His Majesty's Government of Nepal

Kulekhani No.2 Hydroelectric Project

Feasibility Report

January 1979

Japan International Cooperation Agency

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PREFACE

The Government of Japan, in response to a request of the Government of the Kingdom of Nepal, agreed to conduct a feasibility study on the Kulekhani No.2 Hydro-Power Station Project and a study on the Kathmandu Transmission and Distribution System Project. The Government of Japan entrusted to conduct these studies the Japan International Cooperation Agency (JICA).

The JICA, recognizing the importance of these projects in the Social and Economic Development Plan of the country, dispatched a 14 member survey team headed by Mr. Masahiro Fuchimoto (Nippon Koei Co., Ltd.) to Nepal to carry out the studies from November 18, 1977 to March 24, 1978.

A report on these studies has now been completed after further work in Tokyo for submission to the Government of the Kingdom of Nepal.

I hope this report will prove to be useful for the electric power development and electrification of Kathmandu valley in the Kingdom of Nepal.

I wish to express my sincere thanks to the persons concerned of His Majesty's Government and the Nepal Electric Corporation (NEC), for their cooperation so kindly extended to the Japanese survey team.

January 1979

Shinsaku Hogen
PRESIDENT
JAPAN INTERNATIONAL COOPERATION AGENCY

January, 1979

Mr. Shinsaku Hogen
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Hogen,

LETTER OF TRANSMITTAL

We are pleased to submit the feasibility study report on the Kulekhani No.2 Hydroelectric Project located in the Central Region of Nepal. In the report are fully incorporated the advices and suggestions of the authorities concerned for the above-mentioned project in Japan, as well as the comments raised by the Ministry of Water and Power of the His Majesty's Government of Nepal during the final discussion on the draft report held at Kathmandu in November 1978.

The Central Nepal Power System covers Kathmandu Valley, Hetauda - Birganj corridor and their surrounding areas where most of the power demand in Nepal is concentrated. It is anticipated that the system will be short of power supply capacity in and after 1985/86, even with the increase of power generating facilities as presently scheduled. Taking the above facts into account, the timely construction of a hydropower plant is desirable to supplement such shortage.

The Kulekhani No.2 Hydroelectric Project will have an installed capacity of 33,000 kW and produce the primary energy of 95×10^6 kWh and the secondary energy of 25×10^6 kWh annually. The initial investment cost of the project was estimated at US$48 million at August 1978 price level including contingency.

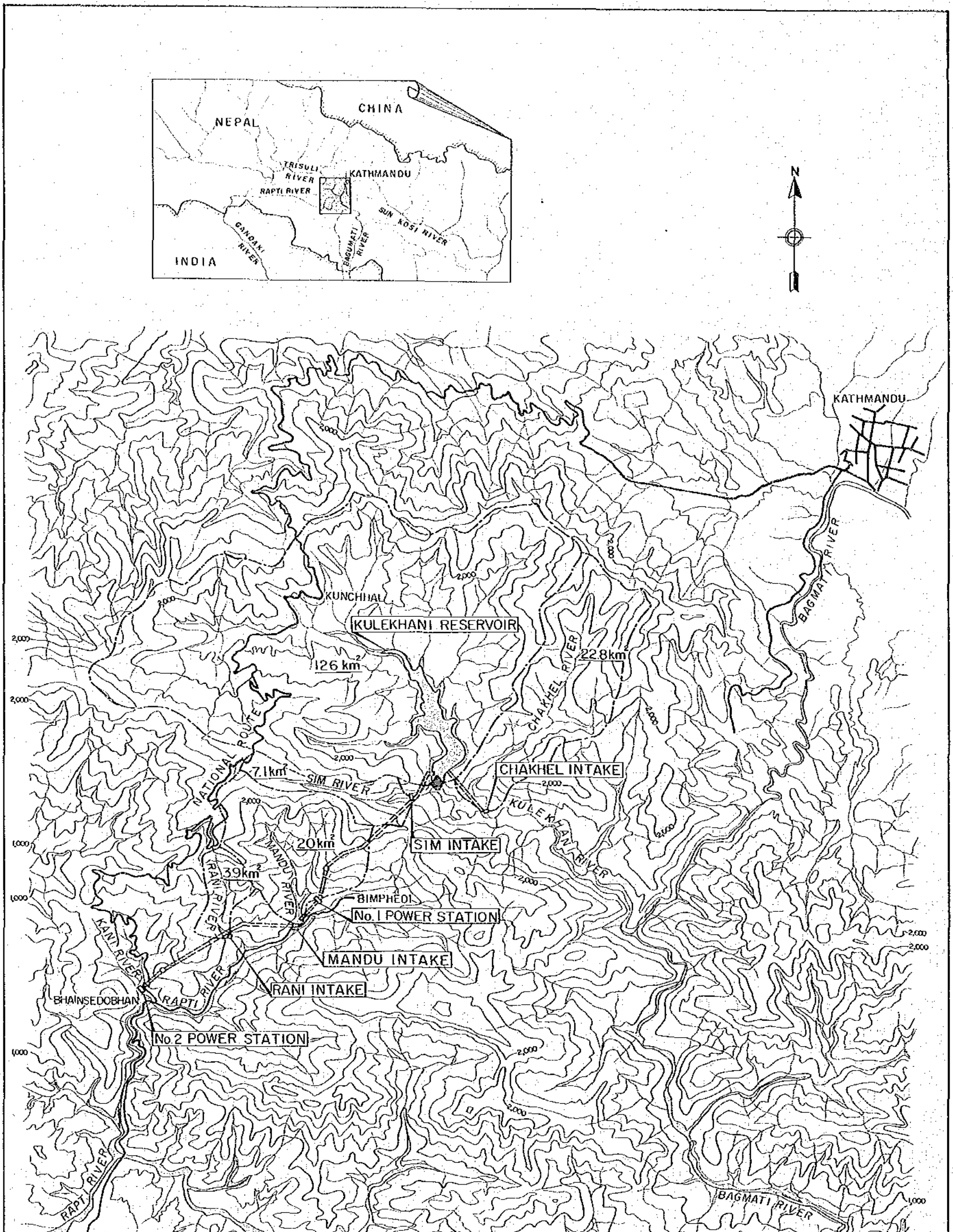
The economic internal rate of return of the proposed project is estimated to be 14.9 per cent, which proves to be economincally feasible to the project. In view of the importance and urgency of the project for the development of hydropower in the Central Nepal, as well as for socioeconomic development of the country as a whole, we recommend that the His Majesty's Government of Nepal will take up the project for implementation.

We wish to take opportunity to express our sincere gratitude to the personnel of your Agency, the Ministry of Foreign Affairs and the Ministry of International Trade and Industry, the Embassy of Japan in Nepal. We also wish to express our heartfelt gratitude to the counterpart experts of the Ministry of Water and Power and other authorities concerned of the His Majesty's Government of Nepal for their close cooperation and assistance extended to us during our field investigation.

Very truly yours,

M. Fuchimoto

Masahiro Fuchimoto
Team Leader
Nippon Koei Co., Ltd.



CHINA
NEPAL
TRISULI RIVER
KATHMANDU
RAPTI RIVER
SUN KOSI RIVER
GANDAKI RIVER
BAGMATI RIVER
INDIA
N
KATHMANDU
BAGMATI RIVER
KUNCHHAL
KULEKHANI RESERVOIR
126 km²
22.8 km²
CHAKHEL RIVER
NATIONAL ROUTE
7.1 km²
SIM RIVER
CHAKHEL INTAKE
KULEKHANI RIVER
SIM INTAKE
20 km²
MANDU RIVER
39 km²
RANI RIVER
BIMPHEDI
No.1 POWER STATION
MANDU INTAKE
KANI RIVER
RANI INTAKE
BHAINSEDOBHAN
RAPTI RIVER
No.2 POWER STATION
RAPTI RIVER
HETAUDA
BAGMATI RIVER
SCALE
0
5
10 km

SUMMARY AND CONCLUSION

1. The Kulekhani Project is a hydropower development project which envisages the development of a series of three power stations, namely the Kulekhani No.1, No.2 and No.3 Power Stations, on the Kulekhani and the Rapti rivers in the Central Region of Nepal. A 107 m high dam is being constructed on the Kulekhani river to create a reservoir with net storage capacity of 73 x 10^6 m^3, and the water regulated by the reservoir will be diverted to the Rapti river. It is planned to develop the hydropower potential by the said three successive power stations on the course of the Rapti river, utilizing a total gross head of more than 1,000 m. The Kulekhani No.1 Power Station with an installed capacity of 60 MW (which is the first stage development of the overall Kulekhani Project), is under construction and is expected to be completed in 1981. The Kulekhani No.2 Power Station is the natural follow-up of the No.1 Power Station. The Project contemplates to generate 33 MW hydropower by utilizing a gross head of about 300 m. The Kulekhani No.3 Power Station will have an installed capacity of 17 MW. The annual energy output produced by the overall Kulekhani Project will be about 430 x 10^6 kWh.

2. The Central Nepal Power System (CNPS) covers Kathmandu Valley, Hetauda-Birganj corridor and their surrounding areas where most of the power demand of Nepal is concentrated. Peak load of the CNPS reached 31,900 kW in 1975/76. The annual peak power demand takes place in the winter season (January or February) corresponding to the early part of the dry season. The installed capacity of the CNPS amounted to 35,226 kW; the power generating facilities consist of hydropower plants of 27,570 kW and diesel power plants of 7,656 kW. However, almost the whole power demand is presently met with hydropower plants most of which are of the run-of-river type, since diesel power plants are operated only in case of emergency and when the power demand of peak time of the dry season cannot be met with hydropower plants.

3. The Lumbini Zone in the southern part of the Western Region is scheduled to be interconnected with the CNPS in 1978/79. Further, the

Gandaki Zone in the northern part of the Western Region is expected to be extended to the CNPS in the near future. When the Kulekhani No.1 and No.2 Power Stations will have materialized, they would serve for such extended CNPS (called the Greater CNPS).

4. The power demand of the CNPS is rapidly increasing along with the recent economic growth of the area. The annual growth rate of peak demand has been around 20 per cent for the latest several years. If future peak demand is forecasted to increase at a rate of 10 to 20 percent per annum, it would reach 66 MW in 1980/81, 114 MW in 1985/86 and 198 MW in 1990/91.

5. To meet with the rapidly increasing power demand, the Government has decided to take such steps as the construction of the Devighat Power Station with an installed capacity of 14,400 kW and the supply of power of 15,000 kW from the Gandaki Power Station. Even if the said steps are taken as scheduled, the CNPS will be short of power supply capacity in and after 1980/81. Besides, taking into account the fact that the CNPS which depends largely on the run-of-river type plants is short of peaking capacity, the timely construction of a hydropower plant with a large reservoir is keenly required to increase the peaking capacity of the system.

6. Hydropower has always been considered as the best source of energy. Especially for countries like Nepal with large hydropower potentials and few or no other source of fuel, it is obvious that the existing water resources should be developed to meet the country's needs. Now, under the circumstances, the Kulekhani No.1 Power Station presented itself for priority for such reasons as it is located in the central power demand area, and it permits a reservoir construction of reasonable magnitude which is valuable when the existing hydropower plants are all of run-of-river type and when more plants of such type are anticipated for the foreseeable future. The construction of Kulekhani No.1 Power Station was started in 1977 and is scheduled to be completed in 1981.

7. Further shortage of the power supply capacity of the CNPS will occur within a few years after commissioning of the Kulekhani No. 1 Power Station due to the said high rate of power demand increase. Such shortage is expected to occur in 1985/86. After 1985/86, operation of a new power plant will be necessary to meet the power demand of the CNPS. As a new power plant, the Kulekhani No. 2 Power Station will be of high priority for such reasons as; i) it is situated in the central power demand area, ii) it is easy to access to the project site since the proposed structure sites are located along the National Route, iii) it may be possible to transfer to the No. 2 Power Station the construction facilities plants and machinery which are being used for the construction of the No. 1 Power Station, and iv) the planning of the project is progressing and it is possible to commence operation in 1985/86 in consideration of the 6½ years which will be needed for financial arrangements, detailed investigation, preparation of tender documents, tendering, mobilization and construction.

8. The Kulekhani No. 2 Power Station site is situated on the upper basin of the Rapti river in the Central Region of Nepal, at about 21 km southwest of Kathmandu. The area is topographically in the stage of early maturity, with ground height ranging from 600 m to 2,500 m. The upper Rapti basin is geologically composed of lower to middle Paleozoic sedimentary rocks with low-grade metamorphism and Quaternary deposits.

9. The Kulekhani No. 2 Power Station will utilize the regulated flow from the Kulekhani No. 1 Power Station and the natural flow from the Mandu river and the Rani river, both tributaries of the Rapti river. Since runoff records in the upstream basin of the Rapti river are not available, the runoff of said tributaries of the Rapti river is converted from that of the Rajaya gaging station which is located on the Rapti river about 40 km downstream of Bhainsedobhan. The average regulated flow from the No. 1 Power Station will be 4.98 m^3/sec in annual mean. By collecting the natural flow from the tributaries of the Rapti river (the Mandu and the Rani basins having a total catchment area of 23.9 km^2) the available total inflow to the No. 2 Power Station increases to 6.23 m^3/sec in annual mean.

10. The Kulekhani No.2 Power Station will have an installed capacity of 33,000 kW. It will generate energy of 117.9 GWh per annum including 95.1 GWh of primary energy and 22.8 GWh of secondary energy. It is anticipated that the total installed capacity of the hydropower plant would have amounted to 111,160 kW, consisting of 51,160 kW of run-of-river type power plant and 60,000 kW of the Kulekhani No.1 Power Station, and 33,000 kW of the Kulekhani No.2 Power Station, when the Kulekhani No.2 Power Station will have been put into operation. In addition, there will be available diesel power plants of 18,650 kW in the Greater CNPS. The Kulekhani No.1 and No.2 Power Stations will be operated to the maximum extent possible in order to meet the largely varying difference between the energy required and energy output of the existing and under-construction hydropower station. In such an operation, the annual energy production of the power plants in the Greater CNPS will be 718.4 GWh in total as listed below:

(Unit: GWh)

	Primary	Secondary	Total
Existing and under-construction hydropower plants	334.2	-	
Kulekhani No.1 P.S.	171.5	30.1	
Kulekhani No.2 P.S.	95.1	22.8	
Diesel power plants	64.7	-	
Total	665.5	52.9	718.4

11. The Project will consist of such construction as the Mandu diversion weir of 54 m in length, a waterway including Mandu intake, a headrace tunnel of about 6 km in length, the Rani tributary intake, a surge tank and a penstock tunnel, and an power station with an installed capacity of 33,000 kW including a tailrace channel of about 160 m in length. The 132 kV transmission line will be constructed between Kathmandu and Hetauda to transmit power from the Kulekhani No.2 Power Station. For receiving the said power, the New Teku substation, which will be newly constructed as a part of the Kulekhani No.1 Hydroelectric Project and will be completed in 1981, will be extended by 39 MVA. The Project

will be completed in $6\frac{1}{2}$ years including the detailed design, tendering, mobilization and the preparatory works.

12. The estimated construction cost of the project is US$48 million equivalent excluding interest during construction, comprising approximately US$40.8 million of foreign currency portion and US$7.2 million equivalent of local currency portion.

13. The economic feasibility is demonstrated by estimating the economic internal rate of return for the evaluation period of 50 years, using the economic benefit and cost stream. For the purpose of evaluating the power benefit of the project, a 33 MW coal-fired thermal power plant is considered to be the most economical alternative plant. Based on the following basic values, the economic internal rate of return is estimated to be 14.9 %, which proves to be economically feasible to the project. Even taking the reduced benefit of 10 % and increased cost of 20 %, the economic internal rate of return is calculated to be 8.9 %.

