INTERIM REPORT
ON
KARNAFULI HYDRO-POWER PROJECT
EAST PAKISTAN

MARCH 1968

GOVERNMENT OF JAPAN

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Preface

In order to undertake a study and investigation at the request of the Government of Pakistan into the feasibility of additional hydroelectric power station construction at the site of Kaptai Dam by utilizing the great reservoir of Karnafuli River which runs along the border line south-east of East Pakistan, the Overseas Technical Cooperation Agency had organized a survey team consisting of four experts headed by Mr. Masahiro Fuchimoto, Technical Adviser of Nippon Koei Co., Ltd.

During the period between October 30, 1967 and February 10, 1968, this team successfully performed the on-the-spot investigation and practical guide to surveying and boring works over the subject area, and also collected data of hydrography, meteorology, topography, geology, power demand, etc. in relation to the power station construction.

Hereby submitted is a report based upon the outcome of the survey undertaken. Nothing would be more gratifying to our Agency than if this report could be of any help for further development of water and power in East Pakistan, and thus contribute to the enhancement of closer economic cooperation and friendship between the two nations – Pakistan and Japan.

Finally I take this opportunity to express my hearty appreciation to the Government of Pakistan and people concerned for their kind cooperation and assistance shown the team while with them.

March, 1968

Shin-ichi Shibusawa
Director General
Overseas Technical Cooperation Agency
Government of Japan

LETTER OF TRANSMITTAL

Mr. Shinichi Shibusawa
President for Overseas Technical
Cooperation Agency
Tokyo, Japan

March, 1968

Dear Sir:

It is our great pleasure to communicate you that the work assigned to the Team has been fulfilled and have the honor to submit herewith the report.

The Team visited East Pakistan from 30 October 1967 to 10 February 1968, and prospected and investigated relevant area of East Pakistan with the heartfelt support from East Pakistan Water and Power Development Authority. Upon return to Japan, the Team prepared this report with the cooperation of engineers of the engineering departments of Nippon Koei Co., Ltd.

In this report, we mentioned the results of this basic investigation and the future study for this project.

In the performance of the report, the Team constantly bears in mind the contribution of the program to the welfare and well-being of the people of East Pakistan.

Yours respectfully,

for Masahiro Fuchimoto
Leader of the Survey Team
for Karnafuli Hydro-Power
Project

Technical Adviser
Nippon Koei Co., Ltd.

CONTENTS

ABBREVIATIONS

kW	kilowatt
MW	Megawatt
kWh	kilowatt-hour
MWh	Megawatt-hour
kV	kilovolt
cu.ft.	cubic foot
imp. gal.	imperial gallon
BTU/lb	British thermal unit per pound
Rp	Rupee
F	Fahrenheit
%	percent
o	degree
'	minute

SUMMARY AND RECOMMENDATIONS

1. The Karnafuli Power Station is the only hydro-power station now operating in East Pakistan, and the water potential for power remains only in the Sangu River basin where development of 87.1 MW is planned possible. However, the implementation of the Sangu River project is still pending owing mainly to the difficulty involved with the land and other compensation, therefore the Karnafuli Power Station plays a key role in the operation of the existing grid.

2. The Karnafuli project had been re-designed many times for years, and its construction suffered much troubles. In addition, compensations to the lands and native families and allocation to the term of the public works are not yet amicably settled between the Government and EPWAPDA. And two units are only installed at present for the final stage of three units. Those causes arise the unit cost per kWh to as high as 0.056 Rp/kWh, but neverthless the Karnafuli is evidently contributing to maintain the average generating cost at 0.0834 Rp/kWh against high production cost thermal plants./1

3. As to the surface area and storage capacity of the Karnafuli reservoir, of which doubts were imposed on the values estimated previously, the only step we can take for checking these values is to wait until the completion of the mapping of the reservoir area being carried out at the hands of the Survey of Pakistan, even though signs contradictory to the estimated values were observed in the discharge tests at the spillway gates.

4. Because of the delay of mapping of the reservoir site, the reservoir capacity cannot now be exactly estimated. But, for the case that the reservoir capacity is larger than that of IECO, the feasibility study was roughly made. To give a sample, the 30 percent larger reservoir capacity will increase output proportionately. Even so, based on the figures in the IECO report, 150 MW at 15 percent overload operation after the installation of third unit will be adequate for the time being insofar operated at a plant factor of upto 38 percent. It is however noted that surplus water in the rainy season will produce valuable energy. For confirmation of the above, needless to say, it is indespensable to ascertain the reservoir capacity and to undertake various detailed investigations and studies including analysis of hydrological data, etc.

5. Besides, the Karnafuli Power Station should be put on the full study as a peaking station, since the Sangu River is the only possible hydro-power development site in East Pakistan.

/1 Most of the thermal power generating installations in East Pakistan is old-fashioned and inefficient, and in addition the fuel cost is rather high and makes the power production much uneconomical. The price of the coal imported from the People's Republic of China is about 150 Rp/long ton, while the furnace oil (Bunker C) costs about 0.067 Rp/Imperial gallon. Thus the fuel cost is 0.115 Rp/kWh at the Goalpara Power Station (coal-fired), and 0.065 Rp/kWh at the Siddhiriganj Power Station (oil-fired).

Rough calculation shows that the production cost of the Karnafuli Power Station of 250 MW installation in total as a peaking station is about 0.058 Rp/kWh. Peaking operation of natural gas fired plant /1 would cost approx. 0.06 Rp/kWh. With due regard to easy operation for peaking, the Karnafuli Power Station is recommendable as a peaking station.

6. The location of the new Karnafuli Power House, insofar observed, is proposed on the both sides of the existing powerhouse, from the viewpoint of topography and geology.

7. As the abovementioned is simply made to picturize the future extension, the following studies should be made in detail to justify those prospects.

   (1) Definite estimation of the storage capacity of the reservoir.

   (2) Determination of the firm continuous output.

   (3) Detailed technical investigation of the expansion plan.

   (4) Detailed study of the reservoir operation.

   (5) Detailed planning of stage introduction of peaking operation.

/1 At natural gas fired steam power stations now under construction production cost per kWh will be something line 0.03 Rp/kWh, when the natural gas recently discovered in the northeast area of Dacca can be available at 0.75 to 1.3 Rp/1,000 cu. ft.

CHAPTER I INTRODUCTION

1-1 BACKGROUND

The East Pakistan Water and Power Development Authority (Abbreviated: EPWAPDA) has requested the Government of Japan to undertake a feasibility study on the expansion plan for the Karnafuli Hydro Plant located in the southeastern part of East Pakistan. In response to this request the Japanese Government entrusted Overseas Technical Cooperation Agency (OTCA) with this feasibility study. Whereupon the OTCA despatched an investigation team formed of the undermentioned four expert engineers to undertake the investigation.

Organization of the investigation team:

Leader:	FUCHIMOTO, Masahiro	(Civil engineer)
Members:	ENOMURA, Akira	(Electrical engineer)
	SUMI, Kazuhiko	(Geologist)
	ARAIDA, Eiichiro	(Civil engineer)

The said team engaged in the investigation at the project site and the collection of the necessary data for about 100 days from October 30, 1967 to February 10, 1968. The report herewith submitted has been prepared, based on our on-the-site investigation and data obtained.

1-2 SCOPE OF INVESTIGATION

The purpose of the present investigation and study is the collection of information and data necessary for the preparation of the feasibility report on this project.

The investigation consists of two investigations, the one conducted by the Pakistan Government and the other performed by the Japanese team.

Investigation performed by the Pakistan Government

(a) Aerial photographing and ground control survey of the Karnafuli reservoir area and its mapping by the Survery of Pakistan

(b) Topographic survey of the proposed power station site by EPWAPDA

(c) Geological survey by boring at the proposed power station site by EPWAPDA

Investigation performed by the Japanese Team

(a) Study of power demand and supply

(b) Reconnaissance of the reservoir area and of the proposed power station site

(c) Collection of meteorological and hydrological data

(d) Investigation of aggregates and sands for the extension works

(e) Collection of data for cost estimation

(f) Check of transmission line route

Information and data obtained are substantial and will contribute much to the carrying out of the feasibility study. However further investigation is believed worthwhile for the preparation of the feasibility report. It is noted that exact storage capacity of the reservoir can only be derived from the contoured maps of the reservoir which is now being undertaken by the Survey of Pakistan.

1-3 ACKNOWLEDGEMENTS

The investigation team wishes to take this opportunity to express its sincere thanks for the assistance and cooperation extended to it by the Government authorities of Pakistan, EPWAPDA, to those mentioned below and Japan Consulting Institute (JCI). Especially cordial thanks are due to Mr. W. Choudhuri of EPWAPDA and Mr. Ryo Sasaki, chief of the Dacca Office of JCI.

EPWAPDA

Chairman	G. A. Madani
Power Wing:	
General Manager	A. N. Mohammed
Deputy General Manager	S. M. Al-Hussainy
Chief Engineer, Power Construction	A. Zaman
Additional Chief Engineer, Line Construction	N. A. Naseem
Secretary to Generam Manager	A. Salan Khan
Additional Chief Manager	W. Choudhuri
Executive Engineer	K. Sharma
Statistics	Md. Nezamuddin
Assistant Deputy General Manager	S. T. Hussain

Assistant Chief Engineer, Line Construction	Ahmed
Assistant Chief Engineer, Power Station Construction	Nijibur Rahman
Director of Planning	A. B. L. Rahman
Deputy Director, Planning	M. A. Ahmed
Deputy Director, Programme	S. T. S. Mahood
Director of Accounts	Ruhul Quddus
Account Officer	M. Anwarul Alam
Superintending Engineer, Line Construction	Abul Hossain
Executive Engineer, G. K. P/S	Q. M. Khaled
Manager, Karnafuli Hydro-Electric Power Station	A. K. M. Shamsddin
Deputy Manager, Karnafuli Hydro-Electric Power Station	Sk. A. Rahman
Water Wing:	
Deputy Director of Planning	A. Hossain
Director, Hydrology	Talukdar
Deputy Director, Hydrology	M. Rahman Talukdur
Director, Geophysical Section	A. F. M. Habibur Rahman
Survey of Pakistan (East Pakistan Government)	
Deputy Surveyor-General	S. Q. Hassan
Office in Charge No. 2 Photogrammatic Office	Wasi Ahmad
Directorate of Agiculture (East Pakistan Government)	
Director of Agriculture Department	Amiral Islam
Project Director, Bureau of Agricultural Statistics	M. A. Hakim
Senior Statistical Office, Bureau of Agricultural Statistics	M. Hussain
Regional Metorological Directorate (East Pakistan Government)	
Director	M. S. Hug
Consulting Engineers to EPWAPDA	
IECO, Hydrologist	D. D. Mussey
" , Adviser	N. B. Boutacoff
H. G. Acres and Company, Ltd.	F. G. A. Tam
Fichtner Consulting Engineer	F. Schlittler
W. P. London and Partner	P. J. Krull
Brown Boveri & Co., Ltd. (Swiss)	Osear Hess

CHAPTER II GENERAL DESCRIPTION

2-1 EAST PAKISTAN

East Pakistan is located between the latitudes 20°30' and 26°45' north and between the longitudes 88°00' and 92°56' east, borders on India on the east, north and west sides, and on Burma on southeastern side, facing the Bay of Bengal in the south. It has an area of approximately 55,126 square miles.

Topographically East Pakistan is characterized by the Ganges Plain and the Chittagong Hill Tracts. The Ganges Plain occupies most part of East Pakistan and forms a wide plain extending from north to south, the Bay of Bengal, at elevations not higher than 30 feet above sea level, through which the Meghna River and a number of its tributaries flow down meandering, where in the rainy season submerge major portions of the southernmost areas in the downstream basins.

On the other hand, the Chittagong Hill Tracts, located in the southeastern part of the country, stand at elevations varying between 100 - 2,000 feet above sea level, where the Karnafuli is the main river. These Tracts are hills rather than to be called as mountains.

Geologically, the Ganges Plain consists of alluvial formation, whereas the Chittagong Hill Tracts are formed mainly of clay and shale.

Except part of the southeastern tropical part, East Pakistan belongs to subtropical zone and the seasons are classified as winter (November to February), summer (March to June) and monsoon (July to October). Temperature varies normally from 50°F to 100°F. It rains intensively in the monsoon season. The average annual rainfall is 75 inches in Dacca area, 105 inches in Chittagong area and more in the Chittagong Hill Tracts.

The population of the country is estimated in 1966 at around 62,000,000, with a density as high as 1,100 persons per square mile. The presumed rate of population increase for the recent 5 years is as high as 2.6 percent.

Agriculture shares major portion of domestic products in this country. Over 80 percent of the population live on forming. Agricultural income occupies about 70 percent of the national income and about 71 percent of the foreign currency earned by export.

2-2 THE KARNAFULI PROJECT

The Karnafuli hydropower station was constructed at about 45 miles eastward from the city of Chittagong which is the second largest city in East Pakistan with a population of about 370,000, well-known as a ocean sea port and an industrial centre. This project was planned as a multipurpose dam project mainly producing power energy and commenced its operation in 1962 after vicissitudes.

The power station was originally planned with an installed capacity of 120,000 kW (40,000 kW x 3) and 2 of 3 units have been on the line and the third unit is expected to be called for tender early in 1968 under the U.S.A.I.D. fund. The unit capacity was increased to 50,000 kW from 40,000 kW of last two units so that the total installed capacity will reach 130,000 kW.

The Karnafuli reservoir has an immense storage capacity. The report prepared by the consultants to this project, International Engineering Co., Inc. (IECO, Los Angeles, California, U.S.A.), states that the reservoir has a H.W.L. 118 feet, a water surface area of 227 square miles, and a total storage capacity of 4.35 million acre-feet.

However, the operation of the power station has shown various indications that the capacity of reservoir would be far larger than those stated in the report. In 1963, to measure the correct reservoir area and the storage capacity aerial photographs were taken, and in 1964 the ground control was performed. Its mapping is now under way at the hands of the Survey of Pakistan.

The EPWAPDA, cognizant of the surmised larger storage capacity of the reservoir, intended to know if there is the possibility of generating more energy. The feasibility study for this purpose was then entrusted to the Japanese Government.

The Karnafuli Dam, as one of its many purposes, should provide the navigation for transport of timber, bamboo, etc. For this purpose IECO proposed in its first report (1954) to construct a lock gate. But this proposal was not taken up for the reason that the time is premature for its construction and the cargo transfer facilities were provided instead. The facilities now became too small in capacity to deal with the annually increasing cargo and the construction of a lock gate is again envisaged. The cargo handle amounts to 250,000 tons per annum.

Electric power generated at the existing station is transmitted to Dacca over a 170 miles long transmission line via Chittagong. In connection with the second power station it is necessary to study whether a new transmission line be needed or not to handle the power to be thereby additionally generated.

CHAPTER III ELECTRIC POWER SITUATION IN EAST PAKISTAN

3-1 EPWAPDA

In East Pakistan, EPWAPDA is the governmental authority to serve electricity to the public. As of the end of 1967 EPWAPDA has generating installation of 225 MW including the Karnafuli Hydro Power Station which is the object of our investigation. The authority also engages in the transmission and distribution services. In the private sector, 71 MW installation belongs to various factories and mills, including fertilizer manufacturing factory at Fengchuganj (36 MW), paper mill, sugar mills, jute mills, etc.

3-2 ELECTRIC POWER FACILITIES

The Karnafuli Power Station with installation of 80,000 kW is supplying power since 1962 to Dacca via Chittagong over a 2-circuit 132 kV transmission line, which is only one grid in East Pakistan at present.

Under the Third 5-year Plan, a national grid to combine cities and towns in the country is now on the high pitch of construction, and part of it is expected to go into operation early in 1968. (See the attached chart)

As of December 1967 the generating installations are counted as follows:

East Wing	164,500 kW
West Wing	60,500 kW
Total:	225,000 kW

Referring to the undermentioned list, most of the plants are small and descrepit other than the facilities at Karnafuli Power Station and the Gas Turbine units at Chittagong.

Generating Facilities in East Pakistan

EPWAPDA

	Installed capacity	Fuel	Operation started in
Eastern Zone	kW		
Dhanmandi Steam	4,500	Coal	1902
Chittagong Diesel	8,000	Oil	1955

	Installed capacity	Fuel	Operation started in
Siddhriganj Diesel	10,000 kW	Oil	1953
Siddhriganj Steam	30,000	"	1959
Karnafuli Hydro	92,000/80,000	-	1962
Miscellaneous, Diesel	7,000	Oil	-
Chittagong Emergency (gas-turbine)	13,000	"	1967
Total:	164,500 kW		

Western Zone

Goalpara Diesel	7,000	Oil	1955
Goalpara Steam	16,000	Coal	1959
Bheramara Steam	8,000	"	1961
Thakurgaon Diesel	10,500	Oil	1966
Miscellaneous, Diesel	19,000	"	-
Total:	60,500 kW		
Grand Total:	225,000 kW		

Private Installation

Fenchuganj fertilizer factory	36,000 kW
Sugar mills	10,310
Jute, spinning mills	17,230
Cement factory	7,540
Total:	71,080 kW

3-3 CONSUMPTION OF ELECTRICITY

In 1966 EPWAPDA produced 657 x 10^6 kWh and sold 526 x 10^6 kWh, and the non-coincident maximum loads at stations reached 133,000 kW. But annual per-capita consumption is estimated at 12 kWh including that of the private sector. This small consumption per capita seems mainly due to insufficient generating facilities and to weak transmission and distribution system. However, the recent foreign aid in construction fund has brought a remarkable progress in the consumption of energy at an annual increase of 25 percent.

