HIS MAJESTY'S GOVERNMENT OF NEPAL

# MASTER PLAN OF HYDROELECTRIC POWER DEVELOPMENT IN NEPAL

September 1974

JAPAN INTERNATIONAL COOPERATION AGENCY

HIS MAJESTY'S GOVERNMENT OF NEPAL

# MASTER PLAN OF HYDROELECTRIC POWER DEVELOPMENT IN NEPAL



September 1974

JAPAN INTERNATIONAL COOPERATION AGENCY

# PREFACE

The Government of Japan, in response to the request of His Majesty's Government of Nepal, agreed to undertake a study for drawing up a master plan of hydroelectric power development in Nepal, in parallel with conducting the feasibility study of the Kulikhani No.1 Hydroelectric Power Project, and commissioned its implementation to the Japan International Cooperation Agency (formerly the Overseas Technical Cooperation Agency), an organization to execute overseas technical cooperation schemes of the Government of Japan.

Accordingly, the Agency organized a survey team consisting of five (5) experts headed by Mr. S. Ichiura, and sent it to Nepal in order to make out the master plan as well as conducting the feasibility study as above mentioned.

The team conducted the field survey works in Nepal during the period of 60 days from November 16, 1973 to January 16, 1974, and office works such as analyses and joint studies based on the results obtained during the field survey, followed in Japan.

The master plan on the development of the electric power in Nepal submitted hereby comprises the results of the survey performed from the stand points of both economic and technical aspects.

Upon completion of this report for submitting, nothing would be more gratifying to our agency if this could be of any help for the development of the electric power in Nepal and could contribute to the further economic interchange and the promotion of friendship between the two countries.

In conclusion, I wish to express my heartfelt gratitude to the authorities concerned of His Majesty's Government of Nepal for their kind and close cooperation and assistance extended to the Japanese survey team.

Shinsaku Hogen
President
Japan International Cooperation Agency
Tokyo, Japan

LETTER OF TRANSMITTAL

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

September 1974

Dear Mr. Hogen,

We are pleased to submit our report on the Master Plan of Hydroelectric Power Development in Nepal. Our assignment is to review the "Master Plan for Power Development and Supply" prepared by the Government of Nepal in 1970, and has consisted of as follows:

Field investigation

(1) Collection of data relevant to hydrology, topography, geology, power demand, and so on.

(2) Reconnaissance of topography and geology of each project site.

Home office work

(3) Review of previous "Master Plan" report.

(4) Study and compilation of hydrological data.

(5) Estimation of the riverflow available for power generation at each project site.

(6) Forecast of power demand.

(7) Preliminary planning of each project.

(8) Estimation of construction cost for each project.

(9) Estimation of power output of the project.

(10) Estimation of production cost of power for each project.

(11) Determination of project priorities.

(12) Preparation of a Master Plan Report.

In this context, the contract has defined the projects as to be the 24 sites which have been taken up in the previous master plan. In our study, however, this has been extended to some more, after elimination of questionable projects and inclusion of some prospective ones found during the course of the investigation. The results of the study are compiled in our report as presented herewith.

The hydroelectric power potential in Nepal is large, but its anticipated load growth will not warrant the implementation of a sizable hydroelectric power project. On the other hand, there is a basic agreement about the exchange of electric power between India and Nepal. While the agreement is intended for solving immediate problem of power shortage at the border towns in both countries, this opens the marketability of Nepal's power if it can be produced at a competent cost.

Under such conditions, our approach to the problem is to identify three types of the hydroelectric power development in Nepal, and different philosophies of development are applied to. The first type is to sell the energy to India on firm commitments. Since the power market in India is extremely large, the development will have to be a large scaled one to pursue its scale merit to the maximum extent in order to attain a competent power cost. The conceivable projects of this type with high priorities are the Chisapani Project on the Karnali River and the Marsyandi Project on the Marsyandi River. The second type is planned primarily to meet the growing domestic needs at all times in order not to hamper the economic development of the country. The surplus energy could be sold to India, but the unused capacity of the powerplant would be only made available during the build-up period of the domestic needs. In this case, the scale of the project and the timing of its implementation become the matter of concern, and the optimum project sequence to yield the minimum investment cost will have to be determined. Greater part of the study has been devoted to this type of development, and, as a result, the Kulikhani No.1 and No.2 Projects on the Bagmati-East Rapti Rivers, the Dev-Ghat Project on the Sapt Gandaki River, the Kankai Project on the Kankai Mai River, and the Sarda Project on the Babai River are recommended. The third type is the micro projects which are extremely small development and aim at the electrification of rural areas. Such projects are very important in view of the national welfare, but they will have to be implemented on the opportunity basis. Some of them are proposed for the earliest implementation based on the feasibility studies. Micro projects are not dealt in detail in this study.

It is admitted that the scope of the study was limited by available man power, time, and fund. Some projects among the recommended ones, detailed mapping and geological survey will be required to prepare preliminary design with cost estimate to the extent necessary for final determination of feasibility and for project preparation. However, it is believed that the conception of the development presented in the report and the conclusion derived therefrom are sufficiently instructive and flexible to delineate the national plan, and easily to be modified to fit the future changing conditions.

It has been our pleasure to work on this interesting assignment. I take this opportunity to express my sincere appreciation to your staff for the help given to us, and the same to the concerned authorities of His Majesty's Government of Nepal for the courtesies and cooperation afforded to us on all occasions during our field reconnaissance period.

Very truly yours,

T. Hashimoto

Toshio Hashimoto
President
Nippon Koei Co., Ltd.
Tokyo, Japan

## SUMMARY

1. Nepal's electric power is presently served by the Central Nepal Power System (CNPS), a number of small isolated public systems, among which some are operated by private companies, and factory-owned self-supplying private plants. In addition, electric power is imported or exported at the border towns based on the agreement set forth between India and Nepal. The present status of installed generating capacity and committed power exchange in each development region (the development region is a planning establishment aiming at balanced economic growth under the guidance of National Planning Commission) are shown in the following tabulation.

| Development Region | Installed Generating Capacity (kW) | | | | Committed power exchange (kW) | |
|---|---|---|---|---|---|---|
| | Hydro | Steam | Diesel | Total | Import | Export |
| Surkhet (Far Western) | - | 125 | 570 | 695 | 2,000 | - |
| Pokhara (Western) | 1,050 | 750 | 1,187 | 2,987 | 1,300 | - |
| Kathmandu (Central) | 31,620 | 1,600 | 9,978 | 43,198 | 1,500 | 5,000 |
| Dhankuta (Eastern) | 240 | 1,400 | 5,115 | 6,755 | 7,700 | |
| Total | 32,910 | 3,875 | 16,850 | 53,635 | 12,500 | 5,000 |

2. The major towns of the Kathmandu Development Region are served by the CNPS. Kathmandu and Hetaura-Birganj corridor in this region is the center of the nation's economic activity, and by far the largest demand center in the country. The Pokhara Development Region is less developed. A new 132 kV transmission line to connect the region with the CNPS is now under construction, and will be completed in 1975/76. The Dhankuta Development Region covers the vast east Terai Plain, which is the most fertile land and suitable for rice and jute cultivation. Biratnagar in this region is famous for its jute production and forest resources, and is the largest

industrial complex today in Nepal. However, this area did not share its due attention in power development, and its power consumption had been seriously suppressed until recently when the power is imported from India. The Surkhet Development Region is the least developed portion of the country. Nepalganj is the only sizable town and an important industrial complex in this region.

3. The forecast of required power generation for these four regions are made up to 1989/90, and summarized in the following tabulation.

| | Power Demand | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Kathmandu | | Dhankuta | | Pokhara | | Surkhet | | Total | |
| Year | Peak (MW) | Energy (GWh) | Peak (MW) | Energy (GWh) | Peak (MW) | Energy (GWh) | Peak (MW) | Energy (GWh) | Peak (MW) | Energy (GWh) |
| 1972/73 | 21.2 | | 4.26 | | 1.62 | | | | | |
| 1974/75 | 30.6 | | 8.31 | | 3.11 | | 0.78 | | 42.80 | |
| 1979/80 | 65.0 | 282.3 | 18.69 | 72.0 | 7.78 | 34.1 | 6.63 | 13.7 | 98.10 | 402.1 |
| 1984/85 | 105.5 | 462.0 | 34.45 | 147.9 | 15.34 | 67.3 | 17.90 | 47.6 | 173.19 | 724.8 |
| 1989/90 | 155.0 | 666.0 | 62.78 | 275.0 | 24.3 | 105.0 | 29.50 | 77.6 | 271.58 | 1,123.6 |

4. While the hydroelectric power potential in Nepal is large, its anticipated load growth as shown above does not warrant the implementation of a sizable hydropower project. However, there is a basic agreement about the exchange of electricity between India and Nepal. This agreement is intended for solving immediate problem of power shortage at the border towns in both countries, but it undoubtedly opens up the marketability of Nepal's power provided that reasonably inexpensive energy can be produced in the country. The conceivable extension of Nepal's power market is practically limited to the Eastern and Northern Regions of India. The forecasted power demands in these regions are shown as follows:

| Year | Power Demand in India | | | | | |
|---|---|---|---|---|---|---|
| | Northern Region | | Eastern Region | | Total of Two Regions | |
| | Peak (MW) | Energy (GWh) | Peak (MW) | Energy (GWh) | Peak (MW) | Energy (GWh) |
| 1969/70 | 2,378 | 12,490 | 1,702 | 9,752 | 4,080 | 22,242 |
| 1974/75 | 4,811 | 22,906 | 2,807 | 15,397 | 7,618 | 38,303 |
| 1979/80 | 9,344 | 49,112 | 4,947 | 26,001 | 14,291 | 75,113 |
| 1984/85 | 16,318 | 85,767 | 8,411 | 44,208 | 24,729 | 129,975 |
| 1989/90 | 26,281 | 138,133 | 13,793 | 72,496 | 40,074 | 210,629 |

5. The hydroelectric power development in Nepal can be classified, taking account of Indian market, into 3 categories: i.e., a large scale development, a medium to small scale development, and a micro project. The distinction of these categories is made based on the mode of the project implementation. The large scale development is planned to sell the energy to India on firm commitments. The objective of the medium to small scale development is to meet the growing domestic demand at all times, and only the surplus energy is sold to India. The micro project is extremely small development and aims at the electrification of rural areas. Different approaches will have to be applied for these 3 types of development.

6. For the large scale development, both capacity and energy values can be sold, but the price will depend upon the power situation in India by the time that such a selling is made. It is conceivable that more nuclear plants will come into being as base load stations in India in the future. The proportion of nuclear power to coal-fired thermal power would be about 15 to 20 per cent at the most even in the year of 1985-90. Then, the cost of producing power by combined nuclear plants and coal-fired thermal plants would be about 16 US mills/kWh in early 1974 price level as a conservative estimate. Therefore, the projects which are likely to offer a power cost of less than 16 US mills/kWh are selected as a prospective large scale development. They are,

    1) Chisapani Project (1,800 MW), Karnali Basin
    2) Marsyandi Project (510 MW), Sapt Gandaki Basin
    3) Kali Gandaki No.1 Project (1,500 MW), Sapt Gandaki Basin
    4) Lakarpata Project (1,200 MW), Karnali Basin

The priorities of the projects are given in above order. The Chisapani Project is prefered as its feasibility study has been completed. The Marsyandi Project is favorable because of its exceptionally good accessibility. The rest are in the order of their apparent project economies. The salient economic figures of these projects are shown as follows.

| Project | Installed Capacity (MW) | Annual output (GWh) | Construction cost: Dam & Power plant ($10^6$US$) | Construction cost: Transmission facilities ($10^6$US$) | Construction cost: Total ($10^6$US$) | Annual cost ($10^6$US$) | Annual Benefit ($10^6$US$) | B/C |
|---|---|---|---|---|---|---|---|---|
| Chisapani | 1,800 | 8,350 | 548 | 17 | 565 | 47.5 | 133.6 | 2.8 |
| Marsyandi | 510 | 2,420 | 181 | 7 | 188 | 15.8 | 38.8 | 2.5 |
| Kali Gandaki No.1 | 1,500 | 6,700 | 478 | 17 | 495 | 41.6 | 107.2 | 2.6 |
| Lakarpata | 1,200 | 5,540 | 520 | 9 | 529 | 44.4 | 88.6 | 2.0 |

7. The medium to small scale development will be considered region-wise, and planned to meet the local demand. In this context, the Kathmandu and Pokhara Development Regions is treated as one system (the combined CNPS), since the unification of these regions will be made in 1975/76, and the anticipated earliest in-service date of a new project is in 1978/79. In formulating the hydropower development plan for these regions, an optimum development sequence of the projects which will meet the system demand at all times and will offer the least total investment is needed to be determined. Studies have been carried out at a discount rate of 6 %, and, as a result, the following implementation sequence is proposed.

In 1978/79, Kulikhani No.1 Project (46 MW)/1
In 1982, Kulikhani No.2 Project (26 MW)/1 /2
In 1984/85, Dev-Ghat Project (150 MW)/2

/1 The installed capacities of the Kulikhani No.1 and the No.2 Projects are revised to be 60 MW and 35 MW respectively in the feasibility report on the Kulikhani hydroelectric project.

/2 The revision of the scale of the Kulikhani projects will differ the installation schedule of the follow-up projects only by one year respectively.

Since the individual project is fitted in that particular position of the sequence, the comparison of benefit and cost for each project is not needed any more. However, to facilitate a means of indicating the superiority of the hydroelectric project over its thermal alternatives, the annual cost and benefit of each project are presented in the following tabulation based on the capacity and energy values of US$63/kW and 20 mills/kWh respectively. The export of surplus energy to India will be of secondary importance, and probably be made at a reasonable low price. This is assumed to be at 8 mills/kWh.

| Project | Installed Capacity (MW) | Annual Energy output (GWh) | Construction cost: Dam & Power-plant ($10^6$US$) | Construction cost: Trans-mission facilities ($10^6$US$) | Construction cost: Total ($10^6$US$) | Annual cost ($10^6$US$) | Annual Benefit ($10^6$US$) | B/C |
|---|---|---|---|---|---|---|---|---|
| Kulikhani No.1 | 46 /1 | 201 | 43.6 | 1.4 | 45.0 | 3.7 | 5.9 | 1.6 |
| Kulikhan No.2 | 26 /1 | 103 | 12.2 | 2.9 | 15.1 | 1.2 | 3.7 | 3.0 |
| Dev-Ghat | 150 | 1,190 | 68.1 | 8.7 | 76.8 | 6.3 | 19.8 | 3.0 |

8. While not included in above project sequence, the possibility of the Bagmati Project on the Bagmati River and the Kulikhani No.3 Project should not be looked over. The Bagmati Project is a multipurpose development, and appears very favorable as far as the hydroelectric power is concerned. However, the major purpose of the project is for irrigation, which requires heavy initial investment of associated irrigation facilities. Its implementation is more governed by irrigation than hydroelectric power. The Kulikhani No.3 Project could be implemented at any time after the No.2 Project, as the No.3 Project has such intangible advantages of easiness of accessibility and availability of existing construction equipment, which may not be able to be appropriately accounted for in the project sequence study. If these two projects come into being, aforementioned development sequence should be adjusted accordingly.

9. The Kankai Project (33 MW) on the Kankai Mai River is proposed for the power supply in the Dhankuta Development Region. It is also multipurpose development for irrigation, power, and flood control. The Kankai Project

/1 Preliminary figures. See the footnote of page 48.

can satisfy the region's demand up to 1985/86 even if the import of energy is stopped and most of thermal plants are shut off. By that time, a 132 kV transmission line connecting this region to the CNPS should be in existence, and the power supply of the eastern and the western regions will be unified. The aforementioned installations in the Kathmandu Development Region together with the Kankai Project can satisfy the unified CNPS demand up to 1991/92. The salient economic figures of the Kankai Project are shown as follows.

Kankai Project

| | | |
|---|---|---|
| Installed Capacity | (MW) | 33 |
| Annual Output | (GWh) | 156 |
| Construction Cost | ($10^6$US$) | |
| Dam & Powerplant | | 12.6* |
| Transmission facilities | | 3.6 |
| Total | | 16.2 |
| Annual Cost | ($10^6$US$) | 1.3 |
| Annual Benefit | ($10^6$US$) | 4.4 |
| B/C | | 3.4 |

* The figure includes 25 % of the dam cost, which is the allocated portion of the joint cost.

10. The power demand in the Surkhet Region has been very small. However, aiming at the balanced economic development of each region in the country, the government formulated the Fifth Five Years Plan putting emphasis on the industrial development of this region. Taking the plan into consideration, rapid growth of power demand is anticipated in this region. The only conceivable medium to small scale development is the Sarda Project (49 MW), which can supply reasonably inexpensive energy to Nepalganj and the surrounding areas, if the surplus power can be exported to India. The project is scheduled to be completed by 1980/81 and will satisfy the industrial and domestic demand of the region for about 15 years.

11. Micro projects are extremely small development, mostly smaller than 100 kW, aiming at the electrification of the rural areas. The Fifth Five Years Plan aims to conduct feasibility studies of the micro projects on 10 remote hilly places, out of which two would be taken up for the earliest construction. Micro projects are important in view of the national welfare. The

capacity and energy values of them are estimated at 94 US$/kW and 54 mills/kWh respectively on the alternative thermal generating cost. While micro projects are not dealt in this report, they should be implemented on the opportunity basis, whenever they appear feasible based on the above power values.

12. The implementation of large scale projects involve many complex problems to be solved beforehand. It is not possible to set forth meaningful implementation schedule at this moment, unless in a very general way. On the other hand, the medium to small scale projects will have to be implemented in such a way to meet the domestic demand at all times, so that financial arrangement should be made well in advance to prepare the project investigation and construction. The medium to small scale projects proposed heretofore are as follows./1

| Project | Region | Expected in-service date |
|---|---|---|
| Kulikhani No.1 | Kathmandu | 1978/79 |
| Kulikhani No.2 | " | 1983 |
| Dev-Ghat | " | 1985/86 |
| Kankai | Dhankuta | 1978/79 |
| Interconnection of Dhankuta to CNPS | | 1985/86 |
| Sarda | Surkhet | 1980/81 |

The investment schedule of implementing these projects is shown in the following tabulation./1

| Year | Investment ($10^6$US$) |
|---|---|
| 1974/75 | 0.6 |
| 75/76 | 4.56 |
| 76/77 | 17.14 |
| 77/78 | 49.58 |
| 78/79 | 46.89 |
| 79/80 | 24.86 |
| 80/81 | 21.84 |
| 81/82 | 22.71 |

/1 Based on the final figures of the Kulikhani projects, the feasibility studies of which are conducted recently.

| Year | Investment ($10^6$ US$) |
|---|---|
| 82/83 | 25.26 |
| 83/84 | 23.83 |
| 84/85 | 13.64 /1 |
| 85/86 | 1.97 |

13. The projects that have been taken up in this study are by no means to cover the all projects in the country. As the total of the capacity of these projects is only a fraction of the total hydro potential in the country, there certainly would be more projects exploitable technically and economically. Much study is remained to be done in the future. For the major river basins, investigation of the integrated development plans are in order, to prevent the individual project jeopardizing each other in the future. Also, more effort should be directed on the investigation of the river of the Bagmati class, as the size of the probable project on this class of the river would be more adequate for early implementation. Attention on the possibility of multipurpose development is indispensable too.

---

/1 Works of preparing the next project to the Dev-Ghat would be commenced by this year, but their costs are not included in the schedule.

THE REPORT

Contents

## LIST OF TABLES

## LIST OF FIGURES

## ABBREVIATIONS, UNITS, AND NEPALESE CALENDER

| | | |
|---|---|---|
| ABBREVIATIONS, | ADB: | Asian Development Bank |
| | BPC: | Butwal Power Company |
| | CNPS: | Central Nepal Power System |
| | GNP: | Gross National Products |
| | GDP: | Gross Domestic Products |
| | NEC: | Nepal Electricity Corporation |
| | OTCA: | Overseas Technical Cooperation Agency |
| | UNDP: | United Nations Development Program |
| Unit, | kW: | kilowatt |
| | MW: | mega watt (1,000 kW) |
| | kWh: | kilowatt hour |
| | MWh | mega watt hour (1,000 kWh) |
| | GWh: | gigawatt hour (1,000,000 kWh) |
| | kV: | kilovolt |
| | Rs: | Nepalese rupees, equivalent to US$0.10 |

CALENDER,

The Nepalese fiscal year begins on July 16 and ends on July 15 of the following year. Hence, 1970/71 or 70/71 means the year from July 16, 1970 to July 15, 1971.

# MASTER PLAN OF HYDROELECTRIC POWER DEVELOPMENT

# IN

# NEPAL

## MAIN REPORT

CHAPTER 1

# GENERAL DESCRIPTION OF NEPAL

The Kingdom of Nepal lies along southern slopes of the Himalaya Ranges. The country extends from North-West to South-East, being sandwitched between India and Tibetan Plateau of China. Its rectangular-shaped land covers an area of 141,000 $km^2$ with 800 km length from East to West and 130 to 240 km width from North to South. The land is situated between the latitudes of $26^{o}30'$N and $30^{o}15'$N and the longitudes of $80^{o}$E to $88^{o}15'$E.

Nepal can be divided into four geographical regions, namely, (i) Terai Plain, (ii) The Inner Terai, (iii) Hills, and (iv) Himalaya. The Terai region lies in the extreme south along the border line with India as the northern fringe of the vast Ganges Plain. It comprises a narrow strip (20 to 40 km) of alluvial plain at a very low altitude ranging from only 60 m to 300 m. The Inner Terai comprises scattered basins enclosed between low Siwalik Hills and Mahabharat ranges. It consists of broad longitudinal valleys composed of gravels and alluvial. Between the Himalaya region in the North and the Mahabharat ranges in the South, lies the most extensive hilly land called the Hill region. It is rightly described as a "Clusterous succession of mountains varying in elevation from 1,200 m to 3,000 m". At intervals, this mountainwall is pierced by gorges of transverse rivers. The Himalaya region which lies parallel to the Hill region, is nestled on both sides of the Main Himalaya. It rises above the snow-line into the peaks of perpetual snow with gigantic glaciers in valleys.

Nepal receives rainfall mostly in summer from the South-East monsoon. Monsoon normally starts from June and lingers on until the end of September. A wide variety of annual rainfall by locality is observed in Nepal. Some areas have that less than 500 mm, while some Himalaya regions receive more than 3,500 mm rainfall. In general, the western half area has less annual rainfall than the eastern half area. The countrywise average annual rainfall is approximately 1,500 mm. This abundant rainfall, together with the steep topography make this country to have a great potential of hydropower development.

A wide variety of climate from frigid zone to even tropical zone is packed into this narrow land because of the world largest altitude variation that the country has. The Himalaya region higher than 5,000 m in altitude is under perpetual snow, while the lowland of the Terai under tropical climate has the highest temperature of 44°C in summer and no freezing temperature even in winter.

From the view point of surface water resources, Nepal can be divided broadly into three basins drained by three major river systems, namely the Sapt Kosi, Sapt Gandaki (Narayani) and Karnali from the East to the West. The Sapt Kosi, a collective name of "Seven rivers," drains the eastern part of the country with its seven tributaries-Sun Kosi, Indra Vati, Tama Kosi, Likhu Khola, Dudh Kosi, Tamur and Arun. The area drained by these rivers is popularly known as the Kosi basin. The central part of the country is drained by another seven tributaries of the Sapt Gandaki, namely, Darondi, Seti Gandaki, Madi, Kali Gandaki, Marsyandi, Buri Gandaki and Trisuli. The Karnali river drains the western part of the country with its three major streams of the Bheri, Seti and Humla Karnali. In addition to the above three major rivers, medium size rivers exist in Nepal, namely the Mahakali along the western border with India, the Babai and West Rapti in the western part, the Bagmati originating from Kathmandu valley, the Kamla and Kankai in the eastern part of the country. Numerous other small streams originating from Siwalik Hill intersect the Terai Plain. Approximately 70 % of the surface water resources in Nepal is occupied by the three major rivers, 21 percent by medium size rivers and the rest by other small streams.

Nepal is divided for administrative purpose into 14 Zones and 75 Districts, as shown in Fig. 1./1 Most of these Zones have four or five Districts each. Many towns and villages in various size are under each District.

In 1973 His Majesty's Government of Nepal has established four Development Regions from the view point of balanced economic growth and proper attention to regional planning. They are called Surkhet

/1 All figures are attached to the end of each chapter.

(Far Western), Pokhara (Western), Kathmandu (Central), and Dhankuta (Eastern) Development Regions. These Regions are responsible for the development work of their respective area under the guidance of National Planning Commission.

The population of Nepal is now approximately 12 million and increasing at about 2 % per year. About one third of the population are living in Terai and two thirds in hilly areas. Kathmandu Valley is populated with about 600,000 and Biratnagar and Birganj have about 60,000 and 30,000 inhabitants respectively. The low economic development in hill areas, constrained by severe natural conditions and considerably high population pressure, obliges the hill people gradually to move toward the towns and Terai Plain in recent years.

The economy of Nepal is essentially agricultural, with 90 % of population depending on agriculture and agro-based industries. The GNP per capita is estimated to be about US$90 equivalent at present. About two thirds of GNP is derived from agriculture, and the agricultural exports accounting for about 90 % of the international trade. The main export products are paddy (or rice), maize, oil seeds, jute, tea and dairy products.

Scarce underground resources in Nepal and a long distance to sea port handicap this country for large scale industrial development. However, the magnificent and beautiful scenery of this country would compensate the above handicap by tourism development. Rich water resources also promise Nepal to utilize them as much as possible for economic and social development.

A good communication system is an indispensable pre-requisite for economic development. Before early 1960's, the communication in Nepal was in a meager condition. But at present the total length of motorable roads reaches to about 3,000 km, 40 % of which are sealed. A noteworthy construction is a highway from Kathmandu to Tibet, a highway from Kathmandu to India via Birganj which is an economic artery of Nepal connecting with Calcutta, and the East-West Highway now half completed which will connect the both ends of the Terai Plain. Recent completion of Kathmandu-Pokhara road and Pokhara-Bhairawa road also makes Pokhara area a tourism center in Nepal.

Airways are the other important mode of inland transportation in such a hilly country. Royal Nepal Airlines Corp. runs 15 commercial airports in Nepal serviced with DC-3 class planes. In hill areas many small airstrips were constructed to accept small planes and helicopters. Extension works of five airports for international level including Kathmandu are underway with a financial loan of the Asian Development Bank (ADB).

Almost all major towns are linked with a wireless network operated by the Government. However, all these telecommunication facilities are still insufficient to meet the ever-increasing needs. The Government is preparing to introduce a microwave network to cover the whole country.

The financial state of Nepal is very sound as indicated by steady increase of foreign exchange holdings which amount to US\$143 x $10^6$ equivalent in mid-July 1973. The balance of international trade shows surplus since 1965. In recent years, US\$8 to 10 x $10^6$ equivalent surplus of foreign exchange is added annually to the holdings. However the world-wide inflation fired by oil shock would affect the economy of Nepal with rise of all the imported commodities.

While the major part of the energy in Nepal is now being served by hydroelectric power, some part is still supplied by oil-fired powerplant, especially for the factories on the Terai Plain. Due to the anticipated difficult supply situation and high cost of fuel in the future, the energy from oil should be substituted by abundant and cheap hydro-power as much as possible.

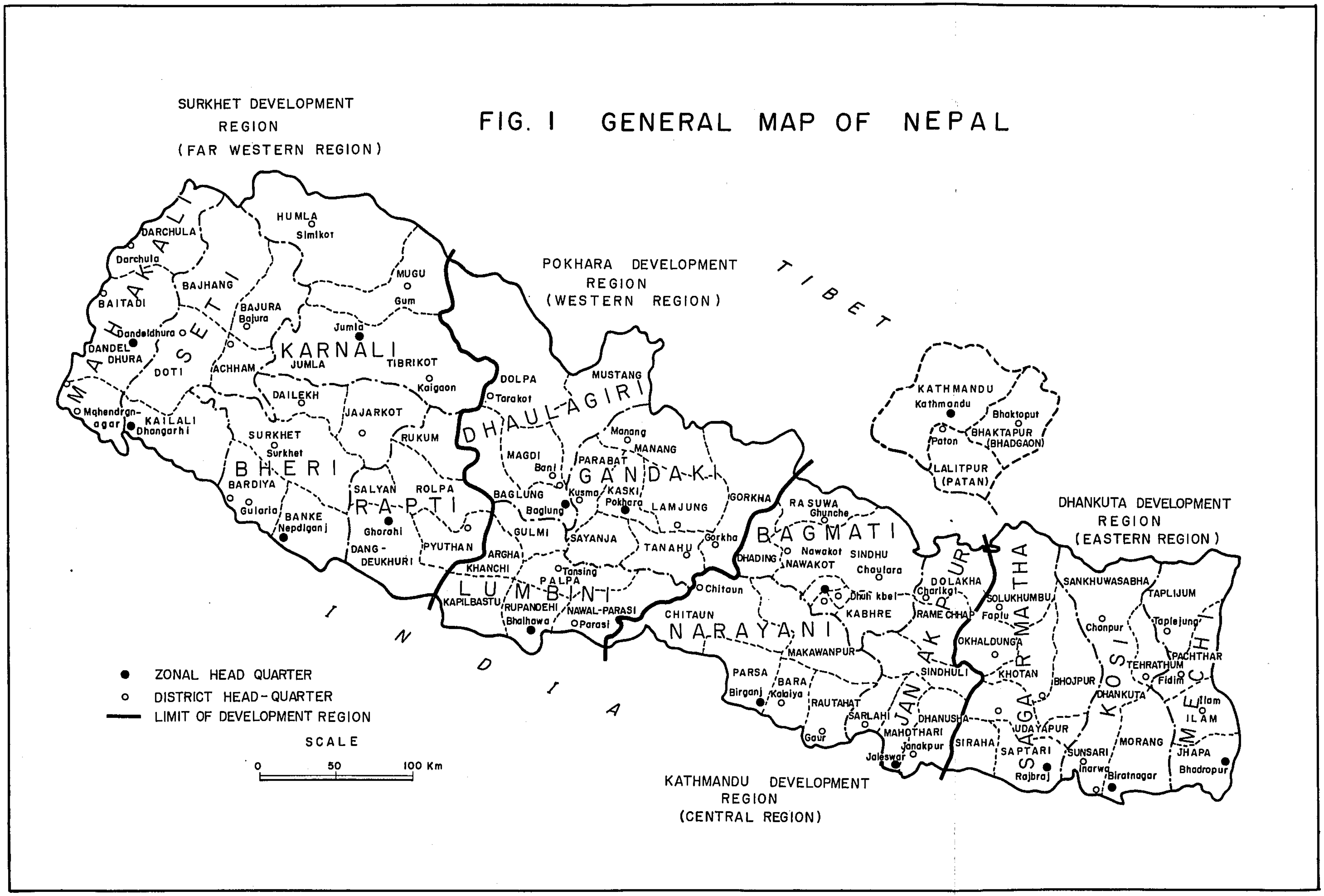



FIG. I GENERAL MAP OF NEPAL

# CHAPTER 2

# PRESENT STATUS OF POWER SUPPLY

## 2.1 General

Nepal's electric power is presently served by the Central Nepal Power System (CNPS), a number of small isolated public systems (some are operated by private companies), factory-owned self-supplying private plants, and import of energy from India.

The total installed generating capacity in whole Nepal was 53,635 kV, at the end of 1973. The composition of the installed capacity was 61 % for hydro, 32 % for diesel and 7 % for steam units. The detailed information is given in Table 3.1 of Appendix 3. The imported energy from India is now serving the border towns in Terai area in accordance with the Agreement between Nepal and India. Peak power imported in 1972/73 was 3,620 kW. A small amount of energy is exported from Birganj to Raxual in India. Details of the power exchange are given in Table 3.2 of Appendix 3.

The electric power consumption of Nepal (public system only) in 1972/73 was 63,244 GWh. The existing facilities of power supply are shown in Fig. 2, and their explanations follows.

## 2.2 Organization of Power Supply

About 90 % of the total generating facilities is being operated for public supply by the following organizations. Remaining 10 % of the facilities are held by private factories.

### 2.2.1 Electricity Department of the Government

Electricity Department of the Ministry of Water Power is responsible for the planning and implementation of the electric power development in Nepal. The Department is also managing the Sun Kosi hydro plant of the CNPS, and supplying electric power by small isolated systems to the towns outside the CNPS, such as Mahendranagar, Dhangarhi, Nepalganj, Bhairawa, Palpa, Pokhara, Rajbiraj, Gaur, Malangwa, Bhadrapur and other border towns in Terai area. The total installed facilities of the Department are 13,767 kW, which are composed of 11,290 kW hydro and 2,477 kW diesel units. In addition, the Department is receiving the power of about 2,570 kW from India in 1972/73.

### 2.2.2 Nepal Electricity Corporation (NEC)

NEC is a governmental corporation and is managing the CNPS (except the Sun Kosi hydro plant) and the Bharatpur diesel plant to supply electricity to Kathmandu valley, Hetaura-Birganj corridor, Chituan valley and their adjoining areas with its generating capacity of 29,854 kW in 1972/73, consisting of 21,570 kW hydro and 8,284 kW diesel capacities.

### 2.2.3 Butwal Power Company (BPC)

BPC is a private company but also partnered by Electricity Department. It was established to construct a 1,000 kW hydro plant on the Tinau Khola. At present BPC is supplying power to Butwal with its generating facilities of 115 kW diesel and 50 kW hydro units.

### 2.2.4 Eastern Electricity Corporation (EEC)

EEC serves power to Biratnagar area with its own diesel plants and power import from Kataiya substation in India. It has an installed diesel capacity of 1,695 kW at Biratnagar and 212 kW at Dharan. The major towns involved in this area are connected through a single circuit of 33 kV transmission line. The import of power is at present 2,000 kW and will come to 6,800 kW ultimately under the agreement between the both government.

### 2.2.5 Factory-owned plants

The generating facilities owned and operated by private factories for their own use amount to 7,942 kW, and scattered all over the country.

2.2.6 Generating capacity and sold energy of power organizations

The generating capacity and annual sold energy in 1967/68 and 1972/73 for aforementioned power organizations except factory-owned plants are shown in the following tabulation.

Table 1 Generating capacity and sold energy of power organizations

| organization | generating capacity (kW) | | number of consumers | | annual energy sold (MWh) | |
|---|---|---|---|---|---|---|
| | 67/68 | 72/73 | 67/68 | 72/73 | 67/68 | 72/73 |
| Electricity Dept. | 5,538 | 13,767 | 2,314 | 4,000 | 1,972 | 1,288 |
| NEC | 17,636 | 29,854 | 21,552 | 52,781 | 18,745 | 55,965 |
| EEC | 1,916 | 1,907 | 1,632 | 2,618 | 3,614 | 5,711 |
| BPC | 115 | 165 | - | 536 | - | 280 |
| Total | 25,493 | 45,693 | 26,451 | 59,935 | 24,762 | 63,244 |

As shown in the table, the number of consumers and annual energy sold in 1972/73 increased to 230 % and 250 % respectively compared with those in 1967/68.

## 2.3 Power Supply in Each Development Region

### 2.3.1 Kathmandu Development Region (Central Region)

This region covers Bagmati, Janakpur and Narayani zones, and the electricity is served by the CNPS managed by NEC. Some factory-owned plants exist, though. The installed capacity in this region including the CNPS and factory owned plants amount to 43,198 kW. Table 3.3 in Appendix 3 presents the details of power plants in this region.

All the hydro power plants in the CNPS are run-of-river type. Therefore, while the system has hydro facilities of 31,620 kW, its peaking capability in dry season drops to about 26,540 kW only.

The peak load and generated energy in the system were 17,500 kW and 65,964 MWh respectively in 1971/72. While the energy loss in the system has shown a slight decreasing tendency for the past few years, it still stood as high as 33 % in 1972. Such a high percentage of loss was caused not only by the poor distribution system, but also by unaccountable energy uses.

A 66 kV double circuit transmission line links Trisuli power station with Kathmandu and Birganj. Sunkosi power station is connected with Kathmandu by a 66 kV single circuit line. The valley of Kathmandu, Hetaura-Birganj and Terai area are well furnished with distribution lines of 11 kV, 3.3 kV and 400/230 V. Under the power exchange agreement between Nepal and India, Nepal is to deliver power up to 5,000 kW to India at Raxual, a border town in India located just opposite side of Birganj. The delivery of peaking power and energy to Raxual in 1972/73 was 1,300 kW and 1,750 MWh respectively.

The statistical data about power generation and consumption in the CNPS are presented in Table 3.5 of Appendix 3.

As for the scheduled addition of power facilities in this region, the Gandaki power station with an installed capacity of 15,000 kW is now being constructed by India. A new 132 kV transmission line of about 75 km from the Gandaki power station to Hetaura via Bharatpur is also under construction by ADB loan. The Devighat power station on the Trisuli River with an installed capacity of 14,000 kW is now in the design stage, and will be implemented soon.

### 2.3.2 Dhankuta Development Region (Eastern Region)

Dhankuta Development Region covers the eastern Nepal, and comprises Sagarmatha, Kosi and Mechi zones. This region is the second biggest power market in the country, but did not share its due attention in power development, and its power consumption had been suppressed due to the shortage of supply until recently when the power is imported from India. Therefore, most of private factories still have their own power supply. The major power suppliers in the region are Electricity Department, Eastern Electricity corporation and Biratnagar Jute Mill. The total capacity of their generating facilities is 6,755 kW.

EEC has diesel generating facilities of 1,695 kW and 212 kW and supplies power to Biratnagar and Dharan. In Dharan, the British military camp has diesel generators of 1,200 kW for its own use.

Biratnagar Jute Mill has one unit of 1,400 kW steam turbine generator and two units of 425 kW diesel generators for its own use and for supply of electricity to Raguphati Jute Mill and other industrial consumers.

Dhankuta is a small old town in the Mahabharat Range and has been electrified since 1972 by a small hydro electric plant of 2 x 120 kW capacity.

The details of generating facilities are shown in Table 3.4 of Appendix 3.

The public electricity supply has been reinforced since the import of energy has been made from the Bihar grid of India. The supply from the Bihar grid is received at Kataiya substation and delivered to Biratnagar and Dharan through a 33 kV single circuit transmission line. Another 33 kV line from Kataiya to Rajbiraj is also serving the electricity to Rajbiraj and other small towns along the line. In 1972/73, this region received the energy of 4,591 MWh and peak power of 2,500 kW from the Bihar grid of India.

The data about generation and consumption of power are shown in Table 3.6 of Appendix 3.

As for the scheduled addition of generating capacity, a 5,000 kW diesel generator will be installed at Biratnagar to meet the immediate growing demand of Biratnagar and Rajbiraj areas.

2.3.3 Pokhara Development Region (Western Region)

Pokhara region comprises Gandaki, Lumbini and Dhaulagiri zones, and is relatively less developed. The electricity of Pokhara town is supplied by a hydro plant with an installed capacity of 4 x 250 kW. However, its firm output is rated as 750 kW. The town has captivating natural beauty of the Himalayas, and has caused rapid growth of inhabitation and ancillary industries of tourism, resulting much higher electric demand than anticipated before. A 66 kV transmission line from Pokhara to Bharatpur is now under planning; upon the completion of this line, Pokhara is eventually connected to the CNPS. For interim purpose, a 500 kW diesel plant will be set up in the town to meet the immediate demand.

Butwal Power Co. has a hydro capacity of 50 kW and a diesel capacity of 115 kW. The company is constructing a 1,000 kW hydro electric power plant, which will meet the energy required by Butwal-Bhairawa area. Towns of Bhairawa, Krishnagar, Taulihawa and Bahaduraganj have small diesel plants, but they are kept as standby units and actual supply of these towns are made by importing electricity from India.

Mahendra sugar mill in Bhairawa is the second biggest mill in Nepal, and its peak demand of about 500 kW is entirely met by their own diesel generator.

Tansen in Palpa district has been supplied electricity by Electricity Department with small diesel generators of 289 kW in total installation. However, the supply is limited for four hours in the evening due to the shortage of fuel.

The details of generating facilities and data about generation and consumption in this region are presented in Table 3.4 and 3.6 of Appendix 3.

### 2.3.4 Surkhet Development Region (Far Western Region)

This region comprises five zones of Mahakali, Karnali, Bheri, Rapti and Seti, but the installed generating capacity in the whole region is only 695 kW including private facilities.

Nepalganj is the industrial center in this region, and its power is supplied by Electricity Department since 1972 with diesel plant of 500 kW. The town is also importing electricity up to 1,000 kW from India. According to the record in 1973/74, the annual peak demand and energy consumed in Nepalganj were 250 kW and 704 MWh respectively.

Other electrified towns are Mahendranagar, Dhangarhi, and Koilabas. For the electrification of Surkhet, Doti and Jumla areas, constructions of small hydro plants are under planning.

The details of generating facilities and data of generation and consumption in this region are given in Table 3.4 and 3.6 of Appendix 3.

## 2.4 Financial Situation

The information of the financial records is available only for NEC, and is presented herein. The financial results of NEC for the year of 1971/72 have been quite satisfactory. The Corporation earned a gross profit of Rs 859,000 after meeting its operational expenses and setting aside the depreciation. Income from sale of electricity for the year amounted to Rs 9,323,000 and miscellaneous income to Rs 306,000 making a total income of Rs 9,629,000. Operating expenses amounted to Rs 8,770,000 including depreciation of Rs 2,958,000 and royalty of Rs 2,256,000. The financial records for the past 5 years are shown in Table 2 and Table 3.

The information of the tariff system is presented in Table 3.7 and Table 3.8 of Appendix 3.

TABLE - 2

Gross Revenue (Classified) of NEC, in $10^6$ Rs.

| Year | 1967/68 | 1968/69 | 1969/70 | 1970/71 | 1971/72 |
|---|---|---|---|---|---|
| 1) Domestic | 4.304 | 5.077 | 5.672 | 5.963 | 6.338 |
| 2) Industrial | 0.645 | 0.491 | 0.680 | 0.799 | 0.942 |
| 3) Commercial | 0.582 | 0.549 | 0.746 | 0.1 | 1.155 |
| 4) Bulk Supply | 0.014 | 0.028 | 0.551 | 0.652 | 0.860 |
| 5) Street Light | 0.095 | 0.088 | 0.077 | 0.099 | 0.097 |
| 6) Miscellaneous | 0.242 | 0.271 | 0.193 | 0.204 | 0.306 |
| 7) Gross Revenue | 5.882 | 6.504 | 7.919 | 8.717 | 9.698 |
| Rebate | 0.183 | 0.103 | 0.108 | 0.104 | 0.069 |
| Net Revenue | 5.699 | 6.401 | 7.811 | 8.613 | 9.629 |
| 8) Increase over previous year (%) | 14.39 | 12.32 | 22.03 | 10.26 | 11.79 |

TABLE - 3

Operating Expenditure Including Depreciation (classified) of NEC, in $10^6$Rs

| | Year | 1967/68 | 1968/69 | 1969/70 | 1970/71 | 1971/72 |
|---|---|---|---|---|---|---|
| 1) | Hydraulic Power Generation | 2.046 | 2.053 | 2.035 | 2.041 | 2.043 |
| 2) | Internal Combustion | 0.508 | 0.452 | 0.439 | 0.320 | 0.172 |
| 3) | System Control | 0.239 | 0.253 | 0.252 | 0.253 | 0.322 |
| 4) | Transmission and distribution | 0.901 | 0.946 | 0.992 | 1.026 | 1.204 |
| 5) | Consurmers Services | 0.344 | 0.349 | 0.449 | 1.080 | 1.138 |
| 6) | Public lighting | 0.046 | 0.041 | 0.041 | 0.034 | 0.051 |
| 7) | General Establishment | 0.916 | 1.063 | 1.347 | 1.495 | 1.584 |
| 8) | Royalty charges | 0.076 | 0.090 | 2.121 | 1.889 | 2.256 |
| | Total | 5.076 | 5.247 | 7.676 | 8.138 | 8.770 |
| 9) | Increase over previous year (%) | 78.32 | 3.37 | 46.29 | 6.01 | 7.76 |

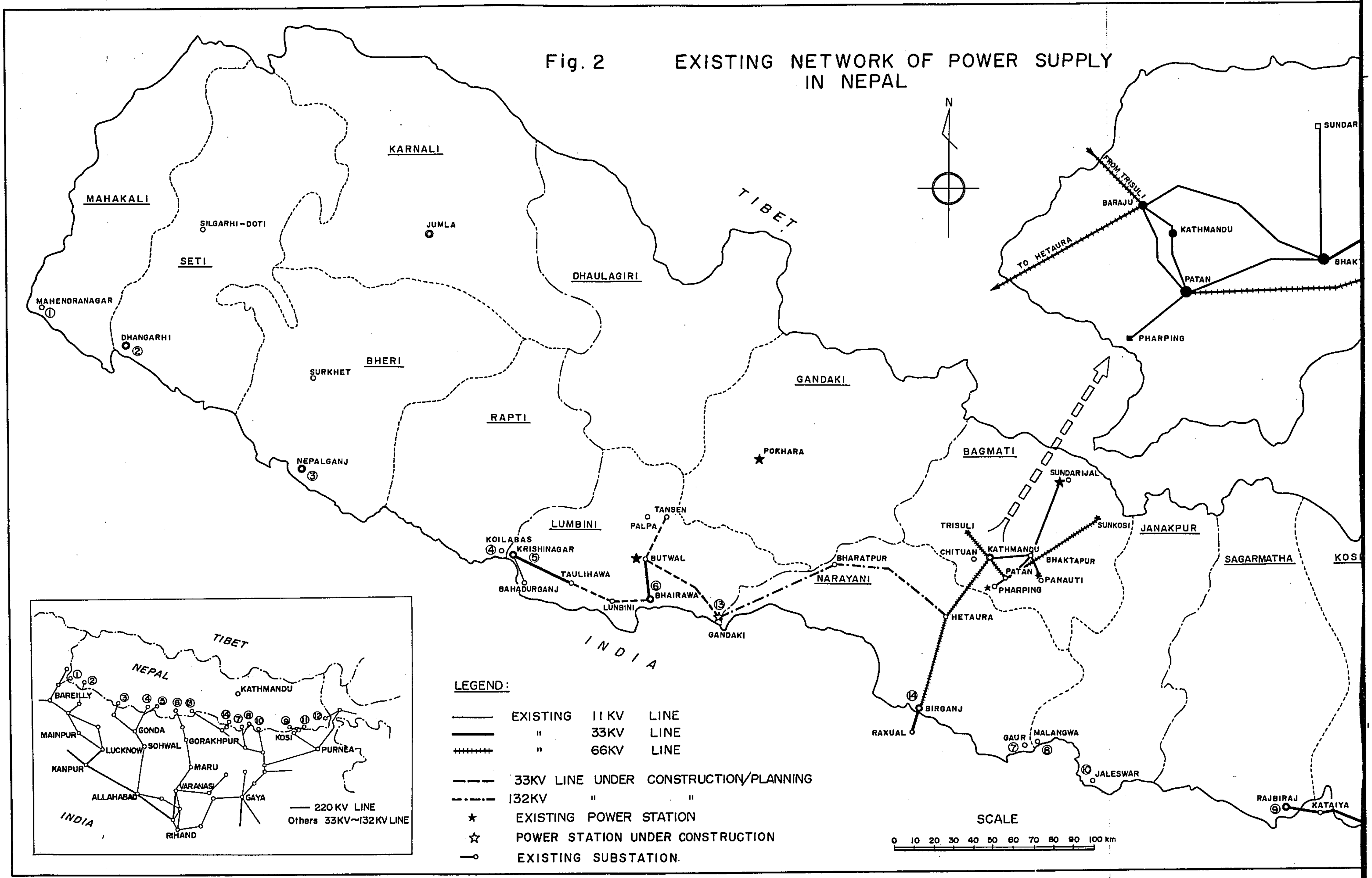



Fig. 2 EXISTING NETWORK OF POWER SUPPLY IN NEPAL

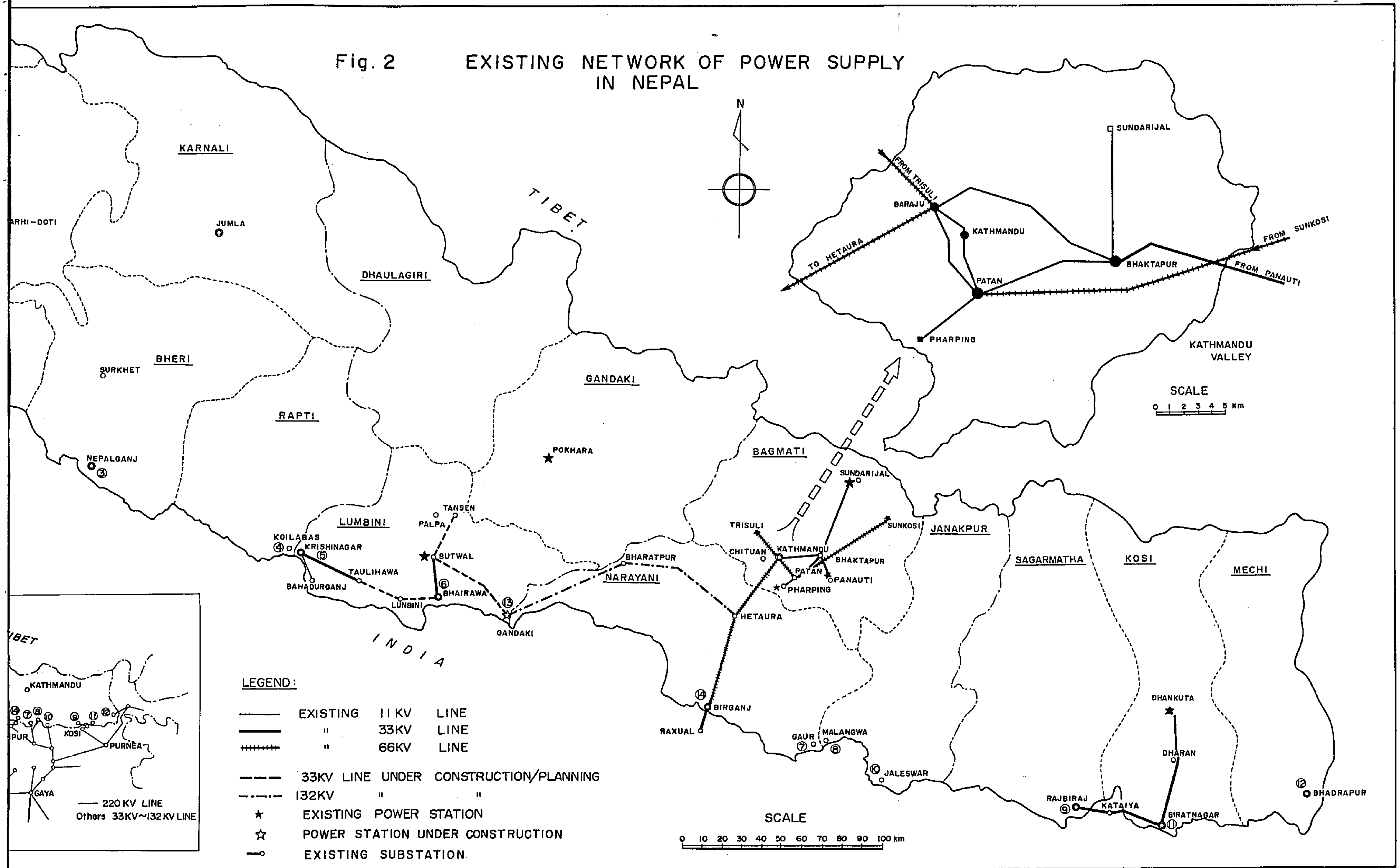



Fig. 2 EXISTING NETWORK OF POWER SUPPLY IN NEPAL

CHAPTER 3

# FORECAST OF POWER DEMAND

## 3.1 Background of Electric Power Development

Nepal is predominantly an agricultural country, and its most important economic resources are probably the forests and hydropower potential.

Kathmandu and Hetaura-Birganj corridor are the center of the nation's economic activity, and by far the largest demand center in the country. The neighbouring Chituan Valley is a very fertile land, and an important development activity of constructing two big pumping stations to lift the Sapt Gandaki River's water for irrigation is now underway, for which ADB has already sanctioned the loan. This area has large potential for agriculture and agro-based industry, such as saw mills and rice mills.

The south of the Pokhara Development Regions covers the vast Terai plain and has abundant agricultural and forest resources, which offer good possibility of developing agro- or timber-based industry. The second largest sugar mill of the country is now located at Bhairawa. The north of this region has captivating natural beauty of the Himalayas, and has caused rapid growth of inhabitation and ancillary industries, resulting much higher electric demand than anticipated before.

The Dhankuta Development Region also covers the vast east Terai plain, which is considered the most fertile land and suitable for rice and jute cultivation. Biratnagar is famous for its jute production and forest resources, and has been the industrial hub-center since old days. It's nearness to the Indian railhead favors this, and is the largest industrial complex today in Nepal. Despite of these favorable situation, Biratnagar area did not share its due attention in power development, and its power consumption had been seriously suppressed due to the shortage of supply until recently when the power is imported from India. Most of private factories in this region, such as jute mills and straw-board mills, have their own power supply by diesel units. If a hydropower development can provide reasonably inexpensive energy, these factory will surely shift their energy sources to the public systems.

The Surkhet Development Region was the least developed portion of Nepal. Nepalganj is the only sizable town and an important industrial complex in this region. It is also a major trading center and an outlet to India. Rice mill, oil mill, sugar mill, and timber-based industries are now being operated. The government is already planning to set up a big sized, modern oil mill here. Attention is also directed to establish a large-sized paper mill.

The historical trend of population increase is also an important information for predicting the nation's power consumption in the future. The population of Nepal is now estimated to be 12,000,000. Its historical trend and projected population in the future are shown in Table 4. Details are presented in Table 3.14 of Appendix 3.

Table 4 Population of Nepal

| Year | Population (x1,000) | Annual growth rate during the period(%) |
|---|---|---|
| Historical/1 | | |
| 1911 | 5,639 | |
| 1921 | 5,574 | -0.12 |
| 1931 | 5,533 | -0.08 |
| 1941 | 6,284 | 1.3 |
| 1961 | 9,413 | 2.0 |
| 1971 | 11,556 | 2.1 |
| Projected | | |
| 1979/80 | 13,591 | 1.9 |
| 1984/85 | 15,109 | 2.1 |
| 1989/90 | 16,797 | 2.1 |

/1 Source: Central Bureau of Statistics.

## 3.2 Forecasting Method of Power Demand

In estimating the power demand, difficulties lies in the lack of information on the future economic development plan. Small markets of isolated towns are often affected by new installation of factories and hospitals, which can hardly be anticipated in advance. Furthermore, forecast has to be made to those towns which have not been electrified yet.

Different approaches are used in predicting the power demand in the areas that have been electrified and that have not been electrified. They are explained as follows.

### (1) For electfified areas

The past trend of energy consumption is studied, and appropriate growth rate in the future is assumed based on experienced judgement, taking account of all relevant factors, such as population, level of energy consumption, installed capacity, development potential of the area, and so on. For the Kathmandu Region (CNPS), the power consumption is categorized for domestic, industrial, commercial and other uses, and different growth rates are applied for each category of consumption. To arrive at the total demand of the region, the consumption of each category is summed up, and energy loss is added to. The energy loss of CNPS is about 33 % of the total generated energy. It is assumed that this rate of energy loss will be gradually improved to the ultimate value of 15 % in the future.

For the other region, only the trend of the total power generation is studied for each town. In applying the growth rate for the demand forecast, the size and local conditions of each town are accounted for.

### (2) For not-electrified areas

For the initial estimate of the domestic and industrial demands of these areas, the following empirical method are used:

Domestic Use

| | |
|---|---|
| Ratio of consumers to population | 6 % |
| Peak power per consumer | 200 W |
| Peak power per inhabitant | 12 W |
| Annual consumption per consumer | 400 kWh |

Industrial Use

| | |
|---|---|
| Ratio of industrial consumer to total number of factories | 15 % |
| Peak demand per factory | 3 kW |
| Annual load factor | 40 % |

These figures are taken from a United Nation's publication,[/1] in which the use is recommended for small scale power generation.

3.3 Demand Forecast for Each Development Region

The results of peak load forecast of four development regions are summarized in the following tabulation.

Table 5 Power Demand in Nepal

| | Region | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Kathmandu | | Dhankuta | | Pokhara | | Surkhet | | Total of Nepal | |
| Year | Peak (MW) | Energy (GWh) | Peak (MW) | Energy (GWh) | Peak (MW) | Energy (GWh) | Peak (MW) | Energy (GWh) | Peak (MW) | Energy (GWh) |
| 1972/73 | 21.2 | | 4.26 | | 1.62 | | | | | |
| 1974/75 | 30.6 | | 8.31 | | 3.11 | | 0.78 | | 42.80 | |
| 1979/80 | 65.0 | 282.3 | 18.69 | 72.0 | 7.78 | 34.1 | 6.63 | 13.7 | 98.10 | 402.1 |
| 1984/85 | 105.5 | 462.0 | 34.45 | 147.9 | 15.34 | 67.3 | 17.90 | 47.6 | 173.19 | 724.8 |
| 1989/90 | 155.0 | 666.0 | 62.78 | 275.0 | 24.3 | 105.0 | 29.50 | 77.6 | 271.58 | 1,123.6 |

Explanation of each development region is given below.

---

/1 "Small Scale Power Generation", Department of Economic and Social Affairs, United Nations, 1967.

### 3.3.1 Kathmandu Development Region

The major towns of this region are served by the CNPS. The peak demand of the system has increased at an annual rate of more than 20 %. This high growth rate will continue for some years to come, as a number of small and medium sized industries and hotels are being planned to be built within the next 5 years in Kathmandu and Hetaura areas. Another conceivable bulk consumer is the proposed Chituan valley irrigation schemes which will require the peak power of 1,100 kW in 1976/77, 2,200 kW in 1977/78 and 7,000 kW in 1979/80. This bulk demand has to be added to the system demand.

The comitted power supply of 5,000 kW to India is included in the demand of this region.

The peak and energy demands for Kathmandu Region is illustrated in Fig. 3, and the growths of categorized energy uses are shown in Fig. 4. The detail of the forecast is presented in Table 3.9 of Appendix 3. Also, the monthly energy production and typical load curves of the CNPS are shown in Figs. 3.1, 3.2, and 3.3 of Appendix 3 for reference.

### 3.3.2 Dhankuta Development Region

This region covers Janakpur-Jaleswar, Lahan-Sirha, Rajbiraj, Biratnagar, Dhankuta and Bhadrapur areas. Brief explanation of these areas are given below.

Janakpur-Jaleswar areas .... The peak demand of these areas was 780 kW in 1973/74. It is anticipated that the peak demand will grow at an annual rate of 20 % for immediate future, and will drop to the ultimate figure of 15 %.

Rajbiraj area .... The peak demand in the area was 670 kW in 1973/74. The estimated growth rate of domestic and industrial uses is 20 % in the immediate future, and 15 % ultimately. In this area, an irrigation program has been planned, which requires peak power of 1,000 kW in 1974/75 and additional 1,000 kW in 1975/76. This power demand is added to the gradual regular growth.

Lahan-Sirha area .... The population of this area in 1975/76 is estimated to be 7,900. The initial power demand in this year is calculated to be 147 kW based on the empirical method as described before. Thereafter, the peak demand is assumed to grow at an annual rate of 20 % for the first 5 year, then the rate will gradually drop to 15 %.

Biratnagar area .... The peak demand of Biratnagar town in 1972/73 was 2,823 kW, and it is estimated to increase at an annual rate of 20 % at first and slow down to 9 % ultimately.

Other area .... The empirical method as described before is applied to. The growth rate is estimated to be 20 % at first, and slow down to 15 % ultimately.

The demand forecast for Dhankuta Development Region is illustrated in Fig. 5. The detail of the forecast is presented in Table 3.10 of Appendix 3.

3.3.3 Pokhara Development Region

Pokhara town is a major tourist center, and has many hotels. The peak demand recorded in 1973/74 was 870 kW. Recently, food and other light industries have been growing up in this area. It is expected that the annual growth rate of the peak demand will vary from 20 % in the immediate future to 15 % in 1983/84, and thereafter will decline to ultimate condition of 10 %.

The total peak demand for Bhairawa, Butwal and Tansen including the load of Mahendra sugar mill was 1,460 kW in 1973/74. A new 33 kV line now under construction will connects these town each other and to the Gandaki powerplant, which will assure the power supply of these areas for some years to come. Considering these situation and the proposed industries which will come into being within the next 5 years, the peak demand of these areas is assumed to grow at an annual rate of 20 % in the immediate future, and will gradually drop to 15 % ultimately.

The forecasted peak demand of Pokhara Region is also illustrated in Fig. 5. Details are presented in Table 3.11 of Appendix 3. The typical load curves in Pokhara area are shown in Fig. 3.4 of Appendix 3 for reference.

### 3.3.4 Surkhet Development Region

The power demand in this region has been very small. Even in the major town, Nepalganj, the peak demand was about 250 kW in 1973/74. However, aiming at the balanced economic development of each region in the country, the government formulated the Fifth Five Years Plan putting emphasis on the industrial development of this region. According to the plan, many industries such as paper mills and rice mills are proposed to be established in Nepalganj, Surkhet and Mahendranagar in this region. Taking the plan into account, rapid growth of power demand is anticipated.

The domestic power demand of each district is forecasted, based on the rural electrification schedule set forth by the government. The total peak demand is calculated by adding the proposed industrial bulky demand to the domestic demand after dividing the bulky demand by 1.2, considering that the peak load time of industrial demand will not coincide with that of domestic demand.

The forecasted peak loads of this region are shown in Fig. 5. The details are presented in Table 3.12 of Appendix 3.

### 3.3.5 Unified Load of CNPS

Kathmandu Development Region is now served by the CNPS. A new 132 kV double circuit transmission line from the Gandaki powerplant via Bharaptur to Hetaura is now under construction, and will be completed in 1975/76. Also, a 66 kV line from Pokhara to Bharaptur will be constructed before 1978. Therefore, unification of all Pokhara Region to the CNPS will be made by that time.

As explained later, the load growths in Kathmandu and Dhankuta Development Regions in the future would require the interconnection of these two regions for the flexible operation of their power systems. It is anticipated that this connection will be made by 1985/86.

The growth of combined load for the CNPS is illustrated in Fig. 6. Details of forecasted peak and energy demands are presented in Table 3.13 of Appendix 3.

Because of its remoteness and low level of energy consumption, Surkhet Region will not be connected to the CNPS for many years to come.

3.3.6 Review of Forecasted Demand from Macroscopic Viewpoint

The relation between electricity generation and GNP is given in Fig. 7. In Nepal, no data on GNP was available, but GDP (gross domestic product) data was published by Nepal Planning Commission in "The Fourth Plan (1970-75)". This is shown in Table 6.

Table 6 GDP in Nepal

| Year | GDP ($10^6$ Rs) | Growth Rate (%) |
|---|---|---|
| 1964/65 | 5,856 | |
| 65/66 | 5,883 | 0.5 |
| 66/67 | 5,896 | 0.2 |
| 67/68 | 6,282 | 6.5 |
| 68/69 | 6,420 | 2.2 |
| 69/70 | 6,561 | 2.2 |

The growth rates of GDP in the last 2 years in Table 6 were 2.2 %. For the future growth, it is assumed that the annual growth rate would gradually increase from 2 % in 1970/71 to 6 % in 1984/85, and keep 6 % annual growth thereafter. Column (2) of Table 7 shows the GDP in the future calculated by this way, based on the exchange rate of US$ 1.00 to Rs. 10.00. Column (3) in Table 7 indicates the estimated future energy output, taken as essentially equal to the energy demand of Table 5. Disregarding minor differences between GNP and GDP, the relationship of GDP and energy output in Table 7 falls within the average zone shown in Fig. 7.

Table 7 Estimated Future GDP, Energy Generation, and Population of Nepal

| Yr | GDP | Energy Generation | Population | Generated Energy per Capita | |
|---|---|---|---|---|---|
| | $(10^6$ US$) | (GWh) | $(10^6$ persons) | (kWh) | Ratio to 5 yrs ago |
| (1) | (2) | (3) | (4) | (5) | (6) |
| 1979/80 | 800 | 402.1 | 13.59 | 29.5 | |
| 84/85 | 1,000 | 724.8 | 15.11 | 47.9 | 1.6 |
| 89/90 | 1,400 | 1,123.6 | 16.80 | 66.9 | 1.4 |

Another check can be made by comparing the energy production per capita shown in Table 7 with similar data of other countries. As shown in Column (6) of Table 7, the forecasted energy production would increase 1.4 to 1.6 times compared with that of 5 years ago. Similar ratios of some other countries are shown below, which seems to be quite compatible.

| | |
|---|---|
| India | 1.4 to 1.6 |
| Pakistan | 1.4 to 1.8 |
| Mongohl | 1.4 to 1.6 |
| The Philippines | 1.3 to 1.7 |

These checks from macroscopic viewpoint implies that the demand forecast presented in this chapter is a fairly reasonable one.

Details of projected annual energy generation per capita are shown in Table 3.15 of Appendix 3.

3.4 Demand Forecast in India

The Central Electricity Authority of India has published the power statics for the years from 1968/69 to 1970/71, and the demand forecast for the years from 1971/72 to 1974/75 as shown in Table 8.

Table 8 Peak Power Demand in India (MW)

| | West | South | North | East | North-East | Total |
|---|---|---|---|---|---|---|
| 1968/69* | 2,052 | 2,177 | 2,086 | 1,652 | 57 | 8,025 |
| 69/70* | 2,304 | 2,453 | 2,373 | 1,702 | 70 | 8,903 |
| 70/71* | 2,568 | 2,692 | 2,672 | 1,802 | 85 | 9,820 |
| 71/72 | 2,945 | 3,120 | 3,253 | 2,053 | 103 | 11,475 |
| 72/73 | 3,371 | 3,466 | 3,709 | 2,247 | 121 | 12,916 |
| 73/74 | 3,835 | 3,936 | 4,233 | 2,460 | 153 | 14,618 |
| 74/75 | 4,422 | 4,406 | 4,811 | 2,807 | 179 | 16,627 |

(* : actual data)

The Authority assumed that the average annual growth rate of peak demand to be 14.56 % for Western Region, 13.12 % for Southern Region, 15.88 % for Northern Region, 11.74 % for Eastern Region and 20.51 % for North-Eastern Region for the period from 1971/72 to 1974/75. These regions are shown in Fig. 8.

For the forecast of the power demand after 1974/75, the following annual growth rate for each region is used, taking account of the assumption made by the Authority.

| | |
|---|---|
| Western region: | 14 % initially to 10 % ultimately |
| Southern region: | 13 % initially to 10 % ultimately |
| Northern region: | 15 % initially to 10 % ultimately |
| Eastern region: | 12 % initially to 10 % ultimately |
| North-Eastern region: | 20 % initially to 13 % ultimately |

Based on these growth rates, the forecasted peak and energy demands were calculated and summarized in Table 9, details being in Tables 3.16 and 3.17 of Appendix 3. The growth of the forecasted demand is also illustrated in Fig. 9.