Benefit

Investment cost	US$27,090 x 10^3	(US$821/kW)
Replacement cost	US$24,390 x 10^3	(US$739/kW)
Annual O & M cost	US$ 810 x 10^3	(US$24.6/kW)
Fuel cost	US mill 35.1/kWh	
Annual energy output		
Primary	136.5 GWh	
Secondary to be exported to India	11.4 GWh	

Cost

Project facilities	
Investment cost	US$40,600 x 10^3
Replacement cost	US$14,290 x 10^3
Annual O & M cost	US$ 250 x 10^3
Associated facility	
Installation cost	US$ 950 x 10^3
Replacement cost	US$ 860 x 10^3
Annual O & M cost	US$ 30 x 10^3

14. For the purpose of the financial analysis of the Project, the financial power cost at a primary substation has been estimated on the basis that the loan conditions are such that the repayment period and annual interest rate are 30 years including 7-years grace period and 4%, respectively. The financial power cost of the Kulekhani No. 2 Power Station is US mill 38.4/kWh. While, in case that a coal-fired thermal power plant (as the alternative means) is constructed instead of the Kulekhani No. 2 Power Station, the financial power cost is also calculated under the loan condition that the repayment period and annual interest rate are 20 years including 7-years grace period and 2.5 %, and its value is US mill 68.5/kWh. It is considered that the financial power cost of the Kulekhani No. 2 Power Station does not show an unreasonable value, as far as the comparison is made with that of a coal-fired thermal power plant.

15. The principal features of the project are summarized in the following table.

PRINCIPAL FEATURES

1. Power Generation

(1) Discharge

Firm discharge:	4.54 m^3/sec
Annual average:	6.23 m^3/sec
Maximum discharge:	14.3 m^3/sec

(2) Head

Intake water level:	EL. 910.0 m
Tailwater level:	EL. 602.5 m
Gross head:	307.5 m
Rated head:	278.0 m

(3) Power and energy output

Installed capacity:	33,000 kW
Dependable peak power output:	33,000 kW
Annual energy output:	
Primary	95.0 GWh
Secondary	25.1 GWh

2. Waterway

(1) Mandu diversion weir

High water level:	EL. 912.5 m
Low water level:	EL. 910.5 m
Effective storage capacity:	12,000 m^3
Crest elevation:	EL. 906.0 m
Weir height:	14.5 m
Weir length:	53.5 m
Gate:	Vertical lift type, 12.5 m wide x 7 m high

(2) Intake

Type:	Provided with settling basin and tank
Gate:	Vertical lift type, 2.5 m wide x 2.5 m high

(3) Headrace tunnel

Type:	Circular section
Length:	5,750 m
Diameter:	2.50 m

(4) Rani tributary intake

Type:	Weir, settling basin and inclined shaft provided

(5) Surge tank

Type:	Restricted Orifice type
Diameter:	8 m
Height:	42 m

(6) Penstock line

Type:	Underground concrete-lined steel pipe
Diameter (varies):	2.0 - 1.7 m
Length:	870 m

(7) Powerhouse

Type:	Above-ground type (Floor 12.5 m x 34 m, 33 m high)

(8) Tailrace

Type:	Double-box culvert type
Dimension:	(2.5 m wide x 2.0 m high) x 2
Length:	160 m

3. Electro-mechanical Equipment

(1) Generating equipment

i) Turbine

Type:	Vertical-shaft Francis for 2 units Horizontal-shaft Pelton for 1 unit
Rated output:	15,200 kW for Francis 3,000 kW for Pelton
Speed:	750 rpm for Francis 600 rpm for Pelton

ii) Generator

Type:	3-phase, vertical-shaft, revolving field type for 2 units 3-phase, horizontal-shaft, revolving field type for 1 unit
Capacity:	2 x 18,000 kVA 1 x 3,600 kVA
Cycle:	50 Hz
Power factor:	0.85

iii) Main transformer

Type:	Single-phase to form a 3-phase bank, oil immersed, self-cooled type
Voltage:	132 - 139 - 145 kV/11 kV
Capacity:	39,000 kVA

(2) Transmission line and substation

i) Transmission line (32 km long between Kathmandu and Hetauda)

Voltage:	132 kV
Conductor:	240 mm^2

ii) New Teku substation in Kathmandu

Capacity to be extended: 39,000 kVA

MAIN REPORT

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ABBREVIATIONS AND UNITS

HMG of Nepal	His Majesty's Government of Nepal
CNPS	Central Nepal Power System
ED	Electricity Department of the Ministry of Water and Power, HMG of Nepal
NEC	Nepal Electricity Corporation
BPC	Butwal Power Company
IDA	International Development Association
OECF	Overseas Economic Cooperation Fund
OPEC	Organization of Petroleum Exporting Countries
L.F.	Load Factor
OMR	Operation, Maintenance and Replacement
EL.	Elevation
mm	Millimeter
cm	Centimeter
m	Meter
km	Kilometer
m^3	Cubic meter
m^3/sec	Cubic meter per second
m^3/hr	Cubic meter per hour
km^2	Square kilometer
ha	Hectare
kg	Kilogram
t (ton)	Metric ton
$k\ell$	Kilolitre
%	Percent
^oC	Degree Centigrade
o	Degree
NNW	North-Northwest
SSE	South-Southeast
rpm	Revolution per minute
HP	Horse Power
W	Watt
kW	Kilowatt
kWh	Kilowatt-hour

MWh	Megawatt-hour
GWh	Gigawatt-hour
V	Volt
kV	Kilovolt
kVA	Kilovolt-ampere
MVA	Megavolt-ampere
US$	United States Dollar
USmill	United States mill (US$1.00 = 1,000 US mill)
Rs.	Nepalese Rupee
Nepali Paisa	Rs.1 = 100 Paisa

LIST OF PARTICIPANTS IN THE FIELD SURVEY AND COUNTERPARTS OF HMG

Field Survey Team

Mr. M. Fuchimoto	Team Leader
Mr. M. Kanda	Electric Engineer
Mr. E. Araida	Civil Engineer
Mr. H. Sasaki	Geologist
Mr. H. Sadamura	Hydrologist
Mr. S. Inoue	Survey Expert
Mr. S. Kamiya	"
Mr. H. Hayasaki	Aerial Photograph Expert
Mr. T. Suzuki	Borling Expert
Mr. H. Kanesawa	Geophysicist
Mr. K. Hayashi	"
Mr. M. Suemori	Coordinator
Mr. S. Okayama	Planner

Counterparts of the Ministry of Water and Power

Mr. S. K. Malla	Chief Engineer
Mr. S. N. Pradham	Superintending Engineer
Mr. R. C. Choudhari	Superintending Engineer
Mr. R.C.L. Pradhan	Superintending Engineer
Mr. M. Prasad	Civil Engineer
Mr. S. L. Ranjitkar	Electric Engineer

Counterparts of NEC

Mr. P. P. Shah	General Manager
Mr. L. M. Dixit	Deputy Manager
Mr. R. M. Sakya	Acting Manager

CHAPTER I

INTRODUCTION

1.1 The Feasibility Study

The Government of Japan decided to take up a feasibility study on the Kulekhani No.2 Hydroelectric Project in 1977, in response to the request made by the His Majesty's Government of Nepal. The Japan International Cooperation Agency (JICA) was appointed as the executing agency of the Government of Japan for the feasibility study and entrusted the work to the Nippon Koei Co., Ltd. in November 1977.

1.2 Work Performed

The field work was performed by the Nippon Koei team in collaboration with the counterparts furnished by the Electricity Department (ED), the Ministry of Water and Power, and Nepal Electricity Corporation (NEC), both of HMG, during a period from November 1977 to March 1978. The main items of the field work are as follows:

(1) Collection of data and information of meteorology, hydrology, topography, geology, power demand and supply, socio-economy and others.

(2) Reconnaissance of the proposed sites for dam, intakes, waterway, powerhouse, transmission line, access roads and other relevant structures.

(3) Aerial photo shooting, ground control survey and mapping covering the proposed sites of power station, penstock line and intake sites.

(4) Core boring and geophysical exploration at the proposed structural sites.

(5) Stream flow measurement on the Mandu, the Rani and the Rapti rivers.

The analysis and detailed study have been carried out in Japan subsequently to the field work, and all the results of the works are presented in this Feasibility Report.

1.3 General Setting of the Project

The hydroelectric power development of the Kulekhani river was first indicated by the Swiss-Nepal Forward Team in 1956. The plan at that time was based on a diversion of the Kulekhani river to the Rapti river to utilize a high water head between the two rivers in the upstream reaches.

A more comprehensive plan was proposed in the Preliminary Design Report on the Kulekhani Hydroelectric Project prepared by a team dispatched by the Government of Japan in 1963. The proposed plan took into account the water head in the Rapti river itself in addition to the water head between the Kulekhani and Rapti rivers. It included a reservoir in the Kulekhani river and three power stations in the Rapti river to develop a potential of 112 MW in a cascade of more than 1,000 m.

The hydroelectric potential so far surveyed in Nepal was classified (in the Masterplan of Hydroelectric Power Development in Nepal by JICA in 1974) into three groups: Large scale development for the export of power to India, medium and small scale development to meet the domestic demand and micro projects for the rural electrification. The Kulekhani Project belongs to the medium and small scale development and it is located in the central Nepal.

His Majesty's Government of Nepal took up the implementation of the Kulekhani Project, in view of the rapid growth of power demand in the central Nepal. A feasibility study[/1] was carried out under the technical assistance program of the Government of Japan between 1973 and 1974 and it was recommended to implement the Kulekhani No.1 Hydroelectric Project as the first stage of the Kulekhani Project.

The Kulekhani No.1 Hydroelectric Project is under construction and should be completed in 1981. It includes a storage dam of $73.3 \times 10^6 m^3$ in active storage capacity on the Kulekhani river and a power station with installed capacity of 60 MW on the Rapti river. The water head utilized is 600 m. The Kulekhani No.2 Hydroelectric Project will develop a potential of 33 MW in a cascade of 300 m immediately below the No.1 Power Station, utilizing the regulated flow from the No.1 Power Station.

/1: Feasibility Report on Kulekhani Hydroelectric Project, JICA, September 1974.

CHAPTER II

BACKGROUND

2.1 Geographic Features of Nepal

The Kingdom of Nepal of 141,000 km^2 is bounded by Tibet of the People's Republic of China in the north and India in the south. The country extends from 26°30' to 30°15' north in latitudes and from 80°00' to 88°15' east in longitudes. It is about 800 km in the east-west direction and from 150 to 240 km in the north-south direction.

The land of Nepal comprises six well defined topographic zones from the south to the north; the Terai belt, Siwalik hills, Mahabharat mountain range, Mid-land zone, Himalayan range and Tibetan plateau.

The Terai belt is the Nepalese portion of a vast flood plain extending from the left bank of the Ganges river and lies between the Indian border and the foot of the Siwalik hills. It has an altitude ranging from 60 m to 300 m and a width from 15 km to 40 km. The southern part is densely populated, partly with people of Indian stock, while the northern part is covered with thick forests.

The Siwalik hills rise sharply from the Terai belt up to an altitude of 1,500 m. Main features of the Siwalik hills are characterized by its rugged relief, dense forest, poor soil consisting of soft sandstone rich in mica and quartz and large-grained conglomerates and a low population.

The Mahabharat range rises to an altitude of some 3,000 m. Geologically, it is a front of the big overthrusted nappes, the breakers against the Siwaliks. In general, the Mahabharat range forms a large syncline which covers nearly the whole length of the country (800 km). The Mahabharat range is very rugged and has steep slopes. Large tributaries of the Ganges river (the Karnali, Bheri, Gandaki and Sapt Kosi rivers) have made deep gorges trending south across the Mahabharat range. The population density is low.

The Midlands of Nepal cover a zone of 65 km to 100 km in width, between the Mahabharat range and the Himalayas. The Midland zone has a terrain of very gentle slopes lying at altitudes ranging from 600 m to 2,000 m.

FIG. 2.1 GENERAL MAP OF NEPAL

The bulk of the country's population is concentrated in this zone. The Midland zone is very fertile, and all kinds of fruits, vegetables and grains of subtropical and moderate climates are grown.

The main range of the Himalayas is divided by the big transversal rivers into different groups. The main tributaries of the Ganges have their origin at the watershed to the north of the Himalaya range and cross through the Himalayas south-wards forming large gorges. The main range of the Himalayas forms the border line between Nepal and Tibet in its eastern part.

In the western half, Nepalese territory extends far beyond the main range of the Himalayas into the Tibetan plateau. The Tibetan plateau in Nepal consists of a mountain desert between 3,000 m and 5,000 m in altitude. With irrigation, barley and other grains are raised besides potatoes. Many Tibetans are engaged in trade extensively with Tibet and India.

The climate of Nepal is affected by the physical features of the land. Terai belt and Siwalik hills are dominated by a sub-tropical climate, with maximum temperatures rising over 40°C in summer (April and May) and minimum temperatures falling to 4°C in winter (January). The annual precipitation in this part is about 2,200 mm to 2,500 mm. The air temperature in the Mahabharat range and the Midlands is usually 6° to 7°C lower than in the Terai belt and Siwalik hills. The annual precipitation over the Mahabharat range varies from about 2,500 mm in the east to 1,000 mm to 1,500 mm in the west. The Himalayas and the Tibetan plateau have a climate peculiar to the high mountains, with the maximum temperatures up to only 21°C and the minimum temperatures falling below freezing point. The annual precipitation is below 1,000 mm.

The population in Nepal is 12.9 million (1976), comprising various races and tribes deriving from the Tibeto-Burmese group, the pure Tibetan group and the Indo-Aryan group. While each sub-group of the people has its own language and dialects, Nepali (Gurkhali) is the national language and is spoken among the people. The population is growing at a rate of 2 % per annum.

2.2 Economy of Nepal

The fiscal year in Nepal runs from mid-July. Gross Domestic Product (GDP) of Nepal has risen at an annual rate of 2.2 per cent during 1965/66 - 1974/75 in real terms. It was Rs.14,800 million (US$1,179 million) or about US$100 per capita in 1974/75. The present Five Year Paln (1975/76 - 1980/81) has planned to increase the GDP at a rate of 4 % every year. The HMG's budget is Rs.2,820 million (US$225 million) in 1977/78 of which about 20 % are foreign grants. The exports were reported to be Rs.1,200 million (US$96 million) and the imports were Rs.2,000 million (US$159 million) in 1975/76. About 70 % of the foreign trade is with India. Major exports to India are rice, timber, linseed and ghee.

The foreign exchange holdings of Nepal has steadily increased and amounted to US$140 million equivalent in 1976/77. Balance of international trade showed a deficit of US$73 million in 1976/77 against US$58 million in the previous year.

Agriculture is Nepal's principal economic activity. It accounts for two-thirds of the GDP, employs 87 % of the labour force including workers in agrobased factories, and contributes about 75 % of the country's export earnings. In addition, it provides much of the raw materials for the industries.

Industry has grown faster than the other sectors and its share of the GDP was 10 % in 1974/75. Industrial policy of HMG has focused on the promotion of import-substituting industries. This is reflected in the recent establishment of cement and textile industries, expansions in the sugar and cigarette factories, and the proposed establishment of new iron and steel, paper, textile, fertilizer, and cement factories.

With a view to promote labor-intensive small-scale and cottage industries, provisions have recently been made to abolish excise duties and sales taxes on the products of small-scale industries. This policy is expediting the private investment in small-scale industries. Tourism has become one of Nepal's major sources of foreign exchange earnings. Foreign visitors were 105,000 in 1976 and are increasing year by year. The Ministry of Tourism, newly established in February 1977, is estimating that the number of visitors will reach 125,000 in 1978. The construction of new hotels and the extension of the existing hotels are being promoted by HMG.

The communications system in Nepal was in a poor condition until the early 1960's, but, at present, the total length of motorable roads has reached 3,500 km, 40 % of which are sealed. A highway from Kathmandu to India via Birganj is an artery of Nepal's economy since it connects with Calcutta where all the goods from foreign countries (except India) to Nepal are landed. Recently, the southern portion of the highway was improved in alignment, and now intersects near Simra with the East-West Highway which runs across the whole length of Nepalese Terai.

Royal Nepal Airlines Corporation operates 15 commercial airports but the country's only international airport is at Kathmandu.

