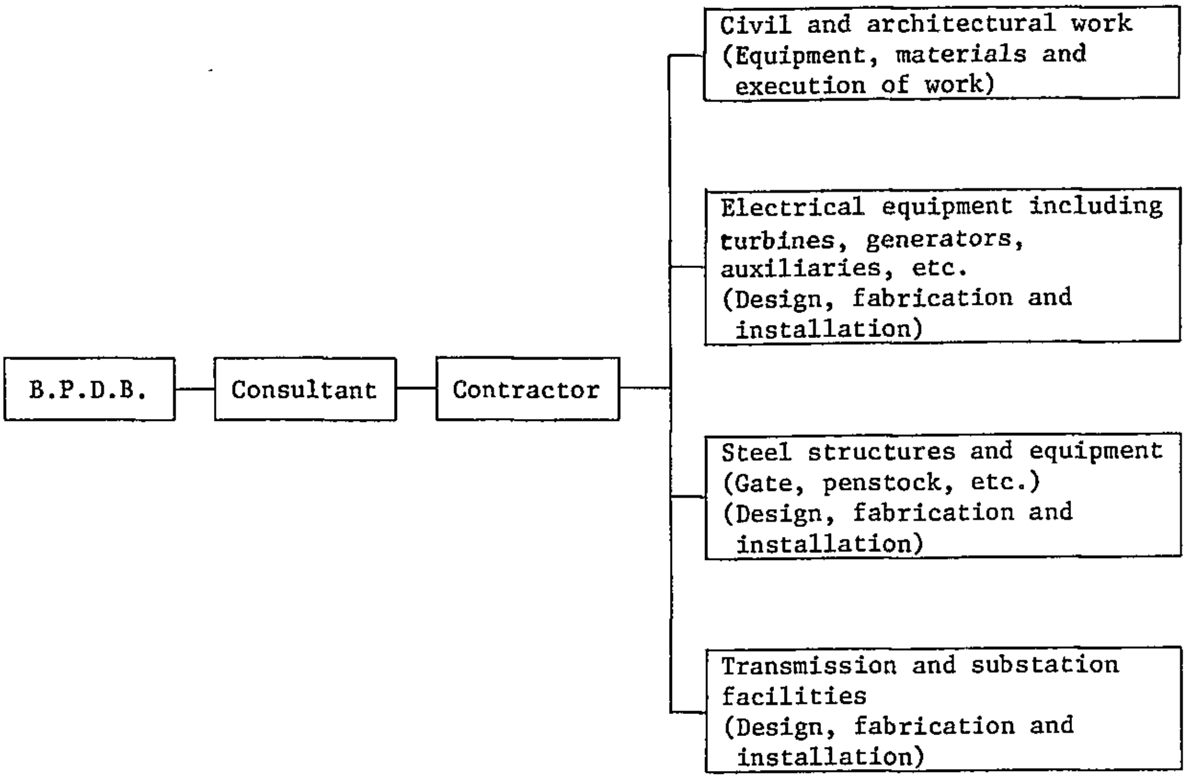
Installation and test runs of electrical equipment:
About 19 months

Gates and penstock:
About 10 months

(2) Work execution system

This work should be implemented according to the execution system shown in the following diagram to attain smooth progress of the work.

Work Execution System



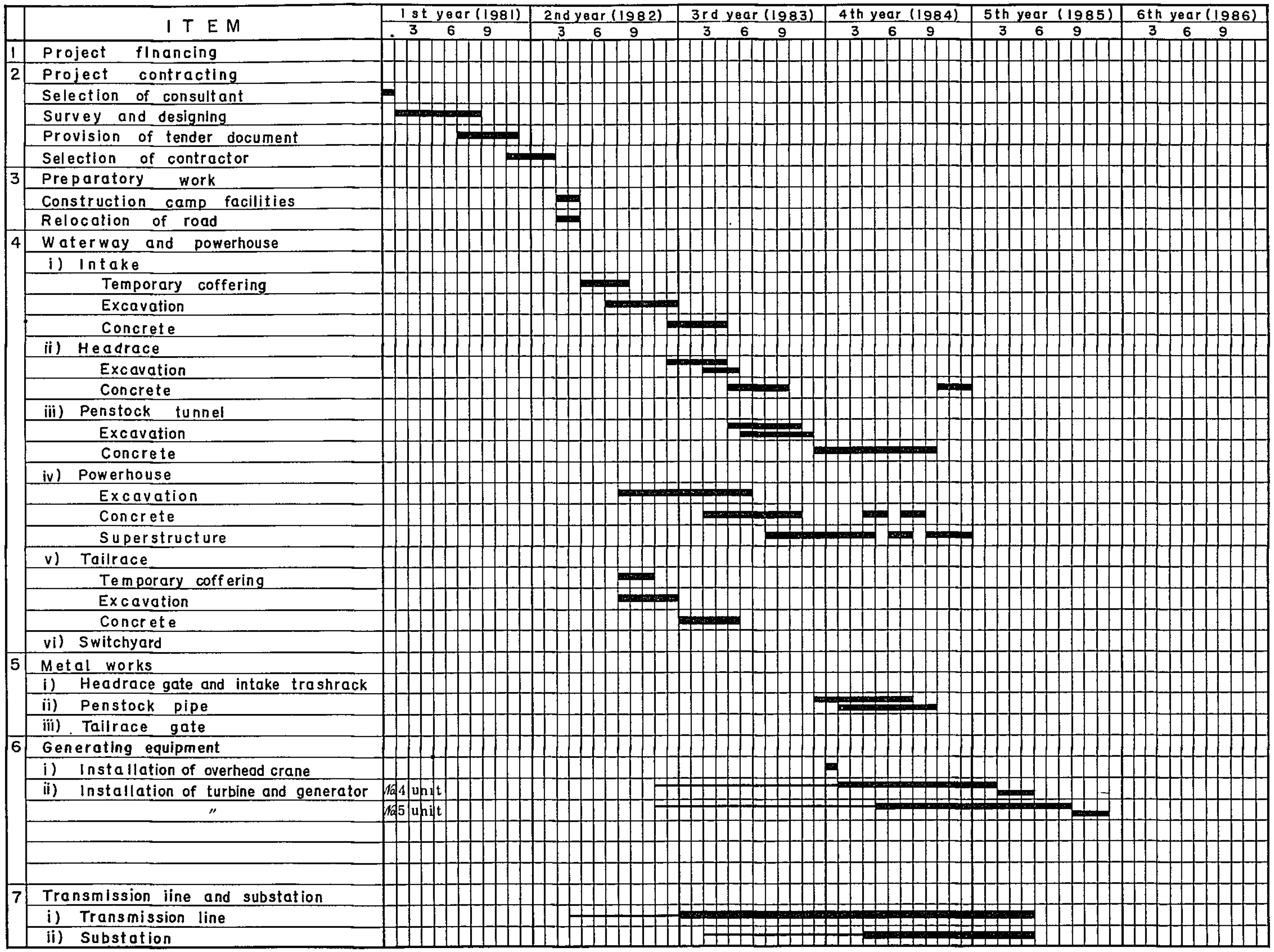
Reference: Breakdown of approximate construction cost for the above works