Table 9 Forecasted Peak and Energy Demand in India

Peak Demand (MW)

| | West | South | North | East | North-East | Whole India |
|---|---|---|---|---|---|---|
| 1969/70 | 2,304 | 2,453 | 2,373 | 1,702 | 70 | 8,903 |
| 74/75 | 4,422 | 4,406 | 4,811 | 2,807 | 179 | 16,627 |
| 79/80 | 8,439 | 7,904 | 9,344 | 4,947 | 420 | 31,054 |
| 84/85 | 15,005 | 12,729 | 16,318 | 8,411 | 874 | 53,337 |
| 89/90 | 24,385 | 20,500 | 26,281 | 13,793 | 1,654 | 86,613 |

Energy Required ($10^6$kWh)

| | West | South | North | East | North-East | Whole India |
|---|---|---|---|---|---|---|
| 1969/70 | 13,682 | 13,080 | 12,490 | 9,752 | 332 | 49,336 |
| 74/75 | 24,159 | 22,848 | 22,906 | 15,397 | 786 | 86,096 |
| 79/80 | 44,355 | 41,543 | 49,112 | 26,001 | 2,208 | 163,219 |
| 84/85 | 78,866 | 66,904 | 85,767 | 44,208 | 4,594 | 280,339 |
| 89/90 | 128,168 | 107,748 | 138,133 | 72,496 | 8,693 | 455,238 |

(Energy was computed with annual load factor of 60 to 62 %)

The conceivable regions for power export from Nepal would be limited to the Eastern and Northern Regions only. Estimated demands for these regions are 24,729 MW and 129,975 GWh in 1984/85, and 40,074 MW and 210,629 GWh in 1989/90. These demands are about 160 to 200 times larger than those estimated for whole Nepal at that time.

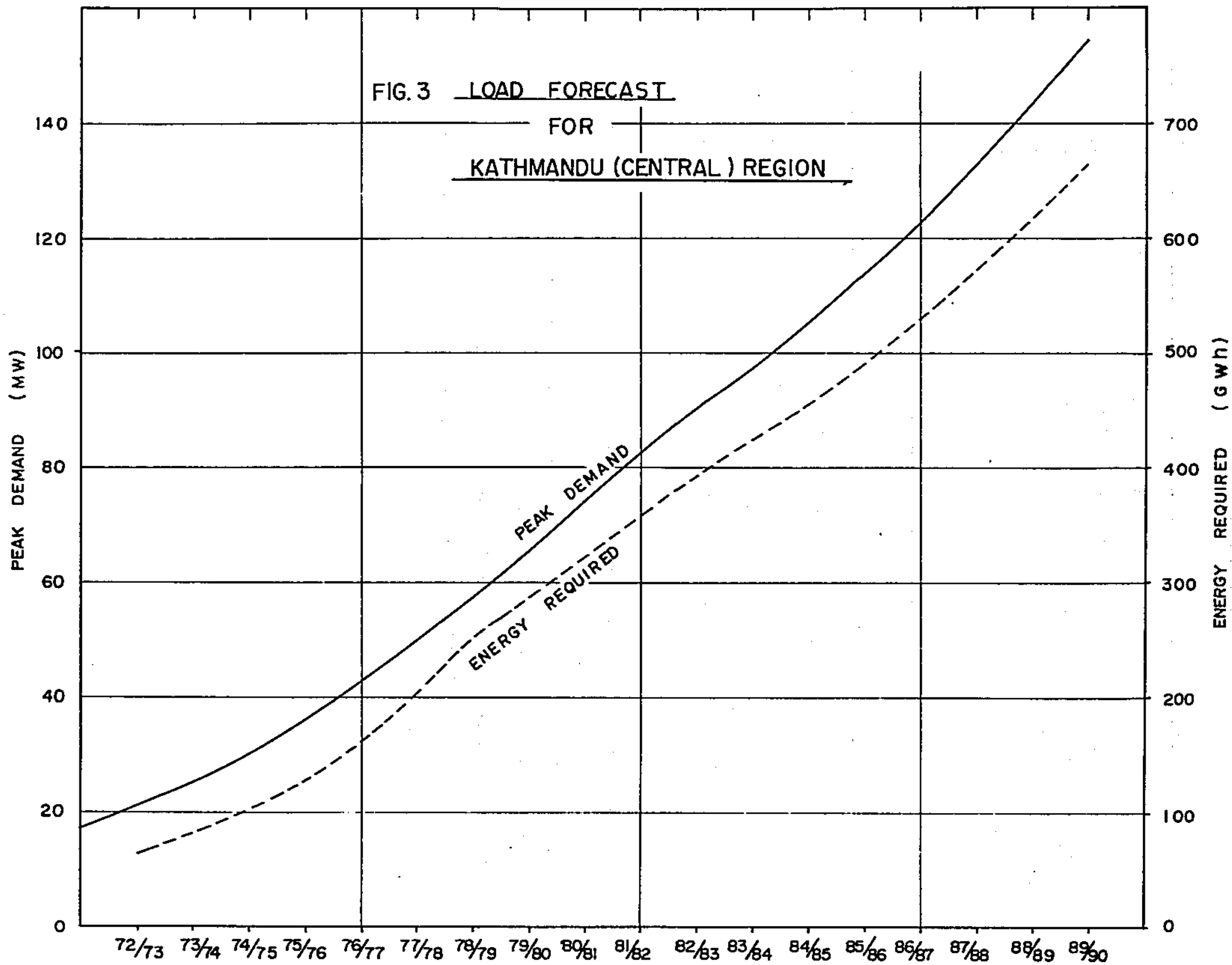
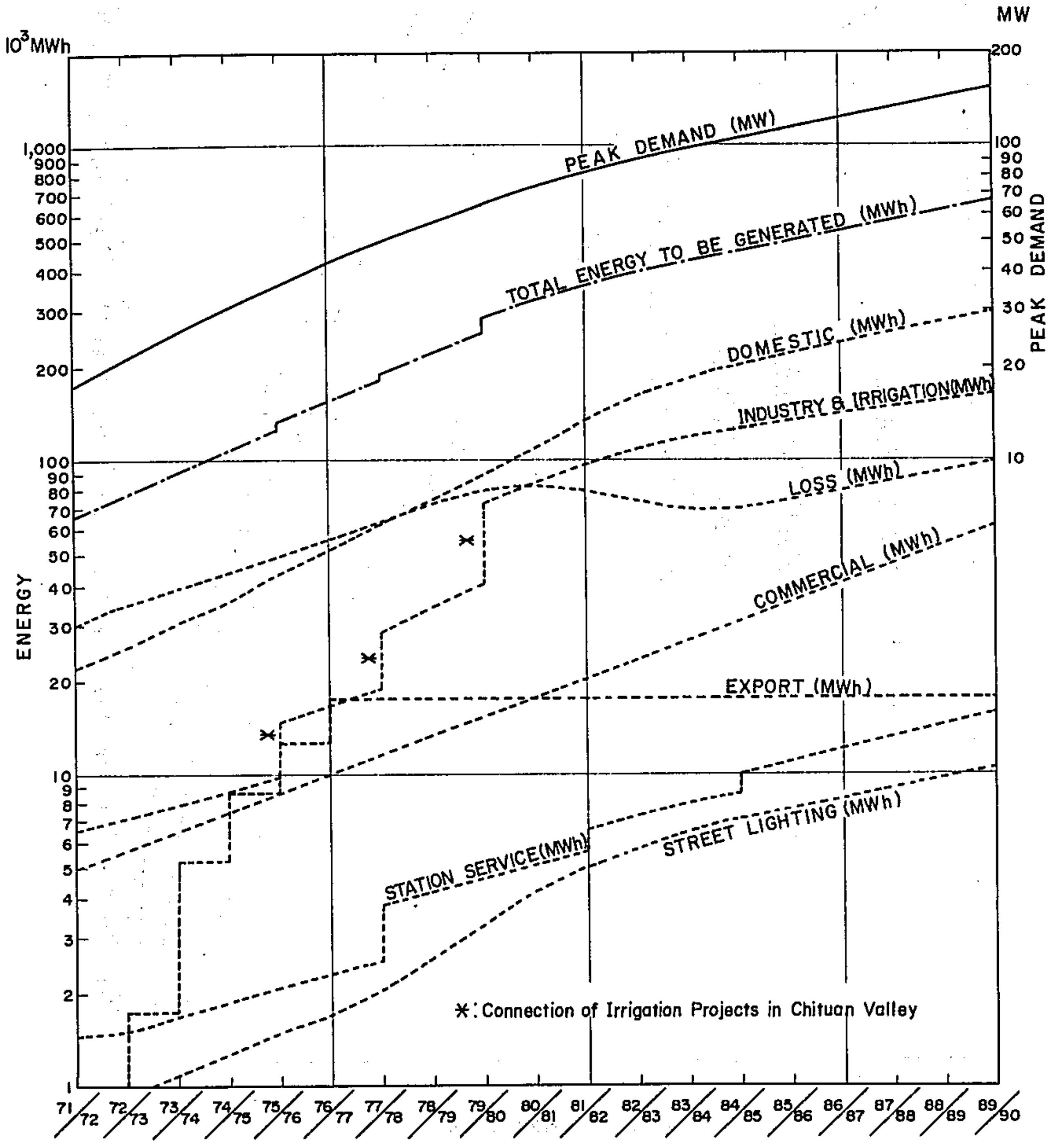



FIG. 3 LOAD FORECAST FOR KATHMANDU (CENTRAL) REGION

FIG. 4 FORECAST OF CATEGORIZED ENERGY USES FOR CENTRAL REGION



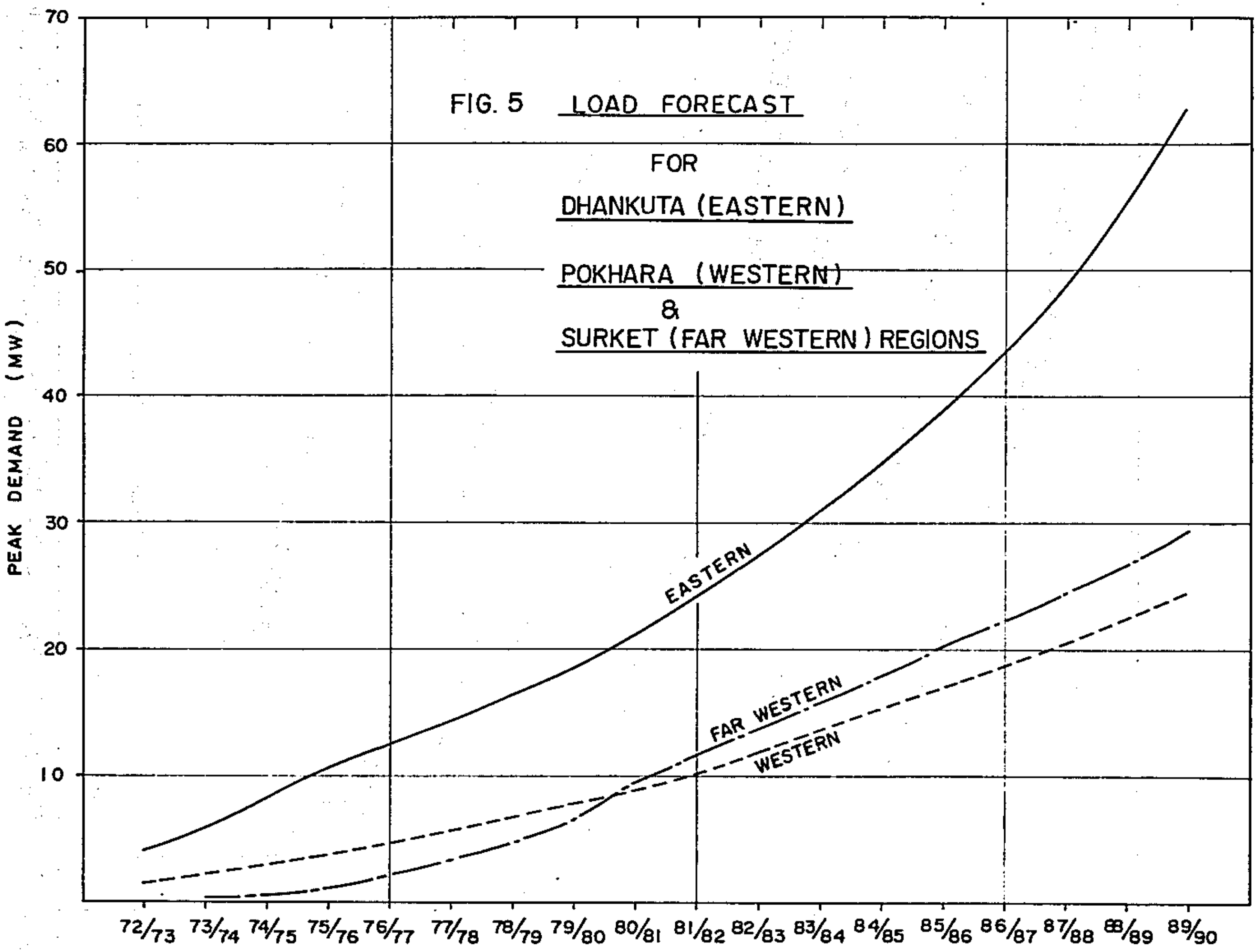



FIG. 5 LOAD FORECAST
FOR
DHANKUTA (EASTERN)
POKHARA (WESTERN)
&
SURKET (FAR WESTERN) REGIONS

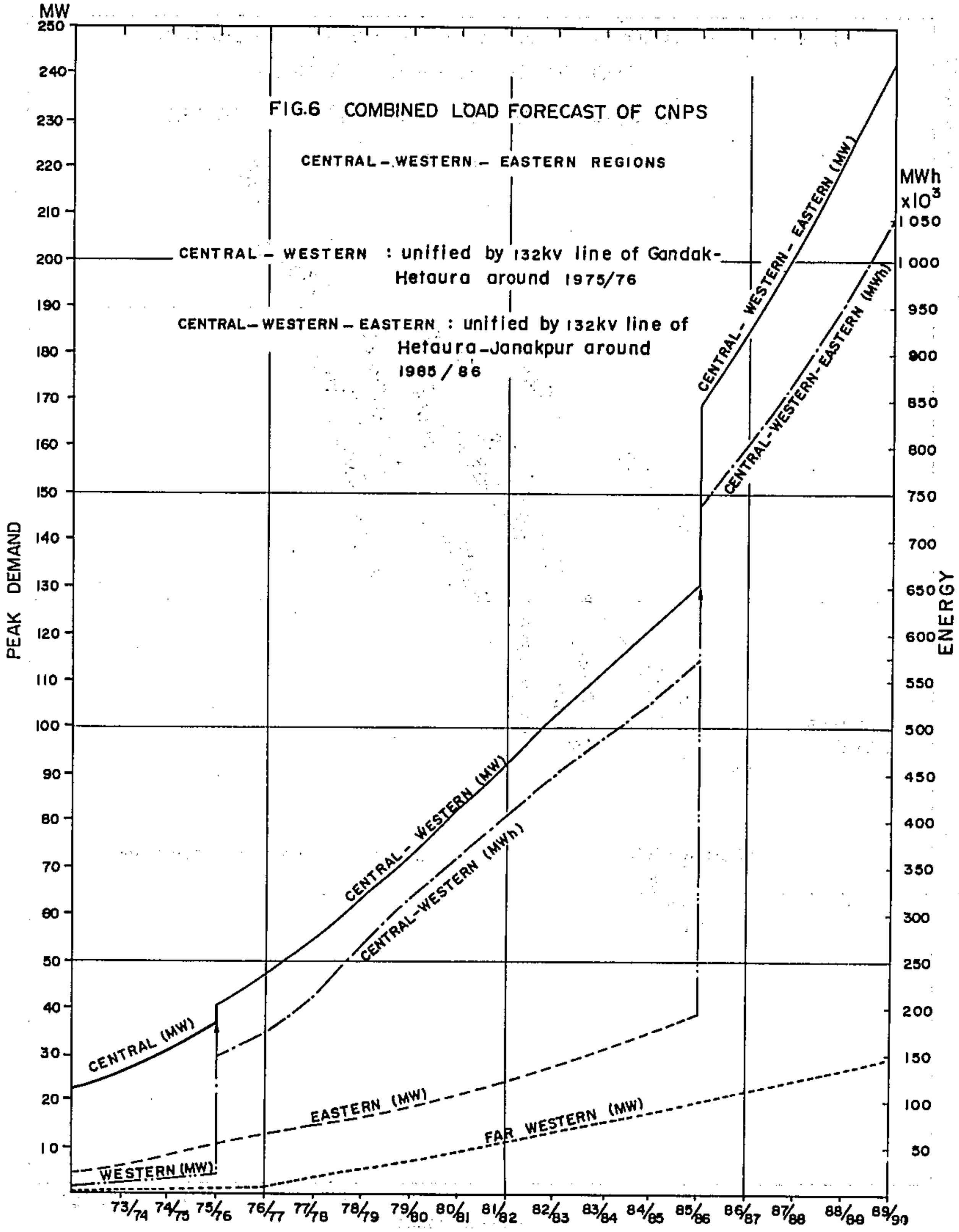


FIG.6 COMBINED LOAD FORECAST OF CNPS
CENTRAL – WESTERN – EASTERN REGIONS
CENTRAL – WESTERN : unified by 132kv line of Gandak-Hetaura around 1975/76
CENTRAL – WESTERN – EASTERN : unified by 132kv line of Hetaura-Janakpur around 1985/86
MW
PEAK DEMAND
MWh x10$^3$
ENERGY
CENTRAL (MW)
WESTERN (MW)
EASTERN (MW)
FAR WESTERN (MW)
CENTRAL – WESTERN (MW)
CENTRAL-WESTERN (MWh)
CENTRAL – WESTERN – EASTERN (MW)
CENTRAL-WESTERN-EASTERN (MWh)
73/74 74/75 75/76 76/77 77/78 78/79 79/80 80/81 81/82 82/83 83/84 84/85 85/86 86/87 87/88 88/89 89/90

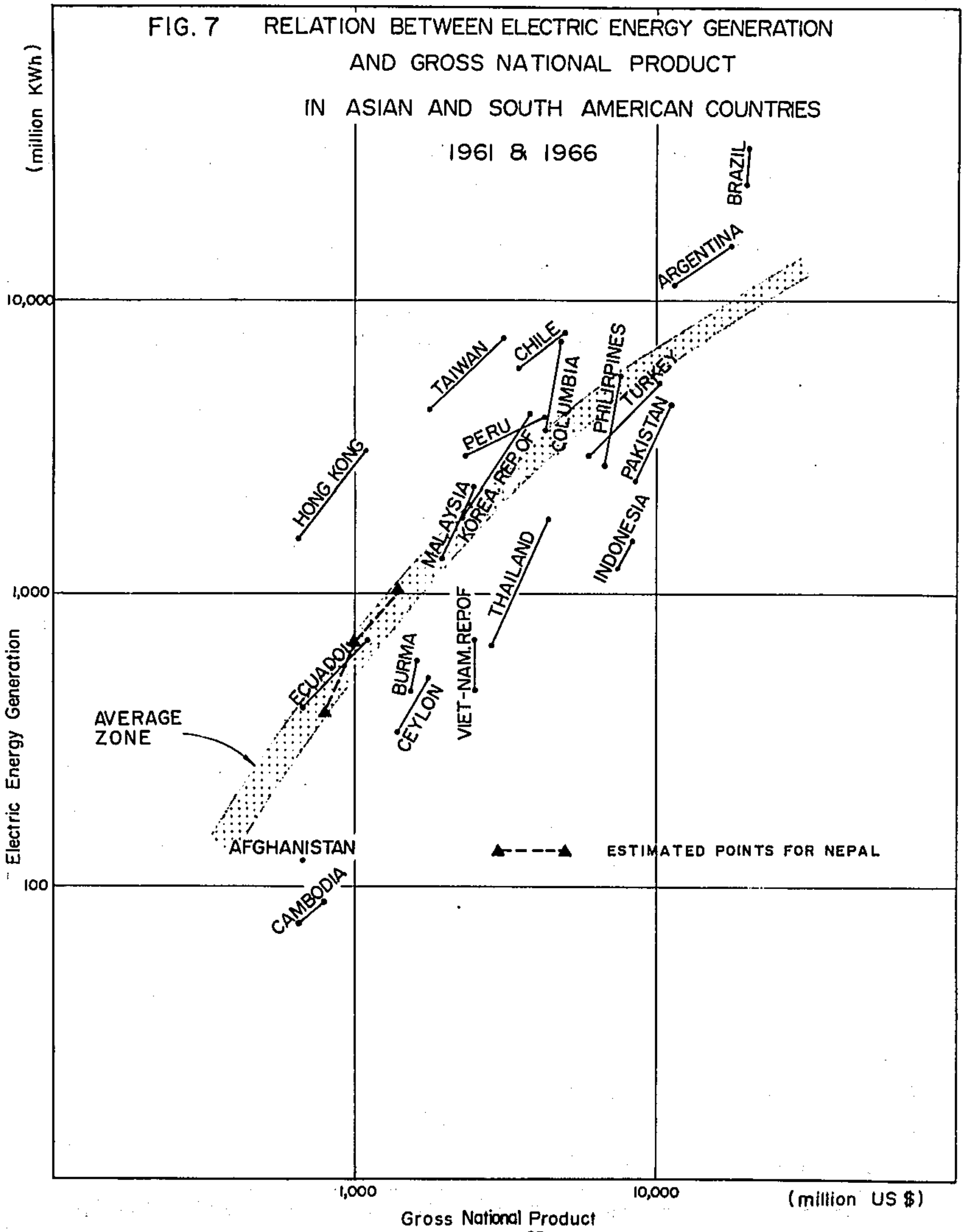


FIG. 7 RELATION BETWEEN ELECTRIC ENERGY GENERATION AND GROSS NATIONAL PRODUCT IN ASIAN AND SOUTH AMERICAN COUNTRIES 1961 & 1966
Electric Energy Generation
(million KWh)
10,000
1,000
100
1,000
10,000
Gross National Product
(million US $)
BRAZIL
ARGENTINA
TAIWAN
CHILE
COLUMBIA
PHILIPPINES
TURKEY
PERU
KOREA, REP. OF
PAKISTAN
HONG KONG
MALAYSIA
INDONESIA
THAILAND
VIET-NAM, REP. OF
BURMA
CEYLON
ECUADOR
AVERAGE ZONE
AFGHANISTAN
CAMBODIA
ESTIMATED POINTS FOR NEPAL

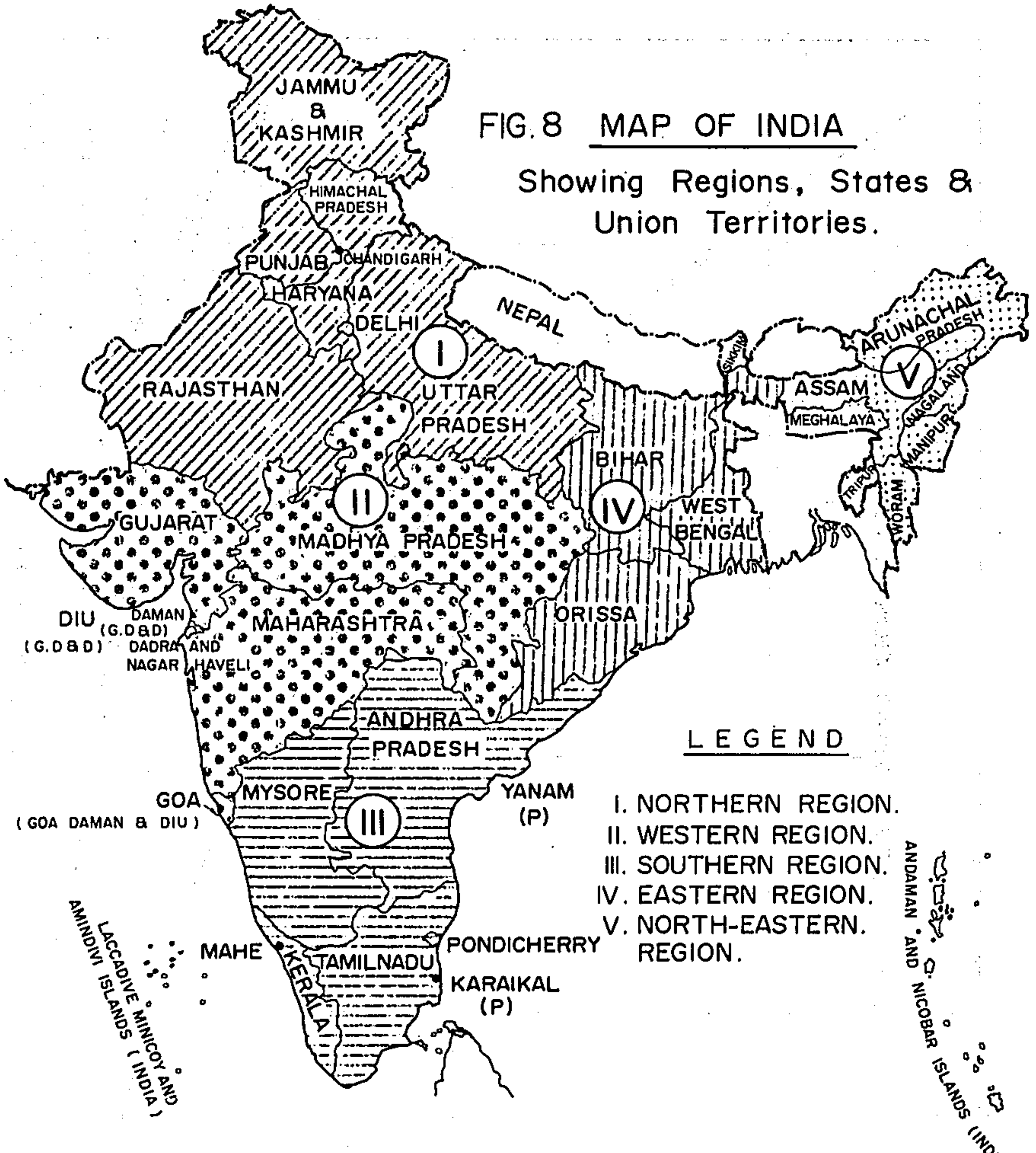


FIG. 8 MAP OF INDIA
Showing Regions, States & Union Territories.
JAMMU & KASHMIR
HIMACHAL PRADESH
PUNJAB
CHANDIGARH
HARYANA
DELHI
NEPAL
RAJASTHAN
UTTAR PRADESH
SIKKIM
ASSAM
MEGHALAYA
ARUNACHAL PRADESH
NAGALAND
MANIPUR
TRIPURA
MIZORAM
BIHAR
WEST BENGAL
GUJARAT
MADHYA PRADESH
DIU (G.D&D)
DAMAN (G.D&D)
DADRA AND NAGAR HAVELI
MAHARASHTRA
ORISSA
ANDHRA PRADESH
GOA (GOA DAMAN & DIU)
MYSORE
YANAM (P)
MAHE
KERALA
TAMILNADU
PONDICHERRY
KARAIKAL (P)
LACCADIVE MINICOY AND AMINDIVI ISLANDS (INDIA)
ANDAMAN AND NICOBAR ISLANDS (INDIA)
LEGEND
I. NORTHERN REGION.
II. WESTERN REGION.
III. SOUTHERN REGION.
IV. EASTERN REGION.
V. NORTH-EASTERN. REGION.

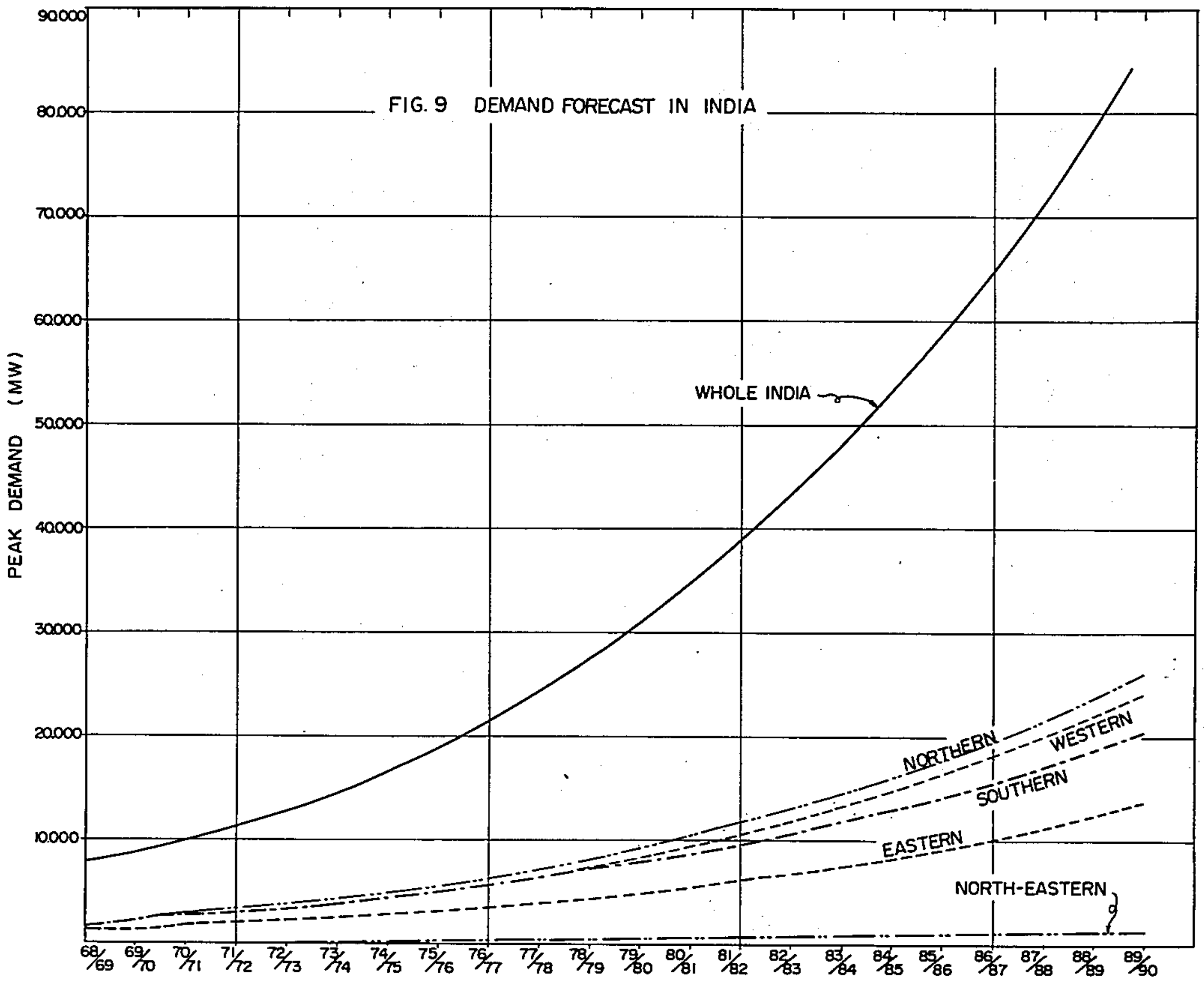



FIG. 9 DEMAND FORECAST IN INDIA

## CHAPTER 4

## JUSTIFIABLE INVESTMENT OF HYDROELECTRIC POWER DEVELOPMENT

### 4.1 Alternative Cost of Thermal Generation

Since the oil shock in the last year, the merit of the hydro-electric power has attaind a better look on the cost basis as well as on its clean nature. Yet its implementation still needs to be compared with the most likely and least costly alternative means of power generation. At present, the conceivable means as such in Nepal is an oil-fired diesel power plant for small demand and a coal-fired steam power plant for medium scale demand. The cost of such a new thermal plant is estimated as shown in Table 10.

Table 10 Costs of Thermal Plant

| | | Diesel Plant | | Coal-fired Steam Plant, (30,000 kW) |
|---|---|---|---|---|
| | | 200 kW | 1,000 kW | |
| Installation cost per kW | (US$) | 370 | 300 | 500 |
| Economic life | (yrs) | 15 | 15 | 25 |
| Amortization for 6 % interest | (%) | 10.3 | 10.3 | 7.8 |
| Operation & Maintenance | (%) | 10.0 | 4.4 | 2.5 |
| Others | (%) | 0.5 | 0.5 | 0.5 |
| Annual Cost | (%) | 20.8 | 15.2 | 10.8 |
| " | (US$/kW) | 77.0 | 45.6 | 54.0 |
| Fuel Consumption per kWh /1 | | 0.318 ℓ | 0.246 ℓ | 0.645 kg |
| Unit Fuel Cost /2 | | 16.8 US¢/ℓ | 16.8 US¢/ℓ | 30 US$/ton |
| Fuel Cost per kWh (Mill) | | 53.4 | 41.3 | 19.4 |

/1 Average values in Seventh Annual Electric Power Survey of India published by the Central Electricity Authority in 1972.

/2 Conversion is made at the rate of US$1.00 = Rs10.00.

## 4.2 Power Values of Hydro Plant

The power values of a hydroplant means its capacity (peak) value and energy value obtained from adjusting the installation cost and energy cost of the alternative thermal plant. Adjustment is made based on the superior nature of hydroelectric power generation with regard to the shorter forced outage and overhaul periods, and less auxiliary power use than the thermal power generation, and difference in loss at primary substation for both types of generation, as indicated below.

| | Hydro Plant | Diesel Plant | Steam Plant |
|---|---|---|---|
| Loss at primary substation | 5.0 % | 1.0 % | 2.0 % |
| Auxiliary power use | 0.3 % | 5.0 % | 6.0 % |
| Forced outage | 0.5 % | 5.0 % | 5.0 % |
| Overhaul | 2.0 % | 15.0 % | 10.0 % |

Based on the above figures, the adjustment factors are calculated as follows:

For Capacity Value

Hydro to Diesel: $\frac{(1-0.05)(1-0.003)(1-0.005)(1-0.02)}{(1-0.01)(1-0.05)(1-0.05)(1-0.15)} = 1.216$

Hydro to Steam: $\frac{(1-0.05)(1-0.003)(1-0.005)(1-0.02)}{(1-0.02)(1-0.06)(1-0.05)(1-0.10)} = 1.173$

For Energy Value

Hydro to Diesel: $\frac{(1-0.05)(1-0.003)}{(1-0.01)(1-0.05)} = 1.007$

Hydro to Steam: $\frac{(1-0.05)(1-0.003)}{(1-0.02)(1-0.06)} = 1.028$

Using these adjustment factors, the power values of a hydro plant compared with various thermal plants are calculated, and show in Table 11.

Table 11 Power Values of Hydro Plant Compared with Thermal Plant

| | Capacity Value (US$/kW) | Energy Value (US Mill/kWh) |
|---|---|---|
| Hydro Plant to: | | |
| Diesel Plant, 200 kW | 94 | 54 |
| Diesel Plant, 1,000 kW | 56 | 42 |
| Steam Plant, 30,000 kW | 63 | 20.0 |

The power values shown in Table 11 can be used in evaluating micro projects, the supply to small towns along the transmission line, and larger terminal towns respectively.

4.3 Power Export to India

The hydroelectric power resources are abundant in Nepal, but the present level of energy consumption does not warrant sizable hydroelectric power development schemes. On the other hand, the power market in India is large, and growing at an annual rate of more than 10 %. Even the Nothern and Eastern Regions only can absorb considerable amount of energy from Nepal, if the hydro energy can be produced in Nepal at a competitive cost with the alternative generation in India. Therefore, the power market of India will have to be looked into for the hydropower development in Nepal.

At present, exchange of small power has been made between India and Nepal under the agreement of the both governments. Nepal is importing the power at the east (Biratnagar and Rajbiraj) and the west (Nepalganj), and exporting at the central (Birganj), all at the order of a few thousand kilowatts. The trade is made on the equal basis, at a rate of 20 US mills/kWh. Adjustment of the rate would be in order after the oil shock. However, if a large power project is implemented in Nepal, it would become one way trade from Nepal to India. Under such condition, it is questionable that the power rate of small trade will be still adopted in the future. Special considerations is required for the export of the power to India.

Two modes of the power export is conceivable: the one is to supply the power on firm commitments, and the other is only to supply the surplus energy and idle capacity of the plant.

If the power is supplied on the firm basis, then both the capacity value and energy value should be able to be recovered. The average selling price (for users) in India was 15.4 mills/kWh in 1968/1. The production

---

/1 Based on "Overseas Electric Power Industry statistics, 1972", by Overseas Electrical Industry Survey Institute, Inc., Japan. No such information is available in "7th Annual Electric Power Survey of India", 1972 (Indian publication).

cost, including generation, distribution, and overhead, would be probably around 14 mills/kWh. While no information is available after the oil shock, it is estimated that the power cost would be at least 60 % more, which would give a figure of around 22 mills/kWh. If the power were exported at this moment, it would probably worth this amount.

However, if a hydroelectric project is implemented at some distant future, then the price will depend upon the power situation in India by that time. It is conceivable that more nuclear plants will come into being as base load stations in the future. However, the proportion of nuclear power to coal-fired thermal power would be about 15 to 20 percent at the most even in the year of 1985-90. The cost of producing power by combined nuclear plants and coal-fired thermal plants would be about 16 mills/kWh in early 1974 price level as a conservative estimate.

In the case of selling the surplus energy, the capacity of a new plant is made available to India only during the build up period of the Nepal's system. After the system uses up the capacity, only surplus secondary energy is supplied to India.

This kind of arrangement has been done for the Nam Ngum Project in Laos. Laos is now selling excess energy to Thailand at a rate of 4.5 mills/kWh. If this can be done between Nepal and India, both parties will be benefited. Nepal can recover part of the capital cost at the early stage, which will be done otherwise. India, which power demand is quite large, can obtain inexpensive energy handily, and only need to make minor adjustment of their own expansion plan according to the growth of Nepal's power demand, which is much smaller than India's. There would be no reason why this kind of arrangement cannot be made, as far as both parties are benefited.

However, such energy supply may be regarded as secondary energy. So it will be sold at fuel replacement value at the best and might be lower than that. It is noted that cheap coal is available in Eastern and Northern Regions of India. The capacities of coal-fired plants in Eastern and Northern Regions are more than 70 % and 50 % of their total generating capacities respectively. The price of coal in these Regions is 22.5 US$/ton[/1] at present, which is about 75 % of that in Nepal. Therefore, the fuel replacement value of coal is estimated at 14.5 mills/kWh[/2]. Also, it should be noted that the fuel replacement cost of nuclear plants is about 3 mills/kWh in early-1974 price level[/3].

While the rate of power export would be determined under the negotiation of both government taking account of production and operation costs in Nepal and India at the time, the description given heretofore should provide a guideline to work out what the export rate of the power in the future would be.

---

/1 At 225 Rs/ton.

/2 Based on the consumption of 0.645 kg/kWh.

/3 Estimation of Mekong River Committee, ECAFE. This figure appears on the lower side.

# CHAPTER 5

# HYDRO POWER POTENTIAL IN NEPAL

## 5.1 Rivers in Nepal

Nepal has a great hydro energy potential owing to its topography and abundant water resources.

According to the "Hydro-power potentiality of Nepal "published by Department of Electricity, 1971, the theoretical hydroelectric power potential has been estimated as 83,000 MW with the annual energy potential of 727,000 GWh. While not all of these potentials are technically and economically exploitable, it is still a tremendous amount of power compared with the area of the country.

The rivers in Nepal are classified into three types, according their sources. The first type rivers are Mahakali, Karnali, Sapt Gandaki (Narayani) and the Sapt Kosi which contribute about 80 % of the total run-off. These have their sources in snow and glaciers in the Himalayas. Except the Mahakali which forms western border with India, other three rivers rise far-north in Tibet plateau of China. Due to the reservoir function of the snow and glacier, these rivers have comparatively more sustained flow, and give many promising sites for power generation, not only for large scales but also for medium or small scale development.

The second type rivers have their sources in the Mahabharat ranges below the snow line, but do not dry up in the dry season and can be developed for power generation, such as the Kankai Mai, Kamla, Bagmati, West Rapti and Babai rivers.

The third category of the rivers belong to those innumerable number of small streams and creeks which originate from Siwalik regions, located northern tip of the Terai Belt. They have no water available during dry season and as such cannot be considered as sources for hydro power generation.

All rivers in Nepal carry heavy sediment load during flood season. Special attention is required in designing hydro structures in these rivers.

5.2 Potential Hydro-Energy

Nepal's chief source of exploitable energy is in the form of water power. The resources of coal, oil, heat of the earth and high-yield nuclear fuel are yet to be proven. Consequently, power has been and continues to be predominantly hydro-electric, for which the basic conditions are adequate.

For better assessment of power potentialities and for more systematic development, the country has been divided into four main energetic divisions.

They are:

a. Sapt-Kosi Basin
b. Sapt-Gandaki Basin
c. Karnali and Mahakali Basins
d. Southern River Basins

Total water power potentiality has been estimated to be about 83,000 MW. Out of this, about 33,000 MW is in the Karnali basin, 21,000 MW in the Gandaki basin, 22,000 MW kW in the Sapt Kosi basin, and the remaining in the other basins as illustrated in Table 12 below:

Table 12 /1

Riverwise theoretical Hydro-Power Potentialities and Their Linear Distribution of Main Rivers

| Names of Rivers | Power Potentiality MW | Linear Distribution kW/km |
|---|---|---|
| 1. Sapt-Kosi Basin | | |
| a. Tamur | 2,077 | 10,500 |
| b. Arun | 6,850 | 45,000 |
| c. Sun-Kosi Main | 4,800 | 18,700 |
| d. Dudh-Kosi | 2,013 | 16,500 |
| e. Tamba-Kosi | 1,864 | 20,700 |
| f. Indrawati | 298 | 4,400 |
| 2. Sapt-Gandaki Basin | | |
| a. Kali-Gandaki Main | 5,200 | 16,500 |
| b. Myandi | 448 | 6,600 |
| c. Barigad | 392 | 4,610 |
| d. Trisuli-Ganga Main | 2,740 | 21,690 |
| e. Buri-Gandaki | 3,920 | 33,500 |

- to be continued -

| | | | |
|---|---|---|---|
| | f. Marsyandi | 2,080 | 13,600 |
| | g. Seti | 622 | 4,970 |
| | h. Madi | 317 | 4,280 |
| 3. | Karnali and Mahakali Basin | | |
| | a. Karnali-Humla Karnali | 12,020 | 30,400 |
| | b. Mugn-Karnali | 3,944 | 20,200 |
| | c. Tila | 1,833 | 16,800 |
| | d. Tanke-Khola (Mugu) | 413 | 6,350 |
| | e. Lohare | 146 | 3,310 |
| | f. Beri Main | 5,140 | 19,500 |
| | g. Sani-Beri | 1,108 | 11,300 |
| | h. Thuli-Beri | 1,834 | 13,500 |
| | i. Seti (Karnali) | 2,493 | 12,350 |
| | j. Buri-Ganga | 590 | 7,020 |
| | k. Mahakali | 3,148 | 14,100 |
| | l. Chamalia | 688 | 8,500 |
| 4. | Southern River Basins | | |
| | a. Kankai-Mai | 224 | 2,070 |
| | b. Kamla | 144 | 1,230 |
| | c. Bagmati | 688 | 4,220 |
| | d. East Rapti | 170 | 1,390 |
| | e. West Rapti | 1,315 | 5,100 |
| | f. Thirmuk (Jhimruck) | 200 | 2,470 |
| | g. Babai | 336 | 1,770 |

/1 Based on "Hydro-Power Potentiality of Nepal", Department of Electricity, 1971.

# CHAPTER 6

# HYDROELECTRIC POWER DEVELOPMENT PROGRAM

## 6.1 Conception of Hydroelectric Power Development

For the development of a new hydroelectric power project, the anticipated load growth in Nepal still does not warrant a large scale development. However, there is a basic agreement about the exchange of electric power between India and Nepal. This agreement is intended for solving immediate power shortage at the border towns of both countries, but it opens up the marketability of the Nepal's power if it can be produced at a competent cost. Therefore, the hydroelectric power development in Nepal can be classified, taking account of Indian market, into 3 categories: i.e., a large scale development, a medium to small scale development, and a micro project. The distinction of these 3 categories is not only the project size, but also the primary objective and the mode of the project implementation. Therefore, different philosophies of development should be applied for.

The large scale development will be planned to sell the energy to India on firm commitments. Since the expected load growth in India is quite large, the major concern of this type of development is the selling price of energy and the financial arrangement.

The objective of the medium to small scale development is primarily to meet the growing domestic needs at all times in order not to hamper the economic development of the country, but the surplus energy will be sold to India. The unused capacity of the plant is only made available to India during the build-up period of the domestic needs. Since this type of selling may be regarded only offering the secondary energy, the energy will have to be sold at a reasonable price acceptable to the both countries.

The medium to small scale development is related to the growth of the domestic needs, which is the reflection of the nation's economic activities. Therefore, the scale of the project and the timing of its implementation become the matter of concern.

Micro projects are extremely small development, mostly smaller than 100 kW, aiming at the electrification of rural areas. Such projects are important in view of the national welfare. The capacity and energy values of micro projects are estimated at 94 US$/kW and 54 mills/kWh respectively based on the alternative thermal generating cost, as shown in Table 11. While micro projects are not dealt in this study, they should be implemented on the opportunity basis, whenever they appear feasible based on above power values. The Fifth Five Years Plan aims to conduct feasibility studies on ten remote hilly places/1, out of which two would be taken up for construction at an earlier opportunity.

## 6.2 Prospective Project Sites

Among the rivers mentioned in 5.1, the border river of the Mahakali is now being investigated by the Government of India. Since it appears that the Government of Nepal has no immediate intention of developing this river, it is not included in this study.

Prospective project sites on the other rivers are selected from the field reconnaissance, map studies on 1 inch to 1 mile scale (1/63,360), and review of the published project reports. Those projects judged not favorable in the previous reports are not included, as this implies that they are not worth further studying. While recommended in some previous project reports, questionable projects found in the field reconnaissance and map studies are also excluded. Efforts are made to bring those project costs on the same level, as of early-1974. The selected prospective projects are shown in Table 13. The location of each project is illustrated in Fig. 10.

In locating a project in series in the same river, the headwater and tailwater of each project are so determined as to form an integrated development plan, taking account of the existence of the upstream or downstream project. However, the installation capacity, annual energy output, and construction costs of the project are estimated as an independent construction, and the effect of the upstream project is not

/1 The places are Dendeldhura, Chainpur, Jumla, Doti, Dunahai, Jomson, Chorjhari, Phidim, Namche and Khandbari.

Table 13 Prospective Hydroelectric Power Project/1

| Source | Main stream | Tributary | Project | No./2 | Installed capacity (MW) | Annual energy output (GWh) Firm | Annual energy output (GWh) Gross/4 | Construction cost/3 ($10^6$ US$) | Unit construction cost Per kW (US$) | Unit construction cost Per kWh (US Cent) Firm | Unit construction cost Per kWh (US Cent) Gross/4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Himalaya | Karnari | Main stem | Chisapani | 1 | 1,800 | 8,350 | 10,715 | 548 | 304 | 6.6 | 5.1 |
| " | " | " | Lakarpata | 2 | 1,200 | 5,540 | 7,110 | 520 | 433 | 9.4 | 7.3 |
| " | " | " | Bhanakot | 3 | 810 | 3,740 | 4,800 | 615 | 759 | 16.4 | 12.8 |
| " | " | Tila | Poliparni | 4 | 41 | 320 | | 34.2 | 834 | 10.7 | |
| " | " | " | Samla | 5 | 45 | 350 | | 36.4 | 809 | 10.4 | |
| " | " | " | Ramni | 6 | 20 | 150 | | 32.1 | 1,605 | 21.4 | |
| " | " | " | Jubitan | 7 | 18 | 140 | | 30 | 1,667 | 21.4 | |
| " | " | Bheri | Surkhet | 8 | 600 | 2,780 | 3,570 | 509 | 848 | 18.3 | 14.3 |
| " | " | " | Thapna | 9 | 500 | 2,320 | 2,980 | 528 | 1,056 | 22.8 | 17.7 |
| " | " | " | Seti (Karnari) | 10 | 270 | 1,250 | 1,600 | 379 | 1,404 | 30.3 | 23.7 |
| " | Sapt Gandaki (Narayani) | Main stem | Dev-Ghat | 11 | 150 | 770 | 1,193 | 68.1 | 454 | 8.8 | 5.7 |
| " | " | Kali Gandaki | Kali Gandaki No.1 | 12 | 1,500 | 6,700 | 8,950 | 478 | 319 | 7.1 | 5.3 |
| " | " | " | Kali Gandaki No.2 | 13 | 300 | 1,240 | 2,000 | 156 | 520 | 12.6 | 7.8 |
| " | " | Buri Gandaki | Buri Gandaki | 14 | 200 | 961 | 1,330 | 96 | 480 | 10.0 | 7.0 |
| " | " | " | Bhomichok | 15 | 120 | 455 | 956 | 109 | 908 | 24.0 | 11.4 |
| " | " | Marsyandi | Marsyandi | 16 | 510 | 2,423 | 3,190 | 181 | 355 | 7.5 | 5.7 |
| " | " | Seti | Seti (Gandaki) | 17 | 230 | 997 | 1,340 | 98.8 | 430 | 9.9 | 7.4 |
| " | Sapt Kosi | Main stem | Sun Kosi High Dam/5 | 18 | 360 | 832 | 2,020 | 103.3 | 287 | 12.4 | 5.1 |
| Mahabarat | Bagmati | Main stem | Bagmati/5 | 19 | 70 | 350 | 490 | 23.4 | 334 | 6.7 | 4.8 |
| " | " | Kulikhani | Kulikhani No.1 | 20 | 46/6 | 157 | 201 | 43.6 | 948 | 27.8 | 21.7 |
| " | East Rapti | Main stem | " No.2 | 21 | 26/6 | 103 | 120 | 12.2 | 469 | 11.8 | 10.2 |
| " | " | " | " No.3 | 22 | 14/6 | 70 | 91 | 19.9 | 1,421 | 28.4 | 21.9 |
| " | Kamla | Main stem | Kamla/5 | 23 | 30 | 74 | 116 | 9.6 | 320 | 13.0 | 8.3 |
| " | Kankai Mai | " | Kankai/5 | 24 | 33 | 142 | 156 | 12.6 | 382 | 8.9 | 8.1 |
| " | " | Main Khola | Mai Khola Loop | 25 | 13 | 47 | 57 | 26 | 2,000 | 55.3 | 45.6 |
| " | Babai | Sarda | Sarda/5 | 26 | 49 | 222 | 249 | 46.8 | 955 | 21.1 | 18.8 |

/1 Installed capacity, energy output, and construction cost of projects are estimated as the projects are independent construction. If the effects of upstream projects are accounted for, the flow pattern of downstream projects would be leveled off, and the effectiveness of the projects would be largely increased.

/2 Nos. correspond to those on Fig. 10.

/3 Costs of transmission line and substation are not included.

/4 Secondary energy included.

/5 Multi-purpose development. Costs are for power sector only.

/6 Preliminary figures. See footnote of page 48.

accounted for. Figs. 11, 12, and 13 show the profiles of three major rivers, i.e., the Karnali, the Sapt Gandaki, and the Sapt Kosi, and the conceivable projects on these rivers.

The construction costs shown in Table 13 include the cost of all necessary access, a big item for the construction in this country, and a contingency allowance of about 20 %, but do not cover interest during construction and compensation of reservoir areas. The interest during construction is taken into account later when such is required in economic evaluation. The compensation cost is deemed insignificant at this moment, but will have to be considered when further study be carried out in the future. Also, the costs refer to the onces at the powerplants. Therefore, if comparison is made at load centers, the transmission costs will have to be added.

Detailed description of the prospective projects is given in Appendix 1.

## 6.3 Large Scale Development

As described in 3.4, the power demand in the Northern and Eastern Regions of India is increasing at about 900 to 1,000 MW per annum now, and will soon exceed 2,000 MW per annum in the future. Therefore, it is quite hopeful to sell more energy to India if the hydro energy in Nepal can be produced at a reasonably low cost. Further, hydropower generation by large reservoirs in Nepal will not only enable India to utilize the regulated flow for consumptive uses, but also will contribute to the abatement of flood damages in its downstream territory.

For the large scale development, Table 13 gives the best indices of evaluating the project priority. The last column of the table indicates the construction cost per kWh. The annual cost per kWh can be roughly taken as 1/10 of this figure.

As the large scale development is to sell the energy to India on firm commitments, both capacity and energy values can be sold, but the price will depend upon the power situation in India by the time that such a selling is made. It is assumed the demend in India by that time is met by nuclear plants and coal or oil-fired thermal plants. As discussed in 4.3, the production cost of such system is assumed to be about 16 mills/kWh.

Therefore, the projects which are likely to offer a power cost of less than 16 mills/kWh are selected as prospective ones for the first choise. They are,

1) Chisapani Project (1,800 MW), Karnali Basin
2) Lakarpata Project (1,200 MW), " "
3) Kali Gandaki No.1 (1,500 MW), Kali Gandaki Basin
4) Marsyandi (510 MW), " "

Among which, the Chisapani Project can be deemed as the first priority project, because (1) it can offer inexpensive energy, (2) the feasibility study has been done by the aid of UNDP, and the viability of the project is already confirmed, and (3) a limestone quarry is located at a favorable place to facilitate the establishment of a cement factory for the project construction. If necessary, the cement factory can be operated even after completion of the project as a key industry of the country to meet the domestic and India's demands.

The Marsyandi Project can be taken as the second priority project. The reasons are, (1) it can offer inexpensive energy, (2) the East-West Highway goes through nearby area and the accessibility to the project site is exceptionally good in this country, and (3) the project can be favorably connected to the CNPS.

For the other projects, the priority is given to Kali Gandaki No.1, and Lakarpata in that order, based on their power costs.

The development of large scale projects requires another facet to be looked into, aside from its heavy investment involved. When a power project is called a key industry, this implies that the energy will be turned to high-value products which in turn have many triggar effects on the nation's economic activity. Such triggar effect cannot be expected from mere export of the energy. Further, selling the energy is usually made more or less on the production-cost basis, so that it would benefit more to others than to Nepal's own self. Therefore, careful planning and prudent political arrangement are required for the large scale development.

### 6.4 Medium to Small Scale Development

#### 6.4.1 General

The forecast of the power demand is discussed in 3.3. The Kathmandu Development Region (Central Region) is by far the largest demand center in Nepal. This region is covered by the CNPS. The neighboring Pokhara Development Region (Western Region) is less developed. The construction of transmission line connecting these two regions are now underway, so that they will be covered by the CNPS soon. The Dhankuta Development Region (Eastern Region) is the second largest demand center, and covers the fertile Terai Plain.

From the load growth of the Kathmandu-Pokhara Regions and the Dhankuta region, it is anticipated that the connection of these systems will be made by 85/86. Before this connection is made, these two systems will have to be developed separately.

The combined power demand of these regions up to 89/90 is shown in Fig. 6. When the power demand of further future is required during the course of the study, the demand curve of Fig. 6 is extended at an annual peak load growth of 9.2 % (equivalent to 89/90's growth rate) and an annual load factor of 50 %.

The power consumption in the Surkhet Development Region is extremely small at present. Though the government is putting stress on the development of this region in pursuance of the government policy of balanced development of each region in the country, the anticipated load growth in the future is still not so large, except Nepalganj. Even for Nepalganj, the expected load growth is still not large enough to warrent the connection to the CNPS.

The hydroelectric power development program for each region is discussed hereinafter.

#### 6.4.2 Kathmandu and Pokhara Development Regions (the CNPS)

Since the unification of these regions will presumably be made in 1975/76, they are treated as one system herein.

The anticipated earliest in-service date for the first project is in 78/79. By that time, the generating capacity of the CNPS would be as follows.

| | |
|---|---|
| Existing facilities | |
| Diesel units | 7,660 kW |
| Hydro project | 26,600 kW (in dry season) |
| Facilities to be added | |
| Gandaki project | 7,000 kW |
| Dev-Ghat project | 14,000 kW |
| Butwal project | 1,000 kW |
| Operation of Trisuli's standby unit | 3,000 kW |
| Connection of Bharatpur plant | 600 kW |
| Facilities in Western system | 3,000 kW |
| Total | 62,860 kW |

More detailed explanations of these facilities are given in the footnotes of 3.1, Appendix 2. The operation of Trisuli's standby unit will require an additional transformer.

From Table 13, Kulikhani No.1 (46 MW), Bagmati (70 MW), and Dev-Ghat (150 MW) are selected as prospective projects based on the cost, project size, and forecasted level of power consumption. Kulikhani No.2 (26 MW) and No.3 (14 MW) can only follow after the No.1 project by their nature. As shown in Fig. 14, the peaking capacity of the system would be a little short for the demand when the first project comes into operation, the Kulikhani No.1 project would be planned as a peaking plant with a plant factor of 37 %. For the Bagmati and Dev-Ghat projects, where the scales are larger than Kulikhani No.1, a plant factor of 60 % is used, as the installation of these projects would permit shut-off of the present uneconomical units and become major energy source in the system.

In formulating the hydroelectric power development plan for these regions, an optimum development sequence of the projects which will meet the system demand at all times and will give the least present worth of the project costs is considered. Detailed explanation and calculation of searching the optimum development sequence is presented in Appendix 2. The calculation is made based on the discount rate of 6 %. Many Asian and European countries have obtained development fund at this rate for the post-War economic reconstruction. This rate is adopted since it is relatively low at the present level of the world economy, yet not too far from the realistic figure of the bank loan. Fig. 14 shows the proposed optimum development sequence superimposed on the growth curve of the system demands. This is given as follows.

In 78/79, Kulikhani No. 1 Project ( 46 MW)/1
In 1982, Kulikhani No. 2 Project ( 26 MW)/2, /3
In 84/85, Dev-Ghat Project (150 MW)/3

It is also anticipated that the connection of the Kathmandu and Dhankuta systems will be made in 85/86. The installations shown above will be able to satisfy the combined demand up to 91/92, both for the peaking capacity and required energy output.

It is noted during the course of the sequence study that the Bagmati Project (70 MW) on the Bagmati River appears a very favorable one, and could be installed at any time, as far as the hydroelectric power is concerned. However, this project is a multi-purpose development, and the power would share only 5 % of the joint cost. Therefore, its implementation is more governed by other project functions. If the Bagmati Project comes into being, aforementioned development schedule should be adjusted accordingly.

---

/1 Preliminary figure. A feasibility study has been carried out as a parallel task to this study. The final figure of the installed capacity becomes 60 MW. Reasoning of this increase is given in the footnote of page I-28, Appendix 1. However, this would further substantiate the conclusion drawn in this report, as described in this report, as described in details in Appendix 2.

/2 The final figure becomes 35 MW.

/3 The revision of the scale of the Kulikhani projects will defer the installation schedule of the follow-up projects only by one year respectively.

Also, the Kulikhani No. 3 project (14 MW)/1 could be implemented at any time after the No. 2 project. After successive completion of the No. 1 and No. 2 projects, it is only natural to consider the No. 3 project for a follow-up, as it has such advantages as easy access, availability of equipment and skilled construction crew etc., which may not be able to be appropriately accounted for in the sequence study.

As may be seen from Table 13, the medium to small scale project such as the Dev-Ghat and Bagmati still appears too large for the predicted load growth in Nepal. Therefore, for these projects, the case of selling the surplus energy to India is examined, based on the assumption that 50 % of the surplus energy is sold at a price acceptable to the both countries, as is discussed in 4.3. The details of calculation is presented in Appendix 2. While this selling of surplus energy would help the early recovery of the initial investment, it would not necessiate to alter the development sequence shown above.

6.4.3 Dhankuta Development Region (Eastern Region)

Fig. 14 includes the forecast of the power demand in this region. The conceivable projects in this region are the Mai Khola Loop, Kamla, and Kankai projects, in which the latter two are multipurpose development. The earliest in-service date of any of above projects will be in 78/79.

The present power supply in this region is as follows.

| | |
|---|---|
| Existing diesel and steam units | 6,700 kW |
| Contracted import from India | 6,800 kW |
| Total | 13,500 kW |

As can be seen in Fig. 14, this capacity of the power supply is not enough to meet the demand up to 78/79. Therefore, additional thermal plant will have to be installed as required.

It can be seen from Table 13 that the power cost of the Mai Khola Loop project is too expensive to be considered as a competitive one. There would be little to choose between the Kamla and Kankai projects

/1 The final figure becomes 17 MW.

with respect to the power cost and the development scale. However, the first stage of the Kankai project, which intends to irrigate part of the Terai plain by the natural flow of the Kankai Mai River, has been already started. The second stage of the project includes the construction of a dam, and should be a follow-up of the first stage. Then, the addition of the power facilities is a relatively easy task. Therefore, the Kankai project (33 MW) is selected in preference to the Kamla project.

As shown in Fig. 14, the installed capacity of the Kankai project would satisfy the region's demand up to 85/86 even if the import of energy from India is stopped and most of the thermal plants are shut off. By that time, the 132 kV, east-central connecting transmission line should come into being. The development after 85/86 should be considered in connection with the CNPS, as is discussed later in 7.4.

### 6.4.4 Surkhet Development Region (Far Western Region)

The power demand in this region has been very small. However, aiming at the balanced economic development of each region in the country, the government formulated the Fifth Five Year Plan putting emphasis on the industrial development of this region. Taking into account of the plan, rapid growth of power demand is anticipated in the region. The conceivable project to meet the power demand is the Sarda project. As shown in Table 13, the Sarda project (49 MW) can supply reasonably inexpensive energy to Nepalganj and the surrounding area if the surplus power can be exported to India. The project is also important as it can provide the energy required for the construction of the Chisapani project, a large scale development in this region. The project is aimed at its completion by 1980/81 and will satisfy the industrial and domestic demand of the region for about 15 years.

Micro project development is also considered for the electrification of the rural area.

