HIS MAJESTY'S GOVERNMENT OF NEPAL

FEASIBILITY REPORT

ON

KULIKHANI HYDROELECTRIC PROJECT

September, 1974

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

The Government of Japan, in response to the request of His Majesty's Government of Nepal, agreed to undertake a feasibility study on the Kulikhani No.1 Hydroelectric Power Project together with a study on a master plan of hydroelectric power development in Nepal, 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 Japanese Government.

The Agency dispatched a survey team consisting of five (5) experts, headed by Mr. S. Ichiura to Nepal over a period of two months from November 16, 1973 to January 16, 1974, to conduct field surveys for the feasibility study on the aforementioned hydroelectric power project as well as drawing up the master plan.

I sincerely hope that this feasibility report, which is prepared for Kulikhani No.1 Hydroelectric Power Project from both technical and economic points of view, will contribute to the hydroelectric power development in Nepal and at the same time to the further economic interchange between Nepal and Japan.

Finally, I wish to express my appreciation to all the people who participated in executing this feasibility study and also to express my heartfelt gratitude to the concerned authority of His Majesty's Government of Nepal for their close cooperation and assistance extended to the Japanese survey team.

Shinsaku Hogen
President
Japan International Cooperation Agency
Tokyo, Japan

LETTER OF TRANSMITTAL

Date September 1974

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

Dear Mr. Hogen,

We are pleased to submit the feasibility study report on the Kulikhani No.1 power station project which is a first stage development of the Kulikhani overall hydropower project.

The Central Nepal Power System covers Kathmandu Valley, Hitaura - Birganj corridor and their surrounding areas where most of the power demand in Nepal is concentrated. It is anticipated that the system will be short of power supply capacity in and after 1978/79, even with the increase of power generating facilities as presently scheduled. Particularly, the present system is short of both peaking capability and energy supply in the dry season because it depends largely on the run-of-river type power plants. Taking the above facts into account, the timely construction of a hydropower plant with a large reservoir is most desirable to supplement such shortage by seasonally controlled operation.

The basic principle in planning the scale of new project is to make fit the power supply characteristics of the whole system to the system demand in terms of load factor. It was first planned in the early part of the present study that the Kulikhani No.1 power station would have an installed capacity of 46,000 kW and produce the primary energy of 157 x 10^6 kWh annually, as referred to in the report on the master plan of hydroelectric power development in Nepal. This original plan also intended to firm up the potential (or secondary) energy of 44 x 10^6 kWh from the existing run-of-river type hydro plants, which would have to be wasted unless this project is realized. During the progress of the study, however, it was revealed that the existing run-of-river type hydro plants would have about 97 x 10^6 kWh of potential energy, much more than the original estimate. The project was then revised to have a larger capacity of 60,000 kW to make available such larger potential energy. In the revised plan the primary energy of 165 x 10^6 kWh will be produced annually. The initial investment cost of the original plan was estimated at US$45 million at January 1974 price level including 15 % contingency, while the estimated cost for the revised plan is US$53 million at July 1974 price level including 20 % contingency. This indicates that the virtual cost increase is small whereas the increase of power benefit attributable to the project is substantial.

Although more studies and investigations on hydrology and geology are necessary before going into the construction stage of the project, we are convinced that the project is technically sound and economically feasible. It is recommended to go forward soonest possible to the implementation of the Kulikhani No.1 power station project.

It has been our pleasure to work on this interest assignment. We hope that the report be satisfactory to you and all the authorities concerned.

Taking this opportunity, we would like to express our sincere appreciation to your staff for the help extended to us, and the same to the authorities concerned of His Majesty's Government of Nepal for the courtesies and cooperations afforded to our field survey team on every occasion during its stay in Nepal.

Very truly yours,

T. Hashimoto

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

SUMMARY

1. The overall Kulikhani project envisages a series of hydropower development of the Kulikhani river and the Rapti river in the Central region of Nepal. A dam of 107 m in height will be constructed on the Kulikhani river to create a reservoir with net storage capacity of $73 \times 10^6 m^3$, and the water regulated by the reservoir will be diverted to the Rapti river. It is planned to develop the hydropower potential by three successive power stations on the course of the Rapti river, i.e., No.1, No.2 and No.3 power stations, utilizing a total gross head of more than 1,000 m.

The proposed installed capacities of the No.1, No.2 and No.3 power stations are 60,000 kW, 35,000 kW and 17,000 kW respectively, making a total capacity of 112,000 kW. While the annual primary energy output of the No.1, No.2 and No.3 power stations will be 165×10^6 kWh, 123×10^6 kWh and 75×10^6 kWh respectively, making a total of 363×10^6 kWh. /1

The Kulikhani No.1 power station project is the first stage development of the overall Kulikhani project.

2. The Central Nepal Power System (CNPS) covers Kathmandu Valley, Hitaura-Birganj corridor and their surrounding areas where most of the power demand of Nepal is concentrated. Peak load of the system reached 25,000 kW in 1973. The annual peak power demand takes place in the winter season, January or February, corresponding to the early part of the dry season. Total installed capacity of the present system is 39,900 kW, consisting of diesel plants of 8,280 kW and hydro plants of 31,620 kW. All the hydro plants are of the run-of-river type and their peaking capability drops to 26,600 kW every year in the dry season. It will become necessary to operate the diesel plants to cover the deficit in peak power supply in the near future, in spite of large installed capacity of the hydro plants.

/1: The annual primary energy output attributable to the Kulikhani project will amount 460 x 10^6 kWh, including the potential energy of the existing run-of-river type hydro plants to be firmed up in the system by the seasonal regulatory operation of the Kulikhani No.1 power station. The secondary energy output of 88 x 10^6 kWh is also expected annually from the Kulikhani project.

3. The Lumbini zone in the southern part of the Western region is scheduled to be interconnected to CNPS in 1976/77. When the Kulikhani No.1 power station will have materialized, it would serve for such extended CNPS.

4. The power demand in the system is rapidly increasing along with the recent economic growth of the area. The annual growth rate of peak demand has been around 20 % for these several years. A number of small and medium sized industries and hotels are planned to be built in the near future in Kathmandu and Hitaura area. The Chitwan valley irrigation scheme now underway will also be a bulk power consumer which will require 7,000 kW for pumping purpose. Taking these factors into account, the peak power demand in the future is estimated to be 73,000 kW in 1979/80, 121,000 kW in 1984/85 and 179,000 kW in 1989/90.

5. To cope with the rapidly increasing power demand, the Government has decided to take such steps as the construction of the Devighat power station with an installed capacity of 14,000 kW and the supply of power from the Gandak power station up to 7,000 kW, i.e., 21,000 kW in total additional capacity. The possibility to operate the standby unit of 3,000 kW in the existing Trisuli power station should also be explored. Even if these steps are taken as scheduled, the system will be short of power supply capacity in and after 1978/79. Besides, taking into account the fact that the system which depends largely on the run-of-river type power-plants is short of peaking capability, the timely construction of a hydropower plant with a large reservoir is keenly required to increase the peaking capability of the system.

6. Nepal enjoys enormous hydropower potentials, most of which, however, still remain to be developed, while she has no other energy resources to look for. The development of hydropower potentials to meet the future power demand would be most sought, especially in the circumstances of the recent world oil situation. Now, under the circumstances, the Kulikhani No.1 power station presents itself for priority for such reasons as; it locates in the central power demand area, it permits a reservoir construction of reasonable magnitude which is valuable when the existing hydro power plants are all of run-of-river type and

when more plants of the same type are anticipated for the foreseeable future, and last but not the least, the investigation of the project has been advanced and is in the most ready position for earlier implementation.

7. The Kulikhani project site is located in the Central region of Nepal, at about 30 km southwest of Kathmandu. The area is topographically in the stage of early maturity, with ground height ranging from 400 m to 2,500 m. Greater part of the area is situated in a low grade metamorphic rock province consisting of schistose sandstone, mica schist and slate. Thick granite mass is located in the middle part and the Tertiary Siwalik formation at the southern end. The Kulikhani river has a catchment area of 126 km^2 at the proposed damsite. Most of the run-off concentrates in the wet season from July to October. The average annual total run-off at the site is about 123 x 10^6 m^3 or 3.90 m^3/sec in annual mean. By collecting run-off of the tributaries, the Chakhel and the Sim having catchment area of 30 km^2 for the both, the available total run-off increases to 157 x $10^6 m^3$ or 4.98 m^3/sec in annual mean. A dam of 107 m in height will be constructed to create a reservoir with an effective storage capacity of 73 x $10^6 m^3$. The reservoir will be operated to use much more discharge in the dry season than in the wet season so that the power supply capacity of the system will meet the system power demand most effectively, firming up the potential energy of the existing run-of-river type hydro plants. Allowing such a reservoir operation, the annual average available discharge for a primary/1 energy generation will be 3.82 m^3/sec and the annual average available discharge for a primary and secondary/2 energy generation will be 4.93 m^3/sec. The regulated discharge and the water head of about 600 m to be created by water diversion to the Rapti river will be utilized for power generation.

/1: Primary energy is defined as the energy consumable in the system.

/2: Secondary energy is defined as the energy not consumable in the system since the system depends largely on the hydropower plants. Secondary energy may be exportable to India.

8. The Kulikhani No.1 power station will have an installed capacity of 60,000 kW. It will generate a primary energy of 165 x 10^6 kWh and a secondary energy of 46 x 10^6 kWh per annum. It is anticipated that the total installed capacity of the hydropower plant would have amounted to 57,800 kW by the time when the Kulikhani No.1 power station would have been put into operation and also that it would all consist of hydro power plant of run-of-river type. The power and energy production of these plants would be firmed up by seasonal regulatory operation of the Kulikhani No.1 power station, and more firming up should be expected if we intensify such regulation, i.e. release storage to its fullest capacity in the dry season even if it sacrifices the power and energy of the Kulikhani No.1 power station itself in the wet season. The expectable firm up energy of the run-of-river type hydro-power plants attributable to the Kulikhani No.1 power station would be about 97 x 10^6 kWh.

9. The project will consist of constructions such as a rockfill dam of 107 m in height, tributary intake weirs on the Chakhel and the Sim, leading tunnel of 2 km in length from the Chakhel intake weir to the reservoir, vertical shaft from the Sim intake to the pressure tunnel, intake, pressure tunnel of 6 km in length, penstock line of 1.3 km in length, underground power station housing two units of 30,000 kW generating equipment and tailrace tunnel of 1 km in length. The existing 66 kV transmission line between Kathmandu and Hitaura will be utilized to transmit power but the existing substation at Kathmandu will be added by 70 MVA. An access road of 20 km in length will be built from the existing highway to the damsite. The project will be completed in 5.5 years including the detailed design, mobilization and the preparatory works.

It is considered that there arise no ecological problems of significant importance to deter or preclude construction of the proposed Kulikhani dam.

10. The estimated total construction cost of the project is US$ 53 million equivalent excluding interest during construction, comprising approximately US$ 43 million of foreign currency portion and US$ 10 million of domestic currency portion.

11. The economic analysis is made under the annual discount rate of 8 % and the evaluation period of 50 years. For the economic evaluation of the project, the dependable peak power and primary energy are evaluated based on the cost of conceivable most economical alternative means. The alternative considered is a coal-fired thermal plant with a unit capacity of 30,000 kW. The unit capacity value and energy value thus estimated are US$ 73/kW and US mill 20/kWh, respectively. On the other hand, the secondary energy which cannot be consumed in the system because it depends largely on the hydropower plants, is evaluated at the rate of US mill 6/kWh, assuming that the 50 % of the secondary energy may be exportable to India at the rate of US mill 12/kWh. Applying these values to the available power and energy from the project, the annual benefit of the project is assessed at US$7.22 million. The annual project cost is estimated to be US$5.05 million comprising the capital recovery cost and operation, maintenance and replacement cost. The project proves economically feasible with such values as the annual net benefit of US$ 2.17 million, the benefit-cost ratio of 1.43 and the internal rate of return of 12.9 %. Even taking the higher discount rate of 10 %, the benefit-cost ratio is calculated to be 1.21.

12. For the purpose of the financial analysis of the project, a financial power cost is calculated assuming the various loan conditions. A financial power cost is defined as power rate at a primary substation, which makes the total net revenue from energy sale to be exactly the same as the total repayment liability of loan, during the loan repayment period. The annual energy to be sold from the project will be 253×10^6 kWh, a sum of the primary energy of the Kulikhani No.1 power station and the firmed up energy of the run-of-river type hydropower plants in the system (incremental portions only) and an averaged energy loss of 3.5 % deducted. A half of the secondary energy is assumed to be exportable to India at a rate of US mill 12/kWh. The loan repayment period is tentatively assumed at 30 years including 5-year grace period, and the rate of interest is varied from 2 % to 7 %. The financial power cost thus calculated are US mill 12.5/kWh for the interest rate of 2 %, US mill 17.3/kWh for the interest rate of 4.5 %, and US mill 23.5/kWh for the interest rate of 7 %.

13. The Kulikhani No.1 power station will supply power and energy to the area covered by the extended CNPS and will contribute greatly to the economic and social development of Nepal and to the saving of foreign currency for oil import. The Kulikhani No.1 power station project also opens the possibility of favourable power development on the Rapti river in future, such prospective projects as Kulikhani No.2 and No.3 power stations, which utilizes the No.1 power station discharge and Rapti's own run-off and available gross head of about 460 m. The Kulikhani No.2 power station which would be a run-of-river type power station, will generate about 123 x 10^6 kWh of firm energy per annum with an installed capacity of 35,000 kW. The Kulikhani No.3 power station which would be a dam-and-conduit type power station, will generate 75 x 10^6 kWh of annual firm energy with an installed capacity of 17,000 kW. The estimated energy costs of the No.2 and the No.3 power stations are US mill 14.5/kWh and US mill 29.3/kWh respectively, while the estimated energy cost of the No.1 power station being US mill 20.7/kWh at the discount rate of 8 % and the evaluation period of 50 years.

The combined energy cost of the No.1 and No.2 power stations is assesed as US mill 18.0/kWh. If it is allowed to take benefit from water supply for irrigation and industrial use in the downstream Rapti basin, from fish farming in the Kulikhani reservoir, etc., at US$500,000 per annum by a rough estimation, the combined energy cost will be further reduced to around US mill 16.6/kWh.

14. The Central Nepal Power System is expected to be short of power in 1978/79 even if the scheduled addition of the power generating facilities are implemented. In view of the time requirement for project completion of 5.5 years including detailed design, mobilization and construction, it is considered very important to move soonest possible for the implementation of the Kulikhani No.1 power station project.

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

PRINCIPAL FEATURES OF KULIKHANI NO.1 P.S.

(1) Water sources

Basin	Catchment Area (km^2)	Runoff Annual total (m^3)	Runoff Mean (m^3/sec)
Kulikhani	126	122.9×10^6	3.90
Chakhel	23	22.4 "	0.71
Sim	7	11.8 "	0.37
	156	157.1×10^6	4.98

(2) Reservoir & Dam

(i) Reservoir

High water level:	EL. 1,530 m
Low water level:	EL. 1,476 m
Drawdown:	54 m
Surface area:	2.2 km^2
Gross storage capacity:	85,300,000 m^3
Effective storage capacity:	73,300,000 m^3

(ii) Dam

Type:	Rockfill with inclined core
Crest elevation:	EL. 1,534 m
Dam height:	107 m
Crest length:	420 m
Embankment volume:	3,500,000 m^3
Upstream slope:	1 : 2.5 in average
Downstream slope:	1 : 1.7 in average

(iii) Spillway

Type:	Open chute with flip bucket
Gate:	Radial gate, 9 m wide x 11 m high x 2 nos.
Flow capacity:	1,300 m^3/sec at reservoir high water level

(3) Power plant

(i) Intake

Type:	Inclined intake
Gate:	Roller gate, 3 m wide x 5 m high

(ii) Headrace tunnel

Type:	Circular section
Length:	5,830 m
Diameter:	2.5 m

(iii) Surge tank

Type:	Chamber type
Diameter:	2 m in surge shaft
Height:	89.5 m

(iv) Penstock

Diameter:	1.6 m (mean)
Length:	Open portion: 910 m Underground portion: 430 m

(v) Power house

Type:	Underground type (Floor 14 m x 43 m, 26.2 m high)

(vi) Tailrace tunnel

Type:	Horse-shoe section
Length:	1,000 m
Dimension:	2.6 m (height) x 3.3 m (width)

(vii) Generating equipment

Turbine

Type:	Vertical pelton, single runner-4 jets x 2 nos.
Elevation of runner center:	EL. 916 m
Gross head:	614 m to 560 m
Effective head:	549.9 m (rated)
Maximum discharge:	13.1 m^3/sec
Installed capacity:	2 x 30,000 kW
Revolution:	600 rpm

Generator

Type:	3-phase vertical shaft synchronous alternator
Capacity:	2 x 35,000 kVA
Voltage:	11,000 V
Cycle:	50 Hz
Power factor:	0.85

Main transformer

Type:	Oil immersed natural-cooling outdoor
Voltage:	63-66-69 kV/10.5 kV
Capacity:	2 x 35,000 kVA

(4) Transmission line and substation

(i) Transmission line (extension of 200 m long, to connect with the existing line between Kathmandu and Birganj)

Voltage:	66 kV double circuit line
Conductor:	154.3 mm^2

(ii) Existing substation in Kathmandu

Capacity to be added:	2 x 35,000 kVA

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ABBREBIATIONS AND UNITS

HMG of Nepal	His Majesty's Government of Nepal
CNPS	Central Nepal Power System
Electricity Department	Electricity Department of the Ministry of Water and Power, HMG of Nepal
NEC	Nepal Electricity Corporation
BPC	Butwal Power Company
P.S.	Power Station
L.F.	Load Factor
OMR	Operation, Maintenance and Replacement
ADB	Asian Development Bank
EL.	Elevation
mm	Millimeter
cm	Centimeter
m	Meter
km	Kilometer
m^3	Cubic meter
m^3/sec	Cubic meter per second
m^3/hr	Cubic meter per hour
km^2	Square kilometer
ha	Hectare
kg	Kilogram
t (ton)	Metric ton
kℓ	Kilolitre
%	Percent
^{o}C	Degree Centigrade
^{o}	Degree
NNW	North-Northwest
SSE	South-Southeast
rpm	Revolution per minute
HP	Horse Power
W	Watt
kW	Kilowatt
kWh	Kilowatt-hour
MWh	Megawatt-hour

V	Volt
kV	Kilovolt
kVA	Kilovolt-ampare
MVA	Megavolt-ampare
US$	United States Dollar
USmill	United States mill
Rs.	Nepalese Rupee US$ 1.00 = Rs. 10.56
Nepali Paisa	Rs.1= 100 Paisa

CHAPTER 1

INTRODUCTION

The power demand in Nepal is forecast to grow rapidly in the future, the annual growth rate for the past five years being about 20 %. Though His Majesty's Government (HMG) of Nepal has been trying to increase power supply capacity by new installation or having recourse to import from India, short of power in the near future is anticipated. The HMG of Nepal, being aware of the situation has prepared a report entitled as "Master Plan for Power Development and Supply" in 1970. In this report the Kulikhani project was given the place for the first priority.

The history of the Kulikhani project dates back to 1956 when the Swiss-Nepal Forward Team made a proposal on the project. In 1963, the Government of Japan, in response to the request of the HMG of Nepal, despatched a survey team to the project site to conduct field investigation and survey on the Kulikhani project. The team prepared a Preliminary Design Report, with an idea to develop a series of hydropower stations on the Rapti river while constructing a dam on the Kulikhani river and diverting water therefrom. Following the above investigation and survey the Government of Japan despatched experts to Nepal to further the feasibility study of the project and at the same time to provide technical aid to the staff of the Electricity Department of Nepal from 1965 through 1967. The experts reviewed the Preliminary Design Report reflecting additional data on hydrology and geology.

Thereafter, the HMG of Nepal requested the Government of Japan to carry out master planning for the hydropower development and a feasibility study on the Kulikhani No.1 project as a first stage development of the overall Kulikhani project, in 1973. The Government of Japan delegated the execution of this undertaking to the Overseas Technical Cooperation Agency of Japan. The Agency awarded the contract for the implementation of this work to Nippon Koei Co., Ltd.

A field work was conducted from December 1973 to January 1974 mainly for the following subjects.

(1) Data collection on meteorology, hydrology, topography, geology and power demand.

(2) Reconnaissance survey on the sites of dam, waterway, power station and other structures.

(3) Geological investigations by test drillings related to the seismic exploration carried out in 1973 and site inspection.

Following the field work, a home work was carried out in Japan for the following subjects.

(1) Review of the "Master Plan for Power Development and Supply" prepared in 1970 by the Government of Nepal, and preparation of a report on a master plan for hydroelectric development in Nepal.

(2) Analysis of hydrological and geological data, and power demand surveys.

(3) Study on the overall development plan of the Kulikhani Project.

(4) Feasibility study on the Kulikhani No.1 power station project, and preparation of a feasibility study report.

This report deals with a feasibility study on the Kulikhani No.1 power station project. A report on a master plan for hydroelectric development in Nepal is presented in a separate volume.

CHAPTER 2

GENERAL DESCRIPTION OF NEPAL

2.1 Land and Population of Nepal

LAND

The Kingdom of Nepal is bounded on the north by the Tibet region of China and on the south by India. The country extends between latitudes $26^{\circ}30'$ and $30^{\circ}15'$ north and longitudes 80° and $88^{\circ}15'$ east, measures about 800 km from east to west and 240 - 150 km from north to south and is 140,798 km^2 in area.