(Unit: 10^6 TK)

Cost items	Construction cost	Foreign currency portion
Civil and architectural work	364.8 (4,852)	176.5 (2,348)
Electrical equipment	528.3 (7,026)	430.4 (5,724)
Steel structures and equipment	144.8 (1,926)	119.2 (1,586)
Transmission and substation equipment	220.5 (2,933)	127.4 (1,694)
Consultant (Engineering)	73.3 (975)	64.9 (863)
Total	1,331.7 (17,712)	918.4 (12,215)

Note: Values in parentheses show construction cost in Yen.

Fig. 6.6 TENTATIVE CONSTRUCTION TIME SCHEDULE



CHAPTER 7

REQUIRED TOTAL INVESTMENT AND DISBURSEMENT PLAN

CHAPTER 7 REQUIRED TOTAL INVESTMENT AND DISBURSEMENT PLAN

7-1 Conditions of Construction Cost Estimation

The construction cost has been estimated as described in the following by giving consideration to natural and local conditions, scale of the project, technical level of local constructors and other conditions:

7-1-1 Materials

Main materials which can be procured locally are cement, gravels, sand and reinforcing bars. The materials other than the above are to be imported from foreign countries. The annual cost escalation factor is assumed to be 6% on imported materials and 9% on materials to be procured locally.

(1) Imported Materials

(a) The specifications and quantity of various materials have been prepared taking into account design and construction.

(b) Escalation factor is incorporated in the prices up to 1983/84.

(c) Import duties and inland transportation cost
The following rates have been determined on the basis of the results of meeting between B.P.D.B. and the survey team on August 20, 1980.

- Duties and taxes : 2.5% of CIF cost
- Landing charge :
- Storing charge :
- Handling charge :
- Transportation :

(Landing, storing, handling and transportation charges: 3% of CIF cost)

(2) Locally Procured Materials

(a) Information on locally procured materials was mainly obtained from the following sources:

- Main and field offices of B.P.D.B.
- Local manufacturers
- Private contractors
- Other sources in Dacca

(b) Cement

Cement produced in Chittagong from imported raw materials, and that produced integratedly in Sylhet in the northern part of the People's Republic of Bangladesh corresponds to 80% of the total domestic demand. The remaining 20% is imported, but since it is subject to Government price control, whether procured locally or imported, the price is the same.

There will be no problem since projects related to the Government are favored with priority supply allocations.

(c) Gravels and sand

Gravels and sand are produced only in Sylhet area. Some are imported from India and the cost is high because of tight supply. Therefore, it has been decided to use less expensive bricks as substitute for cobble stones and lean concrete where high strength is not required.

(d) Reinforcing bars

Reinforcing bars and other steel products are produced only at the local steelworks, the Chittagong Steel Works, which supplies one-third of domestic demand. The remaining two-third is imported from various countries in the form of intermediate steel products which are finished into final products by specialized processing plants in the major cities.

As in the case of cement, prices of steel products are under control of the Government.

7-1-2 Manpower

(1) Wages

(a) Local workers

Information on the wages of local workers was obtained from B.P.D.B. and at the project site. It seems that although unskilled workers are available locally, skilled workers are concentrated in the big cities and it is difficult to hire such workers unless special allowance is paid to let them work at project site. The prevailing rate of such allowance is about 30% of basic wages.

The annual escalation rate of wages is assumed to be 9%.

(b) Manpower availability and skill levels

Unskilled workers are considered to be secured sufficiently because of a densely populated country. However, available number of such workers changes during the farming season and slack season. Therefore, it is necessary to pay particular attention in view of work schedule control.

7-1-3 Others

(1) Field Establishment:
3% of direct cost in local currency portion.
Field expenses required for construction office and others for supervision.

(2) Overhead Costs:
6% of direct cost in local currency portion

(3) Physical Contingency:
10% of the total of direct cost, indirect cost and price escalation contingency.

Expenses in consideration of changes (other than price escalation) which cannot be expected at the time of planning.