Most major towns are linked by a wirelese network operated by the HMG. HMG has planned to introduce a microwave network to cover the entire country.

Nepal is administratively divided into 14 zones and subdivided into 75 districts. In the execution of economic development policy, the territory is divided into the Central (Kathmandu), Eastern (Dankuta), Western (Pokhara) and Far Western (Surkhet) Development Regions. The capital at Kathmandu is located in the Bagmati Zone in the Central Development Region. The so-called Kathmandu-Hetauda-Birganj corridor along the Kathmandu-Culcutta highway is the center of the nation's economic activities.

CHAPTER III

POWER MARKET

3.1 Power Condition in Nepal

The power demand in Nepal has increased at a high rate of 20 %. It was 118 GWh in energy and 46 MW in peak in 1975/76. About 75 % of the demand occurs in the Central Development Region.

Nepal has total installed capacity of 64.3 MW including 37.4 MW of hydroelectric power stations, 23.1 MW of diesel power stations and 3.8 MW of steam power stations. Energy generated in 1975/76 was 142 GWh.

Towns near the boderline between Nepal and India have been connected with Indian power grid based on the agreement between the two countries. In the present agreement, the power rate is 20 mills/kWh. The maximum power imported from India to Nepal is 12 MW and exported from Nepal to India is 7 MW. There are towns importing power from India whereas the only export to India is carried out at Birganj. The power swap between the two countries has rapidly increased as shown in Table 3.1. Nepal imported 25.4 GWh from India and exported 5.9 GWh to India in 1975/76.

Power development and supply are administrated by the Ministry of Water and Power. The Electricity Department of the Ministry of Water and Power (ED) is responsible for the planning and construction of electric power projects. It normally hands over the power generation and transmission facilities to other organization as soon as completed, but it currently operates 5.5 MW of power stations throughout the country. There are two semi-automonous bodies which operate power supply systems. The Nepal Electricity Corporation (NEC) operates the Central Nepal Power System (CNPS) with a generation capacity of 42.3 MW in the Central Development Region. The Eastern Electricity Corperation (EEC) was established in 1974. It manages the power supply system which connects Rajiraj, Kataiya, Biratnagar Dharan in the Eastern Development Region. Butwall Power Company (BPC) is a private company partnered by ED. It supplies Butwal with a power station of 1.2 MW in the Western Development Region.

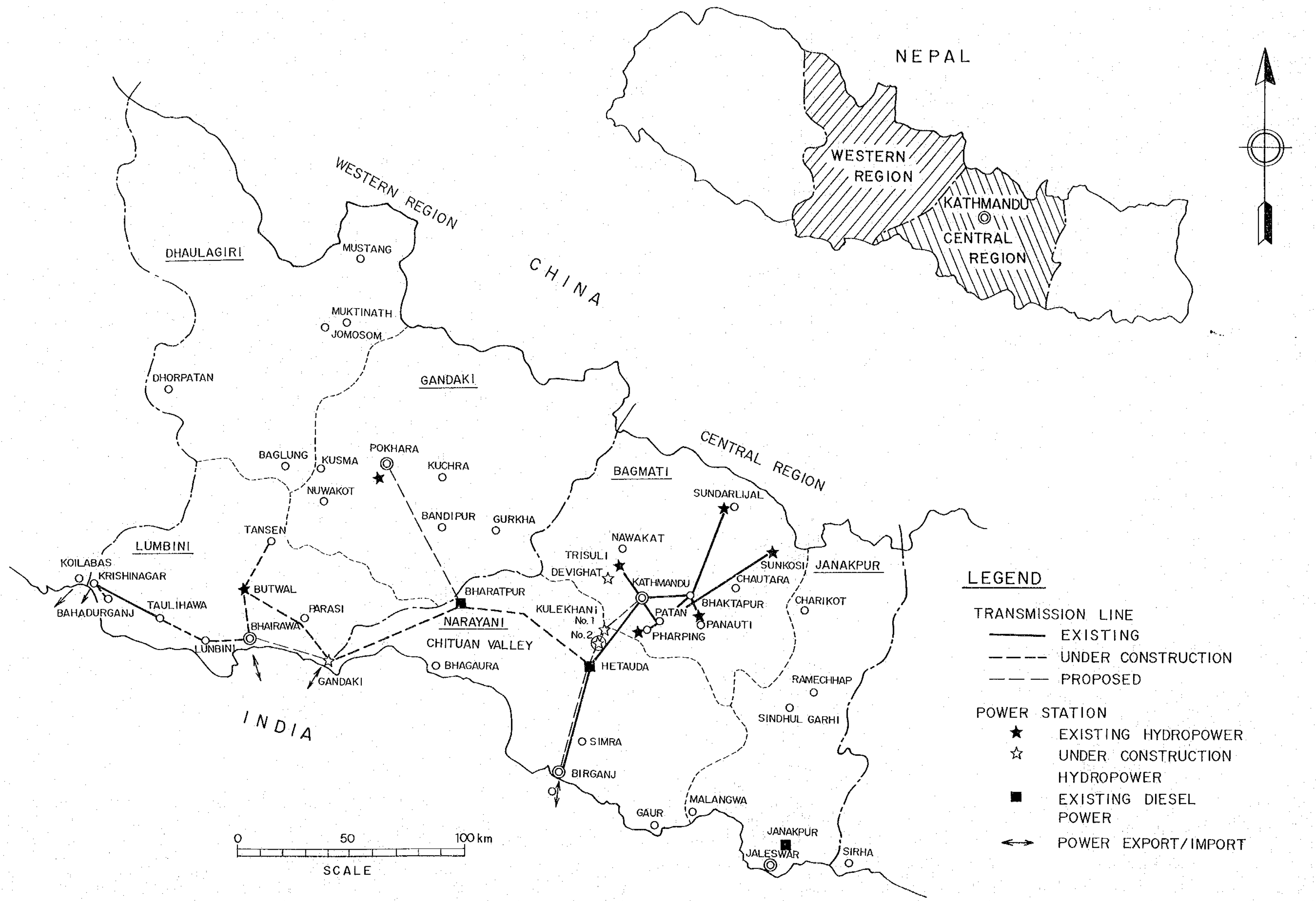

Fig. 3.1 POWER SUPPLY SYSTEM (CNPS)

There is no commercial deposit of fossil fuel such as coal or petroleum so far exploited in Nepal. The import of petroleum products is increasing year by year and amounted to Rs. 281 x 10^6 (US$26.6 x 10^6) in 1974/75. HMG has always made every effort to exploit domestic hydro-power for meeting energy demands in lieu of importing fuel.
The Gandaki Power Station of 15 MW beside the borderline between Nepal and India is nearly completed with the financial assistance of India. The Kulekhani No.1 Power Station of 60 MW is going to be completed in 1980/81. The Devigat Power Station of 14.4 MW will be completed near Trisuli in 1981/82. With completion of these three power stations, the hydroelectric power installation will be increased from the present 34.6 MW to 126.2 MW.

The existing and planned power supply systems are shown in Fig.3.1.

3.2 The Central Nepal Power System (CNPS)

The Kulekhani No.2 Power Station will furnish power to the Central Nepal Power System (CNPS) which supplies most of the power demand in the Central Development Region.

Sundarijal, Sunkosi, Trisuli, Kathmandu, Patan, Panauti, Hetauda and Birganj are connected by 277 km long 11 kV and 66 kV transmission lines of the CNPS. The system has six hydroelectric power stations of 34.6 MW installed capacity, five diesel power station of 8 MW in total capacity, ten substations and five switching stations. More details are shown in Table 3.2.

Table 3.3 shows the power production and consumption in the CNPS between 1963/64 and 1975/76. The power demand has grown at an annual rate of 24 % on an average. The figures indicate that the annual growth rate between 1973/74 and 1975/76 dropped to 14 %. This fact is attributed to the shortage of power generation. It is reported that under-utilization of major factories has become significant because of shortage in power in recent years. The loss in power accounts for 30 % of the total energy generated. This large loss indicates inadequacy of the supply system.

Energy consumed is classified into contract categories in Table 3.7. Domestic demand is 60 %, industrial demand is 20 %, commercial demand is 10 %. Industrial demand is growing at a high rate.

Seasonal variation of power demand is significant with a high demand in winter (dry season) and low demand in summer (wet season) as shown in Fig.3.2. Table A.3.5 of APPENDIX III showed that the average monthly power demand between mid-April and mid November was 82 % of that of the remaining months of the year during the period 1972/73 - 1976/77.

Typical daily load curves in winter and summer in 1976/77 are illustrated in Fig.3.3. From these curves the load factor was estimated to be 60 % for winter and 55 % for summer.

3.3 Interconnection of the CNPS with New Western System

In relation to the on-going construction of the Gandaki Power Station, a 132 kV single circuit transmission line is under construction between Gandaki and Hetauda via Bharatpur, including a 33 kV grid to connect Gandaki, Parasi, Bhairawa, Butwal, Tansen, Lunbini, Taulihawa, Krishinagar and Bahadurganj (the connection between Taulihawa and Krishinagar is an existing 33 kV line). This system will be interconnected with the existing CNPS by enlarging the Hetauda substation. It will be completed within 1978/79.

In addition to the above, the installation plan for a 133 kV transmission line between Bharatpur and Pokhara must be started in the near future because the power demand in Pokhara is growing fast. It is assumed that this line will be eventually connected with the CNPS in 1984/85.

The CNPS connected with the above-mentioned two systems is hereinafter called the Greater CNPS. The power facilities in the Greater CNPS are as listed in Table 3.2.

The energy consumption and peak demand in the towns in the Greater CNPS are summarized in Table 3.6. This table also includes the demand in private factories which have their own diesel generators but will be included in the power supply system when completed.

Table 3.1 Energy Swap with India

Unit: MWh

		1971/72	72/73	73/74	74/75	75/76
Imported from India to Nepal						
Eastern Region	Rajbiraj	-	224	323	-	-
	Bhadrapur	-	-	-	95	418
	Biratnagar	1,829	4,591	6,262	10,188	17,368
	Sirha	-	-	-	101	314
	Total	1,829	4,815	6,585	10,384	18,100
Central Region	Janakpur-Jaleswar	-	11	112	386	1,263
	Gaur	-	28	159	203	282
	Malangawa	-	1	20	146	156
	Total	-	40	291	735	1,701
Western Region	Krishnanagar	-	-	147	331	647
	Bhairahawa	-	188	843	1,191	1,730
	Total	-	188	990	1,522	2,377
Far Western Region	Koilabas	-	-	-	52	125
	Nepalganj	-	159	788	1,648	2,315
	Dhangarhi	-	-	-	93	375
	Mahendranagar	-	-	107	217	360
	Total	-	159	895	2,010	3,175
Grand Total		1,829	5,202	8,761	14,651	25,353
Export from Nepal to India						
Birganj (Central Region)		-	2,324	3,702	4,621	5,940

Table 3.2 Present Power Facilities in CNPS

(1) Hydropower Plants

Present CNPS

Trisuli	18,000 kW
Panauti	2,400 "
Sunkosi	6,000 "
Pharping	500 "
Sundarijal	640 "
Godawari	30 "
Total	27,570 kW

Greater CNPS

Pokhara (Phewa)	1,024 kW
Tinau (Butwal)	1,200 "
Total	2,224 kW

(2) Diesel Power Plants /1

Present CNPS

Mahendra (NEC)	1,696 kW
Patan (NEC)	1,490 "
Hetauda (NEC)	4,470 "
Total	7,656 kW

Greater CNPS

Baratpur (NEC)	528 kW
Pokhara (HMG)	1,038 "
Tansen (HMG)	249 "
Bhairahawa (HMG)	500 "
BPC	120 "
Other HMG plants	207 "
Birganj Sugar Mill	800 "
Other private plant	1,300.74 kW
Total	4,742.74 kW

/1: Total installed capacity will be extend to 14.65 MW when Kulekhani No.1 P.S. (with diesel support of 2,250 kW) will begin its operation.

Table 3.2 (Continued)

(3) Steam Power Plant

Birganj Sugar Mill	1,600 kW

(4) Transmission Lines

66 kV Double Circuit:	Trisuli-Balaju	32 km
	Balaju-Birganj	122 km
66 kV Single Circuit:	Sunkosi-Patan	57 km
33 kV Single Circuit:	Panauti-Bhaktapur	20 km
11 kV Double Circuit:	Kathmandu Ring	36 km
11 kV Single Circuit:	Sundarijal-Bhaktapur	10 km
Total		277 km

(5) Distribution Lines

11 kV Feeder	33 km
3.3 kV Line	64 km
400/230 V, 3 ϕ 4-Wire Network	420 km

(6) Main Substations

(a) Kathmandu Areas

Balaju Substation	66/11 kV, 2 x 11.25 MVA	
Patan Substation	" 2 x 6.3 MVA	
Bhaktapur Substation	33/11 kV, 2 x 1.55 MVA	
Patan Substation Extension	66/11 kV, 36 MVA	in 1980/81
New Teku Substation	" , 36 MVA	

(b) Other Area

Amlekhganj Substation	66/11 kV, 1.5 MVA
Simra Substation	" , 1.5 MVA
Parwanipur Substation	" , 2 x 1.5 MVA
Birganj Substation	" , 2 x 1.5 MVA
Hetauda Substation (Extension)/1	132/66 kv, 10 MVA

In addition to the above substations, there are several switching stations on the Kathmandu ring line; Maharajganj, Chabhel, Thimi, Teku and K2.

/1: To be extended in 1979.

Table 3.3 Engergy Production and Consumption in the CNPS

Year	Engergy Generated (MWh)	Energy Consumed (MWh)	Peak Demand (kW)	Load Factor (%)	Loss Factor (%)
1963/64	13,740	6,400	3,550	44.2	-
64/65	15,690	8,040	3,800	44.8	-
65/66	19,620	9,820	4,800	40.6	-
66/67	22,520	14,209	6,650	44.1	36.9
67/68	30,360	18,645	8,210	42.1	38.6
68/69	36,120	21,807	9,595	41.6	39.6
69/70	44,870	28,461	11,560	44.3	36.6
70/71	53,650	36,761	13,860	44.2	31.5
71/72	65,950	46,534	17,500	43.0	29.4
72/73	81,269	59,076	21,280	43.6	27.3
73/74	96,205	64,728	25,500	43.1	32.7
74/75	109,550	75,786	30,240	41.4	30.8
75/76	124,849	87,423	31,880	44.7	30.0

Table 3.4 Energy Consumption of Each Category in CNPS

Year	Domestic		Industrial		Commercial		Street Light		Other		Total	
	$x10^6$kWh	%	$x10^6$kWh	%	$x10^6$kWh	%	$x10^6$kWh	%	$x10^6$kWh	%	$x10^6$kWh	%
1962/63	3.87	-	0.62	-	-	-	-	-	-	-	4.49	-
63/64	5.32	35.47	0.87	40.32	-	-	0.21	-	-	-	6.40	42.5
64/65	5.83	9.59	1.55	78.16	-	-	0.66	-	-	-	8.04	25.6
65/66	7.46	27.96	1.70	9.68	-	-	0.66	-	-	-	9.82	22.14
66/67	8.89	19.17	1.62	-4.71	1.51	-	0.65	-1.52	1.53	-	14.20	29.10
67/68	11.61	30.60	1.86	14.81	2.09	38.41	0.70	7.69	2.38	55.36	18.64	31.20
68/69	13.66	17.66	2.77	48.92	2.62	25.36	0.92	31.43	2.43	2.01	22.40	16.90
69/70	15.54	13.76	3.08	11.19	3.52	34.35	0.57	-38.04	5.75	136.63	28.46	30.50
70/71	21.15	36.10	3.60	16.88	4.65	32.10	0.71	24.56	6.66	15.83	36.77	29.10
71/72	28.14	33.05	4.32	20.00	5.09	9.46	0.69	-2.82	8.30	24.62	46.54	26.50
72/73	32.63	15.96	6.71	55.30	5.91	16.11	0.74	7.10	10.94	31.81	56.93	26.90
73/74	41.69	27.76	10.57	57.48	6.39	8.19	0.87	17.86	5.21	-52.38	64.73	9.50
74/75	46.87	12.49	13.81	30.74	7.78	21.65	0.88	1.49	6.44	23.61	75.78	17.00
75/76	52.02	10.98	18.21	31.85	8.95	15.08	0.89	1.01	7.38	14.60	87.45	15.30

Note: %: % increase over the previous year

Table 3.5 Power Facilities in Western Region

(1) Hydropower Plants

Pokhara	1,024 kW
Tinau	1,200 kW

(2) Diesel Power Plants (Including private facilities)

Pokhara	1,038 kW
Bhairahawa	528 kW
Tansen	249 kW
Others	611.49 kW
Total	2,426.49 kW

(3) Steam Power Plant

Private facility	750 kW

(4) Substations

33 kV line is directly stepped down to low tension voltage and there is not substation in the region.