PHYSIOGRAPHY

The land of Nepal comprises six well defined regions from south to north as follows:

(1) The Terai belt
(2) The Siwalik hills
(3) The Mahabharat mountain range
(4) The Midlands
(5) The Himalaya mountain range
(6) The Tibetan plateau

The Terai belt is the Nepalese portion of the Gangetic plain and lies between the Indian boundary and the foot of Siwalik hills. It has a mean altitude of 200 m above sea level and a maximum width of 45 km. The southern part of the Terai is densely populated, partly with people of Indian stock. The northern part of Terai is covered with thick forest.

The Siwalik hills rise from the Gangetic plain to altitudes of 1,500 m. The border between the plain and the mountain is sharply defined. The main feature of the Siwaliks is their rough relief and due to this as well as to the thick jungle and poor soil consisting of soft, clear sandstone rich in mica and quartz and large-grained conglomerates, the area is only thinly populated. The area is extremely poor in surface water.

The Mahabharat range rises to 3,000 m. Geologically speaking, it is the front of the big overthrusted nappes, the breakers against the Siwaliks. In general, the Mahabharat range forms a large syncline which covers nearly the whole length of the country (800 km). The Mahabharat range is very rugged and has steep slopes. The great Himalayan rivers cross the Mahabharat range in only four gorges along its entire length of 800 km, through which flow the rivers Karnali, Bheri, Narayani and Sapt Kosi. The population density is rather low in this area. Only in areas where the main range does not exceed an altitude of 1,500 m are there large villages and towns.

The Midlands of Nepal cover a belt 65 to 100 km wide, between the Mahabharat range and the Himalayas. The Midland zone is a terrain with very gentle slopes lying at altitudes ranging from only 600 to 2,000 m. The bulk of the country's population is concentrated in the Midlands. This area is very fertile, and all kinds of fruits, vegetables and grain that grow in subtropical and moderate climates thrive here.

In eastern Nepal the main range of the Himalayas forms the boundary with Tibet. In the western half, Nepalese territory extends far beyond the main range of the Himalayas into the Tibetan plateau. The main range itself is divided by the big transversal rivers into different groups. By way of contrast to most of the other mountains of the world, the main range of the Himalayas is not a main watershed; this lies farther to the north, on a mountain range of only 7,000 m. The watershed separates the drainage patterns of the Tsangpo (Brahmaputra) and Ganges. The main tributaries of the Ganges have their origin at the watershed and cross through the Himalayas south-wards in tremendous gorges.

The Nepalese territory north of the Himalayas has a wholly Tibetan aspect. It consists of a mountain desert between 3,000 and 5,000 m in altitude. Here the monsoon is not important. In winter, the precipitation - usually in the form of snow, is more significant. These most northern Nepalese valleys are populated. There are even pretty towns like Mustang. With irrigation, barley and other grains are grown, besides potatoes. Many of the Tibetans living there trade extensively with Tibet and India.

CLIMATE

The country is under the general influence of the sub-continental climatic pattern and has two distinct seasons, i.e. the summer monsoon season which lasts from June to September and the dry winter season. Also, the climate of Nepal is affected by the physical features of the land as abovementioned.

The southern part of Nepal has a sub-tropical climate, with maximum temperatures rising over 40°C in summer (April and May) and minimum temperatures falling to around 4°C in winter (January). The annual precipitation in this part is about 2,200 to 2,500 mm. The Mahabharat range and the Midlands experience 6° to 7°C lower temperatures than the Terai and Siwaliks. The annual precipitation over the Mahabharat range varies from about 2,500 mm in the east to 1,000 to 1,500 mm in the west. The Himalayas and the Tibetan plateau have a climate peculiar to the high mountains, with the maximum temperatures only up to around 21°C and the minimum temperatures falling below freezing point. The annual precipitation is below 1,000 mm.

POPULATION and LANGUAGE

The country is inhabited by 12 million people (1973), comprising various races and tribes deriving their origins from the Tibeto-Burmese group, the pure Tibetan group and the Indo-Aryan group. While the respective sub-groups of the people have their own languages and dialects, the Nepalese (Gurkhali) is the national language and understood among most of the people. The population is growing at a rate of about 2 % per annum.

RELIGION and CULTURE

Hinduism is most prevalent, and next comes Buddhism. There are also a few Moslems. From ancient times both Hinduism and Buddhism have co-existed and have exerted a great influence in unique ways on the cultures of the past as well as the present.

2.2 General Economy of Nepal

The economy of Nepal is essentially agricultural, with 90 % of population engaged in agriculture and agro-based industries. The GNP per capita is estimated to be about US$90 equivalent in 1973. About two thirds of GNP are derived from agriculture, and agricultural exports account for about 90 % of the total export. The main export products are paddy, maize, oil seeds, jute, tea and dairy products.

Rather poor prospect of mineral resources development and land-locked situation greatly handicap this country for a large scale industrial development. However, this country abounds in water resources, and proper utilization of such water resources would bring about the economic development through energy production as well as the agricultural development. The magnificent scenery to be found everywhere in the country, culminated at the Himalayan sceneries, would also provide a great potentialities of the tourism industry whose development should be a great contribution to the national economy.

In 1973, His Majesty's Government of Nepal has established four Development Regions from the viewpoint of balanced economic growth and proper attention to regional planning. They are called Surkhet (Far Western), Pokhara (Western), Kathmandu (Central), and Dhankuta (Eastern) Development Regions, as shown in Fig. 2-1. These Regions are responsible for the development of their respective area under the guidance of National Planning Commission.

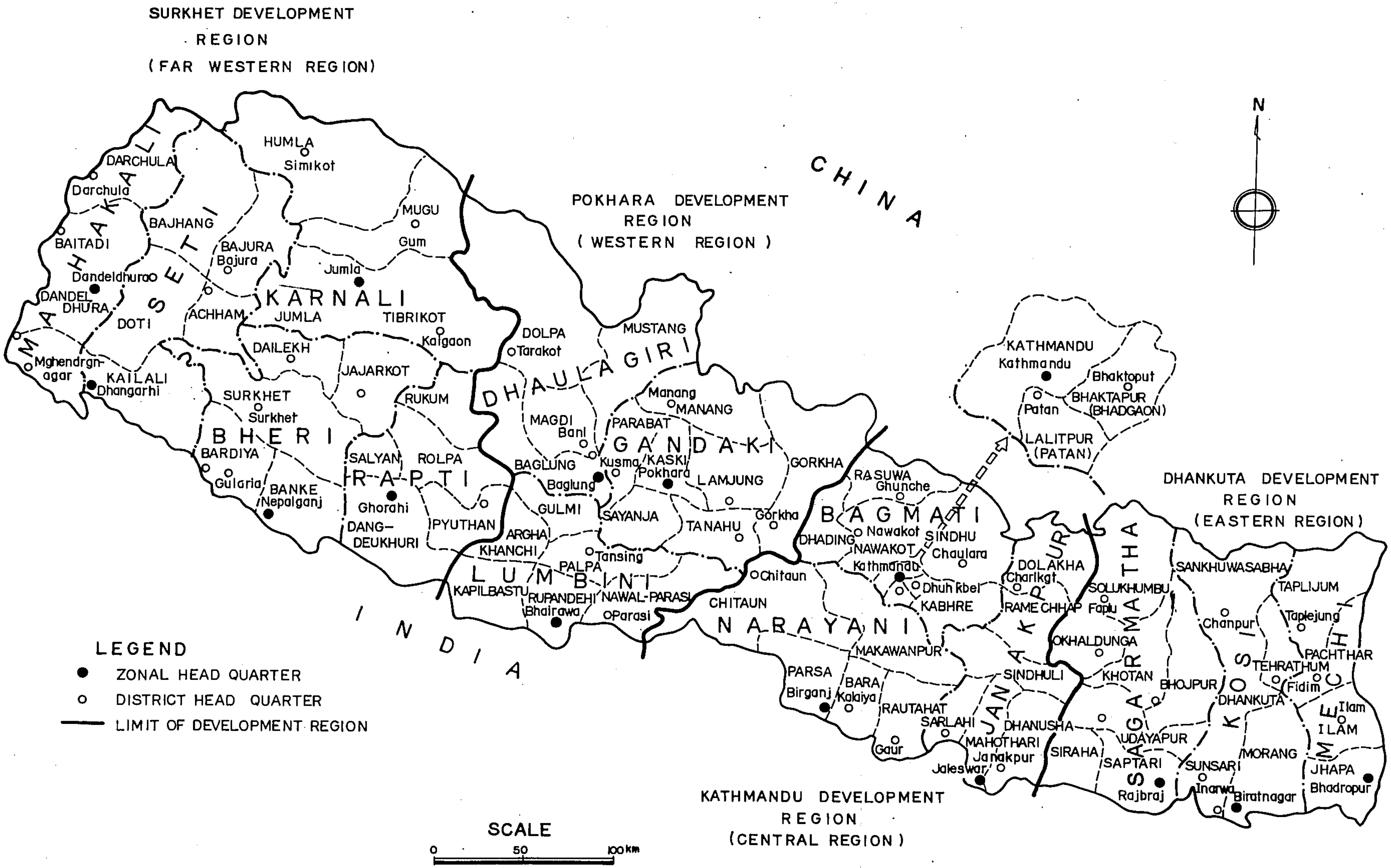
The communication system in Nepal was in a meager condition before early 1960's. But at present the total length of motorable roads reaches about 3,000 km, 40 % of which are sealed. A noteworthy construction is a highway from Kathmandu to Tibet, a highway from Kathmandu to India via Birganj which is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

Airways are another important mode of domestic transportation in Nepal. Royal Nepal Airlines Corporation operates 15 commercial airports in Nepal serviced with DC-3 class planes. In hill areas, many small airstrips accept small planes and helicopters. The Kathmandu airport is the only international airport in Nepal. Extension works of five airports including Kathmandu are under way with a financial aid from the Asian Development Bank.

Almost all major towns are linked with a wireless network operated by the Government. The Government is planned to introduce a microwave network covering the whole country.

The financial state of Nepal is sound as indicated by steady increase of foreign exchange holdings which amounted to US$143 million equivalent in July 1973. The balance of international trade has shown surplus since 1965. In recent years US$8 to 10 million equivalent surplus is added annually to the holdings. However the worldwide inflation triggered by the oil shock would affect adversely on the economy of Nepal accompanying a general price rise of the imported commodities. Since Nepal enjoys enormous water recources for power generation, development of hydropower potentials will play a vital role for the improvement of the national financial state and as a result for the economic and social development of the country, by minimizing the consumption of fuels to be imported for thermal power generation and other domestic and industrial uses, and further by exporting power to India concerning which the basic agreement has already been concluded between both Nepal and Indian Governments.

FIG. 2-1 GENERAL MAP OF NEPAL



CHAPTER 3

TOPOGRAPHY AND GEOLOGY

The project area is situated on and around the Mahabarat ranges distant about 25 to 40 km southwest of Kathmandu. It covers two basins of the different river systems, i.e. the Kulikhani basin which is one of tributaries of the Bagmati river and the upper Rapti river basin neighbouring to south of the Kulikhani across a mountain ridge. The basin height ranges from EL. 400 m in Hitaura on the lower side to EL. 2,500 m at Daman on the higher side. The area shows general topographic features trending west-northwest to east-southeast related with the direction of geological bedding and major fault lines, and northeast to southwest affected by secondary geological dislocation planes and joints.

The Kulikhani river originates about 5 km west of Palung. Gathering tributaries, the river flows about 10 km eastward to Tasar, then turning southeastward and then to south flows meandering toward Kitini, about 7 km south-southeast of Tasar. In the last 9 km of distance between Kitini and the confluence with the Bagmati river, the river takes generally east-southeast direction meandering widely.

The proposed Kulikhani damsite and reservoir area is located in the section between Tasar and Kitini. Open valleys are developed above Okhargaon and around tributaries near Tistung. Below Okhargaon, the slope of the river bed increases showing 1/60 to 1/40 of inclination; in particular the section of about 2 km between the confluence of Sim Khola and Kitini shows steepest slope of 1/25 forming torrents and rapids. In such steep slope sections, the valley is generally narrow and deep due to the downward erosion. Exceptionally, the slope of about 1.5 km long section near Tasar is mild as 1/100 - 1/120 and there the valley is wide open.

Large scale collapses of the slopes are frequently observed on the downstream reaches from the damsite. In the upstream area, however, the slopes are rather stable though collapses or slip-downs of slopes are not necessarily disappeared. The fact should affect favourably in regard to the sedimentation in the reservoir.

The Rapti river, originating on the western slope of the ridge about 4 km east of Bhimphedi, forms an open valley in the section down to Bhainsedobhan where the river flows west-southwestward without remarkable meandering. Downstream from Bhainsedobhan, the river flows southward to the confluence of Kiseri Khola, dissecting deep gorge through slate and siliceous sandstone ridges. To the south of the above confluence, the river flows through the flat of Hitaura surrounded by hills of the Tertiary Siwaliks. Deterioration of slopes is extensive in the upstream-most area near Chisapani, presumably due to faulting and fracturing, and the valleys are filled thick with rock fragments and subangular gravels. Collapses of slopes are also observed along the main stream and tributaries, but they are seen much less frequent and less scale than they are in Chisapani area.

Geological units in this region are, in chronological order, (1) sedimentary facies undergone low grade metamorphism, (2) granitic rock intruding into the said sedimentary facies and (3) sedimentary rocks in the Tertiary Siwalik formation.

Metamorphosed sedimentary facies consists of sandstone and sandy semi-schist, quartzite, slate, phyllite, biotite schist, graphite schist, calcareous schist, crystalline limestone and their alternation. These rocks are generally bluish or greyish dark coloured, except for white quartzite or highly siliceous sandstone, and strongly bedding. Some of quartzite, crystalline limestone and sandstone are fairly hard, whereas others are moderately hard. Sandstone group, including sandy semi-schist and quartzite, is widely developed in the area between Deorali and Bhainsedobhan with sporadic intercalations of slate group and alternations. The Kulikhani area in the northern side of granite ridge is composed of alternating sandstone and slate groups and partial calcareous rocks, each layers of which are not very thick, showing general strike of NNW-SSE. In the southern area from Bhainsedobhan, thick crystalline limestone, quartzite and slate are exposed from north to south in order. Bedding planes show general strike of WNW-ESE or NW-SE and dip of various inclinations toward northeast. The metamorphosed sedimentary facies is terminated by the thrust fault running WNW-ESE along the line of Kiseri Khola located about 3 km north of Hitaura.

Granitic rock mass is mainly composed of biotite-muscovite granite with large crystals of potash feldspar, showing distinct foliation at places. It forms the ridge of Daman, 2,500 m high above sea level, which stretches east-southeast direction to Deorali. In the vicinity of Deorali through which the waterway tunnel from Kulikhani dam is planned, the granite is found on the northern slope of the ridge.

Moderately consolidated sandstone and shale alternation of the Tertiary Lower Siwaliks is encountered in the southern end of the project area, bounded from the metamorphosed sedimentary facies in the northern side by the thrust fault with the WNW-ESE trend located about 3 km north of Hitaura. The alternating beds show strike of E-W or WNW-ESE and dip to north.

Besides the above three geological units, clastic limestone deposit consisting of angular fragments of crystalline limestone of various size up to a few meters in diameter which are cemented with calcareous matrix is found at places along the Rapti river between Bhimphedi and Bhainsedobhan within the height of 300 m from the present river bed. This must conceivably be secondary deposits of limestone formed on the bottom of old valley.

Terrace deposits are found in the valleys of the Kulikhani and the Rapti rivers. Terrace in the largest scale is located in Bhimphedi, where the height of the terrace is more than 30 m and its area over 50 ha. It is composed of poorly sorted sand, gravels and boulders, and forms the ground of whole Bhimphedi town.

Faults show two kinds of trends, i.e., west-northwest to east-southeast and northeast to southwest. The thrust fault bounding the Siwaliks province as mentioned above has the former trend of WNW-ESE; a minor fault in this category is found passing Thansing and the other passing Bhimphedi. A fault of the latter trend of NW-SE runs from Bhimphedi through Chisapani and Deorali toward the Kulikhani valley, which, accompanied with sabordinate dislocation planes, is probably the cause of intensive tendency to slacking of rock in Chisapani area. Two long stretching parallel faults are found running in the direction of NNW-SSE through Darkot and Burlchanr more than 1 km upstream of the Kulikhani damsite, where the Kulikhani valley is dissected in the same direction as the faults. These faults will not result in any mortal difficulties on the technical aspect of the project, so far as some of them are only to be intersected by waterway tunnels at nearly right angle as it is planned at the present.

CHAPTER 4

HYDROLOGY AND METEOROLOGY

4.1 General Climatic Condition

Though no direct observation record in the project area is available, it is assumed that the meteorological condition of the project area should be about the same as observed at Kathmandu, in view of the general topography and the closeness of the both areas.

The average annual rainfall at Kathmandu is about 1,300 mm, of which 80 - 90 % occurs during 5 months in the wet season from May to September.

The average annual mean temperature is 18.3°C at Kathmandu. The temperature reaches the maximum in May, occasionally rises up to about 35°C. The coldest time is the period from December to January, when temperature sometimes falls below freezing point. The temperature at Kathmandu is shown in Appendix II, Fig. A-2-1 included in the end of this report.

The relative humidity varies from about 40 % in April to about 85 % in August respectively.

4.2 Rainfall

No rainfall record is available in the Kulikhani basin. However, the rainfall has been observed in the vicinity of the basin at the places and for the lengths of periods as shown below. The location of these stations are shown in Fig. 4-1.

Station	Observation period
Kathmandu	1942 - 1970
Chisapani	1957 - 1973
Daman	1967 - 1973
Hitaura	1966 - 1973

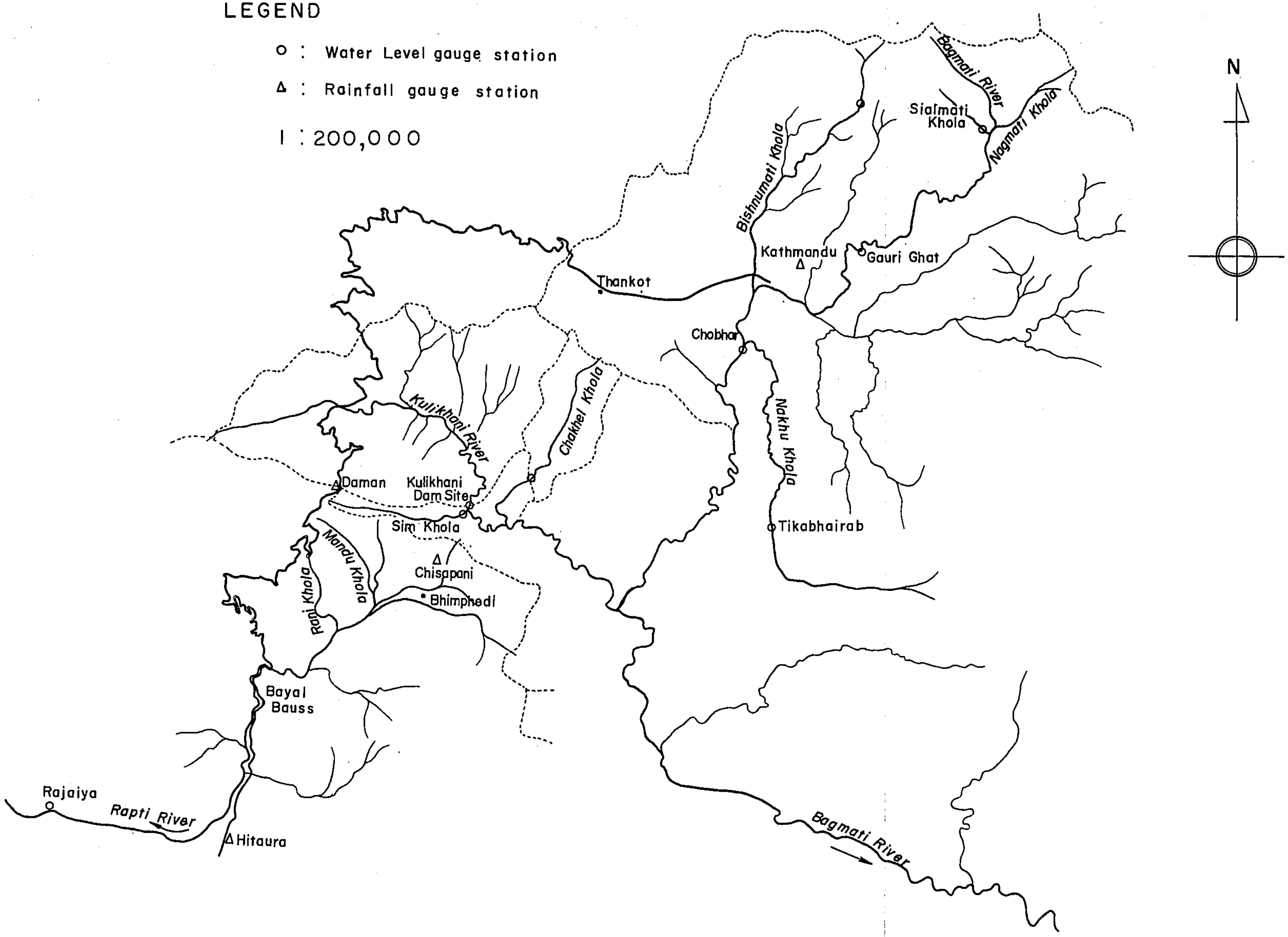


FIG. 4-1 KULIKHANI RIVER BASIN

TABLE 4-1 ANNUAL RAINFALL RECORD

(mm)

Year	Kathmandu	Chisapani	Daman	Hitaura
1943	995.4			
44	1,286.1			
45	1,584.1			
46	1,386.4			
47	1,286.0			
48	1,794.4			
49	1,368.9			
50	1,536.1			
51	1,224.4			
52	1,280.4			
53	1,363.6			
54	1,593.7			
55	1,130.6			
56	1,744.4			
57	1,000.7			
58	1,134.3	1,449.9		
59	1,195.3	1,879.1		
60	1,205.1	1,873.4		
61	1,634.7	2,546.3		
62	1,261.5	2,340.5		
63	1,303.5	-		
64	1,386.8	1,373.3		
65	1,333.2	2,540.0		
66	1,224.8	2,447.0		
67	1,348.6	2,095.9		2,575.2
68	1,519.2	2,196.8	1,251.8	2,279.9
69	1,110.2	1,560.9	1,427.5	-
70	1,426.1	2,514.3	1,259.2	-
71	-	-	1,716.7	-
72	-	2,510.3	2,084.0	1,601.8
Mean	1,344.9	2,102.1	1,547.0	2,152.3

The annual and monthly rainfall records at these stations are given in Table 4-1 and 4-2. The annual rainfall at Kathmandu is also shown graphically in Appendix II, Fig. A-2-2. The table shows that the average annual rainfall during the observation period is 1,345 mm at Kathmandu, 2,102 mm at Chisapani, 1,547 mm at Daman and 2,152 mm at Hitaura. It is also noticed from the table that the fluctuation of annual rainfall from year to year is relatively small. As for the rainfall pattern in the year the records indicate that about 80 % of the rain fall in the months from June to September.