(4) Price Contingency

Estimated on the basis of 9% price escalation a year after 1984/85.

(5) Training Fee

Training of ten (10) engineers of the B.P.D.B. on planning, design, maintenance and operation for four months

(6) Interest during Construction

5% a year (This interest rate corresponds to 5% of 50% of the total of direct cost, indirect cost and contingencies in each year during the construction period)

(7) Exchange Rate

1 TK = ¥13.3

7-2 Required Investment

The total required investment for this project is as follows:

Total required investment: TK 1,331.7 x 10^6
(About ¥17,712 x 10^6)

Foreign currency: TK 918.4 x 10^6
(About ¥12,215 x 10^6)

Local currency: TK 413.3 x 10^6
(About ¥5,497 x 10^6)

1) Regarding the total required investment, refer to Table 7.1.

2) Regarding the breakdown of construction cost, refer to Table 7.2.

7-3 Disbursement Plan

The disbursement plan has been established as a result of study on the basis of the work schedule as shown in Table 7.3.

Table 7.3 Disbursement Plan

Amount \ Years	'80/'81	'81/'82	'82/'83	'83/'84	'84/'85	'85/'86	Total
Foreign currency (10^6 Yen)	75 (5.6)	1,218 (91.6)	2,421 (182.0)	4,945 (371.8)	2,466 (185.4)	1,090 (82.0)	12,215 (918.4)
Local currency (10^6 TK)	1.7	33.2	71.1	149.8	95.4	62.1	413.3
Total (10^6 TK)	7.3	124.8	253.1	521.6	280.8	144.1	1,331.7

(Note): The values in parentheses show 10^6 TK converted from Yen.

Table 7.1 Total Required Investment

	Foreign currency		Local currency	Total
	¥1,000	(TK1,000)	TK1,000	TK1,000
1. Direct cost				
1) Waterway and powerhouse	8,525,000	(641,000)	186,900	827,900
Intake	535,000	(40,200)	26,400	66,600
Headrace	665,000	(50,000)	27,600	77,600
Penstock tunnel	1,100,000	(82,700)	33,900	116,600
Powerhouse	590,000	(44,400)	44,700	89,100
Tailrace	345,000	(25,900)	12,100	38,000
General equipment	4,840,000	(363,900)	27,100	391,000
Switchyard	340,000	(25,600)	8,300	33,900
Temporary equipment	110,000	(8,300)	6,800	15,100
2) Transmission line and substation	1,450,000	(109,000)	66,200	175,200
3) Transportation and shipping cost	0	(0)	28,900	28,900
Subtotal	9,975,000	(750,000)	282,000	1,032,000
2. Indirect cost				
1) Field management cost	69,000	(5,200)	3,300	8,500
2) General administrative expenses	46,000	(3,500)	13,400	16,900
3) Engineering fee	790,000	(59,400)	2,300	61,700
4) Training fee	40,000	(3,000)	0	3,000
Subtotal	945,000	(71,100)	19,000	90,100
Total	10,920,000	(821,100)	301,000	1,122,100
3. Price contingency	224,000	(16,800)	11,000	27,800
4. Physical contingency	1,071,000	(80,500)	34,500	115,000
5. Interest during construction period	0	(0)	66,800	66,800
Total	12,215,000	(918,400)	413,300	1,331,700

(Note): The values in parentheses show TK converted from Yen.

Table 7.2 Breakdown of Construction Cost (Direct Cost)

Items	Quantity	Unit	Unit Cost (¥)	Amount (¥10^3)	Foreign currency (¥10^3)
1. Waterway and powerhouse				11,011,000	8,525,000
1) Intake				886,000	535,000
Temporary coffering	1	set		250,000	
Excavation (outdoor)	48,900	m^3	2,900	141,810	
Concrete	8,800	"	23,000	202,400	
Reinforcing bar	450	t	140,000	63,000	
Screen	330	"	600,000	198,000	
Miscellaneous work	1	set		30,790	
2) Headrace				1,032,000	665,000
Excavation (tunnel)	12,500	m^3	14,000	175,000	
Excavation (vertical shaft)	3,500	"	19,000	66,500	
Concrete (tunnel)	4,800	"	33,000	158,400	
Concrete (vertical shaft)	2,050	"	33,000	67,650	
Reinforcing bar	160	t	140,000	22,400	
Gate	500	"	1,000,000	500,000	
Miscellaneous work	1	set		42,050	
3) Penstock tunnel				1,551,000	1,100,000
Excavation (tunnel)	22,000	m^3	14,000	308,000	
Concrete	6,000	"	23,000	138,000	
Reinforcing bar	95	t	140,000	13,300	
Steel pipes	1,500	"	700,000	1,050,000	
Miscellaneous work	1	set		41,700	
4) Powerhouse				1,185,000	590,000
Excavation (outdoor)	80,000	m^3	2,900	232,000	
Concrete	17,000	"	23,000	391,000	
Reinforcing bar	850	t	140,000	119,000	
Building	17,000	m^3	24,000	408,000	
Miscellaneous work	1	set		35,000	
5) Tailrace				506,000	345,000
Temporary coffering	1	set		60,000	
Excavation (outdoor)	19,000	m^3	2,900	55,100	
Concrete	2,500	"	23,000	57,500	
Reinforcing bar	60	t	140,000	8,400	
Gate	220	"	1,000,000	220,000	
Gantry crane	50	"	1,500,000	75,000	
Miscellaneous work	1	set		30,000	
6) Generating equipment				5,200,000	4,840,000
Turbine	1	set		1,900,000	
Generator	1	"		1,700,000	
Transformer	1	"		80,000	
Switchboard	1	"		200,000	
Crane	1	"		300,000	
Installation and instruction	1	"		900,000	
Miscellaneous work	1	"		120,000	
7) Switchyard	1	set		451,000	340,000
8) Temporary equipment	1	set		200,000	110,000

Items	Quantity	Unit	Unit Cost (¥)	Amount (¥10^3)	Foreign currency (¥10^3)
2. Transmission line and substation				2,331,000	1,450,000
1) Transmission line	1	set		1,718,000	897,000
2) Substation	1	set		613,000	553,000
3. Transportation and shipping cost	1	set		384,000	0
Total				13,726,000 (1,032,000)	9,975,000 (750,000)

Note: Values in parentheses show the construction cost in TK.