The Karnafuli is playing the major role in the Kaptai-Dacca grid, which peaked at 115,600 kW in July 1967 and delivered 67 percent of the total energy produced by EPWAPDA.

The following is the state of energy output and consumption in EPWAPDA system.

Year	Energy output (MWh)				Consumption	Peak load
	Water power	Thermal	Diesel	Total	(MWh)	(kW)
1959	-	73,452	94,353	167,805	138,278	38,000
1960	-	148,596	70,304	218,900	178,520	42,200
1961	-	164,769	93,781	258,550	212,665	56,000
1962	176,420	111,590	40,170	328,180	252,105	69,550
1963	209,000	157,270	49,370	415,640	346,790	81,730
1964	337,000	78,838	41,798	457,636	386,255	96,354
1965	403,181	115,088	48,981	567,250	465,233	110,012
1966	450,935	137,968	68,097	657,000	526,000	133,000
1967	(Sept.)					159,800

Note: Peak load is summed up from the per-hour output in kW at each power station: non-concident maximum.

Number of customers as of 1967 are:

East Wing		
	Karnafuli grid	99,000
	Isolated supply	12,235
West Wing		
	Goalpara-Bheramara	18,849
	Isolated supply	19,291
		149,375 (customers)

The number of customers is about 2.3 per 1,000 persons. Consumption of electricity per customer is about 4,000 kWh/year and this is not particularly small. From this fact it is seen that the small consumption per capita is attributable to the insufficiency of the grid and generating equipment, for which available funds are much concerned.

3-4 UNIT RATE

The unit rate in East Pakistan is as follows:

	Rate/kWh
For lighting and fan	0.31 Rupee
For household use	0.16 "
For small industries	0.16 "
For high voltage users	0.1137"

The high unit rate owes primarily to the high cost of imported fuel. All power plants except the Karnafuli is firing imported coal or oil. In the West, coal was supplied from the Bihar Province of India, but since the 1965 India-Pakistan Conflict the supply of coal was obliged to depend on the imports of low-carlorie coal from the People's Republic of China. The calorie of this coal is as low as 10,000 BTU/lb and the price is as high as 150 Rp/ton (coal from India costed only 60 Rp/ton). Imported furnace oil (equivalent to Bunker C) is priced at 0.67 Rp/imp. gal. in Dacca.

Most of the power plants are old and inefficient. The distributing systems are also insufficient and the transmission loss is assumed as high as 25 percent.

3-5 PRODUCTION COST

Production cost cannot be definitely worked out, since the assets of the Karnafuli Power Station, which supplies the majority of the energy to EPWAPDA, is not yet conclusively assessed because the allocation of the construction cost is still pending between the Government authorities and EPWAPDA. But as of July 1967 the average production cost of EPWAPDA is approximately estimated at 0.0835 Rp/kWh.

If the construction cost of the Karnafuli is wholly burden on EPWAPDA and the annual energy production is 486 x 10^6 kWh (in fiscal year of 1966/67), its production cost is calculated as 0.056 Rp/kWh. *This production cost is not necessarily cheap, but the Karnafuli's role in the* power production of EPWAPDA must be highly estimated.

3-6 POWER DEMAND AND TRANSMISSION PLAN

Investigation on power requirements has been made by EPWAPDA, and "Master Plan Supplement D" prepared in 1964 by IECO, consultant to EPWAPDA, made clear the electric power requirements up to 1985. Further in the report a concrete study is made on the future construction plan of the transmission line system that will become necessary with the increase in the power demand.

Later, at the request of the Pakistan Government Fichtner Consulting Engineer of Germany reviewed the transmission plan and worked out a revised estimate to the following effect.

Year	East Group (MW)	West Group (MW)	East Pakistan (MW)
1970	287	124	411
1975	441.5	202.5	663.7
1980	690	327	1,017
1985	945.5	449.5	1,395

Since the non-coincident maximum load at the power stations was recorded as 154.15 MW in June 1967, the actual increase of demand is likely to be smaller than the above.

3-7 STANDARD VOLTAGE

The standard of voltage in Pakistan is as follows:

Transmission line	132 kV, 66 kV, 33 kV
Distribution line	11 kV, 6.6 kV
Low tension line	400/230 V, 3-phase 4-wire system
Cycle	50 H_z

Extra-high voltage will be determined at 230 kV or 275 kV in connection with intergrid scheme of east and west.

3-8 NATURAL RESOURCES FOR POWER GENERATION

3-8-1 Coal

At present coal is imported from the People's Republic of China, after the dispute between Pakistan and India. Recently the discovery of coal reserves of about 500,000,000 tons at Bagra cast bright rays of hope on the energy situation in this country. This coal appears belong to the Bihar coal vein in the northwestern part of Pakistan running into this country from India. The coal ore however lies at the disadvantage level deep some 3,000 - 4,000 feet below the ground so that economical mining be only possible on large-scale facilities. At the moment, utilization of this coal is only expected after 1980. Under the circumstances the Pakistan Atomic Energy Commission is making efforts to introduce nuclear energy at an early date. When the coal from Bagra becomes available the price would be possibly around 60 Rp/ton.

3-8-2 Petroleum

Investigation for the petroleum reserves is now under way by the U.S.S.R. technical aid. But there appears to be little hope.

3-8-3 Natural Gas

Some 5 x 10^{12} cubic feet of natural gas has been ascertained near Titas in the north of Dacca. The reserves of this gas are considered to equal to an amount that will enable to operate 1,000 MW installation for 30 years if only 40 percent of the resources if appropriated for power generation. This natural gas ensures the construction of nitrogenous fertilizer factories as well as the steam power facilities. This natural gas will be available in Dacca at around 1.3 Rp/1,000 cu.ft.

3-8-4 Hydro-power Potential

In East Pakistan there is no mountain worthy of the name and the plain formed by the flow of Ganges dominates most part of the country and the only river at present availed for hydro-power generation is the Karnafuli River. Outside this river basin there are two possible power sites in the basin of the Sangu River, (about 87.1 MW in total), but the compensation for the land others makes difficult the earlier construction of the project. It is advised that this project is not included in the Third 5-year plan.

3-8-5 Others

There is almost no other natural resources or power potential other than the abovementioned.

3-9 GENERATING FACILITIES AT KARNAFULI POWER STATION

The Karnafuli Power Station was constructed with the fund of U.S.A.I.D. and by the consultants IECO, and Contractor Utah International and put on the line in 1962 with 40 MW x 2. At the same time the transmission lines were constructed to Dacca via Chittagong, 170 miles long, 132 kV and 2-circuits. The energy transmitted is mainly consumed in Dacca and Chittagong.

Energy produced in 1967 at this station is likely to exceed 500 x 10^6 kWh which accounts for nearly 70 percent of the energy produced by EPWAPDA. Thus the importance of the role played by the Karnafuli Station is self-evident. At present, steps are being taken for the purchase of a third generating unit by U.S.A.I.D. and the invitation for tender will be announced early this year. EPWAPDA desires to complete the installation of the third unit by 1970. This unit is called for 50 MW output with 15 percent overload capacity same as the other units.

The causes of the frequent failures of the 1st and 2nd units have already been made clear and adequate countermeasure has been prepared, therefore there would be no further troubles of such nature in future.

3-10 THIRD FIVE YEAR PLAN (OF EPWAPDA)

As of the end of 1967, the Third 5-year plan (1965-1970) has reached its mid-period. The aim of the Third 5-year plan comprises the following:

1.	Generating facilities	721.5 MW
2.	Number of consumers (houses)	250,000
3.	Length of transmission line	823 miles

Breakdown of the necessary fund is as follows:

1.	Power generation	642.11×10^6 Rupees
2.	1st stage transmisssion line	279.43×10^6 "
3.	3rd stage transmission line	505.98×10^6 "
4.	Others	122.48×10^6 "
	Total:	1,550 $\times 10^6$ Rupees

CHAPTER IV FIELD INVESTIGATION

4-1 METEOROLOGICAL AND HYDROLOGICAL DATA

Majority of meteorological data was obtained from EPWAPDA, as referred to appendixes.

Runoff records at Kaptai collected are given in those furnished by EPWAPDA, in IECO's report and in the Report by Bengal Government. The IECO's report and the Report by Bengal Government estimate the runoff at Kaptai before the completion of the dam, 1961, by adding 11 percent to the Rangamati records, to allow for the extra catchment area. However the above three values of runoff at Kaptai are found not identical; each monthly runoff shows different, not to mention the annual runoff, and the difference of mean annual runoff in the period shows about 2 - 3 percent.

The gauging record at Rangamati which may give a conclusive factor to demonstrate exact runoff was not available except for the period of 1954 to 1959, because of imcomplete filing.

Even the converted values for the period of 1954 to 1959 are found different from the abovementioned figures. Therefore the comparative check of those data must be made further in detail.

The data furnished from EPWAPDA include water flow records from 1936 through 1966, in which part for 1961 to 1966 is estimated from the water flow discharge, outflow over the spillway and the storage capacity curve. When the said curve should be modified or corrected, the inflow records during 1961 to 1966 will require to be modified accordingly, for which supporting weather information of rainfall, evaporation value etc. have been obtained during the survey on site. According to our rough study of the rainfall-runoff relation, annual runoff data in 1961 to 1966 appears reasonable.

The study of the reservoir operation made by IECO and the actual operation after 1961 reveals that the surplus water in the rainy season is of large amount. This is because the reservoir storage capacity is too small compared with the annual runoff, about 35 percent in ratio.

The expansion plan of the power station must be made further in detail with due regard to the surplus water in the rainy season.

4-2 RESERVOIR STORAGE CAPACITY

Final estimation of the storage capacity in question of the Karnafuli Reservoir, should eventually depend on the maps of the reservoir area which are now being contoured by the Survey of Pakistan. We have only received 16 sheets among 60 sheets of contoured maps and the completion of the remaining maps is earnestly awaited.

Apart from the approach by aerial mapping, a number of rapid drawdown tests, which spill out water for 24 hours with a constant opening of spillway gate and read the drawdown of reservoir, has been carried out since 1965. According to our check of the results, the reservoir storage capacity seems larger by 30 to 40 percent than that of IECO. However, as the above tests involve some inaccuracy on the measurement method of water level, estimation of the inflow to the reservoir and others, conclusive judgement on the reservoir capacity should not be made easily.

Anyhow, the exact storage capacity of the reservoir has to be concreted upon completion of the maps of the Survey of Pakistan.

4-3 TOPOGRAPHY OF PROPOSED POWERHOUSE SITE

As mentioned in Chapter V, the extension capacity of power plant can not be decided yet. Nevertheless it is necessary to survey the topographical and geological feasibility of the extension work. From topographical and geological points of view, we selected three sites as the new powerhouse site, namely at the present diversion tunnel site (Site I), the existing powerhouse site (Site II) and a site midway between the existing powerhouse and the cargo transfer facility site (Site III). Their locations are shown in Fig. 3.

The reconnaissance of the site desclosed that the existing powerhouse site (Site II) has merits that the site provides enough space for the future two units, and can render the existing access road and cranes, while demerites are the disturbance to the operation of the power station during the construction and the large excavation volume at the forebay.

4-4 GEOLOGY

4-4-1 General

The Geological Survey of Pakistan in Dacca showed and explained us the geological situation of East Pakistan in general, which provided an effective reference to our geological interpretation on and around the Karnafuli Dam Site.

A number of boring and pitching has been made to probe the geology on and around the construction site and recorded in IECO's "Design Report". (Refer to Figs. 4 to 7)

Referring to the previous clause, we requested EPWAPDA to drill the proposed site (Site II), for which locations of drilling and necessary advices were given from our member. (See Fig. 8) 10 days have been spent for drilling and the results have been handed over to us in early February. (See Figs. 9 to 12)

Site exploration and above boring unveiled the geology as stated below.

4-4-2 Geology in Karnafuli Basin

The formation in Karnafuli Basin is classified as follows.

Karnafuli Alluvium	Recent
Tipan Formation	Miocene - Pliocene
Surma Formation	Miocene - Pliocene

The Karnafuli alluvium consists mainly of sand, silt, clay and gravel, while the Tipan and Surma formations are composed of sand-stone and shale, respectively. However, at the existing powerhouse site, the sandstone of Tipan formation is not exposed.

The Surma shale folds are fairly conspicuous in some portion, and its direction is N15 - 20^{o}W and dips toward west with gentle inclination.

4-4-3 Geology of Proposed Powerhouse Site

As mentioned in Clause 4-3, three sites were chosen for the proposed new powerhouse site, the geology of which is interpreted as follows.

a) Diversion Tunnel Site (Site I)

The surface layer is covered with the brown silty sand 50 to 70 feet in thickness. At the side hill of inlet, compact blue grey shale is exposed, while at the outlet channel, soft blue and dark grey shale and sandy shale are exposed. The boundary of compact and soft shales exists at the middle site on the road between the WAPDA Guest House and the village on the right bank.

Therefore, if No. 2 power station is constructed at this site, the beds of the inlet structure and powerhouse will respectively sit on the compact shale and soft sandy shale, and the pressure tunnel will be placed to pass through the soft sandy shale.

b) Existing Powerhouse Site (Site II)

Boring carried out by EPWAPDA and the available informations show that the silty sand in the surface layer is of thin layer compared with those at the diversion tunnel site, and its thickness is presumably 10 to 30 feet.

At the north side of the existing powerhouse, the compact shale is exposed with fairly conspicuous folds. The compact shale appears to have a depth of more than 200 feet.

Therefore, when constructed, the beds of powerhouse and intake structure will be located on the compact shale and the penstock will pass through the compact shale, so that these structures will be very stable.

c) Middle Site between the Existing Powerhouse and Cargo Transfer Facility Site (Site III)

From the folding part at the existing powerhouse site, the shale with developed joint of about 3 to 5 inches strikes horizontally along the Karnafuli River. In the exposed shale layers above the water surface of the Karnafuli River, some hard shale layers are found.

Therefore, all structures will be constructed in the shale layers, and this site has a defect that the upper portion may crumble, when the penstock tunnel will be excavated.

From the above reasons the existing powerhouse site is observed the best site geologically.

4-5 CONCRETE AGGREGATE

The gravel at Silhet site is of the best quality. For construction of Karnafuli Project it was transported by the railway from the site to Chittagong and by ship from Chittagong to Kaptai and used as the concrete aggregate.

After completion of the project, a lot of cobble sand stone of good quality was discovered in the shale at the villages on the hilly side, about 14 miles southeastward from Kaptai. Since 1963, the cobble stones have been quarried, transported to Chittagong and used as crushing stones. The quantity of the sandstone deposits is estimated at about 10^7 cubic feet. However, it appears difficult to quarry a large quantity of stone at a time. The cost of the stone at Kaptai is estimated at 160 Rupees per 100 cubic feet.

The sand for concrete aggregate is found at about 15 miles downstream of Kaptai.

4-6 INFORMATION FOR COST ESTIMATION

The data for cost estimation were furnished to our team by EPWAPDA. The costs listed therein were established in 1965, and EPWAPDA says that the current costs are now 20 percent high.

4-7 ROUTE OF TRANSMISSION LINE

In connection with the second power station, an investigation was conducted on the route from Dacca to Kaptai for a case of a new transmission line construction.

Geological condition along the route appears not to include much troubles, and the undulation between Chittagong to Feni gives an idea that the line runs over the hilly range apart from the coast, to reduce the influence of cyclones, which sometimes caused casualty in Chittagong area.

CHAPTER V FEASIBILITY OF KARNAFULI PROJECT

If the reservoir had been created larger than IECO has estimated, the extension of the Karnafuli Power Station could be feasible more economically. Hereinafter a rough study is made for reference to the detailed investigations to be carried out in the future.

5-1 NORMAL OPERATION

Because of the delay of mapping of the reservoir site, the reservoir capacity, which is the most essential factor to the feasibility study, cannot now be exactly estimated. However, drawn down test on the reservoir water level, as previously mentioned, indicates some 30 to 40 percent larger storage capacity. If so, and when 30 percent larger, same percent larger firm output will be obtained roughly. IECO reported 44,000 kW as an average continuous output for the dry season. Hence the average continuous output is calculated as approx. 57,000 kW.