TABLE 4-2 MONTHLY RAINFALL

(mm)

Month	Kathmandu	Chisapani	Daman	Hitaura
Jan	20.4	27.7	17.3	13.8
Feb	18.5	23.9	27.9	25.3
Mar	30.5	38.1	45.9	90.0
Apr	52.3	68.0	94.1	32.5
May	89.3	132.6	129.7	21.6
Jun	216.6	370.6	371.7	308.1
Jul	377.2	584.0	394.8	720.4
Aug	343.8	523.3	260.0	499.3
Sep	143.8	211.0	146.8	302.3
Oct	44.8	80.3	42.1	88.8
Nov	5.8	5.5	17.6	8.1
Dec	1.8	3.2	0.0	0.2
Total	1,344.9	2,102.1	1,547.0	2,152.3

The maximum daily rainfall recorded at each station are respectively 182 mm at Kathmandu, 300 mm at Chisapani 132 mm at Daman and 262 mm at Hitaura.

4.3 Evaporation

There is no evaporation record available in the Kulikhani basin. Table 4-3 shows the monthly evaporation records observed at Chisapani for a period from February 1963 to March 1965. A standard 20 cm pan was used for the observation. The actual reservoir evaporation was taken in this report to be 0.5 of the pan records.

The evaporation reaches to the maximum in April and May, and the minimum in December.

TABLE 4-3 MONTHLY EVAPORATION RECORD AT CHISAPANI

(Unit: mm)

Month	Year			Mean	Reservoir evaporation
	1963	1964	1965		
Jan	-	63.5	89.1	76.3	38.2
Feb	48.4	96.7	121.2	109.0	54.5
Mar	169.1	214.7	203.1	195.6	97.8
Apr	326.5	310.9	-	318.7	159.4
May	392.7	333.2	-	363.0	181.5
Jun	198.6	291.8	-	245.2	122.6
Jul	87.0	82.5	-	84.8	42.4
Aug	48.3	119.6	-	84.0	42.0
Sep	69.3	90.6	-	80.0	40.0
Oct	81.9	124.3	-	103.1	51.6
Nov	68.8	108.6	-	88.7	44.4
Dec	59.0	74.6	-	66.8	33.4

4.4 Runoff

4.4.1 Available runoff records

The runoff of the Kulikhani river has been observed since 1963 at the proposed Kulikhani damsite collecting 10 year's records before 1972. The catchment area at the damsite is measured 126 km^2. There is also a gauging station in the vicinity of the project area at Chobhar on the Bagmati river. The observation records cover the period of 10 years from

1962 to 1971. The runoff record at this station can be used to check the reliability of the runoff observation at Kulikhani damsite.

In addition, the runoff of the tributaries, the Sim and the Chakhel, were also measured from time to time, to check their runoff.

The locations of these gauging stations are shown in Fig. 4-1.

4.4.2 Runoff at Kulikhani damsite

The gauging station at Kulikhani damsite was established in 1962. The daily staff gauge reading and periodical actual flow measurement have been maintained since the beginning of 1963. A current stage-discharge curve at the gauge site is shown in Appendix II, Fig. A-2-3. The monthly mean runoff records wrought from such readings and measurements, for a period from 1963 to 1972, are shown in Table 4-7.

The average monthly runoff in each month during the observation period is as shown in Table 4-4. As seen in Table 4-4, most of the runoff, about 80 % of the annual total runoff flows out in 5 months from June to October and the remaining 20 % flows out during the rest of the year. The average annual runoff at the site during the observation period is about 123 million m^3 or 3.9 m^3/sec in annual mean. The specific runoff at the site is calculated as 3.1 m^3/sec/100 km^2. The runoff duration curve is shown in Appendix II, Fig. A-2-4.

TABLE 4-4 MONTHLY RUNOFF AT KULIKHANI

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Runoff (m^3/sec)	1.31	1.21	1.14	1.17	1.24	4.57	11.90	10.19	6.73	3.65	2.10	1.56	3.90

The reliability of the runoff record at the Kulikhani damsite is roughly checked by the following two methods.

The one is the check by runoff coefficient. Since there is no rainfall record observed in the basin, rainfall data at Kathmandu and Chisapani are used for rough estimation of the basin rainfall. The average annual rainfall at Kathmandu and Chisapani during the observation period of runoff at Kulikhani are 1,330 mm and 2,130 mm respectively. If assuming that the basin rainfall is the mean value of the rainfalls at the two sites in consideration of their relative locations, the basin rainfall would be 1,730 mm. From the value, the average runoff coefficient during the observation period is roughly calculated as follows.

$$\text{Runoff coefficient} = \frac{\text{Average runoff (in mm)}}{\text{Annual basin rainfall}}$$

$$= \frac{3.90 \text{ m}^3/\text{sec} \times 31.5 \times 10^6 \text{ sec} \times 1{,}000 \text{ mm}/(126 \times 10^6 \text{m}^2)}{1{,}730 \text{ mm}}$$

$$= \frac{980}{1{,}730} = 0.56$$

The calculated average runoff coefficient of 0.56 is considered as reasonable in view of mountainous topography of the basin.

Another check is made by comparison of the specific runoff with the same of the neighbouring river in the vicinity. The Chobhar gauging station on the Bagmati river is located only 15 km north-east from the Kulikhani damsite. It has catchment area of 585 km^2 and observation has been kept for 10 years from 1962 to 1971. The monthly runoff at the Kulikhani damsite is compared with that at the Chobhar as shown in Appendix II, Fig. A-2-5, which shows a general correlation between the two runoff data. The specific runoff at Kulikhani damsite of 3.10 m^3/sec/100 km^2 is larger than the same at Chobhar which is 2.34 m^2/sec/100 km^2. The basin rainfall of Chobhar can be represented by the rainfall at Kathmandu which is about 1,300 mm, whereas the basin rainfall of Kulikhani is presumed to be about 1,700 mm as stated above. In view of the difference of basin rainfall in the two basins, larger specific runoff at the Kulikhani damsite to such extent is deemed reasonable.

As the results of above checks, the reliability of runoff records at the Kulikhani damsite is roughly confirmed. Hence the runoff records are used for project planning.

4.4.3 Runoff of Sim and Chakhel

The runoff of the tributaries of the Kulikhani, the Sim and the Chakhel is planned in this project to be added to the Kulikhani's own runoff and used for power generation. (The details of runoff intake from these tributaries and assessment of the available runoff for the power generation are dealt with in Chapter 6.) The runoff of the tributaries have been measured at intervals several ten times during the period from 1966 to 1973 at the proposed intake weir sites. The catchment areas of the Sim and Chakhel at the gauging sites are 7.1 km^2 and 22.8 km^2 respectively.

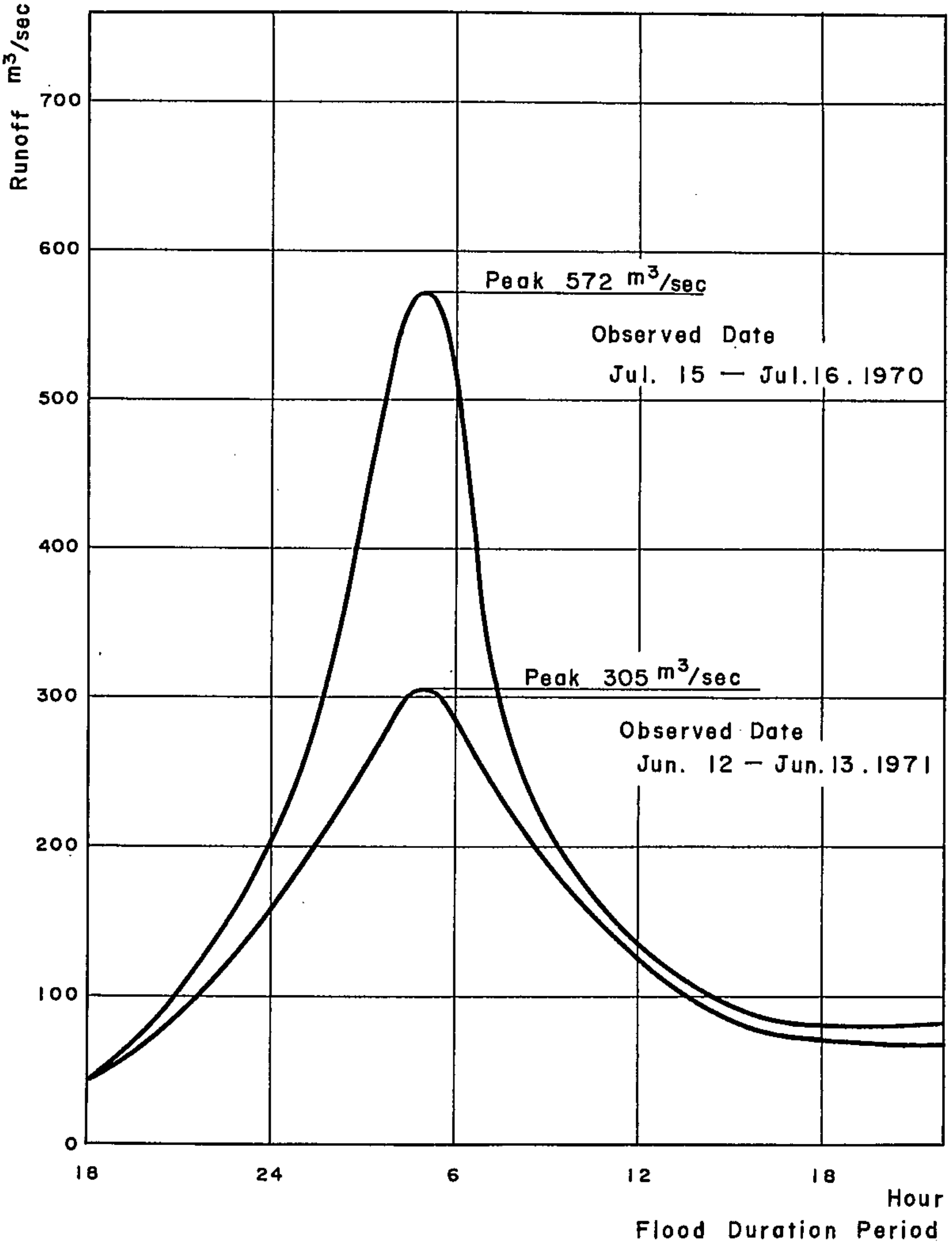
The measured runoff records at these sites were correlated to the corresponding runoff figures at the Kulikhani damsite to find relationships between the former and the latter; refer to Fig. A-2-6 and Fig. A-2-7 in Appendix II. The usability of respective correlation formula was checked by means of comparison of specific annual mean runoff value of the Sim or Chakhel to be obtained by using such correlation formula and the specific annual mean runoff of the Kulikhani itself. It is found that while the specific annual mean runoff of the Sim is reasonably showing characteristics of a basin of much smaller catchment area, the same of the Chakhel was not, i.e. the specific annual mean runoff of the Chakhel is smaller than the same of the Kulikhani river which has much larger catchment area. Therefore, in the case of the Chakhel river a simple ratio of catchment area was used for the runoff conversion from the Kulikhani records instead of using the correlation formula as shown in Fig. A-2-7 as a compromised modification.

The monthly mean runoffs of each month of the Sim and the Chakhel during the period of 10 years from 1963 to 1972 are estimated as shown in Tables 4-8 and 4-9.

4.5 Flood

Several actual flood hydrographs have been recorded at the Kulikhani damsite in the past 10 years. Two largest recorded flood hydrographs are given in Fig. 4-2.

FIG. 4-2 OBSERVED FLOOD HYDROGRAPH AT KULIKHANI DAM SITE



The peak discharges of the annual maximum flood during the period are tabulated in Table 4-5.

TABLE 4-5 PEAK DISCHARGE OF ANNUAL MAXIMUM FLOOD AT KULIKHANI DAMSITE

No.	Date	Peak m^3/sec
1	Sep. 29, 1963	40.0
2	Jul. 15, 1964	148.0
3	Jul. 7, 1965	304.0
4	Aug. 24, 1966	202.0
5	Jul. 10, 1967	277.0
6	Oct. 4, 1968	141.0
7	Aug. 21, 1969	32.6
8	Jul. 16, 1970	572.0
9	Jun. 13, 1971	305.0
10	Jul. 24, 1972	251.0

For estimating probable floods at the site, these flood data are treated statistically by the application of the Gumbel's and Iwai's methods.

The results are given in Table 4-6 and Fig. 4-3.

TABLE 4-6 PROBABLE FLOOD AT KULIKHANI

Recurrence interval (yrs)	Flood peak (m^3/sec)	
	By Gumbel's	By Iwai's
5	395	333
10	521	475
20	643	634
50	800	874
100	917	1,080
200	1,034	1,311
1,000	1,306	1,947

FIG. 4-3 PROBABLE FLOOD AT KULIKHANI

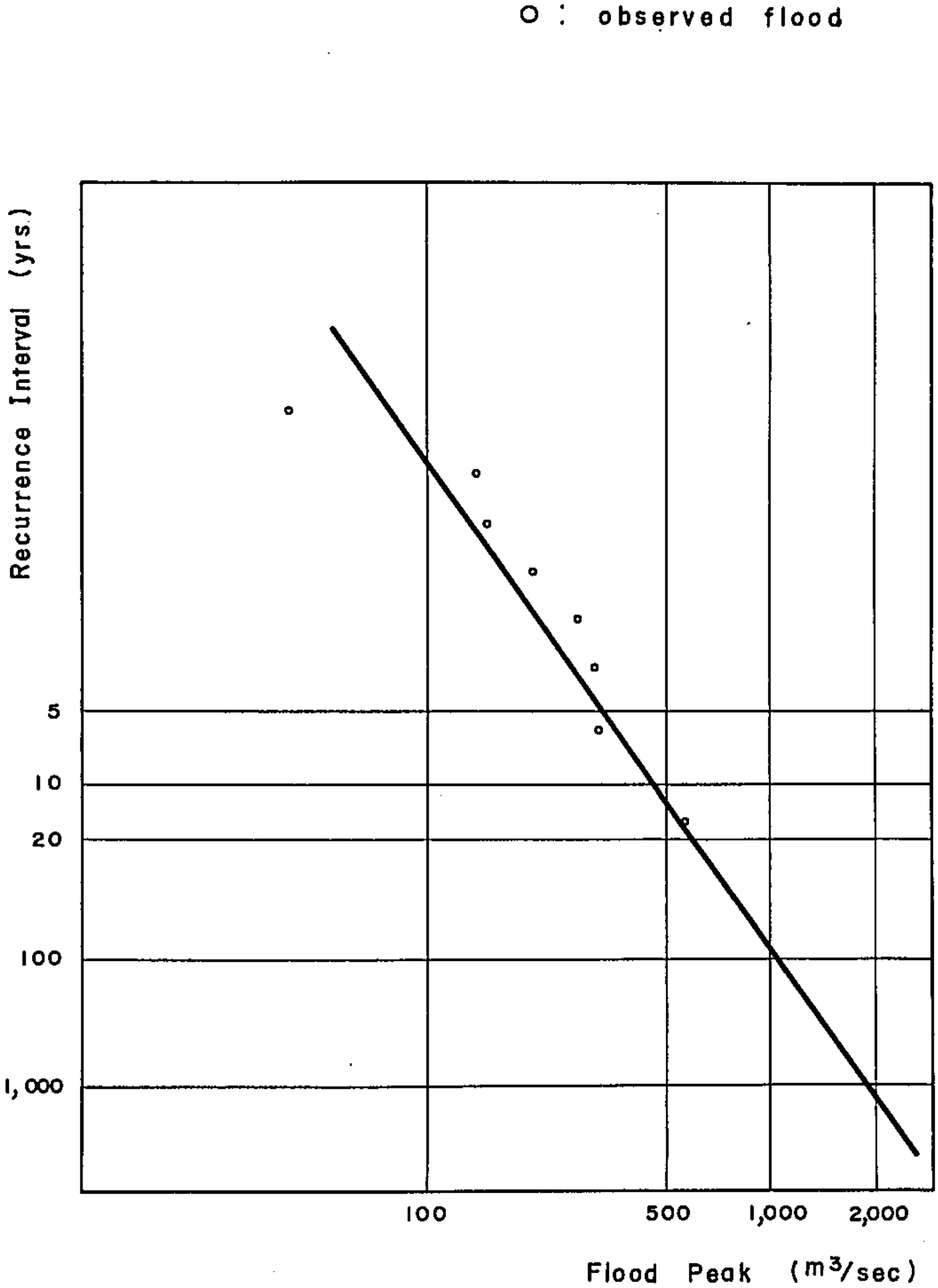


Table 4-6 shows that the peak discharges calculated by the Iwai's method is larger than those by the Gumbel's method. For the conservative sake, the former values are taken as the peak discharges of probable floods for this project.

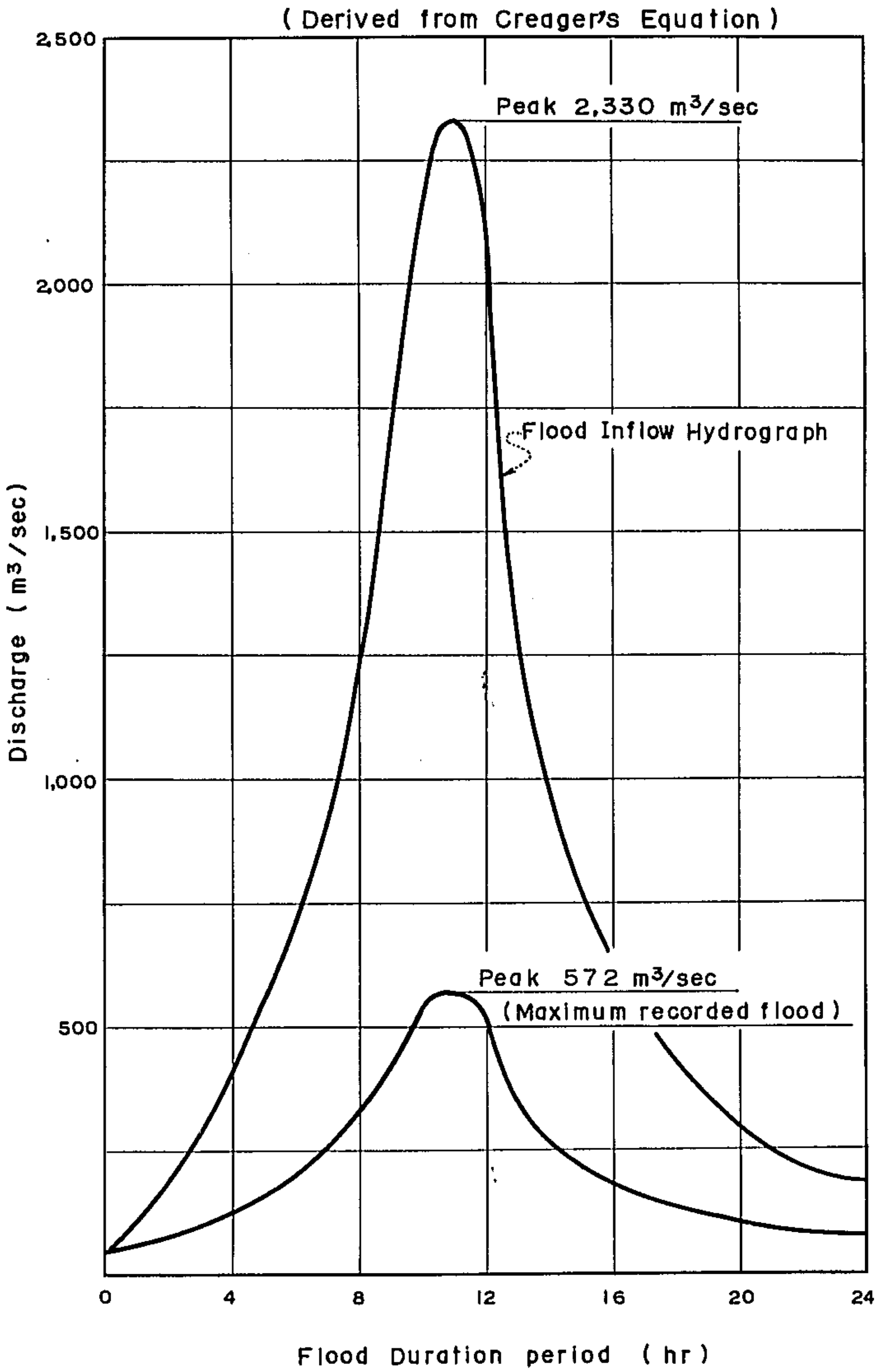
In accordance with the Japanese standard for design of dam, the design outflow flood is determined at 1,300 m^3/sec by taking 20 % allowance to the 100-year flood for expected construction of a rockfill dam. The design outflow flood is defined in the standard as a spillway discharge when the reservoir is at the high water level and the spillway gates are fully open. The extraordinary flood is determined at 1,560 m^3/sec taking additional 20 % allowance to the design flood. The extraordinary flood is defined in the standard as the outflow flood discharge against which structures should be critically safe.