(5) Transmission Lines

33 kV simple circuit	:	Gandaki - Butwal
	:	Tansen - Butwal - Bhairahawa - Taulihawa - Bhahadurgunj

Table 3.6 Energy Consumption & Peak Demand of Western Region

(1) Pokhara

Unit: kWh

Year	Domestic	Industrial	Commerical	Street Lights	Others	Total	Peak Demand
70/71	366,244	149,664	13,114	21,038	-	550,060	320
71/72	432,792	135,573	35,860	43,774	16,253	664,253	440
72/73	594,643	161,629	31,086	50,651	15,965	853,979	515
73/74	854,368	191,286	99,201	41,201	14,505	1,200,983	630
74/75	638,815	126,994	118,504	34,781	161,260	1,070,354	767
75/76	1,203,686	177,801	221,714	-	582,450	2,285,651	955

(2) Butwal

Year	Domestic	Industrial	Commerical	Street Lights	Others	Total	Peak Demand
71/72	150,177	50,894	-	6,850	75,971	283,892	150
72/73	224,899	60,733	-	11,078	35,350	332,060	130
73/74	299,846	127,047	-	19,473	35,425	481,791	140
74/75	511,803	296,787	-	37,732	60,000	906,322	150
75/76	739,287	468,655	-	59,157	51,308	1,318,407	270

(3) Bhairahawa

Year	Domestic	Industrial	Commerical	Street Lights	Others	Total	Peak Demand
71/72	354,926	99,060	-	12,040	24,849	490,855	-
72/73	363,496	101,432	-	12,329	17,400	494,657	310
73/74	536,171	202,971	-	18,055	9,675	766,970	240
74/75	557,458	497,243	-	24,748	44,219	1,123,668	442
75/76	795,523	580,932	-	31,596	68,000	1,476,051	480

(4) Tansen

Year	Energy Required (kW)	Growth Rate (%)	Loss Factor (%)	Energy Generated (kWh)	Load Factor (%)	Peak Demand (kW)
72/73	84,538		14.7	99,124	10.3	110
73/74	130,925	54.9	20.0	163,660	13.8	138
74/75	158,760	21.3	34.3	226,453	17.2	150
75/76	202,468	27.5	9.7	224,088	16.0	160

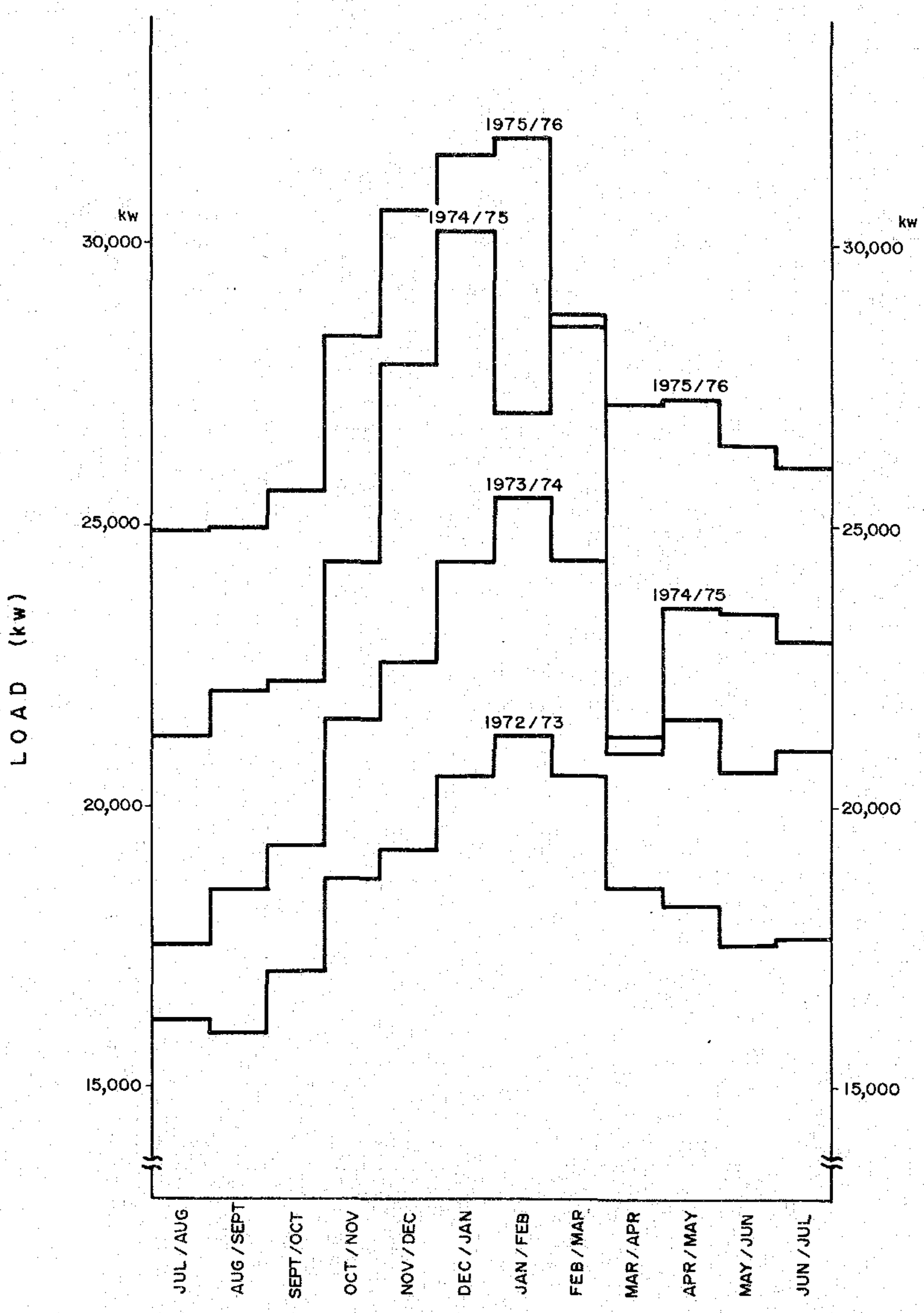

FIG. 3.2 SEASONAL VARIATION OF LOAD (CNPS)

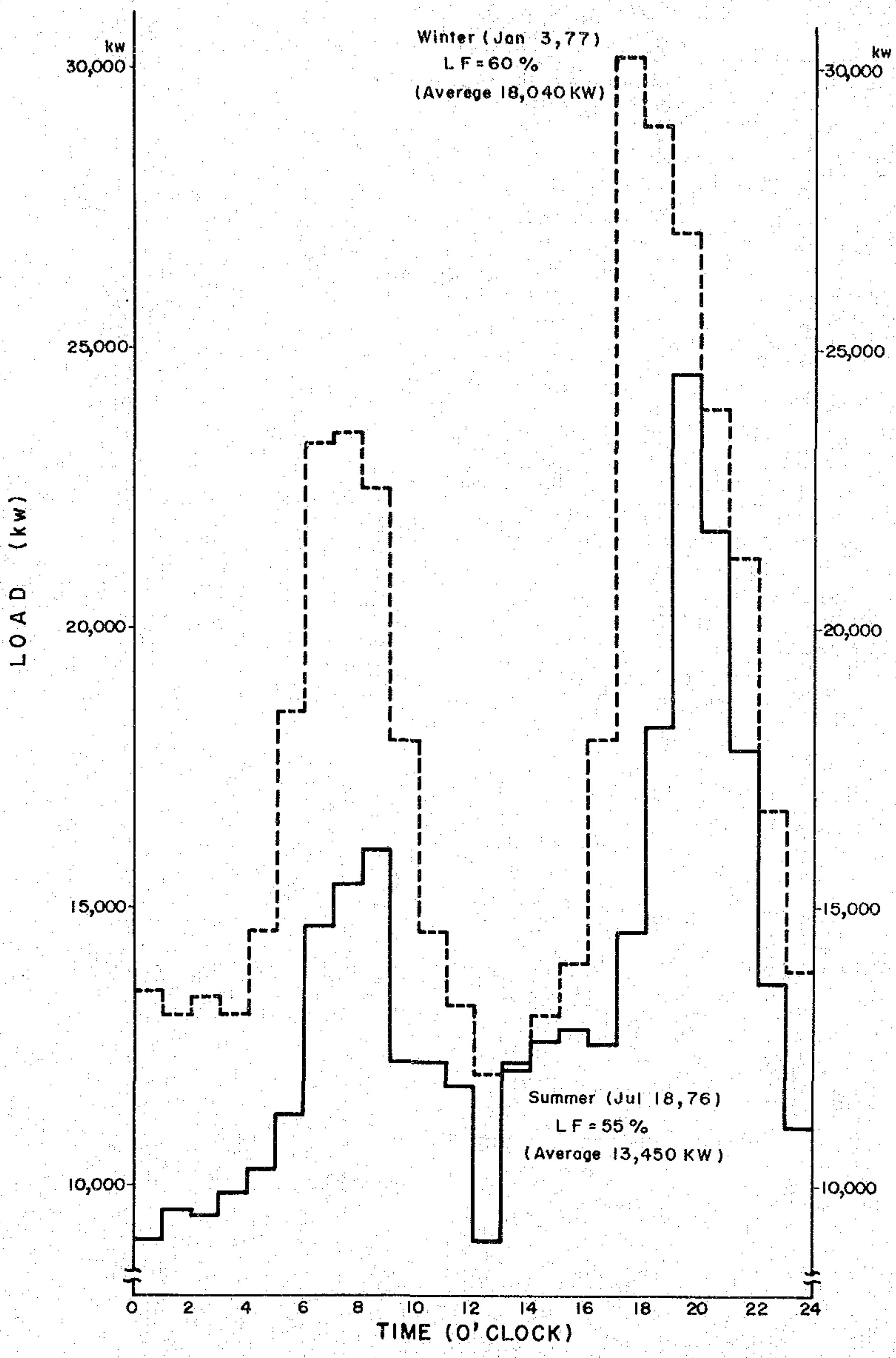

FIG. 3.3 TYPICAL LOAD CURVES IN 1976/77(CNPS)

3.4 Power Demand Projection

A projection of power demand in the Greater CNPS was made based on the historical trend. Assumptions were also introduced for far future projections based on the experiences in various countries. The basis and assumptions introduced in the projection are summarized hereunder:

3.4.1 Demand forecast of CNPS

(a) Domestic Demand

The growth rate of domestic demand in the past few years from 1973/74 through 1975/76 shows 12 % per annum on the average against the growth rate of 25 % for the previous years from 1966/67 through 1973/74, as seen in T ble 3.7. The declined growth rate seems to be caused by both the shortage of power supply and insufficient distribution facilities in the system. Such declined growth should continue until 1980/81 when the improvement and expansion of the distribution network is expected to be start. The annual growth rate of demand is assumed at 7 to 8 % till 1980/81 (suppressed by shortage of distribution capacity), to increase to 15 to 20 % thereafter and settle down to a stable rate of 10 % after 1987/88.

(b) Industrial Demand

As seen in Table 3.7, the annual growth rate of industrial energy consumption in this region was 38 % on the average during the period of 1970/71 through 75/76. The growth rate in the last few years of 1973/74 through 1975/76, however, declined to 30 %. It is not expected that such rapid growth will continue a long period of time. In the forecast, the annual growth rate of the potential demand is therefore assumed to be 25 % till 1979 and thereafter gradually to decrease by 15 %, in consideration of steady industrialization in the region.

(c) Commerical Demands

The annual growth rate of commercial energy consumption was 14 %, varying from 8.2 % to 32.1 % during the period of 1970/71 through 75/76. Most of the energy consumed was by hotels and other accomodations for tourists, according to the information from NEC. The number of tourists visiting this region have increased at an annual average rate of 19 % in a period of 1967/68 through 1976/77. However, the rate worked out from the last several years shows 8 %. The future commercial demand increase is forecasted at an annual growth rate of 10 % to 13 % including the demand expected for the planned new hotels.

(d) Street Light Demands

Demand of street lights is assumed at 1.5 % of the sum of domestic, industrial and commercial demands after reviewing the past records showing the street lights would increase in proportion to growth of those demands.

(e) Other Demands

All other demands including the station demand are assumed to be proportional to the total demand for the categories (a) to (d).

(f) Export to India

Energy export to India is estimated based on the Government commitment, which is referred to in Table 3.3 (a) of "Power Development - Long Term Plan" issued by the ED in October 1977.

The total potential energy demand in the system is forecasted by summing up the future demand required by each category mentioned above, and the total energy to be supplied to the CNPS is estimated by adding energy loss in the system to the energy thus summed up.

The peak load of the system is estimated from the total energy being applied and adequate annual load factor.

Demand forecast estimated for the Central Nepal Power System is summarized in Table 3.7.

3.4.2 Demand Forecast of the Western Region

(1) Pokhara town

The annual average growth rate in a period of 1970/71 through 75/76 was 33 %. The forecast is made under the assumption of an annual growth rate of 30 % till 1978/79 and, thereafter, of a gradually declining annual growth rate to a constant rate of 10 %. The result of this forecast is shown in Table 3.8.

(2) Butwal town

Although the past several years' trend shows a rapid growth rate such as 47 % per annum, it is not expected that the demand will increase at the same rate. The demand forecast for this town is therefore estimated at an annual growth rate of 40 % for a few years after 1976/77, and thereafter gradually decreasing to 10 % to 20 %. The result of this forecast is shown in Table 3.9.

(3) Bhairahawa area

The demand forecast is made assuming an annual growth rate of 30 % for the past trend up to 1979/80 and thereafter at a gradually declined rate down to a constant 10 %. In addition to these public demand, Mahendra sugar mill is expected to be partially connected with the public system from 1986/87 after energy supply from Kulekhani No.2 Power Station will become available. Table 3.10 shows the results of such demand forecast.

(4) Tansen area

Demand in Tansen area is estimated in Table 3.11 assuming an annual growth rate and a loss factor at 20 % to 30 % and 20 %, respectively, which are almost the same rates as those of the past trend.

(5) Other Towns and Private Facilities

Although the past trend of growth rates in minor towns showed 70 % to 107 % immediately after being electrified, this will not last for so long a period. Therefore, the demand forecast for the minor towns is made assuming an annual growth rate of energy at 10 % to 20 %.

The demand forecast to private factories is forecast with an annual growth rate of 10 % to 20 % for energy consumption and 10 % for peak demand. Those factories are assumed to be interconnected to the CNPS by 1985/86.

The results of demand forecast for minor towns and others are shown in Table 3.12.

The total demand forecast in the Western Region to be interconnected with the Central Region is obtained as an aggregate demand of the individual areas in the region, since the peak demand time of those areas is considered to coincide.

The demand forecast of the Western Region is summarized in Table 3.13.

3.4.3 Demand Forecast of the Greater CNPS

The 132 kV transmission line is under construction between Gandaki and Hetauda via Bharatpur with target completion in 1978/79 as stated in Paragraph 3.2.

These transmission lines will link the CNPS with the Western Region and the isolated towns in the Central Region as well.

The combined power demand forecast for such an integrated system is shown in Table 3.14 and Figure 3.4. As seen in the table and figure, the commercial operation of the proposed Kulekhani No.2 Power Station will become necessary by 1985/86.