Installation of third unit (50,000 kW with 15 percent overloading) which is now under purchase, totals the output of the power station to 130,000 kW, or 149,500 kW (≑ 150,000 kW) with 15 percent overloading, which corresponds to plant factor of 38 percent for 57,000 kW. The maximum demand and daily load factor of the Karnafuli system are at present around 130 MW and 73%, therefore, the installation including No. 3 unit would be able to meet the power demand for the time being.

On the other hand, surplus water in the rainy season will bring about a valuable energy, based on which the study should be carefully made for the extension plan of the power station.

5-2 PEAKING OPERATION

Besides the Karnafuli River, the Sangu River (about 87.1 MW) is the only remaining water potential for power generation in East Pakistan. Therefore, following to the cases in the advanced countries, it will be worthwhile to investigate into the problem of peaking power generation.

On the basis of the data available at this time this problem was approximately studied as summarized below:

With the load factor presumed at 20 to 25 percent as a peaking power station, the size and construction cost of the Karnafuli Power Station are approximately estimated as below:

(a) In the case the reservoir capacity remains same as estimated by IECO,

$$\text{Average dry season output } 44{,}000 \text{ kW} \times \frac{1}{20 \text{ to } 25\%} = 176{,}000 \text{ kW to } 220{,}000 \text{ kW}$$

Namely the extension will be around 26,000 kW to 70,000 kW.

(b) In the case the reservoir capacity is larger by around 30 percent,

$$\text{Average dry season output } 57{,}000 \text{ kW} \times \frac{1}{20 \text{ to } 25\%} = 229{,}000 \text{ kW to } 285{,}000 \text{ kW}$$

Namely the extension will be around 80,000 kW to 135,000 kW.

Calculations were made on the premise, for the simplicity of calculation, that one 50,000 kW plant will be installed for the case (a), and two 50,000 kW plants for the case (b).

Detailed calculations are also required for reinforcement of the transmission system. The Fichtner report shows a detailed study made on this point and on the future plan using a network analyser, but this report was not available from EPWAPDA. We worked out the cost estimation taking into account of the construction cost of a transmission line to Mandahat, and obtained the production cost of 0.07 Rp/kWh for the case (a), and 0.058 Rp/kWh for the case (b). /1

Simple study of the gas-fired steam power plant for peaking gives a cost of 0.06 Rp/kWh, then the utilization of the Karnafuli Power Station for peaking operation is believed worthwhile for prudent study.

The extension of the Karnafuli Station, insofar observed, is proposed on the both sides of the existing powerhouse, from the viewpoint of topography and geography, as mentioned in Chapter IV.

The above study, needless to say, has been made to see approximate possibility of the expansion of the Karnafuli Station, for which detailed investigation and further study must be made to the definite confirmation of the feasibility technically and economically.

/1 1)

	Case (a)	Case (b)
Construction cost (10^6 Rp)	580	628
Annual energy, firm continuous (10^6 kWh)	385	500
" , surplus over above (")	313	378

2) Assuming that the surplus electricity produced in the rainy season has the value only in kWh and that by the time peaking operation will become necessary the natural gas will have been fully utilized, the production cost of such surplus energy obtained is assumed equal to the fuel cost of the gas-fired steam power station, for which the price of the natural gas was presumed as 1 Rp/1,000 cu.ft, based on estimated price of natural gas ranging between 0.75 to 1.3 Rp per 1,000 cu.ft. And the said value is reduced from annual expenses for the power station operation, thus the production cost evaluated with surplus generation during rainy season is obtained. Fuel cost per kWh is calculated as 8.6×10^{-3} Rp.

APPENDIX

LIST OF FIGURES

LIST OF TABLES

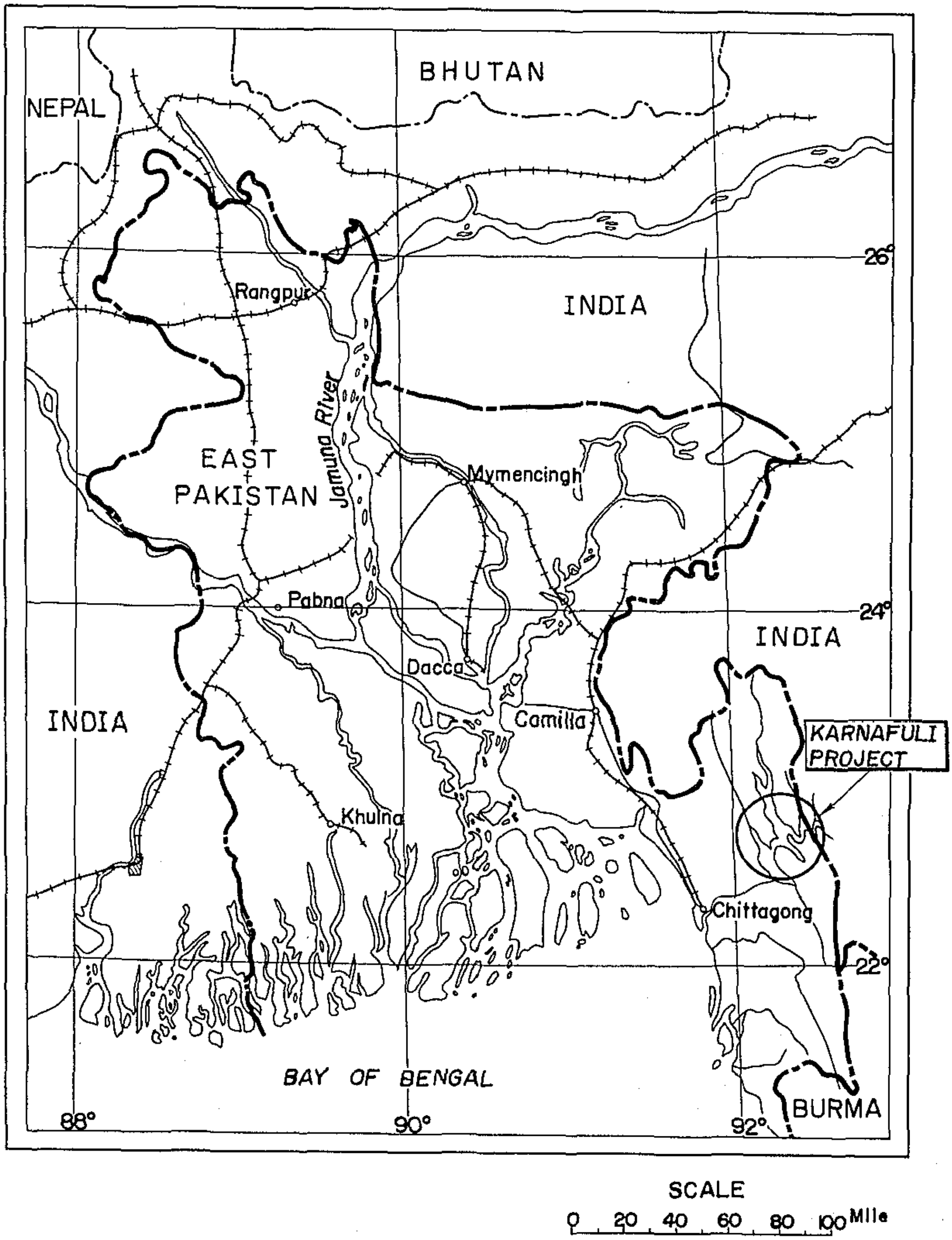


Fig. 1 Location Map

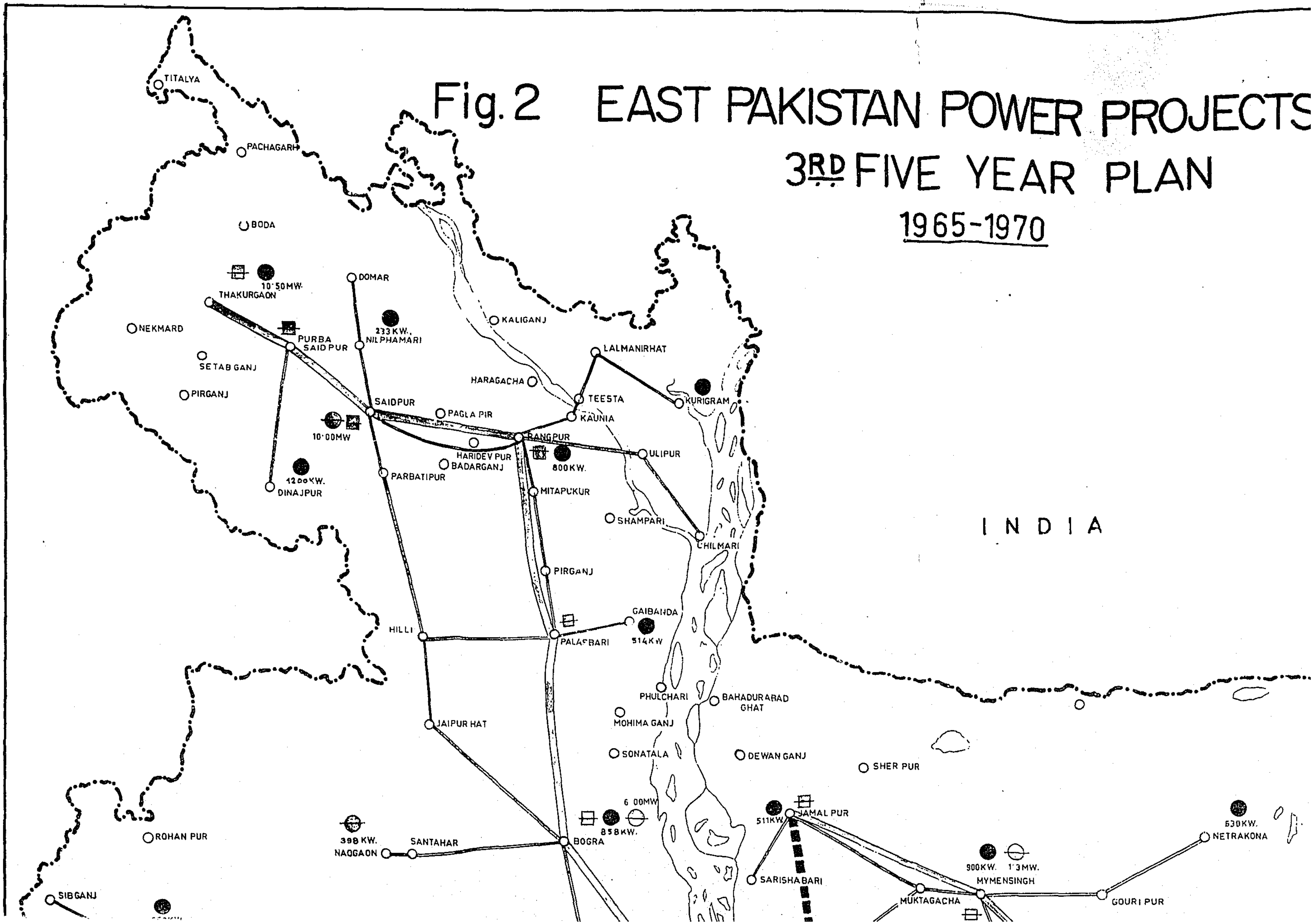
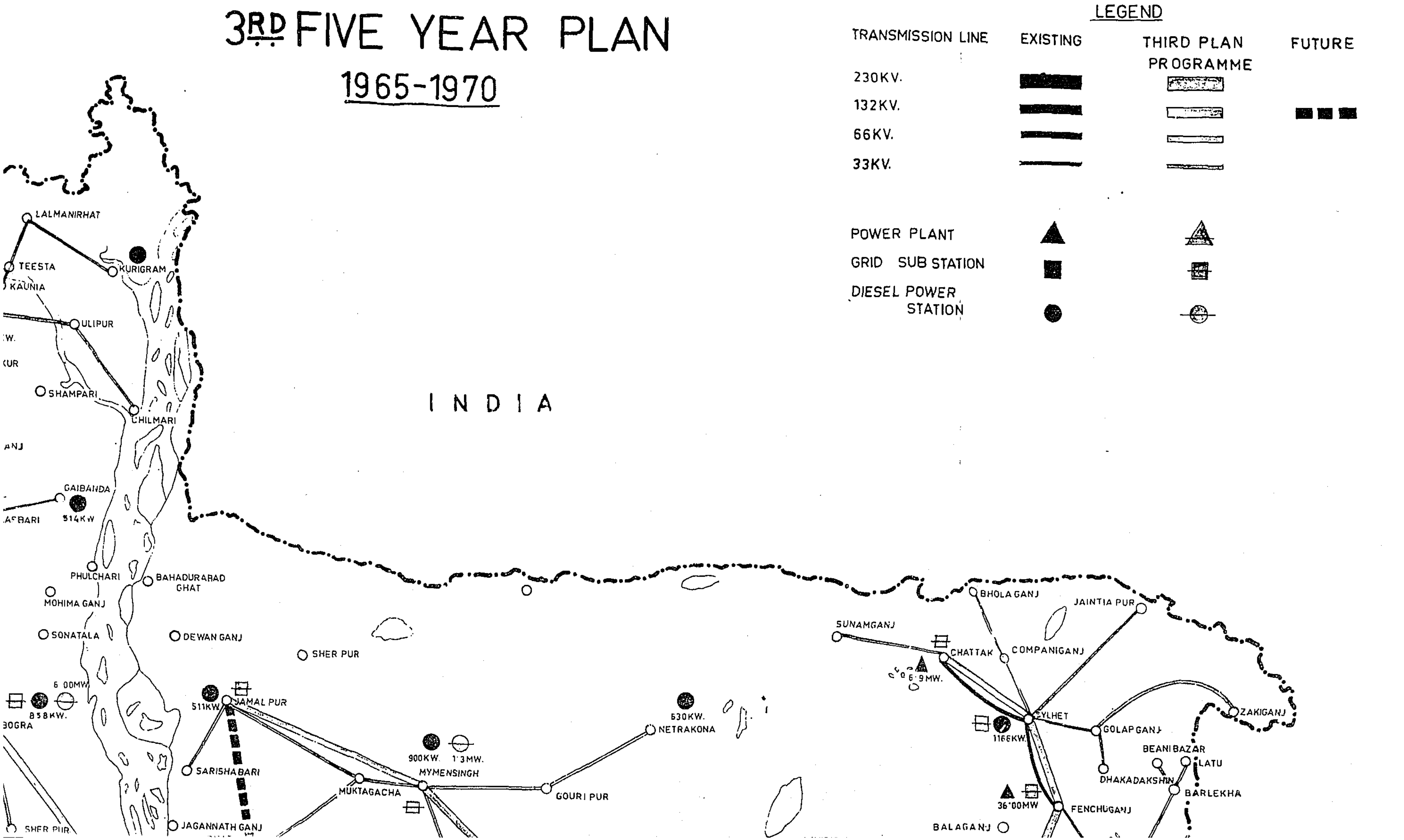


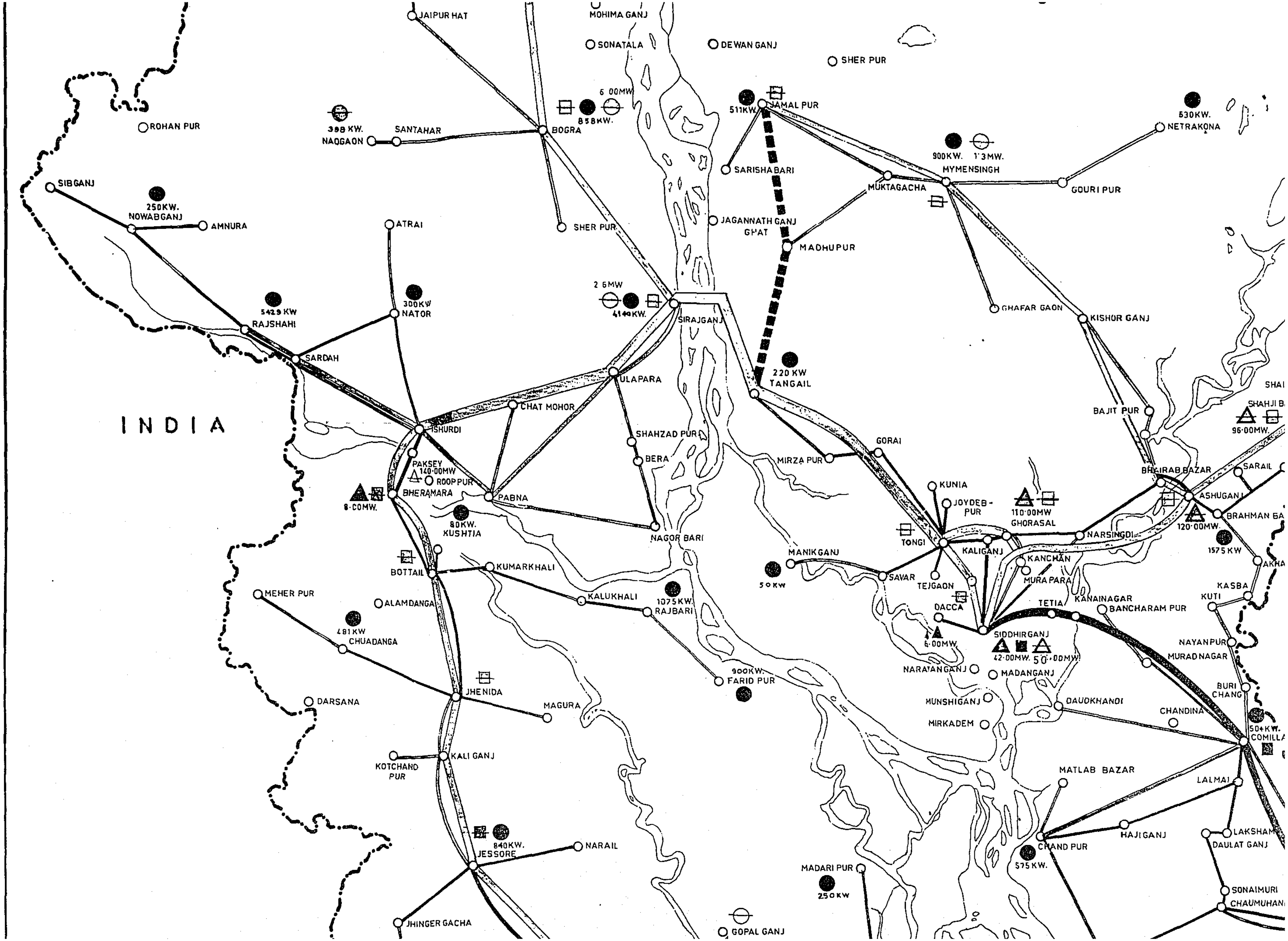
Fig. 2 EAST PAKISTAN POWER PROJECTS
3RD FIVE YEAR PLAN
1965-1970