The determined design flood is roughly checked by the Creager's equation of $Q = 46CA^{\alpha}$, in which α is $0.894A^{-0.048}$, A is the drainage area in square miles, C is the coefficient depending on the characteristics of the drainage basin, and Q is the flood peak in second-feet. The coefficient C in the equation generally ranges from 30 to 100. Taking the largest value of 100 as the coefficient C, the flood peak is calculated at 2,330 m^3/sec. The inflow flood hydrograph with a peak discharge of 2,330 m^3/sec is determined as shown in Fig. 4-4, assuming that the duration of the flood and the distribution of discharge during the flood duration are the same as those of the recorded maximum flood.

The spillway is designed to discharge the design outflow flood of 1,300 m^3/sec at the normal high water level of EL. 1,530 m and the extraordinary flood of 1,560 m^3/sec at the flood water level of EL. 1,531.5 m. However the dam and spillway are designed to be critically safe against the inflow flood of 2,330 m^3/sec taking the retardation effect in the reservoir into account.

Since no rainfall and temperature data are available in the Kulikhani basin, it is difficult to estimate the design inflow flood by the rainfall maximization approach. However it is considered necessary to confirm the adequacy of the spillway capacity by a study of the maximum probable flood and a flood routing through the reservoir, at the time of detailed design.

FIG. 4-4 FLOOD HYDROGRAPH AT KULIKHANI DAM SITE



4.6 Sedimentation

No sediment records are available in the Kulikhani basin. The Preliminary Design Report prepared by Overseas Technical Cooperation Agency of Japan in November 1963 includes the statements concerning the sediment discharge of the Kulikhani basin as quoted below.

> "According to the results of the reconnaissance on the basins of the Kulikhani and the Rapti river, it is concluded that the mountain areas upstream from the proposed damsite is comparatively stable, and accordingly that it is not necessary to estimate much quantity of sedimentation in the Kulikhani reservoir."

> "It is favourable that the basin-like flats exist on the upper reaches of the Kulikhani river and middle reaches of the main tributaries. It is because, even the collapses take place on the upper reaches, the major part of the debris will deposit on these flats and the sedimentation will be little on the lower reaches where the Kulikhani reservoir is to be created."

The above referred report concluded that the sediment discharge at the Kulikhani damsite would be about 400 to 700 $m^3/km^2/year$.

Since the estimate of sedimentation is always difficult, it is desirable to take a conservative side estimation within a reasonable range. The annual sediment for the Kulikhani dam is therefore estimated to be 700 $m^3/km^2/year$, which accumulates to 8.82×10^6 m^3 during 100 years from the catchment area of 126 km^2, assuming the surface of sediment deposit as horizontal. It is desirable, however, to confirm the above estimated figure of sedimentation by actual measurements at the damsite, before finalizing the detailed design of the intake structure.

TABLE 4-7 MONTHLY MEAN DISCHARGE

Kulikhani (126 km^2)

(m^3/sec)

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

TABLE 4-8 MONTHLY MEAN DISCHARGE

Sim Khola (7 km^2)

(m^3/sec)

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

TABLE 4-9 MONTHLY MEAN DISCHARGE

Chakhel Khola (23 km^3)

(m^3/sec)

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

CHAPTER 5

POWER MARKET AND DEMAND FORECAST

5.1 General

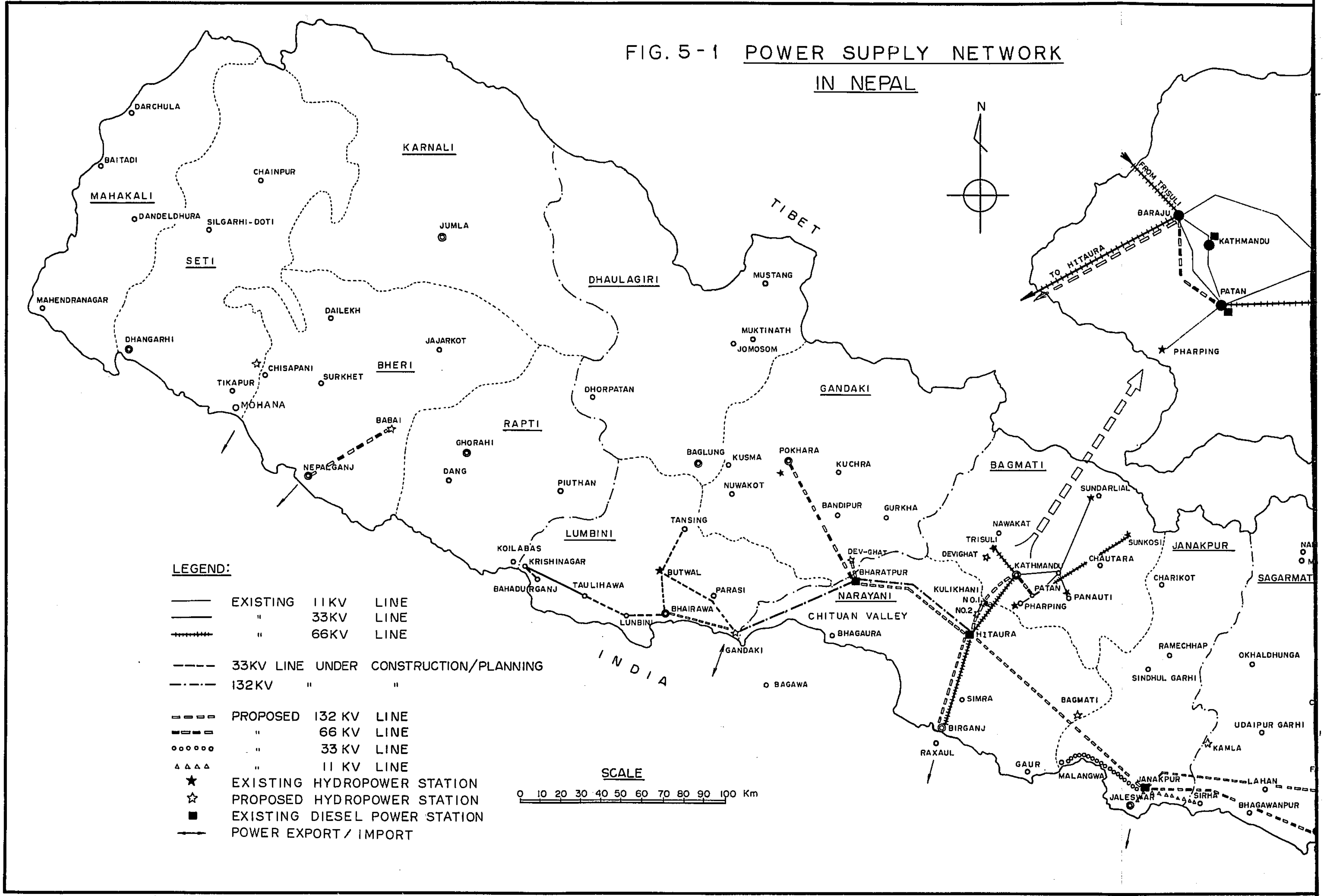
5.1.1 General Description

At present, the electric power supply system in Nepal is mainly operated regionally. The power supply network in Nepal is shown in Fig. 5-1.

Kathmandu and Hitaura-Birganj corridor are the centre of the nation's economic activity. These areas are interconnected with 66 kV transmission lines and covered by the Central Nepal Power System (CNPS), which is by far the largest power system in Nepal and occupies more than 70 % power demand of the whole Nepal. The neighboring Chitwan valley is a very fertile land and an irrigation project is now underway with ADB loan, which envisages to irrigate a land of 15,000 hectares with water pumped up from the Gandak river at two large pumping stations. This area has large potential for agriculture and agro- and timber-based industries, such as saw mills and rice mills.

The southern part (Lumbini Zone) of Western region covers the vast Terai plain and has abundant agricultural and forest resources, which also offer good possibility of developing agro- and timber-based industries. The second largest sugar mill of the country is located at Bhairawa. 33 kV transmission lines are now under construction to interconnect major towns in the area. Construction of a 132 kV transmission line is on progress to interconnect Hitaura and a hydroelectric power station which is under development at Gandak by Indian Authority. After completion of these transmission lines, this area is regarded as a part of CNPS's supply area. The northern part (Gandaki Zone) of this region has captivating natural beauty of the Himalayas, and has shown rapid growth of inhabitation and ancillary industries, resulting in much higher growth of power demand than anticipated before. There is also a plan to interconnect this area with CNPS by a 66 kV transmission line from Bharatpur to Pokhara.

FIG. 5-1 POWER SUPPLY NETWORK IN NEPAL



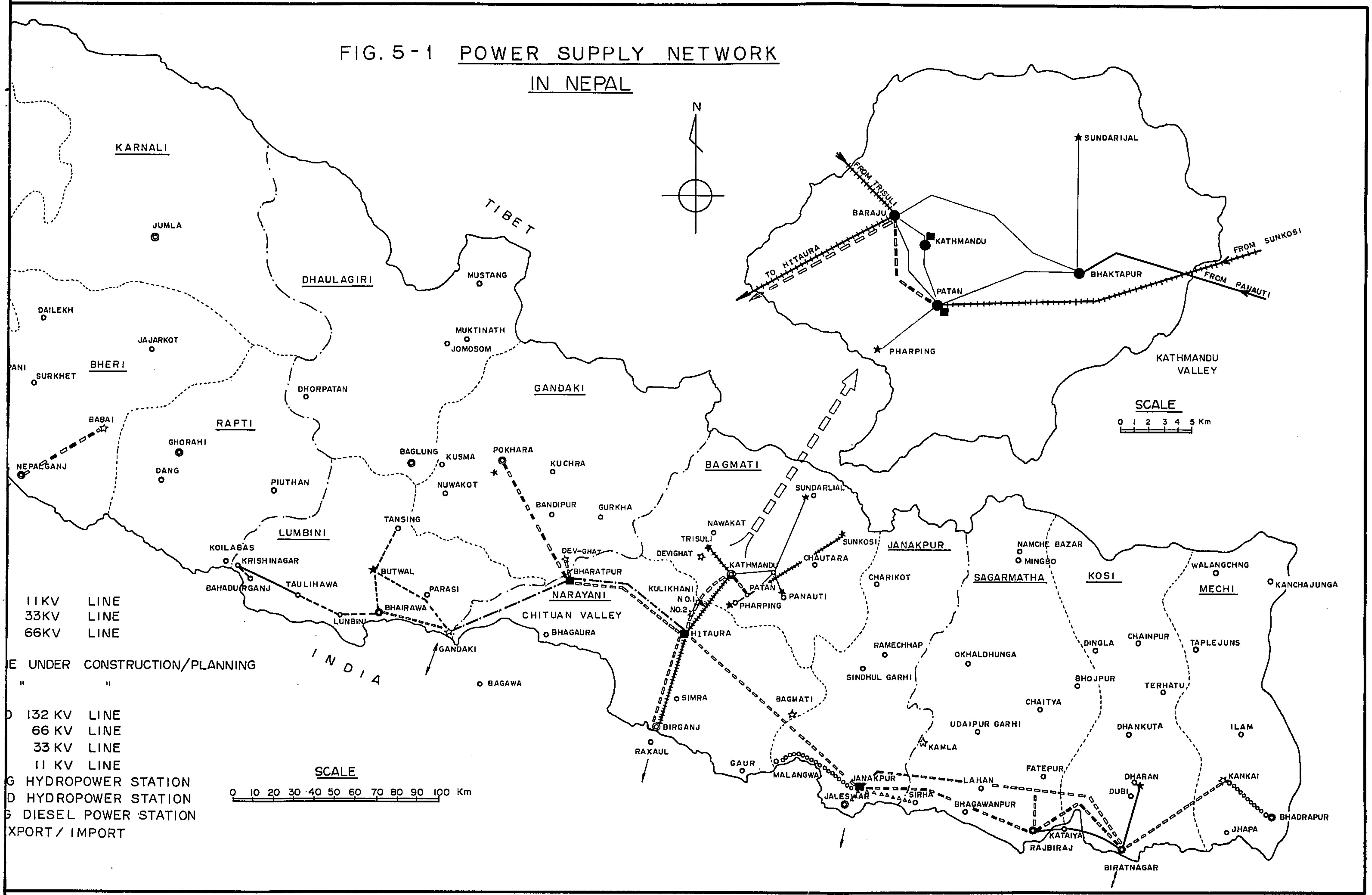


FIG. 5-1 POWER SUPPLY NETWORK IN NEPAL

Though the Kulikhani project is going to be constructed in Central region and connected to CNPS, the future demand is forecast as a combined demand of CNPS and Western region as the both power systems are planned to be interconnected after 1976 as stated above.

5.1.2 Organization of Power Supply

About 90 % of the total generating facilities for public power supply are now operated by the following organizations. The remaining 10 % of the facilities are held by private factories.

Nepal Electricity Corporation

NEC is a governmental corporation supplying electric power in Central region. This Corporation is operating the most of generating facilities and managing CNPS to supply electric power to Kathmandu valley, Hitaura-Birganj corridor, Chitwan valley and their adjoining areas. The total generating capacity is 29,850 kW in 1972/73, consisting of 21,570 kW hydro and 8,280 kW diesel generators.

Electricity Department of Government

Electricity Department of the Ministry of Water and Power is responsible for planning and implementation of the electric power development in Nepal. The Department is supplying electric power to CNPS of NEC with Sunkosi hydropower plant of 10,050 kW capacity and also to the towns outside of CNPS, by small isolated diesel generators, such as Mahendranagar, Dhadrapur and other border towns in Terai plain. The total installed capacity of the Department is 13,770 kW, which is composed of 11,290 kW hydro and 2,480 diesel units. In addition, the Department has been receiving the power of about 2,570 kW from India in 1972/73.

Butwal Power Company (BPC)

BPC is a private company partnered by Electricity Department. This company was originally established to construct a 1,000 kW hydropower 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.

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

Generating Capacity and Sold Energy of Power Organizations

Organization	Generating Capacities (kW)		Number of Consumers		Annual Energy Sold (MWh)	
	67/68	72/73	67/68	72/73	67/68	72/73
NEC	17,636	29,854	21,552	52,781	18,745	55,965
Electricity Dept.	5,538	13,767	2,314	4,000	1,972	1,288
BPC	115	165	-	536	-	280
Total	23,289	43,786	23,866	57,317	20,717	57,533

As seen in the above table, the number of consumers and annual energy sold in 1972/73 increased to 240 % and 280 % respectively compared with the figures in 1967/68.

5.1.3 Power Exchange with India

Nepal's power system having no nationwide network, some of border towns are connected to the Indian power grid and exchange of small power has been made between India and Nepal under the agreement between the both governments. Nepal is importing power at the east (Biratnagar and Rajbiraj) and the west (Nepalganj) and exporting at the center (Birganj); all in the order of few thousand kilowatts. The details for power importing and exporting towns are given in Table 5-1. The trade is made on equal basis at a rate of about US mill 20/kWh equivalent.

TABLE 5-1 EXCHANGE OF ELECTRIC POWER WITH INDIA

Town	Region	Committed Power (kW)	Maximum Power (kW)
1. Importation			
Mahendranagar	Far Western	500	150
Dhangarhi	"	300	-
Nepalganj	"	1,000	300
Kiolabas	"	200	-
Krishnagar	Western	800	100
Bhairawa	"	500	300
Gaur	Central	300	100
Malangwa	"	200	70
Jaleswar	"	1,000	100
Sirha	Eastern	200	-
Rajbiraj	"	500	500
Biratnagar	"	6,000	2,000
Bhadrapur	"	1,000	-
Total		12,500	3,620
2. Exportation			
Birganj	Central	5,000	1,300

5.2 Present Power System in Central Region and its Extension Plan

5.2.1 General

Central region consists of three zones, Bagmati, Narayani and Janakpur. The major parts of this region, Kathmandu valley in Bagmati zone and Hitaura-Birganj corridor in Narayani zone, are covered by 66 kV network (CNPS) and consuming more than 70 % of the whole power demand in Nepal. The power systems in Bharaptur and Janakpur zone are operated without interconnection. However, Bharatpur is going to be interconnected with CNPS after completion of 132 kV Gandak-Hitaura transmission line in 1976.

5.2.2 Present Power Generating Facilities

The present power generating facilities in CNPS consist of hydropower plants of 31,620 kW in total and diesel power plants of 8,280 kW in total as of the end of 1973. These power stations are owned by NEC except Sunkosi hydropower station, which is owned by Electricity Department. Details are given hereunder:

1. Hydro Power Station

Trisuli	18,000 kW	with a 3,000 kW standby unit
Sunkosi	10,050 kW	
Panauti	2,400 kW	
Sundarijal	640 kW	
Pharping	500 kW	
Godawari	30 kW	
Total	31,620 kW	

2. Diesel Power Station

Mahendra	1,696 kW	
Patan	1,490 kW	
Hetaura	4,470 kW	
Bharatpur	628 kW	(not interconnected with CNPS)
Total	8,284 kW	

Trisuli hydro-power plant is the largest one in this power system, having 18,000 kW active capacity with a 3,000 kW standby unit, and Sunkosi hydro-power plant of 10,050 kW installed capacity is the second largest. Hydro-power plants in the system are of run-of-river type with small pondages to meet daily load fluctuation, so they cannot generate rated output in the dry season except Trisuli. The total peaking capability in the dry season is 26,540 kW as given hereunder against the installed capacity of 31,620 kW.

Name of Station	Installed Capacity (kW)	Dry Season Peaking Capability (kW)
Trisuli	18,000	18,000
Sunkosi	10,050	6,000
Panauti	2,400	1,500
Sundarijal	640	640
Pharping	500	400
Godawari	30	-
Total	31,620	26,540

The system also has diesel power plants with peaking capability of 7,650 kW in total, but diesel power generation is strictly limited only to meet unexpected excessive peak load or for emergency use owing to sky-rocketted price of imported fuel.

The detailed list of the existing power stations is shown in Table 5-2. In addition to the power stations in the table, Devighat power station with installed capacity of 14,100 kW and Gandak power station of India with installed capacity of 15,000 kW, out of which 7,000 kW is committed to be shared to Nepal, are planned to be commissioned before completion of Khulikhani project. Besides, the 3,000 kW spare unit of Trisuli power station has possibility to be operated as active power.

5.2.3 Transmission and Distribution System

The Trisuli power is sent to Kathmandu (Balaju substation) with a 66 kV double circuit transmission line, which is extended to Birganj near

TABLE 5-2 INSTALLED CAPACITY OF GENERATING FACILITIES IN NEPAL

As of the end of 1973

Region	Name of Station	Hydro	Diesel or Steam	Total	Zone
		kW /1	kW	kW	
Central	Trisuli	18,000(3,000)		18,000	Bagmati
	Sunkosi	10,050		10,050	"
	Panauti	2,400		2,400	"
	Sundarijal	640		640	"
	Pharping	500		500	"
	Godawari	30		30	"
	Mahendra		1,696	1,696	"
	Patan		1,490	1,490	"
	Hetaura		4,470	4,470	Narayani
	Bharatpur		628	628	"
	Birganj Sugar Mill		1,872 (1,600) /2	1,872	"
	Janakpur		750	750	Janakpur
	Himalayan Iron Steel		100	100	"
	Janakpur Cigarette		572	572	"
	Sub-total	31,620	11,578	43,198	
Western	Pokhara	1,000		1,000	Gandaki
	Bhairawa		528	528	Lumbini
	Taulihawa		50	50	"
	Krishnagar		165	165	"
	Bahadurganj		25	25	"
	Tansing		289	289	"
	Butwal Technical Institute	50	115	165	"
	Mahendra Sugar Mill		765 (750) /2	765	"
	Sub-total	1,050	1,937	2,987	

- to be continued -

Region	Station	Hydro	Diesel or Steam	Total	Zone
		kW	kW	kW	
Eastern	Bhadrapur		100	100	Mechi
	Dhankuta Micro Hydro	240		240	Kosi
	Dharan		212	212	"
	Morang Hydel Co.		1,695	1,695	"
	Biratnagar Jute Mill		2,250 (1,400) /2	2,250	"
	Ilem Tea Plantation		100	100	"
	Morang Sugar Mill		15	15	"
	Reghupati Jute Mill		337	337	"
	Nepal Straw Board		356	356	"
	Golcha Cotton Mill		125	125	"
	Asoko Texitile		125	125	"
	Dharan Millitary Camp		1,200	1,200	"
	Sub-total	240	6,515	6,755	

Note: /1 One unit of 3,000 kW at Trisuli is a standby.

/2 Capacity in parentheses means steam power plant.

the Indian border via Hitaura and forms backbone of CNPS. Another 66 kV single circuit line is connecting Sunkosi hydro-power plant with Kathmandu power system through a 66/11 kV substation at Patan, and this 66 kV line is planned to be extended upto Balaju substation. A 33 kV single circuit line is connecting Panauti hydro-power plant and Bhaktapur substation at the suburb of Kathmandu. 11 kV double circuit ring lines of about 50 km in length are interconnecting eight substations in the Kathmandu valley. The existing transmission line network and its extension plans are indicated in Fig. 5-1.