FIG. 10 LOCATION MAP OF PROSPECTIVE HYDROPOWER PROJECT

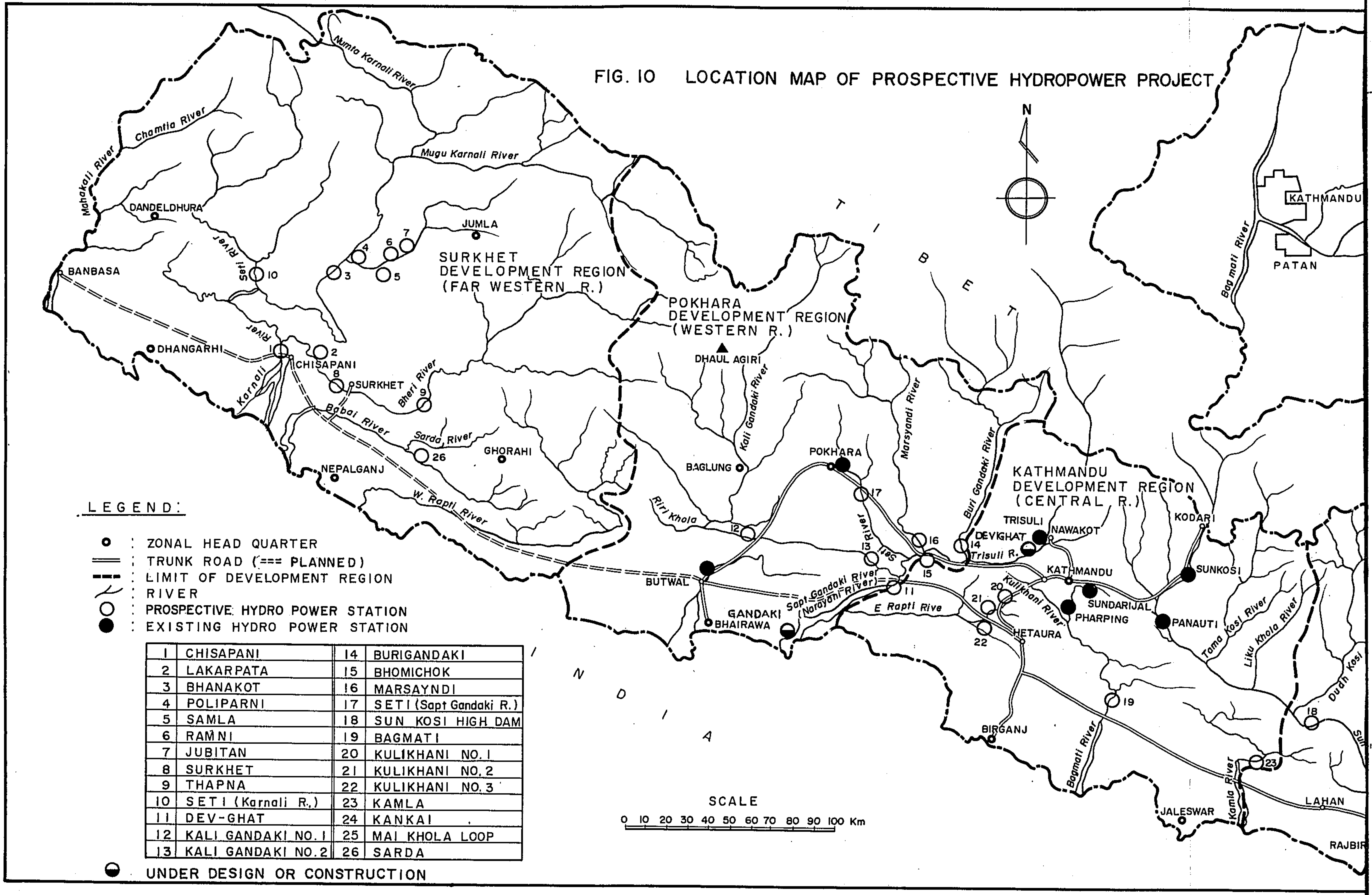
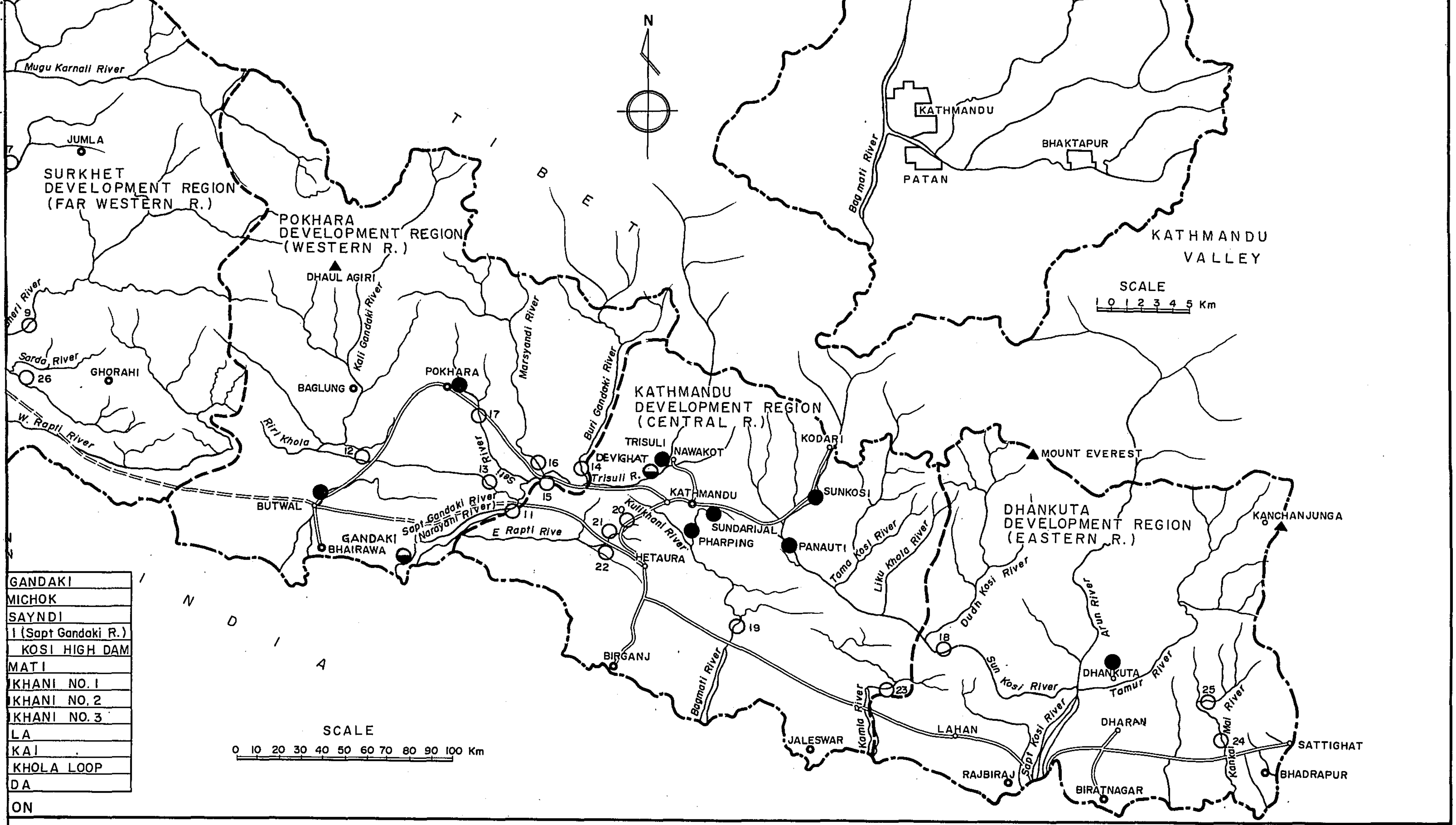


FIG. 10 LOCATION MAP OF PROSPECTIVE HYDROPOWER PROJECT



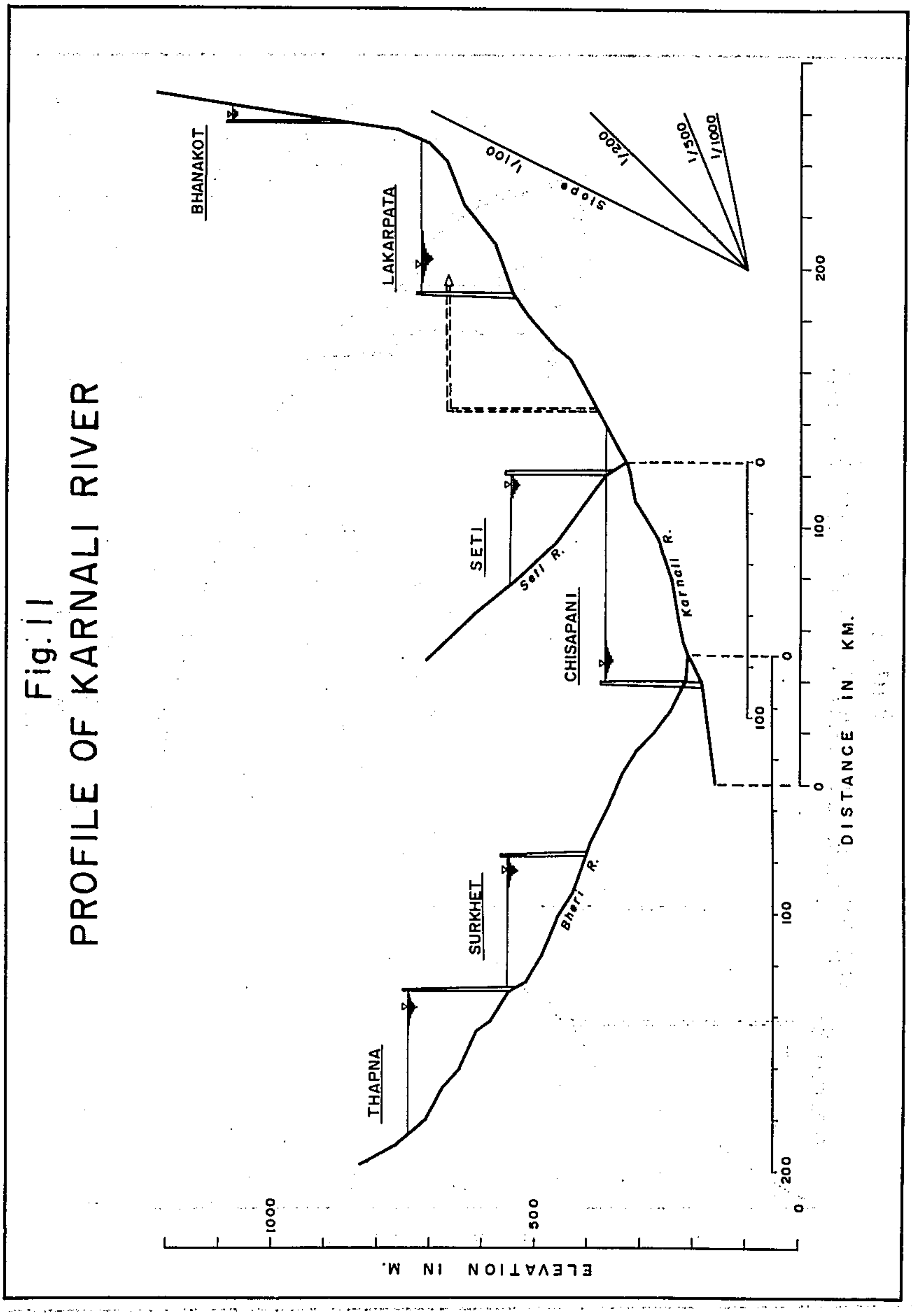
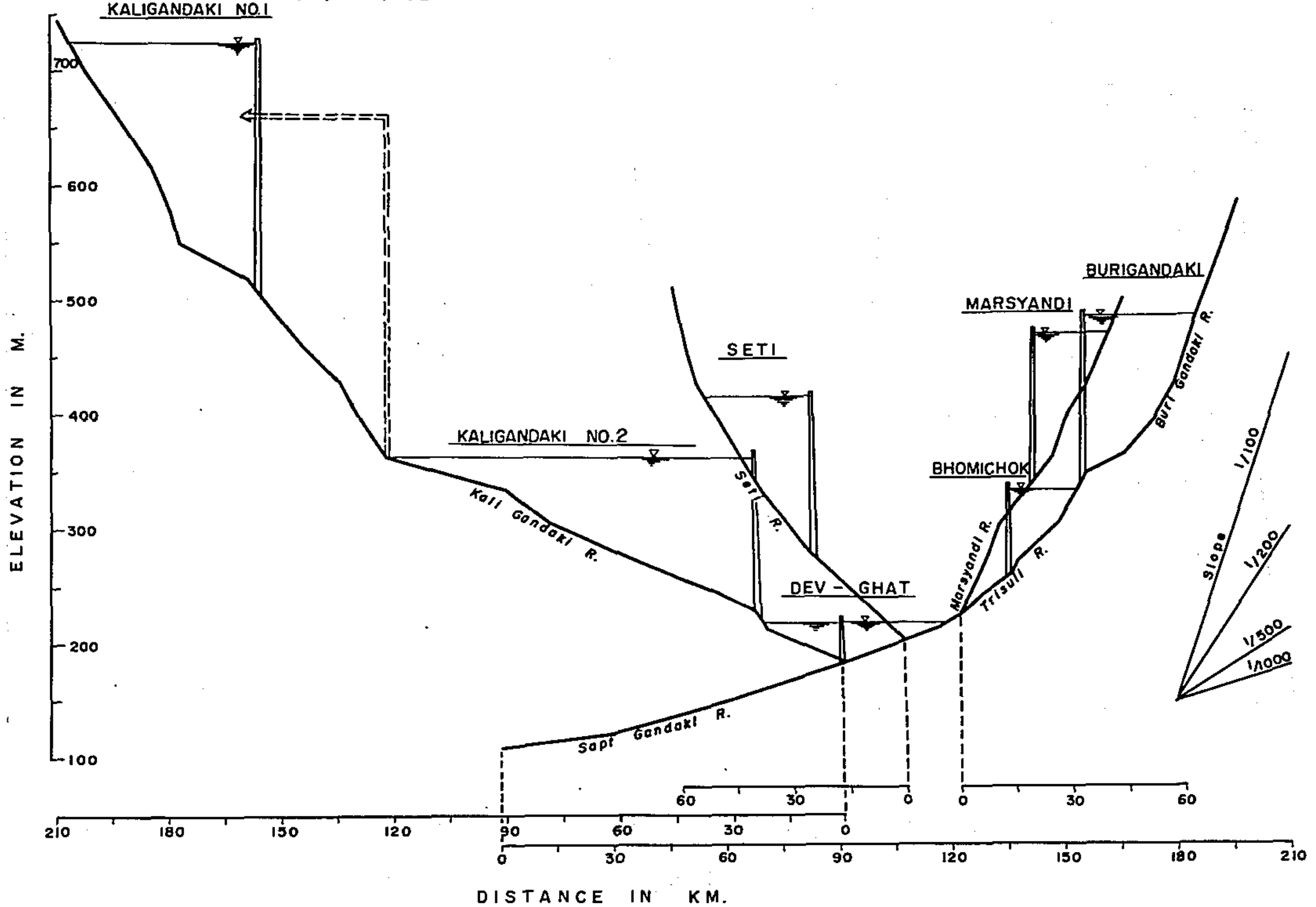
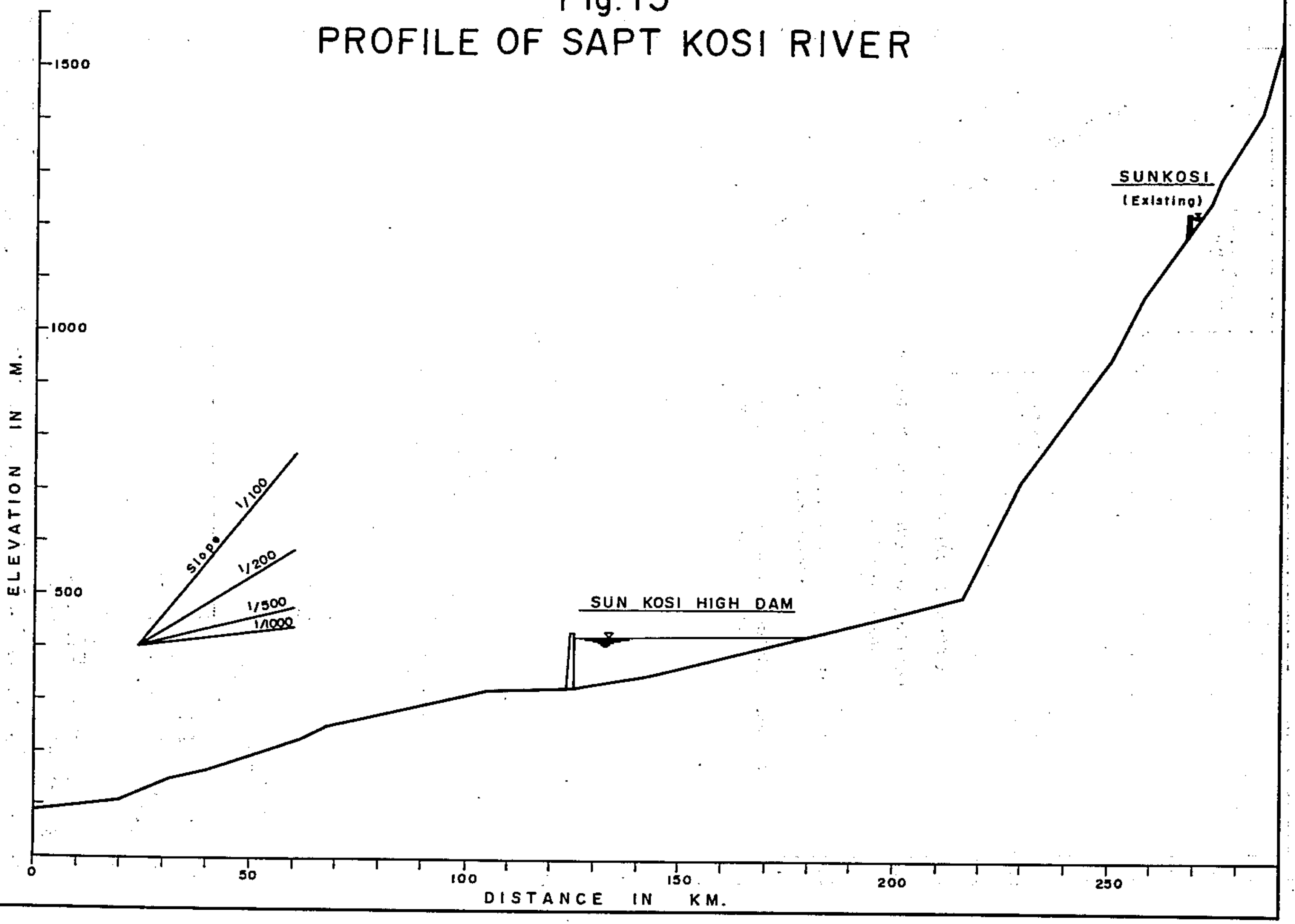


Fig. 11
PROFILE OF KARNALI RIVER
BHANAKOT
LAKARPATA
SETI
CHISAPANI
SURKHET
THAPNA
Slope 1/100
1/200
1/500
1/1000
Seti R.
Karnali R.
Bheri R.
ELEVATION IN M.
1000
500
0
DISTANCE IN KM.
200
100
0
100
0
100
0
100
200

Fig.12
PROFILE OF SAPT GANDAKI RIVER



## Fig. 13
## PROFILE OF SAPT KOSI RIVER



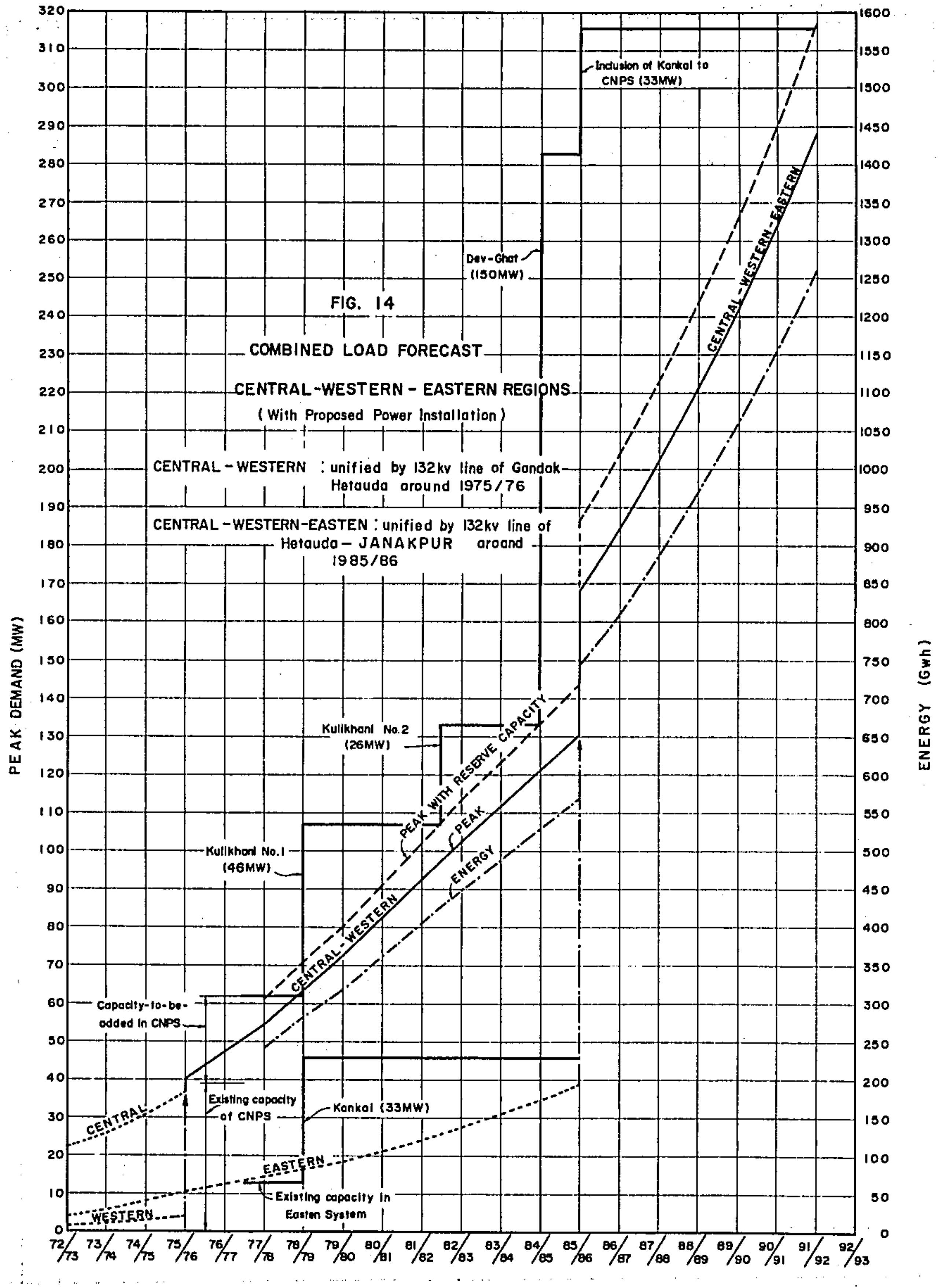


FIG. 14
COMBINED LOAD FORECAST
CENTRAL-WESTERN - EASTERN REGIONS
( With Proposed Power Installation )
CENTRAL - WESTERN : unified by 132kv line of Gandak-Hetauda around 1975/76
CENTRAL - WESTERN-EASTEN : unified by 132kv line of Hetauda - JANAKPUR aroand 1985/86
PEAK DEMAND (MW)
ENERGY (Gwh)
Inclusion of Kankai to CNPS (33MW)
Dev-Ghat (150MW)
CENTRAL-WESTERN-EASTERN
Kulikhani No.2 (26MW)
PEAK WITH RESERVE CAPACITY
PEAK
ENERGY
Kulikhani No.1 (46MW)
CENTRAL-WESTERN
Capacity-to-be-added in CNPS
Existing capacity of CNPS
Kankai (33MW)
CENTRAL
EASTERN
Existing capacity in Easten System
WESTERN
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600
72/73 73/74 74/75 75/76 76/77 77/78 78/79 79/80 80/81 81/82 82/83 83/84 84/85 85/86 86/87 87/88 88/89 89/90 90/91 91/92 92/93

# CHAPTER 7

# TRANSMISSION SYSTEM

## 7.1 Kathmandu and Pokhara Development Regions

The existing and proposed transmission system is shown in Fig. 15.

At present, Kathmandu and Birganj-Hetaura Corridor are connected with 66 kV lines. To which, the Trisuli, Sunkosi, Pharping, Panauti and Sundarijal hydro power stations are connected with 66 kV or 33 kV lines. Many diesel plants are also connected to this system. In Pokhara Region, the existing lines are 33 kV line between Krishnagar and Taulihawa, 33 kV line between Bhairawa and Butwal and 11 kV line between Krishnagar and Bahadurganj.

A new 132 kV transmission line is now under construction from the Gandaki power station to Hetaura via Bharatpur, which will interconnect Kathmandu and Pokhara Regions. Also, construction of a new 33 kV system is in progress between Taulihawa, Lumbini, Bhairawa, Butwal, Tansen and Gandaki. These lines are to be completed within a few years. Besides, another 132 kV line between Gandaki and Bhairawa and a 66 kV line between Pokhara and Bharatpur are planned by the Electricity Department.

When the Kulikhani No.1 Project (46 MW) is installed as the first new project, its energy will be delivered to Kathmandu through the existing 66 kV, double circuit line. Existing substation at Kathmandu will be extended with 2 x 27 MVA transformers.

For the second project of the Kulikhani No.2 (26 MW), the required transmission facilities are a 132 kV, single circuit line of 37 km long from the No.2 powerplant to Kathmandu via the No.1 power plant, a same natured line of 13 km long from the No.2 powerplant to Hetaura, and substations at Kathmandu (1 x 18 MVA) and Hetaura (2 x 10 MVA). The delivery of the No.1 power station's energy will be switched to the 132 kV line at this stage in order to attain more stable power transmission.

The transmission facilities required for the third project of the Dev-Ghat (150 MW) are a 132 kV, double circuit line of 65 km long from the Dev-Ghat powerplant to Hetaura, a same natured branch line of 56 km long from Hetaura to Birganj, addition of a 132 kV, single circuit line of 50 km from Hetaura to Kathmandu, and substations at Kathmandu (3 x 40 MVA), Hetaura (1 x 20 MVA) and Birganj (2 x 20 MVA). The 132 kV line from Hetaura to Birganj would facilitate the export of the surplus energy of the system to India.

7.2 Dhankuta Development Region

Biratnagar and Rajbiraj are now receiving the energy from the Kataiya substation of India through 33 kV lines. The other existing transmission line is a 33 kV line connecting Biratnagar and Dharan.

After implementation of the Kankai Project (33 MW), the power of the Kankai plant will be delivered to Biratnagar through a 132 kV transmission line. A 66 kV transmission line will be constructed to connect Biratnagar to Janakpur via Rajbiraj. A separate 33 kV line from the Kankai plant to Bhadrapur will also be constructed.

Neighbouring towns of Janakpur will receive the power from Janakpur through 33 kV to 11 kV transmission line.

7.3 Surkhet Development Region

The power of the proposed Sarda Project (49 MW) will be delivered to Nepalganj through a 66 kV line. The power will be also transmitted to Surkhet and Tulsipur Ghorahi. The surplus energy of the project will be sold to India.

7.4 Interconnection of Power Systems

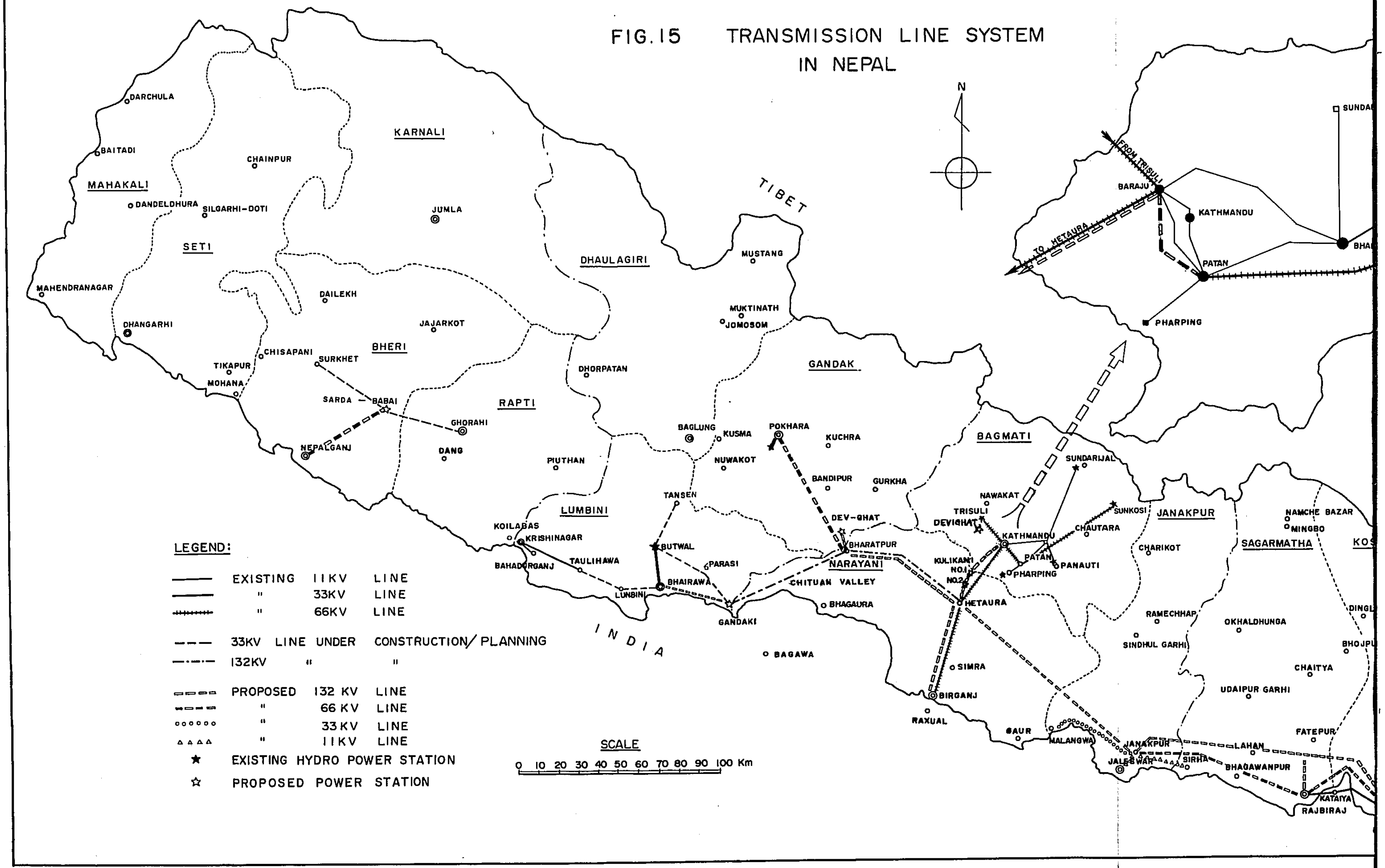
Owing to the great distance from Nepalganj to the Central Nepal, the Nepalganj area will have to be developed independently from the CNPS.

As described in the previous article, the Kankai project can satisfy the power demand of the Eastern Region up to 85/86. Further development of this region is, therefore, the choice between (1) developing another power source by either thermal or hydro means, and (2) interconnection to the CNPS and receiving its excess energy.

The thermal means would be certainly not competitive because the fuel cost alone would cost about 20 mills/kWh, as presented in 4.1 and 4.2

of the text. The interconnection of the CNPS and Eastern system requires the construction of a 132 kV, double circuit, 250 km long transmission line from Hetaura to Biratnagar, and would cost US$9.2 x $10^6$. This is much less than the fund requirement of developing other hydropower projects. Also, such interconnection will have to be made eventually in order to increase the flexibility of the system operation. It is conceived that the year of 85/86 is about the right time to make such interconnection.

FIG. 15 TRANSMISSION LINE SYSTEM IN NEPAL



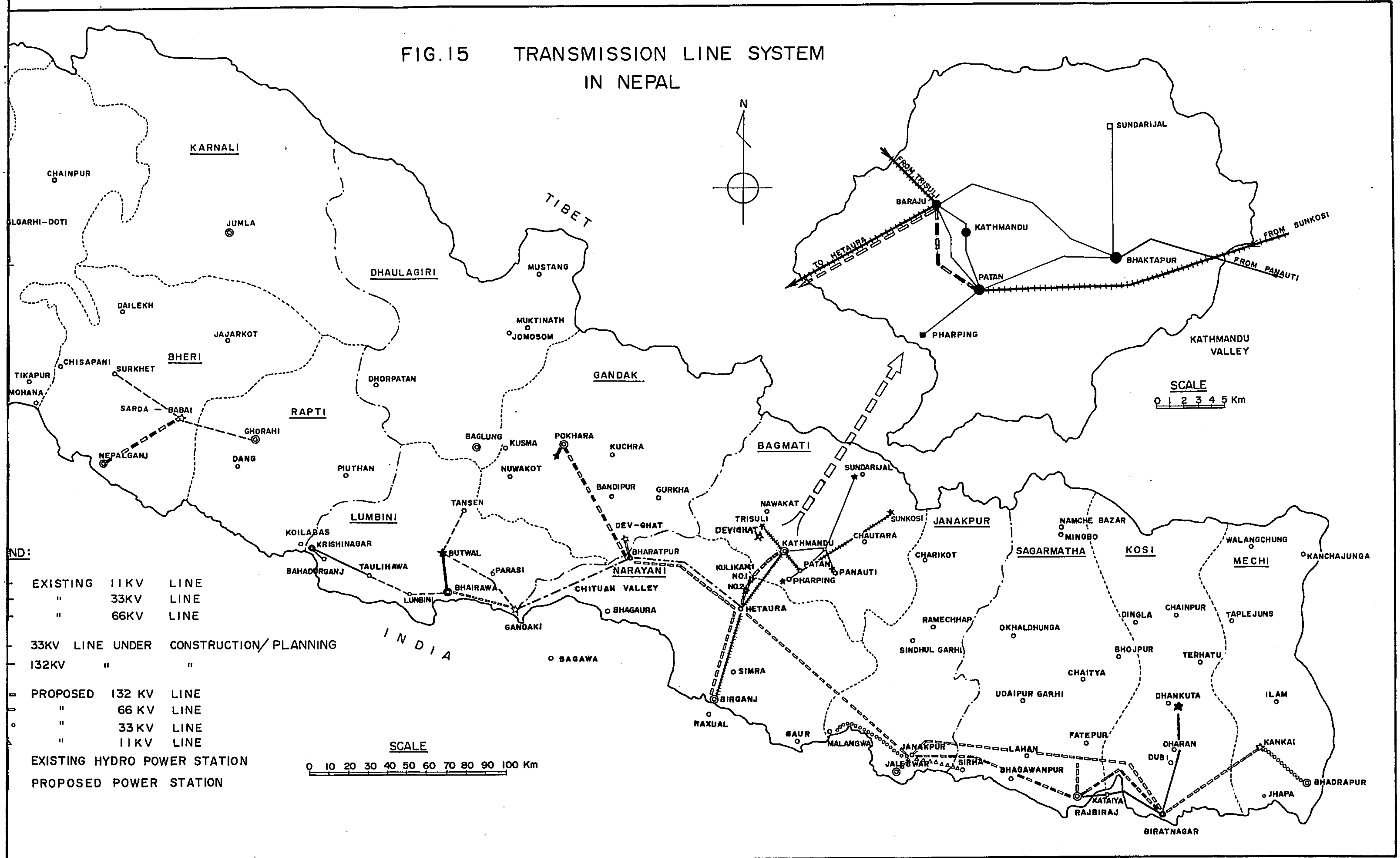



FIG. 15 TRANSMISSION LINE SYSTEM IN NEPAL

CHAPTER 8

# EVALUATION OF PROJECT ECONOMY

## 8.1 Large Scale Development

For evaluation of the large scale projects, it is assumed that the power is delivered to India at appropriate border towns. The costs of the transmission line and substation or switching station should be added to the costs appeared in Table 13. Also, the interest during construction should be included in the project cost. The project cost is then converted to the annual cost and comparison is made with the annual benefit.

An acceptable method of computing interest during construction is as follows: 0.4 x (construction time in years) x (interest rate). For large scale projects, the construction period is taken as 6 years. Therefore, for an interest rate of 6 %, the interest during construction is calculated as 14.4 % of the project cost.

For the calculation of the annual cost, the rates of amortization and O & M costs are set forth as follows:

| | |
|---|---|
| Amortization (6 % i, 50 yr) | 0.06344 |
| O & M costs | 0.01 |
| | 0.07344 |

Therefore, the annual cost can be calculated as 8.4 % (1.144 x 0.07344) of the project cost.

The annual benefit is calculated from the average annual firm energy output shown in Table 13 and the selling price of the power at 16 mills/kWh. The price of the power is discussed in 4.3.

The project costs of the large scale development are presented as follows.

(1) <u>Chisapani Project</u>

The power will be delivered to India at Mohana. A switching station at Mohana and a 440 kV, double circuit, 40 km long transmission line from the powerplant to Mohana are required.

The total construction cost is as follows.

| | |
|---|---|
| Dam and powerplant | US$548 x $10^6$ |
| Transmission facilities | 17 |
| | US$565 x $10^6$ |

(2) Marsyandi Project

The power will be delivered to India at Bhagawa. A switching station and a 230 kV, double circuit, 60 km long transmission line are required. The total cost will be :

| | |
|---|---|
| Dam and powerplant | US$181 x $10^6$ |
| Transmission facilities | 7 |
| | US$188 x $10^6$ |

(3) Kali Gandaki No. 1 Project

The power will be delivered to Bhairawa. A switching station and a 440 kV, double circuit, 50 km long transmission line are required. The total cost is as follows.

| | |
|---|---|
| Dam and powerplant | US$478 x $10^6$ |
| Transmission facilities | 17 |
| | US$495 x $10^6$ |

(4) Lakarpata Project

It is assumed that the Chisapani Project is already realized before the implementation of the Lakarpata Project is considered. The power will be delivered through a 440 kV, double circuit, 27 km long transmission to the Chisapani powerplant and connected to its double bus. Switch gears are required at the Chisapani Powerplant. The total cost would be :

| | |
|---|---|
| Dam and Powerplant | US$520 x $10^6$ |
| Transmission facilities | 9 |
| | US$529 x $10^6$ |

Based on these costs and aforementioned calculation methods, the annual costs and benefits of these project are computed and presented in Table 14.

Table 14 Cost and Benefit of Large Scale Projects

| Project | Annual Cost ($10^6$US$) | Annual Benefit ($10^6$US$) | B/C | B-C ($10^6$US$) |
|---|---|---|---|---|
| Chisapani | 47.5 | 133.6 | 2.8 | 86.1 |
| Marsyandi | 15.8 | 38.8 | 2.5 | 23.0 |
| Kali Gandaki No.1 | 41.6 | 107.2 | 2.6 | 65.6 |
| Lakarpata | 44.4 | 88.6 | 2.0 | 44.2 |

As described in 6.3, the priority of the project is given to Chisapani, Marsyandi, Kali Gandaki No. 1, and Lakarpata in that order.

## 8.2 Medium to Small Scale Development

### 8.2.1 Kathmandu and Pokhara Development Regions

For the development of the CNPS, the following sequence of project implementation is recommended in 6.4.2.

In 1978/79, Kulikhani No. 1 Project (46 MW)/1
In 1982, Kulikhani No. 2 Project (26 MW)/2
In 1984/85, Dev-Ghat Project (150 MW)/2

This development program would satisfy the combined demand of the CNPS and Dhankuta Region up to 1991/92, provided that the Kankai Project is in existence.

---

/1 The final figure in the feasibility report is 60 MW.

/2 The revision of the scale of the Kulikhani projects will defer the installation schedule of the follow-up projects only by one year respectively.

The study presented in Appendix 2 has proved that this sequence is the optimum one which gives the least present worth of the project costs, considering such relevant factors of demand growth, maturing period of the plant capacity, and supply of surplus energy to India.

Calculation of the relationship of the benefit and cost for individual project cannot be done by the same way as described in the previous article. It would be superfluous to calculate the benefit of the hydropower project without taking account of the demand growth. Furthermore, since the individual project is proved to be the best one suited in that position of the sequence as demonstrated in Appendix 2, the comparison of benefit and cost for each project is not needed any more. The procedure presented in Appendix 2 has actually done the same thing in different manner. However, these cost and benefit figures are given later in this article just for the matter of reference. These figures may be used to judge the superiority of the hydro project over its alternative means, which is rather apparent from the high thermal cost as shown in Table 11.

The construction costs of the Kulikhani No. 1 and No. 2, and Dev-Ghat projects including transmission facilities are given in Appendix 2. For the matter of simplicity, the construction period is assumed to be 5 years for all projects. Based on the interest rate of 6 %, construction period of 5 years, and a project life of 50 years, the annual cost is calculated to be 8.2 % of the construction cost.

The energy of the Kulikhani No. 1 project will be used primarily in local market. While the secondary energy will be exported to India, the amount of which is small enough in its economic evaluation. The maturing time of the project is 3.5 years, and its annual energy output at its ultimate condition is 201 GWh/yr. For the estimation of the energy value, the present value of the total energy consumption over the project life is calculated first, then multiplied by the capital recovery factor to obtain the annual value of the energy production. To convert it to the monetary value, the unit energy values applied here are 20 mills/kWh for domestic use and 8 mills/kWh for export. For the method and formulas of calculating the present value of the total energy consumption, reference is made to the explanation in 3.1, (2) of Appendix 2.

For the calculation of the capacity value, the unit capacity value of 63 US$/kW in Table 11 and the installed capacity of 46 MW are used, since the maturing time is very short.

The energy of the Kulikhani No. 2 Project is also used mainly in the local market. The same procedure as described above is applied for.

The power of the Dev-Ghat Project will serve the local market first, but the surplus energy will be sold to India. The estimated amounts of energy sold to both local and Indian market are presented in 3.3, (2) of Appendix 2. A unit energy value of 20 mills/kWh is used for the local market. For the supply of the surplus energy to India, an acceptable price to the both countries of 8 mills/kWh is assumed, based on the consideration as described in 4.3. Other assumption could be made though. Therefore, the study based on this assumption should be taken as an indicative one.

Since the maturing period of the Dev-Ghat Project is relatively long, being 7 years as shown in Fig. 14, the adjustment of the capacity value is made taking account of this maturing period. The average capacity value over the project life can be calculated by the same procedure and formulas given in 3.1, (2) of Appendix 2. As a result, a discounted figure of 126 MW is used for evaluation of capacity ~~value, in~~ instead of its installation capacity of 150 MW.

The calculated benefit and cost of each project is shown in Table 15.

While Table 15 shows large B/C ratios for the later projects in the sequence, this does not mean the alteration of the proposed sequence is necessary. The Kulikhani No. 2 is not an independent undertaking, and can not precede the Kulikhani No. 1, as the No. 2 project uses the tailwater of Kulikhani No. 1, which uses the water regulated by a reservoir. The Dev-Ghat Project would be too large for early implementation, and its larger B/C ratio shown in Table 15 is simply the reflection of the larger demand at the time of the project implementation and its scale merit. Therefore, the development sequence proposed before will stand as they are.

Table 15 Cost and Benefit of the Project for the CNPS

| | Kuli Kani No. 1 | Kuli Kani No. 2 | Dev-Ghat |
|---|---|---|---|
| **Project** | | | |
| Installed Capacity (MW) | 46 | 26 | 150 |
| Construction Cost ($10^6$US$) | 45.0 | 15.1 | 76.8 |
| **Energy Value** | | | |
| Domestic Use | | | |
| Present Value (GWh) | 2,305 | 1,572 | 7,423 |
| Annual Value (GWh) | 146 | 100 | 471 |
| Unit Value (mill/kWh) | 20 | 20 | 20 |
| Energy Value ($10^6$US$) | 2.9 | 2.0 | 9.4 |
| Export of Energy | | | |
| Present Value (GWh) | 273 | 77 | 4,836 |
| Annual Value (GWh) | 18 | 5 | 307 |
| Unit Value (mill/kWh) | 8 | 8 | 8 |
| Energy Value ($10^6$US$) | 0.1 | 0.04 | 2.5 |
| Total Energy Value ($10^6$US$) | 3.0 | 2.04 | 11.9 |
| **Capacity Value** | | | |
| Capacity (MW) | 46 | 26 | 126 |
| Unit Value (US$/kW) | 63 | 63 | 63 |
| Capacity Value ($10^6$US$) | 2.9 | 1.64 | 7.9 |
| **Total Annual Benefit** ($10^6$US$) | 5.9 | 3.68 | 19.8 |
| **Annual Cost** ($10^6$US$) | 3.7 | 1.24 | 6.3 |
| B/C | 1.6 | 3.0 | 3.0 |
| B - C ($10^6$US$) | 2.2 | 2.44 | 13.5 |

### 8.2.2 Dhankuta Development Region

The Kankai Project (33 MW) is recommended for this region. Its average annual energy output is 156 GWh for the ultimate condition. Since the project takes a relatively long maturing period of 7 years, as shown in Fig. 14, the average annual productions of both energy and capacity are adjusted by the same method as described before. The required transmission facilities are described in 7.2.

The benefit and cost of the project is shown in Table 16.

Table 16 Cost and Benefit of Kankai Project

| | |
|---|---|
| Installed capacity (MW) | 33 |
| Construction Cost ($10^6$US$)/1 | 16.2 |
| Energy Value | |
| Present Value (GWh) | 2,061 |
| Annual Value (GWh) | 131 |
| Unit Value (mill/kWh) | 20 |
| Energy Value ($10^6$US$) | 2.6 |
| Capacity Value | |
| Capacity (MW) | 28 |
| Unit Value (US$) | 63 |
| Capacity Value ($10^6$US$) | 1.8 |
| Total Annual Benefit ($10^6$US$) | 4.4 |
| Annual Cost ($10^6$US$) | 1.3 |
| B/C | 3.4 |
| B - C ($10^6$US$) | 3.1 |

8.2.3 Surkhet Development Region

The predicated power demand in this region is expected to increase rather rapidly in consideration of the industrial plan of this region. The sizable town in the region is Nepalganj. The Sarda Project (49 MW) is proposed for the power supply to Nepalganj and other areas. A single circuit transmission line of 66 kV, 60 km long, is required between the power plant and Nepalganj. Other lines from the power plant to Surkhet and Tulsipur Ghorahi are also proposed. The allocated construction cost would be as follows.

| | |
|---|---|
| Dam and Power plant(allocated) | US$46.8 x $10^6$ |
| Transmission Facilities | 2.3 |
| | US$49.1 x $10^6$ |

/1 Allocated portion of dam cost and powerplant US$12.6 x $10^6$
Transmission facilities 3.6
US$16.2 x $10^6$

However, the capacity of the Sarda Project still appears too large for the demand which is 0.2 MW in 1973/74 and 29.5 MW even in 1989/90, as shown in Fig. 5 of the text or Table 3.12 of Appendix 3. Therefore, the energy of the Sarda Project will have to be sold to India.

The forecasted annual growth rate of the peak demand for Nepalganj in 1989/90 is 10%. If the peak demand grows up continuously at this rate, then the demand would reach the Sarda's capacity around 1995/96.

Suppose the Sarda Project will be in service in 1980/81. Then, the peak demand of the region is 9.9 MW, and it takes 15 years to reach the capacity of the Sarda Project in 1995/96. For such a long build-up period, the straight line increase as assumed in 3.1 (2) of Appendix 2/1 is not adequate, as it cause serious over-estimation of peak and energy consumption over that period.

The forecasted peak and annual energy demands at designated years are as follows.

| Year | Peak (MW) | Annual Energy (GWh) |
|---|---|---|
| 1980/81 | 9.9 | 23 |
| 1995/96 | 49 (full) | 135 |

Such growth of demand is more appropriate to be approximated by a concave curve increase having a constant annual growth rate./2 The annual growth rates of the peak and energy in above case are 11.2 % and 12.5 % respectively. The larger growth rate in the energy demand reflects the improvement in the annual load factor assumed in the forecast.

If the energy and capacity values at the local market, and the selling price of surplus energy to India are assumed to be same as those in 8.2.1, then the cost and benefit of the Sarda Project are calculated and shown in Table 17.

---

/1 As applied in 8.2.1 and 8.2.2 of the text.

/2 The present worth (P) at i % interest of investment of 1 $ at the end of the first year and an amount increasing by j % from year to year until the N years are completed can be calculated by the following formula.

$$P = \frac{(1+i)^N - (1+j)^N}{(i-j)(1+i)^N}$$

Table 17 Cost and Benefit of Sarda Project

| | |
|---|---|
| <u>Project</u> | |
| Installed capacity | 49 MW |
| Construction Cost | US$49.1 x $10^6$ |
| <u>Energy Value</u> | |
| Domestic Use | |
| Present Value | 1,327 GWh |
| Annual Value | 84 GWh |
| Unit Value | 20 mills/kWh |
| Energy Value | US$1.68 x $10^6$ |
| Export of Energy | |
| Present Value | 1,101 GWh |
| Annual Value | 70 GWh |
| Unit Value | 8 mills/kWh |
| Energy Value | US$0.56 x $10^6$ |
| Total Energy Value | US$2.24 x $10^6$ |
| <u>Capacity Value</u> | |
| Capacity | 32 MW |
| Unit Value | 63 US$/kW |
| Capacity Value | US$2.01 x $10^6$ |
| <u>Total Annual Benefit</u> | US$4.25 x $10^6$ |
| <u>Annual Cost</u> | US$4.03 x $10^6$ |
| B/C | 1.05 |

The project is barely justifiable. Besides, it should be noted that it is unreasonable to assume the power supply to India would be made at a low price of 8 mills/kWh for 15 years. For such a long-period supply, both capacity and energy value would have to be sold. An appropriate price of energy would have to be set forth for the improvement of the feasibility of the Sarda Project.

## CHAPTER 9

## INVESTMENT SCHEDULE FOR HYDRO ELECTRIC POWER DEVELOPMENT PROGRAM

### 9.1 General

The implementation of large scale projects require very heavy investment, which fund is likely to be raised from international loan organizations. Also, the project will intend to sell the energy to India, the consent of Indian Government is an indispensable portion of the project preparation. Unless these matters are settled beforehand, it is not possible to set forth the investment time-schedule at this moment.

On the other hand, the medium to small scale projects will have to be implemented in such a way to meet the domestic demand at all times. Financial arrangement should be made well in advance to prepare the project investigation and construction. In this chapter, only the investment schedule of medium to small scale projects is presented.

### 9.2 Investment Schedule

Heretofore, the medium to small scale projects are dealt with based on the preliminary figures of the Kulikhani Projects, the installed capacities and construction costs of which are revised in the feasibility study recently conducted in parallel with this study. As far as the investment schedule of these projects, it is considered realistic and reasonable to use the final figures of the Kulikhani Projects and to revise the investment schedule according with the final figures as this modification does not jeopadize the conclusion of the sequence study presented in Appendix 2. Therefore, in this Chapter discussions are made according with the final figures of the Kulikhani Projects.

The medium to small scale projects recommended in this report so far are as follows.

| Project | Region | Expected in-service date |
|---|---|---|
| Kulikhani No.1 | Kathmandu | 1978/79 |
| Kulikhani No.2 | " | 1983 |
| Dev-Ghat | " | 1985/86 |
| Kankai | Dhankuta | 1978/79 |
| Interconnection of Dhankuta to CNPS | | 1985/86 |
| Sarda | Surkhet | 1980/81 |

The detail of the investment schedule, considering the periods of the investigation and construction, is presented in Fig. 16. In the figure, it is noted that the Kankai Project and the Sarda Project are multipurpose development, and the costs shown includes all the joint cost, as the joint structure (a dam) will have to be constructed in one piece, but associated costs of irrigation facilities are not included.

The item of "Investigation and survey" in Fig. 16 is taken as 35 % of the "Engineering and administration" costs given in Appendix 1 for each project. The remaining portion of "Engineering and administration" cost are mainly for project supervision, and are included in construction cost. The distribution of construction costs over the construction period is made by "Sine square S-curve" method except for the Kulikhani No.1 Project/1. The disbursement schedule of the Kulikhani No.1 Project is referred to the feasibility report.

The costs in Fig. 16 do not include expenses for distribution systems nor for future investigation of hydroelectric projects other than listed in the figure. These expenses are small compared with the fund required for project development.

The summary of investment schedule is shown below:

Table 18 Summary of Investment Schedule

| Year | Investment ($10^6$US$) |
|---|---|
| 1974/75 | 0.6 |
| 75/76 | 4.56 |
| 76/77 | 17.14 |
| 77/78 | 49.58 |
| 78/79 | 46.89 |
| 79/80 | 24.86 |
| 80/81 | 21.84 |
| 81/82 | 22.71 |
| 82/83 | 25.26 |
| 83/84 | 23.83 |
| 84/85 | 13.64 /2 |
| 85/86 | 1.97 |
| Total | 252.88 |

/1 The formula of this method is, $y = \sin^2(90x)$
where, $y$ = the decimal fraction of work complete
$x$ = the decimal fraction of total time for completion of work
This has been used by U.S. Corps of Engineer for contractor earnings versus project time.

/2 The work and cost of preparing the next project to the Dev-Ghat are not included, but the work would be commenced around this year.

Fig. 16 INVESTMENT SCHEDULE

(x10$^3$ US$)

| Project Name | Construction Cost (x10$^3$US$) | 74/75 | 75/76 | 76/77 | 77/78 | 78/79 | 79/80 | 80/81 | 81/82 | 82/83 | 83/84 | 84/85 | 85/86 | 86/87 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kulikhani No.1 (60 MW) | 53,000 | 600 | 4,300 | 7,800 | 23,000 | 17,300 | | | | | | | | |
| Investigation & survey | 1,600 | 600 | 1,000 | | | | | | | | | | | |
| Dam & power station | 49,880 | | 3,300 | 7,500 | 22,400 | 16,680 | | | | | | | | |
| Transmission line | 1,520 | | | 300 | 600 | 620 | | | | | | | | |
| Kulikhani No.2 (35 MW) | 17,000 | | | | | 220 | 2,260 | 4,970 | 6,050 | 3,310 | 190 | | | |
| Investigation & survey | 430 | | | | | 220 | 210 | | | | | | | |
| Dam & power station | 13,670 | | | | | | 2,050 | 4,780 | 4,790 | 2,050 | | | | |
| Transmission line | 2,900 | | | | | | | 190 | 1,260 | 1,260 | 190 | | | |
| Dev-Ghat (150 MW) | 76,800 | | | | | | 740 | 7,400 | 16,660 | 20,570 | 20,420 | 10,420 | 590 | |
| Investigation & survey | 1,480 | | | | | | 740 | 740 | | | | | | |
| Dam & power station | 66,620 | | | | | | | 6,660 | 16,660 | 19,980 | 16,660 | 6,660 | | |
| Transmission line | 8,700 | | | | | | | | | 590 | 3,760 | 3,760 | 590 | |
| East-West Transmission Connection | 9,200 | | | | | | | | | 1,380 | 3,200 | 3,200 | 1,380 | |
| Construction work | 9,200 | | | | | | | | | | | | | |
| Kankai (33 MW) | 33,180 | | 260 | 8,620 | 16,200 | 8,100 | | | | | | | | |
| Investigation & survey | 780 | | 260 | 520 | | | | | | | | | | |
| Dam & power station | 28,800 | | | 7,200 | 14,400 | 7,200 | | | | | | | | |
| Transmission line | 3,600 | | | 900 | 1,800 | 10,900 | | | | | | | | |
| Sarda (49 MW) | 63,700 | | | 720 | 10,380 | 21,270 | 21,860 | 9,470 | | | | | | |
| Investigation & survey | 2,200 | | | 720 | 1,480 | | | | | | | | | |
| Dam & power station | 59,200 | | | | 8,900 | 20,700 | 20,700 | 8,900 | | | | | | |
| Transmission line | 2,300 | | | | | 570 | 1,160 | 570 | | | | | | |
| | 252,880 | 600 | 4,560 | 17,140 | 49,580 | 46,890 | 24,860 | 21,840 | 22,710 | 25,260 | 23,830 | 13,640 | 1,970 | |

CHAPTER 10

# NEED OF FUTURE INVESTIGATION

As described in Chapter 5, tremendous amount of hydropower potential is available in Nepal. However, the investigation of hydropower resouces are not sufficient so far due to various reasons, such as difficulties in access and availability of maps, and lack of fund, facilities and qualified personnels. The projects listed in Table 13 are by no means to cover the all projects in the country. As the total of the capacity of these projects is only a fraction of the total potential, there certainly would be more projects exploitable technically and economically.

The investigation of hydroelectric power development should be performed based on the recognition of present and future status of Nepal's economy. In view of natural resources, topography, and population of the country, the export of hydroelectric energy provided by large scale projects could be a largest industry in the future. For large scale projects, investigations of integrated basin planning are in order, to prevent the individual project jeopardizing each other in the future. An inventry of prospecting projects should be prepared and their priorities assigned, in order that the detailed feasibility study and design of the project can be carried out expeditiously when the economic and political situation becomes favorable for promotion of such projects.

On the other hand, the present situation of energy supply and consumption requires small to medium size projects to be implemented urgently to cope with the growing local demand. Attention should be directed to more run-of-river type development, in the short term at least, as they would be easier to be implemented to meet the immediate local demand. While such project sites are not clearly identified yet, they are preferably located not far from the load centers, such as at the upstream or downstream reaches of the existing power stations, as these places are easy to access, and more information of hydrology and geology is available. In this context, the following rivers appear to be promising to provide good sites.

1. Sapt Gandaki Basin
    a) Seti Khola
    b) Andi Khola
    c) Upstream reaches of Trisuli

2. Sapt Kosi Basin
    a) Upstream reaches of Sun Kosi
    b) Indrawati
    c) Tamba Kosi

It is also felt that more effort should be made on the investigation of medium size rivers of the Bagmati class. The size of the probable projects on these medium size rivers would be more adequate for their early implementation. Also, the access to the project site is generally better than those of the major rivers, and the riparian areas of these rivers are more developed, and densely populated. Therefore, the development of these basins is more directly related with the people's living. With this regard, a multipurpose development of the water resources will have to be looked into.

## REFERENCES


1. "Master Plan for Power Development and Supply", Dept. of Electricity, Nepal, May, 1970.
2. "A Brief Survey of the Geology of Nepal", by Tony Hagen, United Nations, Nov., 1960.
3. "Recommendation of Power Site for Priority, Nippon Koei Co., Ltd., Japan, Oct., 1963.
4. "A Preliminary Design Report on the Kulikhani Project, Nepal", OTCA, Japan, Nov., 1963.
5. "Hydroelectric Development of the Karnali River, Nepal", Nippon Koei Co., Ltd., Japan, Feb., 1966.
6. "A Review of the Feasibility Studies of the Chisapani High Dam Project", Snowy Mountain Hydroelectric Authority, Australia, July, 1968.
7. Comments on "A Review of the Feasibility Studies of the Chisapani High Dam Project", Nippon Koei Co., Ltd., Japan, Feb., 1969.
8. "Interim Report on Feasibility Study on Sun Kosi Terai Project", Nippon Koei Co., Ltd., Japan, Oct., 1969.
9. "The Fourth Plan (1970 - 1975)", National Planning Commission, Nepal, July, 1970.
10. "Preliminary Report on Regional Development Areas in Nepal", National Planning Commission, Nepal, July, 1970.
11. "Load Growth Study & 10 year Generation Plan (3rd edition)", NEC, Nepal, Feb., 1971.
12. "Hydropower Potentiality of Nepal", Dept. of Electricity, Nepal, 1971.
13. "Report on the Sarda (Mahakali) River", WAPCO, India, Nov., 1971.
14. "Reconnaissance Report on Hydroelectric Power Schemes on the Babai and Rapti River", Nippon Koei Co., Ltd., Japan, Oct., 1972.
15. "Feasibility Study of Irrigation Development in the Terai Plain (Phase II)", Nippon Koei Co., Ltd., 1972.
16. "Engineering Report on Kankai Dam and Power Project", Dept. of Electricity, Nepal, June, 1972.

17. "A Reconnaissance Report on the Devighat Hydroelectric Power Project", Nippon Koei Co. Ltd., Japan, Sept., 1972.

18. "Feasibility Report on the Devighat Hydel Project", Dept. of Electricity, Nepal, July, 1973.

19. "Statistical Pocket Book", Nepal, 1974.

## Itinerary of Survey Team

## for

## Hydroelectric Development Projects in Nepal

List of Members

| | |
|---|---|
| Head: | Shigeru Ichiura, Senior Civil Engineer |
| Master Plan Project: | Saburo Suzuki, Senior Electrical Engineer<br>Ichiji Mori, Senior Geologist |
| Kulikhani Project: | Yoshitsugu Nakajima, Senior Civil Engineer<br>Shuhei Nishioka, Senior Geologist<br>Minoru Akiyama, Boring Expert |

Itinerary

| Date | Master Plan Project | Kulikhani Project |
|---|---|---|
| Nov.16,1973 | Leave Tokyo | |
| Nov.17, " | Arrive Kathmandu | |
| " 18, " | Visit to Government Authorities concerned, Embassy of Japan, | |
| " 25, " | Preparations for the work | |
| " 26, " | Inspection of the Karnali River projects, etc. from the air | |
| " 27, " | Collection of data concerning Karnali River, collection of hydrology data | |
| " 29, " | Visit to Mr. P. P. Shaha, Executive chairman of Nepal Electricity Corp. | |
| " 30, " | Visit to Sun Kosi Power Plant (10,050 KW, in operation) and upper reaches of the Sun Kosi River | |
| Dec. 1, " | | |
| " 2, " | Visit to Panauti Power Plant (2,400 kW, in operation) | |
| " 3, " | Obtained Feasibility Report of Devighat Project | |

| Date | Master Plan Project | Kulikhani Project |
|---|---|---|
| Dec. 4,1973 | Visit to Trisuli Power Plant (18,000 kW in Operation) | |
| " 5, " | Visit to Tupche Project under investigation (upstream of Trisuli Power Plant), Visit to Balaju Preparatory works for the field trip to Kulikhani | Arrival of Messrs Nakajima and Nishioka at Kathmandu Preparation of the inspection trip to the Kulikhani project site |
| " 10, " | and Terai area | |
| " 11, " | Leave Kathmandu for Kulikhani and Terai area, Visit to Kulikhani Power plant site | Leave Kathmandu for Kulikhani area, visit to power plant site |
| " 12, " | Visit to Birganj, Bagmati R. dam site | Visit to No.3, No.2 project sites, arrival to No.1 dam site |
| " 13, " | Visit to Janakpur, Kamla river dam site | Investigation of check boring site, quarry and borrow pit site for core material |
| " 14, " | Visit to Sapt Kosi and Barak shetra dam sites via Dahran and Chatra | Leave dam site, return to Kathmandu |
| " 15, " | Try to visit Kankai dam site | |
| " 16, " | Visit to Biratnagar Jute Mill and Nepal Straw Board Co., arrival to Kathmandu by air | |
| " 17, " | Data collection at the Bureau of Statistics | Request for leveling survey, Submit the boring schedule to the Department of Electricity |
| " 18, " | Preparation for the trip to Pokhara, Butwal and Bharatpur | Arrival of Mr. M. Akiyama, a boring expert |
| " 19, " | " | Transport of boring equipment to Kulikhani |
| " 20, " | " | Preparation for 2nd trip to Kulikhani |
| " 21, " | Leave Kathmandu for Pokhara, inspection of Buri/Gandaki and Marsyandi damsites en route | Leave for 2nd trip to Kulikhani |
| " 22, " | Visit to the Seti River project site, Inspection to the intake dam of Pokhara Power Plant (1,000 kW, in Operation) | Inspection of sites for No.3 power house penstock and head tank, Preparation for boring equipment |
| " 23, " | Leave Pokhara for Tansen, visit the Andkikhola and Kali Gandaki project sites en route | Inspection of No.2 project site and preparation for boring |

| Date | Master Plan Project | Kulikhani Project |
|---|---|---|
| Dec.24,1973 | Leave Tansen for Riri Bazar, visit to Kali Gandaki damsite | Inspection of tributary intake sites |
| " 25, " | Leave Riri Bazar, arrive Tansen | Inspection sites of No.1 power penstock and surge tank |
| " 26, " | Leave Tansen, visit to Butwal Technical Institute, Tinan Hydro Power Plant (1,200 kW, under construction) visit Mahendra Sugar & General Industry | Leave Bhumpedi moved to Kulikhani |
| " 27, " | Visit to Gandak Power Plant (15,000 kW, under construction) | Inspection of tributary intake site |
| " 28, " | Leave Bhairawa, arrive Kathmandu | |
| " 29, " | Desk study of obtained data | Leave Kulikhani, arrive Bhumpedi inspection of construction road en route |
| " 30, " | Map study of dam sites, obtained statistical pocket book | Supervision of boring works and percolation test, moved to Kathmandu |
| " 31, " | Preparation for Kulikhani damsite inspection trip, copying of 1-mile, 1-inch map | |
| Jan. 1,1974 | | |
| " 2, " | Courtesy visit and discussion with the Minister of Water and Power | " " |
| " 3, " | Preparation of the comment on the mission | Messrs. Nichioka and Akiyama |
| " 4, " | Collection of hydrological data | Preparation of the comment, supervision of boring |
| " 5, " | | |
| " 6, " | Leave Kathmandu for Kulikhani dam site | Supervision of the boring work |
| " 7, " | Detailed inspection of the Kulikhani dam site | |
| " 8, " | Leave Kulikhani arrive at Kathmandu | Supervision of the boring work |
| " 9, " | Report to Mr. P. P. Shaha with Kulikhani team | |

| Date | Master Plan Project | Kulikhani Project |
|---|---|---|
| Jun.10,1974 | Report to Mr. K. D. Adhikary of the Department of irrigation Report and discussion with the Chief Engineer, Mr. S. K. Malla | Arrangement of survey work Supervision and guidance of the boring works |
| " 11, " | Final arrangement of the survey work, Invited members of Nepal authorities for reception | " |
| " 12, " | | |
| " 13, " | Leave Kathmandu for Bangkok | " |
| " 14, " | Stay BKK for data collection | " |
| " 15, " | " | Leave Kathmandu for Tokyo |
| " 16, " | Leave Bankok for Tokyo | Arrive Tokyo |

# MASTER PLAN OF HYDROPOWER DEVELOPMENT

# IN

# NEPAL

## APPENDICES

## TO

## A MASTER PLAN REPORT PREPARED FOR

## JAPAN INTERNATIONAL COOPERATION AGENCY

1. PROSPECTIVE HYDROPOWER PROJECTS
2. SEARCH PROCEDURE FOR PROJECT SEQUENCING PROBLEM AND ITS APPLICATION
3. POWER STATISTICS AND DEMAND FORECAST
4. HYDROLOGY
5. GEOLOGY

# MASTER PLAN

# OF HYDROELECTRIC POWER DEVELOPMENT

# IN NEPAL

## Appendix 1

## Prospective Hydroelectric Power Project

CONTENTS

## LIST OF TABLE AND FIGURES

APPENDIX 1

# PROSPECTIVE HYDROELECTRIC POWER PROJECTS

## 1. General

Nepal is bestowed with a tremendous hydroelectric power potential owing to its steep topography and abundant precipitation. The estimated theoretical hydroelectric power potential is about 83,000 MW with total annual energy of 727,000 GWh.

The rivers in Nepal can be classified into 3 types according to their water sources. The first type of the rivers originates in the Himalayas, and is fed by snow, glacier, and rainfall. The Mahakali, Karnali, Sapt Gandaki, and the Sapt Kosi rivers belong to this type. Among which, the Mahakali is the western border of the kingdom to India. Since India is investigating the Mahakali now, it is not considered in this study. The second type of the rivers originates in the Mahabharat ranges below the snow line, so that only fed by rainfall. The Kankai Mai, Kamla, Bagmati, and the Babai rivers are of this type. The third type is the small streams and creeks in the Siwalik regions. This type of the river drys up in the dry season, and as such is not favorable for hydropower development.

The theoretical hydroelectric power potentials of these rivers are shown in the following tabulation.

| | |
|---|---|
| Karnali River | 32,000 MW |
| Sapt Gandaki River | 21,000 MW |
| Sapt Kosi River | 22,000 MW |
| Rivers from the Mahabharats | 4,000 MW |

Prospective project sites on aforementioned rivers are selected from the field reconnaissance, studies on 1"-1 mile maps (1/63,360 scale), and review of the published project reports. The scope of works of the Contract has stipulated that the projects to be studied are 24 sites as appeared in the previous master plan. However, those projects judged not favorable in the previous project reports are not included, as this implies that they are not worth further studying. While recommended in some previous project reports, questionable projects found in the field reconnaissance and map studies are also excluded. Instead, some prospective projects found during the course of the investigation are included. Efforts are made to bring these project costs on the same level, as of early-1974.

As a result, 26 propective sites are identified altogether, as listed in Table 1.1. Among which 18 sites are located on the river systems of the Himalayas and the remaining 8 on the rivers from the Mahabharat ranges. Fig. 1.1 shows the project locations.

In locating projects in series in the same river, the headwater and tailwater of each project are so determined as to form an integrated development plan, taking account of the existence of the upstream or downstream project. However, the installation capacity, annual energy output, and construction costs of the project are estimated as an independent construction, and the effect of the upstream project is not accounted for. /1

This appendix describes the outline of the proposed plan, project features, and construction costs, and intends to provide basic information of the master plan. The cost does not include interest during construction, compensation of reservoir areas, and transmission facilities. While these costs are small compared with those for dams and powerplants, they should be appropriately accounted for depending upon the purpose of the study.

---

/1 This has to be considered when the selection of the second project becomes the major concern of the study in the future. Also, the position of a particular project in the power supply system will have to be carefully studied in the advanced stage of the project study, as this would affect the optimum installation of that particular project. For this matter, reference is made to the footnote of page 1-28 of this appendix.

Table 1.1 List of Prospective Hydroelectric Power Projects/1

| Serial No. | Name of Project | Installed Capacity (MW) | Annual Energy Output (GWh) Firm | Annual Energy Output (GWh) Gross/3 | Construction Cost/2 (US$1,000) | Unit Const. Cost Per kW (US$) | Unit Const. Cost Per kWh (US Cent) Firm | Unit Const. Cost Per kWh (US Cent) Gross/3 |
|---|---|---|---|---|---|---|---|---|
| Himalaya Range River System | | | | | | | | |
| I. | Karnali River | | | | | | | |
| 1. | Chisapani | 1,800 | 8,350 | 10,715 | 548,000 | 304 | 6.6 | 5.1 |
| 2. | Lakarpata | 1,200 | 5,540 | 7,110 | 520,000 | 433 | 9.4 | 7.3 |
| 3. | Bhanakot | 810 | 3,740 | 4,800 | 615,000 | 759 | 16.4 | 12.8 |
| 4. | Poliparni | 41 | 320 | | 34,200 | 834 | 10.7 | |
| 5. | Samla | 45 | 350 | | 36,400 | 809 | 10.4 | |
| 6. | Ramni | 20 | 150 | | 32,100 | 1,605 | 21.4 | |
| 7. | Jubitan | 18 | 140 | | 30,000 | 1,667 | 21.4 | |
| 8. | Surket | 600 | 2,780 | 3,570 | 509,000 | 848 | 18.3 | 14.3 |
| 9. | Thapna | 500 | 2,320 | 2,980 | 528,000 | 1,056 | 22.8 | 17.7 |
| 10. | Seti | 270 | 1,250 | 1,600 | 379,000 | 1,404 | 30.3 | 23.7 |
| II. | Sapt Gandaki River | | | | | | | |
| 11. | Dev-Ghat | 150 | 770 | 1,193 | 68,100 | 454 | 8.8 | 5.7 |
| 12. | Kali Gandaki No. 1 | 1,500 | 6,700 | 8,950 | 478,000 | 319 | 7.1 | 5.3 |
| 13. | Kali Gandaki No. 2 | 300 | 1,240 | 2,000 | 156,000 | 520 | 12.6 | 7.8 |
| 14. | Buri Gandaki | 200 | 961 | 1,330 | 96,000 | 480 | 10.0 | 7.2 |
| 15. | Bhomichok | 120 | 455 | 956 | 109,000 | 908 | 24.0 | 11.4 |
| 16. | Marsyandi | 510 | 2,423 | 3,190 | 181,000 | 355 | 7.5 | 5.7 |
| 17. | Seti | 230 | 997 | 1,340 | 98,800 | 430 | 9.9 | 7.4 |
| III. | Sapt Kosi River | | | | | | | |
| 18. | Sun Kosi high dam/4 | 360 | 832 | 2,020 | 103,300 | 287 | 12.4 | 5.1 |
| Mahabharat Range River System | | | | | | | | |
| I. | Bagmati-Rapti River | | | | | | | |
| 19. | Bagmati/4 | 70 | 350 | 490 | 23,400 | 334 | 6.7 | 4.8 |
| 20. | Kulikhani No. 1 | 46/5 | 157 | 201 | 43,600 | 948 | 27.8 | 21.7 |
| 21. | Kulikhani No. 2 | 26/5 | 103 | 120 | 12,200 | 469 | 11.8 | 10.2 |
| 22. | Kulikhani No. 3 | 14/5 | 70 | 91 | 19,900 | 1,421 | 28.4 | 21.9 |
| II. | Kamla River | | | | | | | |
| 23. | Kamla/4 | 30 | 74 | 116 | 9,600 | 320 | 13.0 | 8.3 |
| III. | Kankai Mai River | | | | | | | |
| 24. | Kankai/4 | 33 | 142 | 156 | 12,600 | 382 | 8.9 | 8.1 |
| 25. | Mai Khola Loop | 13 | 47 | 57 | 26,000 | 2,000 | 55.3 | 45.6 |
| IV. | Babai River | | | | | | | |
| 26. | Sarda/4 | 49 | 222 | 249 | 46,800 | 955 | 21.1 | 18.8 |

/1 Installed capacity, energy output, and construction cost of projects are estimated as the projects are independent construction. If the effects of upstream projects are accounted for, the flow pattern of downstream projects would be leveled off, and the effectiveness of the projects would be largely increased.
/2 Cost of transmission line and substation are not included.
/3 Secondary energy included.
/4 Multipurpose development. Cost is for power sector only.
/5 Preliminary figures. See footnotes of pages 1-28, 1-29 and 1-30.