EAST PAKISTAN POWER PROJECTS, EPWAPDA

3RD FIVE YEAR PLAN

1965-1970

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MOHIMA GANJ
SONATALA
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6 00MW
858KW.
BOGRA
511KW.
JAMAL PUR
530KW.
NETRAKONA
ROHAN PUR
388 KW.
NAOGAON
SANTAHAR
900KW.
1·3MW.
MYMENSINGH
SARISHABARI
MUKTAGACHA
GOURI PUR
SIBGANJ
250KW.
NOWABGANJ
AMNURA
ATRAI
SHER PUR
JAGANNATH GANJ
GHAT
MADHUPUR
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4140KW.
SIRAJGANJ
5429 KW
RAJSHAHI
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NATOR
GHAFAR GAON
KISHOR GANJ
SARDAH
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TANGAIL
ULAPARA
INDIA
CHAT MOHOR
ISHURDI
BAJIT PUR
96·00MW.
SHAHZAD PUR
GORAI
MIRZA PUR
BERA
PAKSEY
140·00MW
ROOPPUR
BHAIRAB BAZAR
SARAIL
8·COMW.
BHERAMARA
PABNA
KUNIA
JOYDEB-
PUR
110·00MW
GHORASAL
ASHUGANJ
80KW.
KUSHTIA
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NARSINGDI
120·00MW.
TONGI
1575 KW
MANIKGANJ
KALIGANJ
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42·00MW.
50·00MW.
NAYANPUR
MURADNAGAR
900KW.
FARID PUR
NARAYANGANJ
MADANGANJ
BURI
CHANG
JHENIDA
MUNSHIGANJ
DAUDKHANDI
CHANDINA
DARSANA
MAGURA
MIRKADEM
504KW.
COMILLA
KALI GANJ
KOTCHAND
PUR
MATLAB BAZAR
LALMAI
840KW.
JESSORE
NARAIL
HAJIGANJ
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MADARI PUR
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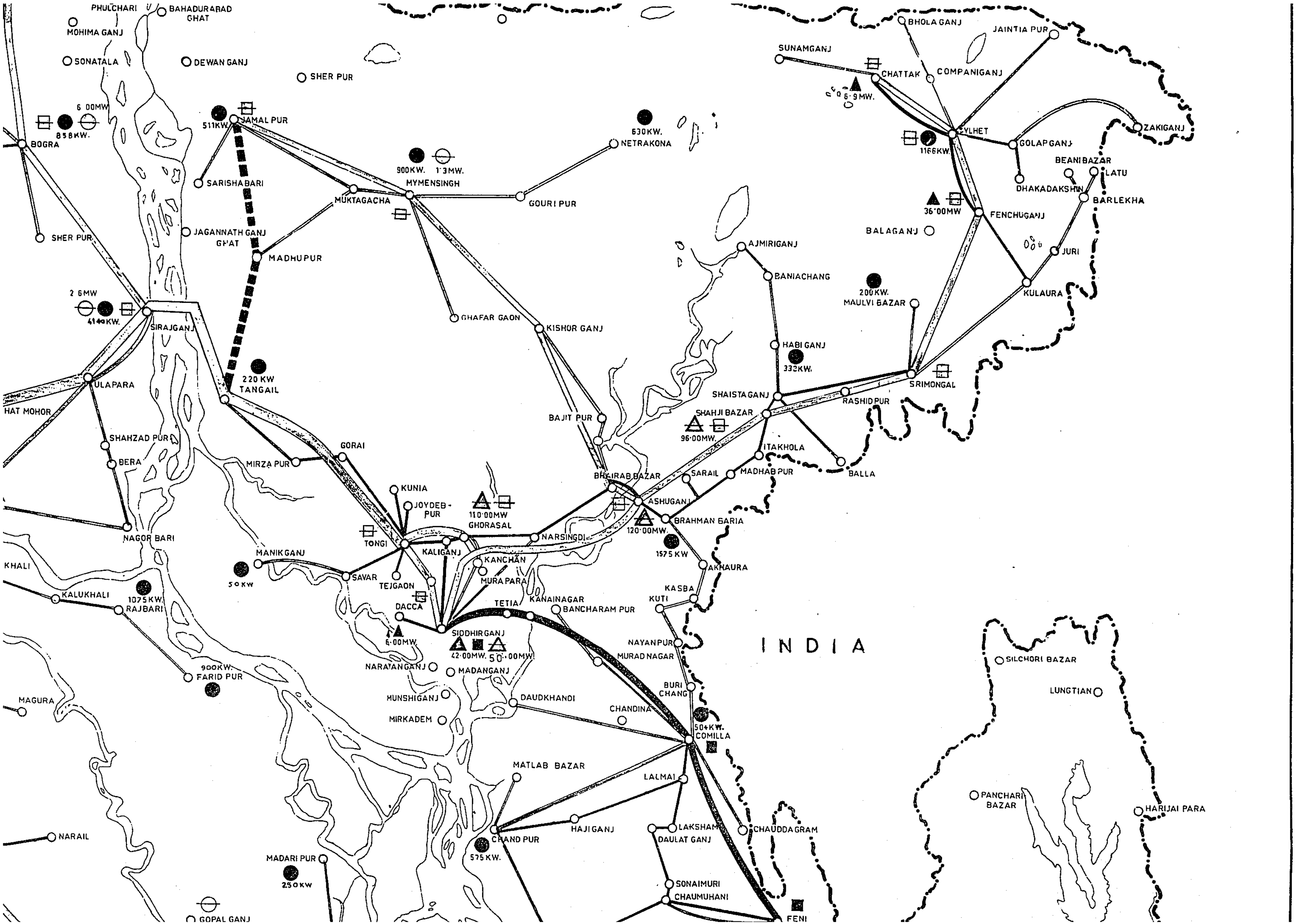
GOPAL GANJ



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DEWAN GANJ
SHER PUR
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BOGRA
511KW.
JAMAL PUR
630KW.
NETRAKONA
900KW.
1·3MW.
MYMENSINGH
SARISHA BARI
MUKTAGACHA
GOURI PUR
SHER PUR
JAGANNATH GANJ GHAT
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SIRAJGANJ
GHAFAR GAON
KISHOR GANJ
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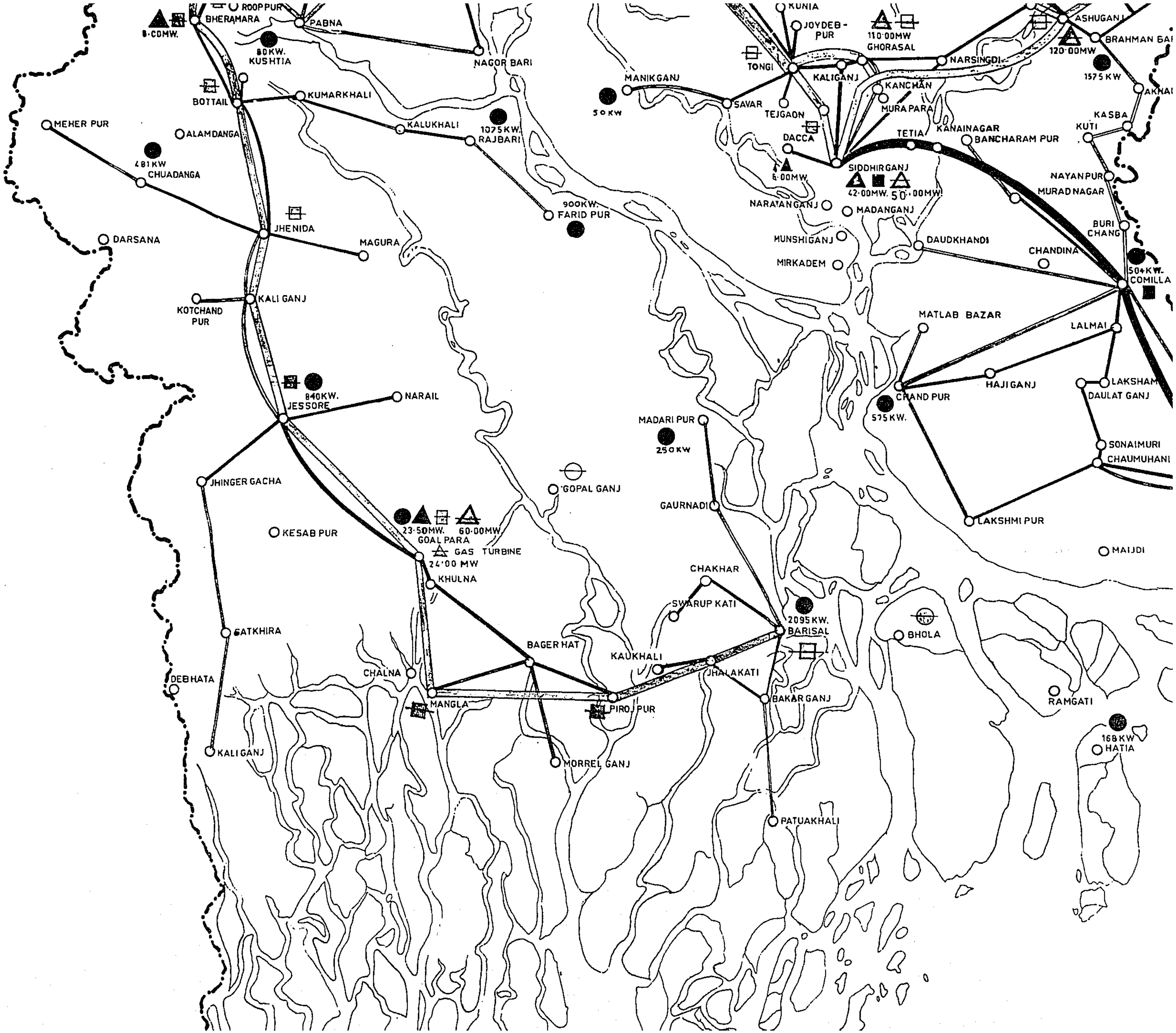
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481 KW
CHUADANGA
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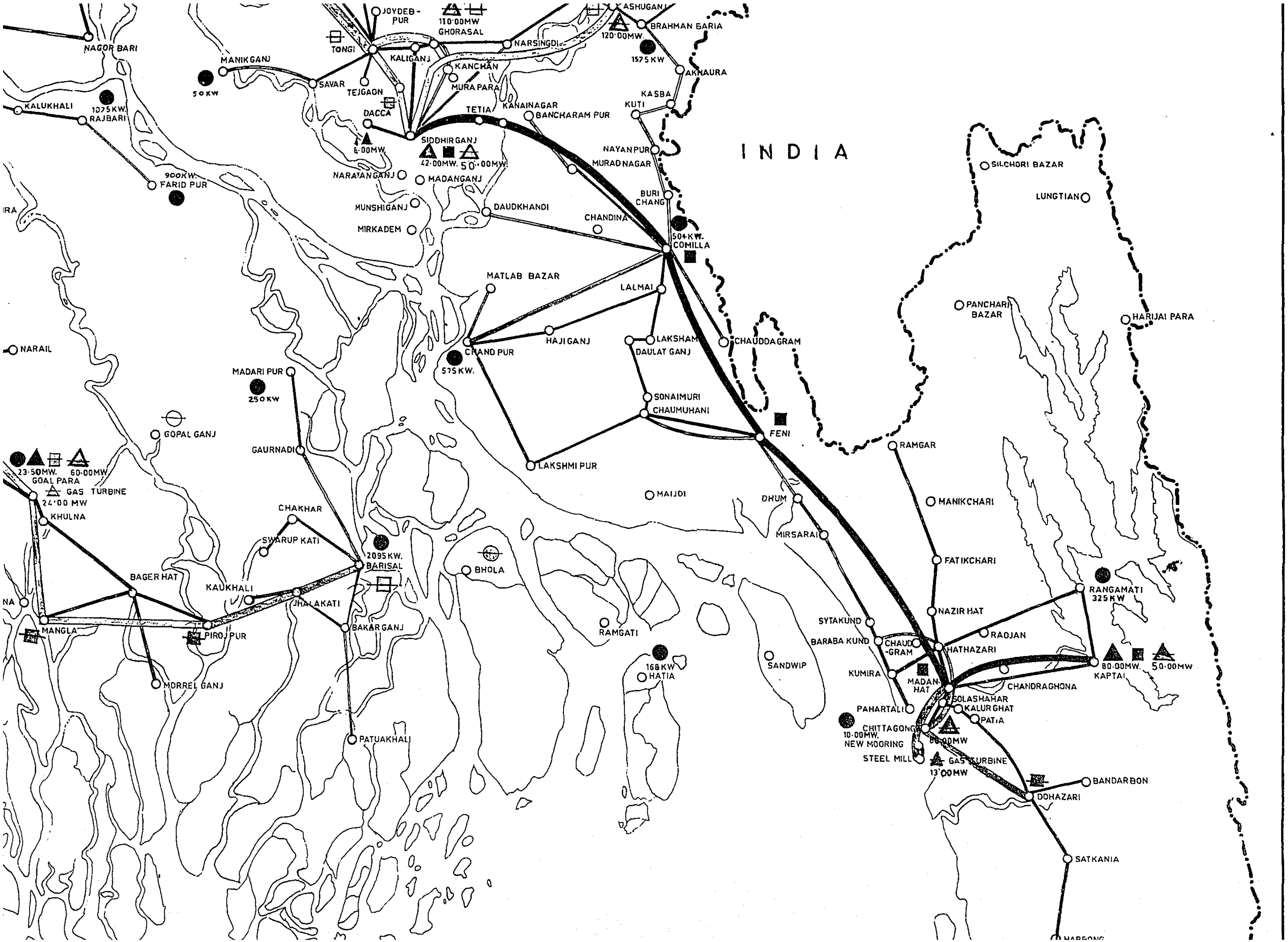
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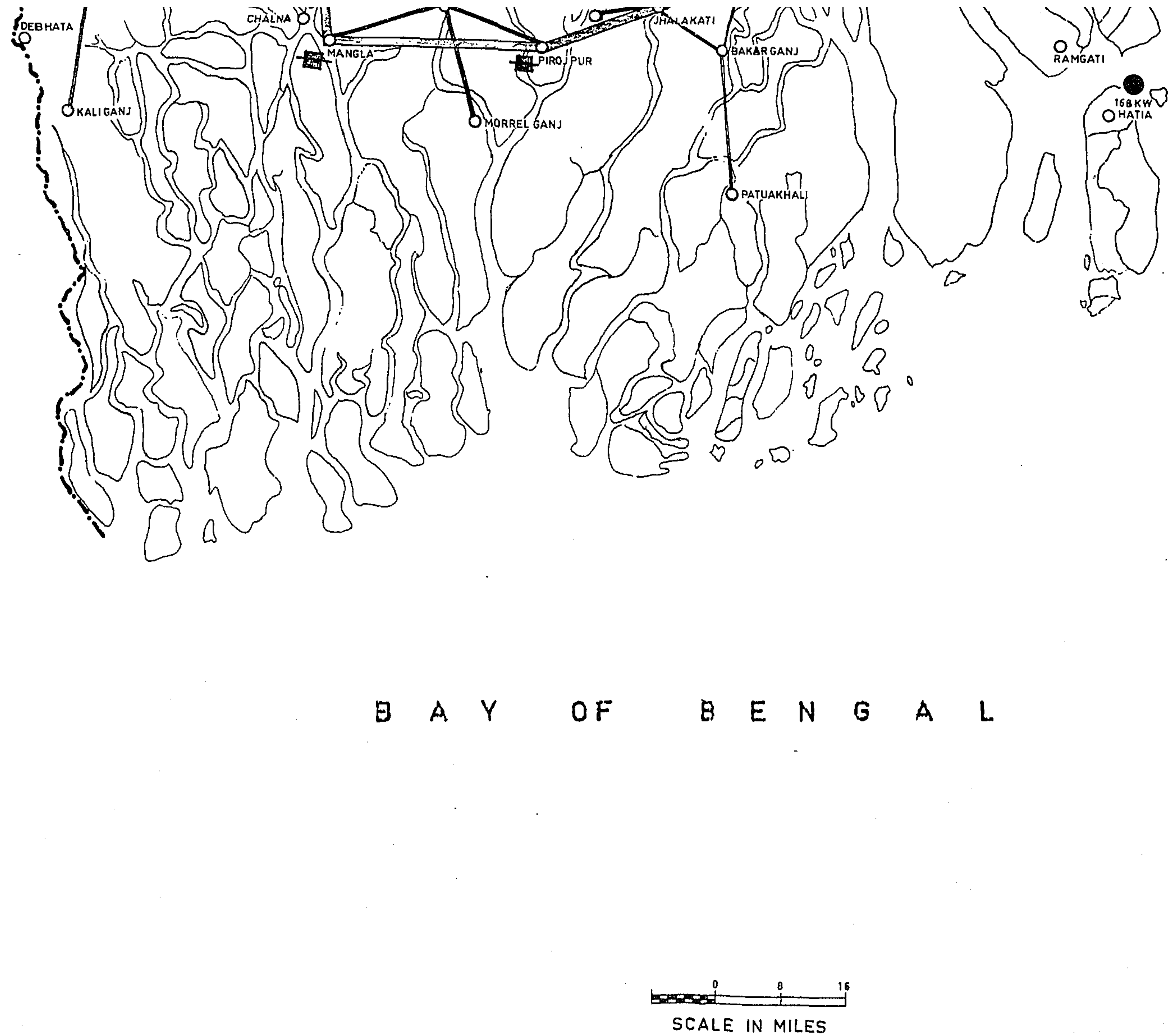