The Kathmandu valley is widely covered with 11 kV and 2.3 kV distribution network and 400/230 V low tension lines. Hitaura and Birganj, important load centers in the corridor, and their surrounding areas are served with electric power through five 66/11 kV substations of 12 MVA in total.

The details of the existing transmission and distribution system are given hereunder:

1. Transmission Lines

66 kV double circuit lines,	Trisuli-Balaju ...	32 km
	Balaju-Birganj ..	122 km
66 kV single circuit line,	Sunkosi-Patan	57 km
Total		211 km
33 kV single circuit line,	Panauti-Bhaktapur..	20 km
11 kV double circuit ring lines in Kathmandu valley		50 km

2. Main Substations

Balaju substation	66/11 kV, 11.25 MVA
Patan substation	66/11 kV, 12 MVA
Bhaktapur substation	33/11 kV, 3 MVA
Hitaura substation	66/11 kV, 3 MVA
Amlekganj substation	66/11 kV, 1.5 MVA
Simera substation	66/11 kV, 1.5 MVA
Parwanipur substation	66/11 kV, 3 MVA
Birganj substation	66/11 kV, 3 MVA

3. Distribution Lines

11 kV distribution lines .... 270 km
2.3 kV distribution lines in Kathmandu city ..... 61 km
400/230 V, 3-phase, 4-wire low tension distribution lines

5.2.4 Power Demand in CNPS

Recent data for energy generation and consumption in CNPS are shown in Table 5-3 and 5-4. During recent five years from 1967/68 to 72/73 energy consumption increased from 20,774 MWh to 51,350 MWh with mean rate of 20 % per annum and annual peak demand from 8,885 kW to 21,280 kW with mean rate of 19 % per annum. The monthly energy production and typical daily load curves are shown in Figures 5-2 to 5-5. The seasonal variation of power demand is remarkable and gives a peak in winter season, from December to March, which causes higher power demand in the dry season when the power generating capacity becomes down. Typical load curves show that the daily load factor is about 65 % in winter and 53 % in summer, 60 % on an average.

The power consumption is predominantly domestic nature as seen in Table 5-4. Out of total energy, over 60 % has been consumed for domestic use and less than 20 % for industrial use. As the electric power has been consumed mainly in domestic sector the annual load factor is relatively low and remains at 40 to 45 % for the past several years as shown in Table 5-3.

Analysis of energy loss is summarized in Table 5-5. The total energy loss, the balance between the generated energy and sold energy in CNPS is as high as 37 % in 1967/68 and gradually decreasing year by year to 33 % in 1972/73. Such high rate of energy loss consists not only physical loss in the power system but also illegal use of energy, which causes great strain on the operating revenue of NEC, although effort is at present being put to minimize the loss to the reasonable limit with reinforcement and improvement of the distribution system.

Table 5-3 YEARLY PRODUCTION OF ELECTRIC ENERGY IN CNPS

Fiscal Year	Energy Generated (MWh)				Annual Average Demand (kW)	Annual Peak Demand (kW)	Load Factor (%)
	Kathmandu	Birganj	Hetaura	Total			
1960/61	9,129	-	-	9,129			
61/62	10,277	-	-	10,277			
62/63	11,213	-	-	11,213			
63/64	13,749	-	-	13,749	1,569	3,550	44.2
64/65	15,693	108	-	15,802	1,804	4,015	44.8
65/66	19,621	534	-	20,154	2,300	5,670	40.6
66/67	25,524	1,035	879	27,438	3,132	7,100	44.1
67/68	30,363	571	1,825	32,759	3,739	8,885	42.1
68/69	36,120	417	1,979	38,515	4,397	10,540	41.6
69/70	44,877	-	-	44,877	5,123	11,560	44.3
70/71	53,649	-	-	53,649	6,124	13,860	44.2
71/72	65,941	-	22	65,964	7,530	17,500	43.0
72/73	81,267			81,267	9,277	21,280	43.0

TABLE 5-4 CLASSIFICATION OF ENERGY CONSUMPTION IN CNPS

Fiscal year	Energy Consumption MWh												Total MWh
	Domestic service		Commercial		St-light		Industrial		Station service		Export to India		
	MWh	% of Total	MWh	%	MWh	%	MWh	%	MWh	%	MWh	%	
1967/68	12,924	62.8	2,196	10.7	750	4.0	3,013	16.6	1,891	10.7			20,774
68/69	15,367	62.1	2,616	10.6	779	2.5	4,381	17.8	1,390	5.7			24,533
69/70	18,274	62.6	3,524	12.0	737	2.5	5,197	17.7	1,524	5.2			29,256
70/71	22,826	64.2	4,567	18.9	784	2.2	5,749	16.4	1,516	4.3			35,442
71/72	30,098	68.5	4,930	11.5	794	1.8	6,648	15.1	1,475	3.2			43,964
72/73	34,300	62.8	5,700	11.2	900	1.4	7,200	17.7	1,500	2.9	1,750	3.2	51,350

TABLE 5-5 ENERGY CONSUMPTION AND POWER DEMAND IN CNPS

Fiscal Year	Energy Consumption (MWh)	Energy Generated (MWh)	Loss (MWh)	% Loss
1967/68	20,774	32,759	11,985	36.6
68/69	24,533	38,515	13,982	36.3
69/70	29,256	44,877	15,621	34.8
70/71	35,442	53,649	18,207	33.9
71/72	43,964	65,964	22,000	33.4
72/73	54,495	81,269	26,774	32.9

5.2.5 Extension of Power System

A 132 kV transmission line of 175 km in length, connecting Gandak power station (15,000 kW) in Western region now under development, to Hitaura in CNPS via Bharaptur is currently under construction with ADB loan with target completion in 1975/76. On completion of this line the western power system will be integrated in CNPS and the Gandak power will be sent to CNPS.

The Electricity Department decided to interconnect the border towns in Lumbini zone with 33 kV lines as given below:

a) Gandak-Parasi-Butwal
b) Butwal-Tansing
c) Butwal-Bhairawa-Lumbini-Taulihawa
d) Taulihawa-Krishnagar (Existing)
e) Krishnagar-Bahadurganj

These transmission lines are now under construction and scheduled to be completed before completion of 132 kV Gandak-Hitaura transmission line.

Except the above, a 66 kV line from Bharatpur to Pokhara and a 132 kV line from Gandak to Bhairawa are also under planning.

Thus the power system in the Western region will be integrated in the CNPS after 1975/76.

5.2.6 Details of the Area to be covered with CNPS

The present situation of the areas to be covered with CNPS is given hereunder.

(1) Chitwan valley

This valley is a very fertile land with very good potential for agricultural activities. The sizable towns in this area are Bharatpur and Narayanghat only and they have been supplied electric power from 628 kW diesel generators installed in Bharatpur.

The Chitwan Valley Development Project, which ultimately consumes 7,000 kW of power, is now under planning with ADB loan.

(2) Western Region

Western Region, consisting of Gandak, Lumbini and Dhaulagiri Zones, is located in the mid-western part of Nepal. This region is relatively underdeveloped but has prosperous potential for future development, the agricultural potentiality in the shouthern part and tourism in the northern part.

The total installed capacity of generating facilities in this region is 2,990 kW as seen in Table 5-2 and corresponds to 5.82 % of all Nepal.

Gandak zone

Pokhara town is supplied electric power from a hydro-power plant with installed capacity of 4 x 250 kW, peak output of which is 750 kW. The town is endowed with fine scenery of the Himalayas and tourism has become booming especially in the recent years. Inhabitation and cottage industries are also rapidly growing resulting in much higher power demand growth than anticipated previously. It is forcast that the maximum demand in 1974/75 will reach 1,040 kW and energy requirement 2,310 MWh in case normal supply being maintained. As an interim purpose, a diesel generating set of 500 kW will be installed.

Lumbini zone

There are many small towns in Terai plain along the Indian borders. As there is no interconnection between these towns, small diesel plants are scattered in these towns, total capacity of which is 1,990 kW including private generation of Mahendra Sugar Mill.

Butwal town is supplied electric power by Butwal Power Company with their 115 kW diesel plant installed at Butwal Technical Institute and 50 kW hydropower plant (165 kW in total). This company is now constructing a 1,000 kW hydropower plant to meet the future energy demand in Butwal-Bhairawa area.

Bahairawa, Krishnagar, Taulihawa and Bahadurganj are served electric power by the Electricity Department. The installed capacity of diesel generators is 768 kW in total, and in addition Nepal is commissioned to receive electric power from India at Bhairawa (upto 500 kW) and Krishnagar (upto 800 kW) as shown in Table 5-1. Total load in the area as of 1972/73 is 370 kW. The power importing rate of US mill 20/kWh is lower than the operating cost of diesel plants and therefore the power demand in the area is entirely met by the imported power and diesel generators are usually kept as standby.

Tansing town is a summer resort in the area and is supplied electric power by the Electricity Department with diesel generators totalling 289 kW.

These towns are going to be interconnected with 33 kV lines as mentioned in Section 5.2.5, and the peak demand of each separated load center as of 1972/73 is as follows:

Tansing	110 kW
Butwal	160 kW
Bhairawa	310 kW
Mahendra Sugar Mill	500 kW
Other towns	60 kW
Total	1,140 kW

Details for power generating facilities and power consumption are shown in Table 5-2 to 5-6.

5.2.7 Power Tariff System and Financial Status of Power Company

The current power tariff system in CNPS is as given in Table 5-7. The previous power tariffs were lowered remarkably at the beginning of 1971, and as a result, electric power consumption was stimulated and has recorded considerable growth in the following years; more than 20 % increase of peak demand per annum during 1969/70 through 1972/73 as mentioned in Section 5.3.2.

TABLE 5-6 POWER STATISTICS OF WESTERN REGIONS

Pokhara Town

	Utilized Energy (MWh)						Energy Loss	Total Generated Energy	Peak Demand	Annual LF
	Domestic	Industrial	Commercial	Street Lighting	Station Service	Total				
	MWh	MWh	MWh	MWh	MWh	MWh	MWh	MWh	kW	%
1969/70	281.3	104.6	17.3	34.4		437.6	219.1	656.7	250	
70/71	366.2	149.7	13.1	21.0		550.0	328.6	878.6	380	
71/72	432.8	135.6	35.9	43.8	16.3	664.4	351.8	1,016.2	440	26.4
72/73	594.7	161.6	31.1	50.7	15.6	854.0	507.9	1,361.9	520	29.9

Bhairawa

	Domestic	Industrial	Commercial	Street Lighting	Station Service	Total	Energy Loss	Total Generated Energy	Peak Demand	Annual LF
1971/72	-	-	-	-	-		-	-		
1972/73	-	-	-	-	-		-	663	310	

Butwal

	Domestic	Industrial	Commercial	Street Lighting	Station Service	Total	Energy Loss	Total Generated Energy	Peak Demand	Annual LF
1971/72	151.8	50.9	-	6.85	22.13	231.68		298.9		
1972/73	224.9	60.73	-	11.07	30.0	326.70		419.9	160	

Tansing

	Domestic	Industrial	Commercial	Street Lighting	Station Service	Total	Energy Loss	Total Generated Energy	Peak Demand	Annual LF
1971/72	-	-	-	-	-	-		-	-	
1972/73	72.44	-	-	8.9	3.2	84.54		99.12	110	11.0

Others (Krishnagar, Bahadurganj, Taulihawa)

	Domestic	Industrial	Commercial	Street Lighting	Station Service	Total	Energy Loss	Total Generated Energy	Peak Demand	Annual LF
1971/72	-	-	-	-	-	-		-	-	
1972/73	-	-	-	-	-	-		110	60	

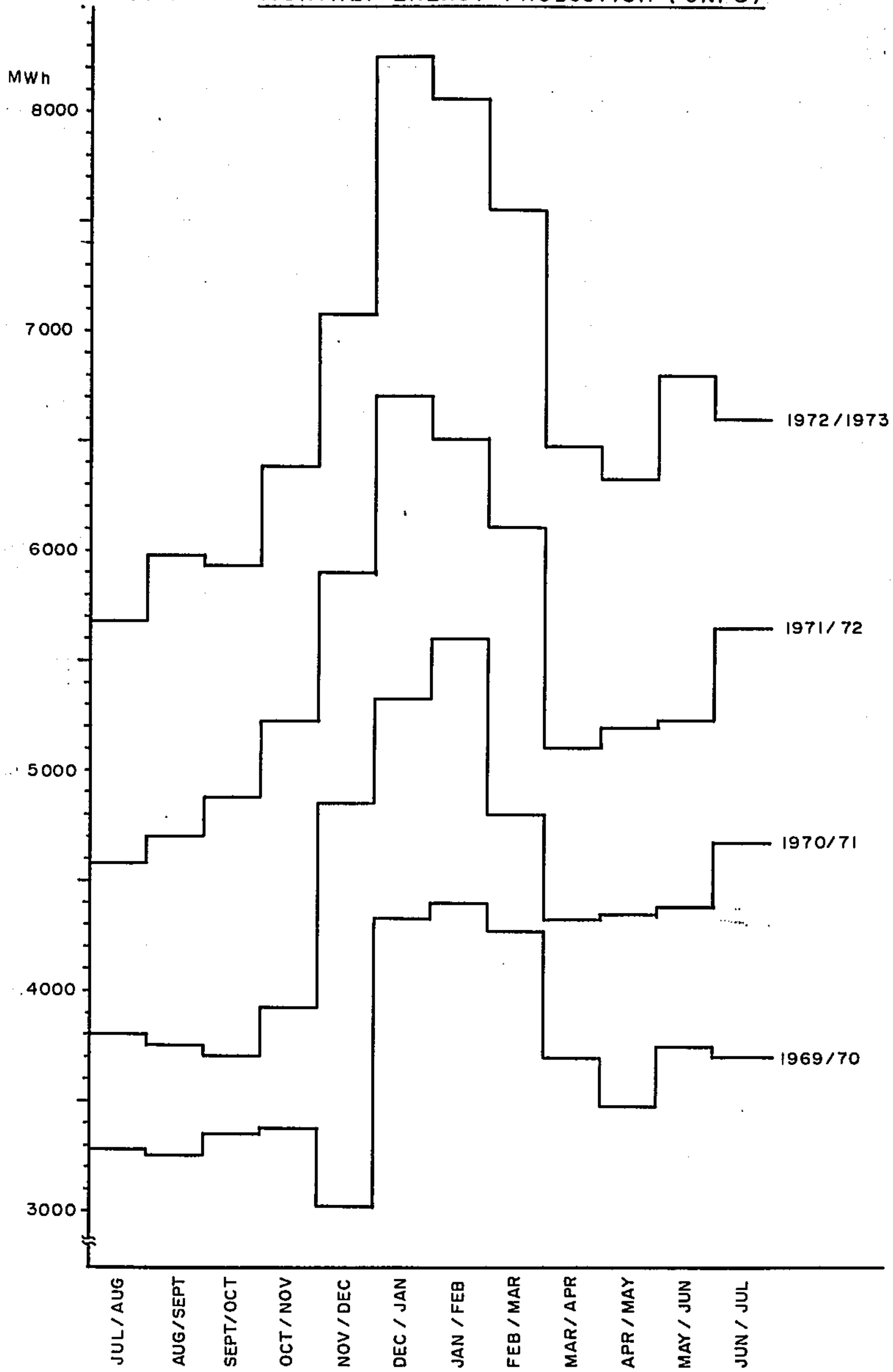
TABLE 5-7 TARIFF SUMMARY

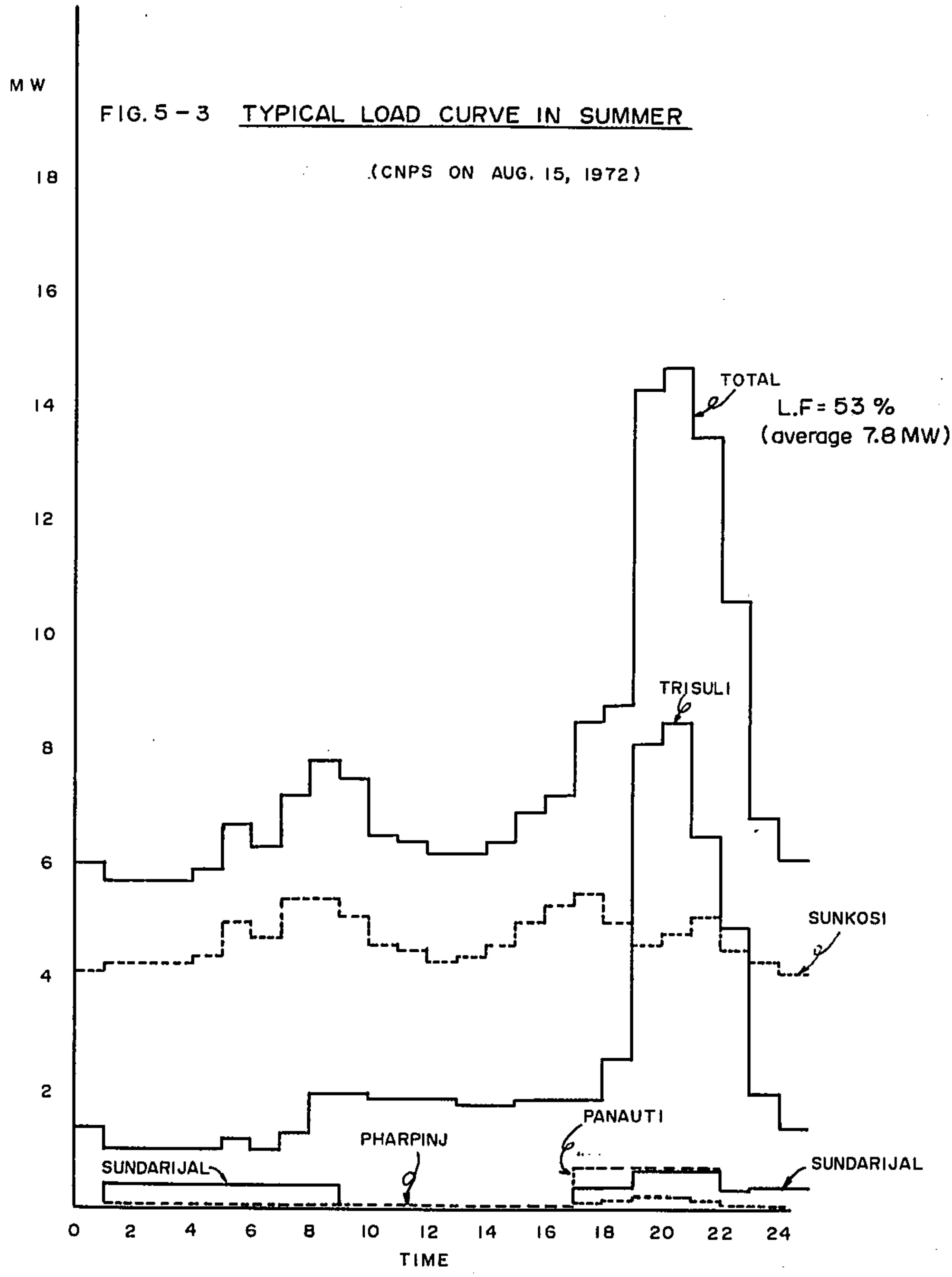
(US$1=Rs.10.56, Rs.1=Nepali Paisa 100)

	Kathmandu		Hitaura - Birganj	
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/w/month		7.5 paisa/w/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
	3.75/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/KVA 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.	"		

The above power tariffs seem very low compared with recent reasonable power tariffs in the other countries. However, the available financial balance of NEC as of 1971/72 shows favorable return. This seems to be caused by the fact that the old power stations now operated was depreciated according to the construction costs at the time of construction without revaluation to suit the present price level and that the CNPS's power is mainly relying on hydropower which is not affected by sharp price increase of fuel oil.