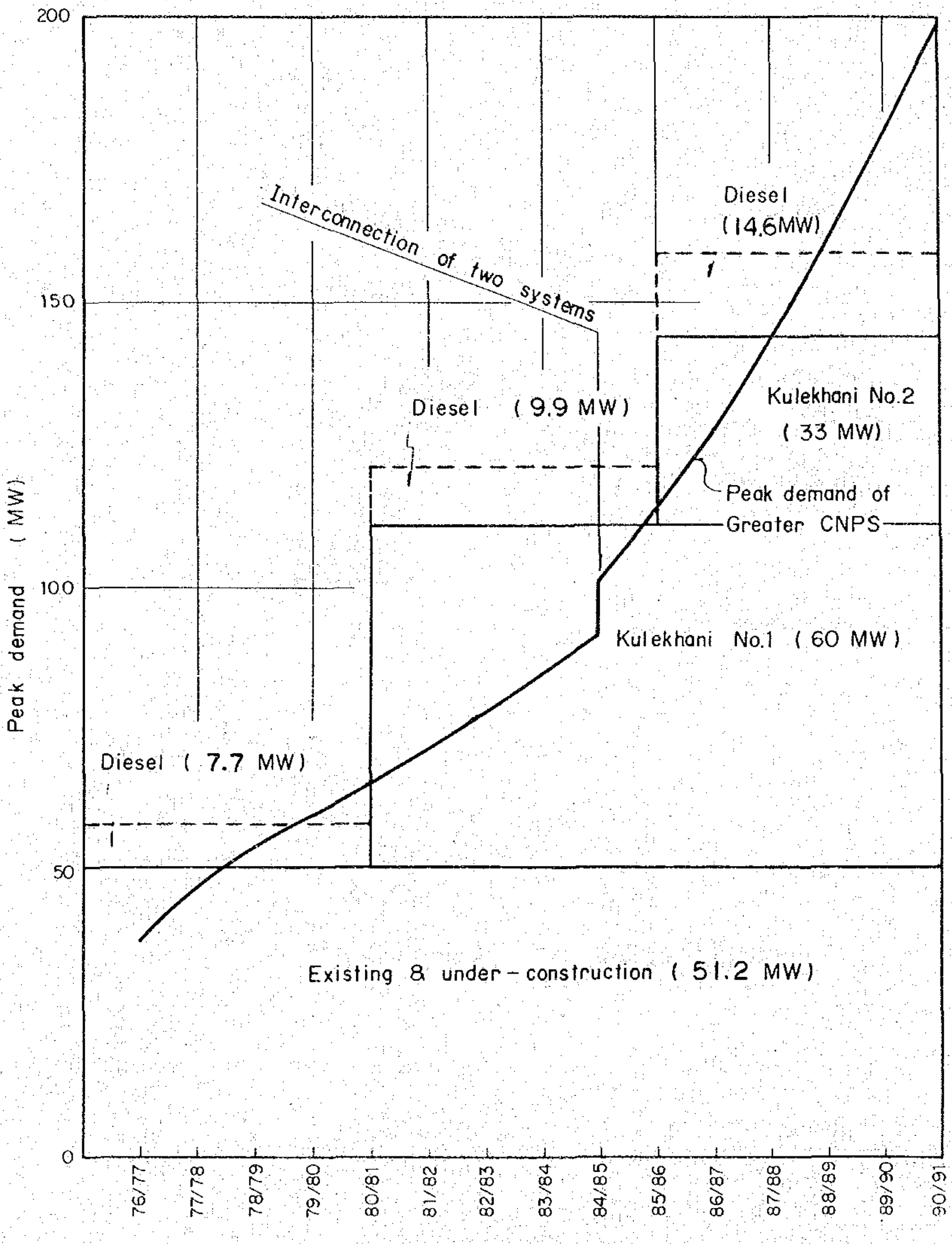

FIG 3.4 PEAK DEMAND AND INSTALLED CAPACITY

Table 3.7 Demand Forecast of CNPS

Year	Domestic (MWh)	Industrial (MWh)	Commercial (MWh)	Street Lights (MWh)	Others (MWh)	Export (MWh)	Toral Energy Required (MWh)	Energy Loss (MWh)	Energy to be supplied (MWh)	Ann. Load Factor (%)	Peak Load (kW)
76/77	56,700	22,770	10,110	1,340	8,120	6,600	105,640	45,270	150,190	45.0	38,280
77/78	61,230	28,460	19,510	1,640	8,930	6,930	126,700	54,300	181,000	45.0	45,920
78/79	66,130	35,570	25,910	1,910	9,820	7,280	146,620	62,840	209,460	46.0	51,980
79/80	70,860	44,460	28,510	2,160	10,800	7,640	164,330	70,430	234,760	47.0	57,020
80/81	75,720	54,690	30,400	2,410	11,770	8,020	183,010	78,430	261,440	48.0	62,180
81/82	83,290	67,270	32,550	2,750	12,830	8,420	207,110	88,760	295,870	49.0	68,930
82/83	95,780	80,720	34,970	3,170	13,990	8,840	237,470	79,160	316,630	50.0	72,290
83/84	114,940	96,870	37,710	3,740	15,250	9,280	277,790	69,450	347,240	51.0	77,720
84/85	137,920	114,300	40,800	4,400	16,470	9,750	323,640	71,040	394,680	52.0	86,640
85/86	162,750	134,880	43,490	5,120	17,790	10,230	374,260	76,660	450,920	53.0	97,120
86/87	190,420	156,440	46,450	5,900	19,210	10,750	429,190	81,750	510,940	53.0	110,050
87/88	218,980	181,490	49,700	6,750	20,750	11,290	488,960	86,290	575,250	53.0	123,900
88/89	240,880	208,710	53,280	7,540	22,200	11,850	544,460	96,080	640,540	53.0	137,960
89/90	264,970	240,020	57,210	8,430	23,760	12,440	606,830	107,090	713,920	53.0	153,770
90/91	291,460	276,020	61,550	9,440	25,420	13,070	676,960	119,460	796,420	53.0	171,540

Note: CNPS

(1) Annual growth rate of domestic demand is assumed at 6% to 8% up to 1980/81, thereafter 10% to 20% up to 1987/88 and 10% steadily.

(2) Annual growth rate of industrial demand is assumed at 25% up to 1979/80 and thereafter 15% to 23%.

(3) Annual growth rate of commercial demand is assumed at 10%, 13%. Besides the natural growth, demands of hotels planned are added to that in 1977/78 with 8,080 MWh, in 1978/79 with 12,990 MWh and thereafter with 13,910 MWh.

(4) Street lighting demand is assumed at 1.5% of sum of the above 3 demands.

(5) Annual growth rate of other demand is assumed at 7% to 10%.

(6) Energy to India is based on the government's commitment.

(7) Energy loss is estimated at less factor of [illegible] up to 1981/82 and 15% to 20% thereafter expecting improvement of the distribution network.

Table 3.8 Demand Forecast (Pokhara)

Year	Energy Required (kWh)	Growth Rate (%)	Loss Factor (%)	Energy Generated (kWh)	Load Factor (%)	Peak Demand (kW)
76/77	2,971,300	30	35	4,571,300	42	1,240
77/78	3,862,800	30	35	5,942,700	42	1,620
78/79	5,021,600	30	34	7,608,400	42	2,070
79/80	6,528,000	30	33	9,743,400	43	2,590
80/81	8,290,600	27	32	12,192,100	44	3,160
81/82	10,280,400	24	31	14,899,100	45	3,780
82/83	12,336,400	20	30	17,623,500	46	4,370
83/84	14,433,600	17	29	20,329,100	47	4,940
84/85	16,454,300	14	28	22,853,300	47	5,550
85/86	18,428,900	12	27	26,245,000	48	6,000
86/87	20,271,800	10	26	27,394,300	48	6,520
87/88	22,298,900	10	25	29,731,900	48	7,070
88/89	24,528,800	10	24	32,277,700	49	7,520
89/90	26,981,700	10	23	35,041,200	49	8,160
90/91	29,679,900	10	23	38,545,300	50	8,800

Table 3.9 Demand Forecast (Butwal)

Year	Energy Required (kWh)	Growth Rate (%)	Loss Factor (%)	Energy Generated (kWh)	Load Factor (%)	Peak Demand (kW)
76/77	1,845,800	40	20	2,307,200	72	370
77/78	2,584,100	40	20	3,230,100	72	510
78/79	3,566,000	38	18	4,348,800	71	700
79/80	4,849,800	36	15	5,914,400	71	950
80/81	6,498,700	34	15	7,645,600	70	1,250
81/82	8,448,400	30	15	9,939,200	70	1,620
82/83	10,644,900	26	15	12,523,400	68	2,100
83/84	12,986,800	22	15	15,278,600	66	2,640
84/85	15,324,400	18	15	18,028,700	64	3,220
85/86	17,623,100	15	15	20,733,100	62	3,820
86/87	19,737,900	12	15	23,221,000	60	4,420
87/88	21,711,600	10	15	25,543,100	60	4,860
88/89	23,882,800	10	15	28,097,400	60	5,350
89/90	26,271,100	10	15	30,907,200	60	5,880
90/91	28,898,200	10	15	33,998,000	60	6,470

Table 3.10 Demand Forecast (Bhairahawa)

Year	Bhairahawa Area			Transferred from Mahendranager Area		Total	
	Energy Required (kWh)	Energy Generated (kWh)	Peak Demand (kW)	Energy Generated (kWh)	Peak Demand (kW)	Energy Generated (kWh)	Peak Demand (kW)
76/77	1,918,900	2,369,000	640	-	-	2,369,000	640
77/78	2,494,500	3,079,700	680	-	-	3,079,700	840
78/79	3,242,900	4,003,600	1,060	-	-	4,003,600	1,060
79/80	4,215,700	5,204,600	1,320	-	-	5,204,600	1,320
80/81	5,354,000	6,610,000	1,680	-	-	6,610,000	1,680
81/82	6,692,500	8,262,400	2,010	-	-	8,262,400	2,010
82/83	8,031,000	9,914,800	2,410	-	-	9,914,800	2,410
83/84	9,396,300	11,278,600	2,700	-	-	11,278,600	2,700
84/85	10,711,800	13,224,400	3,020	-	-	13,224,400	3,020
85/86	11,977,200	14,811,300	3,250	730,800	200	15,542,100	3,450
86/87	13,196,900	16,292,400	3,510	1,151,000	300	17,403,400	3,810
87/88	14,516,600	17,921,700	3,790	1,575,200	400	19,496,900	4,190
88/89	15,968,200	19,713,900	4,100	1,978,500	500	21,692,400	4,600
89/90	17,565,000	21,685,200	4,500	2,365,700	600	24,050,900	5,100
90/91	19,321,500	23,853,700	4,950	2,365,700	600	26,219,400	5,550

Note: Loss factor for the town is assumed as 19 % constant

Table 3.11 Demand Forecast (Tansen)

Year	Energy Required (kWh)	Growth Rate (%)	Loss Factor (%)	Energy Generated (kWh)	Load Factor (%)	Peak Demand (kW)
76/77	263,200	30	20	329,000	17	220
77/78	342,200	30	20	427,700	18	270
78/79	441,400	29	20	551,800	19	330
79/80	569,400	29	20	711,800	20	410
80/81	728,800	28	20	911,000	21	500
81/82	932,900	28	20	1,166,200	22	610
82/83	1,184,800	27	20	1,481,000	24	700
83/84	1,492,900	26	20	1,866,100	26	820
84/85	1,866,100	25	20	2,332,600	28	950
85/86	2,313,900	24	20	2,892,400	30	1,100
86/87	2,846,100	23	20	3,557,700	32	1,270
87/88	3,472,300	22	20	4,340,300	34	1,460
88/89	4,201,500	21	20	5,251,800	36	1,670
89/90	5,041,700	20	20	6,302,200	38	1,890
90/91	6,050,000	20	20	7,562,500	40	2,160

Table 3.12 Demand Forecast (Other Towns and Private Facilities)

	Other Towns		Private Facilities	
Year	Energy Generated (kWh)	Peak Demand (kW)	Energy Generated (kWh)	Peak Demand (kW)
76/77	919,600	350	883,000	310
77/78	1,103,600	420	1,059,600	340
78/79	1,324,300	490	1,271,500	370
79/80	1,575,900	580	1,525,800	410
80/81	1,875,300	670	1,800,500	450
81/82	2,231,600	800	2,124,600	500
82/83	2,633,300	910	2,507,000	550
83/84	3,107,300	1,070	2,958,300	600
84/85	3,666,600	1,230	3,490,800	660
85/86	4,290,000	1,440	4,014,400	730
86/87	5,019,300	1,640	4,616,500	800
87/88	5,872,500	1,920	5,309,000	880
88/89	6,812,100	2,160	6,105,300	970
89/90	7,902,100	2,510	7,021,200	1,060
90/91	9,087,400	2,590	7,934,000	1,170

Table 3.13 Demand Forecast of the Western Region

Year	Energy Demand (MWh) Pokhara	Butwal	Bhairahawa	Tansen	Other Towns	Private Facilites	Total	Total Connected Demand	Peak Demand Forecast (kW) Pokhara	Butwal	Bhairahawa	Tansen	Other Towns	Private Factories	Total	Total Connected Demand
1976/77	(4,571.3)	(2,307.2)	(2,369.0)	(329.0)	(919.6)	(883.0)	(11,379.1)	-	(1,240)	(370)	(640)	(220)	(350)	(310)	(3,130)	-
77/78	(5,942.7)	(3,230.1)	(3,079.7)	(427.7)	(1,103.6)	(1,059.6)	(14,843.4)	-	(1,620)	(510)	(840)	(270)	(420)	(340)	(4,000)	-
78/79	(7,608.4)	4,348.8	4,003.6	551.8	1,324.3	(1,271.5)	19,108.4	10,228.5	(2,070)	700	1,060	330	490	(370)	5,020	2,580
79/80	(9,743.4)	5,914.4	5,204.6	711.8	1,575.9	(1,525.8)	24,675.9	13,406.7	(2,590)	950	1,320	410	580	(410)	6,260	3,260
80/81	(12,192.1)	7,645.6	6,610.0	911.0	1,875.3	(1,800.5)	31,034.5	17,041.9	(3,160)	1,250	1,680	500	670	(450)	7,710	4,100
81/82	(14,899.1)	9,939.2	8,262.4	1,166.2	2,231.6	(2,124.6)	38,623.1	21,599.4	(3,780)	1,620	2,010	610	800	(500)	9,320	5,040
82/83	(17,623.5)	12,523.4	9,914.8	1,481.0	2,633.3	(2,507.0)	46,683.0	26,552.5	(4,370)	2,100	2,410	700	910	(550)	11,040	6,120
83/84	(20,329.1)	15,278.6	11,278.6	1,866.1	3,107.3	(2,958.3)	54,818.0	31,530.6	(4,940)	2,640	2,700	820	1,070	(600)	12,770	7,230
84/85	22,853.3	18,028.7	13,224.4	2,332.6	3,666.6	3,490.8	63,596.4	63,596.4	5,550	3,220	3,020	950	1,230	660	14,630	14,630
85/86	25,245.0	20,733.1	15,542.1	2,892.4	4,290.0	4,014.4	72,717.0	72,717.0	6,000	3,820	3,450	1,100	1,440	730	16,540	16,540
86/87	27,394.3	23,221.0	17,443.4	3,557.7	5,019.3	4,616.5	81,252.2	81,252.2	6,520	4,420	3,810	1,270	1,640	800	18,460	18,460
87/88	29,731.9	25,543.1	19.496.9	4,340.3	5,872.5	5,309.0	90,293.7	90,293.7	7,070	4,860	4,190	1,460	1,920	880	20,380	20,380
88/89	32,277.7	28,097.4	21,692.4	5,251.8	6,812.1	6,105.3	100,236.7	100,236.7	7,520	5,350	4,600	1,670	2,160	970	22,270	22,270
89/90	35,041.2	30,907.2	24,050.9	6,302.2	7,902.1	7,021.2	111,224.8	111,224.8	8,160	5,880	5,100	1,890	2,510	1,060	24,600	24,600
90/91	38,545.3	33,998.0	26,219.4	7,562.5	9,087.4	7,934.0	123,346.6	123,346.6	8,800	6,470	5,500	2,160	2,590	1,170	26,740	26,740

Note: "Total Connected Demand" means total of each demand to be connected with the CNPS, except the demands given in bracket ( ).
A 132 kV transmission line of Gandaki-Hetauda connects Butwal, Bhairahawa, Tansen and minor towns with the CNPS in 1978/79.
Pokhara and others are assumed to be connected with CNPS in 1984/85.