## 2. Himalaya Range River System

### 2.1 Karnali River

The Karnali River flows the western part of the country, and eventually join the Ganges River in India. It drains an area of about 43,000 $km^2$ before leaving Nepal.

The investigation of hydroelectric power development in the Karnali River Basin was carried out in 1966. The study of the basin development plan identified 10 hydropower sites having the generating capacities of 18 MW to 1,800 MW. If all of these were developed, the total capacity would be 5,304 MW. Feasibility reports were prepared for two most favorable sites of Chisapani and Lakarpata (cf. Fig. 1.2).

#### 2.1.1 Chisapani project

General

In the study of the basin plan, the Chisapani project is found to be the largest and most economical one. The project is located in the lower part of the basin near the Indian border, as shown in Fig. 1.2. The catchment area upstream of the dam site is 42,894 $km^2$ and the estimated average annual run-off is 42,200 x $10^6$ $m^3$. A design flood of 25,000 $m^3/s$ is used for planning of the spillway.

The Karnali River flows through the Mahabharat Ranges in a number of long bends, then cuts a gorge through the Siwalik Ranges in north-south direction to debouch on the Terai Plain.

The damsite is located at about the middle of the deepest part of the gorge, where the river width is about 100 m and the side slopes on both banks rise at about $45^o$. The river bed elevation is about 182 m above mean sea level.

The geological formation of the damsite is a monoclinic structure dipping upstream. The rock at the site consists of alternating beds of sandstone and siltstone of the Tertiary Siwalik Zone which form the Siwalik mountains. These rocks are well consolidated and suitable for the construction of a high dam.

Proposed Plan

Chisapani Dam will be an arch gravity structure with a maximum height of 207 m, impounding a storage capacity of 15,100 x $10^6$ $m^3$, of which 7,300 x $10^6$ $m^3$ is effective. The dam will have a mass of 3.7 x $10^6$ $m^3$ of concrete.

The normal water surface will be at El. 370 m, and the low water surface at El. 333.7 m, resulting a maximum drawdown of 36.3 m.

Two side-channel and tunnel type spillways will be laied out on either side of the river, designed to handle a maximum flood of 25,000 $m^3$/s. Each overflow section of the side channel spillway will be 100 m long equipped with four 8 m high drum gates. The discharge tunnel will have an inside diameter of 15.4 m.

The powerplant will be located at the downstream toe of the dam. Six intakes on the upstream face of the dam and the same number of 6 m inside diameter steel penstocks passing through the dam will convey water from the reservoir to the powerplant. The powerplant will house 6 turbine-generator units with capacities of 300 MW each. The total installed capacity will be therefore 1,800 MW.

The firm continuous discharge of the plant will be 787 $m^3$/s, which gives the firm capacity of 990 MW. The average annual firm energy output is estimated to be 8,350 GWh.

A cement factory of 300,000 t/yr capacity will be set up as an independent business enterprise selling the cement to the project at a profit.

An alternative scheme of a gravel fill dam has been considered at the southern end of the Chisapani Gorge, which is about 1.8 km downstream from the concrete damsite. The gravel fill dam will be about 188 m high above the stream bed, and have a volume of 31.5 x $10^6$ $m^3$. A surface power station and an open chute spillway will be located on the right bank side. The installed capacity of the power house will be 1,800 MW. Further study is required before final decision for the site and type of the dam can be made.

Construction Cost

The construction costs of the dam and power station are estimated to be US$548 x $10^6$. From this, the unit construction cost is calculated to be 6.6 US¢/kWh and 304 US$/kW.

The construction costs by features are shown below.

| | |
|---|---|
| Preparatory works: | US$34.3 x $10^6$ |
| Diversion tunnel: | 48.2 |
| Dam: | 142.3 |
| Spillway: | 37.2 |
| Waterway: | 20.9 |
| Power plant: | 28.98 |
| Generating equipment: | 110.0 |
| Sub-Total | US$421.88 x $10^6$ |
| Engineering & Administration: | 42.12 |
| Contingencies: | 84.0 |
| Total | US$584.0 x $10^6$ |

2.1.2 Lakarpata project

The Lakarpata project could be developed either as a high head project with a storage reservoir or as a run-of-river project, but the former is found to be a more profitable scheme. In either case power would be produced by diverting the water of the Karnali River to the Bheri River through a tunnel and underground power house, as shown in Fig. 1.2. The damsite will be located at 135 km upstream of the Chisapani site along the river course. The power station will be located on the Bheri River 24 km above its confluence with the Karnali River. The damsite is composed of hard sandstone and siltstone, suitable for high dam construction.

The Lakarpata storage project comes next to the Chisapani project in terms of development scale and economy. The catchment area above the dam site is 20,970 $km^2$ and the estimated average annual run-off is 16,800 x $10^6$ $m^3$.

The project includes a concrete gravity dam of 197 m high, containing 4.44 x $10^6$ $m^3$ of concrete, to be built in the valley at the tip of the bend, raising the reservoir normal high water level to El. 720 m, and thereby creating a total head of 320 m. At the normal high water surface, the dam will impound a gross storage of 2,600 x $10^6 m^3$. With a maximum drawdown of 60m, the effective storage of the reservoir will be 1,860 x $10^6 m^3$. The installed capacity of the Lakarpata project will be 1,200 MW and will provide the annual firm energy output of 5,540 GWh.

The construction cost of the dam and power station is estimated at US$520 x $10^6$, thereby, the unit construction cost is calculated as 9.4 US¢/kWh end as 433 US$/kW.

2.1.3 Bhanakot project

The backwater of the Lakarpata storage project reaches a point about 8 km downstream from the confluence of the Karnali and the Sinja Khola, as shown in Fig. 1.2. The Bhanakot project is to locate a dam at 2.5 km below the confluence, and lead the water through a 6 km long tunnel to the downstream power plant, which tailwater is set forth in conformity with the Lakarpata's back water. A dam about 200 m high could be built to create a reservoir with its normal water surface at El. 1,080 m. About 320 m of the head is available for power generation.

The catchment area above the dam site is 19,130 $km^2$ and the estimated average annual run-off is 15,300 x $10^6$ $m^3$.

The installed capacity of the Bhanakot project will be 810 MW. About 3,740 GWh of firm energy will be generated annually. The total construction cost is estimated at US$615 x $10^6$, which gives the unit construction cost of 16.4 US¢/kWh and 759 US$/kW.

2.1.4 Jubitan, Ramni, Samla and Poliparni Projects

The gradient of the Sinja Khola, a tributary of the Karnali river joining with the main stream just upstream of the Bhanakot project site, forms a very steep slope of 1/30. This tributary has the possibility for run-of-river type development which can be promoted in series. The projects selected are the Jubithan, Ramni, Samla, and Poliparni as shown in Fig. 1.2. For the Jubithan Project, the most upstream one, the estimated average annual run-off from the catchment area of 2,740 $km^2$ is 2,190 x $10^6$ $m^3$.

The other 3 projects will take the tailwater in turn from the upper project. The total installed capacity and the annual firm energy output of the 4 projects will be 124 MW and 960 GWh, which are shown as follows.

| Projects | Installed capacity (MW) | Annual firm energy output (GWh) |
|---|---|---|
| Jubithan | 18 | 140 |
| Ramni | 20 | 150 |
| Samla | 45 | 350 |
| Poliparni | 41 | 320 |

The construction costs, unit construction costs and the length of the waterway for these projects are as follow.

| Project | Const. Cost (US$1,000) | Unit Const Cost per kWh (Cents) | Unit Const Cost per kW ($) | Length of Waterway (km) |
|---|---|---|---|---|
| Jubithan | 30,000 | 21.4 | 1,667 | 12.0 |
| Ramni | 32,100 | 21.4 | 1,605 | 6.5 |
| Samla | 36,400 | 10.4 | 809 | 9.0 |
| Poliparni | 34,200 | 10.7 | 834 | 6.5 |

2.1.5 Surkhet Project

The Surkhet project is located on the Bheri River at about 70 km upstream from its confluence with the Karnali main stem, see Fig. 1.2. The site is selected taking account of the normal water surface of the Chisapani Project.

The catchment area upstream of the dam site is 11,780 $km^2$ and the estimated average annual run-off is 13,100 x $10^6$ $m^3$.

The Surkhet project will be a reservoir type project. Its normal water surface will be at El. 555 m, thereby creating an active storage of 2,700 x $10^6$ $m^3$ and a head of 160 m.

The installed capacity and annual firm energy output will be 600 MW and 2,780 GWh respectively. The construction cost is estimated to be US$509 x $10^6$. Therefore, the unit construction costs calculated are 848 US$/kW and 18.3 US¢/kWh.

### 2.1.6 Thapna Project

The Thapna project will be also a reservoir type development, and located on the Bheri River about 50 km upstream from the Surkhet damsite, see Fig. 1.2. The catchment area above the damsite is 11,090 $km^2$ and the estimated average annual run-off is 12,300 x $10^6$ $m^3$.

The normal water surface of the reservoir is fixed at El. 740 m. The reservoir will create an active storage of 2,010 x $10^6$ $m^3$ and a head of 160 m.

The installed capacity of the project will be 500 MW, and the annual firm energy output is estimated to be at 2,320 GWh. The total construction cost is about US$528 x $10^6$. The unit construction costs calculated are 1056 US$/kW and 22.8 US¢/kWh.

### 2.1.7 Seti Project

The Seti project is located on the Seti River about 10 km upstream from its confluence with the Karnali main stem, see Fig. 1.2. It will be a reservoir type project at the upper end of the Chisapani reservoir.

The catchment area above the dam site is 7,090 $km^2$, and the average annual run-off is estimated to be at 9,400 x $10^6$ $m^3$.

The normal water surface of the reservoir will be at El. 550 m. An active storage capacity of 1,000 x $10^6$ $m^3$ and a head of 158 m can be created.

The installed capacity of the project will be 270 MW, which will yield an annual firm energy output of 1,250 GWh. The total construction cost of the dam and power station is estimated to be about US$379 x $10^6$. The unit construction costs calculated are 1404 US$/kW and 30.3 US¢/kWh.

## 2.2 Sapt Gandaki River

The Sapt Gandaki River is one of the three large rivers in Nepal draining the central part of the country. The river basin has an area of 34,960 $km^2$ before it leaves the Nepal territory, including about 5,000 $km^2$ in Tibet.

In the Sapt Gandaki basin, two hydropower stations, the Pokhara and Trisuli, were developed with installed capacities of 1,000 kW and 18,000 kW respectively. Also, the feasibility study of the Devighat with an installed capacity of 14,000 kW has been completed, and will be implemented in near future. The hydropower development plans for other sites have not been studied beyond the extent of field reconnaissance.

The seven power project sites for reservoir type development are selected based on the field reconnaissance and the map study of a scale of 1 inch to a mile.

### 2.2.1 Dev-Ghat Project

General

The damsite of the Dev-Ghat Project is located on the Sapt Gandaki main stem about 1 km downstream from the confluence of the Kali Gandaki and the Trisuli Rivers (cf. Figs. 1.1 and 1.3). The catchment area is 32,130 $km^2$ at the damsite and the estimated average annual run-off is $50,380 \times 10^6$ $m^3$.

The damsite is composed of the lower Siwaliks Formation of sandstone, siltstone and shale of Plio-Pleistocene Age. While sandstone is predominant at the site, the rock is not so hard. The river bed is at about El. 182 m, and the width of the stream is about 250 m. Thick alluvial deposits of sand and gravel cover the river bed, the depth being estimated to be 15 to 30 m. Both banks of the river are not high, especially the left bank is very low, forming a very gentle slope. The topography and geology of the site appear to limit the dam at a moderate height.

Since the basin is very large, heavy sediment loads and large floods would become pertinent problems to deal with in the planning of the dam project.

## Proposed Plan

The dam will be an embankment structure, with a maximum height above streambed of 40 m. A sufficient length of upstream impervious branket will be provided to reduce excessive seepage underneath the dam. About 1.5 x $10^6$ $m^3$ of embankment materials will be required.

A chute spillway with gate-controlled crest will be located on the left abutment. The top of the gate will be at El. 220 m and the overflow crest be at El. 208 m, which gives the height of the gate of 12 m. The spillway will have an overflow length of 255 m, and can discharge the estimated maximum flood of 21,100 $m^3/s$.

It is anticipated that the reservoir will be silted up eventually to the overflow crest of the spillway. Therefore, only the gate-controlled portion of the storage will be effective, which amounts to 160 x $10^6$ $m^3$. The storage is sufficient for monthly regulation to keep the firm continuous flow of 314.5 $m^3/s$. The storage curve of the reservoir is shown in Fig. 1.3.

The powerplant will be located downstream of the dam at the right bank. Three 8 m diameter tunnels will lead the flow from the reservoir to the powerplant, by which a maximum gross head of 35 m will be attainable. The installed capacity of the powerplant will be 150 MW, and the average annual firm energy output is estimated to be 770 GWh.

Owing to the occurrence of large floods expected at the site, special consideration is required for the diversion during construction. A 10 m diameter diversion tunnel will be driven in the both abutment, and the concrete works of the spillway will have to be completed before the commencement of the embankment construction. Then the first stage of the embankment will be built higher than the sill elevation of the spillway in one dry season. Incorporated with the completed embankment, floods during construction will be partly diverted through the tunnels, and partly through the spillway.

## Construction Cost

The total construction cost of dam and power station is estimated to be US\$68.1 x $10^6$, which gives the unit construction cost of 454 US\$/kW and 8.8 US¢/kWh.

The construction costs by features are shown in the following.

| | |
|---|---|
| Preparatory works: | US$1,300 x $10^3$ |
| Diversion during construction: | 4,700 |
| Dam: | 5,200 |
| Spillway: | 14,000 |
| Waterway: | 9,800 |
| Power plant: | 3,300 |
| Generating equipment: | 16,100 |
| Sub-total | US$54,400 x $10^3$ |
| Engineering & Administration: | 4,240 |
| Contingencies | 9,460 |
| Total | US$68,100 x $10^3$ |

2.2.2 Kali Gandaki No. 1 Project

General

The damsite of the Kali Gandaki No. 1 project is located on the Kali Gandaki river about 4 km upstream from its confluence with the Riri Khola, a tributary of the Kali Gandaki river as shown in Fig. 1.1 and 1.4. At the vicinity of the damsite, the river runs westward along the Mahabharat Ranges, turns south to cut across the ranges, then flows eastward to form a big loop. The portion of the river cutting across the ranges is a deep gorge suitable for high dam construction. Taking advantage of its topography, the project intends to make a short-cut of the loop to attain a high head for power generation. The catchment area is 9,200 $km^2$ at the damsite, and the estimated average annual run-off is 11,760 x $10^6$ $m^3$.

The geological formation of the damsite is composed of calcareous sandy schist, schistose limestone, siliceous slaty schist, and graphite chlorite talc schist of Pre-Cambrian-Lower Palaeozoic Age. The river at the damsite is very narrow and both banks form high steep slopes. The riverbed elevation is at about El. 518 m, and the river width at the water level is about 60 m.

Proposed Plan

A 214 m high rockfill dam is conceived at this site. It will create a reservoir having a gross storage of 7,000 x $10^6$ $m^3$ at the normal high water surface El. 725 m. With a maximum drawdown of 65 m, the effective storage will be about 4,480 x $10^6$ $m^3$. The storage curve is shown in Fig. 1.4. The dam will require embankment materials of about 43.5 x $10^6$ $m^3$.

Tunnel spillways are considered at this site mainly for the purpose of cost estimation. Four 10 m diameter tunnel spillways with gated overflow crests will be used, located 2 for each bank. The spillways will be designed to handle a maximum inflow flood of 14,000 $m^3$/s.

An alternative spillway site can be located at about 21 km upstream of the dam site where the ridge of the Mahabharat Ranges is very thin, see Fig. 1.4. By cutting this thin ridge, an open chute spillway can be laid out.

The powerplant will be located a little upstream of the alternative spillway site as shown in Fig. 1.4. By short-cutting the narrow ridge of the Mahabharat, a gross head of 362 m can be attained. Three 7.6 m diameter power tunnel will be driven to convey the water to the powerplant. A firm continuous flow of 300 $m^3$/s is available for power generation. The powerplant will have an installed capacity of 1,500 MW. The average annual firm energy output is estimated to be 6,700 x $10^6$ GWh.

Construction Cost

The total construction cost estimated is US\$478 x $10^6$, which gives the unit construction cost of 319 US\$/kW and 7.1 US¢/kWh.

Details of the estimation are shown as follows.

| | |
|---|---|
| Preparatory works: | US\$10,300 x $10^3$ |
| Diversion tunnels: | 8,100 |
| Dam: | 141,000 |
| Spillway: | 25,100 |
| Waterway: | 89,500 |
| Power plant: | 7,500 |
| Generating equipment: | 80,700 |
| Sub-total | US\$362,200 |
| Engineering & Administration: | 36,200 |
| Contingencies: | 79,600 |
| Total | US\$478,000 |

### 2.2.3 Kali Gandaki No. 2 Project

General

The Kali Gandaki No. 2 project is located downstream from the Kali Gandaki No. 1 Project. Its damsite is situated on the Kali Gandaki at about 22 km upstream from its confluence with the Trisuli river, as shown in Fig. 1.1 and Fig. 1.3 The catchment area above the site is 11,330 $km^2$, and the estimated average annual run-off is 17,250 x $10^6 m^3$.

The geological formations are similar to those of the Kali Gandaki No. 1.

Proposed Plan

The dam will be a 140 m high rockfill structure, having an embankment volume of about 9.8 x $10^6 m^3$. At the normal water surface El. 363 m, the dam will impound a gross storage of 640 x $10^6 m^3$. The lake formed by the dam will back up to the tailrace pool at the Kali Gandaki No. 1 power-plant. With a maximum drawdown of 33 m, an effective storage of 360 x $10^6 m^3$ is available. The storage curve is shown in Fig. 1.3. The reservoir can provide a firm continuous flow of 156 $m^3/s$.

Four 10 m diameter tunnel spillways, located two in each bank, are conceived as a preliminary project layout and used for cost estimation. The spillway will be designed for a maximum flood of 16,000 $m^3/s$.

The powerplant will be located at the left bank about 1.6 km down-stream from the dam. Two 7 m diameter tunnels will convey water from the reservoir to the powerplant, by which a maximum gross head of 143 m is attainable. The installed capacity of the powerplant will be 300 MW, and the average annual firm energy output is estimated to be 1,240 GWh.

The total construction cost of dam and power plant is estimated at US$156 x $10^6$ which gives the unit construction cost of 520 US$/kW and 12.6 US¢/kWh. The breakdown of the estimate is shown as follows.

| | |
|---|---|
| Preparatory works: | US$5,800 x $10^3$ |
| Diversion tunnels: | 5,900 |
| Dam: | 33,000 |
| Spillway: | 19,800 |
| Waterway: | 27,800 |
| Power plant: | 3,140 |
| Generating equipment: | 23,000 |
| Sub-total | US$118,440 |
| Engineering & Administration: | 11,560 |
| Contingencies: | 26,000 |
| Total | US$156,000 |

### 2.2.4 Buri Gandaki Project

#### General

The damsite of the Buri Gandaki project is selected on the Buri Gandaki river at about 2 km upstream from its confluence with the Trisuli river, see Fig. 1.1 and Fig. 1.5. The catchment area above the damsite is 5,840 $km^2$, and the annual run-off estimated is 6,460 x $10^6 m^3$. The geology of the damsite is composed of older rock formation of calcareous schist, schistose limestone, quartz schist, garnet epidote schist and semi-schist of slate and siliceous sandstone. Both abutments are fairly steep, and the site appears to be good for high dam construction.

Access to the damsite is good, because the new Kathmandu-Pokhara Highway passes by the vicinity areas.

#### Proposed Plan

The dam will be a rockfill structure, with a maximum height above stream bed of 135 m. About 6.8 x $10^6 m^3$ of embankment materials will be required.

The reservoir will have a storage capacity of 1,270 x $10^6 m^3$ at the normal water surface El. 485 m, of which 770 x $10^6 m^3$ will be available as effective storage with a maximum drawdown of 25 m. The storage curve is shown in Fig. 1.5. The reservoir will provide a firm continuous flow of 101.5 $m^3/s$.

Four 10 m diameter tunnel spillways designed to discharge a maximum flood of 11,500 $m^3/s$ are used for the cost estimation.

The powerplant will be located at the left bank immediately downstream from the dam, and thereby a maximum gross head of 150 m is available. The diameter of the power tunnel will be 8 m. The installed capacity of the powerplant will be 200 MW, and the stimated annual firm energy output will amount to 961 GWh.

Construction Cost

The total construction cost of the dam and power plant are estimated at US\$96 x $10^6$, which gives the unit construction cost of 10 US¢/kWh and 480 US\$/kW.

The details of the estimation are as follows.

| | |
|---|---|
| Preparatory works: | US\$1,830 x $10^3$ |
| Diversion tunnels: | 5,560 |
| Dam: | 25,500 |
| Spillway: | 18,500 |
| Waterway: | 8,460 |
| Power plant: | 2,150 |
| Generating equipment: | 12,000 |
| Sub-total | US\$74,000 x $10^3$ |
| Engineering & Administration: | 7,400 |
| Contingencies: | 14,600 |
| Total | US\$96,000 x $10^3$ |

2.2.5 Bhomichock Project

General

The damsite of the Bhomichock project is located on the Trisuli river at about 15 km upstream from its confluence with the Marsyandi river (cf. Figs. 1.1 and 1.5). The catchment area at the damsite is 12,380 $km^2$, and the average annual run-off is estimated to be 13,520 x $10^6 m^3$.

The geological formation of the site is composed of metamorphic rock of sandstone, slate, quartzite, schist, and gneiss of the late Pre-Cambrian Age. The alluvial deposit of the stream is thin, and some outcrops are observed at the stream bed and brinks. Both abutments are relatively steep, being about 45°. This place appears to be a good damsite.

The Kathmandu-Pokhara Highway, newly completed, is passing by along the Trisuli river. The elvation of the highway will control the head water surface of the project.

Proposed Plan

The dam will be a concrete gravity structure with a maximum height of about 80 m above the streambed. Its length will be approximately 250 m, of which 190 m will be the overflow section equipped with 12 m high gates. The overflow section will be capable to discharge a maximum flood of 16,000 $m^3/s$. The volume of the dam is estimated to be 360,000 $m^3$.

The normal water surface will be set at El. 335 m so that the new highway will not be submerged. The reservoir below the crest of the overflow section will be eventually silted up. Therefore, only the storage controlled by gates will be accounted as effective, which is estimated to be about 10 x $10^6 m^3$. The project will be planned for a 95 % dependable natural flow of 88 $m^3/s$. The effective storage is sufficient for weekly regulation.

The powerplant will be located at about 500 m downstream from the confluence of the Trisuli river and the Marsyandi river. The flow will be conveyed from the damsite to the powerplant through a 7.5 m diameter, 10.5 km long tunnel, by which a maximum head of 115 m is attainable. The installation capacity of the plant will be 120 MW, and produce average annual firm energy of 455 GWh. (This project is likely to be implemented after the Buri Gandaki Project. If so, the power figures would be much more improved than the ones shown above).

Construction Cost

The total construction cost is estimated at US$109 x $10^6$, which gives the unit construction cost of 24.0 US¢/kWh and 908 US$/kW.

Details of the estimation are shown in the following tabulation.

| | |
|---|---|
| Preparatory works: | US$2,050 x $10^3$ |
| Diversion tunnel: | 1,940 |
| Dam: | 20,200 |
| Waterway: | 48,400 |
| Power plant: | 1,610 |
| Generating equipment: | 9,650 |
| Sub-total | US$83,850 x $10^3$ |
| Engineering & Administration: | 8,380 |
| Contingencies: | 16,770 |
| Total | US$109,000 x $10^3$ |

2.2.6 Marsyandi Project

General

The damsite of the Marsyandi project is selected on the Marsyandi river at about 1.0 km upstream from its confluence with the Trisuli river, as shown in Figs. 1.1 and 1.5. The catchment area at the damsite is 4,600 $km^2$, and the estimated average annual run-off is 7,250 x $10^6 m^3$.

The geology of the damsite is composed of semi-schist of chlorite quartz schist, quartz schist, siliceous schist of Pre-Cambrian-Lower Palaezoic Age, being weathered and cracky.

The river width is about 80 m, and the both banks rise up at a slope of about $30^o$. While the overburden of both banks appear to be rather thick, the alluvial deposit of the river is thin.

The access to the damsite is exceptionally good, as the new highway passes by the very vicinity of the site.

Proposed Plan

A rockfill dam with a maximum height of about 140 m is envisaged at this site. About 11.3 x $10^6 m^3$ of embankment materials will be required. At the normal water surface of El. 470 m, the dam will impound a gross storage of 2,800 x $10^6 m^3$. With a maximum drawdown of 30 m, an effective storage of 1,800 x $10^6 m^3$ is attained. The storage curve of the reservoir is shown in Fig. 1.5. The reservoir will provide a firm continuous flow of 151.7 $m^3/s$. Four 10 m diameter tunnel spillways will discharge a maximum flood of 11,000 $m^3/s$.

The powerplant will be located at the right bank of the Trisuli River about 500 m downstream from its confluence with the Marsyandi River, see Fig. 1.5. Two 6.7 m diameter tunnel, driven in the right abutment, will convey water from the reservoir to the powerplant. A gross head of 250 m will be attained. The installed capacity of the plant will be 510 MW, which will produce an average annual firm energy of 2,423 GWh.

Construction Cost

The total construction cost is estimated at US\$181 x $10^6$, which gives the unit construction cost of 7.5 US¢/kWh and 355 US\$/kW.

The details of the construction costs are shown below by features.

| | |
|---|---|
| Preparatory works: | US\$2,400 x $10^3$ |
| Diversion tunnels: | 6,000 |
| Dam: | 39,800 |
| Spillway: | 18,500 |
| Waterway: | 40,400 |
| Power plant: | 3,900 |
| Generating equipment: | 28,000 |
| Sub-total | US\$139,000 x $10^3$ |
| Engineering & Administration: | 14,000 |
| Contingencies: | 28,000 |
| Total | US\$181,000 x $10^3$ |

2.2.7 Seti Project

General

The damsite of the Seti project is located on the Seti river at the point 2.8 km downstream from its confluence with the Madi river (cf. Figs. 1.1 and 1.6). The catchment area is 2,780 $km^2$ at the damsite, and the estimated average annual run-off is 4,640 x $10^6 m^3$. The river at the site is about 100 m wide, and both banks rise up at the slope of about 45°. The bedrock is composed of old metamorphic rocks.

Proposed Plan

The dam will be a rockfill structure of 140 m high from the streambed. The volume of the dam is estimated to be 7.7 x $10^6 m^3$. At the normal water surface of El. 415 m, the reservoir will have a gross storage of 2,360 x $10^6 m^3$. With a maximum drawdown of 40 m, an effective storage of 1,760 x $10^6 m^3$ is attained. The storage curve of the reservoir is shown in Fig. 1.6. The reservoir will provide a firm continuous flow of 121.5 $m^3/s$. Three 10 m diameter tunnel spillways will be able to discharge a maximum flood of 9,100 $m^3/s$.

The powerplant will be located at the left bank immediately downstream of the dam. Owing to the steepness of the topography, an underground plant could be the solution at this site (cf Fig. 1.6). A power tunnel of 8.5 m diameter will convey water from the reservoir to the plant. A gross head of 145 m is available. The installation capacity of the plant will be 230 MW, which can produce an average annual firm energy of 997 GWh.

Construction Cost

The total construction cost is estimated at US$98.8 x $10^6$, which gives the unit construction cost of 9.9 US¢/kWh and 430US$/kW.

Details of the estimation are shown below by features.

| | |
|---|---|
| Preparatory work: | US$2,270 x $10^3$ |
| Diversion tunnels: | 3,990 |
| Dam: | 27,000 |
| Spillway: | 13,900 |
| Waterway: | 12,800 |
| Powerplant: | 2,340 |
| Generating equipment: | 13,700 |
| Sub-total | US$76,000 x $10^3$ |
| Engineering & Administration: | 7,600 |
| Contingencies: | 15,200 |
| Total | US$98,800 x $10^3$ |

## 2.3 Sapt Kosi River

The Sapt Kosi river is one of three major rivers in Nepal draining the eastern part of the country. The river has catchment areas of 60,400 $km^2$ at the border of Nepal and India, of which 32,260 $km^2$ are in the Tibetan plateau.

In the Sapt Kosi river basin, two hydropower stations, namely, the Panauti and Sunkosi, were developed with installed capacity of 2,400 kW and 10,500 kW respectively. Other hydropower projects in the Sapt Kosi river basin that have been studied are the Sun Kosi high dam project and the Barakshetra project.

The Barakshetra project includes the construction of a high dam at about 10 km upstream from Chatra, a town situated near the place where the Sapt Kosi debouches on the Terai Plain. This project was investigated by the government of India, but was found to be not favorable due to the heavy reservoir sedimentation. Since the feasibility of the Barakshatra project has been questioned, only the Sun Kosi high dam project is considered herein.

### 2.3.1 Sun Kosi High Dam Project

General

The development scheme of the Sun Kosi high dam project was finalized in the report of the Feasibility Study of Irrigation Development in Terai Plain, issued in 1972. In this report, a system analysis for the overall planning of the projects was made on various alternative schemes. Two prominent schemes have been considered; one is to divert the Sun Kosi river's water to the Kamla river, intending the irrigation of the eastern Terai Plain as well as the generation of power, the other is to develop the Kamla and Sun Kosi rivers independently. The study has concluded that the latter scheme is more favorable than the former one.

The proposed site for the Sun Kosi High Dam Project is located on the Sun Kosi river near the Chipter village at about 10 km downstream from its confluence with the Dudth Kosi river, see Fig. 1.1 and Fig. 1.7. The catchment area above the damsite is 16,200 $km^2$, which will yield an average annual run-off of $20,150 \times 10^6 m^3$. The geology of the damsite is composed of schist, calciphyre, and metamorphosed limestone. These rocks have many cracks, joints and fissures owing to great lateral pressure related to the Himalayan orogenic motion. The width of the river is about 100 m. The right bank is very steep, the slope being about $50^o$ to $60^o$. The left bank is steep up to about 10 m above the streambed, then turns to be a gentle slope covered by thick talus. The alluvial deposit is very deep at the mid-stream, being about 26 m, and become shallower near the both banks.

## Proposed Plan

The Sun Kosi High Dam Project will be a multi-purpose development, storing water for irrigation and power generation, and providing a temporary reservoir space by surcharge for flood control.

The dam will be a 122 m high concrete gravity structure, having a spillway section at its mid-portion. The concrete volume of the dam is estimated at about $1.74 \times 10^6 m^3$. The design flood of the spillway is about 15,600 $m^3/s$.

The reservoir will have a capacity of $1,840 \times 10^6 m^3$ at normal water surface El. 424.7 m, of which $1,060 \times 10^6 m^3$ are effective and used for irrigation and power generation. The storage curve is shown in Fig. 1.7. The regulated flow will be released to the river and picked up at downstream for irrigation of 746,000 ha of lands, mostly in India. In this context, firm continuous flow of 130 $m^3/s$ is allocated to power generation. The powerplant will be located at the downstream toe of the dam, and a gross head of 120 m is available. With its installed capacity of 360 MW, an annual firm energy of 832 GWh can be generated.

## Construction Cost

The total cost of Sun Kosi High Dam Project including irrigation and power facilities is estimated to be US$$710 \times 10^6$, of which US$$119.0 \times 10^6$ is the joint cost of irrigation and power sectors. One third of the joint cost will be allocated to power sector. The specific cost of power facilities except the transmission lines is estimated to be US$$63.6 \times 10^6$. Therefore, the cost of power sector will amount to US$$103.3 \times 10^6$, which gives the unit construction cost of 12.4 US¢/kWh and 287 US$/kW.

The details of the joint cost and specific cost are given below:

Joint Cost (Dam and ancillary work):

| | | |
|---|---|---|
| Preparatory works: | US$15,700 x $10^3$ | |
| Diversion tunnel: | 3,650 | |
| Dam | 72,300 | |
| Sub-total | 91,650 | |
| Engineering & Administration: | 9,160 | |
| Contingencies: | 18,190 | |
| Total for Dam | US$119,000 x $10^3$ | (Allocation to power is 1/3) |

Power facilities:

| | |
|---|---|
| Waterway: | 4,910 |
| Power plant: | 4,450 |
| Generating equipment: | 39,600 |
| Sub-total | 48,960 |
| Engineering & Administration: | 4,840 |
| Contingencies: | 9,800 |
| Total for power | US$63,600 x $10^3$ |
| Total of Dam and Power facilities | US$182,600 x $10^3$ |
| Allocated cost for power sector: | US$103,300 x $10^3$ |

## 3. Mahabharat Range River System

### 3.1 Bagmati River

The Bagmati river is one of the medium size rivers in Nepal draining through the Kathmandu Valley in Central Nepal. The river basin has an area of 3,610 $km^2$ at the border of Nepal and India. In the Bagmati river basin, two hydropower stations, the Sundarirjal and the Pharping power stations, were developed with installed capacity of 800 kW and 500 kW respectively. Four projects are identified as prospective ones: one on the Bagmati main river and the other are successive development of diverting the Kulikhani's flow (a tributary of the Bagmati) to the East Rapti river. There would certainly be more sites suitable for power generation, and should be looked into carefully in the future.

#### 3.1.1 Bagmati Project

General

The location of the Bagmati project is shown in Figs. 1.1 and 1.8. The damsite is situated at 5 km upstream from the East-West Highway bridge crossing the Bagmati river, so that the accessibility to the site is good. The catchment area above the damsite is 2,715 $km^2$, and the estimated average annual run-off is 4,250 x $10^6 m^3$.

The river at the site is about 80 m wide. The both banks rise up at relatively gentle slopes; the right bank being at $25^o$, and the left bank flatter than that. Both banks open wide about 100 m above the stream bed.

The geological formation of the damsite is composed of alternation of sandstone, shale and siltstone of Lower Siwaliks Formation which belongs to Plio-Pleistocene Age. The rocks are not hard.

The sand and gravel deposits in the river channel are deep, being estimated to be at 15 m to 25 m.

Proposed Plan

The Bagmati project, as planned, is a multipurpose development which includes power generation, irrigation and flood control.

A rockfill dam of about 96 m high is envisaged at this site. The dam will require 6.4 x $10^6 m^3$ of embankment materials. At the normal water surface of El. 217.3 m, the reservoir will have a storage of 2,120 x $10^6 m^3$, of which 1,560 x $10^6 m^3$ is effective. The storage curve of the reservoir is shown in Fig. 1.8. The spillway will be gated open chute designed for discharging a maximum flood of 9,600 $m^3/s$.

The controlled flow will be released to the river and picked up at downstream for irrigating farmlands of 253,000 ha, of which 122,000 ha are in Nepal and the rest in India. A firm continuous flow of 98 $m^3/s$ is allocated to power generation.

The powerplant will be located immediately downstream of the dam, for which a gross head of 83 m is available. The installed capacity of the plant will be 70 MW, which can produce average annual firm energy of 350 GWh.

Construction Cost

The total construction cost of the Bagmati Multipurpose Project including associated irrigation and power costs is estimated to be US$325 x $10^6$, of which US$77.7 x $10^6$ is the joint cost of irrigation and power functions. Irrigation is, however, the main purpose of the development, and the power function will share only 5 % of the joint cost. The joint cost and speclfic cost of power facilities are estimated as follows.

Joint Cost (Dam and ancillary works)

| | |
|---|---|
| Preparatory works: | US$12,000 x $10^3$ |
| Diversion tunnel: | 4,700 |
| Dam: | 32,900 |
| Spillway: | 8,000 |
| Outlet facilities: | 2,400 |
| Sub-total | US$60,000 |
| Engineering & Administration: | 6,000 |
| Contingencies: | 11,700 |
| Total for Dam | US$77,700 x $10^3$ (Allocation to power is 5%) |

Power facilities

| | |
|---|---|
| Penstock and others: | 1,800 |
| Power house: | 1,300 |
| Generating equipment: | 10,000 |
| Miscellaneous: | 2,000 |
| Sub-total | US$15,100 |
| Engineering & Administration: | 1,500 |
| Contingencies: | 3,000 |
| Total for power | US$19,600 x $10^3$ |
| Total of Dam and Power Facilities | US$97,300 x $10^3$ |
| Allocated cost for power sector: | US$23,400 x $10^3$ |

As shown above, the cost for power generation is US$23.4 x $10^6$, so that its unit construction cost is calculated to be 6.7 US¢/kWh and 334 US$/kW respectively.

3.1.2 Kulikhani No. 1 Project

General

The Kulikhani river is a very upstream tributary of the Bagmati river. It flows outside of the south-west fringe of the Kathmandu Valley to the south-east direction, as shown in Fig. 1.1. At the south of the Kulikhani river, the East Rapti river flows westward to join the Sapt Gandaki river. The Kulikhani and East Rapti rivers are separated by a high ridge of the Mahabharat Ranges. Considerable difference in river bed elevations is noticed between these two rivers. Taking advantage of this, the project is intended to create a reservoir on the Kulikhani river and divert the water to the East Rapti river for power generation.

The damsite of the Kulikhani No.1 Project is located 16 km upstream from the confluence of the Kulikhani and Bagmati rivers. The catchment area above the damsite is 126 $km^2$, and yields average annual run-off of 122.9 x $10^6 m^3$.

The foundation rock of the damsite is composed of sandy semi-schist, biotite schist and slate, which have many open cracks.

The width of the river is about 50 m. The right bank rises up at a slope of 1 on 1.2 to 1 on 1.7, and is extensively covered with talus deposits, whereas the left bank forms a very steep cliff of 1 on 0.3 to 1 on 0.6 and bedrocks are widely cropped out.

Proposed Plan

The dam will be a rockfill structure, with a maximum height of about 107 m above streambed. About $3.5 \times 10^6 m^3$ of embankment materials will be required. A chute with controlled crest, designed to discharge a maximum flood of 1,300 $m^3/s$, will be located on the left abutment.

At the normal water surface of El. 1,530 m, the dam will impound a storage of $85.3 \times 10^6 m^3$, of which $73.3 \times 10^6 m^3$ is effective. The low water level of the reservoir will be at El. 1,476 m. The storage curve of the reservoir is shown in Fig. 1.9.

The flow of the Chakhel Khola, a small tributary of the Kulikhani river, will be diverted into the Kulikhani Reservoir to supplement the water source, as shown in Fig. 1.9.

The water of the reservoir will be diverted to the East Rapti river through a 5.8 km long pressure tunnel, penstock, and an underground powerplant. A gross head of 614 m is available. On the way of the diversion, a small flow of the Sim Khola will be picked into the tunnel. Fig. 1.9 shows the general layout of the project.

The powerplant will be planned as a peaking station. Its firm continuous flow and maximum flow regulated by the reservoir will be 3.7 $m^3/s$ and 10.1 $m^3/s$ respectively. The installed capacity of the plant will be 46 MW, which will produce average annual firm energy of 157 GWh.

A feasibility study of the Kulikhani project is now underway. Some sort of amendment or refinement of the preliminary planning as described above may be in order, based on the detailed study of the project.[/1]

Construction Cost

The construction cost of the Kulikhani No. 1 Project is estimated to be US$43.6 x $10^6$, which gives the unit construction costs of 27.8 US¢/kWh and 948 US$/kW.

The details of estimate are shown below.

| | |
|---|---|
| Preparatory works: | US$1,800 x $10^3$ |
| Dam: | 17,600 |
| Spillway: | 3,100 |
| Waterway: | 5,760 |
| Power house: | 1,790 |
| Generating equipment: | 4,150 |
| Sub-total | US$34,200 x $10^3$ |
| Engineering & Administration: | 3,800 |
| Contingencies: | 5,600 |
| Total | US$43,600 x $10^3$ |

---

/1 The final figure of the installation capacity is determined to be 60 MW. In wet season, all other run-of-river hydropower plants in the CNPS have ample flow to produce the energy to their maximum extent. The power generation of the Kulikhani No.1 Project would be kept to the minimum in this season and the reservoir storage would be carried over as much as possible to dry season. The Kulikhani No.1 plant would be then fully utilized in dry season in which the energy outputs of other hydropower plants are the smallest. This consideration leads to the larger installation capacity in this project.

The salient figures of new installation are:

Installed capacity, 60 MW

Energy output,
- Firm 165 GWh
- Gross 211 GWh

In addition to above, firming-up of the potential energy of existing run-of-river plants will amount to 97 GWh.

Construction cost, US$53 x $10^6$ (July/1974 price level; transmission facilities included)

For more details of the new installation, reference is made to its feasibility report.

### 3.1.3 Kulikhani No. 2 Project

General

The East Rapti river downstream of the Kulikhani No. 1 power station has a steep slope of 1/30 for about 20 km reach before it turns to be flatter.

Taking account of this topographical advantage, the Kulikhani No. 2 project is planned to convey the trailwater of the No. 1 project further downstream to gain the head for power generation.

Proposed Plan

The No. 2 power station will be a surface structure located near Bhainse Dobhan, as shown in Fig. 1.9. The tailwater of the Kulikhani No. 1 powerplant will be diverted to the No. 2 powerplant through a 7.0 km long tunnel. On the way, flows of small streams will be diverted into the tunnel, as shown in the figure.

About 305 m head is available at the No. 2 plant. The installed capacity of the plant will be 26 MW/1, and yield average annual firm energy of 103 GWh.

Construction Cost

The construction cost of the Kulikhani No. 2 Project is estimated to be US$12.2 x $10^6$, which gives the unit construction costs of 11.8 US¢/kWh and 469 US$/kW. Details are shown below.

| | |
|---|---|
| Preparatory works: | US$300 x $10^3$ |
| Waterway: | 5,420 |
| Power house: | 600 |
| Generating equipment: | 2,860 |
| Sub-total | US$9,180 x $10^3$ |
| Engineering & Administration: | 1,220 |
| Contingencies: | 1,800 |
| Total | US$12,200 x $10^3$ |

/1 The final figure would be 35 MW.

3.1.4 Kulikhani No. 3 Project

The tailwater of Kulikhani No. 2 plant together with the flow of the East Rapti river will be regulated by constructing a dam at Bayal Bause, which is located on the East Rapti river about 2.0 km downstream from the No. 2 power station, and carried further downstream to the No. 3 station, as shown in Fig. 1.9.

The catchment area of the Rapti river above the damsite is about 122 $km^3$, and yields an average annual flow of 205.4 x $10^6 m^3$. Since the tailwater of the No. 2 plant will contribute an annual flow of 150.0 x $10^6 m^3$, the total inflow of the Bayal Bause Reservoir would become 355.4 x $10^6 m^3$.

The Rapti river at the damsite is about 60 m side. The sand and gravel deposit on the streamed is thick, being estimated to be up to 20 m. Both banks of the site form steep slopes, and bedrocks are cropped out. The rocks are composed of sandstone semi-shist.

A 65 m high rockfill dam is envisaged at this site, which will require the embankment volume of 1.1 x $10^6 m^3$. A tunnel spillway will permit the passage of a maximum flood of 1,200 $m^3/s$. The reservoir will have a storage of 14.0 x $10^6 m^3$ at the normal water surface of El. 605. With the drawdown of 7.5 m, an effective storage of 10.0 x $10^6 m^3$ and a firm continuous flow of 7.1 $m^3/s$ will be available for power generation.

A 4.0 km tunnel will carry the water from the reservoir to the No. 3 powerplant as shown in Fig. 1.9. A gross head of 150 m is attainable. The installed capacity of the No. 3 plant will be 14 MW/1, and can produce annual firm energy of 70 GWh.

The construction cost is estimated to be US$19.9 x $10^6$, which gives the unit construction costs of 28.4 US¢/kWh and 1,421 US$/kW. Details of estimation are given as follows.

| | |
|---|---|
| Preparatory works: | US$500 x $10^3$ |
| Dam: | 5,500 |
| Spillway: | 2,050 |
| Waterway: | 4,850 |
| Power house: | 500 |
| Generating equipment: | 2,300 |
| Sub-total | US$15,700 x $10^3$ |
| Engineering & Administration: | 1,600 |
| Contingencies: | 2,600 |
| Total | US$19,900 x $10^3$ |

/1 The final figure would be 17 MW.

## 3.2 Kamla River

The Kamla river is one of the medium size rivers in Nepal draining the central part of the country. The river basin has an area of 2,160 $km^2$ at the border of Nepal and India. The water resources of the Kamla river basin are important for the irrigation development on the Terai plain as well as for power generation.

### 3.2.1 Kamla Project

The Kamla project will be a multipurpose development, which includes power generation, irrigation and flood control.

The damsite is located on the Kamla River at about 35 km north-east from the town of Janakpur by air distance, as shown in Fig. 1.1. The catchment area above the site is 1,530 $km^2$, and the estimated average annual run-off is 1,401 x $10^6 m^3$.

The river at the damsite is about 70 m wide. The right bank rises very steep up to the height of about 70 m above the stream bed, then turns to be flat land, which is covered by high terraces. The left bank has very gentle slope and is covered by high and low terraces. The low terraces are very thick, being about 20 to 25 m, but the high terrances are relatively shallow, ranging 2 to 10 m depending upon the locality. The alluvial deposits in the river channel are deep in the right bank, and shallow in the left bank, being about 22 m and 4 m respectively. The bedrock is composed of alternation of sandstone, siltstone, mudstone, and shale. All of which are of soft rock. The dam will be an earth and gravel fill structure, with a maximum height of 64 m above the streambed. About 4.3 x $10^6 m^3$ of embankment materials will be required. At the normal water surface of El. 195 m, the reservoir will have a gross storage of 1,180 x $10^6 m^3$, of which 1,040 x $10^6 m^3$ is effective. The storage curve of the reservoir is shown in Fig. 1.10. The regulated flow will be released into the river and picked up at downstream for irrigating 96,000 ha of farmlands on the Terai Plain. A firm continuous flow of 28 $m^3/s$ is allocated to power generation.

The spillway will be gated open chute, designed for a maximum flood of 7,200 $m^3/s$.

The powerplant will be located immediately downstream of the dam, for which a gross head of 52 m is attainable. The installed capacity of the plant will be 30 MW, and will produce annual firm energy of 74 GWh.

The total construction cost of the Kamla Multipurpose Project will be at US\$104 x $10^6$, of which US\$41.5 x $10^6$ is the joint cost of irrigation and power functions. Irrigation is the main purpose of the development, so that the power sector will only share 5 % of the joint cost. The joint cost and specific cost of power facilities are shown below.

| | | |
|---|---|---|
| **Joint facilities (Dam and ancillary works):** | | |
| Preparatory work: | US\$6,000 x $10^3$ | |
| Diversion tunnel: | 2,500 | |
| Dam: | 18,300 | |
| Spillway: | 4,700 | |
| Outlet facilities: | 500 | |
| Sub-total | US\$32,000 | |
| Engineering & Administration: | 3,200 | |
| Contingencies: | 6,300 | |
| Total for Dam | US\$41,500 x $10^3$ | (allocation to power is 5 %) |
| **Power facilities:** | | |
| Penstock & others: | 300 | |
| Power house: | 400 | |
| Generating equipment: | 4,600 | |
| Miscellaneous: | 500 | |
| Sub-total | US\$5,800 x $10^3$ | |
| Engineering & Administration: | 580 | |
| Contingencies: | 1,120 | |
| Total for Power | US\$7,500 x $10^3$ | |
| Total of Dam and Power facilities | US\$49,000 x $10^3$ | |
| Allocated cost for power sector: | US\$9,600 x $10^3$ | |

As shown above, the cost of power sector is US\$9.6 x $10^6$, so that its unit construction costs are calculated to be 13.0 US¢/kWh and 320 US\$/kW.

### 3.3 Kankai Mai River

The Kankai Mai river originates in the Mahabharat range and flows down the south eastern territory of Nepal. The river basin has an area of 1,546 km$^2$ at the Nepal-Indo border. Two hydropower projects, the Kankai and the Mai Khola Loop, are conceived as prospective ones in this study.

#### 3.3.1 Kankai Project

General

The Kankai project will be a mutlipurpose development for power generation, irrigation and flood control.

The damsite of the Kankai project is shown in Figs. 1.1 and 1.11. It is located on the Kankai Mai river at about 5 km upstream from the East-West highway bridge crossing the river. The catchment area above the damsite is 1,190 km$^2$, and the estimated average annual run-off is 1,697 x 10$^6$m$^3$. The river is about 60 m wide, and filled with sand and gravel of 17 to 19 m deep. The river at the vicinity of the damsite forms small double loops, as shown in Fig. 1.11. Both banks of the damsite are steep, being 40$^o$ on the left bank and 47$^o$ on the right bank. The rock formations of the damsite are composed of alternation of sandstone, shale and siltstone of SiwaliksFormation. These rocks are soft and weathered easily.

Proposed Plan

A rockfill dam of about 75 m is proposed at this site. The dam will require 1.45 x 10$^6$m$^3$ of embankment materials. At the normal water surface of El. 186 m, the reservoir will have a storage of 750 x 10$^6$m$^3$, of which 590 x 10$^6$m$^3$ is effective. The maximum drawdown of the reservoir is 25 m. The storage curve of the reservoir is shown in Fig. 1.11.

A gated open chute spillway will be located in the right bank, cutting through the saddle portion. The design flood will be 6,300 m$^3$/s.

The controlled flow will be released to the river and diverted to the main canal by an afterbay weir constructed at about 2 km downstream from the dam. The planned irrigation area is 36,000 ha. A firm continuous flow of 37.5 m$^3$/s is allocated to power generations.

The powerplant will be located at the right bank about 400 m down-stream from the dam. By short cutting the loop, a gross head of 62 m is attainable. The installed capacity of the powerplant will be 33 MW, which will produce annual enrergy of 142 GWh.

Construction Cost

The total construction cost of the Kankai Multipurpose Project is estimated to be US\$65 x $10^6$, of which US\$22.7 x $10^6$ is the joint cost of irrigation and power sectors. The power sector will share 25 % of the joint cost. The joint cost and specific cost of power facilities are shown as follows.

| | |
|---|---|
| **Joint facilities (Dam and ancillary works):** | |
| Preparatory works: | US\$5,000 x $10^3$ |
| Diversion tunnel | 1,500 |
| Dam work: | 8,400 |
| Spillway | 2,800 |
| Sub-total | US\$17,700 x $10^3$ |
| Engineering & Administration: | 1,700 |
| Contingencies: | 3,300 |
| Total for dam | US\$22,700 x $10^3$ (Allocation to power is 25 %) |
| **Power facilities:** | |
| Waterway: | US\$1,080 x $10^3$ |
| Power plant: | 1,030 |
| Generating equipment: | 3,050 |
| Sub-total | US\$5,160 x $10^3$ |
| Engineering & Administration: | 520 |
| Contingencies: | 1,200 |
| Total for power facilities | US\$6,880 x $10^3$ |
| Total of dam and power facilities | US\$29,580 x $10^3$ |
| Allocated cost for power sector: | US\$12,600 x $10^3$ |

As shown above, the cost of power sector is US\$12.6 x $10^6$, so that the unit construction cost is 8.9 US¢/kWh and 382 US\$/kW.

### 3.3.2 Mai Khola Loop Project

The damsite of the Mai Khola Loop Project is located on the Kankai Mai River (or the Mai Khola) at about 3 km upstream from its confluence with the Deomai River (cf. Figs. 1.1 and 1.11). The catchment area above the damsite is 670 $km^2$, and the estimated average annual run-off is 955 x $10^6 m^3$.

The Kankai River forms a big loop at the downstream reaches of the damsite, as shown in Fig. 1.11. The project intends to gain the head by short-cutting this big loop for power generation.

The geological formations at the site are composed of sandstone, siltstone, and shale of moderate hardness, which belong to Lower Siwaliks. The dam will be a 65 m high rockfill structure, having a volume of about 1.5 x $10^6 m^3$. The dam will impound 46 x $10^6 m^3$ of storage at the normal water surface of El. 295 m. With a maximum drawdown of 25 m, an effective storage of 28 x $10^6 m^3$ is available.

Both the spillway and power tunnel will be located at the opposit reservoir shore of the dam, as shown in Fig. 11. The spillway will be a gated open chute, designed to discharge a maximum flood of 3,700 $m^3/s$.

A firm continuous flow of 7.8 $m^3/s$ is available for power generation. The water will be carried down to the powerplant through a 300 m tunnel. The installed capacity of the plant will be 13 MW, which will yield annual firm energy of 47 GWh.

The estimated construction cost is US$26 x $10^6$, details being shown below, which gives the unit construction cost of 55.3 US¢/kWh and 2,000 US$/kW.

| | |
|---|---|
| Preparatory works: | US$5,600 x $10^3$ |
| Diversion tunnel: | 1,060 |
| Dam: | 7,100 |
| Spillway: | 3,920 |
| Waterway: | 1,050 |
| Power plant: | 384 |
| Generating equipment: | 640 |
| Sub-total | US$19,754 x $10^3$ |
| Engineering & Administration: | 1,980 |
| Contingencies: | 4,266 |
| Total | US$26,000 x $10^3$ |

## 3.4 Babai River

The Babai river is one of the medium size rivers originating from the Mahabharat Ranges, and drains the Far Western part of Nepal. Its catchment area in Nepal territory is about 3,270 $km^2$. In this basin, three hydropower schemes have been considered in the previous study: they are the Sarda, Babai Upper, and Babai Lower Projects. However, the study has concluded that the latter two schemes would be eliminated from further consideration because of their high power costs and hazardous sendiment problem. Therefore, only the Sarda Project is taken up as a prospective hydropower project in this study.

### 3.4.1 Sarda Project

The Sarda Project will be a multipurpose development for power generation and irrigation.

The damsite of the Sarda Project is located on the Sarda River at about 16 km upstream of its confluence with the Babai mainstream (cf. Fig.1). The catchment area above the damsite is 860 $km^2$, and the average annual run-off is estimated to be 451 x $10^6 m^3$.

The project is to dam up the water of the Sarda River, and divert it to a power plant located on the Kalleri River, another small tributary of the Babai River, as shown in Fig.1.12.

The foundation rock of the damsite consists of upper tertiary layers of sandstone and shale, which belong to Siwaliks Formation. The river deposit appears not to be excessively deep, presumably being at 10 to 15 m.

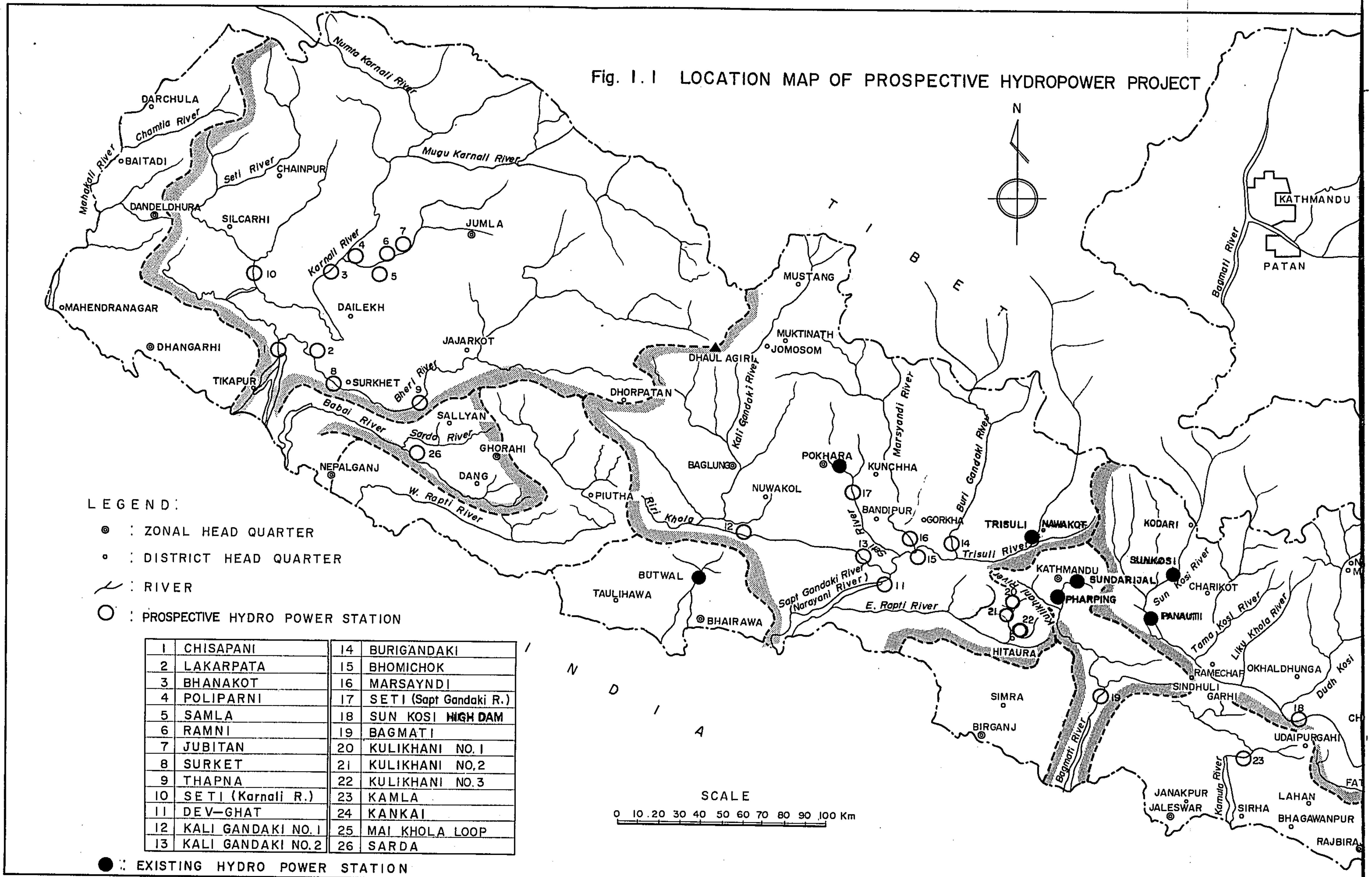
The dam will be a 85 m high rockfill structure, having a volume of 4.8 x $10^6 m^3$. At the normal high water surface of El.730 m, the reservoir will have a gross storage of 260 x $10^6 m^3$, of which 220 x $10^6 m^3$ is effective. The maximum drawdown is 45 m, and the firm continuous flow is estimated to be 12.8 $m^3/s$. The storage curve of the reservoir is shown in Fig.1.12.

An open chute spillway, designed to discharge a maximum flood of 5,400 $m^3/s$ will be located in the right abutment. The power intake will be located on the left bank at about 600 m upstream from the dam. Water will be lead to the power plant through a 4.4 km long tunnel, by which a gross head of 250 m is attainable. The installed capacity of the plant will be 49 MW, which will yield annual firm energy of 222 GWh.