FIG. 5-2 MONTHLY ENERGY PRODUCTION (CNPS)

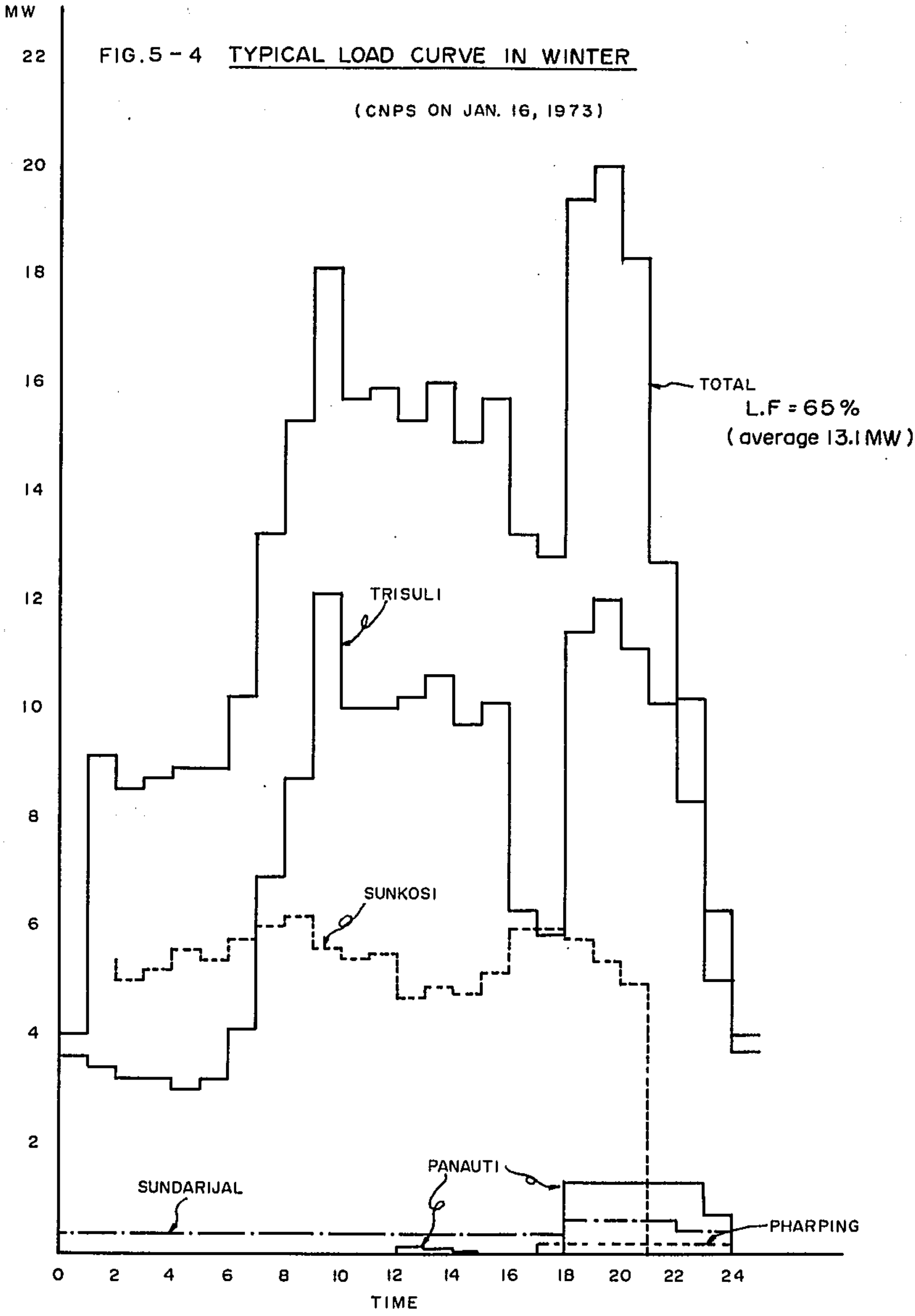


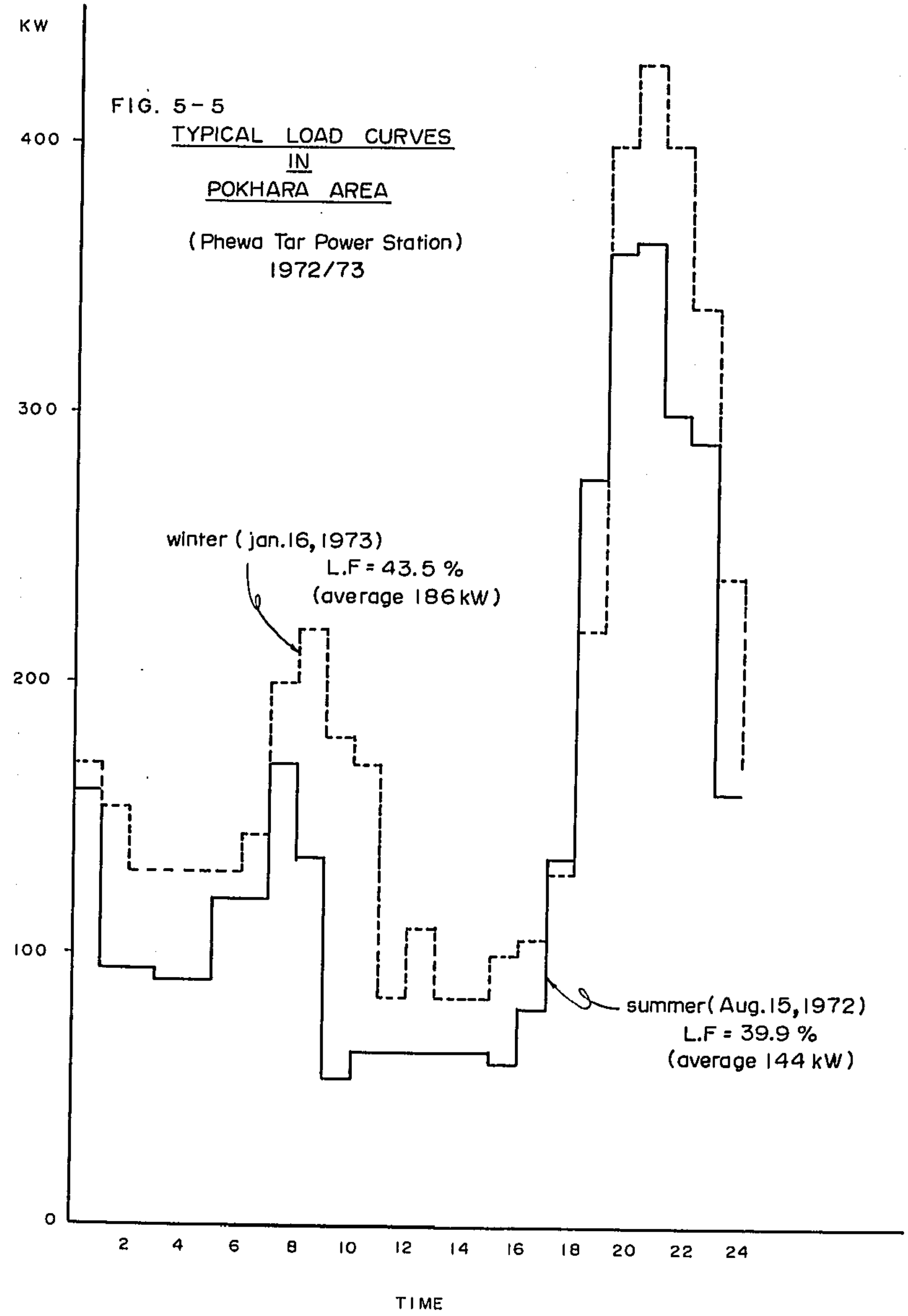


MW
FIG. 5 - 3 TYPICAL LOAD CURVE IN SUMMER
(CNPS ON AUG. 15, 1972)
18
16
14
12
10
8
6
4
2
TOTAL
L.F = 53 %
(average 7.8 MW)
TRISULI
SUNKOSI
PANAUTI
PHARPINJ
SUNDARIJAL
SUNDARIJAL
0
2
4
6
8
10
12
14
16
18
20
22
24
TIME

FIG. 5 - 4 TYPICAL LOAD CURVE IN WINTER

(CNPS ON JAN. 16, 1973)




KW
400
300
200
100
0
FIG. 5-5
TYPICAL LOAD CURVES
IN
POKHARA AREA
(Phewa Tar Power Station)
1972/73
winter (jan.16, 1973)
L.F = 43.5 %
(average 186 kW)
summer(Aug.15, 1972)
L.F = 39.9 %
(average 144 kW)
2
4
6
8
10
12
14
16
18
20
22
24
TIME

5.3 Power Demand Forecast

5.3.1 Forecasting Method of Power Demand

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

Different approaches are used in predicting the power demand in the already electrified areas and not yet electrified areas, as explained below:

(1) For electrified areas

The past trend of energy consumption is analyzed, and appropriate growth rate in the future is assumed based on overall judgement, taking account of such relevant factors as population, level of energy consumption, installed capacity, economic development plan, development potential of the area, and so on. For the Central region (CNPS), the power consumtion 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, at present, about 33% of the total generated energy; it is assumed that this ratio of energy loss will be gradually improved to the ultimate value of 15% in the future.

For the other regions, where the density of power consumption is very low, only the trend of 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 taken into account.

(2) For non-electrified areas

For the initial estimate of the domestic and industrial demand of these areas, the following approaches are employed:

Domestic Demand

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 Demand

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 Nations' publication, "Small Scale Power Generation".

5.3.2 Demand Forecast of Central Region

The major towns of this region, Kathmandu and Hitaura-Birganj corridor, are served by CNPS. The peak demand of the system has increased with an average rate of 19% during these five years as mentioned below:

	Peak Demand	Increase Rate
1967/68	8,885 kW	
1968/69	10,540 kW	18.6 %
1969/70	11,560 kW	9.7 %
1970/71	13,860 kW	20.0 %
1971/72	17,500 kW	26.3 %
1972/73	21,280 kW	21.6 %

Very high rate of 26.3% during 1971/72 period was caused by the drastic reduction in domestic power tariff.

The high growth rate of about 20% is considered to continue for several years to come, as a number of small and medium sized industries and hotels are being planned to be built within coming 5 years in Kathmandu valley and Hitaura-Birganj corridor. Another conceivable consumer is the proposed Chitwan valley irrigation scheme, 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 demand has to be added to the system demand.

In estimating the long term future demand of Central region, the following was assumed referring to the informations from the Electricity Department, Nepal Industrial Development Corporation, etc.:

(1) Domestic demand is forecast based on increase of the number of consumers and annual energy consumption per consumer. Growth rate of the number of consumers is estimated as 10 % per annum upto around 1977/78 extending the past trend of the recent years, then to increase upto 20 % per annum and gradually settle down to a constant rate of 5 % per annum. Annual consumption per customer is assumed to increase at a constant rate of 3 % per annum.

(2) Industrial demand is assumed to grow at a rate of 10 to 12 % per annum for years to come and to settle down to 8 % arround 1985. Besides the natural growth of industrial demand by new industries, private bulk consumers now operating their own diesel generators will shift to use energy from the public power system, when cheap and abundant power supply is secured. Such expected demand is added to the above during 1976/77 through 1982/83.

Besides the above industrial demand, the demand for the proposed Chituan valley irrigation project is added to this category.

(3) The 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 increase of tourists.

(4) Demand for street lighting is assumed as 2 % of the sum of domestic, industrial and commercial demand.

(5) Energy consumption for station service is assumed to grow at a basic rate of 10 % per annum by expansion of electric facilities in proportion to the increase of power demand. The factors of new large installations are added to the above.

(6) Exporting energy to India is assumed as a part of power demand of CNPS and the exporting power is estimated to grow upto contracted limit of 5,000 kW.

(7) Energy loss factor is assumed to be gradually improved from the present rate of 33 % to a constant rate of 15 %.

(8) Annual load factor is assumed to increase from the present level of 41 % to 50 % gradually.

Long term demand forecast for the Central region upto 1989/90 is shown in detail in Table 5-8 and is summarized hereunder.

Fisical Year	Peak Power Demand (MW)	Total Annual Energy (MWh)	Annual Load Factor (%)
1975/76	36.5	132,660	41.4
1979/80	65.0	282,320	49.5
1984/85	105.5	462,000	50.0
1989/90	155.0	666,000	50.0

5.3.3 Demand Forecast of Western Region

(1) Gandeki Zone

The concerned areas are going to be interconnected with CNPS by completion of 66 kV transmission line from Bharaptpur to Pokhara now under planning.

Pokhara town

Pokhara town is a major tourism center in Nepal and has many hotels. Peoples are immigrating into this area from the other parts of the country, which is causing increase of population in Pokhara valley; the average increase of population in this valley during 1970 through 1973 is 4.33% per annum. Recently, food and other light industries have been growing up in this area.

TABLE 5-8 LONG TERM DEMAND FORECAST IN CENTRAL REGION

	Energy (MWh)								
	Domestic (MWh)	Industry & Irrigation (MWh)	Commercial (MWh)	Street Lighting (MWh)	Station Service (MWh)	Export to India (MWh)	Energy Loss (MWh)	Total Energy (MWh)	Peak Power (kW)
1971/72	30,093	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	17,500	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	79,880	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	319,200	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

According to the information from UN Preliminary Survey Mission for Gandaki and Lumbini Region, 1972, the peak demand in 1973/74 is estimated at 870 kW against the record in 1972/73 of 515 kW; in addition to the natural growth, new domestic consumers of 150 kW and new bulk consumer of 160 kW is counted in. As for the future growth after 1973/74, considering from the developing nature of the valley the peak demand is estimated to grow at a rate of 20% per annum upto around 1978/79 and gradually to settle down to a constant rate of 10%.

Thus the peak demand is estimated to reach 2,480 kW in 1980 and 7,500 kW in 1990 as shown in Table 5-9.

Syanja, Kusma & vicinities

This area is expected to be electrified in 1975/76 with initial peak demand of 130 kW and after that the peak demand is estimated to grow at a rate of 15 to 20% per annum.

(2) Lumbini Zone

The major towns in this area are going to be interconnected with Gandak power station by completion of new 33 kV transmission lines now under construction and further to CNPS by completion of the 132 kV Gandak-Hitaura Transmission line.

Krishnagar and Bahadurganj

These towns are electrified since 1972 and the peak demand for 1972/73 was 60 kW. For long term demand forecast, the annual growth rate is assumed as 20 to 15% for several years and to settle down gradually to 10%.

Taulihawa area

According to the market survey carried out by Electricity Department in 1969, the total installed capacity of private generating facilities in five factories was about 100 kW. Assuming that 25% of the private industries will be converted to public supply, the industrial demand was estimated as 25 kW.

Domestic demand is estimated from the population of 8,500 as 125 kW at the beginning.

The initial demand is estimated as 150 kW and the annual growth rate as 20 % initially settling down to 15 %.

Bhairawa, Butwal and Tansing towns

The sum of peak demand of these towns including the load of Mahendra sugar mill was 1,460 kW in 1973/74. By being interconnected with Gandak power station through 33 kV transmission system now under construction, cheap and abundant power will become available and accelerate construction of proposed industries. The peak demand of these areas is assumed to grow at a rate of 20% per annum in the immediate future and to drop gradually to 15% ultimately.

Lumbini and Parasi

These towns are not electrified at present and the future demand is estimated in the same manner as Krishnagar and Bahadurganj.

(3) Total demand of Western region

The total power demand of the Western region to be interconnected with CNPS in future is obtained as a simple sum of the demand for the indivisual areas as the peak load time of each area is considered to almost coincide. The forecast is as shown in detail in Table 5-9 and summarized hereunder:

Fiscal Year	Peak Power Demand (kW)	Total Annual Energy (MWh)	Annual Load Factor (%)
1979/80	7,780	34,100	50
1984/85	15,340	67,300	50
1989/90	24,300	105,000	50

TABLE 5-9 LOAD FORECAST IN WESTERN REGION

	Peak Demand										
	Lumbini Zone						Gandaki Zone (kW)				Total Required Energy (MWh)
	Bhairawa, Butwal & Tansing	Krishnagar & Bahadur-ganj	Tauli-hawa	Parasi	Lumbini	Sub-total	Pokhara	Syanja & Kusma	Sub-total	Total (kW)	
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	180	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	770	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	4,120	8,620	24,300	105,000

5.3.4 Demand Forecast of Greater CNPS

As previously stated in Section 5.2.5, a 132 kV transmission line connecting Gandak power station and Hitaura substation via Bharatpur is under construction with the target completion in 1975/76. By the same time, a 33 kV transmission system to interconnect Gandak power station to several towns in Lumbini Zone, will also be completed. There is also a plan to construct a 66 kV line between Bharatpur and Pokhara. Thus, after interconnection two systems are regarded as one combined system.

As the future power demand of CNPS, the forecast demand of two regions, Central and Western, is simply summed up according to the interconnection schedule because of almost coinciding peak in both regions, and the result is shown in Table 5-10.

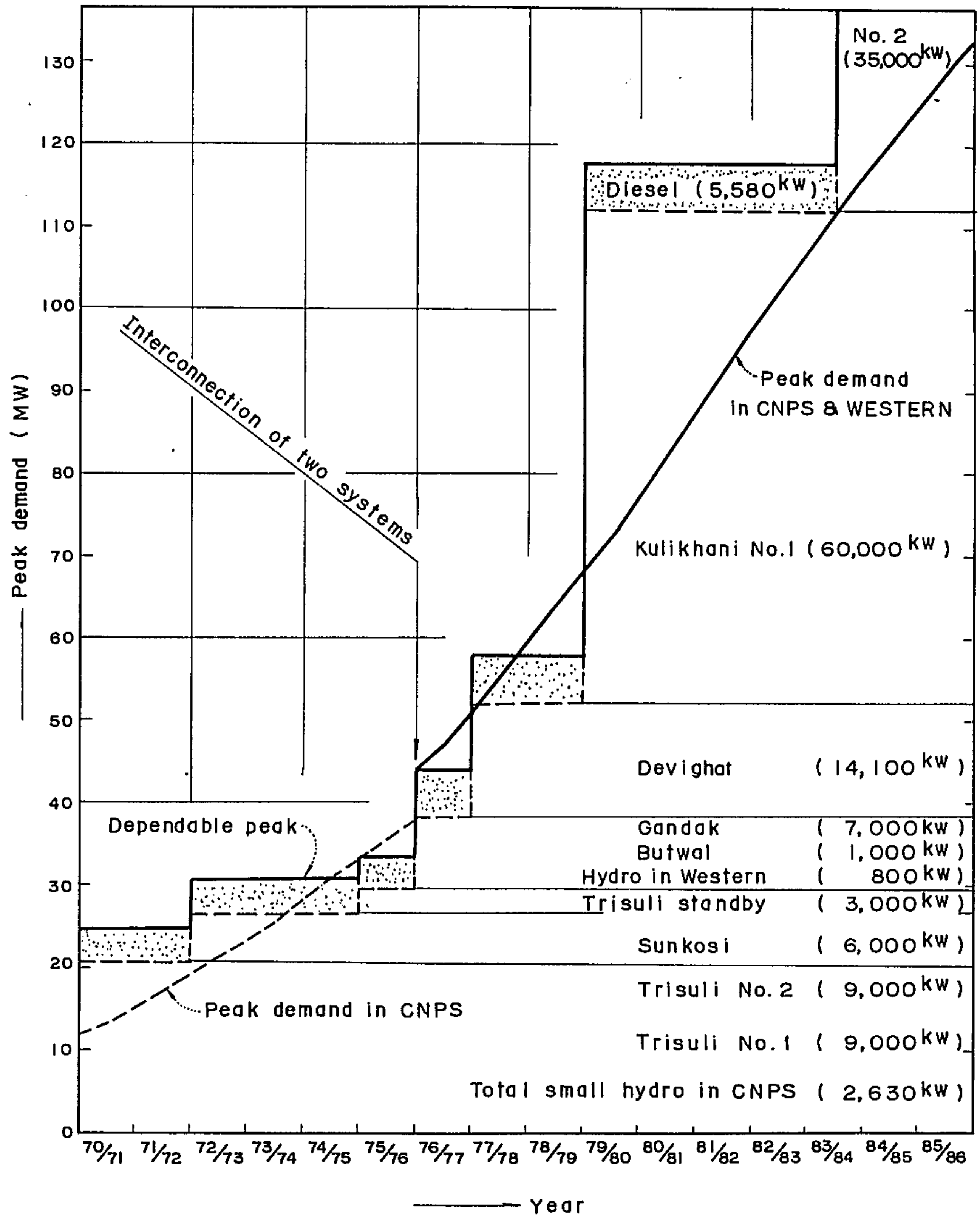
The estimated peak demand of CNPS, including the Western system in and after in 1975/76, is shown in Fig.5-6, which also indicates the kilowatt balance of the dependable peak capacity of the power system. As clear from the figure, Kulikhani No.1 power station will become necessary by the end of 1978/79 fiscal year.

TABLE 5-10 SUMMARY OF POWER DEMAND FORECAST & COMBINED DEMAND FORECAST

	Region Demand Forecast				Conbined Power Demand	
	Peak Demand (kW)		Required Energy (MWh)		Peak Demand	Energy
	Central Region	Western Region	Central Region	Western Region	kW	MWh
1972/73	21,200	1,620	76,650	5,700	21,200	76,650
73/74	25,400	2,430	91,460	8,500	25,400	91,460
74/75	30,600	3,110	107,810	10,900	30,600	107,810
75/76	36,500	3,920	132,660	14,500	40,430 *1	147,160 *1
76/77	42,500	4,700	155,820	17,300	47,200	173,120
77/78	49,500	5,710	190,720	22,100	55,210	212,820
78/79	57,700	6,730	219,020	26,000	64,410	281,500
79/80	65,000	7,780	282,320	34,100	72,780	316,420
80/81	73,500	8,950	322,000	39,200	82,450	361,200
81/82	82,400	10,190	360,000	44,600	92,590	404,600
82/83	90,500	11,960	398,000	52,400	102,460	450,400
83/84	97,700	13,690	428,000	60,000	111,390	488,000
84/85	105,500	15,340	462,000	67,300	120,840	529,300
85/86	114,000	17,010	497,000	74,500	131,010	571,500
86/87	123,000	18,750	535,000	81,500	141,750	616,500
87/88	133,000	20,680	575,000	88,500	153,680	663,500
88/89	143,700	22,710	618,000	96,300	166,410	714,300
89/90	155,000	24,300	666,000	105,000	179,300	771,000

Note: *1 Central and Western regions will be connected by a 132 kV transmission line under construction from Gandak to Hitaura in 1975/76.

FIG. 5-6 PEAK DEMAND AND PEAKING CAPABILITY IN CNPS AND WESTERN REGION



CHAPTER 6

PLAN FORMULATION

6.1 General

The Kulikhani project envisages a hydropower development by a series of three power stations on the Kulikhani and the Rapti river. The Kulikhani No.1 power station is located most upstream and is the first stage development of the entire Kulikhani project. The No.1 power station contemplates to generate hydroelectric power of 40,000-60,000 kW utilizing the annual average runoff of about 4-5 m^3/sec of the Kulikhani river and its tributaries after regulation by a reservoir and harnessing a water head of about 500-600 m obtainable by diverting the water to the Rapti river through a tunnel of about 5-6 km in length.