CHAPTER 8

ECONOMIC EVALUATION

CHAPTER 8 ECONOMIC EVALUATION

Stable supply of energy is a serious problem for Bangladesh, a non-oil producing country. Thus, the country is greatly looking forward to the extension of Kaptai Hydro-Power Station which does not consume fossil fuel.

In this chapter, this extension project is studied in regard to economic feasibility of this project.

8-1 Preconditions and Data

8-1-1 Generated Energy

The generated energy was estimated on the basis of the following concept: Namely, on the assumption that Units 4 and 5 to be extended are operated by using surplus discharge through operation of the existing Units 1, 2 and 3.

The generated energy of Units 1 through Unit 5 according to the new rule curve is as shown in Case 3 of Table 5.8 and the generated energy of Units 1 through Units 3 is as listed in Case 4. The values obtained by reducing the values in Case 4 from those in Case 3 are assumed to be the generated energy satisfying the above conditions. These values are summarized in Table 8.1. Additional total yearly generated energy of 211 x 10^6 kWh in this table is applied in this study as the electric energy to be generated each year by Units 4 and 5.

However, the generated energy of Units 4 and 5 in 1985/86 is assumed to be 140 x 10^6 kWh, two-third the above yearly generated energy.

8-1-2 Relationship between Load and Maximum Generated Power

The results of estimating the monthly maximum generated power of the respective power stations locating in the Chittagong area and covering the load in this area in 1993/94 are shown as one example in Table 8.2 and Fig. 8.1. This estimation is made on the assumptions that the final power loss is 20% (Chapter 4) and the load factor is 0.63 in this year. The monthly figures are introduced from the monthly maximum values in the past.