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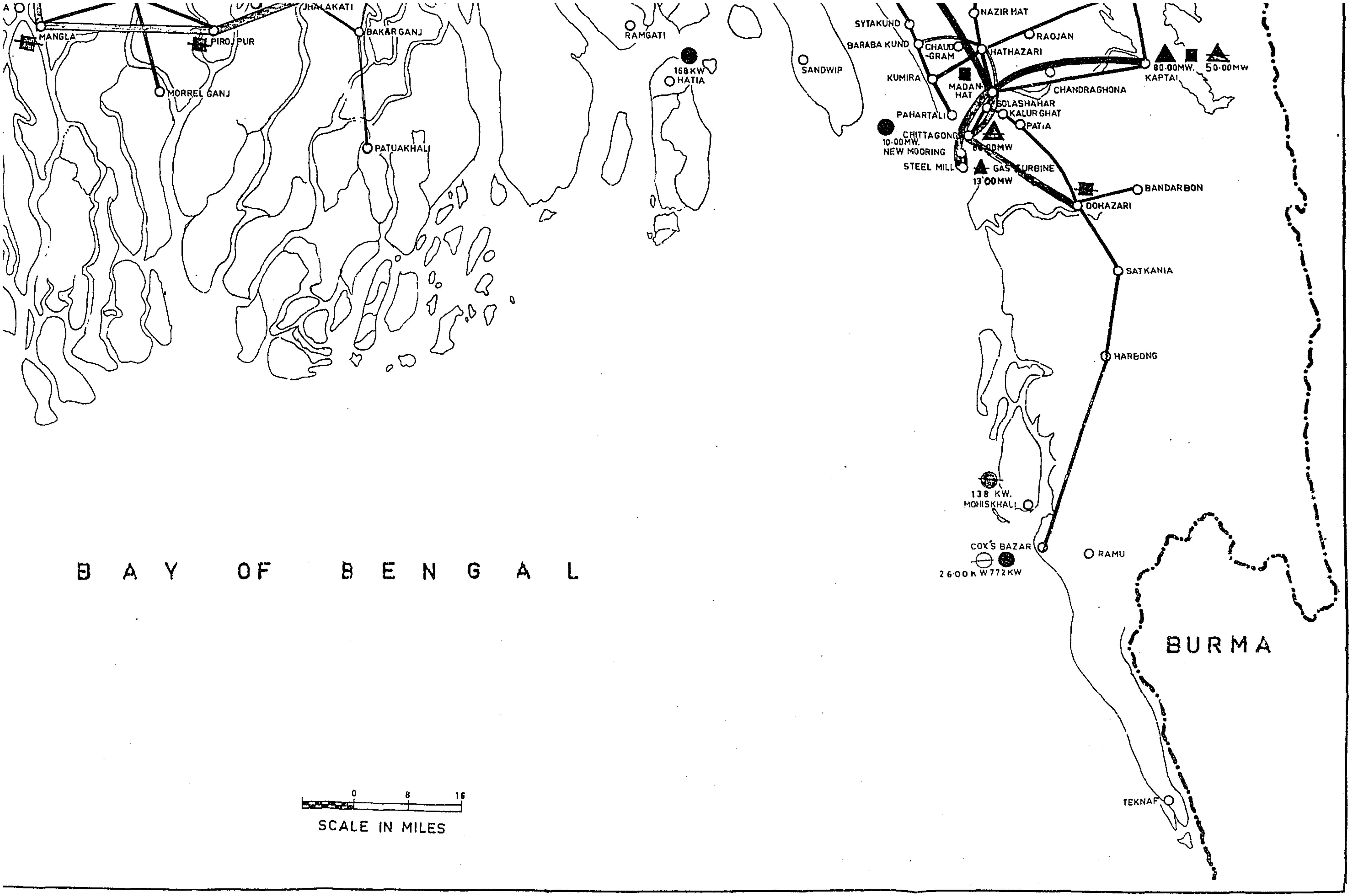
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BARABA KUND
CHAUD -GRAM
NAZIR HAT
RAOJAN
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50.00MW
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SOLASHAHAR
KALURGHAT
PATIA
PAHARTALI
CHITTAGONG
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STEEL MILL
GAS TURBINE
13.00MW
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DOHAZARI
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HARBONG
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MOHISKHALI
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0 8 16
SCALE IN MILES

M MORSHED

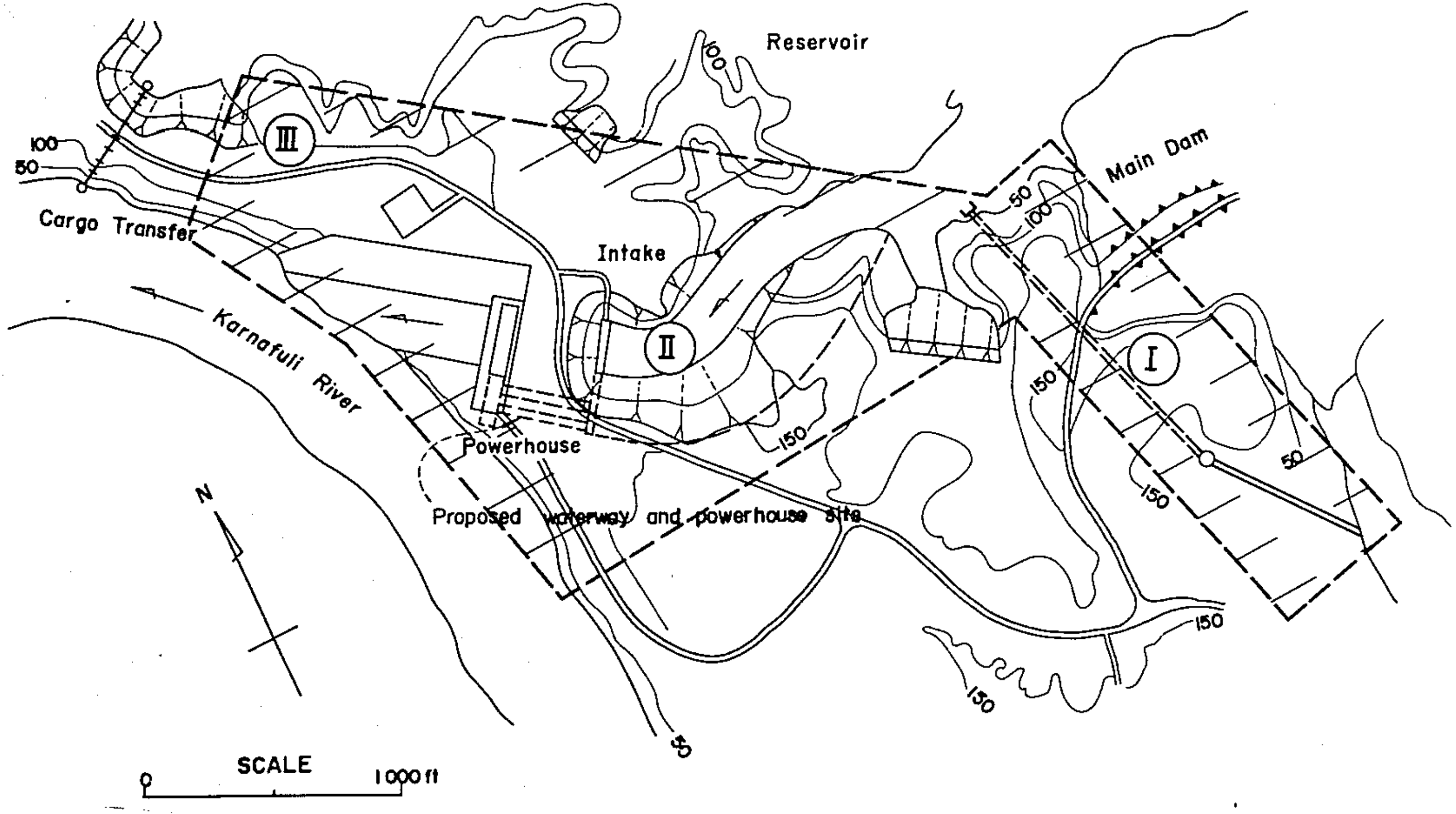


Fig. 3 Proposed Survey Area

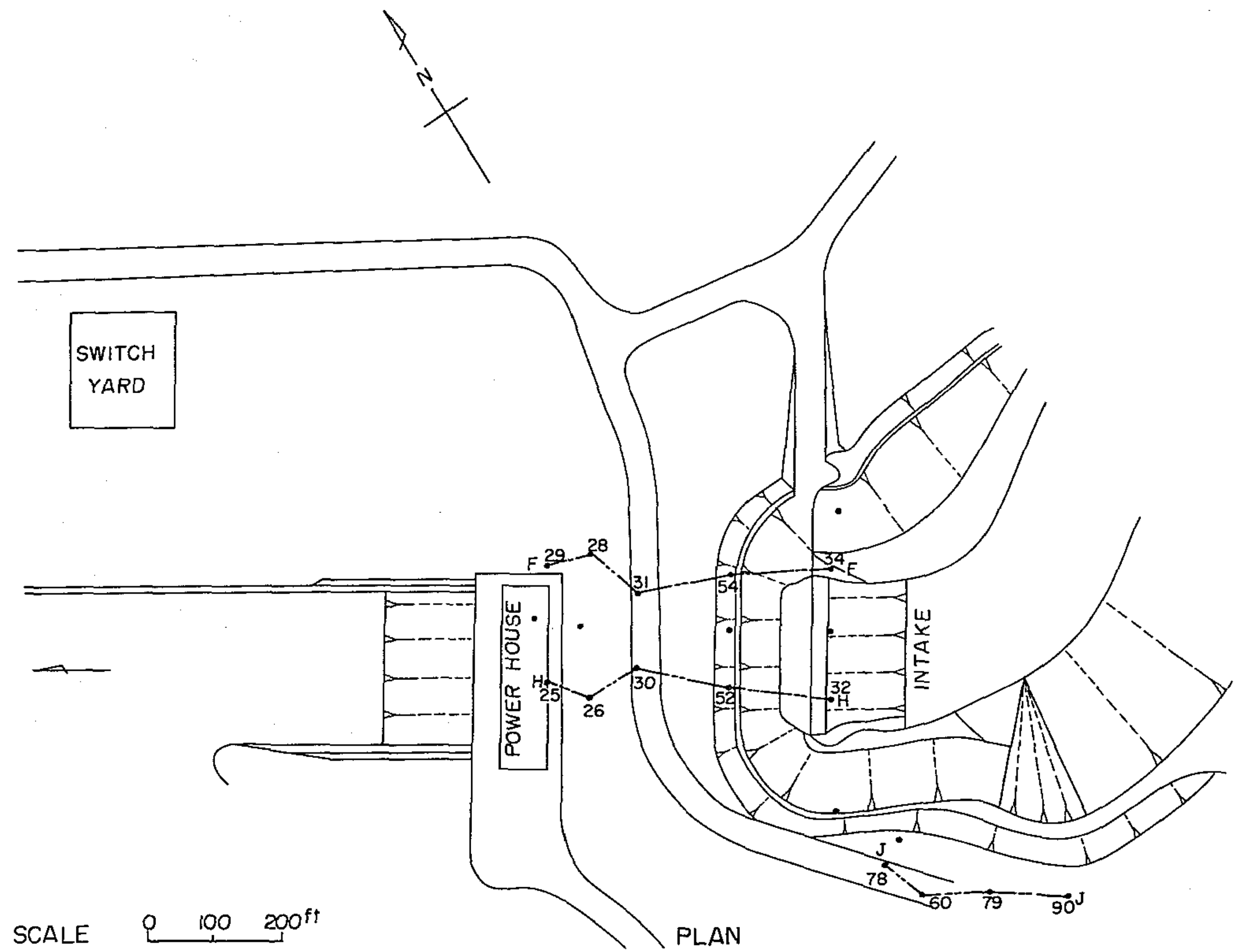
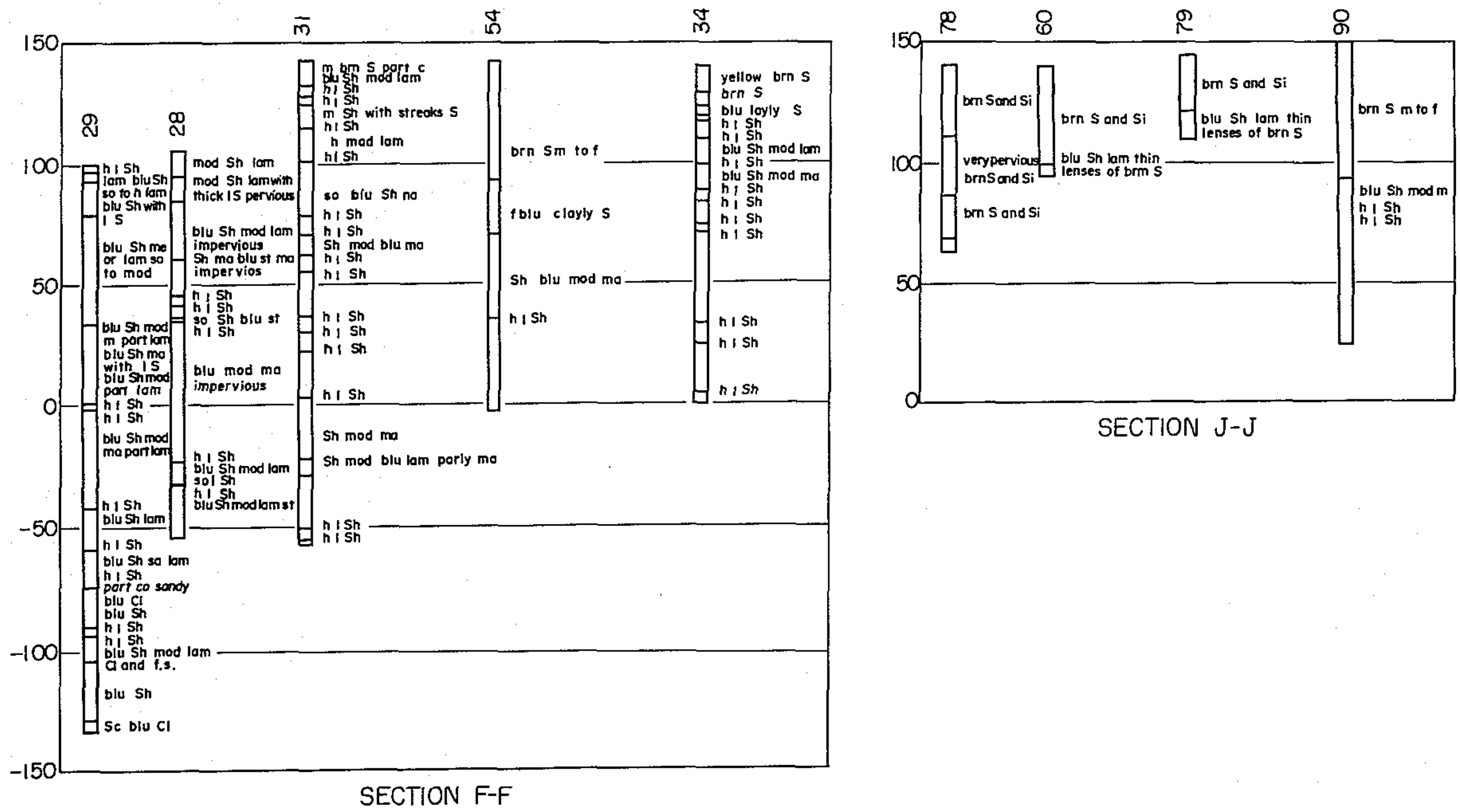
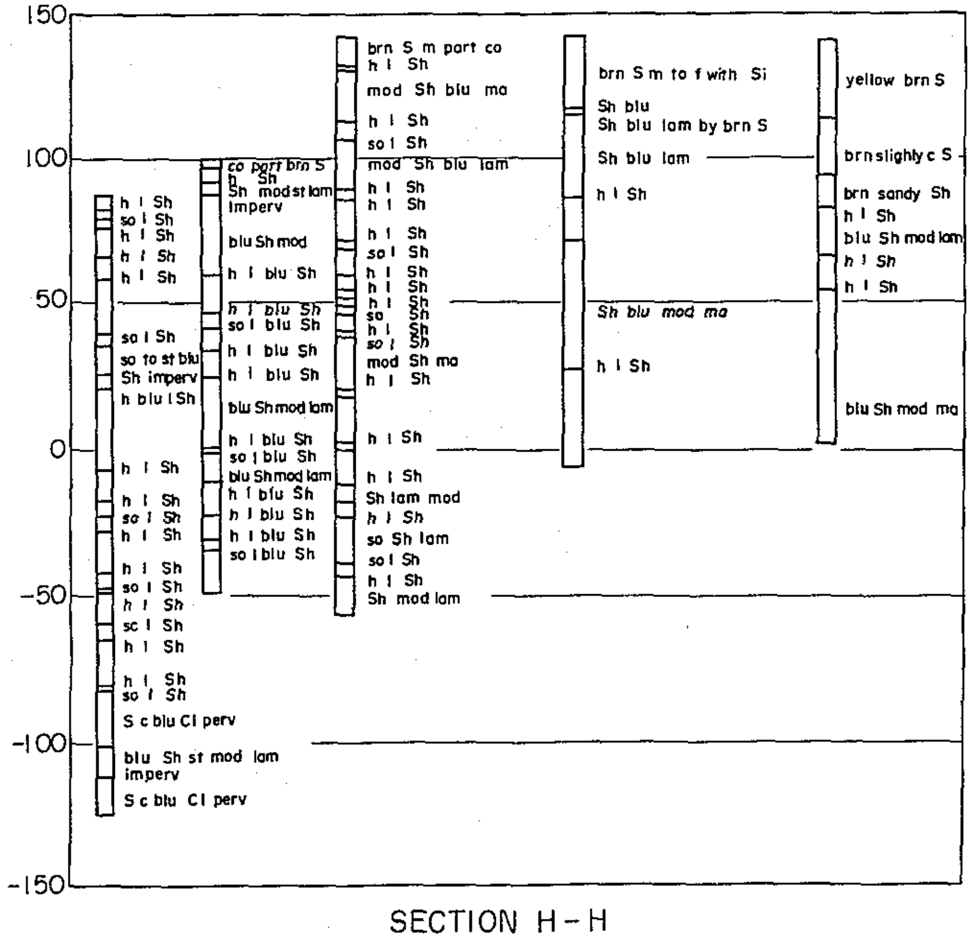