The total construction cost of the Sarda scheme is estimated to be US\$61.5 x $10^6$, out of which the cost of the dam portion shares US\$48.93 x $10^6$. As the Sarda dam will serve both for the power generation and the irrigation, the dam cost can be allocated to the both sectors. It is reported in the reconnaisance report on hydro-electric power shecmes on the Babai and the Rapti rivers that the ratio of the full benefits of power generation and irrigation was calculated approximately at 1 : 3. If it is assumed to allocate the cost of the dam to the both sectors in proportion to the amount of the benefit accrued from each sector, US\$34.2 x $10^6$ could be allocated to the power sector. Then the total allocated cost of the Sarda power scheme will be US\$46.8 x $10^6$, including the power specific cost of US\$12.6 x $10^6$. The unit construction cost is calculated to be 21.1 US¢/kWh and 955 US\$/kW. The details of the construction cost is shown below.

| | |
|---|---|
| Preparatory works: | US\$5,700 x $10^3$ |
| Diversion tunnel: | 6,000 |
| Dam: | 22,200 |
| Spillway: | 3,720 |
| Waterway: | 7,240 |
| Power plant: | 620 |
| Generating equipment: | 1,790 |
| Sub-total | US\$47,270 x $10^3$ |
| Engineering & Administration: | 4,730 |
| Contingencies: | 9,500 |
| Total | US\$61,500 x $10^3$ |

# Fig. 1.1 LOCATION MAP OF PROSPECTIVE HYDROPOWER PROJECT




LEGEND:

◎ : ZONAL HEAD QUARTER

∘ : DISTRICT HEAD QUARTER

～ : RIVER

○ : PROSPECTIVE HYDRO POWER STATION

| | | | |
|---|---|---|---|
| 1 | CHISAPANI | 14 | BURIGANDAKI |
| 2 | LAKARPATA | 15 | BHOMICHOK |
| 3 | BHANAKOT | 16 | MARSAYNDI |
| 4 | POLIPARNI | 17 | SETI (Sapt Gandaki R.) |
| 5 | SAMLA | 18 | SUN KOSI HIGH DAM |
| 6 | RAMNI | 19 | BAGMATI |
| 7 | JUBITAN | 20 | KULIKHANI NO. 1 |
| 8 | SURKET | 21 | KULIKHANI NO. 2 |
| 9 | THAPNA | 22 | KULIKHANI NO. 3 |
| 10 | SETI (Karnali R.) | 23 | KAMLA |
| 11 | DEV-GHAT | 24 | KANKAI |
| 12 | KALI GANDAKI NO. 1 | 25 | MAI KHOLA LOOP |
| 13 | KALI GANDAKI NO. 2 | 26 | SARDA |

● : EXISTING HYDRO POWER STATION

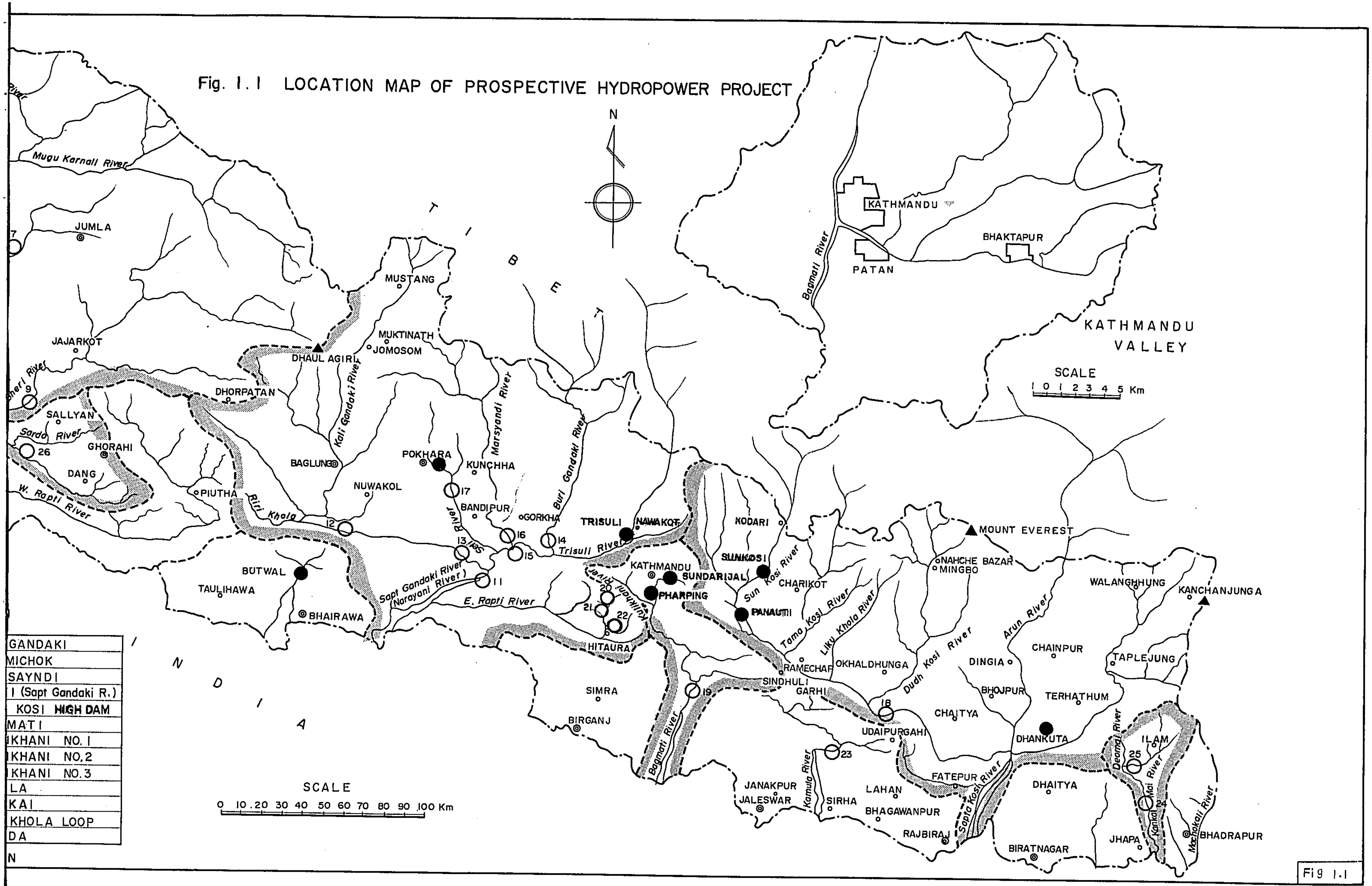


Fig. 1.1 LOCATION MAP OF PROSPECTIVE HYDROPOWER PROJECT

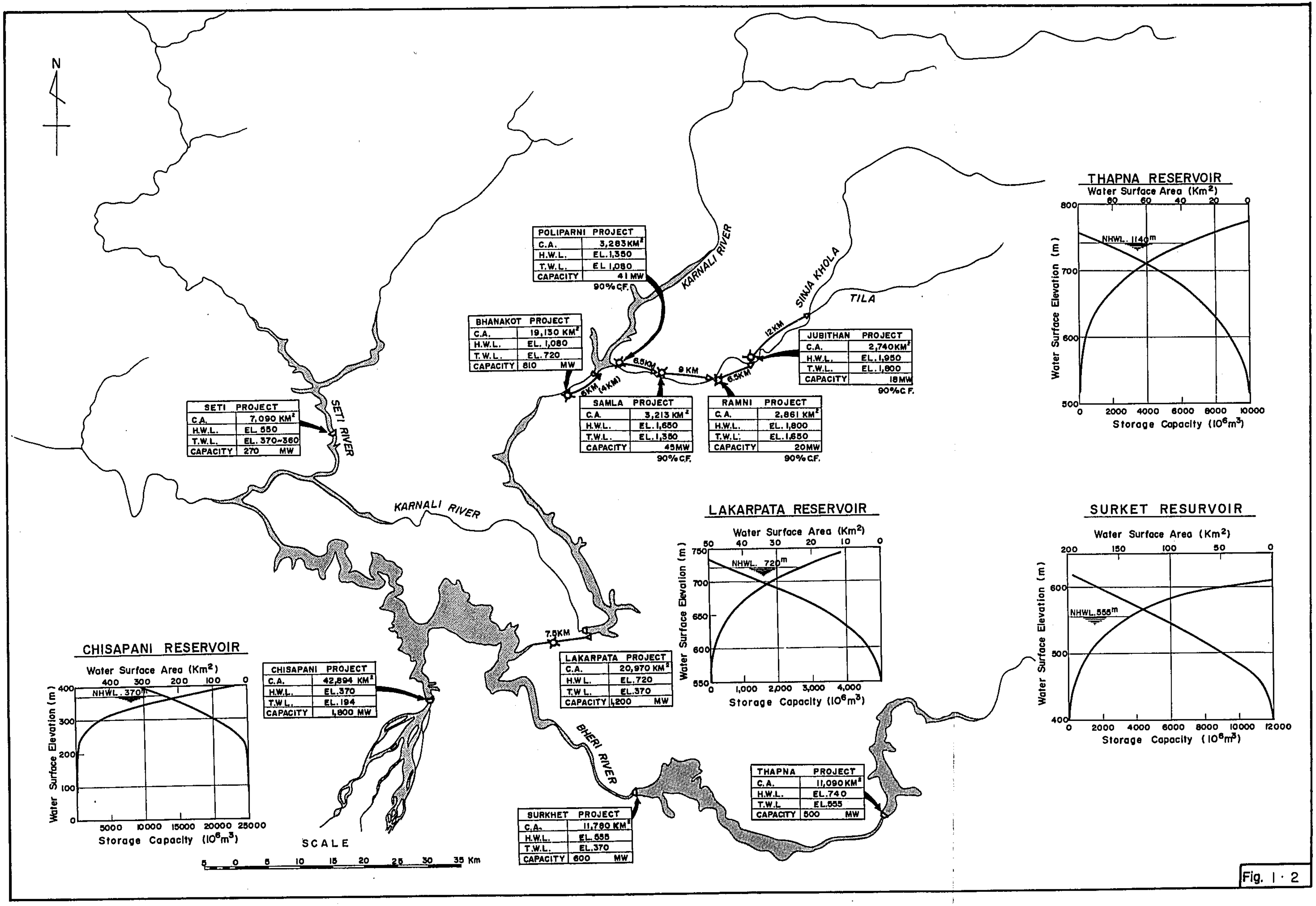

N
POLIPARNI PROJECT
C.A. 3,283 KM²
H.W.L. EL.1,350
T.W.L. EL 1,080
CAPACITY 41 MW
90% C.F.
KARNALI RIVER
SIMJA KHOLA
TILA
12KM
BHANAKOT PROJECT
C.A. 19,130 KM²
H.W.L. EL. 1,080
T.W.L. EL. 720
CAPACITY 810 MW
JUBITHAN PROJECT
C.A. 2,740 KM²
H.W.L. EL. 1,950
T.W.L. EL. 1,800
CAPACITY 18 MW
90% C.F.
6.5KM
9 KM
6.5KM
6KM
(4KM)
SAMLA PROJECT
C.A. 3,213 KM²
H.W.L. EL. 1,650
T.W.L. EL. 1,350
CAPACITY 45 MW
90% C.F.
RAMNI PROJECT
C.A. 2,861 KM²
H.W.L. EL. 1,800
T.W.L. EL. 1,650
CAPACITY 20 MW
90% C.F.
SETI PROJECT
C.A. 7,090 KM²
H.W.L. EL. 550
T.W.L. EL. 370~360
CAPACITY 270 MW
SETI RIVER
KARNALI RIVER
THAPNA RESERVOIR
Water Surface Area (Km²)
80 60 40 20 0
NHWL. 1140m
Water Surface Elevation (m)
800 700 600 500
0 2000 4000 6000 8000 10000
Storage Capacity (10⁶m³)
LAKARPATA RESERVOIR
Water Surface Area (Km²)
50 40 30 20 10 0
NHWL. 720m
Water Surface Elevation (m)
750 700 650 600 550
0 1,000 2,000 3,000 4,000
Storage Capacity (10⁶m³)
SURKET RESURVOIR
Water Surface Area (Km²)
200 150 100 50 0
NHWL. 555m
Water Surface Elevation (m)
600 500 400
0 2000 4000 6000 8000 10000 12000
Storage Capacity (10⁶m³)
7.5KM
LAKARPATA PROJECT
C.A. 20,970 KM²
H.W.L. EL. 720
T.W.L. EL. 370
CAPACITY 1,200 MW
CHISAPANI RESERVOIR
Water Surface Area (Km²)
400 300 200 100 0
NHWL. 370m
Water Surface Elevation (m)
400 300 200 100 0
5000 10000 15000 20000 25000
Storage Capacity (10⁶m³)
CHISAPANI PROJECT
C.A. 42,894 KM²
H.W.L. EL. 370
T.W.L. EL. 194
CAPACITY 1,800 MW
BHERI RIVER
THAPNA PROJECT
C.A. 11,090 KM²
H.W.L. EL. 740
T.W.L EL. 555
CAPACITY 500 MW
SURKHET PROJECT
C.A. 11,780 KM²
H.W.L. EL. 555
T.W.L. EL. 370
CAPACITY 600 MW
SCALE
5 0 5 10 15 20 25 30 35 Km

Fig. 1 · 2

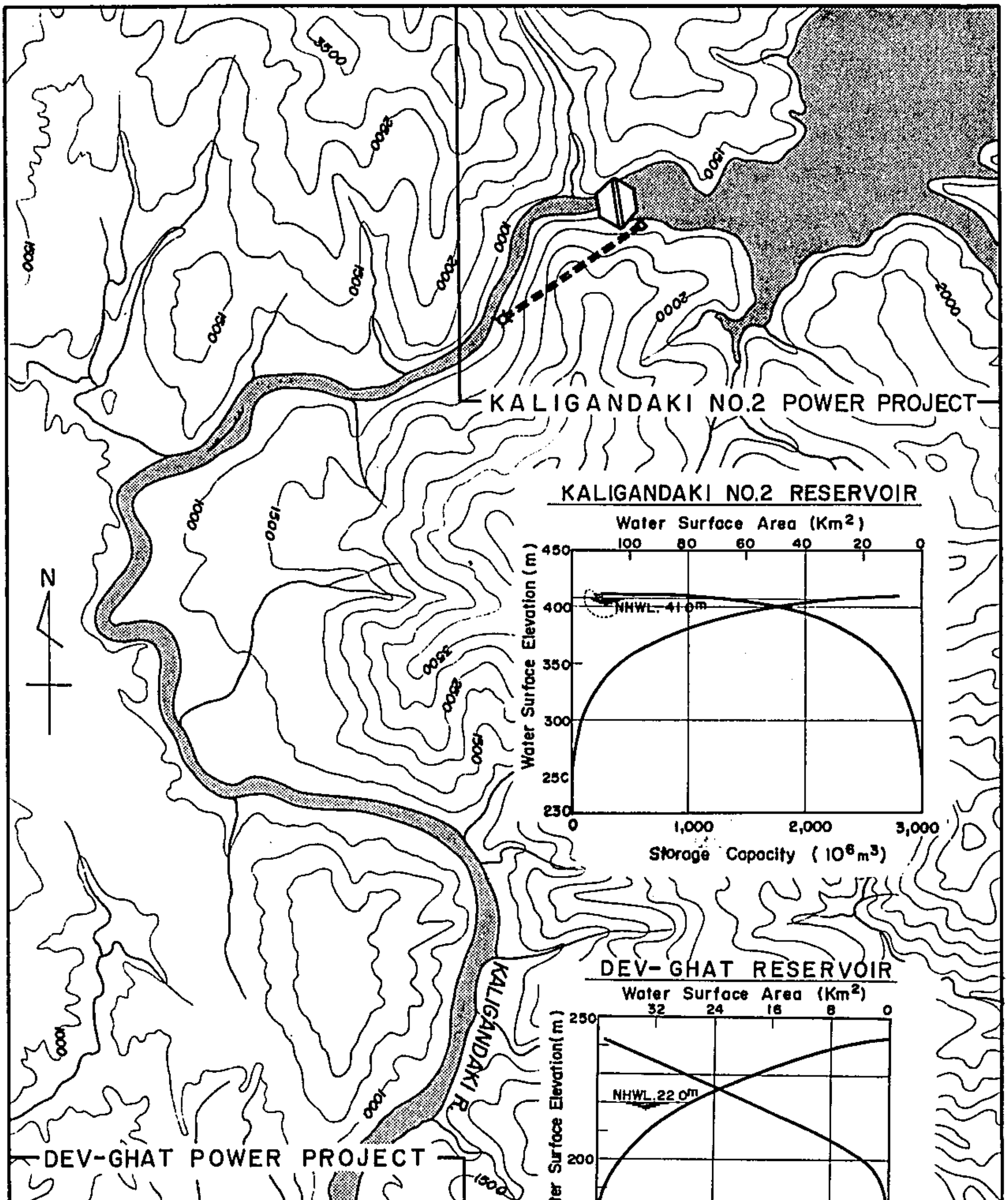
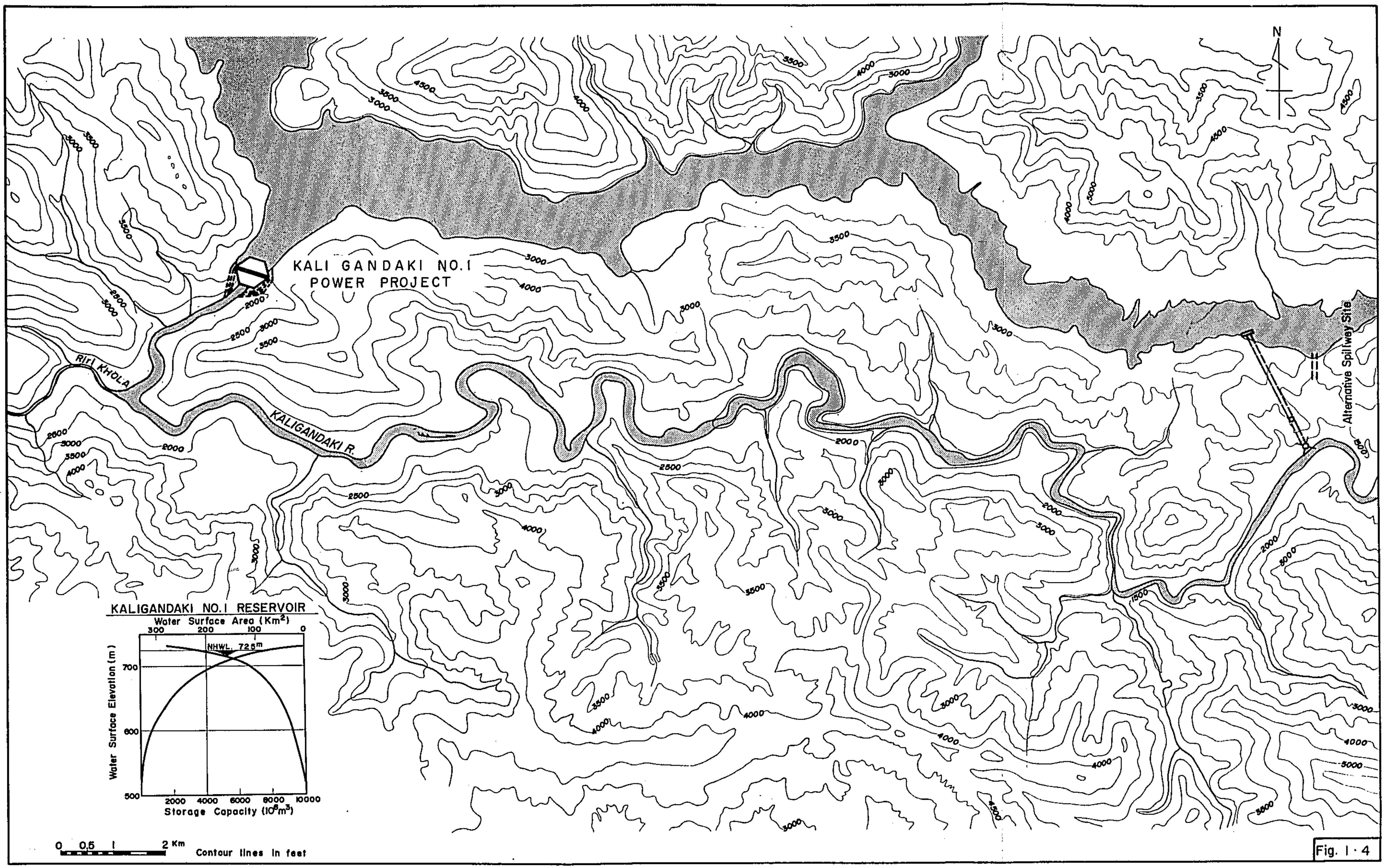
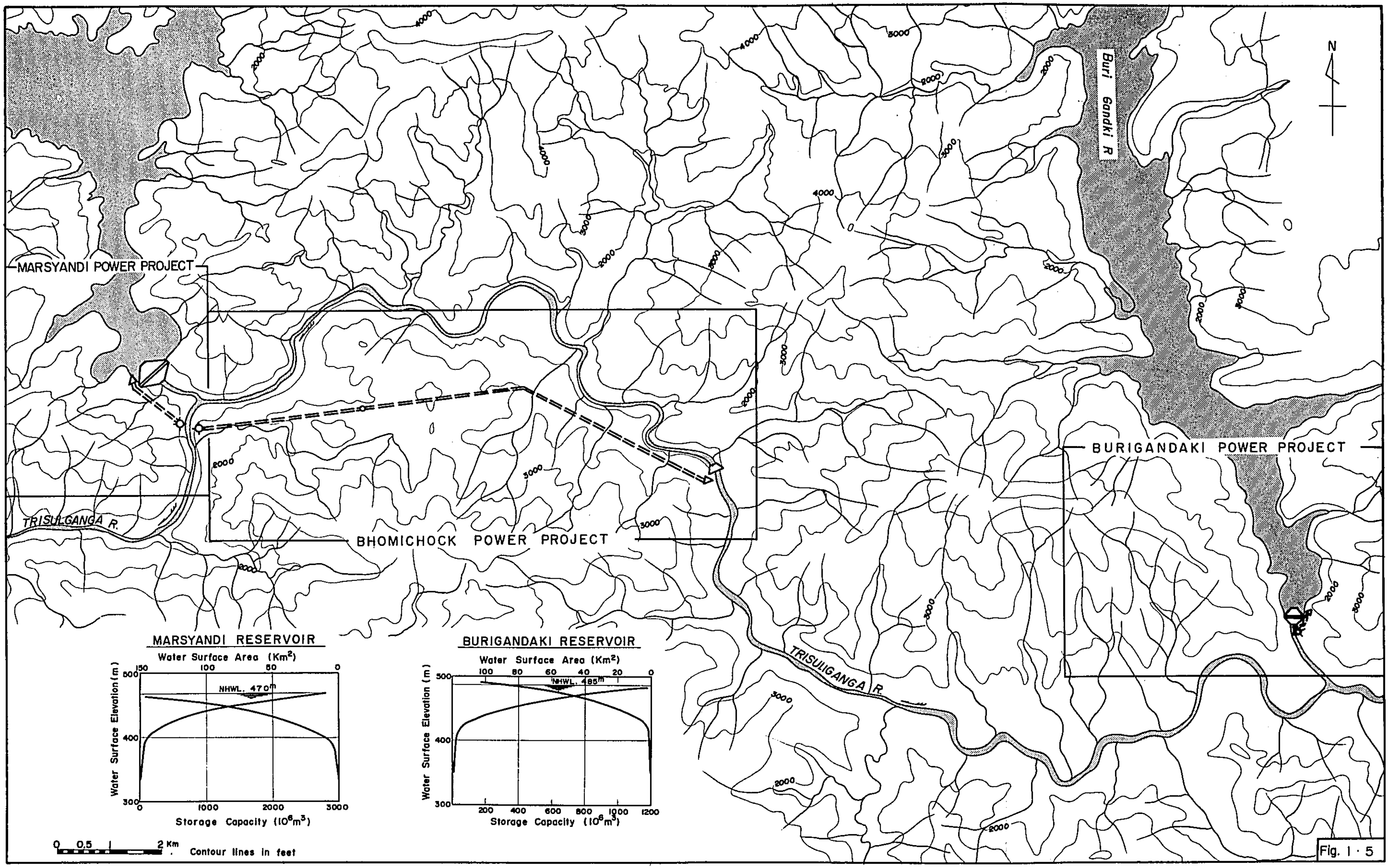

KALIGANDAKI NO.2 POWER PROJECT
KALIGANDAKI NO.2 RESERVOIR
Water Surface Area (Km2)
Water Surface Elevation (m)
NHWL. 410m
Storage Capacity (10⁶m³)
DEV-GHAT RESERVOIR
Water Surface Area (Km2)
NHWL. 220m
Water Surface Elevation(m)
Storage Capacity (10⁶m³)
KALIGANDAKI R.
DEV-GHAT POWER PROJECT
N
0 0.5 1 2 Km
Contour lines in feet

Fig. 1·3



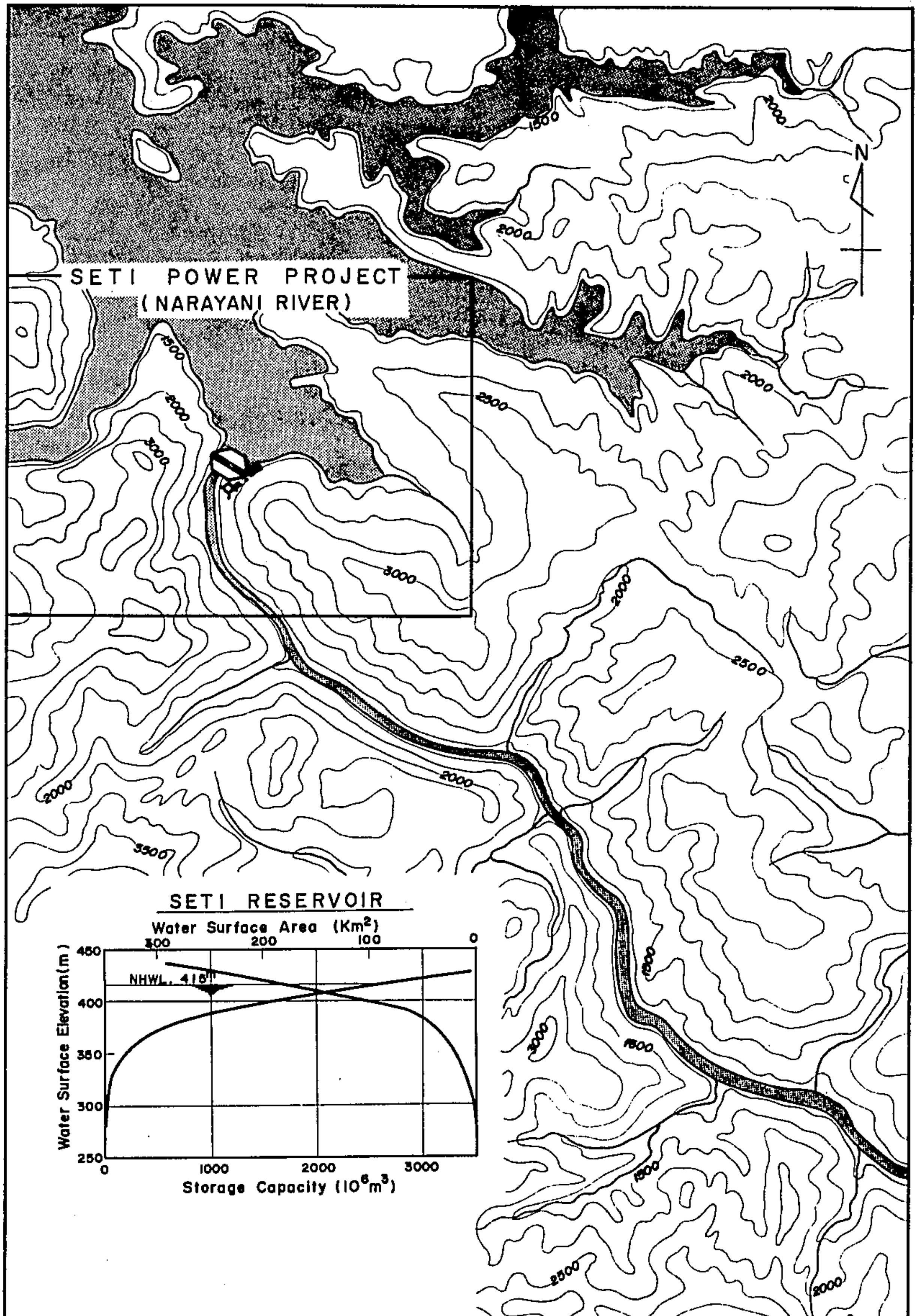
N
KALI GANDAKI NO.1
POWER PROJECT
Riri KHOLA
KALIGANDAKI R.
Alternative Spillway Site
KALIGANDAKI NO.1 RESERVOIR
Water Surface Area (Km²)
300 200 100 0
NHWL. 725m
Water Surface Elevation (m)
700
600
500
2000 4000 6000 8000 10000
Storage Capacity (10⁶m³)
0 0.5 1 2 Km
Contour lines in feet


Fig. 1·4



N
MARSYANDI POWER PROJECT
BHOMICHOCK POWER PROJECT
BURIGANDAKI POWER PROJECT
Buri Gandaki R
TRISULGANGA R.
TRISULIGANGA R
MARSYANDI RESERVOIR
Water Surface Area (Km²)
150 100 50 0
NHWL. 470m
Water Surface Elevation (m)
500 400 300
0 1000 2000 3000
Storage Capacity (10⁶m³)
BURIGANDAKI RESERVOIR
Water Surface Area (Km²)
100 80 60 40 20 0
NHWL. 485m
Water Surface Elevation (m)
500 400 300
200 400 600 800 1000 1200
Storage Capacity (10⁶m³)
0 0.5 1 2 Km
Contour lines in feet


Fig. 1 · 5


SETI POWER PROJECT
(NARAYANI RIVER)
N
1500
2000
2500
3000
3500
SETI RESERVOIR
Water Surface Area (Km²)
300
200
100
0
450
400
350
300
250
Water Surface Elevation (m)
NHWL. 415
0
1000
2000
3000
Storage Capacity (10⁶m³)
0 0.5 1 2 Km
Contour lines in feet
Fig. 1 · 6

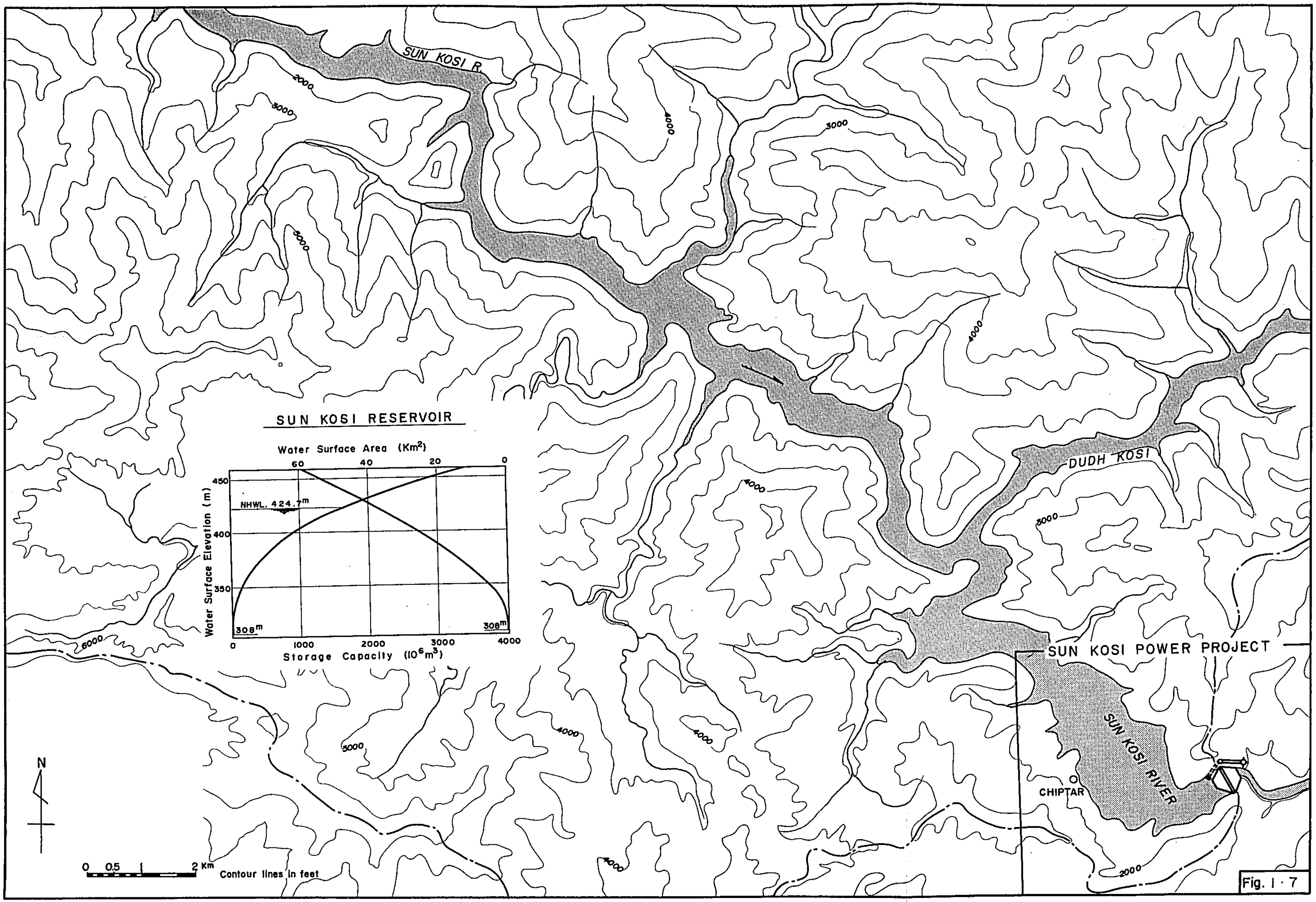
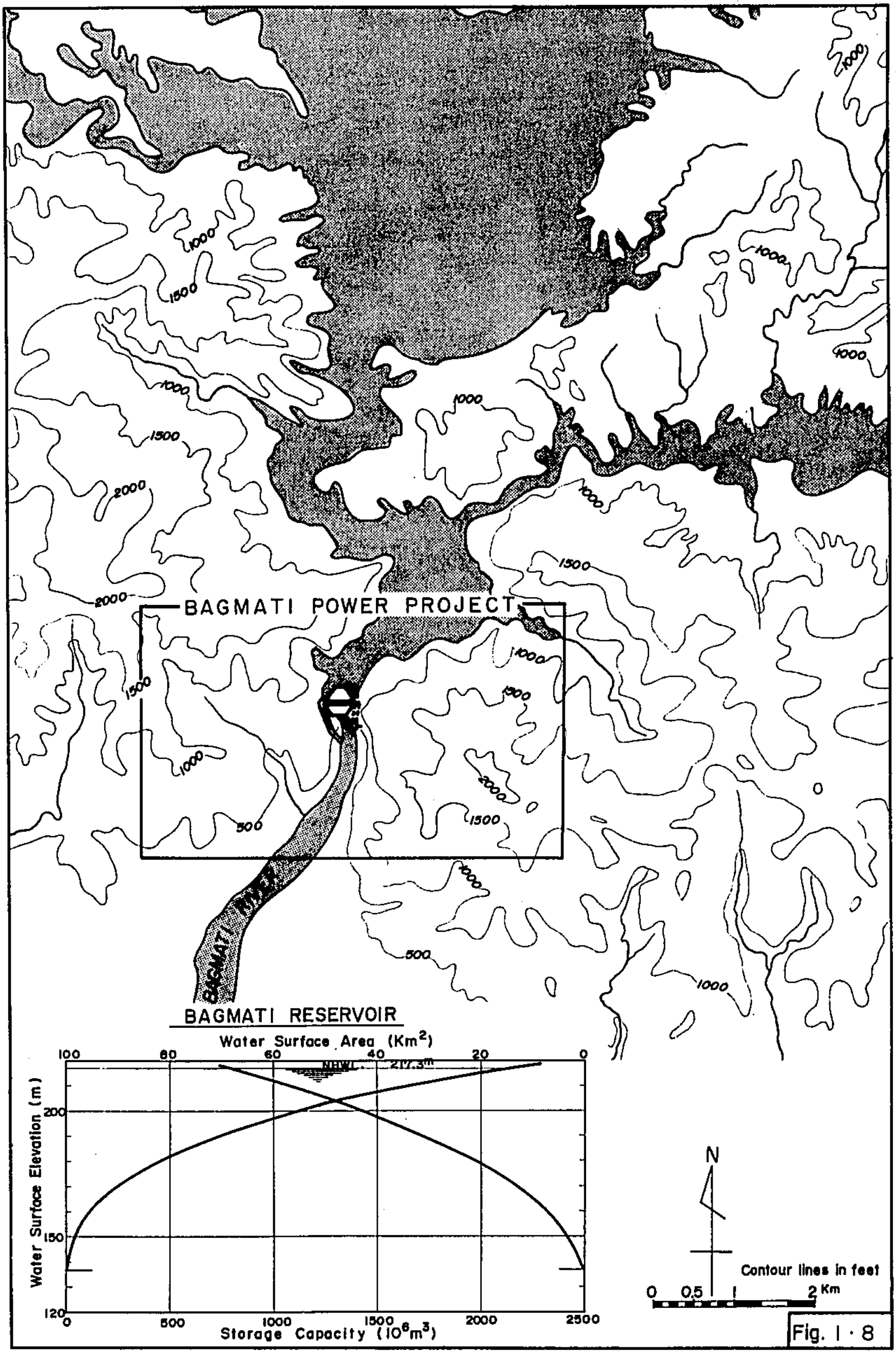
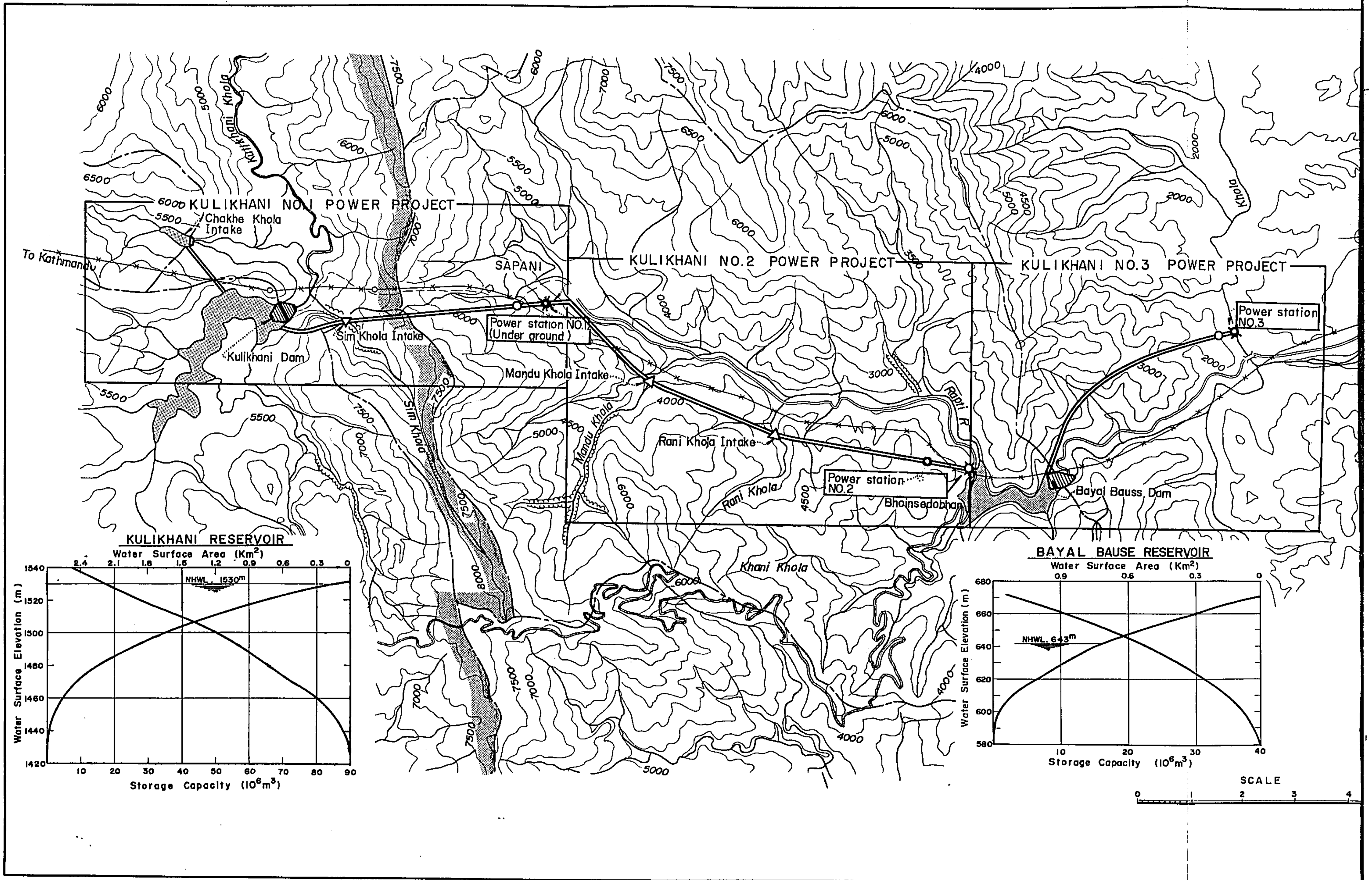

SUN KOSI R.
DUDH KOSI
SUN KOSI RIVER
CHIPTAR
SUN KOSI POWER PROJECT
SUN KOSI RESERVOIR
Water Surface Area (Km²)
Water Surface Elevation (m)
NHWL. 424.7m
308m
308m
Storage Capacity (10⁶m³)
Contour lines in feet
N
0 0.5 1 2 Km

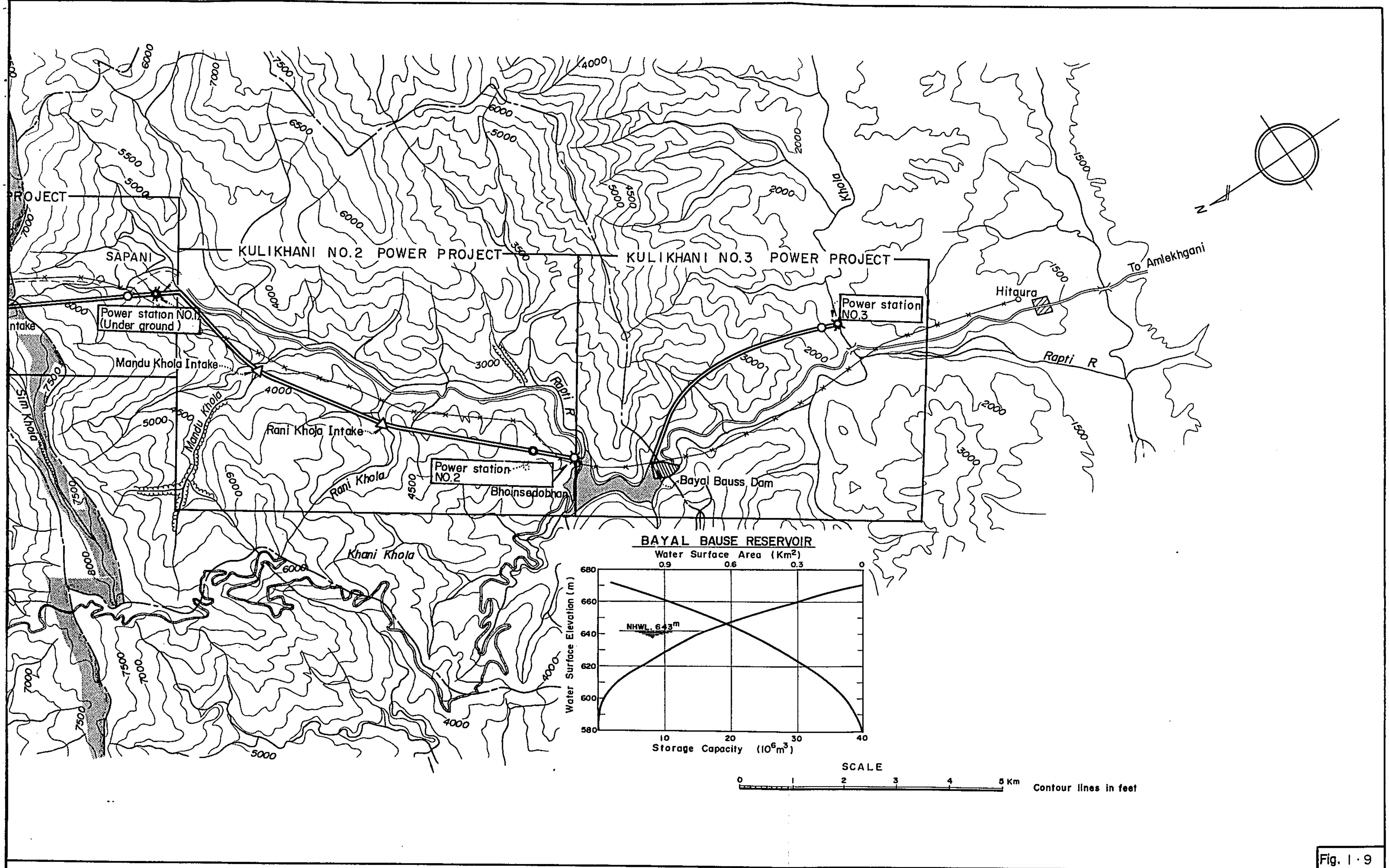
Fig. I · 7



BAGMATI POWER PROJECT
BAGMATI RIVER
1000
1500
2000
500
BAGMATI RESERVOIR
Water Surface Area (Km²)
Water Surface Elevation (m)
Storage Capacity (10⁶m³)
NHWL 217.3m
100
80
60
40
20
0
200
150
120
0
500
1000
1500
2000
2500
N
Contour lines in feet
0
0.5
1
2 Km


Fig. I · 8


KULIKHANI NO.1 POWER PROJECT
KULIKHANI NO.2 POWER PROJECT
KULIKHANI NO.3 POWER PROJECT
Chakhe Khola Intake
To Kathmandu
Kulikhani Dam
Sim Khola Intake
SAPANI
Power station NO.1 (Under ground)
Mandu Khola Intake
Rani Khola Intake
Power station NO.2
Bhainsedobhan
Power station NO.3
Bayal Bauss Dam
Kulikhani Khola
Sim Khola
Mandu Khola
Rani Khola
Khani Khola
Rapti R.
Khola
KULIKHANI RESERVOIR
Water Surface Area (Km²)
Water Surface Elevation (m)
Storage Capacity (10⁶m³)
NHWL. 1530m
BAYAL BAUSE RESERVOIR
NHWL. 643m
SCALE
0 1 2 3 4



PROJECT
KULIKHANI NO.2 POWER PROJECT
KULIKHANI NO.3 POWER PROJECT
SAPANI
Power station NO.1 (Under ground)
Intake
Mandu Khola Intake
Mandu Khola
Rani Khola Intake
Rani Khola
Power station NO.2
Bhoinsedobhan
Rapti R
Bayal Bauss Dam
Power station NO.3
Hitaura
To Amlekhgani
Rapti R
Khola
Sim Khola
Khani Khola
N
BAYAL BAUSE RESERVOIR
Water Surface Area (Km²)
Water Surface Elevation (m)
NHWL. 643m
Storage Capacity (10⁶m³)
SCALE
0 1 2 3 4 5 Km
Contour lines in feet


Fig. 1 · 9

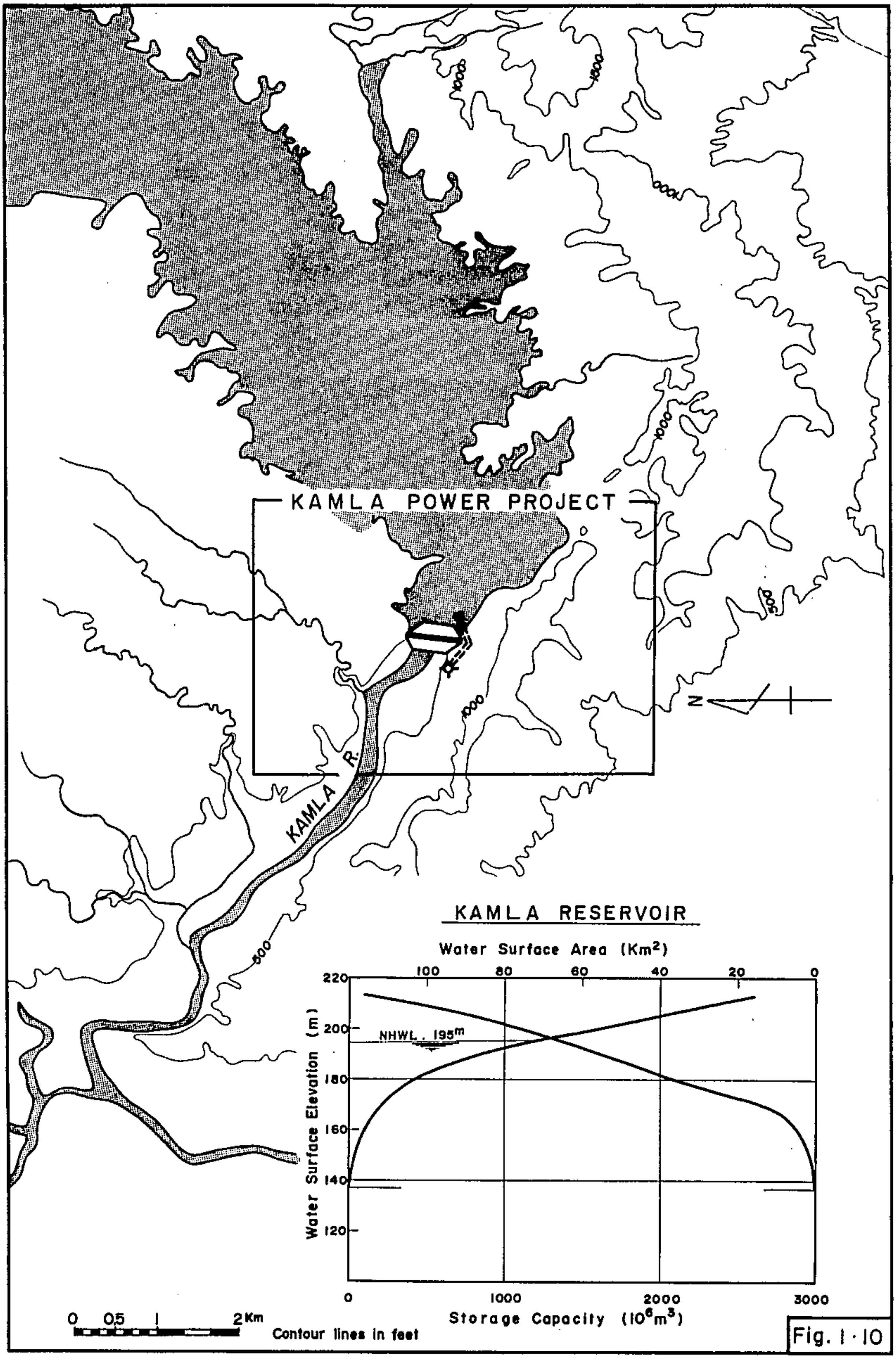

KAMLA POWER PROJECT
KAMLA R.
1000
1500
500
N
KAMLA RESERVOIR
Water Surface Area (Km2)
100
80
60
40
20
0
220
200
180
160
140
120
NHWL. 195m
Water Surface Elevation (m)
0
1000
2000
3000
Storage Capacity (10^6 m^3)
0 0.5 1 2 Km
Contour lines in feet

Fig. 1·10

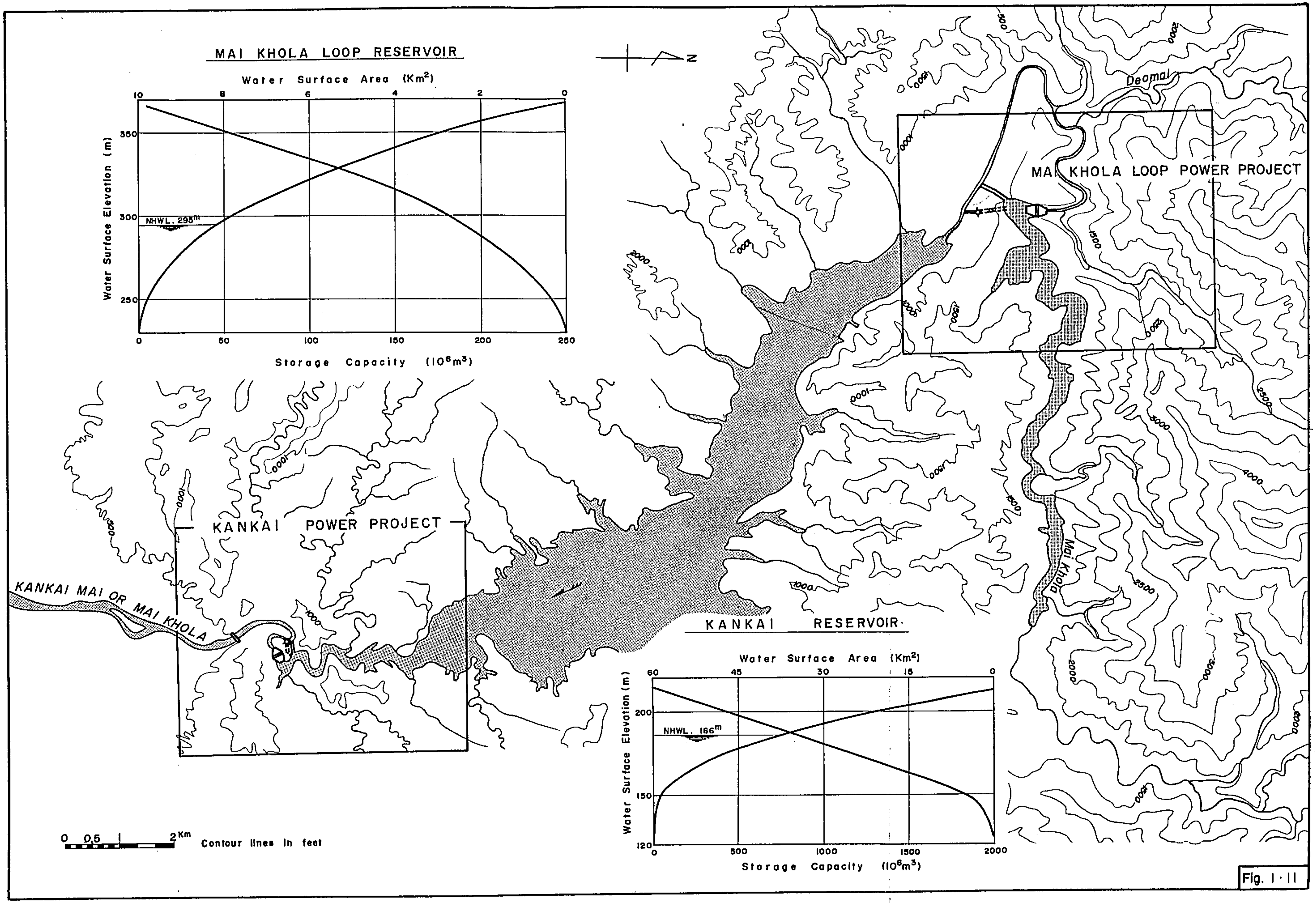
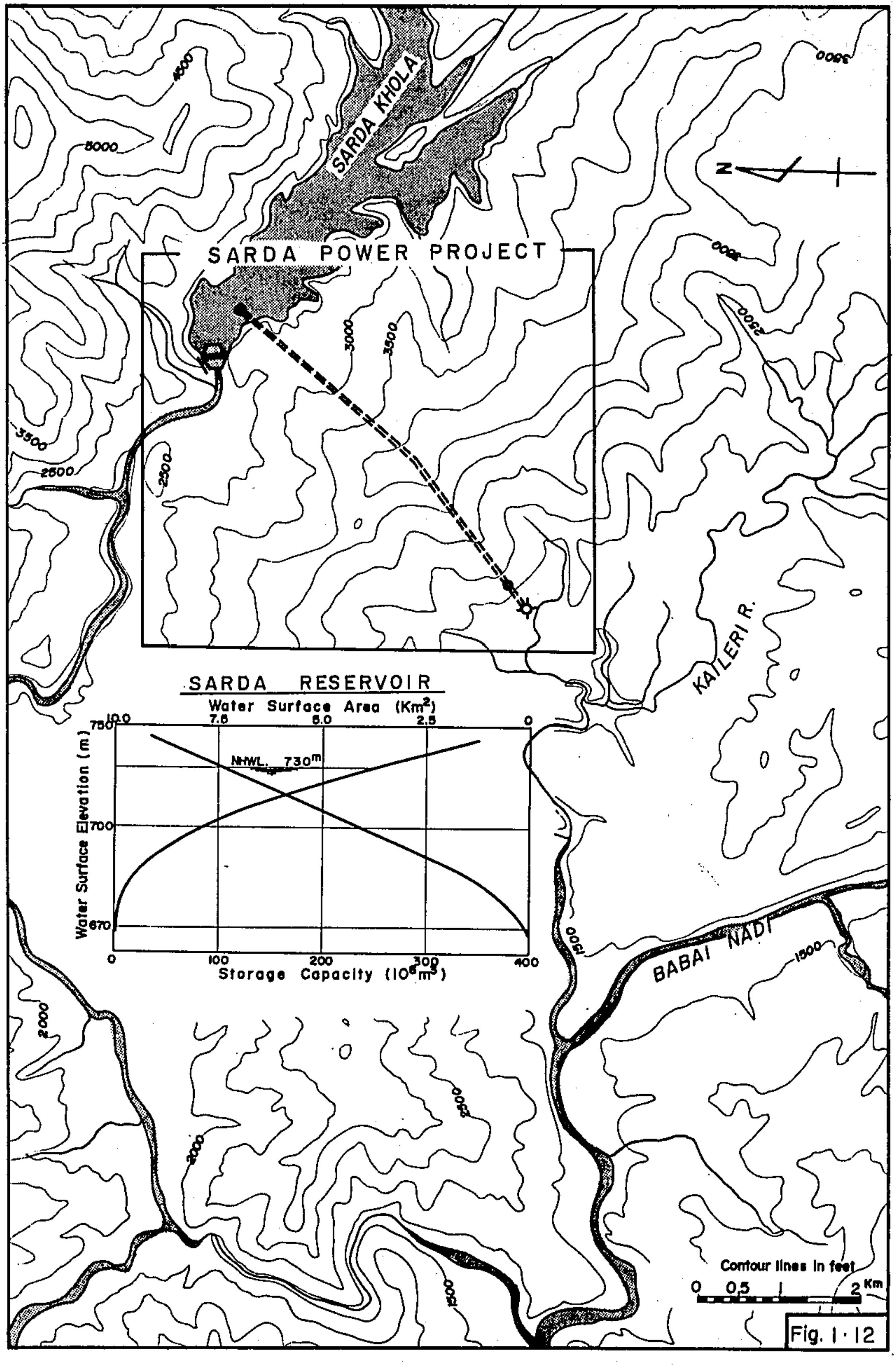

MAI KHOLA LOOP RESERVOIR
Water Surface Area (Km²)
Water Surface Elevation (m)
NHWL. 295m
Storage Capacity (10⁶m³)
MAI KHOLA LOOP POWER PROJECT
Deomai
Mai Khola
KANKAI POWER PROJECT
KANKAI MAI OR MAI KHOLA
KANKAI RESERVOIR
Water Surface Area (Km²)
Water Surface Elevation (m)
NHWL. 186m
Storage Capacity (10⁶m³)
0 0.5 1 2 Km
Contour lines in feet

Fig. 1·11



SARDA KHOLA
SARDA POWER PROJECT
SARDA RESERVOIR
Water Surface Area (Km²)
Water Surface Elevation (m)
Storage Capacity (10⁶m³)
NHWL. 730m
KAILERI R.
BABAI NADI
Contour lines in feet
0 0.5 1 2 Km


Fig. 1·12

# MASTER PLAN OF HYDROELECTRIC POWER DEVELOPMENT

# IN

# NEPAL

## Appendix 2

## Search Procedure for Project Sequencing Problem and Its Application

# APPENDIX 2

## SEARCH PROCEDURE FOR PROJECT SEQUENCING PROBLEM AND ITS APPLICATION

Page



## LIST OF FIGURES

Figure No.

# APPENDIX 2

## SEARCH PROCEDURE FOR PROJECT SEQUENCING PROBLEM AND ITS APPLICATION

### 1. Introduction

Hydropower projects have a long life and the sequence in which they are constructed has an important effect on both the costs involved and the benefit realized. In planning studies, it is relatively easy to compute approximate costs, but a considerably greater effort is required for accurate costs. For hydropower projects, accurate cost estimates can usually only be obtained after there has been extensive field investigation and project designs have been well advanced. The procedure outlined hereinafter can be used in a planning strategy in the following way. All potential projects are identified and their outputs and costs estimated approximately but to some known degree of accuracy. Then the sequential search procedure is carried out and the optimum sequence is found. A sensitivity test may follow at the level of immediate interest. The procedure presented herein is suitable for preliminary planning for problems that can be reduced to that of meeting a growing demand at minimum discounted cost.

### 2. Search Procedure

A simple search procedure for project sequencing proposed by Tsou, Mitten, and Russel/1 is used to find an optimum sequence of the project implementation. The procedure is explained as follows.

If a partial sequence, S, of projects with a total output, X, has already been decided upon and two projects i and j are candidates for the next two positions, then two arrangements are possible, i.e., S' = S, i, j and S" = S, j, i. Under these circumstances project i cannot precede project j if C (S'), the discounted cost of S', is greater than C (S"), the discounted cost of S". Let $C_i$ and $C_j$ = the costs, and $O_i$ and $O_j$ = the outputs from project i and j, respectively; let t (X) = the inverse

---

/1 "Search Technique for Project Sequencing," by C.A. Tsou, L.G. Mitten, and S.O. Russel, (Reviewed by the Technical Council on Water Resources Planning and Management), Jour. of Hydraulic Div., ASCE, May, 1973 demand function, i.e., the time when the demand is X; and let I = the discount rate.

Then

$$C\ (S') = C\ (S) + \frac{C_i}{(1+I)^{t(X)}} + \frac{C_j}{(1+I)^{t(X+O_i)}}$$

Similarly, the cost of S" is

$$C\ (S'') = C\ (S) + \frac{C_j}{(1+I)^{t(X)}} + \frac{C_i}{(1+I)^{t(X+O_j)}}$$

Now the order, i, j, will be preferred to j, i, if $C\ (S') < C\ (S'')$, or

$$\frac{C_i}{(1+I)^{t(X)}} + \frac{C_j}{(1+I)^{t(X+O_i)}} < \frac{C_j}{(1+I)^{t(X)}} + \frac{C_i}{(1+I)^{t(X+O_j)}}$$

Simplification yeilds

$$\frac{C_i}{1-(1+I)^{t(X)-t(X+O_i)}} < \frac{C_j}{1-(1+I)^{t(X)-t(X+O_j)}}$$

or $R_i(X) < R_j(X)$ where for any project n

$$R_n(X) = \frac{C_n}{1-(1+I)^{t(X)-t(X+O_n)}}$$

A useful property of the foregoing condition is that the R-index, $R_n(X)$, depends only upon the total output of the projects already in the sequence and on the cost and output of the project under consideration, but not on the other candidate projects. At any point in a sequence, the R-index can be computed separately for each project and the necessary condition then implies that, at that particular point in the sequence, a project cannot immediately precede another with a lower R-index. The search procedure involves computing the R-index, $R_n(X)$, for each project for the beginning of the sequence (where X = 0) and selecting the project with the lowest index value. Then the procedure is repeated with the remaining projects but this time X is set equal to the output of the project already selected; again the project with the lowest R-index selected. Then X is set equal to the total output of the two projects already selected, the search procedure is repeated with the remaining projects, and so on.

In applying this method to the actual problem, the load demand curve is increased by 10 % to cover the required reserve capacity, and the project sequence is planned to meet this increased demand curve, see Fig. 2.1. For a relatively large project, the installation of generating units and substations could be stage-developed, but, for the matter of simplicity, it is assumed that the cost of each project can be capitalized to the time when it comes into operation. Interest during construction and O & M costs are not particularly accounted for, as these costs can be deemed proportional to the construction cost, so that do not affect the order of the magnitude for R-indices.

This search procedure is related to the value of discount rate. A discount rate of 6 % is used in the forthcoming study. Many Asian and European countries have obtained development fund at this rate for the post-War economic reconstruction. This rate is adopted since it is relatively low at the present level of the world economy, yet not too far from the realistic figure of the bank loan.

It is essential to eliminate as many projects as possible by judgement before this procedure is applied for. Also, since the procedure is an overly simplified one, it should be regarded merely a tool of making decision, and the result should be critically evaluated considering all other relevant factors.

## 3. Application on the CNPS

### 3.1 First Project

The anticipated earliest in-service date for the first project is in 78/79. By that time, the generating capacity of the CNPS would be as follows.

| | | |
|---|---|---|
| Existing facilities | | |
| | Diesel units | 7,660 kW /1 |
| | Hydro project | 26,600 kW (in dry season) /2 |
| Facilities to be added | | |
| | Gandaki project | 7,000 kW /3 |
| | Devighat project | 14,000 kW |
| | Butwal project | 1,000 kW |
| | Operation of Trisuli's standby unit | 3,000 kW /4 |
| | Connection of Bharatpur Diesel Plant | 600 kW |
| | Facilities in Western system | 3,000 kW /5 |
| | Total | 62,860 kW |

From Table 1.1 of Appendix 1, Kulikhani No.1 (46 MW), Bagmati (70 MW), and Dev-Ghat (150 MW) are selected as candidate projects. As shown in Fig. 2.1, the peaking capacity of the system would be a little short for the demand when the first project comes into operation, the Kulikhani No.1 project would be planned as a peaking plant with a plant factor of 37 %. For the other projects, where the scales are larger than Kulikhani

---

/1 Mahendra, Patan, and Hetaura plants, see Table 3.3, Appendix 3.

/2 Trisuli, Panauti, Sun Kosi, Sundarijal, Pharping, and Godawari plants, see Table 3.3, Appendix 3.

/3 Installed capacity will be 15,000 kW, but the committed power is 7,000 kW.

/4 A transformer is required for the operation of the Trisuli's standby unit.

/5 See Table 3.4, Appendix 3. Before Pokhara be integrated to the CNPS, a diesel generating set of 500 kW is planned to be installed to meet the immediate growing demand. Since this set is used only for interim purpose, it is not include in this figure.

No.1, a plant factor of 60 % is used, as the installation of these projects would cause shut-off of the present uneconomical units and become major energy source in the system.

Conceivable transmission system for each candidate project is illustrated in Fig. 2.2(A).

(1) Project cost

Kulikhani No.1 Project (46 MW) /1

The energy of the Kulikhani No.1 project will be used primarily in local market. The energy will be delivered to Kathmandu through existing 66 kV line. The existing substation at Kathmandu will be extended with 2 x 27 MVA transformers. The project cost is estimated as follows.

| | | |
|---|---|---|
| Dam and powerplant | US$ | $43.6 \times 10^6$ |
| Transmission facilities | | 1.4 |
| Total | US$ | $45.0 \times 10^6$ |

From the demand growth curve in Fig. 2.1, the required next installation would be in 1982. Therefore, the mature time is 3.5 years.

Bagmati Project (70 kW)

The Bagmati Project is a multipurpose development, and the power function shares about 5 % of the joint cost. The power can be used for both local market and India. The required transmission facilities are a 132 kV, double circuit line from the Bagmati powerplant to Kathmandu via Birganj and Hetaura, totalling 171 km in length, and substations at Kathmandu (2x35 MVA), Hetaura (10 MVA) and Birganj (10 MVA). The project cost is estimated as follows.

| | | |
|---|---|---|
| Dam and powerplant | US$ | $23.4 \times 10^6$ |
| Transmission facilities | | 6.9 |
| Total | US$ | $30.3 \times 10^6$ |

The required next installation would be in 1984. Therefore, the mature time is 5.5 years.

/1 The final figure of the installed capacity is 60 MW, see the footnote of page 1-28, Appendix 1. However, this would further substantiate the conclusion drawn in this Appendix.

Dev-Ghat Project (150 MW)

This project also can supply the surplus energy to India. The required transmission facilities are a 132 kV, double circuit line from the Dev-Ghat power plant to Kathmandu via Hetaura, totalling 115 km in length, a same natured branch line of 56 km long from Hetaura to Birganj, and substations at Kathmandu (4x33 MVA), Hetaura (2x15 MVA) and Birganj (2x15 MVA). The project cost is estimated as follows.

| | |
|---|---|
| Dam and power plant | US\$68.1 x $10^6$ |
| Transmission facilities | 8.7 |
| Total | US\$76.8 x $10^6$ |

The connection of the Eastern Region to the CNPS would be made in 85/86. As described in 6.4.3 of the text and shown in Fig.2.1, the installation of the Eastern Region is self-satisfied the Region's demand up to 85/86, but the demand beyond that year would have to be met by the excess capacity of the combined CNPS. As can be seen from Fig.2.1, the installation of the Dev-Ghat can satisfy the combined system demand beyond 85/86, and the required next installation in the system is estimated to be in 1989. So, the mature time is 10.5 years.

(2) Surplus energy

The firm energy of the Kulikhani No.1 project will be consumed mainly in the local market. While the excess energy produced in wet years and its maturity period could be exported if so required, the monetary value of it is estimated to share only several per cent of the total cost. This means the secondary energy of the Kulikhani No.1 project has relatively less value in the sequence study compaired with the other candidate projects. The availability of the idle capacity of the plant to India is only possible during its maturity period of 3.5 years.

For the Bagmati and Dev-Ghat projects, it is assumed that (1) the local energy demand when a new project comes into operation will be served by existing units, and the new project will supply only incremental portion of the local energy demand thereafter, (2) the surplus energy after meeting the local demand will be exported to India, and (3) the idle capacity of a new plant capacity will be only made available to India during the build-up period of the local system, and after the system uses up the capacity, only surplus secondary energy will be supplied to India. These are of course over-simplified assumptions and the actual operation will sure be different from them. A sound judgement is required when interpretation is made on the results based on such assumptions. Also, such energy supply to India may be regarded as only offering sedondary energy from the very beginning, and will have to be sold at a low price reasonably accepted to the both countries. Discussion on this matter is given in 4.3 of the text. It is assumed that 50 % of the surplus energy is sold at a price of 8 mills/kWh. Other assumption could be made though. Therefore, the study based on this assumption should be taken as an indicative one.

Bagmati Project

From Fig. 2.1, the energy demand is read to be;

| Year | Energy demand (GWh) |
| --- | --- |
| 78/79 (in-service) | 282 |
| 1984 (matured) | 508 |

It is also assumed that the increasing energy demand after 1984 will be met by new installations. Then, the energy supply from the Bagmati project to the local market is;

| Year | Supply from Bagmati (GWh) |
| --- | --- |
| 78/79 | 0 |
| 1984 | 226 (508 - 282) |
| 1984 to 2028/29 | 226 |

The economic life of the project is taken as 50 years.

From Fig. 2.1, the increase of energy demand from 78/79 to 1984 can be reasonably taken as a straight line. The average annual increase during this period is 46.1 GWh/yr. The present value of the energy for such uniform gradient series is given by

$$PV = \frac{(1 + i)^{N+1} - (1 + Ni + i)}{i^2(1 + i)^N}$$

where, PV = Present value

i = Discount rate

N = Time span to maturing, in year.

From 1984 to the end of the project life, the present value of the energy can be calculated from the formula of uniform series, i.e.,

$$\text{PV at year } N = \frac{(1 + i)^{50-N} - 1}{i(1 + i)^{50-N}}$$

Also,

$$\text{PV at year } 0 = \frac{1}{(1 + i)^N} \times (\text{PV at year } N)$$

The present values of local energy supply calculated by these formulas are,

| | |
|---|---|
| 78/79 - 1984 (5.5 yr) | 591 GWh |
| 1984 - 2028/29 (44.5 yr) | 2,530 |
| | 3,121 GWh |

On the other hand, the annual energy output of the Bagmati project is 490 GWh, as shown in Table 1.1 of Appendix 1. It is assumed that 10 % of each installation is kept as reserved capacity. Therefore, the annual output of operating capacity is 445 GWh. The present value of this energy output for 50 years can be calculated by aforementioned uniform series formula, which amounts to 7,021 GWh.

Based on the assumption, the surplus energy supply to India is,

$$(7,021 - 3,121) \times 0.5 = 1,950 \text{ GWh}$$

For 8 mills/kWh, the monetary value is,

$$0.008 \times 1,950 \times 10^6 = \text{US\$}15.6 \times 10^6$$

Dev-Ghat Project

The same method as described above is used. This is shown below.

| Year | Time span (yr) | Energy demand (GWh) | Supply by original Eastern system | Supply from Dev-Ghat (GWh) |
|---|---|---|---|---|
| 78/79(in-service) | | 282 | | 0 |
| 1989 (matured) | 10.5 | 1,016 | 170 | 564 |
| 2028/29 | 39.5 | | | 564 |

The annual energy output of the project is 1,193 GWh, see Table 1.1 of Appendix 1. As operating capacity is taken as 10 % less, its annual output becomes 1,085 GWh. Therefore, the followings are obtained.

| | |
|---|---|
| Present value of local energy supply | = 7,096 GWh |
| Present value of energy output by operating capacity | = 17,095 GWh |
| Surplus energy to India | = 5,000 GWh |
| Monetary value of surplus energy | = US$40 x $10^6$ |

(3) R-index

The R-indices can easily be calculated as follows.