Fig. 8.1 Monthly Maximum Generated Electric Power in Chittagong Area in 1993/94

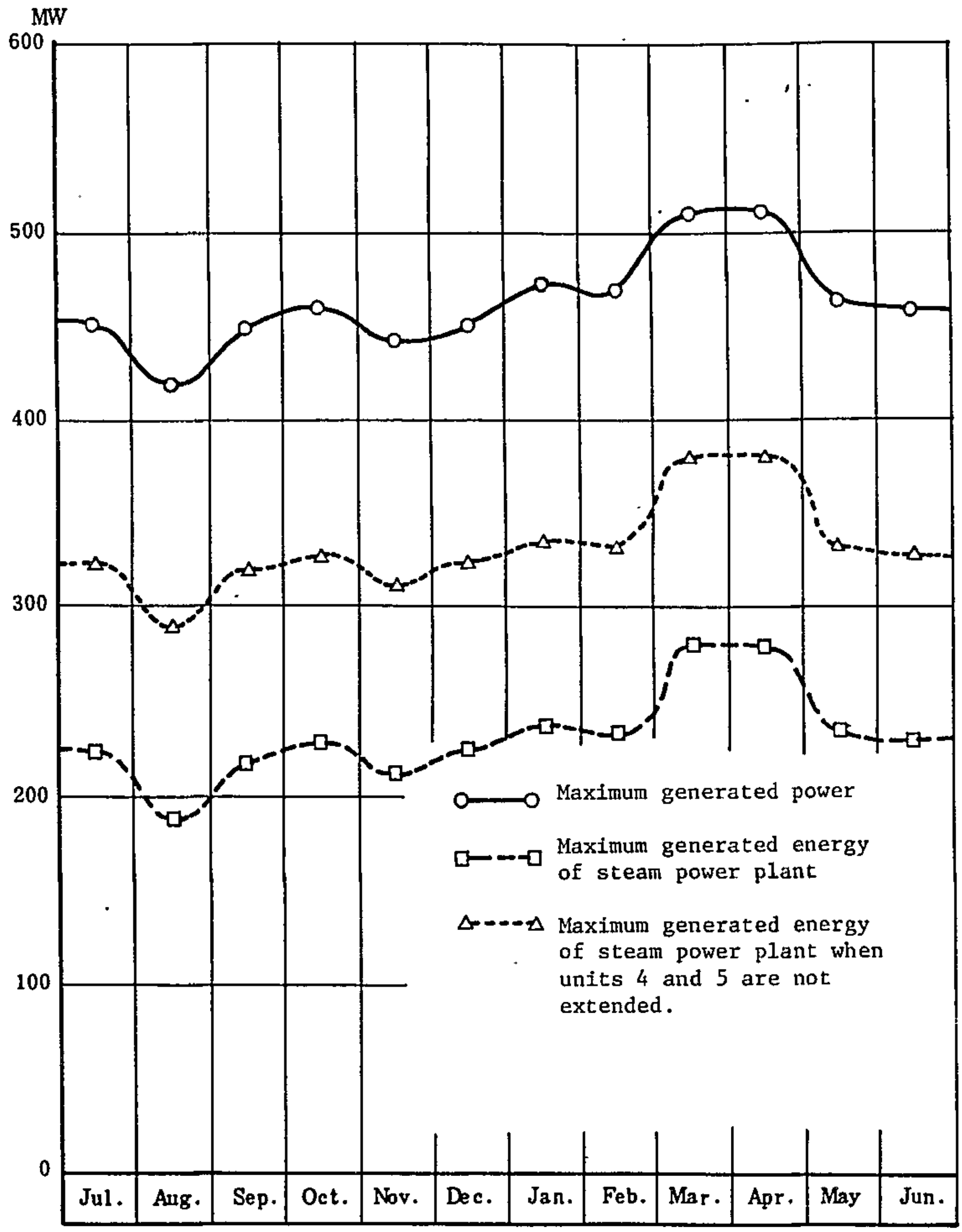


Table 8.1 Energy Generated by Units 4 and 5

(Unit: 10^6 kWh)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Average total in Case 3	57.9	76.7	68.6	70.2	86.4	104.9	140.4	155.0	120.2	63.4	78.0	67.2	1,089
Average total in Case 4	57.9	76.6	68.8	65.3	71.2	73.8	89.8	97.6	93.4	53.6	58.6	71.4	878
Generated energy by No. 4 & 5	0	0.1	-0.2	4.9	15.2	31.1	50.6	57.4	26.8	9.8	19.4	-4.2	211

Though almost no energy is assumed to be generated by Units 4 and 5 in dry season in 8-1-1, these units are actually to be operated in peak hours by decreasing the output of Units 1 through 3. Therefore, the Units 4 and 5 are expected to play a role to cover the peak load particularly in dry season.

8-1-3 Operation Cost of Each Power Station

(1) Kaptai Hydro-Power Station

The cost of water through is deemed to be zero, and the additional maintenance cost required for Units 4 and 5 is assumed to be TK5 million a year.

Table 8.2 Maximum Generated Energy in Chittagong Area in 1993/94

	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.
Maximum generated power	453	422	448	458	443	453	468	463	509	509	463	458
Maximum generated power by Kaptai Units 1 through 3	130	130	130	130	130	130	130	130	130	130	130	130
Maximum generated power by 4.5 units	100	100	100	100	100	100	100	100	100	100	100	100
Maximum generated power by other than Kaptai Hydro-Power Station	223	192	218	228	213	223	238	233	279	279	233	228

(2) Steam power plant

(a) Fuel cost (Natural gas)

The price of natural gas purchased by the B.P.D.B. in Dacca area is TK0.22/m^3 (6.25 TK/Mcft) as of 1979/80. The price has been raised to this level at an annual average rate of 15.5% for the past ten years.

Natural gas constitutes only one fossil fuel resource produced in Bangladesh, and the government places great emphasis on the development of natural gas fields. Besides, the present price of natural gas is depressed to much lower level than the international price level. When taking above factors into consideration, the price is assumed to be raised at about the same annual average rate in the future.

Thus the price will become TK0.52/m^3 (14.84 TK/Mcft) in Dacca area in 1985/86 when Units 4 and 5 are to be commissioned. Moreover, since natural gas has to be transmitted to Chittagong area, the purchase price of natural gas to be fired at the steam power plant is assumed to be 20% higher than that in Dacca area, namely, TK0.63/m^3 (17.8 TK/Mcft).

The amount of natural gas consumed per kWh is calculated to be 0.338 m^3 (0.01195 Mcft) through the data in 1978/79.

Accordingly, fuel cost per kWh becomes:

$$0.63 \text{ TK} \times 0.338 \doteqdot 21 \text{ paisa } (17.8 \text{ TK} \times 0.01195 \doteqdot 21 \text{ paisa})$$

The fuel cost in 1985/86 and after is fixed at this value in this study.

(b) Running and maintenance cost

Assuming 9% escalation up to 1985/86 and taking the past records in consideration, the running and maintenance cost is estimated to become 12.8 paisa/kWh a year.

The operation and maintenance cost is fixed at this value in 1985/86 and after.

8-1-4 Expenses for other than Power Generation

The expenses for other than power generation, namely expenses for transmitting, distributing, sales, management, etc. spent by the B.P.D.B. in 1977/78 was 15.9 paisa per generated kWh. When taking into account an escalation of 9% a year, these expenses are estimated to become 31.6 paisa/kWh in 1985/86. This value is fixed in 1985/86 and after.

8-1-5 Revenue from Sold Energy

The new rate revised in 1980 is 100 paisa/kWh in average. This value is fixed in 1985/86 and after in this study.

8-1-6 Construction Cost for this Project

The construction cost described in Chapter 7 in terms of TK is as listed in Table 8.3 on disbursement basis (TK 1 = ¥13.3).

Table 8.3 Construction cost for Kaptai Hydro-Power Station Extension

(Unit: 1 million in TK and Yen)

Years	80/81	81/82	82/83	83/84	84/85	85/86	Total
Cost in Yen	97	1,660	3,367	6,937	3,735	1,916	17,712
Cost in TK	7	125	253	522	281	144	1,332

8-1-7 Term of Running

The term of running of the power station applied in the calculation for economic analysis is decided 30 years.

8-1-8 Discount Rate

Both 10% and 15% discount rate are adopted for comparison with the alternative plan and the B/C ratio.

8-2 Comparison with Alternative Plan

As described in 8-1-2, the Kaptai Hydro-Power Station is intended to cover the peak load in peak hours. Therefore, if this extension project is not implemented, other steam power plant is required to be constructed to cover the peak load. As an alternative plan, it is considered optimum in view of purchase of land, common use of auxiliary equipment and convenience of operation to construct a single unit 100 MW natural gas firing steam power plant adjacent to the 60 MW Silalbaha Steam Power Station.