Fig. 4 Drill Holes at Powerhouse and Intake Sites (1)



LOG OF DRILL HOLES

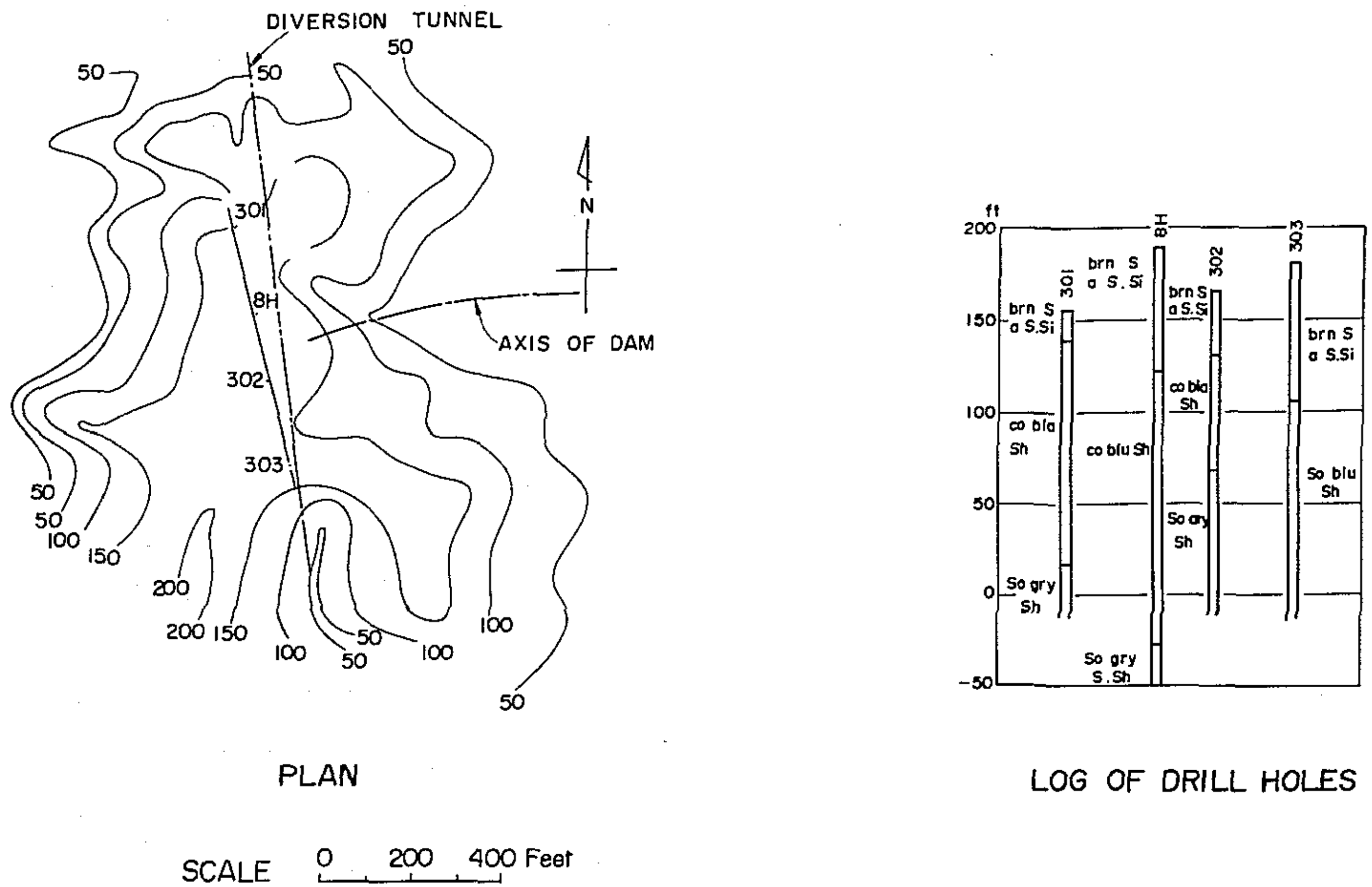
Fig. 5 Drill Holes at Powerhouse and Intake Site (2)



LEGEND

SAND	S
SHALE	Sh
CLAY	Cl
SILT	Si
BLUE	blu
BROWN	brn
GREY	gry
FINE GRAINED	f
MEDIUM GRAINED	m
COARSE GRAINED	cg
SOFT	so
MODERATE	mod
HARD	h
STIFF	st
PARTIALLY	part
COMPACTED	co
LAYERS	l
MASSIVE	ma
LAMINATED	lam

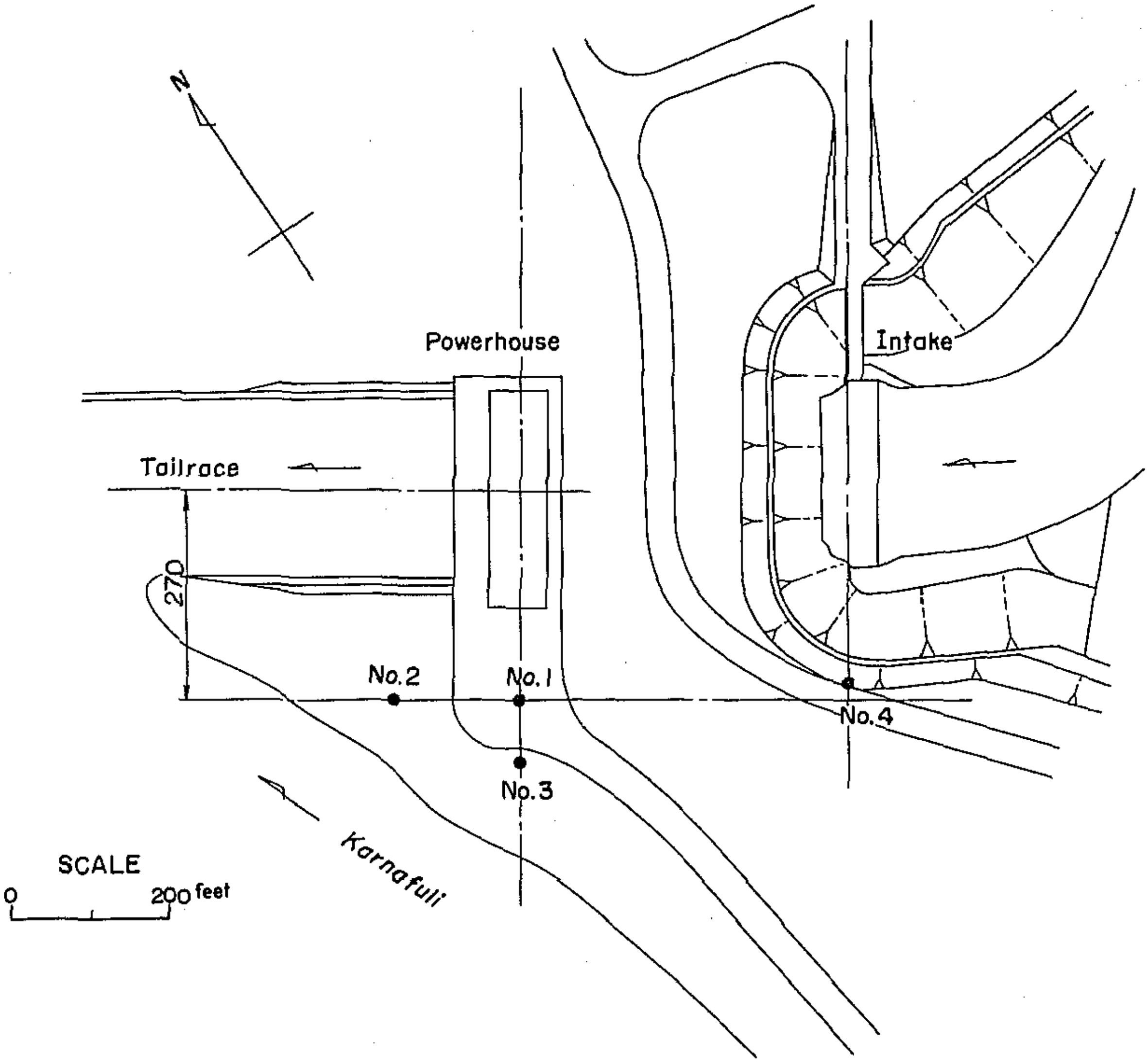
Fig. 6 Drill Holes at Powerhouse and Intake Site (3)



LEGEND

DRILL HOLE	301	SAND	S
BLUE	blu	SHALE	Sh
BROWN	brn	SILT	Si
GREY	gry	SOFT	So

Fig. 7 Drill Holes at Diversion Tunnel Site (By IECO)



		Depth
No. 1	EL.49.0 ~ −70.0 feet	119 feet
No. 2	" 49.0 ~ −21.0 "	70 "
No. 3	" 49.0 ~ −70.0 "	119 "
No. 4	" 140.0 ~ −28.0 "	112 "

Fig. 8 Location of Boring Holes (By WAPDA)

HOLE NO. 1

PROJECT ; KARNAFULI	ELEVATION OF SURFACE, 49 ft
LOCATION ; KAPTAI	ELEV. BOTTOM OF HOLE, -70 ft
DATE STARTED ; 29 JAN. 1968	INCLINATION OF HOLE, VERT.
DATE COMPLETED ; 29 JAN. 1968	DRLLED BY EPWAPOA
DIAMETER OF HOLE; 3 inch	GEOL. LY LOGGED BY M.M. BAIG
MACHINE ;	

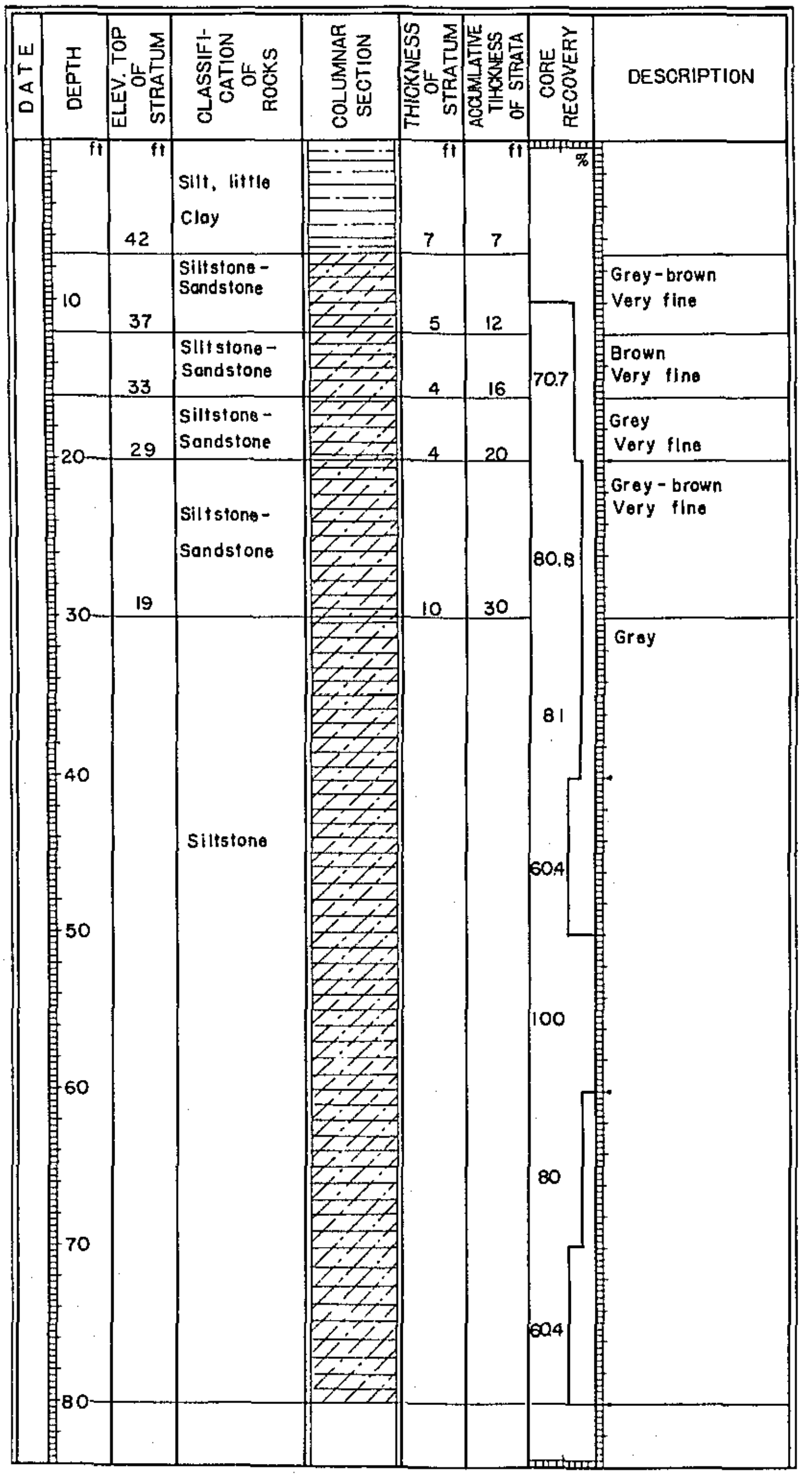


Fig. 9 Geological Record of Bore Hole (1)