Case 1 No supply to India.

i) Kulikhani No.1 Project (46 MW)

$$R = \frac{45.0 \times 10^6}{1 - (1 + 0.06)^{-3.5}} = 245 \times 10^6 \quad /1$$

ii) Bagmati Project (70 MW)

$$R = \frac{30.3 \times 10^6}{1 - (1 + 0.06)^{-5.5}} = 111 \times 10^6$$

iii) Dev-Ghat Project

$$R = \frac{76.8 \times 10^6}{1 - (1 + 0.06)^{-10.5}} = 168 \times 10^6$$

Case 2 Surplus energy to India

In this case, the project can be deemed to be constructed at less cost than the actually required one by the amount equivalent to the discounted present worth of the surplus energy sales. The adjusted project costs are,

Bagmati Project: $30.3 \times 10^6 - 15.6 \times 10^6 = US\$14.7 \times 10^6$
Dev-Ghat Project: $76.8 \times 10^6 - 40.0 \times 10^6 = US\$36.8 \times 10^6$

Therefore, the R-indices are calculated as follows.

i) Bagmati Project

$$R = \frac{18.6 \times 10^6}{1 - (1 + 0.06)^{-5.5}} = 54 \times 10^6$$

ii) Dev-Ghat Project

$$R = \frac{46.8 \times 10^6}{1 - (1 + 0.06)^{-10.5}} = 80 \times 10^6$$

---

/1 If the surplus energy to India is counted for, the R-index is reduced to $234 \times 10^6$.

(4) Selection of the first project and sensitivity test

Based on the comparison of the R-indices, the Bagmati Project appears to be the first choice. However, this project is a multipurpose development and the power function shares only 5 % of the joint cost. Therefore, the implementation of the project is much more affected by other project functions than the power function. The required total fund is much larger than the one appeared in Table 1.1 of Appendix 1. As described in 3.1.1 of Appendix 1, the cost of dam and powerplant will amount to US\$97.3 x $10^6$; for realization of irrigation benefit, another US\$227.7 x $10^6$ will be required.

While the R-indices favor the Dev-Ghat project over the Kulikhani No.1 project, the significance of the difference in the R-indices is examined by a sensitivity test as presented hereinafter.

A sensitivity test can readily be made by equating to R-indices at any particular position in the sequence and computing what the costs of the various projects would have to be before they could be considered for that position. If project p is the chosen project for a point when the demand is X, then the cost of project i ($C_i$) would have to be changed (to $C_i'$) such that $R_i(X) = R_p(X)$ before i could compete with p for its position, i.e.:

$$C_i' = C_i \frac{R_p(X)}{R_i(X)}$$

The sensitivity test between Kulikhani No.1 and Dev-Ghat calculated by this procedure is shown below;

| Project | Kulikhani No.1 | Dev-Ghat |
|---|---|---|
| Cost ($10^6$ US\$) | 45.0 | 76.8 |
| New cost if project were to occupy 1st position | 30.9 | 76.8 |
| Reduction | - 31 % | 0 |

This indicates that if the cost of Kulikhani No.1 project is 31 % less than the estimated cost in Table 1.1 of Appendix 1, or the cost of

Dev-Ghat is 31 % more than the estimated one, then the Kulikhani No.1 project is competitive with the Dev-Ghat project. At the present level of the study, this difference may or may not be regarded as a decisive one depending upon the opinion.

An important point is that the tailwater of the Kulikhani No.1 project will be reused by the No.2 project, which appears a favorable one as seen in Table 1.1 of Appendix 1. The real advantage of the Kulikhani No.1 cannot be utilized unless the No.2 project is realized. Therefore, the No.1 and No.2 projects can be deemed as one project which is constructed in two stages. The R-index and sensitivity test when the No.1 and No.2 projects are considered stage-constructed one project are discussed below.

As shown later in 3.2 (1), the cost of No.2 is US\$15.1 x $10^6$. This is discounted to be US\$12.3 x $10^6$ in 78/79, a base year for the first project. Therefore, the present value of the project cost for Kulikhani No.1 and No.2 becomes US\$57.3 x $10^6$. The maturing year can be taken as the sum of the two projects', i.e., 6 years. The R-index is calculated as follows.

$$R = \frac{57.3 \times 10^6}{1 - (1 + 0.06)^{-6}} = 194 \times 10^6$$

While this R-index is still larger than that of the Dev-Ghat, the significance of their difference is checked by a sensitivity test, which results are presented as follows.

| Project | Kulikhani No.1 and No.2 | Dev-Ghat |
|---|---|---|
| Cost ($10^6$ US\$) | 57.3 | 76.8 |
| New cost if project were to occupy 1st position | 49.6 | 76.8 |
| Reduction | - 13 % | 0 |

This means that if the costs of Kulikhani No.1 and No.2 projects are 13 % less than the presently estimated ones, the combination of No.1 and No.2 is competitive with the Dev-Ghat project. This difference is certainly insignificant at this stage of the study (an independent evaluation of the No.2 project is given later).

It can be seen from Fig. 2.1 that the peaking capacity of the CNPS would be a little in short for the demand, not to speak of the reserve capacity, when the first project comes into operation. In order to respond such an urgent requirement, the Kulikhani No.1 is the only project that has been studied into some detail and likely to be installed in time. The fund requirement is also the least among the candidate projects. Therefore, the Kulikhani No.1 is selected as the first project.

3.2 Second Project

If the Kulikhani No.1 Project is selected as the first project, then the second project would have to be installed in 1982, see Fig. 2.1. The candidate projects for the second installation are,

Kulikhani No.2 Project (26 MW)/1
Bagmati Project (70 MW)
Dev-Ghat Project (150 MW)

The required transmission facilities for each candidate project assuming that the Kulikhani No.1 project is already in existence are illustrated in Fig. 2.2 (B).

(1) Project cost

<u>Kulikhani No.2 Project (26 MW)</u>

The energy will be supplied to local market only. The required transmission facilities are a 132 kV, single circuit line of 29 km long from the No.2 powerplant to Kathmandu via No.1 powerplant, the same natured transmission line of 13 km long from the No.2 powerplant to Hetaura, addition of 18 MVA transformer at Kathmandu, and 2 x 10 MVA substation at Hetaura. Supply to Birganj will be made from Hetaura through the existing 66 kV line. The project cost is estimated as follows.

| | | |
|---|---|---|
| Waterway facilities and powerplant | US$ | $12.2 \times 10^6$ |
| Transmissipn facilities | | 2.9 |
| Total | US$ | $15.1 \times 10^6$ |

/1 The final figure would be 35 MW.

From the demand curve (Fig. 2.1), the required next installation is estimated to be in 84/85. So, the mature time is 2.5 years.

Bagmati Project (70 MW)

The required transmission lines are same as described before (3.1). The substation facilities are as follows: addition of 2 x 24 MVA at Kathmandu, and substations at Hetaura (18 MVA) and Birganj (18 MVA). So, the project cost would be,

| | | |
|---|---|---|
| Dam and powerplant | US$ | $23.4 \times 10^6$ |
| Transmission facilities | | 6.5 |
| Total | US$ | $29.9 \times 10^6$ |

The required next installation, considering the connection of the Eastern system, is estimated to be in 1987, so that the mature time is 5 years.

Dev-Ghat Project (150 MW)

The required transmission lines are same as described before (3.1). The substations are addition of 3 x 40 MVA at Kathmandu, and 2 x 18 MVA each at Hetaura and Birganj. The project cost would be,

| | | |
|---|---|---|
| Dam and powerplant | US$ | $68.1 \times 10^6$ |
| Transmission facilities | | 8.7 |
| Total | US$ | $76.8 \times 10^6$ |

The installation of the third project would be in 90/91, so that the mature time is 8.5 years.

(2) Surplus energy

The energy demands in the CNPS at the limiting years for the second project are as follows.

| Year | Energy Demand in the CNPS (GWh) |
|---|---|
| 1982 | 428 |
| 1987 | 887 |
| 90/91 | 1,156 |

The energy demand after 85/86 is for the combined CNPS and Eastern systems. The original installations in the Eastern system can supply 170 GWh per annum. The supply of the surplus energy to India can be calculated by the same way as described before. The results are shown as follows.

| Project | Ann. energy output of operating capacity (GWh) | PV of energy output (GWh) | PV of energy supply in Nepal (GWh) | PV of surplus energy to India (GWh) | PV of surplus energy to India ($10^6$ US$) |
|---|---|---|---|---|---|
| Bagmati | 445 | 7,021 | 4,053 | 1,484 | 11.9 |
| Dev-Ghat | 1,085 | 17,095 | 7,056 | 5,020 | 40.1 |

(3) R-index

The results of calculating the R-index for each project is given below.

Case 1 No supply to India

| Project | R-index ($10^6$) |
|---|---|
| Kulikhani No.2 | 112 |
| Bagmati | 118 |
| Dev-Ghat | 197 |

Case 2 Surplus energy to India

Adjusted project cost:

| | |
|---|---|
| Bagmati project | US$18.0 x $10^6$ |
| Dev-Ghat project | US$36.7 x $10^6$ |

R-index:

| Project | R-index ($10^6$) |
| --- | --- |
| Bagmati | 71 |
| Dev-Ghat | 94 |

(4) Selection of the second project

The Bagmati is a good project, but it is set aside in this project selection by the same reason described in the previous article.

The Kulikhani No.2 offers a smaller R-index than the Dev-Ghat does, but vice versa if the secondary energy is counted. However, it is considered reasonable to select the Kulikhani No.2 Project, attaching more importance to the result of Case I. The fund requirement of the Kulikhani No.2 is much smaller than that of the Dev-Ghat. Since the primary concern of the medium to small scale development is to find an economical way of meeting the local demand, the Kulikhani No.2 is selected as the second project.

## 3.3 Third Project

After the implementation of the Kulikhani No.1 and No.2, the third project is required to be installed in 84/85, based on the load forecast. The candidate projects are,

Kulikhani No.3 project (14 MW)/1
Bagmati project (70 MW)
Dev-Ghat project (150 MW)

Conceivable transmission facilities of each project are illustrated in Fig.2.2 (C).

(1) Project cost

Kulikhani No.3 Project (14 MW)

After the installation of the No.1 and No.2 plants, no transmission line is required for the No.3 project. Required extensions of the substations are 1 x 10 MVA at Kathmandu, and 1 x 6 MVA at Hetaura.

/1 The final figure would be 17 MW.

The project cost is estimated as follows.

| | |
|---|---|
| Dam and powerplant | US$ 19.9 x $10^6$ |
| Transmission facilities | 0.5 |
| Total | US$ 20.4 x $10^6$ |

The required next installation would be in 85/86, so that the mature time is 1 year.

Bagmati Project (70 MW)

If the Bagmati Project is installed after the Kulikhani No.1 and No.2, the required transmission facilities are a 132 kV, double circuit transmission line from the powerplant to Hetaura via Birganj, an addition of 132 kV, single circuit line from Hetaura to Kathmandu via the Kulikhani No.1 and No.2 powerplants, and substations at Kathmandu (2x30 MVA) and Birganj (2x10 MVA). The project cost would be,

| | |
|---|---|
| Dam and powerplant | US$ 23.4 x $10^6$ |
| Transmission facilities | 6.1 |
| Total | US$ 29.5 x $10^6$ |

The required next installation would be in 88/89, so that the mature time is 4 years.

Dev-Ghat Project (150 MW)

For the third place, the Dev-Ghat Project requires the transmission facilities of a 132 kV, double circuit line from the powerplant to Birganj via Hetaura, an addition of 132 kV, single circuit line from Hetaura to Kathmandu via the Kulikhani No.1 and No.2 powerplants, and substations at Kathmandu (3x40 MVA), Hetaura (1x20 MVA), and Birganj (2x20 MVA). The project cost would be,

| | |
|---|---|
| Dam and powerplant | US$ 68.1 x $10^6$ |
| Transmission facilities | 8.1 |
| Total | US$ 76.2 x $10^6$ |

The required next installation would be in 91/92, so that the mature time is 7 years.

(2) Surplus energy

The energy demand of the CNPS at the limiting years for the third project is as follows.

| Year | Energy Demand in the CNPS (GWh) |
|---|---|
| 84/85 | 529 |
| 88/89 | 971 |
| 91/92 | 1,261 |

Among these figures, the original installation of the Eastern system can supply the energy of 170 GWh per annum.

Based on above figures, the supply of the surplus energy to India is estimated as follows.

| Project | PV of energy supply in Nepal (GWh) | PV of surplus energy to India (GWh) | ($10^6$US$) |
|---|---|---|---|
| Bagmati | 3,917 | 1,552 | 12.4 |
| Dev-Ghat | 7,423 | 4,836 | 38.7 |

(3) R-index

The results of calculation are shown below.

Case 1 No supply to India

| Project | R-index ($10^6$) |
|---|---|
| Kulikhani No.3 | 358 |
| Bagmati | 142 |
| Dev-Ghat | 227 |

Case 2 Surplus energy to India

Adjusted project costs:

Bagmati project: US$17.1 x $10^6$

Dev-Ghat project: US$37.5 x $10^6$

R-index:

| Project | R-index ($10^6$) |
|---|---|
| Bagmati | 82 |
| Dev-Ghat | 112 |

(4) Selection of the third project

Again the Bagmati project is the best. But if this is excluded, the Dev-Ghat project offers a smaller R-index than the Kulikhani No.3 does. The Kulikhani No.3 project is apparently too small at this stage of the development. Therefore, the Dev-Ghat project is selected as the third project.

4. Conclusion

The anticipated earliest in-service date of the first project is estimated to be in 78/79. The proposed development sequence is as follows.

In 78/79, Kulikhani No.1 Project (46 MW)
In 1982, Kulikhani No.2 Project (26 MW)
In 84/85, Dev-Ghat Project (150 MW)

It is also anticipated that the connection of the Kathmandu and Dhankuta systems will be made in 85/86, as described in the text. The installations shown above will be able to satisfy the combined demand up to 91/92.

It should be noted that the Bagmati Project (70 MW) on the Bagmati River appears a very favorable one, and could be installed at any time, as far as the hydroelectric power is concerned. However, this project is a multi-purpose development, and the power would share only 5 % of the joint cost. Therefore, its implementation is more governed by other project functions. If the Bagmati Project comes into being, aforementioned development schedule should be adjusted accordingly.

While the Kulikhani No.3 project is not casted in the aforementioned construction sequence, the project could be implemented at any time after the No.2 project. After successive completion of the No.1 and No.2 projects, it is only natural to consider the No.3 project for a follow-up, as it has many advantages such as easiness of accessibility and availability of existing construction equipment, which may not be able to be appropriately accounted for in the search procedure. The result of the study presented heretofore is, however, important as it implies that, it is about the right time to consider the implmentation of the Dev-Ghat project, a relatively large project as for Nepal, at the designated year.

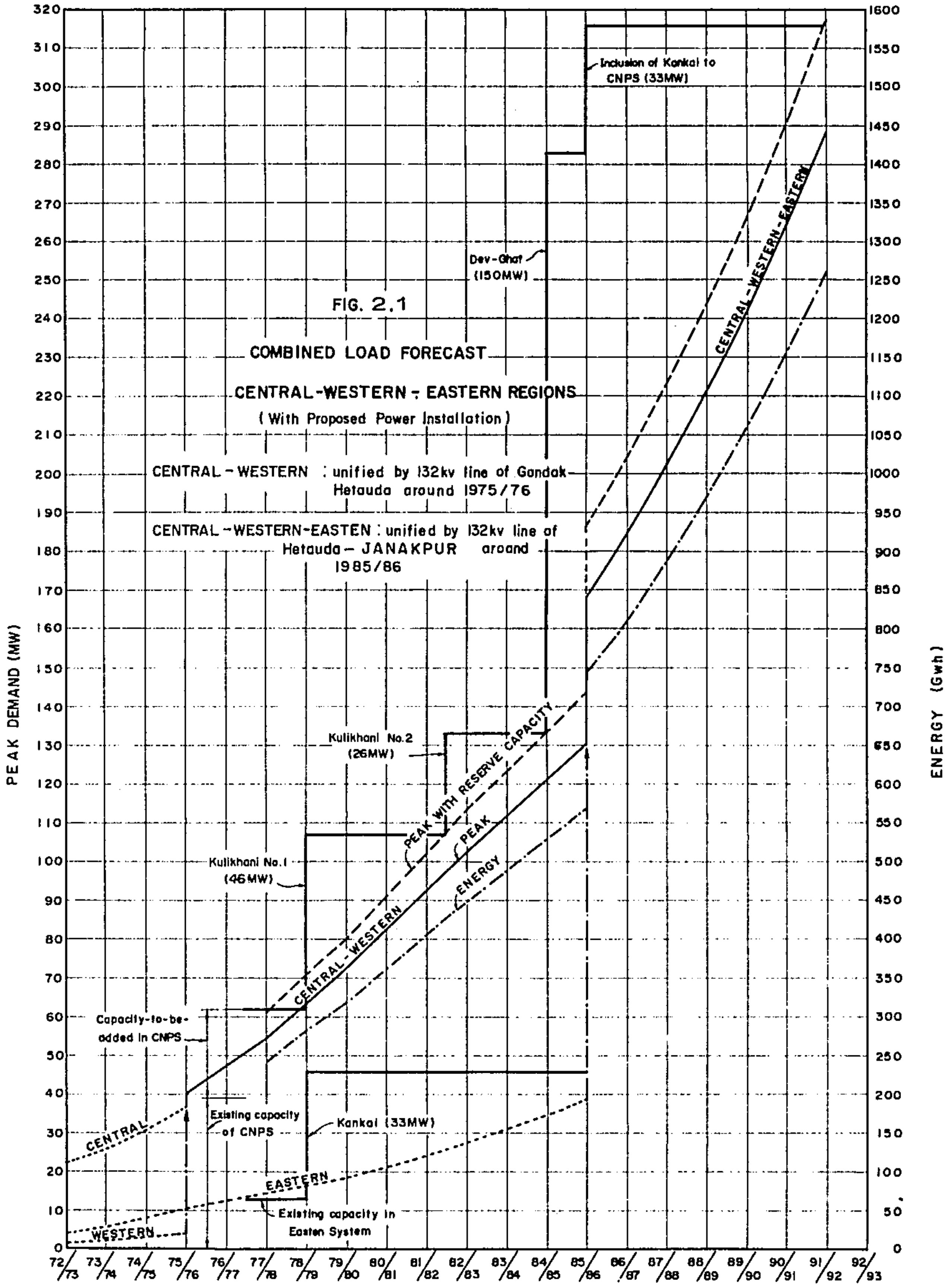
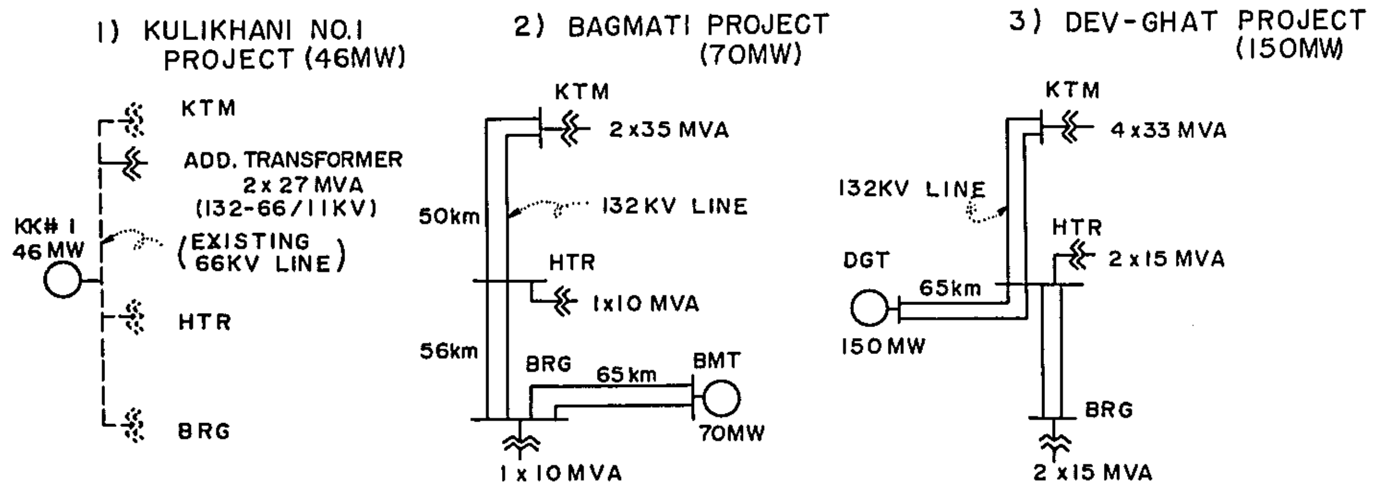
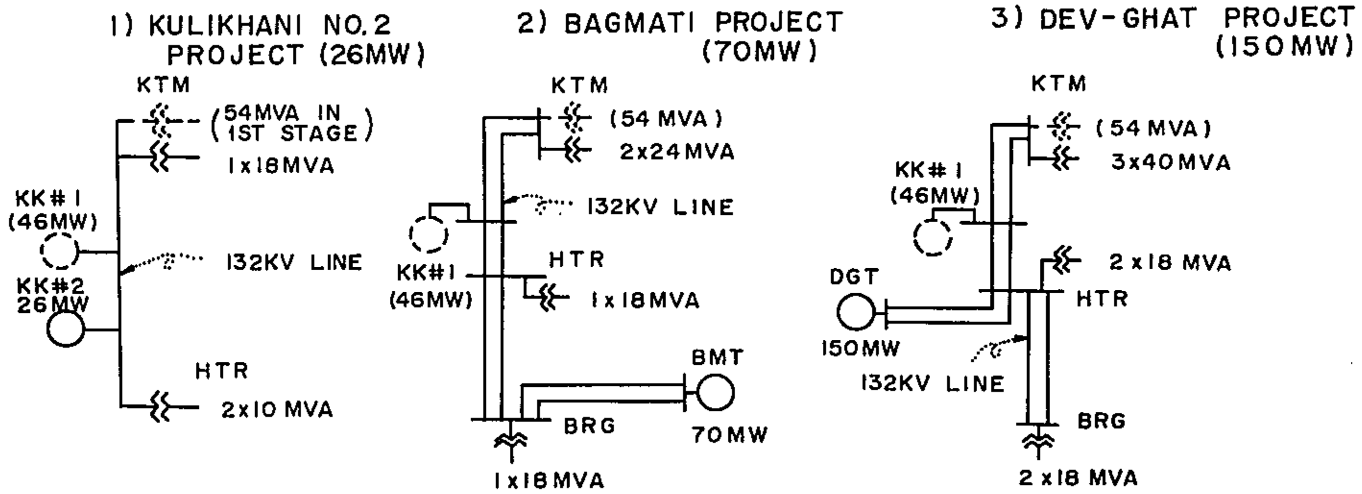


FIG. 2.1
COMBINED LOAD FORECAST
CENTRAL-WESTERN - EASTERN REGIONS
( With Proposed Power Installation )
CENTRAL - WESTERN : unified by 132kv line of Gandak-Hetauda around 1975/76
CENTRAL - WESTERN-EASTEN : unified by 132kv line of Hetauda - JANAKPUR aroand 1985/86
PEAK DEMAND (MW)
ENERGY (Gwh)
Inclusion of Kankai to CNPS (33MW)
Dev-Ghat (150MW)
Kulikhani No.2 (26MW)
Kulikhani No.1 (46MW)
Capacity-to-be-added in CNPS
Existing capacity of CNPS
Kankai (33MW)
Existing capacity in Easten System
PEAK WITH RESERVE CAPACITY
PEAK
ENERGY
CENTRAL-WESTERN
CENTRAL-WESTERN-EASTERN
CENTRAL
EASTERN
WESTERN

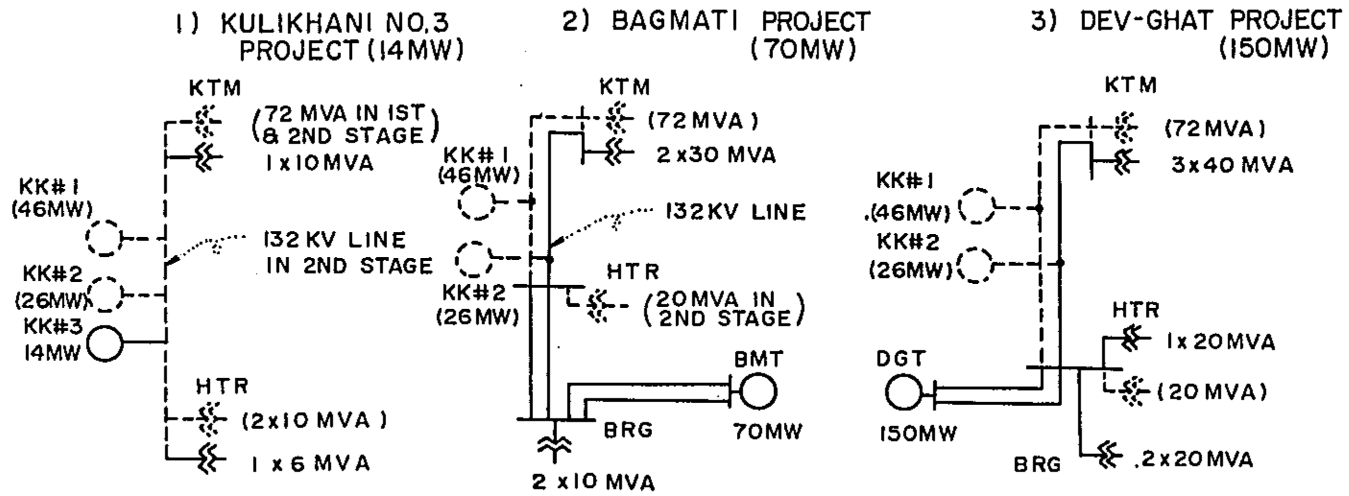
(A) First Project




(B) SECOND PROJECT
(AFTER KULIKHANI NO.1 PROJECT)




(C) THIRD PROJECT
(AFTER KULIKHANI NO.1 & NO.2 PROJECTS)




(REMARK) KTM ····· KATHMANDU
HTR ····· HETAURA
BRG ····· BIRGANJ
KK ····· KULIKHANI
BMT ····· BAGMATI
DGT ····· DEV-GHAT

DOTTED LINES MEAN EXISTING FACILITIES OR INSTALLED UNITS IN PREVIOUS STAGE OF DEVELOPMENT.

FIG.2.2 TRANSMISSION SYSTEM FOR VARIOUS POWER DEVELOPMENT SCHEME

2-21

# MASTER PLAN OF HYDROELECTRIC POWER DEVELOPMENT

# IN

# NEPAL

## APPENDIX 3

## POWER STATISTICS & DEMAND FORECAST

## APPENDIX - 3

### POWER STATISTICS & DEMAND FORECAST

TABLE - 3.1

INSTALLED GENERATING CAPACITY IN NEPAL

(As of the end of 1973)

| DEVELOPMENT REGION | UTILITY | INSTALLED CAPACITY (kW) | | | |
|---|---|---|---|---|---|
| | | HYDRO | STEAM | DIESEL | TOTAL |
| SURKHET | E.D. | - | - | 570 | 570 |
| | Private | - | 125 | - | 125 |
| | Sub-total | - | 125 | 570 | 695 |
| POKHARA | E.D. | 1,000 | - | 1,057 | 2,057 |
| | B.P.C. | 50 | - | 115 | 165 |
| | Private | - | 750 | 15 | 765 |
| | Sub-total | 1,050 | 750 | 1,187 | 2,987 |
| KATHMANDU | N.E.C. | 21,570 | - | 8,284 | 29,854 |
| | E.D. | 10,050 | - | 750 | 10,800 |
| | Private | - | 1,600 | 944 | 2,544 |
| | Sub-total | 31,620 | 1,600 | 9,978 | 43,198 |
| DHANKUTA | E.D. | 240 | - | 100 | 340 |
| | D.E.C. | - | - | 212 | 212 |
| | M.H. | - | - | 1,695 | 1,695 |
| | Private | - | 1,400 | 3,108 | 4,508 |
| | Sub-total | 240 | 1,400 | 5,115 | 6,755 |
| TOTAL | | 32,910 | 3,875 | 16,850 | 53,635 |

E.D. : Electricity Department of the Government (13,767 kW)/1

B.P.C. : Butwal Power Company (165 kW)

N.E.C. : Nepal Electricity Corporation (29,854 kW)

D.E.C. : Dharan Electric Company (212 kW)

M.H. : Morang Hydro Electric Co. (1,695 kW)

/1 Figures in parentheses indicate total installed capacities.

TABLE - 3.2

IMPORTING & EXPORTING POWER FROM/TO INDIA
(1972/73)

Unit in kW

| DEVELOPMENT REGION | TOWNS | PRESENT IMPORTATION | COMMITTED POWER |
|---|---|---|---|
| Far Western | Mahendranagar | 150 | 500 |
| " | Dhangarhi | - | 300 |
| " | Nepalganj | 300 | 1,000 |
| " | Koilabas | - | 200 |
| Western | Krishnagar | 100 | 800 |
| " | Bhairahawa | 300 | 500 |
| Central | Gaur | 100 | 300 |
| " | Malangwa | 70 | 200 |
| " | Jaleswar | 100 | 1,000 |
| Eastern | Rajbiraj | 500 | 500 |
| " | Sirha | - | 200 |
| " | Biratnagar | 2,000 | 6,800 |
| " | Bhadrapur | - | 1,000 |
| | TOTAL | 3,620 | 13,300 |

| DEVELOPMENT REGION | TOWN | PRESENT EXPORTATION | COMMITTED POWER |
|---|---|---|---|
| Central | Raxual | 1,300 | 5,000 |

TABLE - 3.3

DETAILED GENERATING FACILITIES (1972/73)

IN

KATHMANDU (CENTRAL) DEVELOPMENT REGION (BAGMATI, NARAYANI & JANAKPUR)

| STATION | TYPE | INSTALLED CAPACITY (kW) | PEAKING CAPABILITY IN DRY SEASON (kW) | ZONE | REMARKS |
|---|---|---|---|---|---|
| Trisuli | Hydro (Francis) | 18,000(3,000)/1 | 18,000 | Bagmati | CNPS |
| Panauti | " " | 2,400 | 1,500 | " | " |
| Sunkosi/3 | " " | 10,050 | 6,000 | " | " |
| Sundarijal | " (Pelton) | 640 | 700/2 | " | " |
| Pharping | " " | 500 | 400 | " | " |
| Godawari | " | 30 | 30 | " | " |
| Mahendra | Diesel | 1,696 | | " | " |
| Patan | " | 1,490 | | " | " |
| Hetaura | " | 4,470 | | Narayani | " |
| Bharatpur/4 | " | 628 | | " | |
| Birganj Sugar Mill | " | 272 | | " | |
| " | Steam | 1,600 | | " | |
| Janakpur/3 | Diesel | 750 | | Janakpur | |
| Himalayan Iron & Steel | " | 100 | | " | |
| Janakpur Cigarette | " | 572 | | " | |
| Total | | 43,198 | | | |

/1 One unit of 3,000 kW at Trisuli is a standby, which is not included in the installed capacity of 18,000 kW.

/2 Nominal capacity is 640 kW, but actually 700 kW is available.

/3 Managed by Electricity Department.

/4 Managed by NEC.

TABLE - 3.4

DETAILED GENERATING FACILITIES

IN

SURKHET, POKHARA & DHANKUTA REGIONS (1972/73)

| REGION & STATION | INSTALLED CAPACITY (kW) | | | |
|---|---|---|---|---|
| | HYDRO | STEAM | DIESEL | TOTAL |
| SURKHET | | | | |
| Nepalganj | – | – | 500 | 500 |
| Dhangadi | – | – | 50 | 50 |
| Mahendranagar | – | – | 20 | 20 |
| Sheri | – | 125 | – | 125 |
| Total | – | 125 | 570 | 695 |
| POKHARA | | | | |
| Pokhara | 1,000 | – | | 1,000 |
| Bhairawa | – | – | 528 | 528 |
| Taulihawa | – | – | 50 | 50 |
| Bahadurganj | – | – | 25 | 25 |
| Krishnagar | – | – | 165 | 165 |
| Tansen | – | – | 289 | 289 |
| Butwal Power Co. | 50 | – | 115 | 165 |
| Mahendra Sugar Mill | – | 750 | 15 | 765 |
| Total | 1,050 | 750 | 1,187 | 2,987 |
| DHANKUTA | | | | |
| Bhadrapur | – | – | 100 | 100 |
| Dhankuta | 240 | – | – | 240 |
| Dharan (EEC) | – | – | 212 | 212 |
| Morang (EEC) | – | – | 1,695 | 1,695 |
| Biratnagar Jute Mill | – | 1,400 | 850 | 2,250 |
| Ilam Tea Plantation | – | – | 100 | 100 |
| Morang Sugar Mill | – | – | 15 | 15 |
| Raghupati Jute Mill | – | – | 337 | 337 |
| Nepal Straw Board | – | – | 356 | 356 |
| Golcha Cotton Mill | – | – | 125 | 125 |
| Asoka Textile | – | – | 125 | 125 |
| Dharan Military Camp | – | – | 1,200 | 1,200 |
| Total | 240 | 1,400 | 5,115 | 6,755 |

TABLE - 3.5

POWER STATISTICS OF CENTRAL NEPAL POWER SYSTEM (BAGMATI & NARAYANI ZONES)

| YEAR | UTILIZED ENERGY (MWh) | | | | | | ENERGY LOSS | TOTAL GENERATED ENERGY | PEAK DEMAND | NO. of DOMESTIC CONSUMERS | ENERGY CONSUMPTION PER CONSUMER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | DOMESTIC MWh (% growth) | INDUSTRY MWh (% growth) | COMMERCIAL MWh (% growth) | STREET LIGHT MWh (% growth) | STATION SERV. MWh (% growth) | TOTAL MWh (% growth) | MWh (% for total) | MWh (% growth) | kW (% growth) | Nos. (% growth) | (kWh) |
| 1966/67 | - | - | - | - | - | - | - | 27,437 | - | - | - |
| 67/68 | 12,924 | 3,013 | 2,196 | 750 | 1,891 | 20,774 | 11,985 (37.0) | 32,759 (19.5) | 8,885 | 21,585 | 494 |
| 68/69 | 15,367 (19.0) | 4,381 (45.5) | 2,616 (19.0) | 779 (4.0) | 1,390 (-36.0) | 24,533 (18.0) | 14,509 (37.6) | 38,515 (17.5) | 10,540 (19.0) | 28,307 (31.0) | 543 |
| 69/70 | 18,274 (19.0) | 5,197 (18.5) | 3,524 (35.0) | 737 (-6.0) | 1,524 (9.5) | 29,256 (19.0) | 15,621 (34.8) | 44,877 (16.5) | 11,560 (9.5) | 34,595 (22.0) | 528 |
| 70/71 | 22,826 (25.0) | 5;749 (11.0) | 4,567 (29.0 | 784 (6.5) | 1,516 (-0.5) | 35,442 (21.0) | 18,207 (34.0) | 53,649 (20.0) | 13,860 (20.0) | 40,951 (18.5) | 557 |
| 71/72 | 30,098 (31.0) | 6,648 (15.5) | 4,930 (8.0) | 794 (1.5) | 1,494 (-1.5) | 43,964 (24.0) | 22,000 (33.33) | 65,964 (23.0) | 17,500 (26.5) | 45,493 (11.1) | 661 |

TABLE - 3.6

POWER STATISTICS OF POKHARA, SURKHET & DHANKUTA REGIONS

POKHARA REGION

| | UTILIZED ENERGY (MWh) | | | | | | ENERGY LOSS | TOTAL GENERATED ENERGY | PEAK DEMAND | NO. of DOMESTIC CONSUMERS | ENERGY CONSUMPTION PER CONSUMER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | DOMESTIC MWh (% growth) | INDUSTRY MWh (% growth) | COMMERCIAL MWh (% growth) | STREET LIGHT MWh (% growth) | STATION SERVICE MWh (% growth) | TOTAL MWh (% growth) | MWh (% for total) | MWh (% growth) | kW (% growth) | Nos. (% growth) | (kWh) |
| 1969/70 | 281.3 | 104.6 | 17.3 | | 34.4 /1 | 437.6 | 219.1 (33.0) | 656.7 | 250 | 873 | 322 |
| 70/71 | 366.2 (30.2) | 149.7 (43.2) | 13.1 (-32.0) | | 21.0 | 550.0 (26.0) | 328.6 (33.0) | 878.6 (31.5) | 380 (15.2) | 1,064 (21.9) | 344 |
| 71/72 | 432.8 (18.2) | 135.6 (-10.0) | 35.9 (27.4) | 43.8 | 16.3 | 664.4 (20.5) | 351.8 (35.0) | 1,016.2 (15.5) | 440 (16.0) | 1,274 (19.7) | 340 |
| 72/73 | 594.7 (37.0) | 161.6 (19.0) | 31.1 (-15.3) | 50.7 (16.0) | 15.6 (-4.5) | 854.0 (28.5) | 507.9 (37.0) | 1,361.9 (34.0) | 520 (18.0) | 1,497 (17.5) | 398 |

SURKHET REGION IN 1972/73

| | Mahendranagar | Dhangrhi | Nepalganj |
|---|---|---|---|
| Domestic Use (MWh) | 8.563 | 7.04 | 143.1 |
| Industrial Use (MWh) | - | - | - |
| Commercial Use (MWh) | - | - | - |
| Street Lighting (MWh) | 1.152 | 1.00 | 13.25 |
| Station Service (MWh) | 2.20 | 1.10 | 16.81 /2 |
| Total Consumption (MWh) | 11.915 | 9.14 | 173.16 (704) |
| Nos. of Domestic Consumer | 63 | 114 | 540 |
| Consumption per Domestic Consumer (kW) | 136 | 180 | 352 /2 |
| Peak Demand (kW) | 20 | 29 | 160 (250) |

/1 Sum of street light and station service.

/2 Record in 1973/74.

DHANKUTA REGION IN 1971/72 & 1972/73

| | Biratnagar | | Dhankuta | | Dharan | |
|---|---|---|---|---|---|---|
| | 71/72 | 72/73 | 71/72 | 72/73 | 71/72 | 72/73 |
| Domestic Use (MWh) | 13.44 | 16.36 | * | 45.77 | 229.0 | 308.5 |
| Industrial Use (MWh) | 27.57 | 34.16 | * | 15.54 | 23.3 | 86.2 |
| Commercial Use (MWh) | 149.39 | 194.58 | * | * | 17.0 | 21.6 |
| Street Light or Municipal Use (MWh) | 132.4 | 217.2 | * | * | 26.8 | 26.6 |
| Station Use (MWh) | 110.7 | 71.8 | * | * | 21.8 | 26.6 |
| Total Consumption (MWh) | 433.5 | 534.1 | * | * | 317.9 | 469.5 |
| Nos. of Domestic Consumer | 1,486 | 1,839 | * | * | * | * |
| Consumption per Domestic Consumer (kW) | 9.0 | 8.9 | * | * | * | * |
| Peak Demand (kW) | 1,055 | 2,820 | * | 110 | 187 | 210 |

* : No data available

TABLE - 3.7

TARIFF SUMMARY OF NEC (January, 1971)

| | Kathmandu (Nepal Electricity Corp.) | | Hetaura- Birganj (Electricity Dept.) | |
|---|---|---|---|---|
| Domestic | 20 paisa/kWh subject to min. charge Rs 5/month | | 35 paisa/kWh subject to min. charge Rs 6/month | |
| Irrigation and Water Supply | | | | |
| off peak use | 10 paisa/kWh | | 20 paisa/kWh | |
| other time | 15 " | | 30 " | |
| Temporary use | 60 " | | | |
| Street Lighting | | | | |
| Metered | 14 " | | 20 " | |
| Unmetered | 5 paisa/watt/month | | 7.5 paisa/watt/month | |
| Manufacturing and Processing Industry | Installation or Max. demand Charge (Rs/month) | Energy Charge (paisa/kWh) | Installation or Max. demand Charge (Rs/month) | Energy Charge (paisa/kWh) |
| Small (up to 100 kW) | 5/kW or | 15 | 5/kW | 25 |
| | 3.5/HP | " | | |
| Medium (101 to 500 kW) | 7.5/kW or | 12 | 7.5/kW or | 20 |
| | 5.6/HP or | " | 7.5/kVA max. | " |
| | 7.5/kWh max. | " | | |
| Bulk (above 500 kW) | 10/kVA max. | | 10/kVA max. | 15 |
| up to 100,000 kW/month | | 10 | | |
| Next 200,000 " | | 9 | | |
| All in excess 200,000 " | | 8 | | |
| Commercial and Service Industry | | | | |
| Ordinary (50 to 500 kW) | 7.5/kW or | 18 | 7.5/kW or | 30 |
| | 5.6/HP or | " | 7.5/kW max. | " |
| | 7.5/kVA max. | " | | |
| Bulk (above 500 kW) | 10/kVA max. | 15 | 10/kVA max. | 25 |
| Transport Industry | 7.5/kW or | 15 | | |
| | 5.6/HP or | " | | |
| | 7.5/kVA max. | " | | |

TABLE - 3.8

SALES OF ELECTRICITY PER UNIT FOR NEC (CLASSIFIED)

in Paisa/kWh

| Year | 1967/68 | 1968/69 | 1969/70 | 1970/71 | 1971/72 |
|---|---|---|---|---|---|
| 1) Domestic | 37.07 | 37.17 | 36.50 | 28.19 | 22.52 |
| 2) Industrial | 34.68 | 17.73 | 22.08 | 22.19 | 21.81 |
| 3) Commercial | 27.85 | 20.95 | 21.13 | 21.51 | 22.69 |
| 4) Bulk Supply | 2.50 | 2.50 | 12.49 | 12.49 | 12.50 |
| 5) Street Light | 13.57 | 9.57 | 13.51 | 13.94 | 14.06 |
| Mean of the total | 34.97 | 30.84 | 28.48 | 24.67 | 20.79 |

NOTE: Classified income devided by corresponding units sold.

TABLE - 3.9

LOAD FORECAST IN CENTRAL REGION

| | ENERGY (MWh) | | | | | | | | PEAK POWER (kW) |
|---|---|---|---|---|---|---|---|---|---|
| | DOMESTIC | INDUSTRY & IRRIGATION | COMMERCIAL | STREET LIGHTING | STATION SERVICE | EXPORT TO INDIA | ENERGY LOSS | TOTAL ENERGY | |
| 1971/72 | 30,098 | 6,648 | 4,930 | 794 | 1,494 | - | 22,000 | 65,964 | 17,500 |
| 72/73 | 34,300 | 7,200 | 5,700 | 900 | 1,500 | 1,750 | 25,300 | 76,650 | 21,200 |
| 73/74 | 38,800 | 7,900 | 6,500 | 1,100 | 1,700 | 5,260 | 30,200 | 91,460 | 25,400 |
| 74/75 | 43,900 | 8,850 | 7,600 | 1,200 | 1,900 | 8,760 | 35,600 | 107,810 | 30,600 |
| 75/76 | 49,500 | 14,800 | 8,700 | 1,500 | 2,100 | 12,260 | 43,800 | 132,660 | 36,500 |
| 76/77 | 56,000 | 16,800 | 10,000 | 1,700 | 2,300 | 17,520 | 51,500 | 155,820 | 42,500 |
| 77/78 | 64,000 | 28,800 | 11,500 | 2,100 | 3,800 | 17,520 | 63,000 | 190,720 | 49,500 |
| 78/79 | 74,500 | 34,500 | 13,200 | 2,600 | 4,200 | 17,520 | 72,500 | 219,020 | 57,700 |
| 79/80 | 89,000 | 73,200 | 15,200 | 3,600 | 4,600 | 17,520 | 79,200 | 282,320 | 65,000 |
| 80/81 | 110,000 | 84,400 | 17,500 | 4,200 | 5,100 | 17,520 | 83,280 | 322,000 | 73,500 |
| 81/82 | 135,000 | 96,200 | 20,200 | 5,000 | 6,600 | 17,520 | 79,480 | 360,000 | 82,400 |
| 82/83 | 160,000 | 108,900 | 23,200 | 5,800 | 7,300 | 17,520 | 75,280 | 398,000 | 90,500 |
| 83/84 | 181,000 | 118,400 | 26,700 | 6,500 | 8,000 | 17,520 | 69,880 | 428,000 | 97,700 |
| 84/85 | 201,000 | 125,700 | 30,700 | 7,100 | 10,000 | 17,520 | 69,980 | 462,000 | 105,500 |
| 85/86 | 218,000 | 132,200 | 35,300 | 7,600 | 11,000 | 17,520 | 75,380 | 497,000 | 114,000 |
| 86/87 | 236,500 | 139,200 | 40,600 | 8,300 | 12,100 | 17,520 | 80,780 | 535,000 | 123,000 |
| 87/88 | 255,000 | 146,700 | 46,600 | 9,000 | 13,300 | 17,520 | 87,880 | 575,000 | 133,000 |
| 88/89 | 276,000 | 154,700 | 53,500 | 9,700 | 14,600 | 17,520 | 91,980 | 618,000 | 143,700 |
| 89/90 | 297,500 | 163,400 | 61,500 | 10,400 | 16,000 | 17,520 | 99,680 | 666,000 | 155,000 |

Note: (1) Domestic demand is forecasted based on increase of the number of consumers and annual energy consumption per customer.

Growth rate of the number of consumers is estimated at 10 % per annum up to 1977/78 as extraporated from the recent tendency, then makes a gradual increase to 20 % up to 1983/84, and thereafter settles down to a constant rate of 5 %.

Annual consumption per consumer is assumed to increase at a constant rate of 3 % per annum, which corresponds to the average growth rate of the recent 5 years.

(2) The annual growth rate of industrial demand is estimated to be at 10 to 12 % up to 1975/76. It is assumed that private industries now being operated by their own generators will shift their power sources to public system during 1976/77 to 1982/83, as cheap and abundant power will be made available. Therefore, the annual growth rate during this period is assumed to be started at 20 %, hitting the peak of 40 %, and drop to 10 % in 1984/84. A constant growth rate of 8 % is applied for thereafter.

In addition, this category includes the expected power demand of the irrigation project in the Chituan Valley; i.e., 1,100 kW in 76/77, 2,200 kW in 77/78, and 7,000 kW in 79/80.

(3) Past trend shows very good correlation between the commercial demand and number of tourists. Commercial demand is assumed to increase at a constant rate of 15 % per annum in proportion to the increase of tourists.

(4) Power demand for street lighting is assumed to be at 20 % of the sum of domestic, industrial and commercial demands.

(5) Energy consumption at station is estimated to grow at a constant rate of 10 % per annum, taking account of the increase of plant consumption at substations accompanying the general demand growth.

(6) Exporting energy to India is based on the data of the Government of Nepal.

(7) Energy loss is assumed to be at 33 % initially referring to the records of recent years, and gradually improved to a constant rate of 15 %.

(8) Annual load factor is assumed to be at 41 % initially referring to the past trend, and to increase to 50 % gradually.

TABLE 3.10 LOAD FORECAST IN EASTERN REGION

| | PEAK DEMAND | | | | | | | | | | | | | | TOTAL /6 ENERGY REQUIRED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | JANAKPUR & RAJBIRAJ AREA | | | | BIRATNAGAR AREA | | | | | | OTHERS | | | Total | |
| | Janakpur & Jaleswar (kW) | Rajbiraj (kW) | Lahan & Sirha (kW) | Total (kW) | Birat-nagar (kW) | /1 Dharan (kW) | /2 Dubi (kW) | /3 Itahavi (kW) | /4 Rangeli (kW) | Total (kW) | /5 Bhadra-pur (kW) | Dhan-kuta (kW) | Total (kW) | (kW) | (MWh) |
| 1972/73 | 560 | 500 | - | 1,060 | 2,820 | 210 | - | - | - | 3,030 | 60 | 110 | 170 | 4,260 | 14,900 |
| 73/74 | 780 | 670 | - | 1,450 | 3,380 | 250 | 350 | 110 | - | 4,090 | 100 | 130 | 230 | 5,770 | 20,200 |
| 74/75 | 940 | 1,810 | - | 2,750 | 4,060 | 300 | 420 | 130 | 130 | 5,040 | 380 | 140 | 520 | 8,310 | 29,100 |
| 75/76 | 1,120 | 2,970 | 150 | 4,240 | 4,870 | 360 | 500 | 160 | 160 | 6,050 | 450 | 150 | 600 | 10,890 | 41,100 |
| 76/77 | 1,330 | 3,150 | 180 | 4,860 | 5,800 | 430 | 600 | 190 | 190 | 7,210 | 530 | 160 | 690 | 12,760 | 46,900 |
| 77/78 | 1,580 | 3,370 | 200 | 5,150 | 6,850 | 500 | 680 | 230 | 230 | 8,490 | 640 | 170 | 710 | 14,350 | 54,100 |
| 78/79 | 1,860 | 3,620 | 240 | 5,720 | 7,800 | 580 | 800 | 270 | 270 | 9,720 | 720 | 190 | 910 | 16,350 | 61,600 |
| 79/80 | 2,200 | 3,800 | 280 | 6,280 | 9,050 | 670 | 930 | 320 | 320 | 11,290 | 920 | 200 | 1,120 | 18,690 | 72,000 |
| 80/81 | 2,580 | 4,100 | 330 | 7,010 | 10,400 | 770 | 1,070 | 370 | 370 | 12,980 | 1,040 | 210 | 1,250 | 21,240 | 83,700 |
| 81/82 | 3,020 | 4,460 | 390 | 7,870 | 11,900 | 880 | 1,230 | 420 | 430 | 14,860 | 1,220 | 230 | 1,450 | 24,180 | 97,400 |
| 82/83 | 3,470 | 4,830 | 460 | 8,760 | 13,450 | 1,000 | 1,410 | 490 | 490 | 16,840 | 1,430 | 240 | 1,670 | 27,270 | 112,300 |
| 83/84 | 3,760 | 5,250 | 530 | 9,540 | 15,200 | 1,300 | 1,630 | 560 | 560 | 19,250 | 1,650 | 250 | 1,900 | 30,690 | 129,000 |
| 84/85 | 4,100 | 5,730 | 620 | 10,450 | 17,200 | 1,470 | 1,880 | 640 | 650 | 21,840 | 1,900 | 260 | 2,160 | 34,450 | 147,900 |
| 85/86 | 4,700 | 6,290 | 710 | 11,700 | 19,400 | 1,660 | 2,160 | 740 | 750 | 24,710 | 2,180 | 270 | 2,450 | 38,860 | 170,200 |
| 86/87 | 4,870 | 6,800 | 820 | 12,490 | 21,900 | 1,880 | 2,480 | 850 | 860 | 27,970 | 2,510 | 280 | 2,790 | 43,250 | 189,400 |
| 87/88 | 5,600 | 7,510 | 940 | 14,050 | 24,700 | 2,120 | 2,850 | 980 | 990 | 31,640 | 2,880 | 290 | 3,170 | 48,860 | 214,000 |
| 88/89 | 6,440 | 8,350 | 1,080 | 15,870 | 27,900 | 2,400 | 3,380 | 1,120 | 1,140 | 35,940 | 3,310 | 300 | 3,610 | 55,420 | 242,700 |
| 89/90 | 9,300 | 9,300 | 1,290 | 17,990 | 31,500 | 2,710 | 3,890 | 1,260 | 1,310 | 40,670 | 3,810 | 310 | 4,120 | 62,780 | 275,000 |

Note:
/1 Based on 210 kW of actual record in 1972/73 and assumed growth rate of 20% initially to 15% ultimately.
/2 Based on population of 6,000 and number of factory of 15.
/3 Based on population of 7,360.
/4 Based on population of 6,910 and number of factory of 10.
/5 Based on population of 22,000 and number of factory of 60.
/6 Energy being estimated on the assumption of annual load factors of 40% up to 74/75, 42% up to 76/77 and thereafter gradually increased and kept at 50%.

TABLE 3.11 LOAD FORECAST IN WESTERN REGION

| | PEAK DEMAND | | | | | | | | | | TOTAL /5 ENERGY REQUIRED (MWh) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | BUTWAL-BHAIRAWA AREA (kW) | | | | | | POKHARA AREA (kW) | | | TOTAL (kW) | |
| | Bhairawa, Butwal & Tansing | /1 Krishnagar & Bahadur-ganj | /2 Tauli-hawa | /3 Parasi | Lumbini | Total | Pokhara | Syanja /4 & Kusma | Total | | |
| 1972/73 | 1,040 | 60 | | | | 1,100 | 520 | | 520 | 1,620 | 5,700 |
| 73/74 | 1,460 | 100 | | | | 1,560 | 870 | | 870 | 2,430 | 8,500 |
| 74/75 | 1,750 | 110 | 150 | | 60 | 2,070 | 1,040 | | 1,040 | 3,110 | 10,900 |
| 75/76 | 2,100 | 140 | 170 | 70 | 70 | 2,550 | 1,250 | 130 | 1,380 | 3,930 | 14,500 |
| 76/77 | 2,520 | 170 | 210 | 80 | 80 | 3,060 | 1,490 | 150 | 1,640 | 4,700 | 17,300 |
| 77/78 | 3,100 | 200 | 240 | 100 | 100 | 3,740 | 1,790 | 180 | 1,970 | 5,710 | 22,100 |
| 78/79 | 3,600 | 240 | 300 | 110 | 110 | 4,360 | 2,150 | 220 | 2,370 | 6,730 | 26,000 |
| 79/80 | 4,150 | 270 | 340 | 140 | 140 | 5,040 | 2,480 | 260 | 2,740 | 7,780 | 34,100 |
| 80/81 | 4,760 | 320 | 390 | 160 | 160 | 5,790 | 2,840 | 320 | 3,160 | 8,950 | 39,200 |
| 81/82 | 5,500 | 360 | 450 | 180 | 180 | 6,670 | 3,160 | 360 | 3,520 | 10,190 | 44,600 |
| 82/83 | 6,320 | 420 | 520 | 220 | 210 | 7,790 | 3,750 | 420 | 4,170 | 11,960 | 52,400 |
| 83/84 | 7,300 | 480 | 590 | 250 | 240 | 8,860 | 4,350 | 480 | 4,830 | 13,690 | 60,000 |
| 84/85 | 8,200 | 530 | 670 | 290 | 280 | 9,970 | 4,820 | 550 | 5,370 | 15,340 | 67,300 |
| 85/86 | 9,100 | 560 | 770 | 330 | 310 | 11,070 | 5,300 | 640 | 5,940 | 17,010 | 74,500 |
| 86/87 | 10,000 | 640 | 890 | 380 | 340 | 12,250 | 5,760 | 740 | 6,500 | 18,750 | 81,500 |
| 87/88 | 11,000 | 700 | 1,020 | 440 | 370 | 13,530 | 6,300 | 850 | 7,150 | 20,680 | 88,500 |
| 88/89 | 12,100 | 720 | 1,170 | 500 | 400 | 14,890 | 6,850 | 970 | 7,820 | 22,710 | 96,300 |
| 89/90 | 13,100 | 840 | 1,350 | 580 | 440 | 16,310 | 7,500 | 1,120 | 8,620 | 24,300 | 105,000 |

Note:
/1 Based on 95 kW in 1973/74 at a growth rates of 20 to 15 %.
/2 Based on population of 8,500 and industries of 25 kW at a growth rate of 20 to 15 %.
/3 Based on population of 3,200 and industries of 29 at a growth rate of 20 to 15 %.
/4 Based on population of 7,300 and assumed industries of 10 kW at a growth rate of 20 % to 15 %.
/5 Energy being estimated on the assumption of annual load factor of 40 % up to 74/75, 42 % up to 76/77, 44 % up to 78/79 and 50 % constant thereafter.

## TABLE - 3.12 LOAD FORECAST IN FAR WESTERN REGION

| Year | Peak Demand (kW) | | | Energy Demand (MWh) | | |
|---|---|---|---|---|---|---|
| | Domestic/1 | Industry/2 | Total | Domestic | Industry | Total |
| 1972/73 | - | - | - | - | - | - |
| 73/74 | - | - | 250 | - | - | 710 |
| 74/75 | 605 | 170 | 775 | 1,370 | 350 | 1,720 |
| 75/76 | 1,060 | 270 | 1,330 | 2,300 | 580 | 2,880 |
| 76/77 | 2,005 | 360 | 2,365 | 4,400 | 760 | 5,160 |
| 77/78 | 2,620 | 1,630 | 4,250 | 5,640 | 1,870 | 7,450 |
| 78/79 | 3,770 | 1,850 | 5,620 | 7,990 | 2,940 | 10,930 |
| 79/80 | 4,580 | 2,050 | 6,630 | 9,810 | 3,890 | 13,700 |
| 80/81 | 5,340 | 4,550 | 9,890 | 11,610 | 11,390 | 23,000 |
| 81/82 | 6,340 | 5,400 | 11,740 | 13,530 | 14,490 | 28,020 |
| 82/83 | 7,360 | 6,200 | 13,560 | 15,860 | 17,130 | 32,990 |
| 83/84 | 8,540 | 7,200 | 15,740 | 18,210 | 19,760 | 37,970 |
| 84/85 | 9,700 | 8,200 | 17,900 | 20,720 | 26,870 | 47,590 |
| 85/86 | 11,060 | 9,200 | 20,260 | 23,730 | 29,490 | 53,220 |
| 86/87 | 12,170 | 10,030 | 22,200/3 | 26,100 | 32,200 | 58,300/3 |
| 87/88 | 13,390 | 11,010 | 24,400 | 28,710 | 35,490 | 64,200 |
| 88/89 | 14,730 | 12,670 | 26,800 | 31,580 | 39,020 | 70,600 |
| 89/90 | 16,200 | 13,300 | 29,500 | 34,740 | 42,860 | 77,600 |

/1 Based on the electrification schedule set forth by the Government.

/2 Based on the demand of proposed bulky consumers after dividing it by 1.2.

/3 Annual growth rate of peak and energy demand is 10 % after 1986/87.

TABLE - 3.13 SUMMARY OF POWER DEMAND FORECAST AND COMBINED DEMAND FORECAST

| | REGIONAL DEMAND FORECAST | | | | | | | | | | COMBINED DEMAND OF CNPS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PEAK DEMAND (kW) | | | | | ENERGY REQUIRED (kWh) | | | | | PEAK DEMAND | ENERGY |
| | KATHMANDU REGION | DHANKUTA REGION | POKHARA REGION | SURKHET REGION | TOTAL | KATHMANDU REGION | DHANKUTA REGION | POKHARA REGION | SURKHET REGION | TOTAL | kW | MWh |
| 1972/73 | 21,200 | 4,260 | 1,620 | 160 | 27,240 | 76,650 | 14,900 | 5,700 | 180 | 97,430 | - | - |
| 73/74 | 25,400 | 5,770 | 2,430 | 250 | 33,850 | 91,460 | 20,200 | 8,500 | 710 | 120,870 | - | - |
| 74/75 | 30,600 | 8,310 | 3,110 | 775 | 42,795 | 107,810 | 29,100 | 10,900 | 1,720 | 149,530 | - | - |
| 75/76 | 36,500 | 10,890 | 3,930 | 1,330 | 52,650 | 132,660 | 40,100 | 14,500 | 2,880 | 190,140 | 40,430 /1 | 147,160 /1 |
| 76/77 | 42,500 | 12,760 | 4,700 | 2,365 | 62,325 | 155,820 | 46,900 | 17,300 | 5,160 | 225,180 | 47,200 | 173,120 |
| 77/78 | 49,500 | 14,350 | 5,710 | 4,250 | 73,810 | 190,720 | 54,100 | 22,100 | 7,450 | 274,370 | 55,210 | 212,820 |
| 78/79 | 57,700 | 16,350 | 6,730 | 5,620 | 86,400 | 219,020 | 61,600 | 26,000 | 10,930 | 317,550 | 64,410 | 281,500 |
| 79/80 | 65,000 | 18,690 | 7,780 | 6,630 | 98,100 | 282,320 | 72,000 | 34,100 | 13,700 | 402,120 | 72,780 | 316,420 |
| 80/81 | 73,500 | 21,240 | 8,950 | 9,890 | 113,580 | 322,000 | 83,700 | 39,200 | 23,000 | 467,900 | 82,450 | 361,200 |
| 81/82 | 82,400 | 24,180 | 10,190 | 11,740 | 128,510 | 360,000 | 97,400 | 44,600 | 28,020 | 530,020 | 92,590 | 404,600 |
| 82/83 | 90,500 | 27,270 | 11,960 | 13,560 | 143,290 | 398,000 | 112,300 | 52,400 | 32,990 | 595,690 | 102,460 | 450,400 |
| 83/84 | 97,700 | 30,690 | 13,690 | 15,740 | 157,820 | 428,000 | 129,000 | 60,000 | 37,970 | 654,970 | 111,390 | 488,000 |
| 84/85 | 105,500 | 34,450 | 15,340 | 17,900 | 173,190 | 462,000 | 147,900 | 67,300 | 47,590 | 724,790 | 120,840 | 529,300 |
| 85/86 | 114,000 | 38,860 | 17,010 | 20,260 | 190,130 | 497,000 | 170,200 | 74,500 | 53,220 | 794,920 | 169,870 /2 | 741,700 /2 |
| 86/87 | 123,000 | 43,250 | 18,750 | 22,200 | 207,200 | 535,000 | 189,400 | 81,500 | 58,300 | 864,200 | 85,000 | 805,900 |
| 87/88 | 133,000 | 48,860 | 20,680 | 24,400 | 226,940 | 575,000 | 214,000 | 88,500 | 64,200 | 941,700 | 202,540 | 977,500 |
| 88/89 | 143,700 | 55,420 | 22,710 | 26,800 | 248,630 | 618,000 | 242,700 | 96,300 | 70,600 | 1,027,600 | 221,830 | 957,000 |
| 89/90 | 155,000 | 62,780 | 24,300 | 29,500 | 271,580 | 666,000 | 275,000 | 105,000 | 77,600 | 1,123,600 | 242,080 | 1,046,000 |

/1 Kathmandu and Pokhara regions will be connected by a 132 kV transmission line, now under construction, from Gandaki to Hetaura in 1975/76.

/2 Dhankuta region will be connected with Kathmandu-Pokhara regions by a 132 kV transmission line from Hetaura to Janakpur in 1985/86.