8-2-1 Construction Cost

The construction cost of the steam power plant is estimated on the basis of the price level in 1983/84 as in the case of Kaptai Hydro-Power Station. The period of construction is assumed to be two years from July 1983 through June 1985. The breakdown of the construction cost is as shown in Table 8.4, and the cash flow is assumed to be constant in these two years.

8-2-2 Operation Cost

The yearly operation cost of the respective power plants is estimated as shown in Table 8.5 according to generated energy in 8-1-1 and operation cost in 8-1-3.

Table 8.4 Construction Cost of 100 MW Steam Power Plant

(Unit: 1 million TK)

	Cost items	Amount
1	Preparatory work	1.52
2	Building	36.75
3	Residential for employees	8.05
4	Boiler Plant	190.54
5	Turbine-generator Plant	265.97
6	Auxiliary equipment	103.39
7	Foundation and installation	187.70
8	Substation Plant	103.65
9	Foundation for and installation of substation equipment	30.69
10	Transport and construction machines	16.89
	Sub Total	945.15
1	Engineering and Supervising	29.14
2	Custom's duties	132.09
3	Several charges	66.05
4	Field establishment	58.62
5	Contingency	36.93
6	Overhead expenses	36.93
7	Interest during construction	152.65
	Total	1,457.56

Table 8.5 Operation Cost of Respective Power Stations

	Types of Plants	Generated energy (10^6 kWH)	Fuel cost		Running Maintenance Cost		Total
			Unit cost (16^6 TK)	Total (10^6 TK)	Unit Cost (TK)	Total (10^6 TK)	(10^6 TK)
Cost per year after 1985/86	Kaptai Units 4 and 5	211	0	0		5.0	5.0
	Steam power plant	220	0.21	46.2	0.128	28.2	74.4
Cost in 1985/86	Kaptai Units 4 and 5	140	0	0		5.0	5.0
	Steam power plant	146	0.21	30.7	0.128	18.7	49.4

Note: Generated energy is calculated on the assumption that 0.8% of generated energy is consumed at a hydro-power station, and 5% of generated energy is consumed at a steam power plant as station service energy. Power loss from the respective power plants to consumers is assumed to be the same.

Table 8.6 Present Values for Each Power Station

(Unit: 10^6 TK)

Project	Remarks		80/81	81/82	82/83	83/84	84/85	85/86	86/87 - 2014/15		Total
									1 year	Total	
Extension of Kaptai Units 4 and 5	Construction cost		7	125	253	522	281	144			1,332
	Operation cost							5	5	145	150
	Total		7	125	253	522	281	149	5		1,482
	Discount rate: 10%	Coefficient	1,000	0.9091	0.8264	0.7513	0.6836	0.6209			
		Present value	7	114	209	392	192	93		29	1,036
	Discount rate: 15%	Coefficient	1.000	0.8696	0.7561	0.6575	0.5718	0.4972			
		Present value	7	109	191	343	161	74		16	901
Construction of 100 MW steam power plant	Construction cost					729	729				1,458
	Operation cost							49.4	74.4		2,207
	Total					729	729	49.4			3.665
	Discount rate: 10%	Coefficient				0.7513	0.6836	0.6209			
		Present value				548	498	31		433	1,510
	Discount rate: 15%	Coefficient				0.6575	0.5718	0.4972			
		Present value				479	417	25		242	1,163

Note: The following formula is applied in calculating the present value for 1986/87 through 2014/15:

$$PV = a\ [\ (1 - X^{35}) - (1 - X^{6})\ ] \div (1 - x)$$

Where,

PV: Present value

a : Actual value in each year from 1986/87 through 2014/15.

$x : \frac{1}{1 + r}$

r : Discount rate

8-2-3 Comparison with Alternative Plan

The cost converted into the present value by using the data described in 8-2-1 and 8-2-2, employing the discount rate of 10% and 15%, is shown in Table 8.6.

These are summarized as follows:

$$\frac{\text{Steam power plant cost}}{\text{Hydro-power plant cost}} = \frac{1,510}{1,036} = 1.46$$

In case of 15% discount rate:

$$\frac{\text{Steam power plant cost}}{\text{Hydro-power plant cost}} = \frac{1,163}{901} = 1.29$$

When each cost is compared according to the least cost method, it has been concluded that the Kaptai Hydro-Power Extension Project is far more advantageous than the alternative plan.

Other advantages in the hydro-power plant over the steam power plant are:

(a) Troubles occur more frequently in steam power plant than hydro-power plant. Shutdown of a steam power plant results in instable power supply and causes serious damage to consumers. Moreover, excessive amount of fuel has to be spent to start up the shutdown plant.

(b) Maintenance of a hydro-power plant is easier than that of a steam power plant.

(c) Invaluable escalation of natural gas price in the future, should result serious affect upon operation and maintenance of a steam power plant. On the other hand, a hydro-power plant is not so seriously subject to inflation as in the case of a steam power plant.

8-3 Financial Analysis

Financial analysis is carried out in respect to the internal rate of return and the B/C ratio by using the data described in 8.1.

Generated energy in 1985/86:	140×10^6 kWh
Generated energy after 1985/86:	211×10^6 kWh
Yearly operation cost of Units 4 and 5:	5×10^6 TK
Total loss:	20%
Sales power rate/kWh:	1 TK
Expenses for other than power generation/kWh:	0.316 TK

Using above data and 0.8% loss the income by only units 4 and 5 I'

$$I' = \text{Generated energy} \times (1 \times 0.8 - 0.316)$$

When 5×10^6 TK of operation cost is deducted from I', the net income from Units 4 and 5 becomes as follow:

Net income in 1985/86:	62.7×10^6 TK
Net income after 1985/86:	97.1×10^6 TK

8-3-1 Internal Rate of Return (I.R.R.)