The studies on the basic project layout and development scale of the No.1 power station are set forth in this chapter.

6.2 Main Factors Affecting Project Planning

a) Expected supply and demand condition in future

Total installed capacity of the Central Nepal Power System (CNPS) is 39,280 kW at the end of 1973 which consists of hydro plants of 31,620 kW and diesel plant of 7,660 kW. However, almost whole power demand is presently met with hydro power, and operation of the diesel plants is limited only for emergency use and at the peak time of the dry seasons when the peak power demand cannot be met by the hydro-power. The Government of Nepal desires to maintain such operation of the system also in the future because of the high cost of diesel oil in this country.

All the existing hydro plants are of the run-of-river type with daily regulating capacity. The peaking capability as well as energy output of the power system drops in the dry season due to the shortage of available runoff. At the time when the Kulikhani No.1 power station is put into operation the total peaking capability of hydro plants in the system except the Kulikhani No.1 power station is expected to be 57,800 kW in the wet season, but be reduced to about 52,500 kW in the dry season, and also mean potential power output of 44,300 kW in the wet season will reduce to 33,500 kW in the dry season, as shown in Table 6-1. Besides, the average power demand in the CNPS is larger in the winter season corresponding to the early part of the dry season from December to March next than that in the rest of the year. Annual peak demand generally takes place in January or February. Both peak demand and energy demand averaged for 8 months from April to November are about 80 % of those averaged for the 4 months of winter season on an average. The Kulikhani No.1 power station should be planned so as to be most effective under the above existing and future power supply and demand condition in the system. The daily load factor will be about 60 % and the annual load factor be about 50 %, under which the Kulikhani No.1 power station will be operated.

b) Characteristics of the project

The project is characterized by a high head and a small discharge. Meanwhile, the construction of a tunnel of 5-6 km in length is required to divert the water to the Rapti river. A tunnel with inside diameter of less than about 2.5 m is considered to be difficult from the viewpoint of efficient and economical construction, which means that a tunnel with the minimum size will have a flow capacity of over 10 m^3/sec. This flow capacity will be too large, if the power plant be planned as an ordinary plant with a plant factor of 0.5-0.6 in view of the small available runoff. The effective utilization of the excessive capacity of the tunnel should be considered in planning.

6.3 Basic Project Layout

The basic layout and development scale of the project are determined as follows, taking account of the above conditions and factors.

a) Selection of damsite

At the time of the preliminary survey in 1963, two alternative damsites were considered and surveyed; one, the upper site, is located at a river bend near Burlchanr and the other, the lower site, is located about 100 m downstream from the suspension bridge at Kulikhani. The distance between these two sites is approximately 1 km.

TABLE 6-1 POWER SUPPLY CAPACITY OF EXTENDED CNPS

(Existing and Scheduled Additions)

Unit: (kW)

	Installed Capacity	Peak output		Firm output	
		Dry season	Wet season	Dry season	Wet season
(1) Diesel	9,456	5,576 /1	-	5,576 /1	-
(2) Hydro					
Pharping	500	400	500	200	500
Sundarijal	640	700 /2	700	600	700
Panauti	2,400	1,500	2,400	700	1,500
Trisuli	18,000	18,000	18,000	12,000	12,000
Sunkosi	10,050	6,000	10,050	4,700	10,050
Godawari	30	30	30	15	30
Pokhara	1,000	750	1,000	750	1,000
Butwal	50	50	50	25	50
Sub total	32,670	27,430	32,730	18,990	25,830
(3) Proposed hydro					
Trisuli standby	3,000	3,000	3,000	-	-
Gandak	15,000	7,000	7,000	3,500	7,000
Butwal	1,000	1,000	1,000	500	1,000
Devighat	14,100	14,100	14,100	10,500	10,500
Sub total	33,100	25,100	25,100	14,500	18,500
Grand total (1) + (2) + (3)	75,226	58,106	57,830	39,066	44,330
Total of hydro (2) + (3)	65,770	52,530	57,830	33,490	44,330

/1: (Total installed capacity - one largest unit) x 0.7
= (9,456 - 1,490) x 0.7 = 5,576 kW

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

As the result of the studies in 1969, the upper site was abandoned due to the reason that the construction of a dam higher than 56 m is not possible at the site owing to the topographic condition and the storage capacity of about 20 x 10^6 m^3 obtainable at the site is far less than the required storage capacity for the project of at least more than 60 x 10^6 m^3, while, at the lower site, the construction of a dam higher than 100 m is possible and a storage capacity of more than 80 x 10^6 m^3 can be secured.

The study on the lower site was continued in subsequent years. Seismic explorations and test drillings performed from 1973 to 1974, revealed that the foundation rock on the right bank of the lower site was intensively fractured to the depth of some 50 m. To avoid the dam foundation resting on the fractured portion, the right bank abutment of the dam was shifted upstream for about 50 m making the dam axis diagonal to the river channel.

b) Intake of tributary runoff

As stated in Section 6.2. (b), this project is characterized by very high available head and small available runoff, besides, the tunnel has to be constructed in larger size than necessary being restricted by the minimum size for construction. In order to take advantage of the high available head to the utmost extent as well as to utilize the allowance in the flow capacity of the tunnel effectively, the runoff of the tributaries in the vicinity is desirable to be collected and used for power generation as much as possible. The conceivable tributaries are the Chakhel and the Sim.

The pressure tunnel will pass under the Sim about 1.6 km downstream from the intake. The runoff of the Sim can be fully taken into the pressure tunnel with 13.1 m^3/sec capacity only by constructing simple structure of intake shaft. The intake of the water of the Sim is decided because it is advantageous without doubt. In order to collect the water of the Chakhel, the construction of an intake weir on the Chakhel and a connecting tunnel of about 2.3 km in length to the reservoir is necessary. Since the proposed size of tunnel has a flow capacity of over 3 m^3/sec, most of the runoff of the Chakhel is led to the reservoir.

The intake of the water of the Chakhel is decided because the economic study proves it also advantageous. Therefore the discharge available for power generation is determined as a sum of the runoff of the Kulikhani itself, the Chakhel and the Sim.

c) Waterway alignment and site and type of power station

A pressure tunnel of more than 5 km in length will be needed to divert water of the Kulikhani basin to the Rapti basin. This water diversion will create a head of about 600 m for power generation. The alignment of the tunnel is so determined as to be apart from the fault running from Chaisapani to Deorali by several hundred meters, and at the same time to secure a sufficient rock covering, more than 30 m in depth, for almost its entire section. The convenience to provide an access adit to facilitate tunnel construction is also taken into account before arriving at the final alignment of the tunnel.

As to the power station layout, an underground type power station is selected from the following considerations.

- The construction of an underground power station is technically feasible in view of the geological conditions of the proposed site.

- More head will become available in the underground layout compared with the open power house layout.

- The underground type will be safer than the open type which is subjected to the danger of surface erosion or possible collapse of the mountain slopes.

The tailwater level is determined at EL. 916 m, releasing water to the Mandu river, a tributary of the Rapti river. Water release to the Rapti river is avoided because the river is wild and unstable. The arrangement to release water to the stable Mandu river is easily made by the adoption of an underground power station through a tailrace tunnel of about 1 km in length.

6.4 Determination of Development Scale

In selecting optimum development scale, i.e. dam height and installed capacity of the power station, an economic comparison was carried out by the following procedure on the basis of the basic project layout.

1) For the economic comparison, the four development scales with different high water levels are selected, i.e., EL. 1520 m, EL. 1525 m, El. 1530 m, and EL. 1535 m, respectively.

2) The reservoir operation study, estimation of power and energy output for each case of development is made by using runoff mass curve for the period of 10 years from 1963 to 1972, which is prepared from monthly runoff data for the same period, as a sum of the runoff of the Kulikhani, the Chakhel and the Sim as shown in Tables 4-7, 4-8 and 4-9.

3) In consideration of effective use of the river flow for power generation in ordinary years, the installed capacity for each case of development is decided based on the available controlled flow in the second driest year on the above mass curve (standard runoff year) instead of that in the driest year, allowing some power shortage in the driest year. The expected power shortage, however, is to the extent of about 20 % of the power generation of the standard runoff year in the system and probability of its occurrence is only once in ten years. Such extent of power shortage can be easily overcome by power saving or by the operation of diesel plants without any significant adverse effect on the economy in the CNPS area.

4) The power demand in the system is larger in the dry season than in the wet season, besides, the power supply capacity of the existing hydroplants drops in the dry season. Thus the portion of the system load to be met by the power from the Kulikhani No.1 power station (system load allotted to the power station) is much larger in the dry season, both in peak power and energy, than in the wet season. The system load allotted to the power station in both dry and wet seasons can be determined for each case of development, respectively, based on the power supply capacity of the CNPS and the power demand condition in the year when the power station comes into full operation.

Out of the power generated by the power station, power in conformity with the system load allotted to the power station is regarded as primary power which is consumable in the system and power in excess of the system load allotted to the power station is regarded as secondary power. One half of secondary energy is assumed to be exportable to India.

5) For assessment of the project benefit, the dependable peak power and primary energy are evaluated based on the cost of the most economical alternative means conceivable. The alternative considered is a coal-fired thermal plant with a unit capacity of 30,000 kW. The unit capacity value and energy value thus estimated are US$73/kW and US mill 20/kWh, respectively. On the other hand, the secondary energy to be exported to India is evaluated conservatively at US mill 12/kWh, in consideration of energy cost in India and other relevant factors. The annual project benefit is assessed applying these unit values to the available power and energy. Details of evaluation of the unit power values are shown in Section 9.2.

6) The annual project cost is assessed from the total construction cost and operation, maintenance and replacement cost under the condition of an annual discount rate of 8 % and a project life of 50 years.

7) The annual net benefit which is the annual project benefit less the annual project cost and the benefit-cost ratio are used as the measure for economic comparison of each case of development.

The summary of the economic comparison is shown in Table 6-2. The economic comparison shows that the development with the reservoir high water level of EL. 1,530 m and installed capacity of 60,000 kW offers the largest net benefit and highest benefit-cost ratio, which should be selected as the optimum development scale of the project.

6.5 Ecological Aspects

(1) Resettlement

The Kulikhani river is presently a suitable habitat of fishes. People are settled along the river, engaging in agriculture, i.e.,

TABLE 6-2 SUMMARY OF ECONOMIC COMPARISON

Item	Case I	Case II	Case III	Case IV
(1) H.W.L. (m)	EL. 1520	EL. 1525	EL. 1530	EL. 1535
(2) Effective Storage (x 10^6 m^3)	52.9	62.5	73.3	85.5
(3) Construction Cost (x 10^3US$)				
Direct Cost	34,420	36,740	39,080	42,610
Indirect Cost	11,180	12,060	13,920	15,090
Sub total	(46,600)	(49,800)	(53,000)	(57,700)
Interest	5,960	6,370	6,780	7,390
Total	52,560	56,170	59,780	65,090
(4) Annual Cost (x 10^3US$)				
Capital Cost	4,300	4,590	4,890	5,320
OM & R Cost	360	360	360	360
Total	4,660	4,950	5,250	5,680
(5) Peaking Capacity (kW)	51,900	56,800	60,000	62,600
(6) Annual Energy (x 10^6 kWh)				
Primary	127	148	165	175
Secondary	76	59	46	39
(7) Annual Benefit (x 10^3 US$)				
Capacity Benefit /1	3,790	4,150	4,380	4,570
Energy Benefit /2	3,000	3,310	3,580	3,730
Total	6,790	7,460	7,960	8,300
(8) Benefit-cost ratio	1.46	1.51	1.52	1.46
(9) Annual net benefit (x 10^3 US$)	2,130	2,510	2,710	2,620

/1 Capacity value is US$73/kW under the dicount rate of 8 %.

/2 Energy value is US mill 20/kWh for the primary energy and US mill 12/kWh for half of the secondary energy.

rain-fed cultivation of the riverside flat lands and livestock breeding.

The proposed Kulikhani reservoir will inundate the area of about 220 ha, of which the cultivated land is about 150 ha. In the area to be inundated, there is no noteworthy infrastructures, mineral and forestry resources nor matters of archaeological interest. Several hundreds of inhabitants will need to be resettled. It will be essential to prepare a detailed resettlement plan, primarily to ensure that the resettled population can earn a living under conditions at least equal to those now existing. The preparation of this plan will be the responsibility of the Electricity Department of the Ministry of Water and Power, Government of Nepal, cooperated with other relevant government authorities. This plan should contain a proper compensation to the reparian people in the downstream Kulikhani river who will suffer from the shortage of water for domestic use in the dry season since the Kulikhani dam is not planned to release water downstream in the dry season. Such reparian people will have to shift domestic water source to small tributaries or brooks nearby, because the groundwater table is deep and difficult to extract.

(2) Watershed erosion

In 1963, a field survey in respect to the surface erosion conditions of the Kulikhani basin was made by Japanese experts and the results are compiled in Appendix II of the Preliminary Design Report on the Kulikhani Project prepared by Overseas Technical Cooperation Agency of Japan in November 1963. According to the report, the erosion in the Kulikhani basin is not active in the upper reach of the river and the devastation of the Kulikhani basin is much less than that of the Rapti basin where far more collapse and quantity of materials deposited on the river bed is observed than in the Kulikhani basin.

The erosion of the mountain slopes in the Kulikhani catchment area is considered not intensive but moderate. However, the forestation of the area will be recommendable to reduce sediment discharges, because the mountain slopes are not covered with thick vegitation at present.

(3) Health

The major health problem will be malaria which, if not combatted, could seriously affect the health of persons migrating to the dam during its construction and the inhabitants of the area thereafter. Malaria and other diseases, however, may be controlled through adequate health services and eradication programs.

(4) Aquatic plants

The excessive growth of aquatic plants, which may be a potential problem to reservoir management, will probably not take place since the area is not located in a tropical area. This problem, if happens to arise, may be mitigated by mechanical, chemical or biological control. Since the water of the Kulikhani river is suitable for fish growing, fish farming may be positively considered in the Kulikhani reservoir not only for fisheries but also for a biological control of aquatic weeds.

(5) Tourism

A positive benefit likely to result would be related to tourism or recreation since the damsite is only 30 km apart from Kathmandu, and the project will create a large reservoir in Nepal for the first time.

6.6 Definite Plan

The optimum development scale of the Kulikhani No.1 power station is determined as a plan with an installed capacity of 60,000 kW and the reservoir high water level of EL. 1,530 m, as described in the previous section. The No.1 power station will be operated in combination with the existing and scheduled additions of power supply facilities to meet the system power demand most effectively.

A dam of 107 m in height will be constructed on the Kulikhani river to create a reservoir with the effective storage capacity of 73×10^6 m^3, which regulates the runoff of the Kulikhani river from a catchment area of 126 km^2 and the runoff of the Chakhel, a tributary of the Kulikhani river, from a catchment area of 23 km^2, to be led to the reservoir through a leading tunnel of 2 km in length. Regulated water will be taken from the reservoir and be diverted to the Rapti river through a pressure tunnel of about 5.8 km in length. The runoff of the Sim, another tributary of the Kulikhani river with a catchment area of 7 km^2, is to be pushed into the pressure tunnel through a vertical shaft of 90 m in height. The increased discharge will be further led through a penstock line of 1.3 km in length into the power station of underground type and generate power utilizing a gross head of 614 m to 560 m to be made available by water diversion. The tailrace discharge will be released to the Mandu river, a tributary of the Rapti river, through a tailrace tunnel of about 1 km in length.

The firm continuous discharge is planned to be 6.2 m^3/sec averaged for the dry season from January to April, 2.1 m^3/sec in the wet season from June to November and 4.2 m^3/sec for transition months of May and December, resulting in an annual averaged firm discharge of 3.82 m^3/sec. This firm discharge is derived from a mass curve analysis, taking the second driest year of 1968 to 69 out of the total analysis period of 10 years from 1963 to 1972. The annual primary energy is calculated to be 165 x 10^6 kWh from the firm discharge of 3.82 m^3/sec in terms of an annual average.

The average usable discharge is 4.93 m^3/sec excluding the evaporation loss. The balance between the usable discharge and the firm discharge will be able to generate the secondary energy minimizing the waste of water by spillout. The secondary energy calculated from the mass curve as the difference between the gross energy and the primary energy is 46 x 10^6 kWh per annum on an average.

The peaking capability is 60,000 kW when a reservoir water level maintains above the rated water level of EL. 1,510.5 m, but drops to 56,600 kW when the water level draws down to the reservoir low water level of EL. 1,476 m. According to the past data on monthly peak demand, the annual peak demand is observed to take place in the early part of the dry season, from December to February. The reservoir water level is expected to be maintained above the rated water level during the early part of the dry season and, therefore, it may be allowed to take the dependable peak output of the Kulikhani No.1 power station as 60,000 kW.

The mass curve and the recommended pattern of water use for power generation are shown in Fig. 6-1, based on the tentative reservoir operation rule as follows.

(1) The firm discharge, 6.2 m^3/sec for the dry season from January to April, 2.1 m^3/sec for the wet season from June to November and 4.2 m^3/sec for the transition months of May and December, is secured as far as the reservoir capacity permits.

(2) During the high flow period of the Kulikhani river, from July to October, water is used as much as possible to minimize the energy loss through spillout of water, as far as the reservoir high water level is recovered to the high water level at the end of the high flow period.

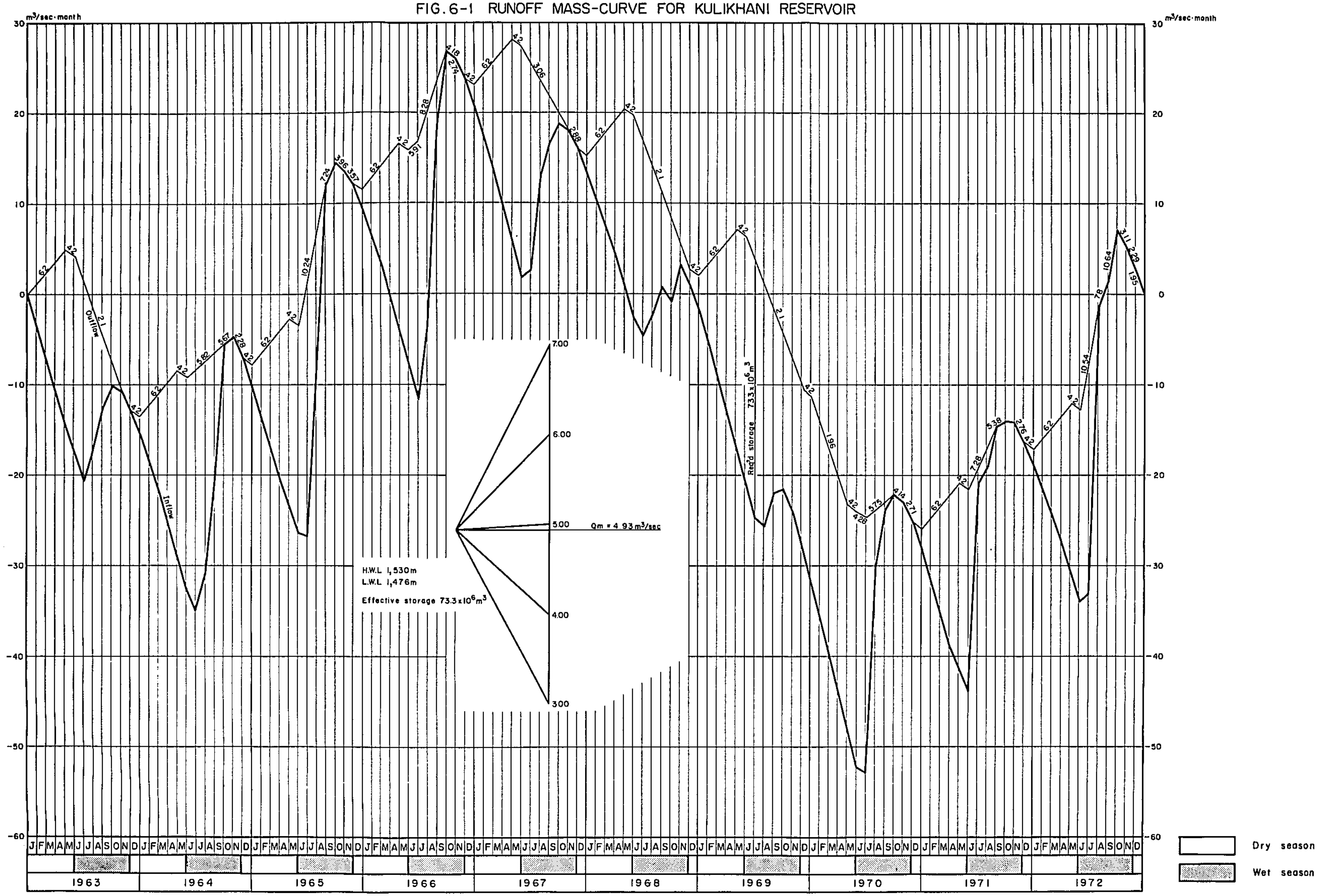
The proposed water use pattern that much more water is used in the dry season than in the wet season is preferable not only to the Kulikhani No.1 power station but also to the Kulikhani No.2 power station. Limited tailwater discharge of the No.1 power station in the wet season is supplemented by abundant natural runoff of the Rapti, Mandu and Rani rivers. Consequently, a fairly constant discharge will become available throughout the year and will be effectively utilized for power generation by the Kulikhani No.2 power station of a run-of-river type.

The proposed power generation plan is summarized in Table 6-3.