Table 3.14 Demand Forecast of Combined Greater CNPS

Year	Energy (MWh)		Peak Demand (kW)		Combined Demand	
	CNPS	Western	CNPS	Western	Energy (MWh)	Peak Demand (kW)
1976/77	150,910	-	38,280	-	150,910	38,280
77/78	181,000	-	45,920	-	181,000	45,920
78/79	209,460	10,230	51,980	2,580	219,690	54,560
79/80	234,760	13,410	57,020	3,260	248,170	60,280
80/81	261,440	17,040	62,180	4,100	278,480	66,280
81/82	295,870	21,600	68,930	5,040	317,470	73,970
82/83	316,630	26,550	72,290	6,120	343,180	78,410
83/84	347,240	31,530	77,720	7,230	378,770	84,950
84/85	394,680	63,600	86,640	14,630	458,280	101,270
85/86	450,920	72,720	97,120	16,540	523,640	113,660
86/87	510,940	81,250	110,050	18,460	592,190	128,510
87/88	575,250	90,290	123,900	20,380	665,540	144,280
88/89	640,540	100,240	137,960	22,270	740,780	160,230
89/90	713,920	111,220	153,770	24,600	825,140	178,370
90/91	796,420	123,350	171,540	26,740	919,770	198,280

Note: Energy and peak demands of the CNPS are extracted from Table 3.8 and the same of the Western Region is from Table 3.14

CHAPTER IV

PROJECT AREA

4.1 General Features of the Kulekhani and Rapti River Basins

The east side and half of the north side of the Kulekhani river basin faces to the Kathmandu valley and the Bagmati river basin. The remaining half of the north side faces to the Trisuri river basin, whereas the west and the south sides face to the Rapti river basin. See Fig. 5.1. The Kulekhani No.1 Power Station is to take water for power generation from the Kulekhani river at the damsite located about 21 km southwest of Kathmandu.

Originating in a ridge about 5 km west of Palung which has a peak elevation of some 2,500 m, the Kulekhani flows about 10 km eastward to Tasar. The riverbed elevation at Palung about 1,770 m and about 1,550 m at Tasar. The river then turns its course southeastward to southward and meanders to Kitini located about 7 km southeast of Tasar, where it flows in a generally east-southeasterly direction for about 9 km to the confluence with the Bagmati river. The elevation at the confluence is about 1,070 m. The drainage area of the Kulekhani basin is measured at 126 km^2 at the damsite and 220 km^2 at the confluence with the Bagmati.

The Rapti river basin is adjacent to the Kulekhani river basin shown in Fig. 5.1. The Rapti river, originating in a ridge on the Mahabarat range about 4 km east of Bhimphedi, forms an open valley down to Bhainsedobhan. In these reaches, (called the Upper Rapti hereinafter), the river flows east-southeastward without remarkable meanderings. The riverbed elevation of the river is 1,100 m at Bhimphedi and 600 m at Bhainsedobhan (located about 11 km downstream). Slopes on the both banks rise up to 1,800 m in elevation within a distance of 3 km. Two major tributaries; the Mandu and the Rani, both running generally in a southery direction, pour into the Upper Rapti from the northern bank.

The regulated flow from the Kulekhani No.1 Power Station is designed to be released to the Mandu intake at a place about 400 m upstream from the confluence of the Rapti and Mandu rivers.

Joining with the Kani river at Bhainsedobhan, the Rapti river turns its course southward to Hetauda for a distance of about 9 km. In this section the river cuts a deep gorge for a length of about 4 km downstream of Bhainsedobhan, where a damsite was proposed for the Kulekhani No.3 Power Station. After it joins with the Karra river west of the Hetauda, the Rapti river changes course a westerly direction and flows through an open valley to Rajaya. The riverbed elevation of the Rapti river is 436 m at the confluence with Karra river and is 332 m at Rajaya Gage Station. The drainage areas of the tributaries and the main stem are as follows:

Rapti at confluence with the Mandu	32 km^2
Mandu at confluence with the Rapti	20 km^2
Rani at confluence with the Rapti	6 km^2
Kani at confluence with the Rapti	23 km^2
Rapti	
at Bhainsedobhan	115 km^2
at Rajaya gaging station	579 km^2

The western slopes of the west divide of the Upper Rapti are drained by the Manhari river which flows into the Rapti about 11 km downstream of Rajaya. The Rapti river finally flows into the Kaligandaki river near Chilha.

4.2 The Kulekhani No.1 Hydroelectric Project

The Kulekhani damsite is located on the Kulekhani river at 21 km southwest of Kathmandu. Annual inflow from the catchment area of 126 km^2 averages 126 x 10^6 m^3. The active storage capacity of 73 x 10^6 m^3 will be obtained by constructing a rockfill dam of 107 m in height. The regulated flow will be drawn to the power station through the headrace tunnel of 6,223 m in length and a 1,198 m long penstock. Water amounting to 1 x 10^6 m^3 will be collected from the Sim river with a catchment area of 7.1 km^2 and channeled into the headrace. The Kulekhani No.1 Power Station will be an underground power station housing two sets of Pelton turbines and generators. The installed capacity will be 60 MW at the rated water head of 550 m with the maximum discharge of 13.1 m^3/sec. The outflow from the power station will be released to the Mandu river near the confluence of the Mandu river and the Rapti river. The water surface at the tailrace outlet is at EL.912.5 m.

4.3 <u>Geology in the Project Area</u>

The Project area is situated in the Upper Rapti river basin lying in the Mahabharat mountain range. The Upper Rapti basin is geologically composed of lower to middle Paleozoic sedimentary rocks with low-grade metamorphism and Quaternary deposits, the details of which are described below.

Crystalline limestone: White coloured, with fine crystals, located downstream from Bhainsedobhan. Thickness is approximately 800 m. Thin layers of sericite schist and sandstone are intercalated at places.

Sandstone and slate alternation: Sandstone is light grey to grey coloured, generally fine grained, massive, dense and hard. Slate is dark grey coloured, moderately hard and intensively foliated, and forms rather thin strata. This is exposed in the lower parts of the right bank slope at Bhainsedobhan and in the hilly area on the right bank 0.5 to 1.5 km downstream from the Rani river confluence; in the latter area it is isolated from the surrounding sandstone semi-schist by two faults.

Slate phyllite and biotite schist: Generally dark coloured and intensively foliated. Biotite schist is often accompanied with intercalating quartzite with 50 cm to 1 m of thickness. These rocks are extensively developed in the upper parts of the slope behind Bhainsedobhan, where these rocks overlie the sandstone and slate alternation conformably and transitionally.

Sandstone semi-schist: Grey sandstone is composed predominantly of fine quartz grains. Dolomite bearing chert layers are intercalated at places. Also, intercalated are thin layers of green phyllites with cleavages intersecting the foliation. It bears fine veins of pyrite and mineralization accompanied with weak chloritizations.

Brecciated limestone deposits: Consisting of angular fragments of crystalline limestone of various size up to a few meters in diameter which are cemented with calcareous matrix and agglutinated with calcium carbonates. This is found at Ranikholagaon, Pandrang and Bhainsedobhan along the Rapti river within the height of 300 m from the present riverbed. These are conceivably a part of the secondary deposit of limestone debris formed on the bottom of valley in old Quarternary age.

Terrace deposit: Terrace along the right bank of the Rapti river is generally narrow and limited in area, except for the high and large ones developing upstream from the Mandu river confluence. Some large river terraces in the downstream area are located only around the Rani river confluence and in Nibuwater. The terrace deposite are composed of poorly sorted sand, gravels and boulders which have been rather loosely sedimented.

In the aspect of geological structure, this area is situated in a triangle zone surrounded by three major fault lines, i.e. Bhimphedi-Kathmandu fault running NE-SW through Bhimphedi, Kalitar fault running ENE-WSW through the area west from Bhainsedobhan and the oldest and biggest Main Boundary Thrust which runs WNW-ESE about 5 km south of Bhainsedobhan bounding the Tertiary Siwalik zone to the south. These major faults are not encountered in the project area, but some subordinate faults are found in the area between Rani river and Bhainsedobhan. Their predominant trends are ENE-WSW and WNW-ESE. No fractured zone of a large scale is observed accompanying those minor faults.

Bedding of the formations shows WNW-ESE of strike and northward dipping in general, though minor variations due to faulting and small folding are seen frequently. Amount of dip varies from 30^{o} to 75^{o}.

CHAPTER V

METEOROLOGY AND HYDROLOGY

5.1 General Climatic Conditions

The climate of the Project area is humid subtropical and characterized distinctly by dry and wet seasons. The dry season lasts from November to April, and the wet season from June to September, with May and October being transition periods.

There is no meteorological observatory in the project river basin which has past records of temperature and humidity. Observatories which have such records in the vicinity are located at Kathmandu and Hetauda. However, it seems that the general features in the climate in the project area are not far from mean values of those at Kathmandu and Hetauda.

The Kathmandu observatory has meteorological records for the period from 1966 to 1974, but Hetauda observatory has records for only the year 1967.

According to the records, average annual mean temperature at Kathmandu is 18.1°C. The maximum temperature usually takes place in June and sometimes rises up to about 35°C, while the minimum temperature usually occurs in December or January, sometimes falling below the freezing point. The monthly mean temperatures at Kathmandu are shown in the attached Fig.5.2.

The annual mean temperature at Hetauda is 23.4°C, the maximum of 39°C occurs in June and the minimum is 4.9 C occurring in December, according to the record for 1967.

The relative humidity varies around 40 % in April and 85 % in August at Kathmandu, while the records at Hetauda in 1967 show 65 % in April and 97 % in October.

Evaporation was measured at Chisapani Garhi for a period from 1963 to 1965. This is located 2 km north of Bhimphedi, at an elevation of 1728 m. The average annual mean evaporation was 1815 mm during the period. The maximum monthly evaporation was 392 mm in May 1963 and the minimum was 59 mm in December 1963.

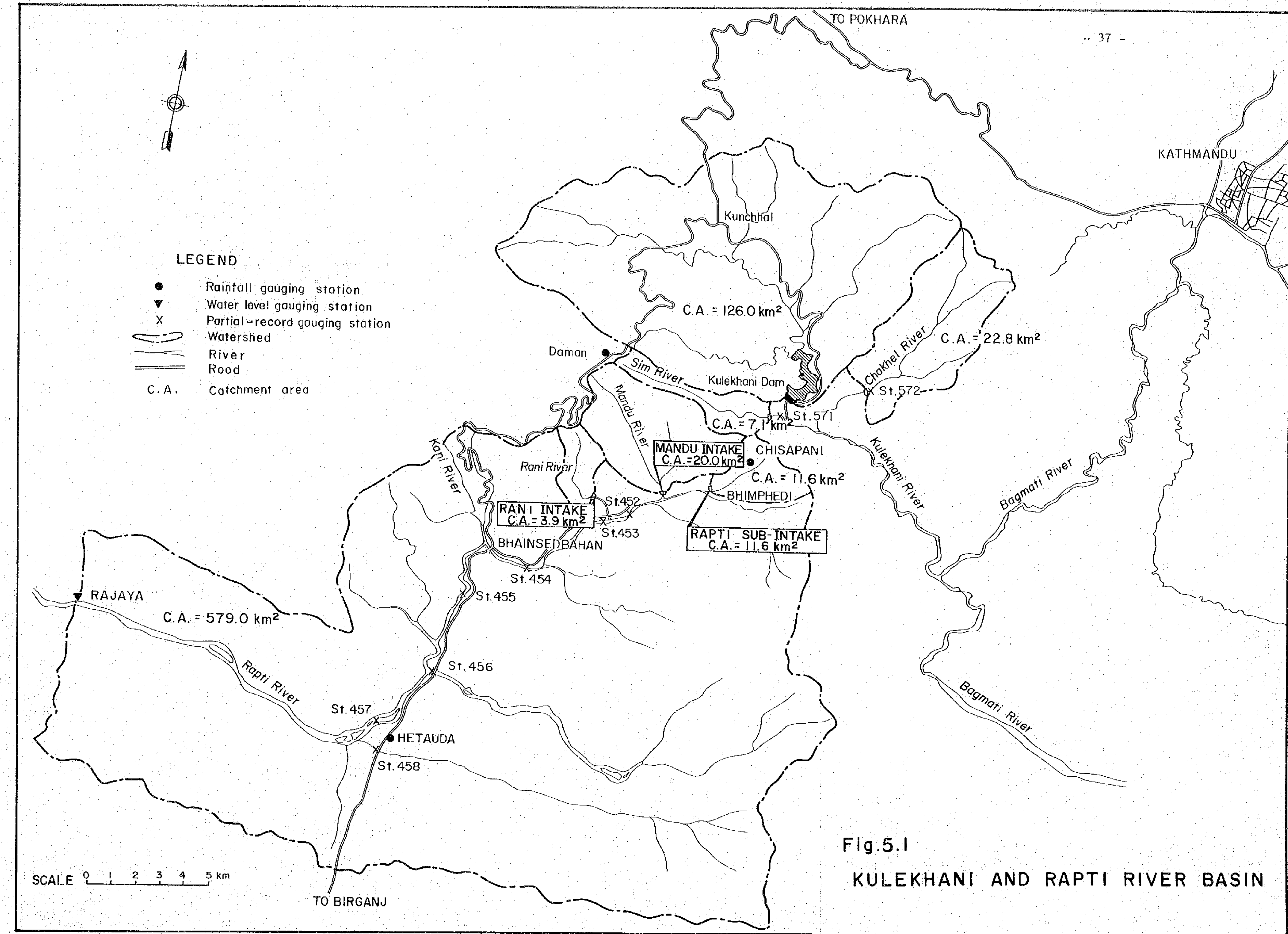

Fig.5.1

KULEKHANI AND RAPTI RIVER BASIN

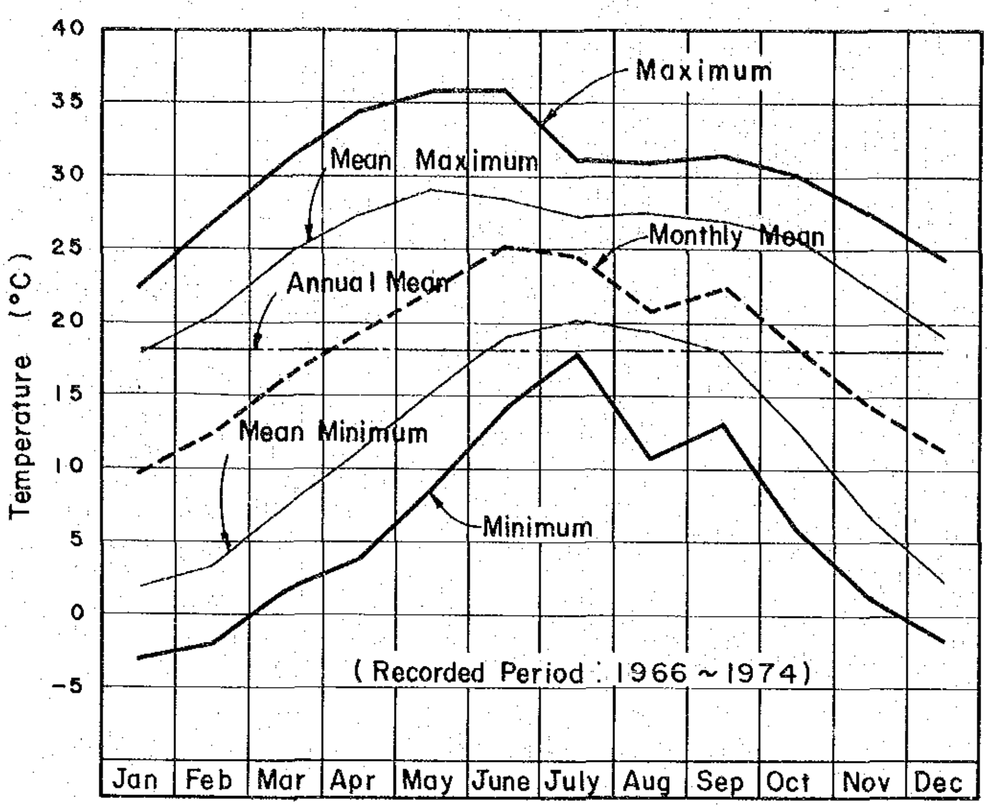

FIG.5.2 AIR TEMPERATURE AT KATHMANDU

5.2 Rainfall

There are four rainfall gaging stations in and around the project area as listed below:

Table 5.1 Rainfall Gaging Stations in and around Project Area

Name of Station	Station No./1	Established Date	Elevation
Kathmandu I.E.	1014	1 Jan. 1949	1,323 m
Chisapani	0904	13 May 1956	1,728 m
Hetauda N.P.I.	0906	23 Sept.1965	303 m
Daman	0905	24 Sept.1965	2,364 m

/1 Station No. refers to publication entitled "Climatological Records of Nepal".