The construction cost and the net income in case the discount rate is 5% and 6% become as shown in Table 8.7 according to a supplementary method.

$$\text{I.R.R.} = 5\% + \frac{1,201 - 1,150}{(1,201 - 1,150) + (1,119 - 1,003)} = 5.37\%$$

8-3-2 B/C Ratio

The following B/C ratio was obtained by using the data in Table 8.7:

In case of 10% discount rate:

$$B/C = \frac{604}{1,003} = 0.60$$

In case of 15% discount rate:

$$B/C = \frac{347}{883} = 0.39$$

Table 8.7 Calculation Process for Financial Analysis

(Unit: 10^6 TK)

Remarks			80/81	81/82	82/83	83/84	84/85	85/86	86/87 - 2014/15		Total
									1 year	Total	
Construction cost			7	125	253	522	281	141			1,332
Net income								62.7	97.1	2,816	2,878.7
Discount rate: 5%	Coefficient		1.000	0.9524	0.9070	0.8638	0.8227	0.7835			
	Present value	Construction cost	7	119	229	451	231	113			1,150
		Net income						49		1,152	1,201
Discount rate: 6%	Coefficient		1.000	0.9434	0.8900	0.8396	0.7921	0.7473			
	Present value	Construction cost	7	118	225	438	223	108			1,119
		Net income						47		986	1,033
Discount rate: 10%	Coefficient		1.000	0.9091	0.8264	0.7513	0.6836	0.6209			
	Present value	Construction cost	7	114	209	392	192	89			1,003
		Net income						39		565	604
Discount rate: 15%	Coefficient		1.000	0.8696	0.7561	0.6575	0.5718	0.4972			
	Present value	Construction Cost	7	109	191	343	161	72			883
		Net income						31		316	347

8-4 Other Benefits

Other benefits which can be brought about according to the extension of Kaptai Hydro-Power Station are as outlined in the following lines:

8-4-1 Saving of fossil fuel

This project is intended to make effective use of non-effective discharged water resource, and should this project be implemented, it will become possible to save valuable fossil fuel which will make the import of chemicals cut down if it is used for the production of chemicals. Moreover, it will be possible to save foreign currency if natural gas is liquefied and exported.

8-4-2 Stablized power transmission

In relation to this project, construction of two circuits of transmission lines is also proposed in this study. In the past, the existing transmission lines were subjected to collapse due to flood thereby making it impossible to transmit power from the Kaptai Hydro-Power Station. As a result, reservoir water was discharged uselessly and consumers in the Chittagong area experienced serious troubles due to load fluctuation. When taking into all these facts, it is considered to be largely beneficial to extend the power station in view of effective use of water source and power supply at stable load.

8-4-3 High quality power supply

A hydro-power station permits easy output control and enables to cope with load fluctuation. The higher the ratio of hydro-power source is to the total power source, the lower the fluctuation in voltage and frequency in the total power system is. In this sense, this project is also beneficial.

8-4-4 Increased opportunity for maintenance and inspection

Implementation of this project provides opportunity for executing maintenance and inspection of Units 1, 2 and 3 thereby making it possible to avoid occurrence of troubles.

APPENDIX

1. THE TEAM ACTIVITIES IN THE FIELD SURVEY

2. STORAGE FUNCTIONAL METHOD

3. LIST OF RUNOFF AND DISCHARGE IN EACH CASE

4. GENERATED ELECTRIC ENERGY OF
   KAPTAI HYDRO-POWER STATION

5. PLANS
   (1) GENERAL LAYOUT
   (2) GENERAL PLAN
   (3) PROFILE of WATERWAY NO. 4
   (4) PROFILE of WATERWAY NO. 5
   (5) INTAKE PLAN
   (6) INTAKE SECTION
   (7) POWERHOUSE FLOOR PLAN EL.49.00
   (8) POWERHOUSE FLOOR PLAN EL.22.50
   (9) POWERHOUSE FLOOR PLAN EL. 5.00
   (10) POWERHOUSE TRANSVERSE SECTION
   (11) POWERHOUSE LONGITUDINAL SECTION
   (12) POWERHOUSE DOWNSTREAM ELEVATION

6. FEASIBILITY OF KAPTAI HYDRO-POWER EXTENSION
   PROJECT BY PUMPED STORAGE POWER PLANT

1. THE TEAM ACTIVITIES IN THE FIELD SURVEY

Field Survey (Site Survey)

No.	Date	Day	Place	Time	Activity	Participant	Contents	Remarks
1	3/1	Sat.	Bangkok	11:00 17:10	Lv. Narita Ar. Bangkok	Iwata, Nakano, Ouchida and Murata		
2	3/2	Sun.	Bangkok			"		
3	3/3	Mon.	Dacca	16:45 18:05	Lv. Bangkok Ar. Dacca	"	Discussion with Mr. Tateishi on survey (work) schedule	Joined with Mr. Tateishi
4	3/4	Tue.	Dacca	8:30	Japanese Embassy JICA office and B.P.D.B.	All members	Courtesy visit	
5	3/5	Wed.	Dacca	8:30	B.P.D.B.	B.P.D.B. staff	Meeting on survey (work) schedule	Mr. Munim Mr. Isulam Mr. Rahman Mr. Kabir, etc.
6	3/6	Thu.	Dacca	8:30	B.P.D.B.	B.P.D.B. staff	Signing of S/W, M/M and presentation of list of materials required	
7	3/7	Fri.	Dacca Via Chittagong Kaptai	9:30 10:20	Lv. Dacca Ar. Chittagong	Iwata, Nakano, Ouchida, Murata and counterparts		Trip, parted from Mr. Tateishi
8	3/8	Sat.	Kaptai	8:30	Kaptai Hydro- Power Station	All members, counterparts and staff of power station	Meeting on survey schedule, collection of data and site survey	