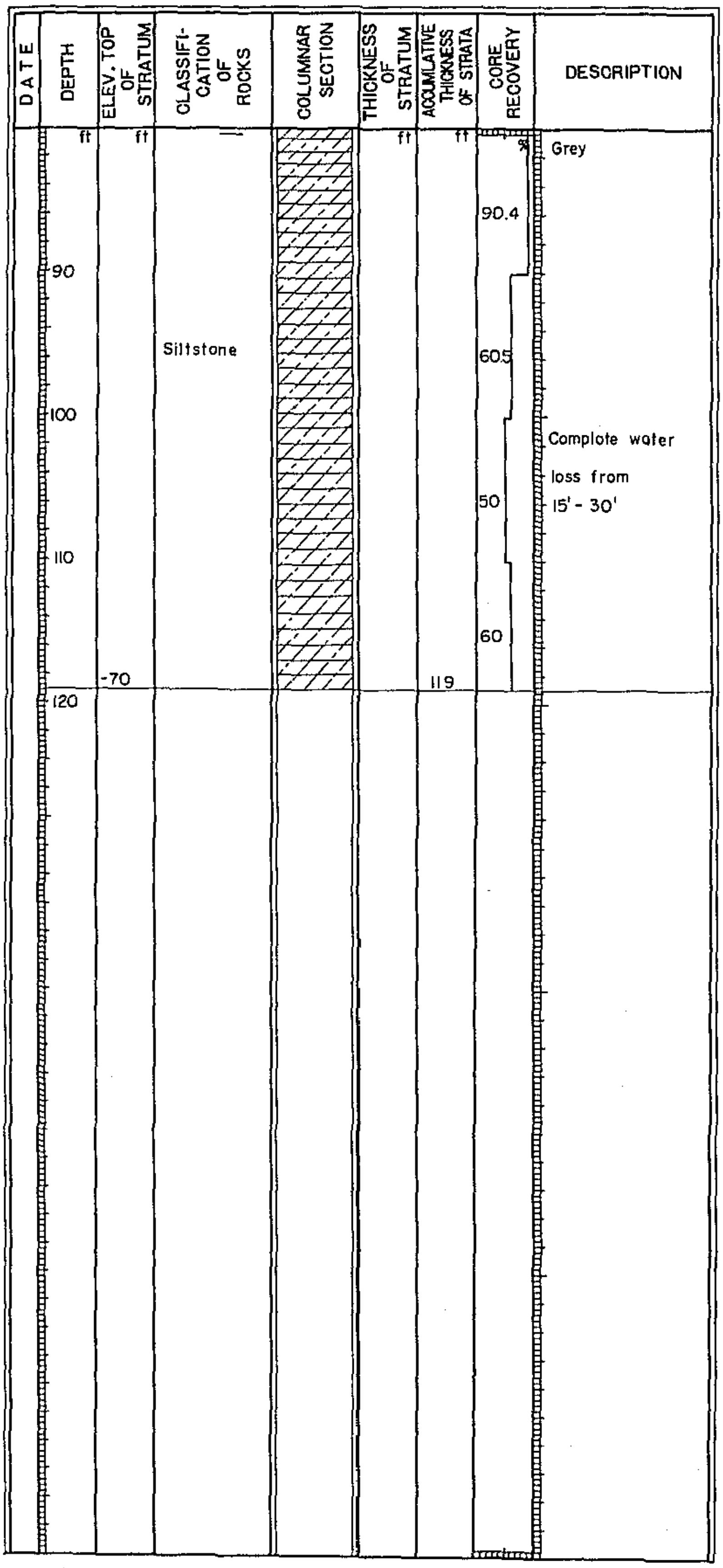


Fig. 9 Geological Record of Bore Hole (1) (continued)

HOLE NO. 2

PROJECT ; KARNAFULI	ELEVATION OF SURFACE, 49 ft
LOCATION ; KAPTAI	ELEV. BOTTOM OF HOLE, -21 ft
DATE STARTED ; 29 JAN. 1968	INCLINATION OF HOLE, VERT.
DATE COMPLETED ; 30 JAN 1968	DRLLED BY EPWAPDA
DIAMETER OF HOLE ; 3 inch	GEOL. LY LOGGED BY M.M BAIG
MACHINE ;	

DATE	DEPTH (ft)	ELEV. TOP OF STRATUM (ft)	CLASSIFI-CATION OF ROCKS	COLUMNAR SECTION	THICKNESS OF STRATUM (ft)	ACCUMLATIVE TIHCKNESS OF STRATA (ft)	CORE RECOVERY (%)	DESCRIPTION
		46	Silty very fine sand		3	3		
	10		Siltstone-Sandstone		7	10	50.4	Grey-brown Very fine
	20	29	Sandstone		10	20	10.2	Brown Very fine
		24	Silt		5	25		Trace mica
	30, 40	4	Siltstone with sandstone		20	45	90, 80	Grey
	50, 60, 70	-21	Siltstone			70	90, 99	Grey Thinly laminated

Fig. 10 Geological Record of Bore Hole (2)

HOLE NO. 3

PROJECT : KARNAFULI	ELEVATION OF SURFACE, 49 ft.
LOCATION : KAPTAI	ELEV. BOTTOM OF HOLE, -70 ft.
DATE STARTED ; 24 JAN 1968	INCLINATION OF HOLE, VERT.
DATE COMPLETED : 26 JAN 1968	DRLLED BY EPWAPDA
DIAMETER OF HOLE: 3 inch	GEOL. LY LOGGED BY M.M. BAIG
MACHINE :	

DATE	DEPTH	ELEV. TOP OF STRATUM	CLASSIFI-CATION OF ROCKS	COLUMNAR SECTION	THICKNESS OF STRATUM	ACCUMLATIVE TIHCKNESS OF STRATA	CORE RECOVERY	DESCRIPTION
	ft	ft 44	Silt with sand		ft	ft 5	%	Very fine
	10	39	Sandstone interbedded siltstone		5	10	49.9	Brown fine
	20	28	Siltstone interbedded sandstone		11	21	40.2	Grey
	30	17	Siltstone		11	32	50 Missed	Grey
		12	Siltstone with sandstone		5	37	80.8	Grey
	40	4	Siltstone		8	45	Missed 80.8	Grey Hard friable
	50	-6	Siltstone		10	55	99.5	Grey
	60	-16	Siltstone		10	65	99.9	Grey Hard friable
			Siltstone with sand				90.6	Grey Very fine sand
	80		Siltstone				80.9	Grey Thinly laminated

Fig. 11 Geological Record of Bore Hole (3)

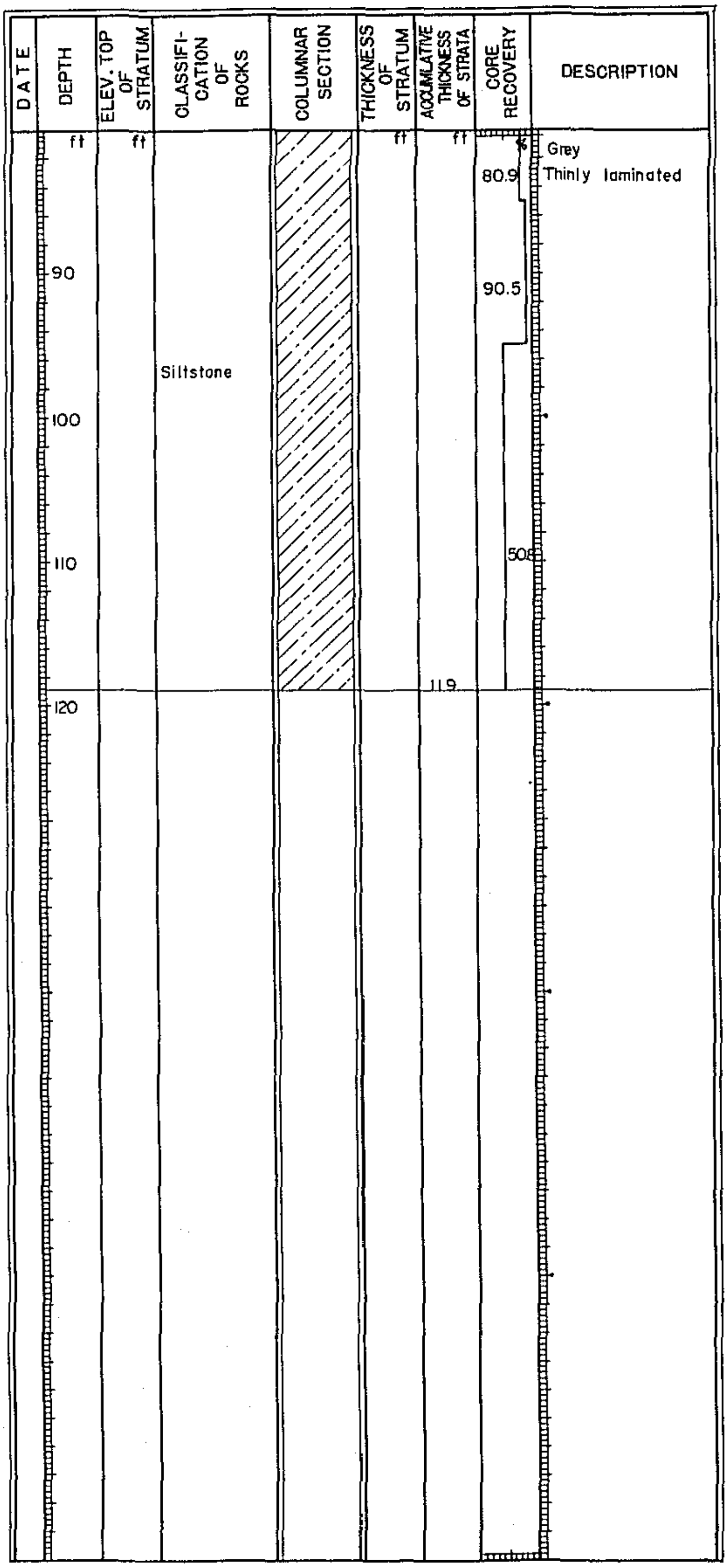


Fig. 11 Geological Record of Bore Hole (3) (continued)

HOLE NO.4

PROJECT : KARNAFURI — ELEVATION OF SURFACE, 140ft.

LOCATION ; KAPTAI — ELEV. BOTTOM OF HOLE,- 28ft.

DATE STARTED ; 21 JAN.1968 — INCLINATION OF HOLE, VERT.

DATE COMPLETED ; 23 JAN 1968 — DRLLED BY EPWAPDA

DIAMETER OF HOLE; 3 inch — GEOL. LY LOGGED BY M.M.BAIG

MACHINE ;

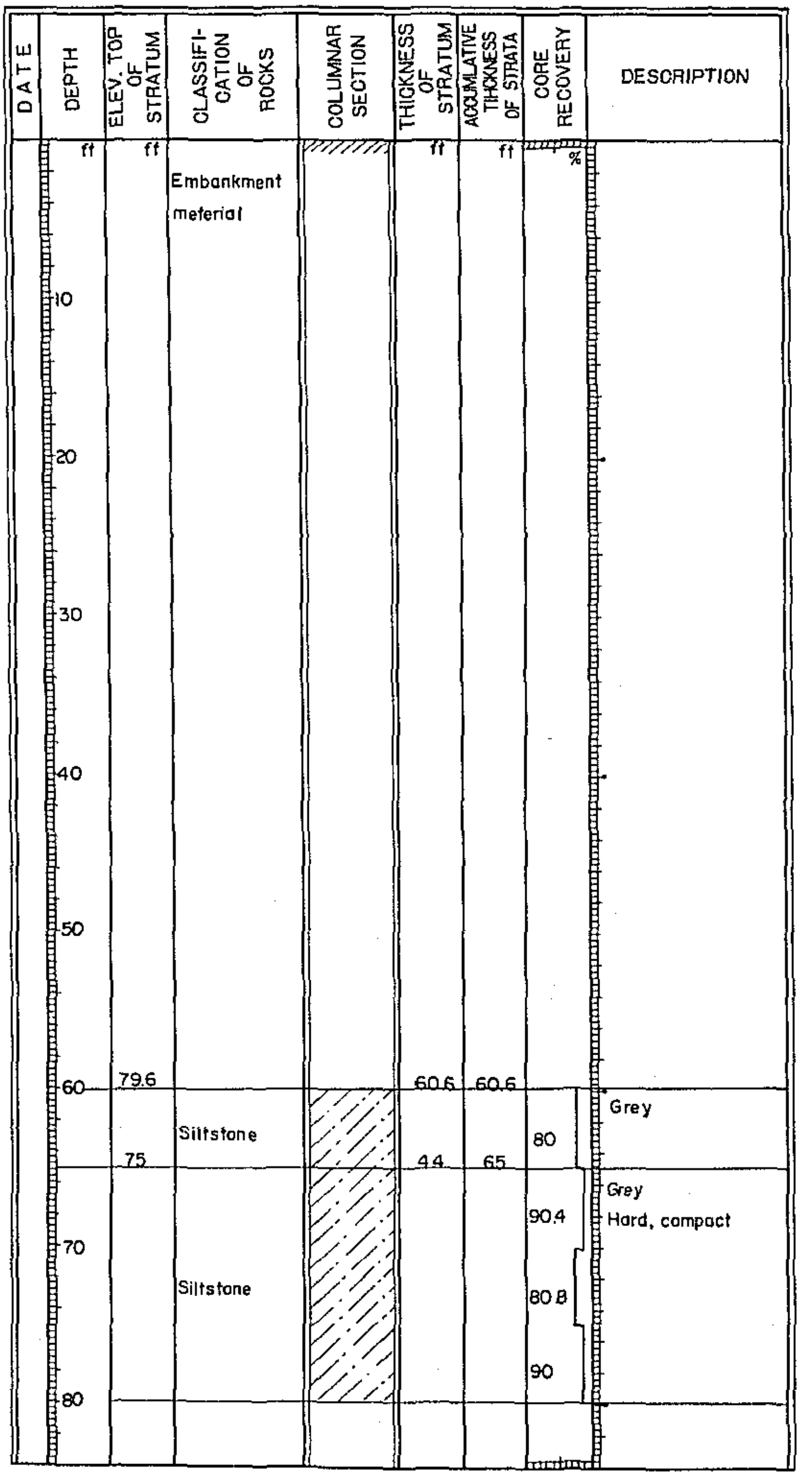


Fig. 12 Geological Record of Bore Hole (4)

DATE	DEPTH (ft)	ELEV. TOP OF STRATUM (ft)	CLASSIFICATION OF ROCKS	COLUMNAR SECTION	THICKNESS OF STRATUM (ft)	ACCUMLATIVE THICKNESS OF STRATA (ft)	CORE RECOVERY (%)	DESCRIPTION
	90	50	Siltstone		25	90	99	Grey Hard, compact
	100 110	-28	Siltstone			112	99.9 80	Grey With thin lagers of very fine sandstone
	120							

Fig. 12 Geological Record of Bore Hole (4) (continued)

Table 1

Monthly Rainfall at Kaptai
(From Agricultural Department)

(Unit: inch)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1936	*Nil*	*0.42*	-	-	*17.99*	*21.51*	*22.61*	*30.19*	*9.16*	-	*2.35*	*5.21*	*(115.67)*
1937	0.75	0.53	6.22	4.25	20.04	17.67	14.07	27.91	12.73	7.05	0.75	Nil	105.97
1938	Nil	0.30	Nil	4.39	19.31	24.67	10.09	19.68	22.01	6.43	3.40	Nil	110.28
1939	0.04	0.01	Nil	4.65	12.31	16.03	31.14	22.41	15.63	-	2.45	Nil	106.94
1940	Nil	5.20	8.31	Nil	12.01	19.63	15.00	13.70	22.96	4.94	Nil	0.86	102.61
1941	0.02	4.00	0.01	13.82	18.52	33.56	35.54	17.64	16.36	6.89	0.99	Nil	147.35
1942	Nil	0.02	1.45	9.25	5.34	13.29	10.31	15.68	18.04	2.12	10.45	1.08	87.03
1943	0.81	-	5.55	3.01	3.48	19.67	18.34	16.35	12.37	7.27	Nil	Nil	86.87
1944	*2.50*	0.46	*2.75*	*0.85*	*4.50*	*16.51*	*16.62*	*16.04*	*14.06*	*3.75*	*Nil*	Nil	78.04
1945	-	-	-	1.65	9.57	26.99	17.21	26.22	18.51	6.56	1.48	-	-
1946	Nil	0.50	5.46	8.59	14.82	15.38	38.40	17.32	19.35	14.99	Nil	5.00	139.81
1947	Nil	Nil	0.50	6.12	14.42	36.45	48.91	-	20.51	4.33	Nil	2.58	(133.82)
1948	0.30	1.79	2.30	15.21	28.57	16.41	22.52	16.68	22.18	3.14	Nil	Nil	129.10
1949	Nil	Nil	1.67	14.96	-	30.12	23.56	27.06	29.38	9.83	0.68	Nil	(137.26)
1950	*0.78*	1.31	0.59	*5.84*	20.78	*14.42*	*19.71*	*32.59*	*10.95*	-	3.46	-	*(110.43)*
1951	-	-	-	-	-	-	-	30.33	19.77	18.06	0.28	-	-
1952	-	-	*4.41*	6.52	*19.99*	28.52	-	-	-	-	-	-	-
1953	Nil	Nil	Nil	2.77	30.81	28.62	15.73	20.63	18.43	14.30	0.30	-	131.67