The locations of these stations are shown in Fig.5.1. Kathmandu I.E. lies in the Bagmati river basin. The Kulekhani river is one of the tributaries of the Bagmati. Chisapani and Hetauda N.F.I. are located in the Rapti river basin in which the project area is included, and Daman is situated just on the divide of both basins. Chisapani gaging station in the project area can be regarded to show representative rainfall of the project area.

The annual rainfall and average monthly rainfall at each gaging station are tabulated in Table 5.2 and Table 5.3.

The average annual rainfall through the observation period is 1,379 mm at Kathmandu I.E., 2,199 mm at Chisapani, 2,341 mm at Hetauda N.F.I. and 1,837 mm at Daman. The annual rainfall at Chisapani and Hetauda N.F.I. are larger than those at Kathmandu I.E.

The annual rainfall patterns as shown in Table 5.3 indicates a distinct influence of subtropical weather. The maximum monthly rainfall occurs in July and the minimum in December,and about 80 % of the annual rainfall is recorded during the wet season from June to September.

The recorded maximum daily and monthly rainfalls are given in Table 5.4. The values at Chisapani and Hetauda N.F.I. are larger than those at Kathmandu I.E. and Daman.

Table 5.2 Annual Rainfall

(Unit: mm)

Year	Kathmandu I.E.	Chisapani	Hetauda N.F.I.	Daman
1943	995.4			
1944	1,286.1			
1945	1,584.1			
1946	1,386.2			
1947	-			
1948	1,794.4			
1949	1,368.9			
1950	1,536.1			
1951	1,224.4			
1952	1,280.4			
1953	1,363.6			
1954	1,593.7			
1955	1,130.6			
1956	1,744.4			
1957	1,000.7			
1958	1,134.3	1,449.9		
1959	1,195.3	1,879.1		
1960	1,205.1	1,873.4		
1961	1,634.7	2,546.3		
1962	1,261.5	2,340.7		
1963	1,404.5	1,730.1		
1964	1,386.8	1,373.3		
1965	1,333.2	2,540.0		
1966	1,224.8	2,447.0		
1967	1,348.6	2,095.9	2,575.2	
1968	1,519.2	2,196.8	2,279.9	1,251.8
1969	1,131.2	1,560.9	-	1,427.5
1970	1,439.8	2,514.3	-	1,259.2
1971	1,581.0	2,267.6	-	1,716.7
1972	1,509.5	2,510.3	1,601.8	2,084.0
1973	1,969.2	2,719.2	2,525.9	2,392.3
1974	1,135.5	2,889.8	2,397.4	2,308.1
1975	1,526.7	2,676.2	2,709.3	2,159.9
1976	-	2,173.1	2,300.6	1,929.4
Mean	1,379.0	2,199.2	2,341.4	1,836.5

Table 5.3 Average Monthly Rainfall

(unit: mm)

Year	Kathmandu I.E.	Chisapani	Hetauda N.F.I.	Deman
Jan.	20.4	26.3	27.7	27.6
Feb.	19.4	21.8	19.9	27.1
Mar.	31.2	39.3	48.1	36.4
Apr.	55.8	79.2	39.4	76.9
May	93.3	143.6	119.8	157.5
June	233.5	407.9	424.1	385.9
July	366.0	601.0	724.1	457.8
Aug.	342.2	500.6	514.1	314.4
Sept.	157.2	284.9	376.2	278.9
Oct.	51.8	83.7	42.4	61.2
Nov.	6.3	8.1	3.5	11.9
Dec.	1.9	2.8	2.1	0.9
Total	1,379.1	2,199.2	2,341.4	1,836.5

Table 5.4 Maximum Daily and Maximum Monthly Rainfall

(unit: mm)

Station	Daily		Monthly	
	Date	Amount	Date	Amount
Kathmandu I.E.	2 Aug. 1945	182.4	June 1971	697.5
Chisapani	7 July 1965	300.0	July 1970	1,215.0
Hetauda N.F.I.	31 Aug. 1974	279.2	July 1975	1,171.1
Daman	2 Sep. 1974	181.7	July 1972	957.9

5.3 Runoff

5.3.1 General

In the Kulekhani river and the Rapti river basins, stream flows have been observed at two stream-flow gage stations: Kulekhani station on the Kulekhani from 1963 and Rajaya Station on the Rapti from 1963. Other than the above two, partial measurement records are available on the Chakhel and the Sim, both the tributaries of the Kulekhani, and some places on the Rapti.

For study of the Project, available runoff data at the following sites are required:

i.	Kulekhani damsite	
ii.	Chakhel intake site	at Kulekhani basin
iii.	Sim intake site	
iv.	Rapti sub-intake site	
v.	Mandu intake site	at Rapti basin
vi.	Rani intake site	

The runoff at sites i to iii above in the Kulekhani basin was estimated during the feasibility study on Kulekhani No.1 Project but recent data were added to them in this study, and those at the remaining sites in the Rapti basin are estimated on the basis of the observed records at Rajaya.

5.3.2 Reliability of records at Kulekhani and Rajaya stations

Reliability of the records at the Kulekhani gage station was discussed and concluded reliable in the "Feasibility Report on Kulekhani Hydroelectric Project".

Reliability of the records at Rajaya is checked by means of a double mass curve with the data at Manhari gage station on the Manhari river, which is a tributary to the Rapti draining the next basin to the west side of the Upper Rapti basin. As a result, the records at Rajaya are found

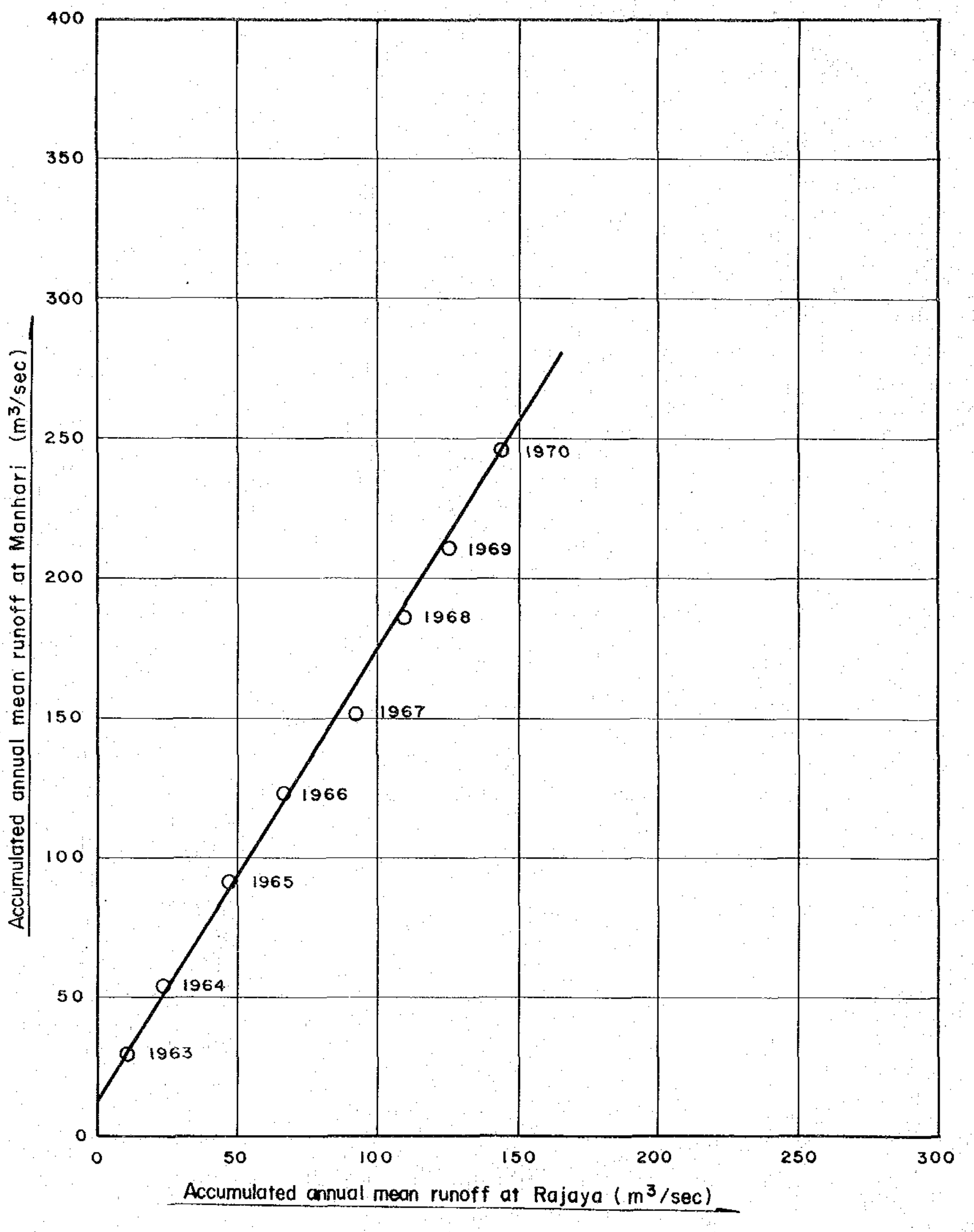

FIG. 5.3 ACCUMULATED RUNOFF RELATION BETWEEN RAJAYA AND MANHARI (Double Mass Curve Method)

quite well reliable as seen in the attached Fig. 5.3. Checking by specific runoff and runoff coefficient based on the records at Rajaya has also been made, and does not indicate the records to be unreliable. Details of the methodology for the above checking are shown in the Appendix II.

5.3.3 Available runoff

Runoff into Kulekhani reservoir

Kulekhani Gage Station exists just downstream of the Kulekhani Damsite. At the site, flow observation has been made from 1963 up to the date. The runoff data for the period from 1963 to 1972 were used for feasibility study of Kulekhani No.1 Power Station. Additional data of runoff for the years 1973 and 1974 have been collected and supplement the data used for the previous study. The monthly runoff at the Kulekhani Damsite is given in Table 5.5.

A comparison of runoff coefficient and specific runoff is made between the stages of feasibility study on the Kulekhani No.1 Power Station and of the present study as follows:

Stage	Basin rainfall (mm)	Mean runoff (m^3/sec)	Total runoff (mm)	Specific runoff (m^3/sec/100 km^2)	Coefficieny
No.1 P.S. F/S	1,730	3.9	976	3.10	0.56
Present	1,820	4.01	1,004	3.18	0.55

The estimate of runoff at Sim and Chakhel intake sites is made according to the methods given in the "Feasibility Study on Kulekhani Hydroelectric Project". The runoff at Sim intake was determined by the following formula:

$$Qs = 0.0745\ Qk^{1.128}$$

and that at Chakhel intake by the following:

$$Qc = 0.18\ Qk$$

Where Qs: Runoff at Sim intake (m^3/sec)
Qc: " at Chakhel intake (m^3/sec)
Qk: " at Kulekhani Gage station (m^3/sec)

The monthly runoff at Sim and Chakhel intake sites, estimated based on the above correlation, is tabulated in the attached Table 5.6 and 5.7, respectively.

Runoff at intake sites in Rapti basin

As direct measurement records at each intake site in the Rapti basin are not available, estimates of runoff are required.

In general, there are several methods for estimating runoff, if sufficient data are available. However, judging from the availability of meteo-hydrological data in the project area, only the following method is applicable for estimating runoffs at each intake site in the Rapti river basin.

The Rajaya gauging station is located on the Rapti river about 14 km downstream from Hedauda. The runoff data at this station is available only for the period from 1963 to the date, however, several runoff measurement records are available for each intake site. These partial records are correlated to the runoff data for the Rajaya on the corresponding dates to obtain the correlation between the runoff at Rajaya and those at each intake site. The correlation obtained shows that the runoff at each intake site can be converted from the records at Rajaya in a simple proportion of their drainage areas. The details of the study are referred to the Appendix II.

Estimated runoff at each intake site based on the above correlation is given in the attached Tables 5.9 to 5.11.

The runoff at Rapti sub-intake site given in Table 5.11 was obtained after further adjustment to the estimated value by the above method in consideration of the fact that according to local inhabitants the discharge disappears completely in the riverbed on the reaches of the Rapti north of Bhimphedi during almost the entire year, except several weeks during the heavy rainy season from July to September.

Table 5.5 Monthly Mean Runoff at Kulekhani

(Unit: m^3/sec)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1963	1.17	1.06	1.13	1.15	1.64	1.13	6.60	7.64	5.75	3.53	2.16	1.75	2.89
1964	1.47	1.39	1.16	0.91	1.27	2.21	7.24	12.12	15.23	4.49	1.84	1.50	4.24
1965	1.32	1.29	1.22	1.76	1.47	3.74	19.54	18.36	5.72	3.16	2.86	1.75	5.18
1966	1.55	1.41	1.14	0.75	1.12	1.14	10.37	20.78	10.29	3.33	2.20	1.70	4.65
1967	1.08	0.94	0.85	1.01	0.65	4.52	11.80	6.92	5.66	3.36	2.32	1.68	3.40
1968	1.66	1.46	1.63	1.21	1.11	2.52	5.72	6.33	2.62	7.12	2.25	1.47	2.93
1969	1.18	0.89	0.87	0.92	0.95	0.88	3.10	6.89	4.18	1.91	1.10	0.83	1.98
1970	0.82	0.72	0.64	0.61	0.64	3.42	21.29	8.98	5.26	3.30	2.18	1.47	4.11
1971	1.15	1.11	1.10	1.98	2.13	21.64	5.09	7.68	4.27	3.82	2.22	1.86	4.50
1972	1.72	1.78	1.62	1.41	1.38	4.54	28.27	6.15	8.36	2.49	1.85	1.58	5.10
1973	1.38	1.24	1.80	0.96	1.29	10.20	7.34	7.97	9.51	9.51	5.14	2.74	4.92
1974	1.59	1.33	1.14	1.17	1.26	1.74	7.14	15.61	12.23	3.50	1.96	1.50	4.18
Mean	1.34	1.22	1.19	1.15	1.24	4.81	11.13	10.45	7.42	4.13	2.34	1.65	4.01

Location: About 400 m on the Kulekhani upstream of the confluence with Sim river.