TABLE-3.14 POPULATION OF NEPAL

| REGION / YEAR | FAR WESTERN | WESTERN | CENTRAL | EASTERN | TOTAL | EXPECTED ANNUAL GROWTH RATE (%) |
|---|---|---|---|---|---|---|
| 1911 | - | - | - | - | 5,638,749 | |
| 1920 | - | - | - | - | 5,573,788 | |
| 1930 | - | - | - | - | 5,532,574 | |
| 1941 | - | - | - | - | 6,283,649 | |
| 1952/54 | - | - | - | - | 8,473,478 | |
| 1961 | - | - | - | - | 9,412,996 | |
| 1971 | 2,427,190 | 2,465,540 | 2,599,998 | 4,063,255 | 11,555,983 | 1.95 |
| 72/73 | 2,474,520 | 2,513,618 | 2,650,698 | 4,142,488 | 11,781,324 | 1.95 |
| 73/74 | 2,523,021 | 2,562,885 | 2,702,652 | 4,223,681 | 12,012,239 | 1.96 |
| 74/75 | 2,572,725 | 2,613,374 | 2,755.894 | 4,306,888 | 12,248,881 | 1.97 |
| 75/76 | 2,623,922 | 2,665,380 | 2,810,736 | 4,392,595 | 12,492,633 | 1.99 |
| 76/77 | 2,679,287 | 2,721,620 | 2,870,043 | 4,485,279 | 12,756,229 | 2.11 |
| 77/78 | 2,736,356 | 2,779,591 | 2,931,175 | 4,580,815 | 13,027,937 | 2.13 |
| 78/79 | 2,794,914 | 2,839,074 | 2,993,902 | 4,678,844 | 13,306,734 | 2.14 |
| 79/80 | 2,854,725 | 2,899,830 | 3,057,972 | 4,778,971 | 13,591,498 | " |
| 80/81 | 2,915,816 | 2,091,886 | 3,123,413 | 4,881,241 | 13,882,356 | " |
| 81/82 | 2,978,214 | 3,025,270 | 3,190,254 | 4,985,700 | 14,179,438 | " |
| 82/83 | 3,041,948 | 3,090,011 | 3,258,525 | 5,092,394 | 14,482,878 | " |
| 83/84 | 3,107,046 | 3,156,137 | 3,328,257 | 5,201,371 | 14,792,811 | " |
| 84/85 | 3,173,537 | 3,223,678 | 3,399,482 | 5,312,680 | 15,109,377 | " |
| 85/86 | 3,241,451 | 3,292,665 | 3,472,231 | 5,426,371 | 15,432,718 | " |
| 86/87 | 3,310,818 | 3,363,128 | 3,546,537 | 5,542,495 | 15,762,978 | " |
| 87/88 | 3,381,670 | 3,435,099 | 3,622,433 | 5,661,104 | 16,100,306 | " |
| 88/89 | 3,454,038 | 3,508,610 | 3,699,953 | 5,782,252 | 16,444,853 | " |
| 89/90 | 3,527,954 | 3,583,694 | 3,779,132 | 5,905,992 | 16,796,772 | " |

Remarks:

1) Far Western : Mahakali, Seti, Karnali, Bheri & Rapti Zones
   Western : Dhaulagiri, Lumbini & Gandaki Zones
   Central : Bagmati & Narayani Zones
   Eastern : Janakpur, Sagarmatha, Kosi & Mechi Zones

2) Population in 1971 : from the result of the census

3) Annual growth rate : Estimation of National Planning Commission of Nepal in "The Fourth Plan"

TABLE-3.15 PROJECTED ANNUAL ENERGY GENERATION PER CAPITA (kWh)

| | Kathmandu | Dhankuta | Pokhara | Surket | Average |
|---|---|---|---|---|---|
| 72/73 | 28.92 | 3.60 | 2.27 | 0.07 | 8.27 |
| 74/75 | 39.12 | 6.74 | 4.17 | 0.67 | 12.20 |
| 79/80 | 93.32 | 15.07 | 11.76 | 4.80 | 29.58 |
| 84/85 | 135.90 | 27.84 | 20.88 | 15.01 | 47.96 |
| 89/90 | 176.23 | 46.56 | 29.30 | 21.98 | 66.88 |

TABLE-3.16 PEAK DEMAND FORECAST OF INDIA

(MW)

| | WESTERN REGION | SOUTHERN REGION | NORTHERN REGION | EASTERN REGION | NORTH EASTERN REGION | TOTAL |
|---|---|---|---|---|---|---|
| 1968/69 | 2,052 | 2,177 | 2,086 | 1,652 | 57 | 8,025 |
| 69/70 | 2,304 | 2,453 | 2,373 | 1,702 | 70 | 8,903 |
| 70/71 | 2,568 | 2,692 | 2,672 | 1,802 | 85 | 9,820 |
| 71/72 | 2,945 | 3,120 | 3,253 | 2,053 | 103 | 11,475 |
| 72/73 | 3,371 | 3,466 | 3,709 | 2,247 | 121 | 12,916 |
| 73/74 | 3,835 | 3,936 | 4,233 | 2,460 | 153 | 14,618 |
| 74/75 | 4,422 | 4,406 | 4,811 | 2,807 | 179 | 16,627 |
| 75/76 | 5,041 | 4,979 | 5,533 | 3,144 | 215 | 18,912 |
| 76/77 | 5,747 | 5,626 | 6,363 | 3,521 | 256 | 21,513 |
| 77/78 | 6,551 | 6,301 | 7,253 | 3,944 | 302 | 24,351 |
| 78/79 | 6,466 | 7,057 | 8,269 | 4,417 | 356 | 27,565 |
| 79/80 | 8,439 | 7,904 | 9,344 | 4,947 | 420 | 31,054 |
| 80/81 | 9,537 | 8,694 | 10,558 | 5,541 | 491 | 34,821 |
| 81/82 | 10,776 | 9,563 | 11,825 | 6,150 | 570 | 38,884 |
| 82/83 | 12,070 | 10,520 | 13,244 | 6,826 | 661 | 43,321 |
| 83/84 | 13,518 | 11,572 | 14,701 | 7,577 | 760 | 48,128 |
| 84/85 | 15,005 | 12,729 | 16,318 | 8,411 | 874 | 53,337 |
| 85/86 | 16,655 | 14,002 | 17,950 | 9,336 | 997 | 58,940 |
| 86/87 | 18,321 | 15,402 | 19,745 | 10,363 | 1,136 | 64,967 |
| 87/88 | 20,153 | 16,942 | 21,720 | 11,399 | 1,296 | 71,510 |
| 88/89 | 22,168 | 18,636 | 23,892 | 12,539 | 1,464 | 78,699 |
| 89/90 | 24,385 | 20,500 | 26,281 | 13,793 | 1,654 | 86,613 |

TABLE-3.17 FORECAST OF ENERGY REQUIRED IN INDIA

(GWh)

| | WESTERN REGION | SOUTHERN REGION | NORTHERN REGION | EASTERN REGION | NORTH EASTERN REGION | TOTAL |
|---|---|---|---|---|---|---|
| 1968/69 | 12,407 | 11,620 | 11,220 | 9,500 | 259 | 45,009 |
| 69/70 | 13,682 | 13,080 | 12,490 | 9,752 | 332 | 49,336 |
| 70/71 | 15,075 | 14,757 | 13,396 | 10,013 | 374 | 53,618 |
| 71/72 | 16,853 | 16,501 | 15,697 | 11,426 | 439 | 60,921 |
| 72/73 | 18,942 | 18,262 | 17,856 | 12,499 | 512 | 68,077 |
| 73/74 | 21,207 | 20,586 | 20,231 | 13,584 | 657 | 76,271 |
| 74/75 | 24,159 | 22,848 | 22,906 | 15,397 | 786 | 86,096 |
| 75/76 | 26,495 | 26,170 | 29,081 | 16,525 | 1,130 | 99,401 |
| 76/77 | 30,172 | 29,570 | 33,444 | 18,506 | 1,346 | 113,038 |
| 77/78 | 34,432 | 33,118 | 38,122 | 20,730 | 1,587 | 126,989 |
| 78/79 | 39,241 | 36,092 | 43,462 | 23,216 | 1,871 | 144,882 |
| 79/80 | 44,355 | 41,543 | 49,112 | 26,001 | 2,208 | 163,219 |
| 80/81 | 50,126 | 45,696 | 55,493 | 29,123 | 2,581 | 183,019 |
| 81/82 | 56,639 | 50,263 | 62,152 | 32,324 | 2,996 | 204,374 |
| 82/83 | 63,440 | 55,293 | 69,610 | 35,877 | 3,474 | 227,694 |
| 83/84 | 71,051 | 60,822 | 77,268 | 39,825 | 3,995 | 252,961 |
| 84/85 | 78,866 | 66,904 | 85,767 | 44,208 | 4,594 | 280,339 |
| 85/86 | 87,539 | 73,595 | 94,345 | 49,070 | 5,240 | 309,789 |
| 86/87 | 96,295 | 80,953 | 103,780 | 54,468 | 5,971 | 341,467 |
| 87/88 | 105,924 | 89,047 | 114,160 | 59,913 | 6,812 | 375,856 |
| 88/89 | 116,515 | 97,951 | 125,576 | 65,905 | 7,695 | 413,642 |
| 89/90 | 128,168 | 107,748 | 138,133 | 72,496 | 8,693 | 455,238 |

Fig. 3.1

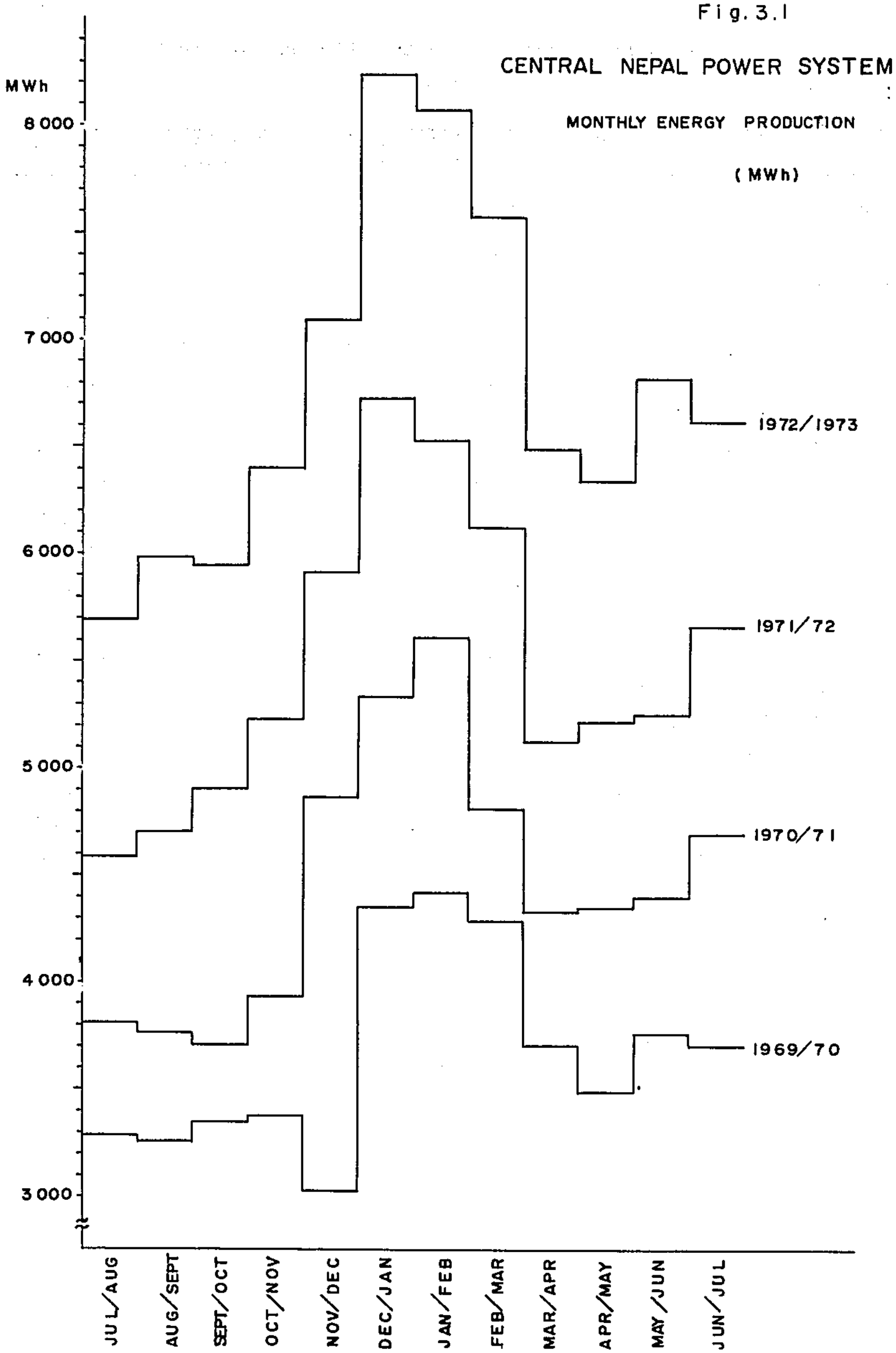
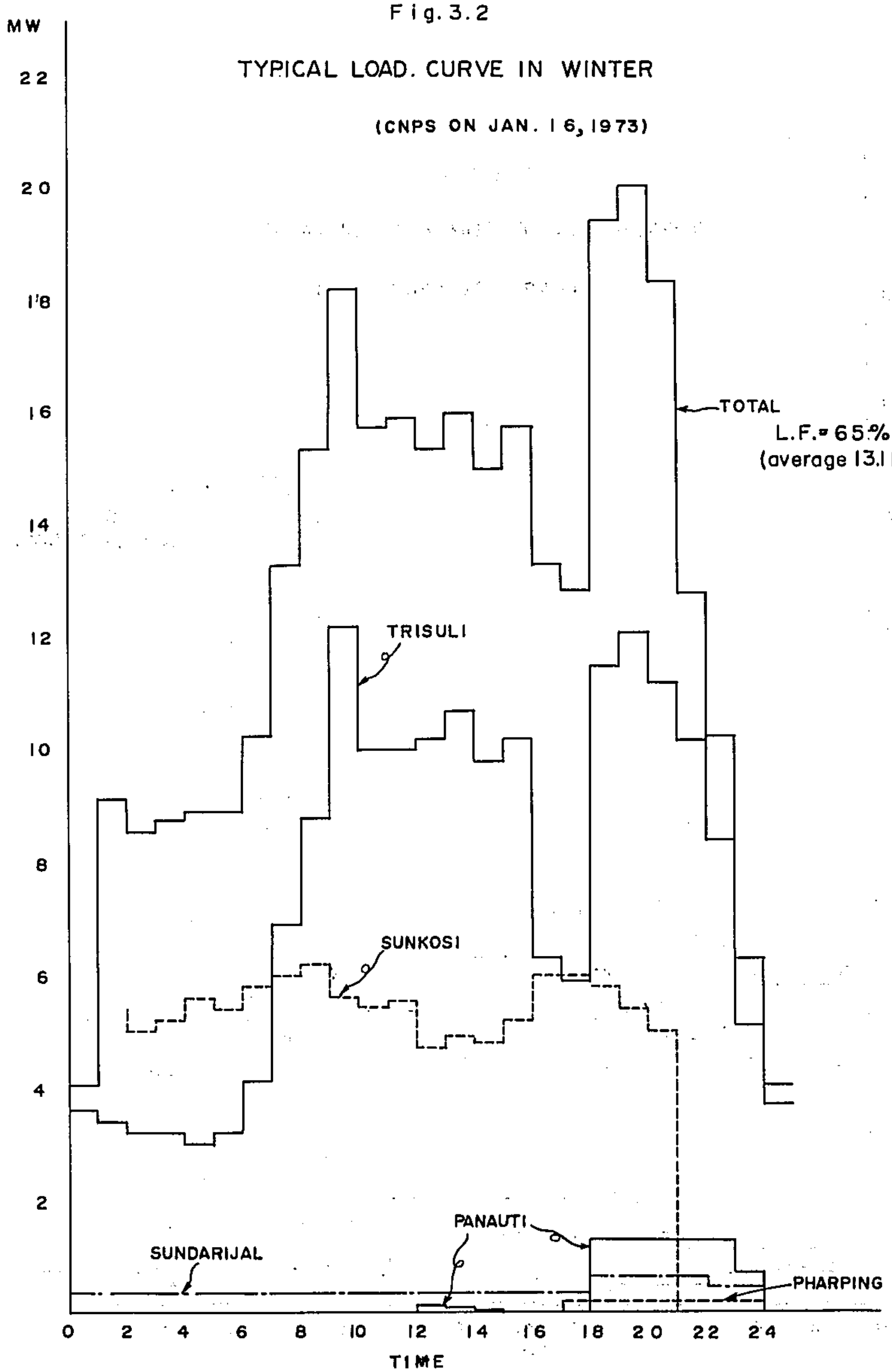

CENTRAL NEPAL POWER SYSTEM
MONTHLY ENERGY PRODUCTION
(MWh)
MWh
8 000
7 000
6 000
5 000
4 000
3 000
1972/1973
1971/72
1970/71
1969/70
JUL/AUG
AUG/SEPT
SEPT/OCT
OCT/NOV
NOV/DEC
DEC/JAN
JAN/FEB
FEB/MAR
MAR/APR
APR/MAY
MAY/JUN
JUN/JUL

Fig. 3.2

TYPICAL LOAD CURVE IN WINTER

(CNPS ON JAN. 16, 1973)



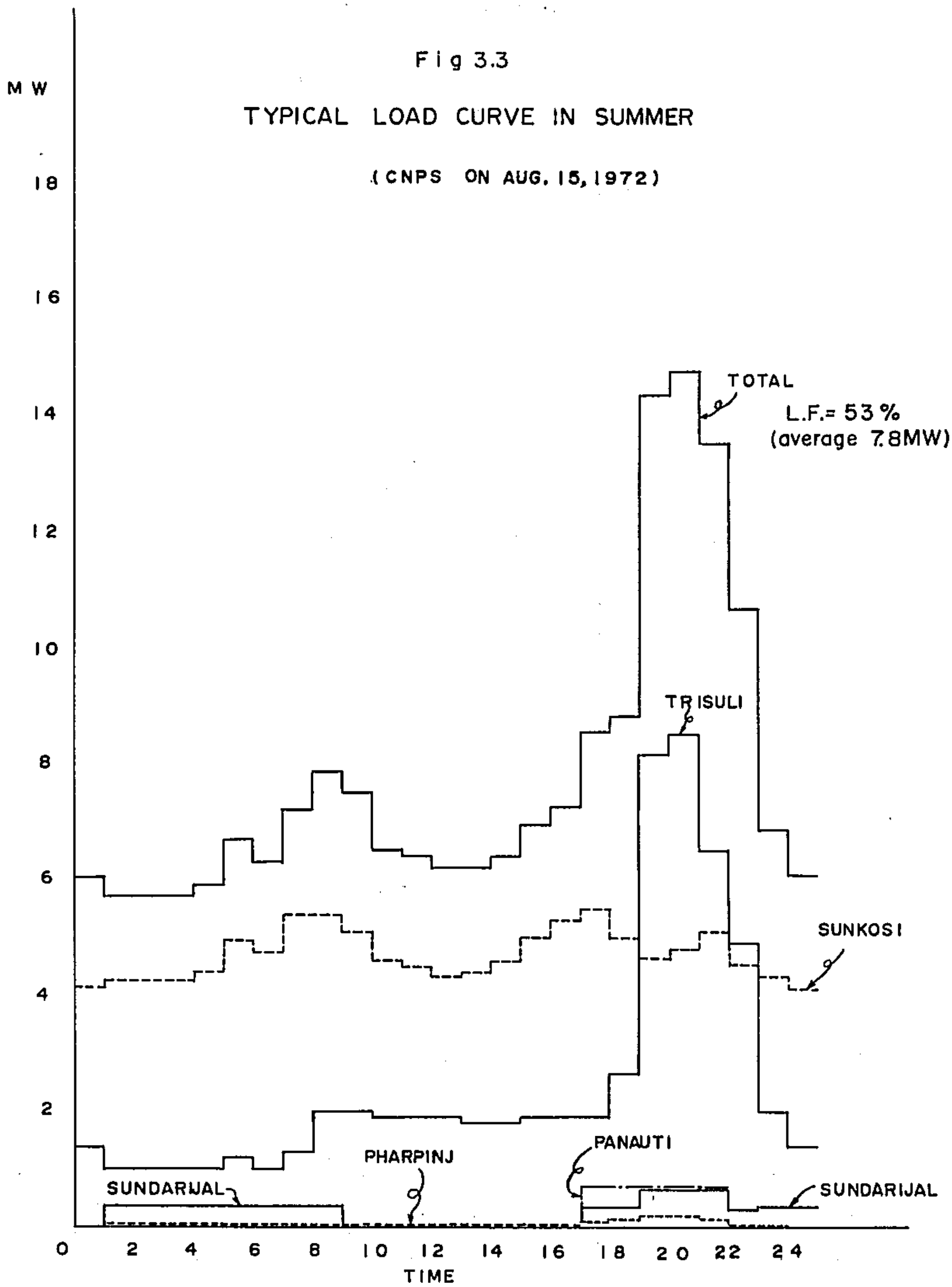
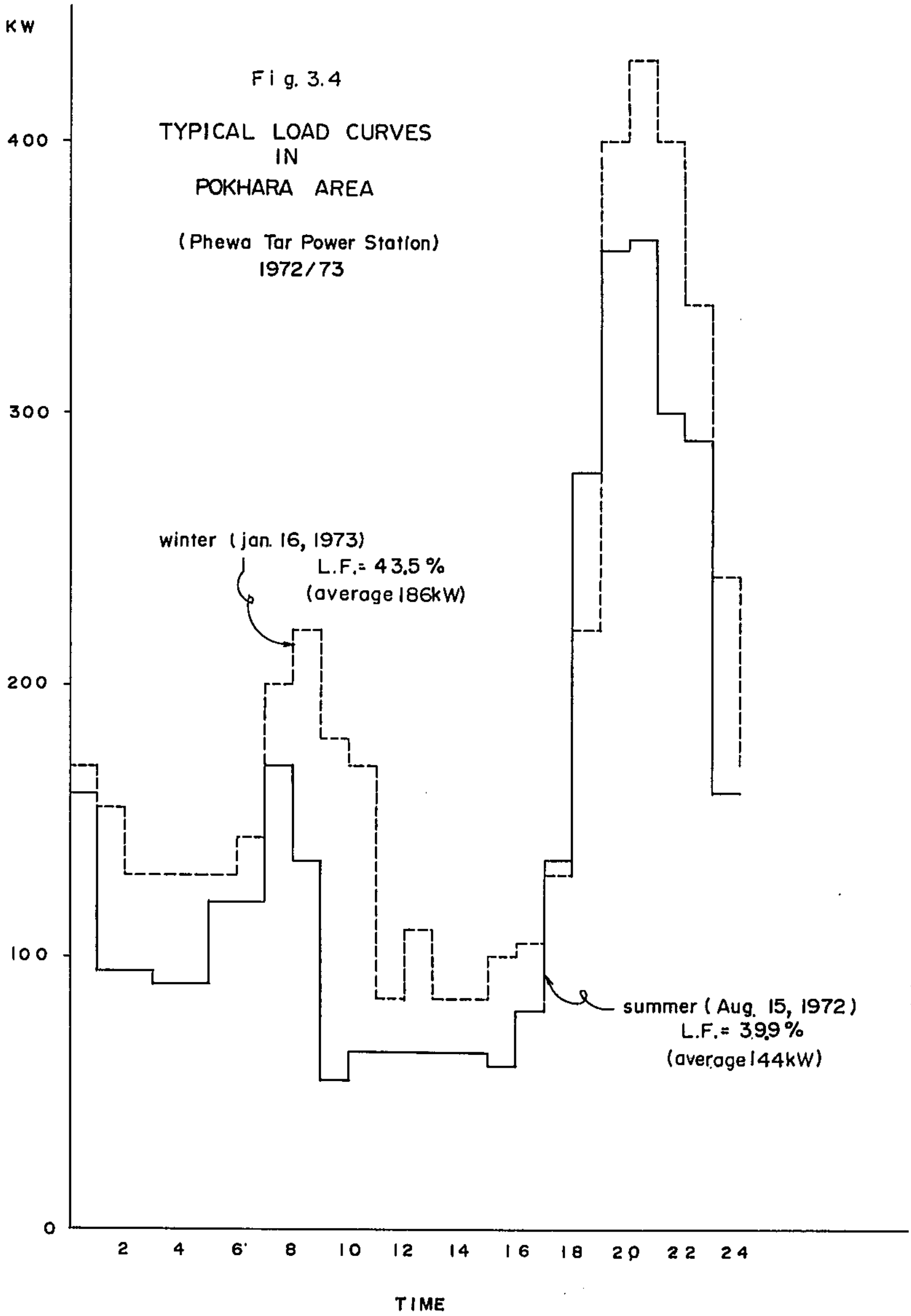


Fig 3.3
TYPICAL LOAD CURVE IN SUMMER
(CNPS ON AUG. 15, 1972)
MW
18
16
14
12
10
8
6
4
2
0
2
4
6
8
10
12
14
16
18
20
22
24
TIME
TOTAL
L.F.= 53%
(average 7.8MW)
TRISULI
SUNKOSI
PANAUTI
PHARPINJ
SUNDARIJAL
SUNDARIJAL


KW
400
300
200
100
0
Fig. 3.4
TYPICAL LOAD CURVES
IN
POKHARA AREA
(Phewa Tar Power Station)
1972/73
winter (jan. 16, 1973)
L.F.= 43.5 %
(average 186kW)
summer (Aug. 15, 1972)
L.F.= 39.9 %
(average 144kW)
2
4
6
8
10
12
14
16
18
20
22
24
TIME

# MASTER PLAN OF HYDROELECTRIC POWER DEVELOPMENT

# IN

# NEPAL

## APPENDIX 4

## HYDROLOGY

# APPENDIX 4 HYDROLOGY

Table 4.1 to Table 4.22 show the monthly mean stream flows at the prospective hydropower project sites. The maximum and minimum values during the recording period are shown underlined in the tables. These flows are derived from the records of the nearest gauging stations to the project sites. The flow data of run-of-river type projects which will use the tailwater of the upstream project are not included. The Sun Kosi High Dam, Kamla, and Bagmati sites have flow data of more than 10 years, but the data of the other sites are all less than 10 years. The original flow records of existing gauging stations are compiled in the annual report issued by Ministry of Water and Power, His Majesty's Government of Nepal.

LIST OF TABLES

Table 4.1 Monthly Mean Flow at Chisapani Damsite

Drainage area: 42,894 km$^2$ Unit: m$^3$/s

| Month Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1962 | 495 | 471 | 498 | 561 | 741 | 1,719 | 2,876 | 5,706 | 3,993 | 1,455 | 691 | 468 | 1,641.2 |
| 1963 | 357 | 298 | 363 | 450 | 725 | 1,549 | 3,549 | 5,594 | 3,428 | 1,094 | 630 | 453 | 1,540.8 |
| 1964 | 355 | 292 | 273 | 389 | 468 | 981 | 3,441 | 3,928 | 3,441 | 1,209 | 623 | 457 | 1,321.4 |
| 1965 | 366 | 342 | 360 | 482 | 569 | 1,096 | 2,003 | 2,481 | 1,653 | 718 | 478 | 346 | 907.8 |
| 1966 | 282 | 273 | 261 | 293 | 525 | 1,066 | 2,390 | 4,378 | 1,957 | 741 | 466 | 352 | 1,082.0 |
| 1967 | 279 | 240 | 233 | 286 | 387 | 821 | 2,668 | 4,530 | 2,586 | 960 | 549 | 416 | 1,162.9 |
| 1968 | 371 | 335 | 369 | 402 | 655 | 1,584 | 3,479 | 4,302 | 2,106 | 1,052 | 580 | 418 | 1,304.4 |
| 1969 | 366 | 318 | 325 | 405 | 791 | 1,329 | 2,709 | 4,123 | 3,638 | 1,350 | 677 | 462 | 1,374.4 |
| 1970 | 379 | 333 | 319 | 420 | 573 | 1,409 | 3,842 | 4,076 | 2,297 | 1,242 | 661 | 473 | 1,335.3 |
| 1971 | 385 | 351 | 383 | 536 | 609 | 2,789 | 4,114 | 5,087 | 3,534 | 1,387 | 809 | 557 | 1,711.8 |
| Mean | 363.5 | 325.3 | 338.4 | 422.4 | 604.3 | 1,434.3 | 3,109.1 | 4,420.5 | 2,863.3 | 1,120.8 | 616.4 | 440.2 | 1,338.2 |

Table 4.2 Monthly Mean Flow at Lakarpata Damsite

Drainage area: 20,970 $km^2$ Unit: $m^3/s$

| Month Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1962 | 206.9 | 179.7 | 201.5 | 262.5 | 357.2 | 938.7 | 1,327.5 | 2,065.8 | 1,332.9 | 508.6 | 276.6 | 198.2 | 654.7 |
| 1963 | 156.8 | 134.0 | 160.1 | 216.7 | 397.5 | 842.9 | 1,388.5 | 1,887.2 | 1,196.8 | 430.2 | 262.5 | 190.6 | 605.3 |
| 1964 | 154.6 | 136.1 | 139.4 | 198.2 | 238.5 | 510.7 | 1,329.7 | 1,502.8 | 1,146.7 | 459.6 | 265.7 | 193.8 | 523.0 |
| 1965 | 152.5 | 139.4 | 149.2 | 221.1 | 304.9 | 666.5 | 871.2 | 799.3 | 561.9 | 282.1 | 198.2 | 147.0 | 374.4 |
| 1966 | 118.9 | 111.5 | 107.5 | 144.7 | 284.6 | 560.6 | 970.0 | 1,588.9 | 716.9 | 317.1 | 206.6 | 149.4 | 439.7 |
| 1967 | 117.9 | 101.7 | 101.1 | 135.1 | 215.0 | 466.9 | 1,059.7 | 1,819.7 | 1,023.9 | 374.7 | 225.0 | 161.0 | 483.5 |
| 1968 | 133.5 | 131.4 | 164.2 | 207.0 | 352.8 | 813.5 | 1,319.9 | 1,584.5 | 693.4 | 336.9 | 206.6 | 146.6 | 507.5 |
| 1969 | 138.9 | 122.1 | 140.3 | 200.9 | 510.6 | 925.7 | 1,293.7 | 1,652.0 | 1,187.0 | 546.0 | 310.9 | 177.8 | 600.5 |
| 1970 | 139.3 | 121.8 | 124.7 | 221.6 | 343.6 | 698.6 | 1,272.0 | 1,481.0 | 923.9 | 476.9 | 268.1 | 178.8 | 520.9 |
| 1971 | 130.0 | 106.8 | 124.8 | 214.5 | 257.8 | 1,203.4 | 1,505.0 | 1,759.8 | 1,158.7 | 551.0 | 317.7 | 209.6 | 628.3 |
| Mean | 144.9 | 128.5 | 141.3 | 202.2 | 326.2 | 762.7 | 1,233.7 | 1,614.1 | 994.2 | 428.3 | 253.8 | 175.3 | 533.8 |

Table 4.3 <u>Monthly Mean Flow at Bhanakot Damsite</u>

Drainage area: 19,130 $km^2$ | Unit: $m^3/s$

| Month / Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1962 | 188.7 | 163.9 | 183.7 | 239.3 | 325.7 | 856.0 | 1,210.5 | <u>1,883.7</u> | 1,215.4 | 463.7 | 252.2 | 180.7 | 597.0 |
| 1963 | 143.0 | 122.1 | 146.0 | 197.6 | 362.5 | 768.6 | 1,266.1 | 1,720.9 | 1,091.3 | 392.2 | 239.3 | 173.8 | 551.9 |
| 1964 | 141.0 | 124.1 | 127.1 | 180.7 | 217.5 | 465.7 | 1,212.5 | 1,370.3 | 1,045.6 | 419.1 | 242.3 | 176.8 | 476.9 |
| 1965 | 139.0 | 127.1 | 136.0 | 201.6 | 278.0 | 607.7 | 794.4 | 728.9 | 512.4 | 257.2 | 180.7 | 134.1 | 341.4 |
| 1966 | 108.4 | 101.7 | 98.0 | 132.0 | 259.5 | 511.2 | 884.5 | 1,448.8 | 653.7 | 289.2 | 188.4 | 136.2 | 401.0 |
| 1967 | 107.5 | 92.8 | <u>92.2</u> | 123.2 | 196.0 | 425.7 | 966.3 | 1,659.3 | 933.6 | 341.7 | 205.2 | 146.8 | 440.9 |
| 1968 | 121.7 | 119.9 | 149.7 | 188.8 | 321.7 | 741.8 | 1,203.5 | 1,444.8 | 632.2 | 307.2 | 188.4 | 133.7 | 462.8 |
| 1969 | 126.6 | 111.3 | 127.9 | 183.2 | 465.6 | 844.1 | 1,179.7 | 1,506.4 | 1,082.4 | 497.9 | 283.5 | 162.2 | 547.6 |
| 1970 | 127.0 | 111.0 | 113.7 | 202.1 | 313.3 | 637.0 | 1,159.8 | 1,350.5 | 842.5 | 434.8 | 244.5 | 163.1 | 474.9 |
| 1971 | 118.6 | 97.4 | 113.8 | 195.6 | 235.0 | 1,097.3 | 1,372.3 | 1,604.7 | 1,056.6 | 502.5 | 289.7 | 191.2 | 572.9 |
| Mean | 132.2 | 117.1 | 128.8 | 184.4 | 297.5 | 695.5 | 1,125.0 | 1,471.8 | 906.6 | 390.6 | 231.4 | 159.8 | 486.7 |

Table 4.4 Monthly Mean Flow at Jubitan Damsite

Drainage area: 2,740 $km^2$ Unit: $m^3/s$

| Month / Year | Jan | Feb | Jar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1962 | 27.0 | 23.4 | 26.3 | 34.2 | 46.6 | 122.4 | 173.1 | 269.4 | 173.8 | 66.3 | 36.1 | 25.8 | 85.4 |
| 1963 | 20.5 | 17.5 | 20.9 | 28.3 | 51.8 | 109.9 | 181.1 | 264.1 | 156.1 | 56.1 | 34.2 | 24.9 | 78.9 |
| 1964 | 20.2 | 17.8 | 18.2 | 25.8 | 31.1 | 66.6 | 173.4 | 196.0 | 149.5 | 59.9 | 34.7 | 25.3 | 68.2 |
| 1965 | 19.9 | 18.2 | 19.5 | 28.8 | 39.8 | 86.9 | 113.6 | 104.2 | 73.3 | 36.8 | 25.8 | 19.2 | 48.8 |
| 1966 | 15.5 | 14.5 | 14.0 | 19.0 | 37.1 | 73.1 | 126.5 | 207.2 | 93.5 | 41.4 | 26.9 | 19.5 | 57.4 |
| 1967 | 15.4 | 13.3 | 13.2 | 17.6 | 28.0 | 69.9 | 138.2 | 237.3 | 133.5 | 48.9 | 29.3 | 21.0 | 63.0 |
| 1968 | 17.4 | 17.1 | 21.4 | 27.0 | 46.0 | 106.1 | 172.1 | 206.6 | 90.4 | 43.9 | 26.9 | 19.1 | 66.2 |
| 1969 | 18.1 | 15.9 | 18.3 | 26.2 | 66.6 | 120.7 | 168.7 | 215.4 | 154.8 | 71.2 | 40.5 | 23.2 | 78.3 |
| 1970 | 18.2 | 15.9 | 16.3 | 28.9 | 44.8 | 91.1 | 165.9 | 193.1 | 120.5 | 62.2 | 35.0 | 23.3 | 67.9 |
| 1971 | 17.0 | 13.9 | 16.3 | 28.0 | 33.6 | 156.9 | 196.2 | 229.5 | 151.1 | 71.9 | 41.4 | 27.3 | 81.9 |
| Mean | 18.9 | 16.8 | 18.4 | 26.4 | 42.5 | 99.5 | 160.9 | 120.5 | 129.6 | 55.9 | 33.1 | 22.9 | 69.6 |

Table 4.5 Monthly Mean Flow at Surkhet Damsite

Drainage area: 11,780 $km^2$ Unit: $m^3/s$

| Month Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1962 | | | | | | | | | | | | | |
| 1963 | 109.2 | 88.1 | 97.8 | 117.3 | 191.9 | 387.7 | 1,352.2 | 2,073.4 | 1,156.6 | 354.2 | 184.4 | 131.7 | 520.4 |
| 1974 | 100.2 | 84.4 | 78.8 | 94.4 | 119.4 | 286.2 | 1,022.3 | 1,347.4 | 1,350.3 | 459.6 | 189.5 | 134.9 | 438.9 |
| 1965 | 107.3 | 88.3 | 84.8 | 120.9 | 135.5 | 252.8 | 581.1 | 889.9 | 620.0 | 226.1 | 144.2 | 102.4 | 279.4 |
| 1966 | 77.5 | 73.2 | 68.6 | 75.8 | 122.8 | 284.7 | 784.9 | 1,496.0 | 764.2 | 220.6 | 134.5 | 101.4 | 350.3 |
| 1967 | 77.3 | 63.5 | 63.2 | 77.5 | 92.7 | 255.4 | 819.2 | 1,361.8 | 829.4 | 267.8 | 151.8 | 112.0 | 347.6 |
| 1968 | 99.6 | 82.7 | 80.8 | 93.9 | 141.6 | 452.6 | 1,084.6 | 1,531.5 | 681.2 | 301.5 | 170.2 | 131.4 | 404.3 |
| 1969 | 96.5 | 78.6 | 75.7 | 97.4 | 177.0 | 290.1 | 1,001.2 | 1,591.9 | 1,468.2 | 429.3 | 178.8 | 122.9 | 467.3 |
| 1970 | 96.6 | 80.8 | 75.1 | 84.9 | 95.7 | 566.0 | 1,488.4 | 1,412.6 | 925.2 | 350.0 | 175.2 | 112.3 | 455.2 |
| 1971 | 91.8 | 70.1 | 85.3 | 119.5 | 173.1 | 822.3 | 1,273.6 | 1,437.5 | 1,053.0 | 284.2 | 193.0 | 126.6 | 477.5 |
| Mean | 95.1 | 78.8 | 78.9 | 97.9 | 138.9 | 399.7 | 1,045.3 | 1,460.2 | 983.1 | 321.5 | 169.1 | 119.5 | 415.7 |

Table 4.6 Monthly Mean Flow at Thapna Damsite

Drainage area: 11,090 $km^2$ Unit: $m^3/s$

| Month Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1962 | | | | | | | | | | | | | |
| 1963 | 102.7 | 82.8 | 92.0 | 110.3 | 180.5 | 364.7 | 1,271.8 | 1,950.1 | 1,087.8 | 333.1 | 173.5 | 123.8 | 489.4 |
| 1964 | 94.3 | 79.4 | 74.1 | 88.7 | 112.3 | 269.2 | 961.5 | 1,267.3 | 1,270.0 | 432.2 | 178.2 | 126.9 | 412.9 |
| 1965 | 100.9 | 83.0 | 79.7 | 113.7 | 127.5 | 237.8 | 546.5 | 837.0 | 583.1 | 212.7 | 135.7 | 96.3 | 262.8 |
| 1966 | 72.9 | 68.8 | 64.5 | 71.3 | 115.5 | 267.8 | 738.3 | 1,407.1 | 718.8 | 207.5 | 126.5 | 95.3 | 329.5 |
| 1967 | 72.7 | 59.7 | 59.4 | 72.9 | 87.2 | 240.2 | 770.5 | 1,280.8 | 780.1 | 251.8 | 142.8 | 105.4 | 327.0 |
| 1968 | 93.7 | 77.7 | 76.0 | 88.3 | 133.2 | 425.7 | 1,020.2 | 1,440.5 | 640.7 | 283.6 | 160.1 | 123.6 | 380.3 |
| 1969 | 90.7 | 73.9 | 71.2 | 91.6 | 166.5 | 272.9 | 941.7 | 1,497.3 | 1,381.0 | 403.7 | 168.1 | 115.6 | 439.5 |
| 1970 | 90.8 | 76.0 | 70.6 | 79.8 | 90.0 | 532.4 | 1,399.9 | 1,328.7 | 870.2 | 329.2 | 164.8 | 105.6 | 428.2 |
| 1971 | 86.4 | 65.9 | 80.2 | 112.4 | 162.8 | 773.4 | 1,197.9 | 1,352.1 | 990.4 | 267.3 | 181.5 | 119.1 | 449.1 |
| Mean | 89.5 | 74.1 | 74.2 | 92.1 | 130.6 | 376.0 | 983.1 | 1,373.4 | 924.7 | 302.4 | 159.0 | 112.4 | 391.0 |

Table 4.7 Monthly Mean Flow at Seti Damsite (Karnari Basin)

Drainage area: 7,090 $km^2$ Unit: $m^3/s$

| Month Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1962 | | | | | | | | | | | | | |
| 1963 | 66.6 | 54.6 | 82.1 | 85.1 | 124.5 | 286.9 | 788.5 | 1,433.6 | 874.0 | 250.8 | 137.8 | 95.0 | 356.6 |
| 1964 | 72.3 | 62.1 | 59.5 | 79.7 | 96.9 | 188.1 | 910.1 | 1,046.9 | 911.1 | 280.3 | 121.6 | 82.4 | 325.9 |
| 1965 | 63.7 | 70.8 | 85.6 | 105.5 | 90.6 | 208,1 | 537.7 | 619.4 | 378.1 | 143.5 | 101.7 | 66.8 | 205.9 |
| 1966 | 48.2 | 49.1 | 42.6 | 44.7 | 91.0 | 209.2 | 548.8 | 951.0 | 435.4 | 154.2 | 90.9 | 69.2 | 227.9 |
| 1967 | 55.9 | 42.5 | 41.6 | 56.4 | 67.5 | 164.3 | 773.2 | 1,104.7 | 615.5 | 205.5 | 112.8 | 87.6 | 277.3 |
| 1968 | 72.8 | 70.6 | 91.1 | 89.9 | 121.8 | 338.2 | 791.3 | 1,013.7 | 543.6 | 223.0 | 122.6 | 84.4 | 296.9 |
| 1969 | 79.5 | 69.5 | 73.1 | 84.6 | 129.8 | 200.0 | 523.6 | 930.4 | 907.1 | 301.5 | 138.5 | 84.2 | 293.5 |
| 1970 | 69.0 | 61.1 | 57.3 | 72.7 | 98.8 | 345.8 | 1,031.7 | 995.6 | 476.6 | 239.1 | 115.8 | 82.9 | 303.9 |
| 1971 | 67.9 | 66.3 | 71.9 | 106.4 | 108.6 | 763.0 | 923.8 | 1,235.0 | 964.3 | 305.2 | 161.0 | 102.5 | 406.3 |
| Mean | 66.2 | 60.7 | 67.2 | 80.6 | 103.3 | 300.4 | 758.8 | 1,036.7 | 678.4 | 233.7 | 122.5 | 83.9 | 299.4 |

Table 4.8 Monthly Mean Flow at Dev-Ghat Damsite

Drainage area: 32,130 $km^2$ Unit: $m^3/s$

| Month / Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1963 | 477.2 | 362.7 | 299.3 | 421.2 | 721.6 | 1,744.9 | 3,885.6 | 5,328.8 | 3,845.3 | 1,759.4 | 1,108.5 | 846.9 | 1,733.5 |
| 1964 | 467.5 | 389.4 | 320.7 | 426.8 | 458.7 | 1,219.1 | 4,195.5 | 4,757.5 | 3,688.2 | 1,822.4 | 1,019.3 | 659.4 | 1,618.9 |
| 1965 | 487.5 | 334.1 | 276.5 | 485.9 | 663.2 | 1,574.5 | 3,236.8 | 4,758.6 | 2,909.3 | 1,355.5 | 985.1 | 611.2 | 1,473.2 |
| 1966 | 380.8 | 323.6 | 252.8 | 294.3 | 635.0 | 1,371.0 | 3,605.6 | 5,501.4 | 3,488.8 | 1,365.8 | 879.9 | 602.5 | 1,558.5 |
| 1967 | 445.4 | 338.8 | 318.9 | 436.1 | 596.9 | 1,448.4 | 3,920.7 | 4,190.4 | 3,083.9 | 1,430.9 | 832.8 | 559.0 | 1,467.0 |
| 1968 | 420.0 | 318.6 | 331.0 | 377.8 | 657.4 | 1,983.6 | 4,619.1 | 4,314.3 | 3,251.2 | 2,915.5 | 1,078.6 | 692.6 | 1,746.6 |
| Mean | 446.4 | 344.5 | 299.9 | 407.0 | 622.1 | 1,556.9 | 3,910.5 | 4,808.8 | 3,377.8 | 1,774.9 | 984.0 | 661.9 | 1,599.6 |

Table 4.9 Monthly Mean Flow at Kali Gandaki No.1 Damsite

Drainage area: 9,200 $km^2$ Unit: $m^3/s$

| Month / Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1964 | 75.4 | 65.0 | 62.0 | 89.9 | 106.7 | 305.6 | 1,139.8 | 1,183.3 | 1,019.6 | 400.6 | 188.8 | 112.5 | 395.8 |
| 1965 | 81.6 | 62.9 | 58.9 | 97.4 | 124.9 | 354.2 | 807.0 | 1,091.4 | 570.3 | 234.2 | 156.0 | 95.2 | 311.2 |
| 1966 | 70.4 | 59.6 | 54.0 | 61.5 | 119.0 | 313.7 | 907.6 | 1,275.6 | 742.9 | 243.3 | 147.5 | 90.3 | 340.5 |
| 1967 | 60.5 | 48.8 | 42.9 | 58.2 | 94.7 | 300.8 | 946.2 | 1,020.3 | 914.3 | 262.9 | 139.5 | 90.6 | 315.0 |
| 1968 | 67.0 | 51.6 | 58.1 | 69.4 | 128.9 | 421.1 | 1,083.2 | 1,011.6 | 782.1 | 573.7 | 196.7 | 115.3 | 379.9 |
| 1969 | 51.7 | 35.5 | 37.9 | 44.2 | 90.0 | 291.6 | 940.5 | 1,227.6 | 1,148.0 | 343.4 | 159.1 | 91.2 | 371.7 |
| 1970 | 58.0 | 42.7 | 40.7 | 79.1 | 114.3 | 475.0 | 1,293.3 | 1,475.4 | 847.8 | 369.8 | 156.3 | 85.3 | 419.8 |
| 1971 | 51.7 | 36.0 | 38.7 | 84.9 | 137.7 | 792.6 | 1,226.0 | 1,394.9 | 823.2 | 513.7 | 208.8 | 109.2 | 451.5 |
| Mean | 64.5 | 50.3 | 49.2 | 73.1 | 114.5 | 406.8 | 1,043.0 | 1,210.0 | 831.0 | 367.7 | 169.1 | 98.7 | 373.2 |

Table 4.10 Monthly Mean Flow at Kali Gandaki No.2 Damsite

Drainage area: 11,330 $km^2$ Unit: $m^3/s$

| Month / Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1964 | 117.8 | 106.8 | 97.7 | 103.4 | 112.5 | 269.5 | 1,822.7 | 2,131.8 | 1,654.8 | 533.9 | 263.4 | 167.5 | 615.2 |
| 1965 | 124.2 | 108.3 | 92.4 | 109.6 | 115.5 | 284.6 | 981.7 | 2,147.7 | 1,142.9 | 506.5 | 347.5 | 234.2 | 524.6 |
| 1966 | 193.4 | 176.0 | 161.1 | 154.0 | 200.5 | 481.8 | 1,378.5 | 2,410.1 | 1,416.3 | 485.1 | 307.1 | 215.5 | 631.6 |
| 1967 | 169.9 | 148.9 | 118.9 | 86.3 | 99.0 | 295.4 | 1,067.4 | 1,409.3 | 991.3 | 352.0 | 174.2 | 115.0 | 419.0 |
| Mean | 151.3 | 135.0 | 117.5 | 113.3 | 131.9 | 357.8 | 1,312.6 | 2,024.7 | 1,301.3 | 469.4 | 273.0 | 183.0 | 547.6 |

Table 4.11 Monthly Mean Flow at Buri Gandaki Damsite

Drainage area: 5,840 $km^2$ Unit: $m^3/s$

| Month Year | Jan | Feb | Mar | Apr | May | June | July | Aug. | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1964 | 48.5 | 38.1 | 38.9 | 68.9 | 71.8 | 256.6 | 582.6 | 610.1 | 270.9 | 236.9 | 115.9 | 68.0 | 217.3 |
| 1965 | 46.5 | 36.0 | 36.2 | 98.2 | 189.8 | 338.0 | 533.3 | 620.5 | 386.0 | 169.2 | 115.9 | 72.0 | 220.1 |
| 1966 | 53.4 | 48.6 | 48.1 | 75.7 | 143.2 | 277.2 | 549.3 | 710.9 | 408.2 | 169.5 | 91.8 | 56.2 | 219.3 |
| 1967 | 38.9 | 32.1 | 32.5 | 59.9 | 68.3 | 193.5 | 532.2 | 492.6 | 328.1 | 168.9 | 80.0 | 50.8 | 173.2 |
| 1968 | 39.7 | 33.1 | 46.4 | 70.7 | 122.5 | 314.6 | 583.2 | 522.5 | 365.2 | 255.2 | 114.0 | 76.8 | 212.0 |
| 1969 | 52.7 | 43.4 | 49.0 | 70.5 | 122.7 | 247.7 | 464.9 | 451.6 | 369.6 | 174.8 | 94.8 | 64.8 | 183.9 |
| 1970 | 48.0 | 40.7 | 43.3 | 88.1 | 126.4 | 263.1 | 497.8 | 505.5 | 372.2 | 240.3 | 134.1 | 93.4 | 204.4 |
| 1971 | 53.9 | 44.5 | 47.2 | 95.7 | 124.8 | 412.9 | 490.5 | 491.0 | 343.2 | 222.1 | 131.3 | 76.4 | 211.1 |
| Mean | 47.7 | 39.6 | 42.7 | 78.5 | 121.2 | 288.0 | 529.2 | 550.6 | 380.4 | 204.6 | 109.7 | 69.8 | 205.2 |

Table 4.12 Monthly Mean Flow at Bhomichock Damsite

Drainage area: 12,380 $km^2$ Unit: $m^3/s$

| Month / Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1967 | 109.0 | 88.3 | 85.8 | 120.8 | 162.6 | 396.6 | 1,166.8 | 1,259.7 | 811.2 | 345.0 | 179.0 | 122.2 | 403.9 |
| 1968 | 95.7 | 80.5 | 92.3 | 127.9 | 218.5 | 640.5 | 1,301.7 | 1,231.8 | 781.1 | 506.2 | 226.2 | 152.3 | 454.6 |
| 1969 | 112.6 | 95.9 | 98.0 | 126.8 | 214.9 | 445.0 | 1,054.2 | 1,119.2 | 415.5 | 361.0 | 194.9 | 135.1 | 364.4 |
| 1970 | 102.3 | 87.9 | 87.5 | 148.0 | 223.0 | 503.5 | 1,190.6 | 1,262.5 | 801.9 | 464.5 | 257.8 | 179.2 | 442.4 |
| 1971 | 120.5 | 101.7 | 101.7 | 164.5 | 221.2 | 927.9 | 1,153.2 | 1,303.2 | 817.5 | 449.3 | 251.9 | 157.5 | 480.8 |
| Mean | 108.0 | 90.9 | 93.1 | 137.6 | 208.0 | 582.7 | 1,173.3 | 1,235.3 | 725.4 | 425.4 | 222.0 | 149.2 | 429.2 |

Table 4.13 Monthly Mean Flow at Marsyandi Damsite

Drainage area: 4,600 $km^2$ Unit: $m^3/s$

| Month / Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1964 | 48.5 | 33.5 | 26.4 | 27.8 | 33.1 | 99.4 | 409.3 | 676.0 | 1,363.0 | 451.7 | 104.3 | 56.5 | 277.3 |
| 1965 | 36.1 | 28.9 | 28.8 | 37.4 | 25.2 | 288.7 | 812.6 | 1,106.8 | 680.5 | 361.8 | 147.1 | 66.0 | 301.7 |
| 1966 | 49.6 | 41.6 | 37.3 | 32.1 | 25.1 | 71.6 | 1,148.7 | 774.9 | 716.5 | 429.8 | 253.3 | 140.1 | 310.1 |
| 1967 | 51.5 | 35.8 | 34.9 | 43.6 | 55.6 | 88.5 | 595.5 | 554.0 | 351.5 | 143.2 | 81.2 | 66.4 | 175.1 |
| 1968 | 51.1 | 40.1 | 40.1 | 41.6 | 41.9 | 181.3 | 465.7 | 460.0 | 346.2 | 282.7 | 104.9 | 64.9 | 176.7 |
| 1969 | 49.3 | 38.3 | 38.6 | 33.4 | 40.5 | 78.9 | 354.0 | 554.3 | 455.5 | 193.0 | 84.7 | 55.2 | 164.6 |
| 1970 | 41.6 | 38.1 | 32.0 | 29.4 | 29.9 | 152.1 | 558.1 | 649.8 | 381.6 | 223.2 | 93.7 | 57.3 | 190.6 |
| 1971 | 42.5 | 34.2 | 32.3 | 53.4 | 78.4 | 481.1 | 602.8 | 633.1 | 457.2 | 298.2 | 138.8 | 69.0 | 243.4 |
| Mean | 46.3 | 36.3 | 33.8 | 37.3 | 41.2 | 180.2 | 618.1 | 676.1 | 594.0 | 298.0 | 126.0 | 71.9 | 229.9 |

Table 4.14 Monthly Mean Flow at Seti (Sapt Gandaki Basin)

Drainage area: 2,780 $km^2$ — Unit: $m^3/s$

| Month / Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1964 | 45.0 | 43.1 | 42.7 | 45.2 | 97.8 | 110.6 | 190.5 | 653.5 | 444.2 | 159.1 | 116.3 | 76.4 | 168.7 |
| 1965 | 48.3 | 41.8 | 42.2 | 46.4 | 51.5 | 214.3 | 416.3 | 522.9 | 275.1 | 88.8 | 66.5 | 44.4 | 154.9 |
| 1966 | 34.8 | 31.4 | 29.8 | 27.5 | 31.5 | 90.1 | 324.1 | 368.4 | 226.7 | 93.7 | 54.7 | 36.2 | 112.4 |
| 1967 | 29.2 | 29.4 | 28.5 | 32.4 | 34.7 | 82.0 | 328.1 | 302.5 | 263.6 | 109.5 | 61.7 | 48.0 | 112.5 |
| 1968 | 35.3 | 29.1 | 35.1 | 35.9 | 49.6 | 201.3 | 476.8 | 407.1 | 315.8 | 514.3 | 88.0 | 53.0 | 186.8 |
| 1969 | 26.0 | 20.7 | 21.6 | 21.2 | 23.6 | 48.8 | 181.6 | 446.9 | 374.5 | 112.7 | 57.1 | 54.6 | 115.8 |
| 1970 | 25.5 | 24.5 | 23.1 | 34.9 | 50.0 | 129.5 | 540.1 | 584.7 | 286.8 | 150.6 | 80.6 | 47.4 | 164.8 |
| 1971 | 33.6 | 26.4 | 26.6 | 41.4 | 56.2 | 266.4 | 412.9 | 426.5 | 302.0 | 206.7 | 96.0 | 56.7 | 162.6 |
| Mean | 34.7 | 30.8 | 31.2 | 35.6 | 49.4 | 142.9 | 358.8 | 464.1 | 311.1 | 179.4 | 77.6 | 52.1 | 147.3 |

Table 4.15 Monthly Mean Flow at Sun Kosi High Damsite

Drainage area: 16,200 $km^2$ Unit: $m^3/s$

| Month / Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1948 | 190.3 | 147.9 | 130.8 | 161.5 | 254.4 | 547.5 | 1,524.4 | 1,641.6 | 1,601.1 | 952.5 | 379.7 | 263.4 | 694.6 |
| 1949 | 215.6 | 178.6 | 168.7 | 204.8 | 344.6 | 835.3 | 1,958.2 | 2,513.0 | 2,050.3 | 906.5 | 451.9 | 258.0 | 840.4 |
| 1950 | 196.6 | 159.7 | 149.7 | 148.8 | 199.3 | 745.9 | 1,695.8 | 2,379.5 | 1,524.4 | 500.6 | 311.2 | 225.5 | 686.4 |
| 1951 | 178.6 | 147.9 | 134.4 | 128.1 | 236.3 | 722.5 | 1,609.2 | 2,096.3 | 1,373.8 | 546.6 | 352.7 | 235.4 | 646.8 |
| 1952 | 176.8 | 149.7 | 145.2 | 150.6 | 253.5 | 566.5 | 1,573.1 | 2,016.9 | 1,654.3 | 719.8 | 387.9 | 243.5 | 669.8 |
| 1953 | 187.6 | 155.1 | 172.3 | 135.3 | 194.8 | 483.6 | 1,821.1 | 1,684.9 | 1,417.1 | 597.1 | 298.6 | 215.6 | 613.5 |
| 1954 | 172.3 | 143.4 | 120.9 | 131.7 | 217.4 | 909.2 | 1,822.9 | 2,436.3 | 1,621.8 | 718.0 | 364.4 | 206.6 | 738.7 |
| 1955 | 164.2 | 132.6 | 117.3 | 114.6 | 176.8 | 464.5 | 1,486.5 | 1,779.7 | 1,274.5 | 562.0 | 337.4 | 118.2 | 560.7 |
| 1956 | 181.3 | 143.4 | 131.7 | 146.1 | 324.7 | 1,085.1 | 1,235.7 | 1,440.5 | 1,139.2 | 604.3 | 365.3 | 235.4 | 586.1 |
| 1957 | 228.2 | 230.0 | 157.0 | 169.6 | 184.0 | 423.9 | 1,404.4 | 1,843.7 | 1,115.8 | 488.0 | 278.7 | 204.8 | 560.7 |
| 1958 | 166.0 | 138.9 | 120.0 | 136.2 | 182.2 | 414.0 | 1,202.4 | 2,165.7 | 1,327.7 | 638.6 | 322.0 | 230.0 | 587.0 |
| 1959 | 176.8 | 146.1 | 128.1 | 142.5 | 201.2 | 521.4 | 1,351.2 | 1,991.6 | 1,343.1 | 829.8 | 403.2 | 270.6 | 625.5 |
| 1960 | 193.9 | 163.3 | 152.4 | 138.0 | 231.8 | 638.6 | 1,637.1 | 1,991.6 | 1,690.4 | 939.9 | 344.6 | 209.3 | 694.3 |
| 1961 | 175.9 | 140.7 | 125.4 | 134.4 | 199.3 | 595.3 | 957.9 | 1,861.7 | 1,353.0 | 807.3 | 414.0 | 230.0 | 582.9 |
| 1962 | 170.5 | 155.1 | 169.6 | 174.1 | 227.3 | 1,008.4 | 1,537.0 | 2,209.0 | 1,529.8 | 608.0 | 344.6 | 235.4 | 697.4 |
| 1963 | 166.0 | 148.8 | 142.5 | 145.2 | 213.8 | 799.2 | 1,751.7 | 2,030.4 | 1,365.6 | 691.8 | 365.3 | 206.6 | 668.9 |
| 1964 | 161.5 | 130.8 | 112.8 | 130.8 | 188.5 | 506.0 | 1,463.0 | 1,690.4 | 1,235.7 | 658.5 | 387.0 | 233.6 | 574.9 |
| 1965 | 203.0 | 149.7 | 120.9 | 153.3 | 193.9 | 622.4 | 1,438.7 | 1,858.1 | 1,089.6 | 484.4 | 309.4 | 179.5 | 566.9 |
| 1966 | 152.4 | 119.1 | 92.9 | 89.3 | 151.5 | 488.9 | 1,785.1 | 2,328.9 | 1,594.7 | 486.2 | 308.5 | 226.4 | 652.0 |
| 1967 | 167.8 | 148.8 | 117.3 | 132.6 | 174.1 | 433.0 | 1,517.2 | 1,776.0 | 1,186.1 | 648.5 | 380.6 | 258.9 | 578.4 |
| Mean | 181.3 | 151.5 | 135.5 | 143.4 | 217.5 | 640.5 | 1,538.6 | 1,986.8 | 1,424.4 | 669.4 | 355.3 | 224.3 | 639.0 |

Table 4.16 Monthly Mean Flow at Bagmati Damsite

Drainage area: 2,715 $km^2$ Unit: $m^3/s$

| Month / Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1957 | 23 | 21 | 20 | 18 | 17 | 49 | 240 | 300 | 81 | 35 | 22 | 22 | 70.7 |
| 1958 | 21 | 20 | 18 | 17 | 38 | 64 | 125 | 445 | 245 | 73 | 29 | 24 | 93.3 |
| 1959 | 23 | 22 | 20 | 20 | 23 | 208 | 153 | 210 | 160 | 170 | 31 | 24 | 88.7 |
| 1960 | 21 | 22 | 20 | 17 | 30 | 165 | 410 | 420 | 530 | 145 | 29 | 23 | 152.7 |
| 1961 | 21 | 22 | 20 | 17 | 21 | 175 | 128 | 395 | 230 | 196 | 28 | 23 | 98.8 |
| 1962 | 22 | 21 | 22 | 21 | 31 | 300 | 265 | 420 | 320 | 94 | 26 | 23 | 130.4 |
| 1963 | 21 | 20 | 19 | 24 | 95 | 275 | 420 | 343 | 105 | 205 | 40 | 30 | 133.1 |
| 1964 | 23 | 21 | 20 | 26 | 49 | 22 | 690 | 450 | 480 | 173 | 32 | 25 | 167.6 |
| 1965 | 26.2 | 18.0 | 14.2 | 26.9 | 26.6 | 250 | 1,026 | 716 | 290 | 60.9 | 43.1 | 30.0 | 210.7 |
| 1966 | 36.2 | 31.2 | 23.2 | 20.5 | 23.6 | 69.6 | 510 | 600 | 300 | 40.8 | 18.9 | 14.5 | 140.7 |
| 1967 | 19.1 | 16.3 | 17.9 | 18.4 | 17.4 | 75.6 | 498 | 443 | 421 | 153 | 33.4 | 25.4 | 144.9 |
| 1968 | 33.3 | 27.0 | 26.4 | 18.2 | 23.0 | 184 | 685 | 532 | 336 | 429 | 49.4 | 30.8 | 197.8 |
| 1969 | 24 | 21 | 20 | 20 | 22 | 200 | 310 | 430 | 310 | 81 | 31 | 26 | 124.6 |
| Mean | 24.1 | 21.7 | 20.1 | 20.3 | 32.0 | 156.7 | 420.0 | 438.8 | 292.9 | 135.8 | 31.8 | 24.7 | 134.9 |

Table 4.17 Monthly Mean Flow at Kulikhani No.1 Damsite

Drainage area: 127 $km^2$ Unit: $m^3/s$

| Month / Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1963 | 1.2 | 1.1 | 1.1 | 1.2 | 1.7 | 1.1 | 6.7 | 7.7 | 5.8 | 3.6 | 2.2 | 1.8 | 2.9 |
| 1964 | 1.5 | 1.4 | 1.2 | 0.9 | 1.3 | 2.2 | 7.3 | 12.2 | 15.4 | 4.5 | 1.9 | 1.5 | 4.3 |
| 1965 | 1.3 | 1.3 | 1.2 | 1.8 | 1.5 | 3.8 | 19.7 | 18.5 | 5.8 | 3.2 | 2.9 | 1.8 | 5.2 |
| 1966 | 1.6 | 1.4 | 1.2 | 0.8 | 1.1 | 1.2 | 10.5 | 21.0 | 10.4 | 3.4 | 2.2 | 1.7 | 4.7 |
| 1967 | 1.1 | 1.0 | 0.9 | 1.0 | 0.7 | 4.6 | 11.9 | 7.0 | 5.7 | 3.4 | 2.3 | 1.7 | 3.4 |
| 1968 | 1.7 | 1.5 | 1.6 | 1.2 | 1.1 | 2.5 | 5.8 | 6.4 | 2.6 | 7.2 | 2.3 | 1.5 | 3.0 |
| 1969 | 1.2 | 0.9 | 0.9 | 0.9 | 1.0 | 0.9 | 3.1 | 7.0 | 4.2 | 1.9 | 1.1 | 0.8 | 2.0 |
| 1970 | 0.8 | 0.7 | 0.6 | 0.6 | 0.7 | 3.4 | 21.5 | 9.1 | 5.3 | 3.3 | 2.2 | 1.5 | 4.1 |
| 1971 | 1.2 | 1.1 | 1.1 | 2.0 | 2.2 | 21.8 | 5.1 | 7.8 | 4.3 | 3.9 | 2.2 | 1.9 | 4.5 |
| Mean | 1.3 | 1.2 | 1.1 | 1.2 | 1.2 | 4.6 | 10.2 | 10.7 | 6.6 | 3.8 | 2.1 | 1.6 | 3.8 |

Table 4.18 Monthly Mean Flow at Kulikhani No.3 Damsite

Drainage area: 119 $km^2$ Unit: $m^3/s$

| Month / Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1963 | 1.6 | 1.4 | 1.2 | 1.1 | 1.3 | 4.4 | 13.5 | 18.9 | 14.6 | 6.8 | 3.4 | 2.0 | 5.8 |
| 1964 | 1.6 | 1.3 | 1.1 | 1.0 | 1.2 | 2.3 | 15.3 | 11.4 | 14.2 | 9.2 | 2.8 | 1.7 | 5.3 |
| 1965 | 1.5 | 1.4 | 1.4 | 0.9 | 0.8 | 3.6 | 17.4 | 35.1 | 15.1 | 6.0 | 4.3 | 2.2 | 7.5 |
| 1966 | 1.7 | 1.4 | 1.2 | 1.1 | 1.4 | 2.5 | 10.7 | 32.5 | 19.1 | 4.2 | 2.6 | 1.9 | 6.7 |
| 1967 | 1.6 | 1.3 | 1.4 | 1.4 | 1.3 | 3.0 | 19.3 | 15.3 | 14.8 | 4.4 | 2.1 | 1.4 | 5.6 |
| 1968 | 1.4 | 1.2 | 1.1 | 1.0 | 1.0 | 6.9 | 18.4 | 28.6 | 12.9 | 9.2 | 3.8 | 2.6 | 7.3 |
| 1969 | 2.1 | 1.6 | 1.4 | 1.3 | 1.5 | 2.9 | 9.2 | 16.8 | 13.2 | 5.8 | 3.1 | 2.1 | 5.1 |
| 1970 | 1.7 | 0.7 | 1.1 | 1.0 | 1.0 | 4.6 | 27.3 | 19.7 | 14.0 | 9.2 | 3.8 | 2.3 | 7.2 |
| 1971 | 1.5 | 1.0 | 0.6 | 1.4 | 4.6 | 18.6 | 14.0 | 18.5 | 12.2 | 7.1 | 3.5 | 2.3 | 7.1 |
| Mean | 1.6 | 1.3 | 1.2 | 1.1 | 1.6 | 5.4 | 16.1 | 21.9 | 14.5 | 6.9 | 3.2 | 2.1 | 6.4 |

Table 4.19 Monthly Mean Flow at Kamla Damsite

Drainage area: 1,530 $km^2$

Unit: $m^3/s$

| Month / Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1957 | 8.4 | 4.6 | 2.9 | 1.5 | 1.2 | 24.0 | 61.5 | 84.8 | 37.5 | 19.6 | 5.8 | 6.0 | 21.5 |
| 1958 | 4.5 | 2.9 | 1.4 | 1.1 | 10.5 | 18.5 | 33.1 | 146.0 | 65.5 | 35.5 | 14.5 | 9.3 | 28.6 |
| 1959 | 7.2 | 6.3 | 3.3 | 3.3 | 4.7 | 53.0 | 39.1 | 53.2 | 50.0 | 51.0 | 16.7 | 9.4 | 24.8 |
| 1960 | 4.6 | 2.7 | 3.5 | 1.2 | 7.7 | 41.9 | 130.0 | 137.0 | 189.0 | 48.5 | 15.1 | 8.3 | 49.1 |
| 1961 | 4.5 | 5.6 | 3.6 | 1.4 | 3.9 | 44.6 | 33.8 | 124.0 | 62.6 | 42.9 | 13.9 | 8.3 | 29.1 |
| 1962 | 5.6 | 5.1 | 6.2 | 4.0 | 8.1 | 84.8 | 71.7 | 136.0 | 93.5 | 40.8 | 11.4 | 8.1 | 39.6 |
| 1963 | 4.9 | 3.3 | 2.6 | 5.2 | 26.1 | 75.1 | 135.0 | 102.0 | 42.9 | 56.2 | 22.3 | 15.7 | 40.9 |
| 1964 | 7.3 | 5.1 | 2.9 | 5.1 | 13.9 | 4.1 | 271.0 | 150.0 | 162.0 | 51.4 | 17.9 | 11.0 | 58.5 |
| 1965 | 6.1 | 4.4 | 3.3 | 1.9 | 1.7 | 38.2 | 319.0 | 375.0 | 139.0 | 58.5 | 33.4 | 13.5 | 82.8 |
| 1966 | 11.5 | 6.9 | 3.4 | 1.8 | 7.8 | 9.4 | 195.0 | 395.0 | 127.0 | 32.6 | 16.9 | 15.0 | 68.5 |
| 1967 | 9.4 | 5.9 | 6.0 | 4.6 | 3.2 | 34.5 | 143.0 | 88.1 | 136.0 | 33.8 | 11.1 | 11.0 | 40.5 |
| 1968 | 8.1 | 6.0 | 3.9 | 1.8 | 3.4 | 74.3 | 165.0 | 153.0 | 136.0 | 74.6 | 21.3 | 15.7 | 55.2 |
| 1969 | 9.0 | 4.8 | 3.7 | 3.5 | 4.4 | 50.7 | 88.8 | 138.0 | 89.9 | 37.5 | 17.2 | 12.4 | 38.3 |
| Mean | 7.0 | 4.9 | 3.6 | 2.8 | 7.4 | 42.5 | 129.7 | 160.2 | 102.4 | 44.9 | 16.7 | 11.1 | 44.4 |

Table 4.20 Monthly Mean Flow at Kankai Damsite

Drainage area: 1,190 $km^2$ Unit: $m^3/s$

| Month / Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1965 | 13.0 | 10.5 | 8.5 | 9.2 | 16.4 | 46.5 | 81.9 | 199.9 | 97.8 | 40.2 | 30.5 | 17.1 | 47.6 |
| 1966 | 16.2 | 10.2 | 6.6 | 4.9 | 6.3 | 12.4 | 147.4 | 198.0 | 131.7 | 36.6 | 15.6 | 9.3 | 49.6 |
| 1967 | 7.3 | 6.5 | 6.9 | 6.0 | 9.4 | 26.9 | 226.3 | 94.1 | 99.6 | 35.1 | 21.9 | 18.2 | 46.5 |
| 1968 | 10.4 | 6.2 | 5.2 | 5.4 | 9.3 | 35.7 | 183.4 | 166.2 | 163.1 | 268.4 | 30.0 | 23.1 | 75.5 |
| 1969 | 15.0 | 11.1 | 9.4 | 7.3 | 13.1 | 25.2 | 137.5 | 145.7 | 140.5 | 44.1 | 32.4 | 19.7 | 50.1 |
| Mean | 12.4 | 8.9 | 7.3 | 6.6 | 10.9 | 29.3 | 155.3 | 160.8 | 126.5 | 84.9 | 26.1 | 17.5 | 53.9 |

Table 4.21 Monthly Mean Flow at Mai Khola Loop Damsite

Drainage area: 670 $km^2$ Unit: $m^3/s$

| Month / Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1965 | 7.3 | 5.9 | 4.8 | 5.2 | 9.3 | 26.2 | 46.1 | 112.6 | 55.1 | 22.6 | 17.2 | 9.6 | 26.8 |
| 1966 | 9.2 | 5.8 | 3.7 | 2.7 | 3.5 | 7.0 | 83.0 | 111.5 | 74.2 | 20.6 | 8.8 | 5.2 | 27.9 |
| 1967 | 4.1 | 3.7 | 3.9 | 3.4 | 5.3 | 15.1 | 127.4 | 53.0 | 56.1 | 19.8 | 12.3 | 10.2 | 26.2 |
| 1968 | 5.8 | 3.5 | 2.3 | 3.1 | 5.3 | 20.1 | 103.3 | 93.6 | 91.9 | 151.2 | 16.9 | 13.0 | 42.5 |
| 1969 | 8.4 | 6.3 | 5.3 | 4.1 | 7.4 | 14.2 | 77.4 | 82.1 | 79.1 | 24.8 | 18.3 | 11.1 | 28.2 |
| Mean | 7.0 | 5.0 | 4.0 | 3.7 | 6.1 | 16.5 | 87.5 | 90.6 | 71.3 | 47.8 | 14.7 | 9.8 | 30.3 |

Table 4.22 Monthly Mean Flow at Sarda Damsite

Drainage area: 860 $km^2$ Unit: $m^3/s$

| Month Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1964 | 3.5 | 2.6 | 2.6 | 2.7 | 3.1 | 6.4 | 24.3 | 50.2 | 23.4 | 21.9 | 17.2 | 4.7 | 13.6 |
| 1965 | 6.2 | 4.4 | 4.5 | 1.9 | 0.6 | 8.0 | 24.5 | 41.3 | 21.6 | 10.8 | 5.5 | 3.8 | 11.09 |
| 1966 | 4.6 | 2.8 | 2.1 | 1.4 | 0.8 | 9.3 | 25.6 | 44.1 | 20.7 | 7.3 | 4.1 | 3.3 | 10.5 |
| 1967 | 4.1 | 3.7 | 3.2 | 2.4 | 1.9 | 4.6 | 51.5 | 27.9 | 39.7 | 13.6 | 6.3 | 5.3 | 13.7 |
| 1968 | 5.1 | 3.7 | 2.2 | 1.8 | 1.4 | 22.4 | 41.6 | 50.9 | 38.5 | 16.9 | 6.5 | 4.5 | 16.3 |
| 1969 | 4.3 | 3.3 | 2.4 | 2.0 | 2.3 | 6.5 | 19.2 | 55.9 | 51.4 | 19.4 | 8.5 | 5.2 | 15.0 |
| 1970 | 4.1 | 3.7 | 2.9 | 2.1 | 2.2 | 19.9 | 89.1 | 45.5 | 32.9 | 25.7 | 7.7 | 5.1 | 20.1 |
| Mean | 4.6 | 3.5 | 2.8 | 2.0 | 1.8 | 11.0 | 39.4 | 45.1 | 32.6 | 16.5 | 8.0 | 4.6 | 14.3 |

# MASTER PLAN OF HYDROELECTRIC POWER DEVELOPMENT

# IN

# NEPAL

## APPENDIX 5

## GEOLOGY

APPENDIX 5 GEOLOGY

## LIST OF FIGURE

1. GENERAL GEOLOGY OF THE KINGDOM OF NEPAL

Nepal is long at NWW-SEE direction, being about 830 km, narrow at NS direction, being about 180 km in average. Nepal belongs to the left watershed of the Ganges River of India, and has many tributaries of the Ganges flowing down to south. These tributaries flow out mainly from Himalaya mountain range or Tibet area of China except small rivers. The Himalayan mountain range is located along northern border of Nepal. Between the Himalayan mountain range and the Ganges alluvial plain, there are many thrust faults and nappes along NWW-SEE direction (i.e., parallel to Nepal's longitudinal direction). The area near Indian border is so-called "Terai plain" which is composed of fan deposits of sand, gravel and silt, having very gentle slope, or rather flat surface. Several kilometers wide zone of foot area of Churia hill or Siwalik range side on the Terai Plain is called "barbal zone", being covered by crusty ground surface scattered with jungle or forest of shrub or tall trees. Fig. 5.1 shows the general geology of Nepal.