No.	Date	Day	Place	Time	Activity	Participant	Contents	Remarks
9	3/9	Sun.	Kaptai	10:00	Internal meeting	All members	Arrangement of collected data and meeting on survey schedule	
10	3/10	Mon.	Kaptai	8:30 10:00	Kaptai Hydro-Power Station Chandraghona district	All members, counterparts and staff of power station Iwata, Nakano, Ouchida and counterparts	Survey on operation conditions of power station Survey of downstream areas on boat	
11	3/11	Tue.	Kaptai	8:30	Power station areas	Iwata, Nakano and counterparts	Detail survey of proposed sites for the extension project	
			Chittagong	9:00	Lv. Kaptai Ar. Chittagong	Ouchida, Murata, counterparts and branch staff	Survey of transmission line route and collection of data	Trip
12	3/12	Wed.	Kaptai	8:30	Power station areas	Iwata, Nakano and counterparts	Detail survey of proposed sites for the extension project	
			Chittagong	8:30	B.P.D.B. branch	Ouchida, Murata, counterparts and branch staff	Data collection	
13	3/13	Thu.	Kaptai	8:30	Rashyapara district	Iwata, Nakano and counterparts	Survey of upstream areas on boat	
			Chittagong	8:30	B.P.D.B. branch	Ouchida, Murata, counterparts and branch staff	Data collection	

No.	Date	Day	Place	Time	Activity	Participant	Contents	Remarks
14	3/14	Fri.	Kaptai	8:30	Kaptai Hydro-Power Station	Iwata, Nakano, counterparts and staff of power station	Data collection	
			Chittagong	8:30	Shikalbaha Power Station	Ouchida, Murata and counterparts	Survey of thermal power station and substation	
15	3/15	Sat.	Kaptai	8:30	Kaptai Hydro-Power Station	Iwata, Nakano, counterparts and staff of power station	Data collection	
			Chittagong	8:30	B.P.D.B. branch	Ouchida, Murata, counterparts and branch staff	Data collection	
16	3/16	Sun.	Kaptai	8:30	Rangamati district	Iwata, Nakano and counterparts	Survey of upstream areas on boat	
			Chittagong	10:00	Internal meeting	Ouchida, Murata and counterparts	Arrangement of collected data and meeting on survey schedule	
17	3/17	Mon.	Chittagong	9:00 15:00	Lv. Kaptai Ar. Chittagong	Iwata and Nakano	Survey of trans-mission line route	Trip, joined with Mr. Murata
			Dacca	11:00 12:30 14:00	Lv. Chittagong Ar. Dacca B.P.D.B.	Ouchida B.P.D.B. staff	Meeting	Trip

No.	Date	Day	Place	Time	Activity	Participant	Contents	Remarks
18	3/18	Tue.	Chittagong Dacca	8:30 10:00 17:30 18:20	B.P.D.B. branch Chittagong district Lv. Chittagong Ar. Dacca	Iwata, Nakano, Murata, and branch staff Nakano, Murata Iwata, Nakano and Murata	Data collection Survey of trans-mission line route	Trip, joined with Ouchida
19	3/19	Wed.	Dacca	8:30	B.P.D.B., Embassy of Japan and JICA Office	All members and B.P.D.B. staff	Report of site survey	
20	3/20	Thu.	Dacca	8:30	B.P.D.B. B.W.B.D. and Survey of B	All members and B.P.D.B. staff Iwata, Nakano and counterparts	Data collection and meeting Aerial photographing Request of maps	
21	3/21	Fri.	Dacca	8:30	B.P.D.B. LANDSAT Center	All members and Mr. Kabir Iwata, Nakano and counterparts	Data collection and discussion Request of photographs from LANDSAT	
22	3/22	Sat.	Dacca	8:30	B.P.D.B. Survey of B	All members and Mr. Murtafa Nakano and counterparts	Data collection and discussion Obtaining of maps	
23	3/23	Sun.	Dacca	10:00	Internal meeting	All members	Arrangement of collected data and meeting	

No.	Date	Day	Place	Time	Activity	Participant	Contents	Remarks
24	3/24	Mon.	Dacca	8:30	B.P.D.B. LANDSAT Center	All members and Mr. Murtafa Iwata, Nakano and counterparts	Obtaining of data for economic appraisal Obtaining of photo-graphs	
25	3/25	Tue.	Dacca	8:30	B.P.D.B. Survey of B	All members and Mr. Murtafa Nakano and counterparts	Hearing on electric power demand forecast Obtaining of maps	
26	3/26	Wed.	Dacca	8:30	B.P.D.B. Siddhirgang Power Station Internal meeting	All members Ouchida, Murata and counterparts All members	Data collection Survey of thermal power station Discussion on the report of site survey	
27	3/27	Thu.		8:30	B.P.D.B. Embassy of Japan, JICA office	All members and B.P.D.B. staff	Report on site survey Courtesy visit	
28	3/28	Fri.	Bangkok	19:25 22:40	Lv. Dacca Ar. Bangkok	All members	Preparation for return to Japan	
29	3/29	Sat.		9:50 17:20	Lv. Bangkok Ar. Narita	All members	Return to Japan	