Drainage area: 126 km^2

Gage: Staff gage read three times daily. Elevation of gage at 1,480 m

Extremes recorded: Maximum, 572 m^3/sec on 16 July 1970
Minimum, 0.11 m^3/sec on 4 June 1967

Table 5.6 Monthly Mean Runoff at Sim Intake Site
($C.A.\ 7.1\ km^2$)

(Unit: m^3/sec)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1963	0.09	0.08	0.09	0.09	0.13	0.09	0.63	0.74	0.54	0.31	0.18	0.14	0.26
1964	0.12	0.11	0.09	0.07	0.10	0.18	0.70	1.24	1.61	0.41	0.15	0.12	0.41
1965	0.10	0.10	0.09	0.14	0.12	0.33	2.13	1.99	0.53	0.27	0.24	0.14	0.52
1966	0.12	0.11	0.09	0.05	0.09	0.09	1.04	2.28	1.03	0.29	0.18	0.14	0.46
1967	0.08	0.07	0.06	0.08	0.05	0.41	1.21	0.66	0.53	0.29	0.19	0.13	0.31
1968	0.13	0.11	0.13	0.09	0.08	0.21	0.53	0.60	0.22	0.68	0.19	0.12	0.26
1969	0.09	0.07	0.06	0.07	0.07	0.06	0.27	0.66	0.37	0.16	0.08	0.06	0.17
1970	0.06	0.05	0.05	0.04	0.05	0.30	2.35	0.89	0.49	0.29	0.18	0.12	0.40
1971	0.09	0.08	0.08	0.16	0.18	2.39	0.47	0.74	0.38	0.34	0.18	0.15	0.44
1972	0.14	0.14	0.13	0.11	0.11	0.41	3.23	0.58	0.82	0.21	0.15	0.13	0.51
1973	0.11	0.09	0.14	0.07	0.10	1.02	0.71	0.77	0.95	0.95	0.47	0.23	0.47
1974	0.13	0.10	0.09	0.09	0.10	0.14	0.68	1.65	1.26	0.31	0.16	0.12	0.40
Mean	0.11	0.09	0.09	0.09	0.10	0.47	0.99	1.07	0.73	0.35	0.20	0.13	0.38

Table 5.7 Monthly Mean Runoff at Chakhel Intake Site
($C.A.\ 22.8\ km^2$)

(Unit: m^3/sec)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1963	0.21	0.19	0.21	0.21	0.30	0.21	1.20	1.38	1.04	0.64	0.39	0.32	0.52
1964	0.27	0.25	0.21	0.16	0.23	0.40	1.31	2.19	2.76	0.81	0.33	0.27	0.77
1965	0.24	0.23	0.22	0.32	0.27	0.68	3.54	3.32	1.04	0.57	0.52	0.32	0.94
1966	0.28	0.26	0.21	0.14	0.20	0.21	1.88	3.76	1.86	0.60	0.40	0.31	0.84
1967	0.20	0.17	0.15	0.18	0.12	0.82	2.14	1.25	1.02	0.61	0.42	0.30	0.62
1968	0.30	0.26	0.30	0.22	0.20	0.46	1.04	1.15	0.47	1.29	0.41	0.27	0.53
1969	0.21	0.16	0.16	0.17	0.17	0.16	0.56	1.25	0.76	0.35	0.20	0.15	0.36
1970	0.15	0.13	0.12	0.11	0.12	0.62	3.85	1.61	0.95	0.60	0.39	0.27	0.74
1971	0.21	0.20	0.20	0.36	0.39	3.92	0.92	1.39	0.77	0.69	0.40	0.34	0.81
1972	0.31	0.32	0.29	0.26	0.25	0.82	5.12	1.11	1.51	0.45	0.33	0.29	0.92
1973	0.25	0.22	0.32	0.17	0.23	1.84	1.32	1.43	1.71	1.71	0.93	0.49	0.89
1974	0.29	0.24	0.21	0.21	0.23	0.31	1.29	2.81	2.20	0.63	0.35	0.27	0.75
Mean	0.24	0.22	0.22	0.21	0.23	0.88	2.03	1.91	1.35	0.75	0.43	0.30	0.72

Table 5.8 Monthly Mean Runoff at Rajaya

(Unit: m^3/sec)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1963	7.86	6.77	5.62	5.10	6.07	21.36	65.55	91.79	70.86	33.15	16.30	9.58	28.51
1964	7.59	6.43	5.29	4.97	5.64	11.16	74.35	55.53	69.10	44.55	13.35	8.06	25.62
1965	7.16	6.63	6.74	4.45	3.82	17.48	84.26	170.5	73.43	28.93	20.62	10.88	36.56
1966	8.27	6.88	5.95	5.09	6.83	11.90	51.84	157.5	92.63	20.29	12.53	9.42	32.66
1967	7.55	6.28	6.70	6.72	6.32	14.36	93.67	74.28	72.04	21.12	10.01	6.69	27.33
1968	6.73	5.82	5.27	4.66	4.91	33.44	89.38	138.8	62.41	44.75	18.46	12.43	35.81
1969	10.17	7.68	6.91	6.11	7.29	13.78	44.82	81.47	64.61	28.03	14.80	10.25	24.57
1970	7.99	6.98	5.34	5.04	4.76	22.44	132.4	95.46	68.09	44.74	18.18	11.08	35.24
1971	7.30	4.65	2.91	6.62	22.21	90.24	67.88	89.81	59.29	34.49	17.10	11.38	34.64
1972	8.69	7.93	6.47	4.88	5.11	16.10	66.96	63.66	61.49	29.56	15.83	10.33	24.40
1973	8.61	6.69	5.80	3.13	6.25	43.72	45.30	64.43	77.93	57.44	24.74	15.32	30.06
1974	11.92	8.90	7.24	6.53	7.71	15.15	61.15	103.0	120.5	34.23	15.69	13.30	33.92
Mean	8.32	6.80	5.85	5.28	7.24	25.93	73.13	98.85	74.37	35.11	16.47	10.73	30.79

Location: At Rajaya on the Rapti, about 15 km west of Hetaura

Drainage area: 579 Km^2

Gage: Water stage recorder, elevation of gage at 332 m

Extremes: Maximum, 1050 m^3/sec on 26 Aug. 1968
Minimum, 1.1 m^3/sec on 4 - 8 April 1971

Table 5.9 Monthly Mean Runoff at Mandu Intake Site
($C.A.\ 20.0\ km^2$)

(Unit: m^3/sec)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1963	0.27	0.23	0.19	0.18	0.21	0.74	2.26	3.17	2.45	1.14	0.56	0.33	0.98
1964	0.26	0.22	0.18	0.17	0.19	0.39	2.57	1.92	2.39	1.54	0.46	0.28	0.88
1965	0.25	0.23	0.23	0.15	0.13	0.60	2.91	5.89	2.54	1.00	0.71	0.38	1.26
1966	0.29	0.24	0.21	0.18	0.24	0.41	1.79	5.44	3.20	0.70	0.43	0.33	1.13
1967	0.26	0.22	0.23	0.23	0.22	0.50	3.24	2.57	2.49	0.73	0.35	0.23	0.94
1968	0.23	0.20	0.18	0.16	0.17	1.15	3.09	4.79	2.16	1.55	0.64	0.43	1.24
1969	0.35	0.27	0.24	0.21	0.25	0.48	1.55	2.81	2.23	0.97	0.51	0.35	0.86
1970	0.28	0.24	0.18	0.17	0.16	0.78	4.57	3.30	2.35	1.55	0.63	0.38	1.23
1971	0.25	0.16	0.10	0.23	0.77	3.12	2.34	3.10	2.05	1.19	0.59	0.39	1.20
1972	0.30	0.27	0.22	0.17	0.18	0.56	2.31	2.20	2.12	1.02	0.55	0.36	0.86
1973	0.30	0.23	0.20	0.11	0.22	1.51	1.56	2.23	2.69	1.98	0.85	0.53	1.04
1974	0.41	0.31	0.25	0.23	0.27	0.52	2.11	3.56	4.20	1.18	0.54	0.46	1.17
Mean	0.26	0.24	0.20	0.18	0.25	0.90	2.53	3.42	2.57	1.21	0.57	0.37	1.07

Table 5.10 Monthly Mean Runoff at Rani Intake Site
($C.A.\ 3.93\ km^2$)

(Unit: m^3/sec)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1963	0.05	0.05	0.04	0.03	0.04	0.14	0.44	0.62	0.48	0.22	0.11	0.06	0.19
1964	0.05	0.04	0.04	0.03	0.04	0.08	0.50	0.38	0.47	0.30	0.09	0.05	0.17
1965	0.05	0.04	0.05	0.03	0.03	0.12	0.57	1.16	0.50	0.20	0.14	0.07	0.25
1966	0.06	0.05	0.04	0.03	0.05	0.08	0.35	1.07	0.63	0.14	0.08	0.06	0.22
1967	0.05	0.04	0.05	0.05	0.04	0.10	0.64	0.50	0.49	0.14	0.07	0.05	0.19
1968	0.05	0.04	0.04	0.03	0.03	0.23	0.61	0.94	0.42	0.30	0.13	0.08	0.24
1969	0.07	0.05	0.05	0.04	0.05	0.09	0.30	0.55	0.44	0.19	0.10	0.07	0.17
1970	0.05	0.05	0.04	0.03	0.03	0.15	0.90	0.65	0.46	0.30	0.12	0.08	0.24
1971	0.05	0.03	0.02	0.04	0.15	0.61	0.46	0.61	0.40	0.23	0.12	0.08	0.24
1972	0.06	0.05	0.04	0.03	0.03	0.11	0.45	0.43	0.42	0.20	0.11	0.07	0.17
1973	0.06	0.05	0.04	0.02	0.04	0.30	0.31	0.44	0.53	0.39	0.17	0.10	0.20
1974	0.08	0.06	0.05	0.04	0.05	0.10	0.41	0.70	0.81	0.23	0.11	0.09	0.23
Mean	0.06	0.05	0.04	0.04	0.05	0.18	0.50	0.67	0.50	0.24	0.11	0.07	0.21

Table 5.11 Monthly Mean Runoff at Rapti Sub-intake Site (Adjusted)

(Unit: m^3/sec)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1963	0	0	0	0	0	0.06	0.57	0.98	0.59	0.08	0	0	0.19
1964	0	0	0	0	0	0	0.71	0.30	0.54	0.12	0	0	0.14
1965	0	0	0	0	0	0.03	0.89	2.55	0.61	0	0	0	0.34
1966	0	0	0	0	0	0.04	0.32	2.31	1.05	0	0	0	0.31
1967	0	0	0	0	0	0	1.12	0.63	0.59	0	0	0	0.20
1968	0	0	0	0	0	0.15	0.93	1.92	0.39	0.22	0	0	0.30
1969	0	0	0	0	0	0	0.20	0.81	0.43	0	0	0	0.12
1970	0	0	0	0	0	0.09	1.90	1.05	0.50	0.17	0	0	0.31
1971	0	0	0	0	0.05	0.98	0.50	0.94	0.33	0.05	0	0	0.24
1972	0	0	0	0	0	0.11	0.78	0.42	0.38	0.01	0	0	0.14
1973	0	0	0	0	0	0.31	0.13	0.44	0.70	0.33	0	0	0.16
1974	0	0	0	0	0	0.02	0.43	1.22	1.57	0.06	0	0	0.28
Mean	0	0	0	0	0	0.15	0.71	1.13	0.64	0.09	0	0	0.23

5.3.4 Floods

As the direct measurement records of floods are not available in the upper Rapti basin, the flood data at each intake site and powerhouse site had to be estimated by some means.

The most reliable method of estimating probable flood at each strategic site in this case is to derive from the probable floods at Rajaya by means of an equation as "$Q = C.A^n$", where Q is peak discharge of flood, A is the catchment area at the site and C and n are coefficients. Other methods than the above would not be applicable because of lack of reliable data. Regarding "n" in the above equation, "0.5" is taken.

Based on the records of annual maximum flood peak at Rajaya, as shown in the attached Table 5.13, a probability of recurrence is computed in Gumbel's and Iwai's methods. Since Gumbel's shows always larger values than Iwai's, the Gumbel's method is applied in determination of probable floods.

The basin coefficient "C" is determined for each probable flood with respective recurrence period. In determining the "C" values, the catchment area of 579 km^2 at Rajaya and the value of flood peak of each probable flood at Rajaya are applied to the above equation. The probable floods at each site are estimated on the basis of "C" thus obtained and the drainage area at each site. The results are shown in attached Tables 5.14 and 5.15.

5.3.5 Sediment

There are no records of sediment on the Upper Rapti river, however, the measurement records of suspended silt on the Lothar river give a guide for estimating sediment yield in the Upper Rapti basin. The Lothar river drains southern slopes of the Mahabharat mountain range and pours into the Rapti from the right bank about 22 km downstream of Rajaya gage station. It seems that the Upper Rapti basin is similar to the Lothar basin in the topography and meteorologic conditions. The drainage area at the Lothar gage station is measured at 169 km^2. Table 5.15 indicates the records of suspended load at the Lothar gage station.

When it is assumed that all the sediment is produced in the wet season from June to October, average concentration of suspended load in wet season is obtained as a simple mean of the records in the months from June to October as shown in Table 5.15. The average annual total suspended load is obtained by applying the above average concentration to the average total runoff in the wet season from June to October. The bed load is assumed to be 15 % of suspended load. The annual sediment yield including suspend and bed load thus estimated is about 420,000 t/year or 2,480 t/km^2/year. When unit weight of silt is at 1.3 t/m^3, the annual specific sediment yield is computed at 1,900 $m^3/year/km^2$.

On the other hand, some examples of estimate of sediment yield in other river basins in Nepal are shown in Table 5.16. Those estimates are based on the actual measurement records, and on the basin conditions of those rivers which are similar to that of the project river basin.

Referring to the values of sediment yields of Lothar basin and also those other river basins, the annual sediment yield of the Upper Rapti basin is estimated at 2,000 $m^3/km^2/year$.

Table 5.12 Annual Maximum Flood Runoff at Rajaya

Year	Maximum flood runoff (m^3/sec)	Occurrence date	Order
1963	691	16 Sept.	6
1964	368	2 Sept.	8
1965	971	7 July	3
1966	964	24 Aug.	4
1967	798	10 July	5
1968	1,050	26 Aug.	1
1969	310	19 Aug.	12
1970	604	17 July	7
1971	318	13 June	11
1972	357	27 July	9
1973	356	26 Sept.	10
1974	1,000	31 July	2

Table 5.13 Probable Flood Runoff and Coefficient "C" at Rajaya

Recurrence interval (Years)	Gumbel's method		Iwai's method	
	Flood runoff (m^3/sec)	Coefficient "C"	Flood runoff (m^3/sec)	Coefficient "C"
5	940	39.1	880	36.6
10	1,160	48.2	1,080	44.9
20	1,370	56.9	1,280	53.2
50	1,640	68.2	1,550	64.4
100	1,840	76.9	1,760	73.1
200	2,050	85.2	1,970	81.9
1,000	2,520	104.7	2,500	103.9

Table 5.14 Probable Flood Runoff at Each Intake Site

(Unit: m^3/sec)

Recurrence interval (Years)	Mandu intake site (20 km^2)	Rapti sub-intake site (11.6 km^2)	Rapti intake site (52.6 km^2)	Rani intake site (3.93 km^2)
5	175	133	284	77
10	216	164	350	96
20	254	194	413	113
50	305	232	495	135
100	344	262	558	152
200	381	290	618	169
1,000	468	357	759	208

Remarks:

Figures in brankets ( ) show the catchment area.

Table 5.15 Sediment Concentration at Lothar on the Lothar River

Month	Max. (P.P.M.)	Min. (P.P.M.)	Mean. (P.P.M.)	Measurement Days
July 1975	5,670	4,080	4,875	2
Aug. 1975	2,030	637	1,276	4
Sept.1975	1,880	530	1,220	4
Oct. 1975	1,290	672	981	2
Sept.1976	800	37	190	14
Oct. 1976	560	16	80	30
Nov. 1976	92	12	39	12
Dec. 1976	70	6	23	26
Jan. 1977	490	17	60	31
Feb. 1977	100	39	70	12
Mar. 1977	392	45	116	16
Apr. 1977	421	29	1 121	7
May 1977	7,850	39	2,721	7

Table 5.16 Specific Average Annual Sediment Yield (Suspended Load only)

Name of River	Gaging Site	Sediment Yield ($m^3/km^2/year$)
Sapt Kosi	Sunakambi	2,000
Karnali	Chisapani	1,500
Kamla	Chisapani	1,800
Bagmati	Chobhar	1,000
	Mean	1,600