The East-West Highway is having been constructed at this barbal zone and its neighbouring area under foreign aids for many years. The east half of the highway has beencompleted, but the west half is not. The Churia Hill or Siwalik Range rises up at the close north of the Terai Plain from east to west. This Churia hill or Siwalik range is composed of sandstone, shale, siltstone and conglomerate of Siwaliks Formation of Plio-Pleistocene Age. These rocks are not so hard, but rather soft, having a compressive strength of 50 $kg/cm^2$ to 400 $kg/cm^2$. This Siwaliks Formation has an average width of about 24 km at NS direction, and divided into 3 stratigraphic divisions of upper, middle and lower. The hardness of the rocks decreases from the Lower to Upper Siwaliks Formations. However, distinction of these divisions is not clear in some areas.

The formation located north of the Siwaliks is called "Mahabharat Series", which is composed of metamorphic rocks of Pre-Cambrian to upper Palaeozoic Age. Both the Siwaliks and Mahabharat Formations extend to the general east-west direction, approximately in parallel way. The west halves of these formations are contacted each other by thrust planes, but the Gondwanas Formation of upper Palaezoic Age lies between the east halves of the Siwaliks and Mahabharat Formations. This Gondwanas Formation is composed of sandstone, limestone, shale, black shale, phyllitic shale, etc., and sheared remarkably, being long at east-west direction, and narrow at north-sourth direction. Accompanying with the great Himalayan orogenic movement, these formations have many thrusts of general strike of WWN-EES direction, and many nappes. This situation is particularly emphasized in the Gondwanas Formation. Igneous rocks (granite, grano-diorite, tourmaline granite, etc.) are scattered over the metamorphic formations of the Mahabharat, but there are no basic or ultra-basic rocks nor volcanic rock in Nepal. Generally, these metamorphic rocks are weathered, sheared and disturbed remarkably, and have open cracks, open joints and open fissures in surface zone, showing mosaic structure. These metamorphic rocks and igneous rocks have numerous mica minerals of sericite, biotite, muscovite, phlogopite, etc. in their texture. Also, calcareous rocks and limestones (ordinary or metamorphosed) distribute over many places as semi-metamorphic rocks or metamorphic rocks. Therefore, sand and silt which derived from weathering of these rocks include many mica flakes and calcareous components. These sands are of poor quality for concrete aggrigates.

The rivers in Nepal cross the country in general direction of the north to the south. On the way, when the rivers meet the Mahabharat and/or the Siwalik Ranges, they flow in very flat course along the northern slopes of the ranges in the east-west direction, then find the outlet and cut through these mountain ranges to the south before debouching on the Terai Plain. This topography is favorable for hydropower generation, as vast river bends can be by-passed by relatively short tunnels, and flat river courses along the mountain range can provide large pockets for storage. The places where the rivers cut across the Mahabharat form gorge sections of metamorphic rocks, suitable for high dam construction. Those in the Siwaliks are composed of relatively soft rocks of younger ages. Except in the Lower Siwaliks Formation of harder nature, those places in the Middle and Upper Siwaliks are generally not suitable for concrete high dams, but more suited for embankment structures. The alluvial deposits of sand, gravel, and silt in all river channels are relatively thick, presumably to be 20 m to 30 m in slow flowing places of the rivers, and 10 m to 15 m in rapid flowing courses, deep water places, small rivers, and uppermost reaches of the rivers.

## 2. RIVERS FROM HIMALAYA /1

### 2.1 KARNALI RIVER BASIN

The conceivable projects in the Karnali river basin are as follows.

| | |
|---|---|
| Chisapani project | (1) /2 |
| Lakarpata project | (2) |
| Bhanakot project | (3) |
| Poliparni project | (4) |
| Samala project | (5) |
| Ranmi project | (6) |
| Jubitan project | (7) |
| Surkhet project | (8) |
| Thapna project | (9) |
| Seti project | (10) |

These project sites were not inspected this time. The geologic information of the Chisapani and Lakarpata project sites is available in their feasibility reports. Summarized description is given as follows.

#### 2.1.1 Chisapani Dam Site (1)

The Karnali River flows through the Mahabharat mountains in a number of long bends, then cuts a gorge through the Siwalik mountains in a north-sourth direction to debouch on the Terai plain.

The dam site is located at about the middle of the deepest part of the gorge, where the river width is about 100 m and the side slopes on both banks rise at about 45°. The river bed elevation is EL. 182 m.

The rock at the dam site consists of alternating beds of sandstone and siltstone of the Lower Siwaliks Formation. Generally, the sandstone beds prevail over the siltstone beds, and between them shale and calcareous rock beds are sandwiched. The sandstone is classified into two kinds; the one is medium to fine grained sandstone with grey or dark grey colours,

---

/1 For all geological description given hereinafter, the general geological map of Fig. 5.1 attached to this appendix and Fig. 1.1 to Fig. 1.12 of Appendix 1 are always referred to. Sketch maps for some damsites are attached, but no intension is made to duplicate detailed geological maps available elsewhere in the published project reports.

/2 Numerals refer to corresponding project sites in Fig. 10 of the text.

and the other is medium to coarse grained one containing mica and having a greyish-white colour. The latter occurs in massive beds, some of them being more than 20 m thick. The siltstone is relatively soft and brittle and exists in thin layers. The shale found here is hard but brittle, and it also exists generally in thin layers. The calcareous rock is classified into two types, i.e., the sandy stone and the silty stone. Both are hard. All members of these rocks are well consolidated and partially contain breccia or nodules.

The rock formations show a monoclinic structure with a strike of N $70^{\circ}$ to $90^{\circ}$ W and a dip of $50^{\circ}$ to $70^{\circ}$ NE. The river intersects these layers at an angle of about $85^{\circ}$.

There are no large faults or tectonic lines which would be important for the dam foundation, but the joints in an approximately north-south direction are prominent and it is deduced that the reason the Karnali runs through the Siwalik mountains in a north-south direction must have been the structurally weak lines along these joints. However, these joints do not necessarily impair the adequacy of the foundation for dam construction. Small strike faults which exist at the site could be easily treated and would present no serious problems.

### 2.1.2 Lakarpata Dam Site (2)

The river banks at the proposed dam site of Lakarpata Project rise at a steep slope of $36^{\circ}$ to $45^{\circ}$. Along the river bank, hard and fresh sandstone beds are exposed. The river bed elevation is about EL. 532 m.

The mountain range through which the power tunnel is to pass rises up to EL. 1,100 m to 1,200 m. The rock formation has a general strike of N $30^{\circ}$ - $60^{\circ}$ W, and a dip of $40^{\circ}$ - $70^{\circ}$ NE, and is divided into two geological zones. One is the Piuthan zone (the Cretaceous - Eocene of the Tertiary system) in the north eastern region and the other is the Siwalik zone of the Neogene Tertiary in the south-western region. The boundary of these two zones can not be seen directly due to the overburden, but it is thought to be a great fault which runs in a NW-SE direction.

The Siwalik zone mainly consists of alternate beds of sandstone and siltstone of grey and grey brown colour, and contains some shale layers. The layers are slightly calcareous. The sandstone is classified into a mica sandstone of fine and medium grains. There may be found some soft zones, but as a whole it can be said to be a hard mass of rock. The Piuthan zone consists of four sub-zones. From the Siwalik zone side, they are (1) the limestone zone located in between the Lakarpata-Kalyankana ridge and the Siwalik zone, about 2,000 m wide, (2) a quartzite sandstone zone, about 100 m wide, (3) a shale zone, 200 to 700 m wide and (4) a shale and sandstone zone, about 2,000 m wide.

The limestone near the ridge is hard with grey and bluish grey colours and with stripes. At the foot of the range, however, certain disturbances in the rock are found. This portion is covered with fractured but agglutinated limestone or lime crust and thick overburden. The limestone zone contains two thin sandstone beds, and springs are seen everywhere along their north-eastern edges.

The quartzite-sandstone zone is very hard and contains some quartzite and ferruginous shale.

The shale zone is phyllitic, schistose and brittle. From inspection of the outcrops, a possibility of swelling due to water absorption is anticipated. This zone also contains some hard sandstone.

The shale and sandstone zone is formed with alternating beds and is very hard. The dam site is located in this zone. It will provide a good foundation for the dam after comparatively shallow excavation.

Generally speaking, the geology of the Lakarpata area does not present any serious problems, except for certain difficulties to be expected when the power tunnel is driven through the shale zone and the boundary fault of the Piuthan and Siwalik zones. Such zones or fault areas should be avoided when planning the construction of surge tank and power house.

## 2.2 SAPT GANDAKI RIVER BASIN

### 2.2.1 Dev-Ghat Dam Site (11)

This site is located on the Sapt Gandaki River at about 1 km downstream from the confluence of the Kali Gandaki and the Trisuli Rivers. The site is composed of Lower Siwaliks Formation of sandstone, siltstone, shale, etc. of Plio-Pleistocene Age, in which sandstone predominates. The sandstone is not so hard, and its compressive strength ranges about 100 $kg/cm^2$ - 400 $kg/cm^2$. General strike of the formation is N $60^\circ$ W, and dipping $20^\circ$ - $45^\circ$ NE.

Both banks are not high; especially the left bank is very low, forming a very gentle slope. Fig. 5.2 shows the sketch map of the dam site. The bedrocks crop out at the both banks of the river up to 15 m above the brinks. Weathering of the rocks is estimated to reach 5 m to 10 m deep. The left bank above the rock slope is covered by sand, which is derived from weathering and decomposition of sandstone, siltstone, and shale. There are some thin terraces of sand and gravel (1 m to 3 m) on the upper portion of the left bank slope. The overburden of the right bank is thin, being estimated to be 1 m to 5 m. Thick alluvial deposits of sand and gravel cover the river bed, the depth being estimated to be 15 m to 30 m. There are also large and thick sand and gravel deposit at the confluence of the Kali Gandaki and Trisuli Rivers.

The right bank upstream and downstream of the proposed dam axis is dissected by two small ravines of N $60^0$ W direction. It appears that these ravines are not faults, but formed by erosion along the strike direction of laminated weak shale.

Based on the geological conditions, the height of the dam would better be limited up to 60 m above the river bed. Up to this height, both concrete gravity and embankment dams could be built, but the latter appears to be more safe and economical. The core material can be located at the downstream area of the left bank.

2.2.2 Kali Gandaki No.1 Dam Site (12)

This dam site is located on the Kali Gandaki River at about 4 km upstream from its confluence with Riri Khola, a tributary of the Kali Gandaki River. At the vicinity of the damsite, the Kali Gandaki River runs westward along the northern slope of the Mahabharat Ranges, turns south to cut accross the ranges, then flows eastward along the Mahabharat to form a big loop.

The river at the damsite is very narrow, and forms a high gorge. The river width at the water level is about 60 m, and the both banks rise up practically vertical up to 80 m to 100 m. Above it, the valley opens rather wide, and a terrace deposit exists at the left bank. Fig. 5.3 shows the sketch maps of the damsite.

The geology of the damsite is composed of calcareous schistose sandy rock, some slaty schist, and graphite chlorite talc schist of Pre-Cambrian - Lower Palaeozoic Age. The formation strikes N75$^{o}$ - 60$^{o}$W and dips 20$^{o}$NE$\pm$. The compressive strength of the rocks would range 600 kg/cm$^2$ to 1,300 kg/cm$^2$. There are some cracks, fissures and joints along the schistocity as well as vertical to the schistocity. One minor vertical fault or joint is seen at the right bank near the dam axis, but does not appear to penetrate deeply.

As there are many joints, cracks, and fissures at the damsite, while not open ones, cement or chemical grouting will be required before construction of the dam. If an embankment dam is conceived, core materials can be located at the both banks within 2 km range from the damsite.

The depth of water at the gorge is about 20 m - 25 m in dry season. The sediment deposit of sand and gravel appears to be not so thick, being about 10 m - 15 m.

There is a deep ravine located in the left bank at about 150 m downstream from the proposed dam axis, which appears to be a weak or disturbed zone. Since this might affect the stability of the left abutment, prudent investigation of this area is required in the future.

To avoid the abovementioned concern, an alternative damsite can be located keeping away from this ravine. The alternative site is located about 800 m upstream from the original site. Both banks of the alternative site form high steep slopes, but not as steep as the original one. The right bank is higher than the left bank. The geology of this site is composed of calcareous sandy schist, schistose limestone, some siliceous slaty schist, and graphite chlorite talk schist. The formation strikes N60° - 70°W, and dips 10° - 25°NE. It is noticed that parallel joints having a strike of N75°E and a dip of 45°SE are developed at the brink of the left bank. These parallel joints are not open joints, so that will not cause problems for construction of the dam. The overburden of the site is not so thick, being about 1 m - 5 m. The weathered zone of the rock appears to be about 5 m - 10 m deep.

While the volume of the dam at this alternative site will be larger than the original site, it still appears to be a good site for high dam construction, either for concrete or embankment structures.

### 2.2.3 Kali Gandaki No.2 Site (13)

This site is not inspected on the ground this time. The dam site is located on the Kali Gandaki River downstream from the Kali Gandaki No.1 damsite, and at about 22 km upstream from its confluence with the Trisuli River. The geological conditions appear to be almost similar to those of the Kali Gandaki No.1 site, and suitable for high dam consturction.

### 2.2.4 Buri Gandaki Dam Site (14)

The proposed Buri Gandaki Dam site is located on the Buri Gandaki River at about 2 km upstream from its confluence with the Trisuli River. At the vicinity of this confluence, the new Kathmandu-Pokhara Highway passes by along the left bank of the Trisuli River. The damsite is accessible through a footpath which is branched off from the highway and goes the right bank of the Buri Gandaki River. Crossing of the Trisuli River is made by a ferry boat. This footpath extends deep into the footland of the Himalayas, and its passenger trafic is busy all through the year, indicating an important trading pass to the interior.

The site of Buri Gandaki Dam is composed of older rock formation of calcareous schist, schistose limestone, quartz schist, garnet epidote schist, and semi-schist of slate and siliceous sandstone. Fig. 5.4 shows the sketch map of the damsite. The formation strikes EW direction, and dips vertical. The right bank forms a steep slope, being about $45^{\circ}$ - $65^{\circ}$ of uniform inclination. Most part of the right bank show the outcrop of rocks. The left bank forms a very steep rock cliff ($70^{\circ}$ - $80^{\circ}$) up to about 80 m above the river surface, then turns to be a gentle slope covered with rather thick overburden and talus. Therefore, the both banks are not the same shape. The compressive strength of rocks is estimated to be around 600 $kg/cm^2$ - 1,300 $kg/cm^2$.

While the rocks crop out at the brinks of both banks, the riverbed is covered with sand and gravel deposit, which thickness is estimated to be 10 m - 20 m.

It appears that a high dam up to about 200 m can be built at this site. Excavation of tunnels will not cause any difficulty. However, these have to be confirmed by detailed geological investigation in the future.

2.2.5 Bhomichok Dam Site (15)

This damsite is located on the Trisuli River at about mid-point between its confluences with the Marsyandi River and with the Buri Gandaki River. The new Kathmandu-Pokhara Highway passes along the left bank of the Trisuli River.

The geology of the damsite is composed of midland meta-sediment (or semi-schist) of metamorphic rock of sandstone, slate, quartzite, siliceous mica schist, green schist, graphite chlorite quartz schist, mica gneiss, and granitic gneiss of late Pre-Cambrian Age. The general strike of these rock formations varies from N$70^{\circ}$E to EW, and the dip varies from $40^{\circ}$S to $90^{\circ}$. Both banks are of similar slopes, being about $35^{\circ}$ - $45^{\circ}$. The overburden on the slopes is not thick, being about 1 m - 5 m.

The weathering and decomposed conditions of the bedrock are of similar pattern to that of other damsites in Nepal. Grouting is necessary for consolidating the foundation and sealing cracks and fissures. The deposit of gravel and sand in the river channel is not so thick, and is about 1 m - 5 m. Some outcrops of bedrock are observed at the brinks as well as at the riverbed. The geological conditions of this site are suitable for either concrete gravity dam or embankment dam. Impervious materials for embankment dam can be located on the left bank of the Trisuli River a few kilometers upstream or downstream of the dam site, based on the field reconnaissance.

2.2.6 Marsyandi Dam Site (16)

The proposed dam site is located on the Marsyandi River at about 1.0 km upstream from its confluence with the Trisuli main stream. The new Kathmandu-Pikhara Highway goes along the left bank of the Trisuli River, and crosses it at a little downstream from the Trisuli-Marsyandi confluence, then passes by the right bank of the Marsyandi River. This makes the accessibility of the site exceptionally good as for Nepal.

The dam site is composed of semi-schist of chlorite quartz schist, quartz schist, siliceous schist of Pre-Cambrian-Lower Palaeozoic Age. The general strike of schistocity is N70$^{\circ}$E to EW, and the dip is 0$^{\circ}$ - 50$^{\circ}$N to NE. Generally, these rocks are weathered to a few meters deep and very cracky. Some minor sub faults exist at both banks of the dam site. These disturbances are not dislocated, so that will not cause serious problems in the construction.

The river width of the damsite is about 80 m, and the both banks rise up at gentle slopes of about 30$^{\circ}$. The both banks are covered by comparatively thick top soil and some terraces of gravel and sand. The gravel and sand deposit at the river bed is not so thick, being about 5 m to 10 m.

The proposed site appears to be stable, but rather wide. Narrower alternative sites could be located at upstream of the proposed site. One alternative site is located at about 2.75 km upstream, near an anticlinal axis. The dam axis crosses the anticlinal axis obliquely.

The obliquity was measured to be about 42° at the right bank. A fault line scarp is seen along just southeast of the left bank summit, extending about 1,200 m long. The deposit of gravel and sand at the riverbed appears to be not thick. Another alternative site is located further upstream of about 625 m, where the right bank forms a steep cliff of about 50 m high. The Kathmandu-Pokhara Highway passes by this site by cutting the rock cliff. A fault passes through this alternative site at the direction of EW, dipping 35° - 80°N. The sediment deposit of gravel and sand at the river channel of this alternative site appears to be not so thick either, being about 5 m.

While the proposed site is prefered to the alternative sites at this moment because of its stable appearance, the final decision will have to be made based on the detailed study in the future.

#### 2.2.7 Seti Dam Site (17)

This site is located on the Seti River at about 2.8 km downstream from its confluence with the Madi River. The Pokhara-Kathmandu Highway passes by the site. The geology of the site is composed of old metamorphic rock. The general strike is about EW, dipping to south. This information was attained by a short glance from the travelling car, but detailed observation of the site was not made this time.

### 2.3 SAPT KOSI RIVER BASIN

#### 2.3.1 Sun Kosi High Dam Site (18)

The dam site is located on the Sun Kosi River near the Chiptar village at about 10 km downstream from its confluence with the Dudh Kosi River. The site was called Sun Kosi (B) site previously, and boring and seismic exploration have been carried out. Fig. 5.5 is a sketch map of the damsite. The site is composed of metamorphic rocks of calcareous mica quartz schist, quartz epidote green schist, calciphyre, metamorphosed limestone (slightly banded), hornblende pyroxene schist, garnet bearing calcareous mica schist, quartz vein etc. of the Mahabharat Formation, which belongs to Pre-Cambrian - Lower Palaezoic Age. Among which, calcareous schist (calciphyre) and limestone predominate.

These rocks have many cracks, joints and fissures of parallel, oblique or rectangular to the schistosity owing to weathering and great lateral pressure related to the Himalayan orogenic motion. The strikes of the formation vary, being $N40^{\circ}W$ - EW - $N40^{\circ}E$, and the dips also vary, being $10^{\circ}$ - $65^{\circ}$SW - SE.

The right bank is very steep, having a slope of about $50^{\circ}$ - $60^{\circ}$. Bedrocks crop out at most of the slope, and only small areas are covered by overburden and talus.

The left bank is steep up to about 10 m above the streambed, then turns to be a gentle slope covered by thick talus. A main fault exists in the right bank at about 120 m upstream of the proposed dam axis, striking $N25^{\circ}$ - $30^{\circ}W$ and dipping $70^{\circ}$NE. This fault does not run into the left bank. The fault would have no influence on the construction of the dam.

The sand and gravel deposits in the river channel are very thick, being about 26 m near the center of the channel along the dam axis, and 7 m at the point of 3 m from the right bank.

The compressive strengths of the bed rocks are estimated to be 600 $kg/cm^2$ - 1,200 $kg/cm^2$. Decomposed zone of about 3 m thick, at least, should be excavated. Cement or chemical grouting is necessary to fill up cracks and fissures of the bed rocks.

## 3. RIVERS FROM MAHABHARAT

### 3.1 BAGMATI RIVER BASIN

#### 3.1.1 Bagmati Dam Site (Bagmati river) (19)

The dam site is located on the Bagmati River at about 5 km upstream from the existing East-West Highway bridge crossing the Bagmati River. At this site, the river debouches from the Siwalik Range into the Terai Plain.

The geology of the site is composed of the alternation of sandstone, shale and siltstone of the Lower Siwaliks Formation, which belongs to Plio-Pleistocene Age. General strike of these rocks is EW±, which dips to $20^{\circ}$S±. Some foldings appear at the downstream of the damsite. These rocks are not so hard, having compressive strength of 100 $kg/cm^2$ - 300 $kg/cm^2$. The thickness of gravel and sand deposit in the river channel of the damsite is estimated to be 15 m - 25 m. Considering surface weathering and hardness of the bed rocks, an embankment dam of less than 100 m in height is suited at this site. Access to the site is not difficult. A 5 km long access road branched from the East-West Highway to the damsite can be constructed in either bank of the Bagmati River with ease.

#### 3.1.2 Kulikhani No.1 Project Site (20)

The Kulikhani River flows outside of the south-west fringe of the Kathmandu Basin to the south-east direction and joins the Bagmati River. At the south of the Kulikhani River, the East Rapti River flows westward to join the Sapt Gandaki River. The Kulikhani and East Rapti Rivers are separated by a high ridge of the Mahabharat Ranges. The project is to create a reservoir on the Kulikhani River, and divert its water to the Rapti River for power generation.

The damsite of the Kulikhani No.1 project is located on the Kulikhani River at about 16 km upstream from its confluence with the Bagmati River. Boring and seismic exploration have been carried out on this site. The width of the river bed at the damsite is about 50 m. The right bank rises up with an inclination of 1 on 1.2 to 1 on 1.7, and is extensively covered with talus deposit composed of earth and rock fragments.

The left bank forms a very steep cliff inclining at 1 on 0.3 to 1 on 0.6 up to a height of about 100 m above the river bed, in which bed-rocks are widely cropped out.

The foundation rock of the Kulikhani damsite is composed of sandy semi-schist, biotite schist and slate, strongly bedded with common strike of NW25°-30° and dip of 30°-40°NE. The rock beds cross the river obliquely from the right bank toward the left bank, forming an acute angle of 55° to 60°.

Sandy semi-schist has many open cracks and is weathered in the surfacial zone; rock blocks of 10 to 30 cm in diamter are easily detached due to separation by cracks in some outcrops. Slate and schist are also fairly weathered in the surfacial zone. Some strike faults are developed, and two distinct fissures with copper bearing quartz-chlorite-epidote vein are observed running at the same trend as the strike of bedding. These are of minor scale and would not affect the foundation stability, but likely to provide water paths for leakage through foundation. Intensive foundation treatment will be required for these faults and the surfacial cracky zones.

The spillway in the left bank, as planned, will require excavation of thick talus deposit for 6 to 10 m. Below the talus is expected intensively weathered or cracked rock zone for another 10 m in thickness. The diversion tunnel through the left bank will encounter fresh or slightly weathered rocks in most of its course. Some minor faults exist, but will not cause serious problem.

Impervious materials and rock quarry can be located within 1 km range from the damsite.

A waterway tunnel will be driven through the high ridge of the Mahabharat, and convey the reservoir water to the power plant. The tunnel will be in the slaty rocks and sandstone - slate alternation for the first 500 m reach, which have a low seismic velocity. Heavy support and lining will be required for this portion. The rest of the tunnel route will go through granite and metamorphosed sedimentary facies consisting mostly of sandstone and quartzite. No construction difficulty is anticipated for this portion.

An underground powerplant is envisaged in this project. The plant will be situated among the alternating formations of sandy semi-schist, biotite schist and slate. Sandy semi-schist is moderately hard. Biotite schist and slate are a little softer and friable. General strike shows NW-SE trend but many other trends are also observed; dip is various in inclination and direction. In view of friability and intensive foliation of schistose rocks, swelling and collapse of excavated wall may occur when the rock is saturated by ground water. Some sort of special protection such as rock bolting will be required besides heavy supports and lining. According to the boring results, serious disturbance of rock beds is not found, but a weak fractured zone presumably caused by fault has been detected. Such weak zone could be evaded by shifting the location of the powerplant slightly.

### 3.1.3 Kulikhani No.2 Project Site (21)

The tailwater of the Kulikhani No.1 powerplant will be further carried down to the No.2 powerplant.

The geology of the waterway route is composed of alternation of sandstone and slate, sandstone semi-schist, brecciated limestone deposit, etc., which are metamorphosed slightly and weathered, having cracks and joint fissures. The general strike of the formation is N $50^{o}$W, and the dip is $35^{o}$NE. These rocks are hard and belong to Lower Palaeozoic Age except brecciated limestone, which is cemented terrace deposits of much younger age, presumably be in Pleistocene.

The waterway crosses a fault (which strike is N $85^{o}$E direction) on the way to the powerplant at a point about 2 km to go. The geology of the No.2 plant site is composed mainly of alternation of sandstone and slate of Lower Palaeozoic Age, and have some cracks and joint fissures. The brecciated limestone appears just at the east of the No.2 plant. This rock is not so hard. Heavy structures should be kept off from this formation.

### 3.1.4 Kulikhani No.3 Project Site (22)

The tailwater of the Kulikhani No.2 plant together with the flow of the East Rapti River will be regulated by constructing a dam at Bayal Bause, which is located in the Rapti River about 2.0 km downstream from the No.2 powerplant, and carried further downstream to the No.3 plant.

The dam site is composed mainly of sandstone semi-schist, which strikes NW - ES, and dips $60^{o}$N - vertical. Both banks form steep slopes, and suitable for concrete or rockfill dam. The thickness of river gravel and sand is estimated to be 20 m or less. Boring and seismic exploration have not been made at this site yet.

The waterway tunnel, about 4.0 km in length, will penetrate alternating formations of (1) crystalline limestone, (2) alternation of slate, phyllite, and biotite schist, and (3) sandstone semi-schist of old Age, and (4) the alternation of sandstone and shale of the Lower Siwaliks. The Lower Siwaliks Formation of Pliocene Age appears at about the last 600 m reach of the tunnel route. The old formations have a general strike of N $60^{o}$W, and a dip of $40^{o}$ NE. The Siwaliks Formation strikes N $85^{o}$W, and dips $40^{o}$ N. The boundary of the old formations and the Siwaliks is formed by a thrust plane, which strikes N $70^{o}$W.

The powerplant will be located in the Siwaliks. The compressive strength of the Siwalik sandstone is estimated to be 200 $kg/cm^2$ to 300 $kg/cm^2$.

## 3.2 KAMLA RIVER BASIN

### 3.2.1 Kamla Dam Site (23)

Fig. 5.6 shows the sketch map of the damsite. The geology of this site is composed of Upper and Middle Siwaliks Formations of Plio-Pleistocene Age. The rock is composed of alternation of sandstone, shale (grey, white, and yellowish grey), siltstone, conglomeratic silty mudstone, sandy shale, and some lenticular lignite. The strike varies N$70^{o}$ - $20^{o}$ E, and the dip is $0^{o}$ - $40^{o}$N to ES, indicating existence of anticline. These rocks are soft, very soft in some places, and highly weathered and decomposed. Boring tests have been carried out at this site. The characteristics of this site are the existence of old terraces still remaining in high elevation on both banks. The right bank rises up very steep up to about 70 m above the stream bed, then turns to be flat, which is covered by high (old) terraces. The left bank has very gentle slope and is covered by high and low (new) terraces. The low terraces are very thick, being about 20 to 25 m, but the high terraces are relatively thin, ranging 2 to 10 m depending upon the locality. These high and low terraces are composed of gravel and sand (size of gravel is about 10cm - 30cm, so-called "Dun Gravel").

The thickness of alluvial deposits in the river bed varies from 4 m to 22 m. The surface of bed rocks under the alluvial deposit is very irregular, and deep in the left side of the river channel. It is presumed that, in older time, the right bank of the river had projected and the flow had scoured the left bank deeply. Then, the right bank projection has been eroded out, and the river forms the present configuration. The rocks of the both right and left banks are weathered and decomposed strongly. The compressive strength of the rocks at the dam site is about 50 $kg/cm^2$ - 400 $kg/cm^2$, with an average of 180 $kg/cm^2$. Embankment dam of 50m - 65m in height would be suitable at this site. Embankment materials can be located within 2 km range downstream from the damsite.

## 3.3 KANKAI MAI RIVER BASIN

### 3.3.1 Kankai Dam Site (24)

The damsite is located on the Kankai Mai River at about 5 km upstream from the East-West Highway bridge crossing the river.

The river bed of the damsite is about 60m in width, and is filled with sand and gravel of about 17 - 19m in thickness. Rocky talus is piled on the left bank due to collapse of the bank slope. The slopes of the both banks of the valley are rather steep, being $40^{o}$ on the left bank and $47^{o}$ on the right bank.

The rock formations of the damsite are composed of alternation of sandstone, shale, and siltstone with a strike of N$40^{o}$ - $60^{o}$E and a dip of $40^{o}$ - $50^{o}$NW. These formations belong to Middle or Upper Siwaliks Formation of Plio-Pleistocene Age. They are rather soft and easily weathered, having compressive strength of 100 - 300 $kg/cm^2$ and specific gravity of 2.3 - 2.4. Shale is predominantly exposed on the left bank and its dip is almost parallel to the slope. On the other hand, sandstone prevails on the right bank and dips perpendicular to its slope.

A mojor fault of N40° - 70°E, accompanying breccia and clayey material appears to run through the left abutment about 300m inside. Cement or chemical grouting may be necessary to prevent leakage or capillary phenomena through the fault plane. A spillway will be constructed on the saddle of the right bank. Sandstone of NS-strike and eastward dip prevails all over the area. The spillway would be founded on sufficiently fresh and sound sandstone bedrock after removing superficial weathered and loose rocks. The depth of excavation is estimated at several meters to 10 m.

The headrace tunnel and diversion tunnels will also be located in the right abutment. The inlet and outlet portals should be built after excavating weathered and cracky superficial zone of sandstone formation, but no difficulty of tunnel construction is anticipated.

A rock quarry can be located in a gentle slope of the left bank at about 400 - 800m south of the damsite. The quarry is predominantly composed of sandstone with some intercalation of shale and siltstone, with rather thin overburden of 1 - 2m in thickness. A borrow area of residual soil suitable for impervious materials can be located at the plain area along the border zone between the Siwalik hills and the Terai plain. The hauling distance to the damsite is about 2.0 km - 2.5 km.

### 3.3.2 Mai Khola Loop Damsite (25)

The dam site is located on the Kankai Mai River, at about 3.0 km upstream from its confluence with the Doe Mai River. The Kankai Mai River forms big loop at the downstream of the damsite. The geology of the site is composed of sandstone, siltstone and shale of Lower Siwaliks, but the sandstone predominates. The sandstone is moderately hard, and has compressive strength of about 200 $kg/cm^2$. Its specific gravity is about 2.3 to 2.4.

The boundary between the older rock formation of metamorphic rock and Lower Siwaliks Formation runs through SW - NE direction at about 700 m north of the dam site. These two formations are bordered by thrust, but this has no influence for construction of a dam at this site.

The rock formation strikes EW and dips steeply for 70° - 90°N. The thickness of the overburden over the bed rocks is about 1m - 3m. The thickness of gravel and sand in the river channel is estimated to be 2m - 15m. A low concrete dam of less than 50 m could be constructed, but an embankment structure is more suitable for this site.

### 3.4 BABAI RIVER BASIN

#### 3.4.1 Sarda Dam Site (26)

The dam site is located on the Sarda River at about 16 km upstream from its confluence with the Babai main stream. The foundation area consists of upper tertiary layers of sandstone and shale, with sandstone of predominant. The general strike of the formation is NW-ES, and the dip is 70° NE to 20° NE. The compressive strength of these sandstone and shale, which belong to the Siwaliks Formation, is estimated to be 100 $kg/cm^2$ - 400 $kg/cm^2$. The river deposit at the damsite appears to be not excessively deep, presumably be around 10m - 15m. Embankment materials can be located at nearby areas of the damsite.

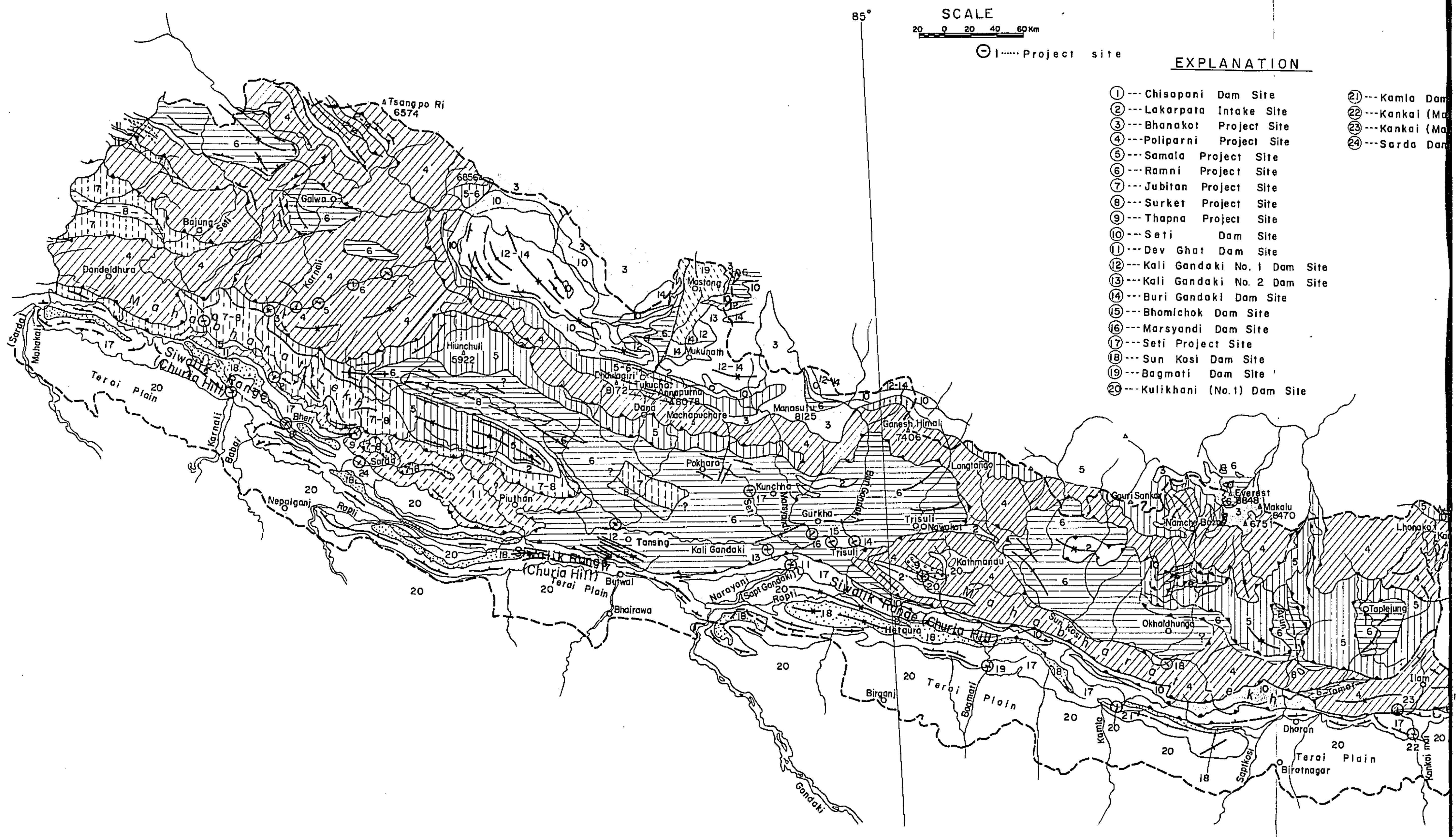
An important geological feature at the site is the tectonic thrust which passes through the right bank of the Sarda river along NW-ES direction, i.e., the river course direction.

The northeast side of this thrust is composed of sandstone, shale, quartzite and greenish rock of older rock formation of Carboniferous - Mesozoic Age, and the southwest side is of the Siwaliks Formation. This thrust plane crosses the Sarda river at about 7 km upstream from damsite, where the river runs up to north. Since the water of the reservoir will back up only to a point about 0.5 km before reaching this thrust, the leakage of water may not be a serious problem. However, the existence of the thrust plane at the right bank of the reservoir might cause land slide or collapse of slopes after the reservoir is filled up. Prudent study on this point is required in the future.

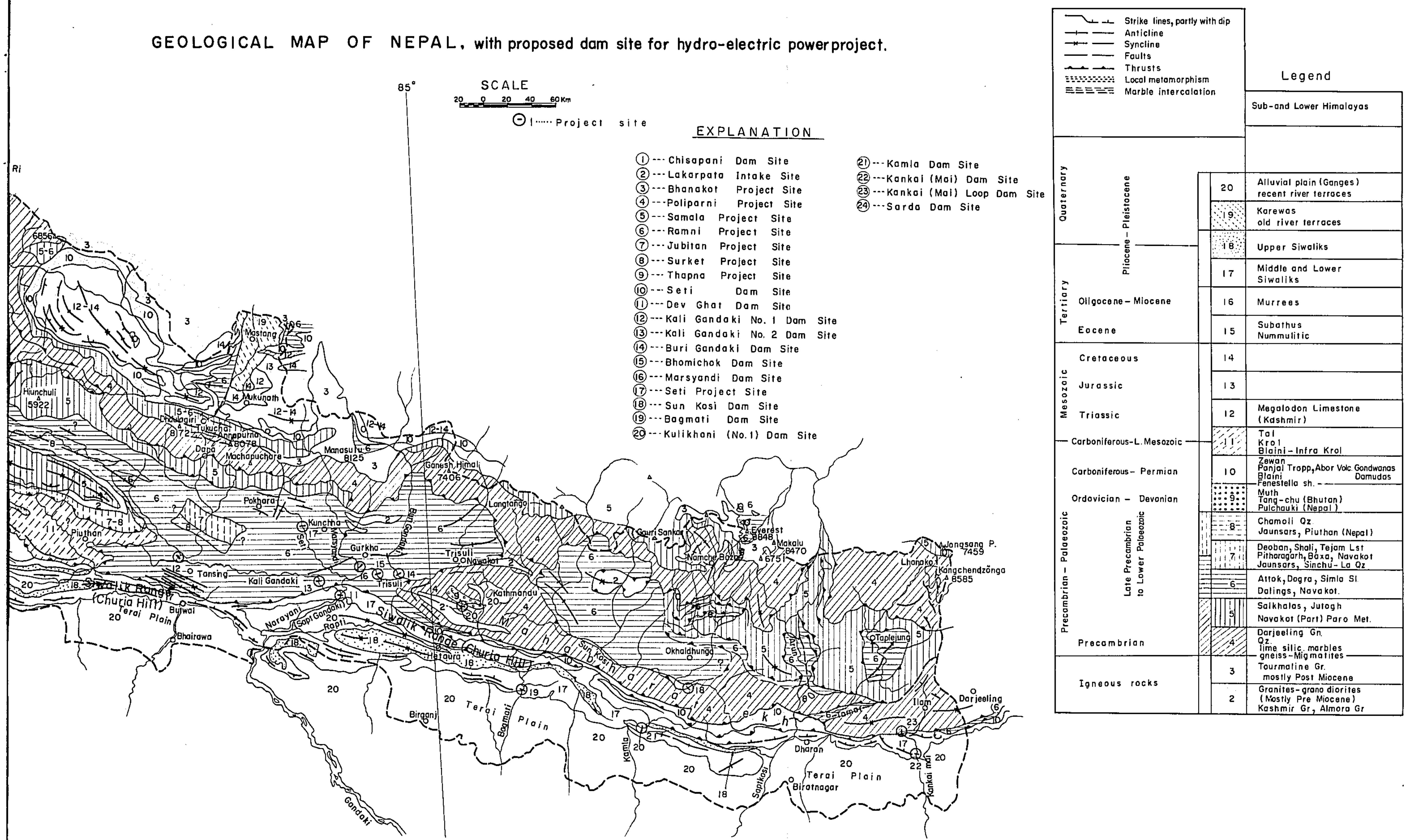
The waterway tunnel will be driven across the left bank ridge of the Lower Siwaliks Formation. The Siwaliks Formation between the tunnel inlet and outlet shows a fold at about N40°E - N57°E direction. A steeply dipped fault probably exists and crosses the tunnel at about 0.8 km from the inlet. The dip of the Siwaliks Formation is to NE in most part of the tunnel route, and turns to be SW near the outlet because of the fold. Therefore, the penstock line would be parallel to the dip direction. Care must be taken to prevent the foundation slippage of the penstock.

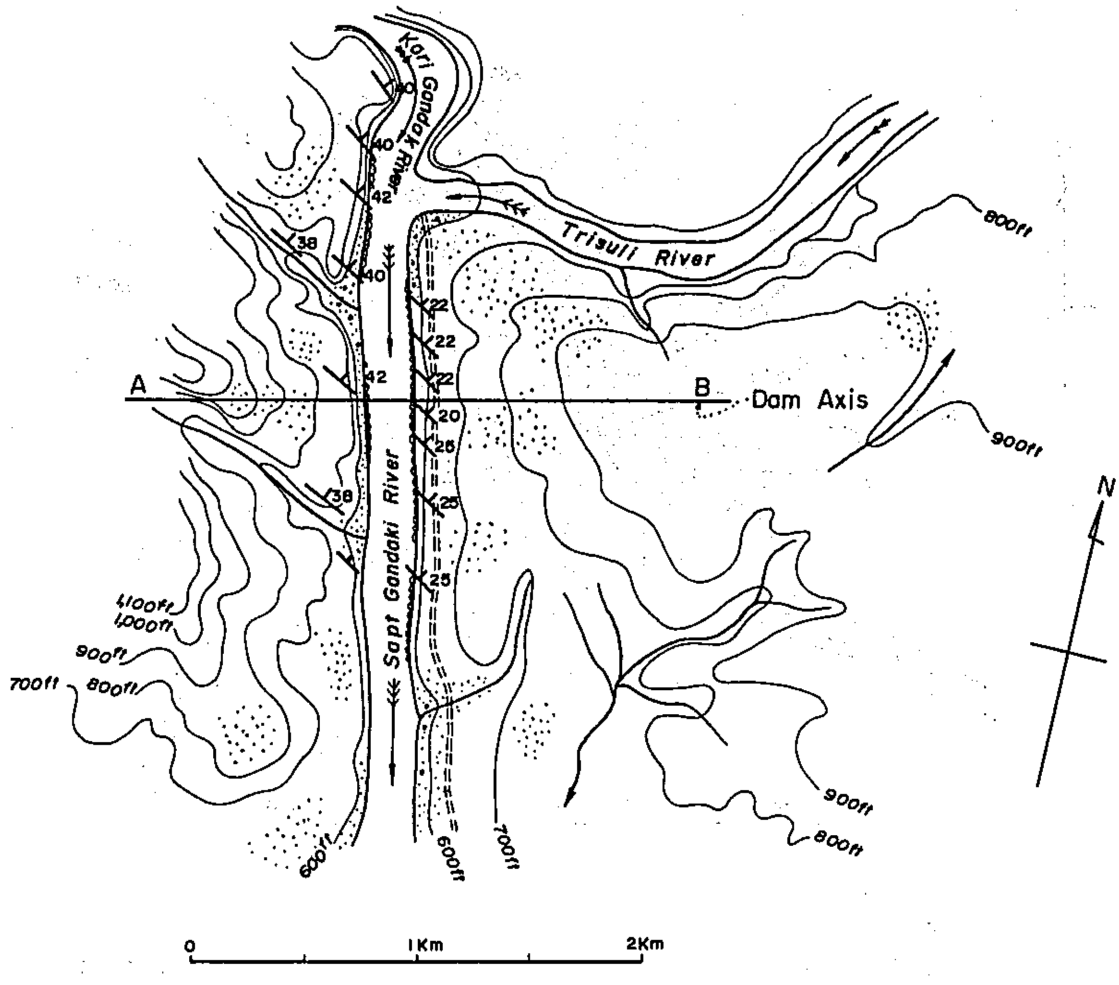
The geology of the powerplant site is composed of sandstone and shale of the Lower Siwaliks Formation. Its dip is about $60^{o}$SW. These lower Siwalik rocks are not so hard, having a compressive strength of about 100 $kg/cm^2$ - 400 $kg/cm^2$, similar to those at the damsite.

# GEOLOGICAL MAP OF NEPAL, with proposed dam site for hydro-electric powerproject.

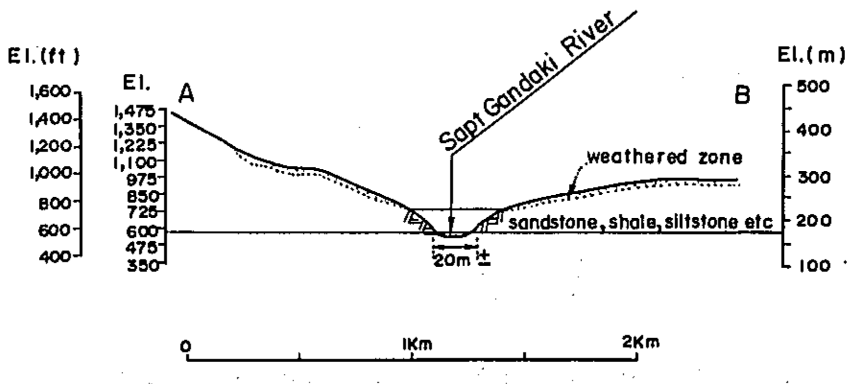


# GEOLOGICAL MAP OF NEPAL, with proposed dam site for hydro-electric powerproject.






PLAN

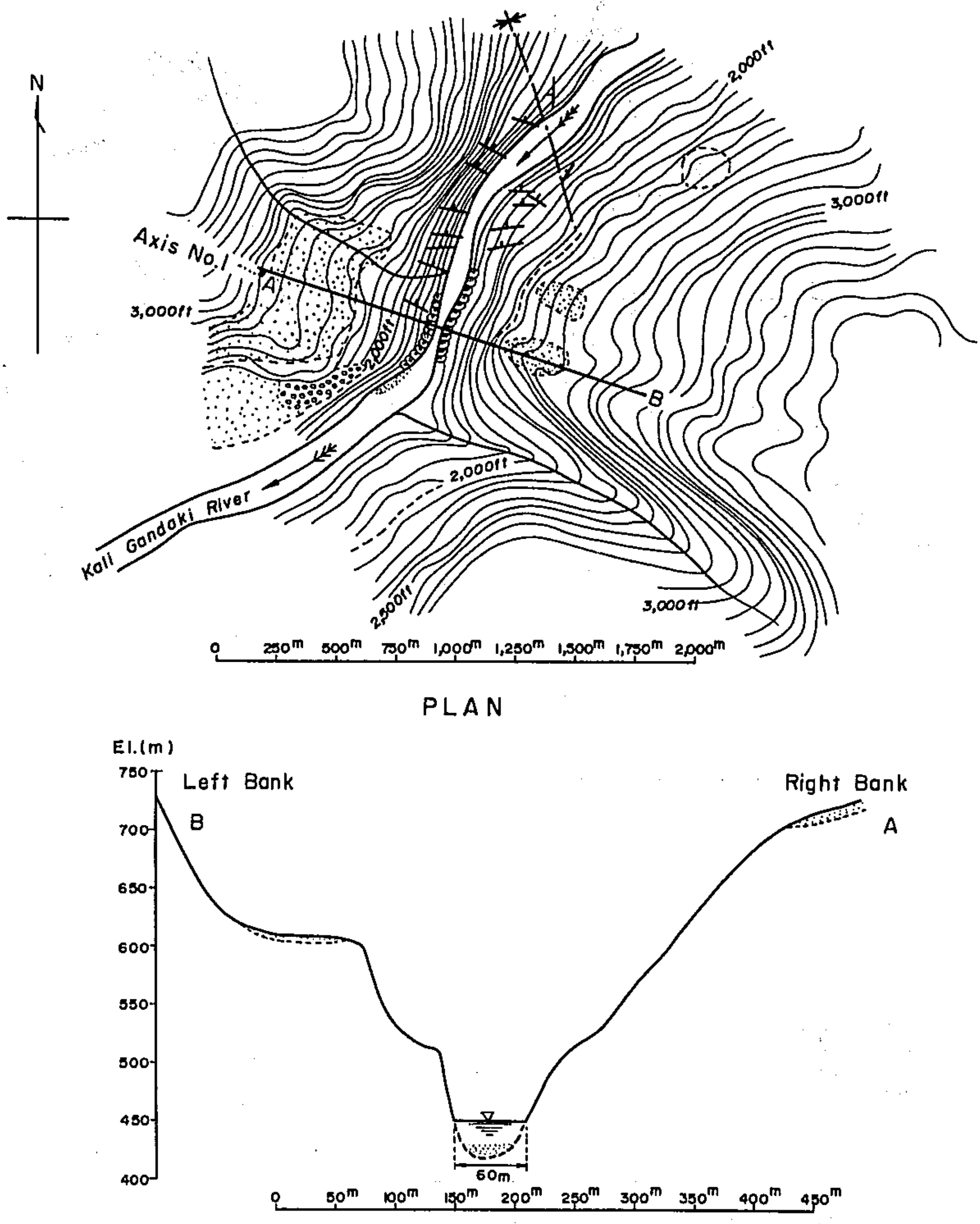



SECTION ALONG DAM AXIS

Legend

- ····River gravel and sand
- ····Terrace deposit and overburden (sand & gravel)···comparatively thin.
- ····Alternation of sandstone, shale and siltstone (Lower Siwaliks Formation)···Pliocene Age.
- or ····Outcrop of sandstone, shale, siltstone. ····Motorable road (not paved)

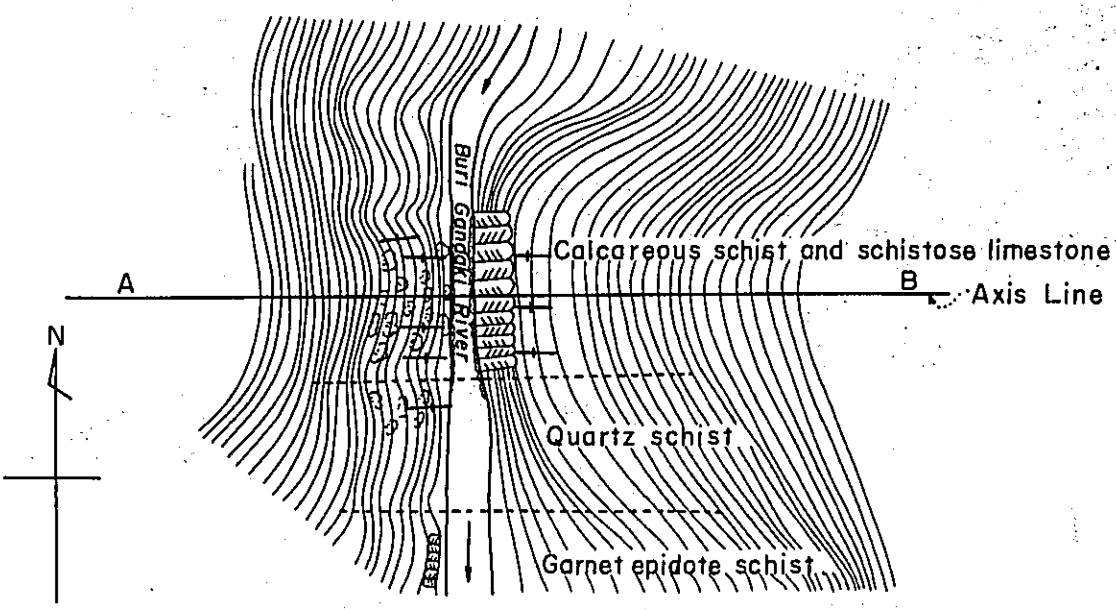
Fig. 5.2 SKETCH MAP OF DEV-GHAT DAM SITE



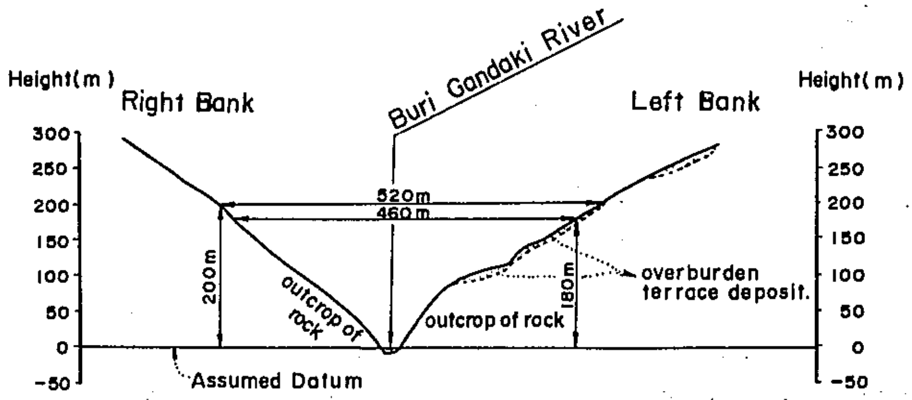

**Legend**

- River terrace & overburden (soil)
- Younger conglomerate and gravel (higher terrace deposits)
- Unconformity
- Old metamorphic rock, semi-schist etc.
- Syncline axis

Fig.5.3 SKETCH MAP OF KALI GANDAKI NO.1 DAM SITE




PLAN scale 1/10,000 (approximate)
contour interval 10m




Geological section along dam axis line (A – B)
scale 1/10,000 (approximate)

# Fig.5.4 SKETCH MAP OF BURI GANDAKI DAM SITE

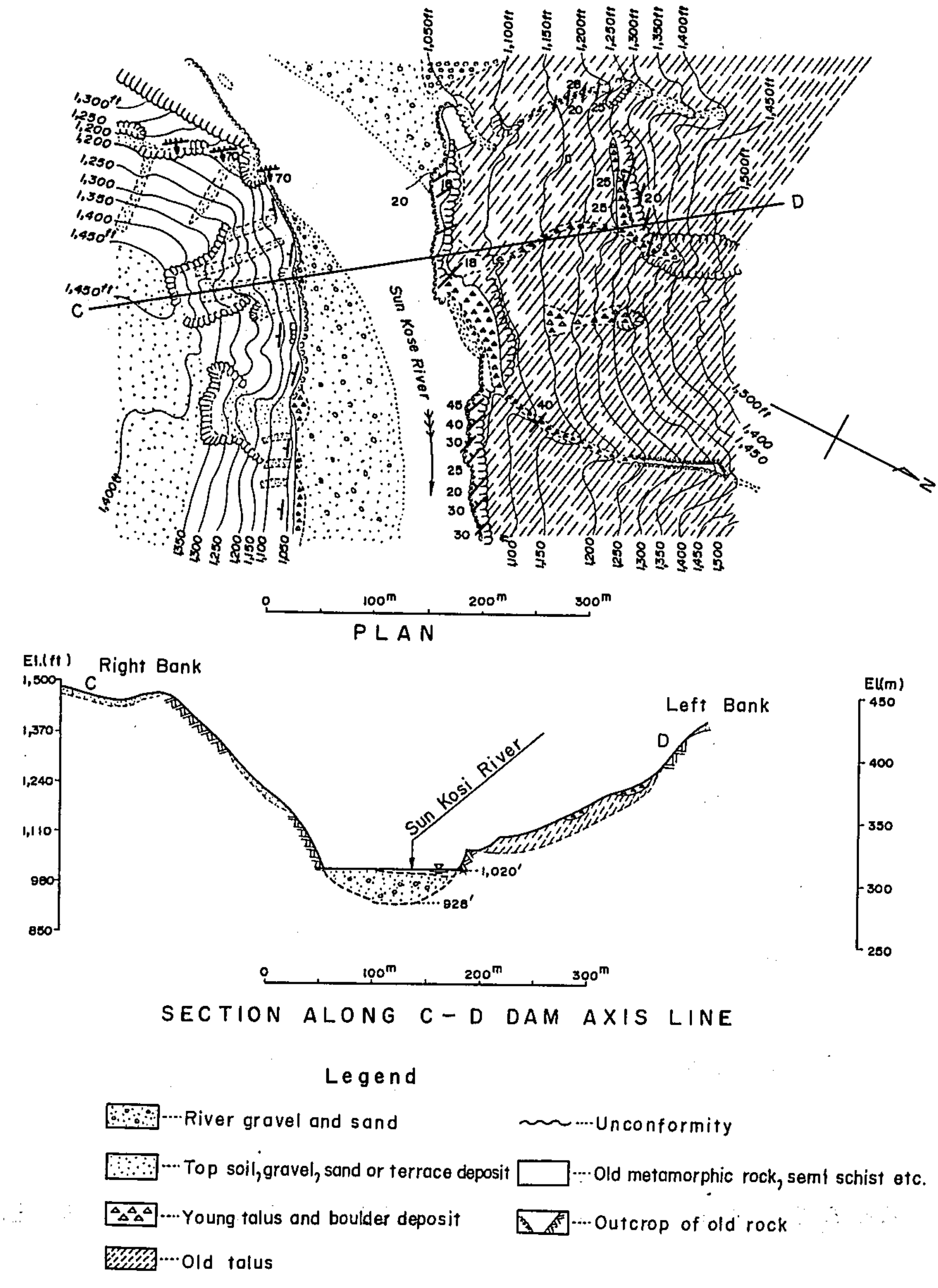
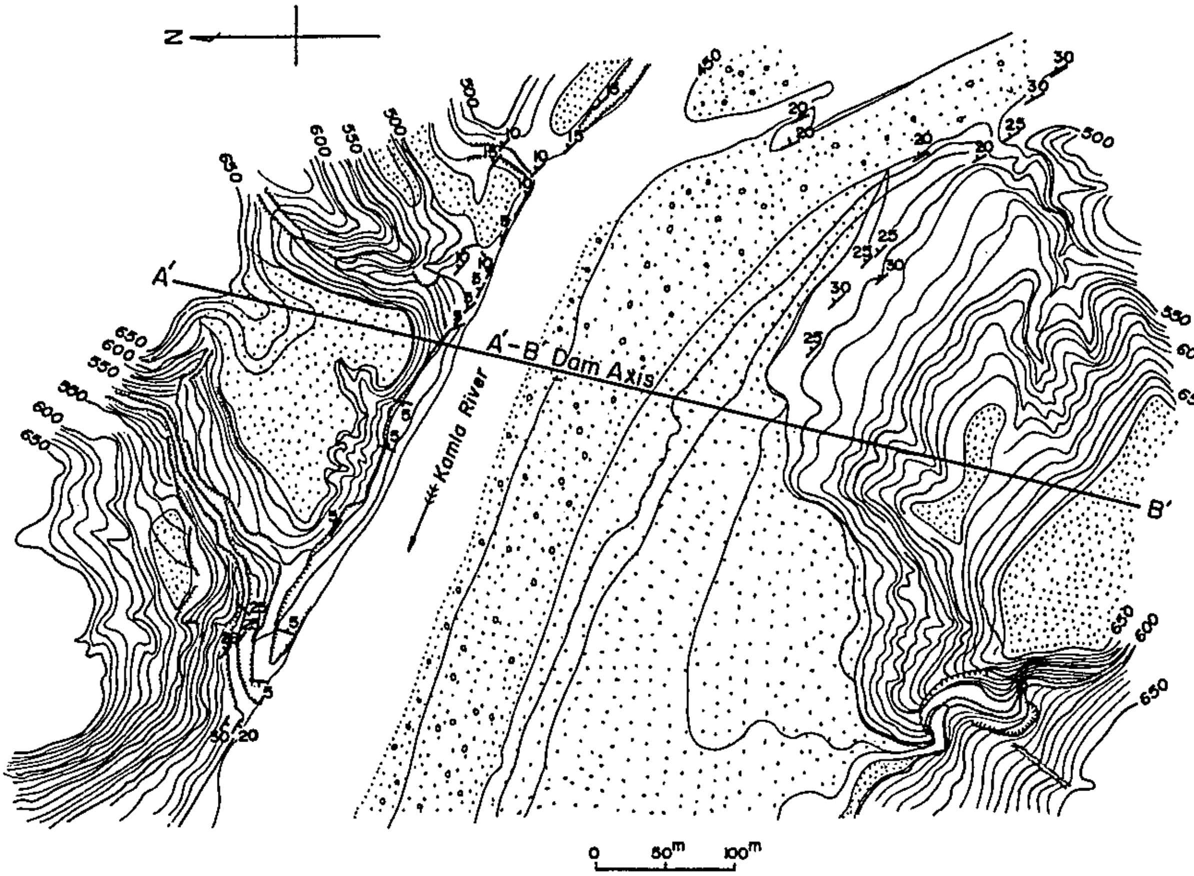
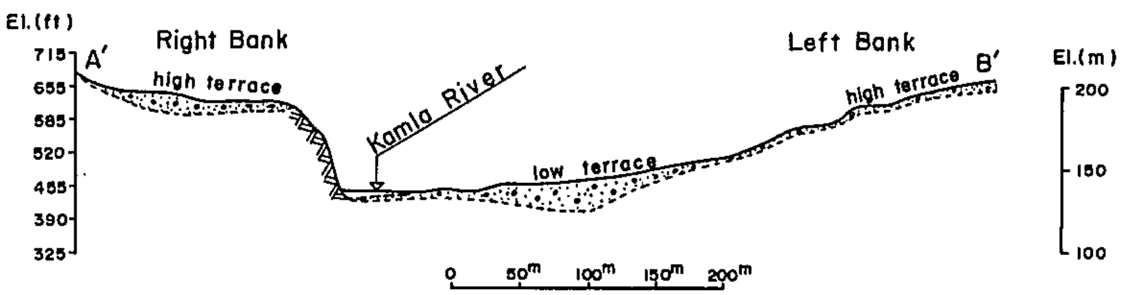



Fig. 5.5 SKETCH MAP OF SUN KOSI DAM SITE




PLAN




SECTION ALONG AXIX (A'- B')

Legend

- ----River gravel and sand, terrace deposit (high···old, low···young)
- ----Overburden, top soil etc.
- ----Upper Siwaliks Formation (alternation of sandstone, shale, siltstone, mudstone conglomeratic muddy stone etc.)---- soft, weathered. (compressive strength 50 kg/cm² ~ 150 kg/cm²)

Fig.5.6 SKETCH MAP OF KAMLA DAM SITE