Table 1 (continued)

(Unit: inch)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1954	Nil	2.60	0.38	2.94	12.60	31.95	28.80	30.95	12.38	15.37	Nil	Nil	137.97
1955	Nil	-	7.24	3.21	1.99	14.29	37.76	17.99	7.53	5.86	-	-	(105.87)
1956	-	-	-	-	17.85	-	17.40	28.25	15.13	5.31	5.19	0	-
1957	2.35	0.49	0.18	0.44	7.99	27.33	7.64	8.35	13.16	6.53	0	0	74.46
1958	0.44	0.16	1.70	1.11	7.38	11.13	8.15	8.20	10.52	5.22	0.51	0.39	54.91
1959	0.04	4.02	6.65	0.65	5.49	19.21	10.27	19.91	12.97	8.68	0	3.12	91.01
1960	0	0	0.29	0	7.87	14.67	33.29	10.42	8.52	5.05	0.43	0.04	80.58
1961	0.06	0.27	1.37	1.15	5.66	26.59	31.27	25.89	10.11	15.65	0.62	0	118.73
1962	0.26	0.12	0	1.08	9.65	35.21	13.22	13.29	8.21	6.77	0	0	87.81
1963	0	0	7.30	11.80	14.12	28.82	44.04	9.37	12.08	9.86	-	-	(137.39)
1964	0	0.26	0.03	9.92	5.68	18.62	19.78	14.50	17.00	6.01	1.54	0	93.34
1965	0	3.56	0.35	1.20	7.53	26.19	31.87	20.27	20.94	9.48	0	4.05	125.44
1966	0.57	0	0.67	3.32	15.12	25.61	17.18	19.31	14.45	7.63	0.57	4.95	109.38

Table 2 **Evaporation at Kaptai**
(From Karnafuli Power Station)

(Unit: inch)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1963	3.455	4.582	6.276	6.658	6.179	4.055	3.551	4.205	4.941	-	4.253	3.913	(52.068)
1964	4.033	4.969	7.396	(5.966)	7.080	4.036	4.367	5.241	5.923	4.804	-	3.547	(57.362)
1965	4.332	4.291	6.055	8.346	7.763	3.473	4.558	4.003	4.448	4.381	4.079	3.091	58.820
1966	3.414	5.577	6.386	8.062	8.027	3.040	4.468	4.656	4.401	4.659	4.126	2.773	59.589
1967	2.951	4.009	(4.808)	6.843	7.109	5.694	4.936	5.198	4.303	5.045	4.398	5.169	(60.463)
1968	3.688												

Table 3 *Monthly Mean Runoff at Kaptai*

(From WAPDA)

(Unit: cusec)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL MEAN
1936	768	614	345	4,600	19,500	30,000	34,500	59,000	29,850	14,225	3,070	1,920	16,533
1937	768	650	384	768	3,840	20,630	23,400	76,000	35,700	17,850	3,070	8,900	15,998
1938	1,300	958	1,150	958	12,250	37,200	30,250	51,900	68,600	21,610	11,700	4,100	20,165
1939	2,300	1,536	1,150	3,070	4,980	11,700	30,100	71,000	38,900	26,200	3,450	2,300	16,391
1940	958	768	3,070	958	6,500	27,600	15,700	41,000	56,000	11,500	3,070	1,340	14,039
1941	958	2,300	364	4,790	36,800	67,900	91,500	42,900	39,800	40,700	4,790	2,300	27,925
1942	1,340	768	8,820	768	10,350	29,700	59,300	52,900	43,700	22,400	5,360	2,880	19,858
1943	1,340	1,150	1,070	2,380	1,540	10,150	28,900	35,200	42,900	8,620	2,300	1,340	11,408
1944	958	768	575	1,150	2,690	31,600	39,100	26,100	36,800	12,250	2,880	2,490	13,113
1945	2,300	2,110	768	768	5,160	25,300	20,100	53,200	47,750	14,350	4,790	4,980	15,131
1946	958	768	1,536	2,880	12,250	12,650	83,300	33,300	36,200	22,000	4,790	4,600	17,936
1947	1,300	958	768	1,150	4,980	36,700	70,500	114,000	67,000	37,800	6,320	3,250	28,727
1948	1,536	1,536	1,340	3,405	22,400	22,200	18,300	48,000	43,700	14,750	3,250	1,750	15,181
1949	950	575	768	4,790	14,400	20,900	50,100	33,900	35,800	30,200	5,080	1,920	16,616
1950	1,150	1,072	1,150	1,340	1,725	8,030	9,050	53,300	28,000	19,350	10,500	1,920	11,382
1951	1,150	768	768	1,920	10,350	35,700	56,700	48,500	36,600	59,000	9,000	5,750	22,184
1952	3,840	2,680	2,300	4,790	8,430	39,300	57,600	32,000	36,800	39,400	10,730	3,450	20,110
1953	1,536	1,150	958	1,150	14,400	41,000	28,330	57,100	65,500	23,750	6,500	3,450	20,402

Table 3 (continued)

(Unit : cusec)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL MEAN
1954	2,490	1,340	1,150	1,725	2,490	24,100	33,300	74,800	37,900	32,900	7,480	4,025	18,642
1955	4,025	2,680	4,600	8,420	12,250	31,200	52,400	48,500	22,000	10,380	16,680	3,070	18,017
1956	1,536	1,150	1,340	958	7,480	109,500	48,250	57,600	39,500	18,000	12,250	2,490	25,000
1957	2,940	1,340	958	768	2,490	9,580	24,100	13,600	21,820	15,900	2,680	1,725	8,121
1958	1,150	958	768	690	4,975	6,900	12,450	14,170	28,800	21,610	5,940	1,536	8,329
1959	1,536	2,300	3,450	1,536	4,600	55,500	36,600	36,800	28,000	27,200	21,820	10,380	19,144
1960	1,920	1,536	1,536	1,340	1,920	21,080	55,800	21,420	23,750	221,080	7,730	3,840	30,246
1961	2,220	1,920	3,070	2,375	2,300	56,932	20,809	62,000	35,187	9,700	3,500	1,499	16,793
1962	1,600	1,500	1,885	4,350	3,760	65,250	21,450	38,435	36,450	15,500	5,744	2,579	16,542
1963	2,677	2,210	2,657	6,960	9,700	87,806	96,625	28,103	14,452	33,766	15,119	3,210	25,284
1964	3,295	3,082	3,876	9,150	15,939	14,514	27,297	26,442	30,994	28,355	5,229	7,907	14,673
1965	4,127	5,813	4,001	3,382	15,350	28,737	53,431	50,858	19,223	28,435	6,037	7,605	18,917
1966	8,524	6,170	4,053	4,916	7,812	31,399	45,048	35,313	40,206	22,902	5,881	6,043	18,189

Table 4

Monthly Runoff at Kaptai
(From Irrigation Department)

(Unit: million cu.ft.)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1913						149,677	204,783	111,604	42,189	51,374	18,394	10,588	
1914	10,588	15,689	12,651	33,504	57,981	112,656	90,828	176,387	32,534	51,960	10,682	39,647	645,107
1915	8,591	8,591	10,617	22,939	63,325	57,532	90,121	115,138	44,289	53,084	11,443	6,397	492,067
1916	6,397	6,397	6,397	40,007	17,376	71,510	109,785	88,674	87,436	165,555	10,699	7,446	617,679
1917	7,446	7,641	7,446	60,015	13,402	40,842	40,283	146,891	47,328	18,198	15,967	5,736	411,195
1918	5,736	5,736	8,870	19,666	56,837	153,944	211,243	124,579	68,906	13,678	16,558	11,847	707,600
1919	11,847	11,847	11,847	16,494	21,235	42,154	82,562	47,221	61,816	10,899	16,328	4,870	339,120
1920	4,870	7,351	26,810	6,543	26,894	46,046	38,862	86,804	80,253	17,237	5,360	5,249	352,279
1921	7,900	5,437	54,106	12,497	22,341	47,296	139,466	59,527	115,117	123,317	8,093	7,529	602,626
1922	7,529	7,529	7,529	22,269	37,154	110,324	55,227	104,488	60,041	46,268	6,876	6,876	472,110
1923	6,876	7,861	6,876	14,405	81,460	108,700	30,836	99,646	155,427	67,228	39,321	8,221	626,857
1924	8,221	16,767	8,221	16,879	78,128	192,419	54,295	113,479	33,003	28,935	15,620	8,191	574,158
1925	16,087	8,191	8,191	36,892	74,295	90,210	74,389	102,880	37,069	15,704	33,932	6,344	504,184
1926	6,470	8,312	18,550	34,097	34,536	67,452	107,025	87,947	47,774	45,852	15,664	11,447	485,063
1927	6,573	21,783	9,415	133,755	76,021	113,200	52,788	91,204	164,543	65,521	9,483	8,786	753,072
1928	8,786	8,786	8,786	9,079	46,470	62,224	65,289	86,436	68,039	21,917	6,794	5,791	398,397
1929	5,791	5,791	5,791	48,965	24,622	444,981	53,117	75,790	34,917	19,457	12,683	12,683	744,588
1930	12,683	12,683	31,134	15,856	93,693	104,105	96,747	32,487	37,896	11,847	33,235	5,650	488,016

Table 4 (continued)

(Unit : million cu.ft.)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1931	5,650	5,650	8,124	9,485	52,985	67,008	76,438	33,557	84,346	45,558	12,859	5,611	407,271
1932	5,444	6,036	6,322	11,347	61,440	235,707	149,080	79,602	55,694	15,337	51,128	10,835	687,972
1933	10,835	10,835	11,978	33,433	53,740	61,102	97,683	115,683	51,247	19,999	6,785	6,785	480,105
1934	6,785	18,062	6,785	17,994	44,177	70,074	197,804	41,994	53,113	51,619	28,972	7,562	544,941
1935	7,562	8,073	7,562	29,760	23,278	49,218	55,571	185,642	100,125	29,863	10,654	7,254	514,562
1936	5,495	4,822	4,270	19,553	34,214	76,951	93,727	149,933	90,631	47,800	13,468	7,402	548,266
1937	5,249	4,423	4,069	4,612	13,543	58,115	64,687	179,619	90,466	50,109	12,374	22,045	509,311
1938	6,807	4,927	5,246	4,952	34,527	91,499	80,563	128,518	159,565	59,541	34,855	14,576	626,576
1939	9,906	5,407	6,416	12,375	17,484	35,097	78,169	170,636	98,813	64,900	12,915	9,619	521,737
1940	6,069	5,030	12,288	6,125	20,712	72,128	44,591	102,116	122,443	34,331	12,928	8,303	459,064
1941	5,764	8,248	4,495	13,832	97,275	161,537	209,323	108,630	81,695	57,195	15,684	9,839	773,517
1942	7,063	4,891	5,583	4,020	19,800	78,100	62,700	104,500	129,800	8,800	63,800	8,800	497,857
1943	7,700	5,500	7,700	7,700	90,038	34,930	75,208	88,087	107,947	27,034	9,894	7,160	468,898
1944	6,437	5,454	4,983	7,512	14,776	79,210	103,427	70,363	94,049	35,353	11,705	9,183	442,452
1945	9,247	8,100	5,481	5,219	17,284	63,774	54,123	126,763	118,481	42,351	15,725	17,296	483,844
1946	6,860	4,845	8,527	12,075	33,455	36,552	193,593	88,357	95,348	58,885	16,397	14,159	569,053
1947	8,144	5,729	5,758	6,819	17,343	159,531	162,434	260,737	158,755	93,436	21,719	12,645	913,050
1948	8,566	8,287	7,004	12,117	55,026	59,839	53,746	115,734	110,854	42,339	12,969	8,607	495,088

Table 4 (continued)

(Unit : million cu.ft.)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1949	6,209	4,511	5,428	16,344	37,372	75,546	126,269	88,870	93,777	79,531	17,960	9,707	561,524
1950	7,135	6,016	6,635	7,416	9,125	31,720	36,325	117,925	66,834	54,907	28,173	9,982	382,193
1951	6,657	5,026	5,682	17,319	18,968								

Table 5 **Monthly Runoff at Kaptai**
(From IECO)

(Unit: million cu.ft.)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1935										26,000	7,050	3,260	
1936	1,660	1,320	899	11,500	50,400	79,000	90,000	155,000	88,500	44,000	8,450	5,100	535,829
1937	1,450	1,150	760	1,300	10,200	53,500	60,500	198,000	92,000	47,000	8,680	18,600	493,140
1938	2,810	1,400	1,550	1,510	31,600	97,600	79,500	135,500	179,000	57,000	30,600	10,700	628,770
1939	6,100	3,650	2,150	8,400	13,200	30,200	78,800	185,000	101,000	68,800	9,490	5,620	512,770
1940	2,140	1,340	8,180	2,310	16,100	71,200	40,800	107,000	146,000	30,000	9,080	4,350	438,500
1941	1,900	6,600	1,080	12,200	94,800	177,000	239,000	112,000	104,000	56,000	12,300	6,110	822,990
1942	3,130	1,480	1,990	1,670	26,500	77,600	102,500	138,000	114,000	59,000	14,400	8,020	548,290
1943	3,660	2,730	2,590	5,540	3,750	26,800	75,700	91,800	112,000	22,600	6,330	3,150	356,650
1944	2,460	1,880	1,530	3,710	7,810	82,300	101,500	68,300	95,500	31,600	7,900	5,560	410,050
1945	5,390	4,570	1,730	1,880	13,700	65,000	52,700	139,000	124,000	37,500	12,200	13,500	471,170
1946	2,730	1,380	4,600	7,940	31,200	32,600	218,000	87,000	94,100	56,600	12,400	11,200	559,750
1947	4,020	1,990	1,600	3,030	13,100	174,000	184,000	298,000	175,000	99,000	17,100	8,680	979,520
1948	4,480	4,400	2,800	9,140	57,900	57,700	50,100	120,000	114,000	38,400	8,770	4,230	471,920
1949	1,960	1,030	1,530	12,300	36,400	78,500	131,000	88,900	93,500	79,300	13,200	5,200	542,820
1950	2,830	2,140	2,520	3,460	4,870	22,600	20,900	139,000	72,500	50,700	26,100	5,690	353,310
1951	2,360	1,310	1,660	5,540	26,500	92,400	148,000	126,000	95,400	154,000	23,300	15,100	691,570
1952	10,300	7,010	6,230	12,300	21,800	102,000	150,000	84,000	95,300	103,000	28,400	9,300	629,640

Table 5 (continued)

(Unit : million cu.ft.)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1953	4,490	2,510	2,080	2,530	37,600	107,000	73,600	149,000	171,000	61,200	17,600	9,030	637,640
1954	5,700	3,850	3,300	4,450	6,532	63,302	86,609	195,087	109,157	86,007	19,764	10,830	594,588
1955	10,830	7,351	11,839	21,292	31,402	80,920	136,463	126,265	57,784	36,704	43,585	8,177	572,612
1956	3,960	2,277	2,465	1,696	19,381	286,026	125,612	147,959	102,305	47,402	31,467	7,737	778,287
1957	7,731	3,522	2,118	1,545	7,030	24,945	62,328	35,366	56,775	41,249	6,472	4,515	253,596
1958	3,273	2,617	1,730	1,439	12,814	18,673	32,061	37,184	74,328	57,052	14,894	4,368	260,433
1959	3,264	5,726	9,250	3,274	11,676	87,731	95,795	95,880	73,128	71,272	57,465	36,220	550,681
1960	5,667	3,528	3,457	2,983	5,420	55,041	145,825	57,066	61,985	55,033	20,570	10,040	426,615
1961	5,720	4,751	8,602	6,006	5,768								

Table 6

Monthly Mean Runoff at Rangamati
(From Karnafuli Power Station)

(Unit: cusec)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL MEAN
1954					3,040	22,740	32,830	90,290	38,790	28,600	8,500	2,870	-
1955	2,880	2,100	3,500	-	9,060	25,950	53,600	37,200	19,700	13,120	16,470	3,600	(11,560)
1956	2,070	1,460	1,600	1,260	7,700	154,900	44,300	62,760	34,800	16,400	11,800	3,400	28,540
1957	1,845	1,065	710	629	2,010	7,810	19,760	12,590	21,640	15,290	2,056	1,260	7,220
1958	929	846	639	606	3,775	5,720	9,580	10,920	18,890	14,080	3,600	1,130	5,890
1959	945												

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