There will exist hydropower plants of run-of-river type with a total installed capacity of 57,800 kW, when the Kulikhani No.1 power station is put into operation. Some of these run-of-river type power plants have a potential to generate more energy, especially in the wet season, than the energy actually consumed. This potential is expected to be fully utilized by the introduction of the Kulikhani No.1 power station which is to be operated at a low plant factor allowing the run-of-river type power plants to generate energy at their full potential.

Such additional energy to become consumable owing to the operation of the Kulikhani No.1 power station is estimated to be 97 x 10^6 kWh per annum as shown below.

FIG. 6-1 RUNOFF MASS-CURVE FOR KULIKHANI RESERVOIR



(1) Annual consumable energy without Kulikhani P.S.

Peaking capability in the dry season

Hydro plants	52,530 kW
Thermal plants	5,580 "
Total	58,110 kW

Annual firm output

Annual load factor	50 %
Firm output	29,060 kW

Annual consumable energy

29,060 kW x 8,760 hrs = 255 x 10^6 kWh

(2) Potential energy of run-of-river type hydro plants

Dry season (Ref. to Table 6-1)

33,490 kW x 4 months x 730 hrs = 98 x 10^6 kWh

Wet season (Ref. to Table 6-1)

44,330 kW x 6 months x 730 hrs = 194 x 10^6 kWh

Transition period (Average of dry season and wet season)

38,910 kW x 2 months x 730 hrs = 57 x 10^6 kWh

Total potential energy 349 x 10^6 kWh

(3) Annual consumable energy with Kulikhani P.S.

Peaking capability	118,110 kW
Annual load factor	50 %

Consumable energy

118,110 kW x 0.5 x 8,760 hrs = 517 x 10^6 kWh

(4) Annual energy output with Kulikhani P.S.

Run-of-river type hydro plants	349 x 10^6 kWh
Kulikhani No. 1 P.S.	165 x 10^6 kWh
Thermal plants	3 x 10^6 kWh
Total energy output	517 x 10^6 kWh

(5) Energy increase attributable to Kulikhani P.S.

517 x 10^6 kWh - 255 x 10^6 kWh = 262 x 10^6 kWh

(6) Energy of run-of-river type hydro plants to be made consumable by Kulikhani P.S.

$$262 \times 10^6 \text{ kWh} - 165 \times 10^6 \text{ kWh} = 97 \times 10^6 \text{ kWh}$$

Table 6-3 PROPOSED POWER GENERATION PLAN OF THE KULIKHANI NO. 1 P. S.

Hydrology	
Annual mean discharge	4.98 m^3/sec
Evaporation loss	0.05 "
Mean usable flow	4.93 "
Reservoir	
Gross storage capacity	85.3 x 10^6 m^3
Net storage capacity	73.3 x 10^6 m^3
Discharge	
Firm discharge	
Wet season (Jun. - Nov.)	2.1 m^3/sec
Dry season (Jan. - Apr.)	6.2 "
Transition period (May & Dec.)	4.2 "
Annual average	3.82 "
Maximum discharge	13.1 "
Head	
High water level	EL. 1,530 m
Low water level	EL. 1,476 m
Tailwater level	EL. 916 m
Gross head	614 m - 560 m
Annual averaged water level	EL. 1,510.5 m
Average gross head	594.5 m
Average effective head	590.7 m
Rated water level	EL. 1,510.5 m
Rated head	549.9 m
Installed Capacity	60,000 kW
Dependable Peak Output	60,000 kW
Annual Energy Output	
Firm output	18,750 kW
Primary energy output	165 x 10^6 kWh
Gross energy output	211 x 10^6 kWh
Secondary energy output	46 x 10^6 kWh

CHAPTER 7

DESIGN AND CONSTRUCTION PLAN

7.1 General

On the basis of the basic layout determined in the previous chapter, the preliminary design is prepared. According to the basic layout, the project includes constructions of the Kulikhani dam of 107 m in height, an intake waterway including penstock line of about 7.1 km in length. an underground power station with installed capacity of 60,000 kW, about 1.0 km long tailrace tunnel, the Chakhel intake weir and about 2 km long connecting tunnel, the Sim tributary intake, about 0.2 km long 66 kV transmission line to tap the existing 66 kV line between Hitaura and Kathmandu and the extension of the existing substation in Kathmandu by 70 MVA.

Based on a topographical map of 1 to 1,000 in scale with 2-m contour for the damsite and maps of 1 to 10,000 in scale with 10-m contour for the reservoir area, waterway, power station and other structure sites, a preliminary design of each structure is made as set forth in this chapter. /1

7.2 Design of Project Works

7.2.1 Kulikhani Dam and Reservoir

The proposed damsite for the Kulikhani dam is situated on the Kulikhani river about 16 km upstream from its confluence with the Bagmati river. The Kulikhani reservoir will have a gross storage capacity of 85.3×10^6 m^3 of which active storage capacity is 73.3×10^6 m^3, with the normal high water level of EL. 1,530 m, the low water level of EL. 1,476 m and the drawdown of 54 m.

(1) Geology of the Kulikhani Damsite

The foundation rock of the Kulikhani damsite is composed of sandy semi-shist, biotite schist, and phyllite, strongly bedding with common strike of NW25 - 30° and dip of 30° - 40° NE. The geological map of the damsite is shown in DWG. No.7. The dam axis proposed in the preliminary

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/1 These topographic maps were prepared in 1972/73 based on the aerial photographs and the ground control surveys, under the Agreement between Electricity Department of HMG of Nepal and Nippon Koei.

design report is shown as the axis 0-0 in Fig. A-1-2. Along the dam axis, the river width is about 50 m and the right bank rises at an inclination of 1:1.2 to 1:1.7 and is extensively covered with talus deposit composed of earth and rock fragments, whereas the left bank forms a very steep cliff inclining at 1:0.3 to 1:0.6 up to EL. 1,530 m where rock bed is widely cropped out. Along the section about 150 m upstream from the dam axis, on the right bank, overburden is thinner and rock is better exposed in the lower parts, and on the contrary some talus is formed on the lower parts of the left bank.

According to the results of seismic exploration and test drilling, the condition of rock underneath the talus deposit on the right bank along the dam axis 0-0 is very weak to the depth over 45 m. Rocks appear intensively fractured, and the irregularity of dips including horizontal foliation is suggestive of the fracture due to old sliding. The thickness of the fractured layer decreases to the upstream side and it is 20 - 25 m at the site about 140 m upstream from the axis 0-0.

At the top of the cliff on the left bank along the axis 0-0, top soil and decomposed rock shows 20 m of thickness and underlying rock is fairly solid. In view of stable rock exposure below EL. 1,530 m, no problem is seen for the left bank.

The proposed type of dam is a rockfill dam with inclined earth core as decided in the next paragraph. In consideration of the geological condition of the damsite stated above, the axis of dam is selected as line B-B shown in DWG. No.7, shifting the right bank abutment about 100 m upstream from the previous axis 0-0, in order to avoid extremely deep excavation to set the foundation of impervious core zone on firm rock.

According to the results of the water pressure tests carried out in the bore holes in the talus area on the right bank, water leakage is large even in the r ock bed below fractured layer.

River deposit at the damsite ranges from 2 m to 6.5 m and biolite schist underlying the river deposit is partly sheared and weakened to about 13 m of depth.

(2) Design of Dam

In view of the geological condition at the damsite stated in the preceding paragraph, the only conceivable type of dam at the site is a filltype dam. As to the embankment material, rock material is obtainable in sufficient amount in the vicinity but the available amount of earth material is limited and is not sufficient to construct an earth dam as stated in the next paragraph. In view of the availability of embankment material, a rockfill dam with inclined earth core is selected as the type of dam at the site. The inclined core type is adopted because the type requires less excavation than the center core type to set the foundation of the core portion on the firm rock under the geological condition at the damsite.

The maximum height of dam above the river bed is about 107 m and the crest length is 420 m. The crest elevation of the dam is set at EL. 1,534 m securing a free board of 4 m above the normal high water level.

The dam will be a zoned rockfill dam, consisting of an inclined core zone, filter zones and quarry run rock zones in which grain size of the material changes gradually from coarse to fine toward the inside. The typical section of the dam is shown in DWG. No.6. The total embankment volume is 3,500,000 m^3 of which rock portion is 2,620,000 m^3, filter portion, 420,000 m^3 and core portion, 460,000 m^3.

Deep excavation to 20 m or partly 30 m of depth will be require especially on the right bank for the foundation of impervious core zone, to remove the overlying fractured rocks. Intensive grouting of at least some 30,000 m in hole length has to be planned for cut-off curtain in anticipation of about 70 m of each hole length at 1 meter's spacing plus 50 % of additional grout holes, considering the thickness of highly pervious rock zone.

(3) Embankment material of dam

Rock

The rock material for the dam embankment can be obtained as required from the proposed quarry site at the granite mountain slope located on the right bank of the Kulikhani river approximately 500 to 800 m downstream from the damsite as shown in DWG. No.3. There is extensively exposed massive granite and weathering is not intensive in the lower part of the slope.

Earth

The required volume of earth material is about 500,000 m^3. It is considered difficult to obtain sufficient quantity from a single borrow pit due to the lack of large deposit area. Some 150,000 m^3 of earth material is expected on the slope of the right bank of the damsite. Nearly the same quantity is expected from each of such sites as the slope behind a village on the left bank just upstream of the damsite, the saddle ridge about 1 km east of the damsite and the staged farm on the slopes near Burlchanr about 1.5 km upstream of damsite and in Purauagaon downstream. The location of these borrow pits are shown in DWG. No.3. The total volume expected is about 600,000 m^3. The samples taken from the slope of the right bank of the damsite were tested in the laboratory in 1967 and the results of the tests proved the material is suitable for core material. The material at other sites are not tested but from the visual and tactile observations, they are judged to be not much different from the material tested and considered also suitable for core material.

Filter material

The required quantity of filter material for the dam is about 400,000 m^3. Sand and gravel deposit in the river bed is not expected as the source of filter material for the reason that; (1) many boulders over 1 m of diameter contained in the Kulikhani river deposit makes it extremely difficult to collect sand and gravel of appropriate grading, and (2) the range of collecting area will extend over 6 km of length along the river because of the narrowness of the river bed and the difficulty of deep excavation due to river water and large boulder content. Therefore the filter material will be produced by crushing granite in the condition as intensively weathered as possible. With this in view, the source of the filter is selected on the north-eastern slope of Deorali which is approximately 1.5 km from the damsite and is the nearest weathered granite area from the damsite.

(4) Spillway

Spillway will be constructed on the left bank. At the site, surface layer of the base rock is intensively weathered or cracked for about 10 m in depth at entrance portion and end portion, the talus deposits of 5 m to 10 m in thickness exist on the weathered rock zone. The rock underneath those layers is fresh and sound.

The spillway is overflow chute type equipped with gates. The overflow crest is fixed at EL. 1,519 m, where the two radial gates, 11 m high and 9 m wide, will be installed. The chute way narrows its width from 20.5 m to 15 m along its route of 210 m. A flip bucket is provided at the lower end of the chute way.

The peak discharge of the design outflow flood is determined at 1,300 m^3/sec by taking 20 % allowance to the 100-year flood. The spillway is designed to discharge the design flood of 1,300 m^3/sec under the condition that the reservoir water level is at the high water level of EL. 1,530 m and the spillway gates are fully open. By allowing the reservoir water level to rise to EL. 1,531.5 m, the spillway is able to discharge the extraordinary flood with peak outflow of 1,560 m^3/sec safely.

For the inflow flood with a peak discharge of 2,330 m^3/sec as derived from the Creager's equation in Section 4.5, the spillway will be critically safe, allowing the maximum water level of EL. 1,532.7 m and the peak spillway outflow of 1,880 m^3/sec with the aid of retardation effect of the surcharge of the reservoir above the high water level, as shown in Fig. A-2-8 of Appendix II.

The construction of the spillway requires a deep cut and a large volume of rock excavation, but large portion of the excavated rock can be used as embankment rock material of the dam. The details of the design of the spillway are shown in DWG. No.5 and No.6.

7.2.2 Waterway

(1) Intake

The intake will be located on the right bank about 200 m upstream from the dam. It consists of a bellmouth entrance structure, inclined gate shaft and transition section which is connected to the pressure tunnel. The entrance structure will be equipped with fixed trash racks and the elevation of the entrance sill will be set at EL. 1,471 m, 1 m above the expected silt deposit surface. The entrance structure is designed so that the inflow velocity will not exceed 0.5 m/sec even when the maximum discharge of 13.1 m^3/sec is taken. For closing the pressure tunnel, an inclined roller gate, 5 m high and 3 m wide, is equipped at the end of the intake structure, which will be operated by hoisting machine through the inclined gate shaft. Considering the difficulty in estimating sedimentation, such measures as a stop-log structure may be desirable in front of the intake entrance to protect the intake from being subjected to a possible silting.

(2) Headrace tunnel

The headrace tunnel of 5,800 m in length will pass through slaty rocks and sandstone-slate alternation for the upstream portion of 600 m, then through granite for the middle portion of 2,400 m, and through metamorphosed sedimentary facies consisting mostly of sandstone and quartzite for the downstream portion of 2,800 m.

In the upstream 600 m section where the tunnel route is near to the fractured layer on the right bank of the damsite, heavy support will be required for tunnel excavation. In the middle section of 2,400 m, any problem will not be encountered considering the sufficient depth of rock cover and massive structure of the granite rock. In the downstream portion of 2,800 m, also no problem will be expected except in the downstream-most portion near the outlet and the surge tank where the tunnel may cross a fault and heavy support will be necessary for excavation in a length of about 300 m.

The headrace tunnel is a pressure tunnel with circular cross section. The inside diameter of the tunnel is determined at 2.5 m which is the practical minimum size in consideration of economical and effective construction. A tributary intake will be provided at about 1,600 m downstream from the intake to take water of the tributary Sim into the tunnel. The total length of the tunnel is 5,800 m. The tunnel will be divided in two divisions for construction by two adits, i.e., the first division of 1,600 m and the second division of 4,200 m. The longitudinal profile of the tunnel is determined in consideration of easy drainage during the construction and the hydraulic gradient of the tunnel, i.e., the base slope for the portion from the intake to the Sim tributary intake will be 1 to 300, that from the Sim intake to the point 2,100 m therefrom 1 to 2,000 and that for the rest upto the surge tank 1 to 300.

(3) Surge tank

The surge tank will be a chamber type surge tank, consisting of the upper, lower and middle chambers and a surge shaft. The upper chamber will be a circular tank which has a sufficient capacity to allow the instantaneous full load rejection under the condition that the reservoir water level is at the high water level. The lower chamber will be two circular tunnels which has a sufficient capacity to allow the instantaneous load increase from half to full under the condition that the reservoir water level is at the low water level. The middle chamber will be provided between the upper and lower chambers to prevent excessive fluctuation of water level in the surge shaft.

(4) Penstock line

Penstock line is situated on the sandstone above EL. 1,300 m or so, and on and in the sandstone and schist alternation below the above elevation. The rock is covered by a few meters of talus deposit. Generally the sound rock condition is expected except at the top of slope where a fault line is supposed in the close distance.

A single lane of steel pipe with flow capacity of 13.1 m^3/sec will be installed between the surge tank and power house. The total length of penstock line is 1,335 m, of which for the upper and lower portions of 170 m and 255 m respectively, the pipe will be installed in penstock tunnels and for middle portion of 910 m, on the ground.

The penstock pipe will be equipped with a butterfly valve at the end of the upper penstock tunnel and it bifurcates at immediate upstream of the power house by spherical branch for the two turbines.

The inside diameter of the pipe is designed to decrease gradually downstream wards from 1.9 to 1.25 m as a result of economic calculation.

The lower penstock tunnel is designed with a larger size than necessary to install penstock pipe, and will be commonly used as a power cable duct and access tunnel to the underground power house for construction and maintenance, and ventilation.

(5) Tailrace tunnel

The tailrace outlet will be located at the left bank of the Mandu river about 500 m upstream from its confluence with the Rapti river. The tailrace tunnel of about 1.0 km in length will be constructed between the underground power station and the outlet site.

The tunnel route passes through sandstone and schist alternation in the upper two-third length and then passes through solid sandstone beds, dipping northeast. Though the rock beds form a wing of folding in this part, any serious disturbance is not observed at the outcrops on the ground surface.

The tailrace is a free flow concrete lined tunnel with horse shoe shape cross section with inside height of 2.6 m and inside width of 3.3 m. The base slope of the tunnle is 1 to 1,000.

(6) Sim tributary intake

The Sim river, a tributary of the Kulikhani river crosses the headrace tunnel at the site about 1.6 km downstream from the intake. The Sim tributary intake will be constructed at the site about 0.9 km upstream from its confluence with the Kulikhani river to take runoff of the river from the catchment area of about 7 km^2 into the headrace tunnel. The intake structure consists of an intake weir, an inlet, a settling basin and a vertical shaft. The intake weir is a 20 m long and 6 m high concrete weir. Elevation of its overflow crest will be set at EL. 1,548 m. Water taken in from the inlet constructed immediately upstream from the intake weir will be desilted through the settling basin, then led to the headrace tunnel through the vertical shaft.

(7) Chakhel tributary intake and connecting tunnel

The chakhel river is also a tributary of the Kulikhani river, which joins with the main stream at the site about 5 km downstream from the Kulikhani damsite. The Chakhel tributary intake is located at about 3.5 km east from the Kulikhani damsite and its catchment area at the site is about 23 km^2. The Chakhel intake structure consists of an intake weir, an inlet and a settling basin. The intake weir is a 58 m long and 12 m high concrete weir. Elevation of its overflow crest will be set at EL. 1,534.3. Water taken in from the inlet constructed immediately upstream from the intake weir will be desilted through the settling basin, then led to the Kulikhani reservoir through a connecting tunnel. The connecting tunnel is about 2 km in length. The tunnel is a free flow tunnel with hemicycle-rectangular cross section with inside height of 1.8 m and inside width of 1.8 m.

7.2.3 Power House and Switch Yard

The power station will be of underground type, which will be located 1.5 km northeast from the confluence of the Mandu river with the Rapti river and 300 m below the ground surface.

The proposed underground power station site is situated among the alternating sandy semi-schist, sandstone, biotite schist and slate. Sandy rocks are hard to moderately hard in general. Biotite schist and slate are moderately hard and rather friable with intensive foliation. The beds show strike trending NW-SE and dip of 30° to 40° to NE in the southern part and to SW in the northern part, which suggests the existence of gently warping syncline. Nevertheless, this proposed site is more stable than the other alternatives in the eastern area where the change of strike and dip is more frequent.

The inside dimensions of the power house will be 43 m in length, 14 m in width and 26.2 m in height, so as to house two units of 30,000 kW hydro-turbine generator.

Each turbine will be of vertical-shaft pelton type with four jets, and will generate the rated output 30,600 kW under the rated head of 550 m and rated discharge of 6.55 m^3/sec. The rated speed will 600 revolutions per minute. The generators will be 3-phase vertical-shaft revolving-field type and rated at 35,000 kVA. The generators will be directly coupled with the water turbines.

Two units of main transformers will be 3-phase, forced-oil-circulation, forced-air cooled type rated at 35,000 kVA and the high voltage windings will have provisions for use of 66 kV or 132 kV system. The transformers will be installed in the outdoor switchyard on the terrace near the entrance of the lower penstock tunnel.

The generator voltage of 11 kV will be stepped up to transmission voltage of 66 kV, 132 kV in the future stage, and the generated power will be connected with 66 kV transmission lines at the outdoor switchyard.

The power and control cables will be installed in the lower penstock tunnel to connect the power house with outdoor switchyard. This power station will normally be operated from the control room in the outdoor switchyard without operator attendance in the power house.

7.2.4 Transmission Lines and Substation

The existing 66 kV double circuit transmission line between Kathmandu and Birganj via Hitaura will be utilized to transmit the generated power at Kulikhani No.1 power station. However, a new 132 kV transmission line will be required after the completion of No.2 power station. For connecting the outdoor switchyard with the existing line, a branch line of about 200 m long will be newly installed.

Two sets of 35,000 kVA transformer will be newly added at the existing substation at Kathmandu.

7.3 Construction plan

7.3.1 Preparatory Works

Prior to the commencement of the main work, substantial preparatory works are required, such as construction of access roads, water and power supply for construction and camp use, communication system, offices and camps.

(1) Access road

The existing road, 6-m wide sealed highway running between Kathmandu and the Indian border and 5-m wide gravel road about 10 km long branching from the highway at Bhainsedobhan is available as an access to the proposed power station site. However, the gravel road including bridges is required to be improved to enable transportation of heavy construction machinery and generating equipment and to allow regular traffic in all weather.

The working roads with a width of 5 m and a total length of 5 km will be constructed to each working areas, such as the quarry site, borrow areas, working adits for headrace tunnel, etc.

Further, the new road about 20 km long from the proposed power station site to the proposed dam site will be constructed with a width of 5 m.

A temporary bridge will be constructed across the Kulikhani river about 500 m downstream from the proposed dam site.

(2) Power supply

The electric power for construction and camp use will be taken from the existing 66 kV transmission line. A temporary substation will be installed on the line and the construction power will be supplied there from by 6.6 kV line.

The peak power requirement is estimated at 2,100 kW and the installed capacity of the temporary substation will be 3,000 kVA.

(3) Water supply

The water supply system for construction and camp use will be constructed separately at each working area by pumping up water from the Kulikhani river and brooks nearby.

(4) Communication service

An independent wireless communication system will be provided for communication service between the project site and Kathmandu.
An internal telephone system is to be set up to connect all camps, offices and working areas.

7.3.2 River Diversion Works

Prior to the construction of the main dam, a diversion tunnel will be constructed through the left bank abutment of the main dam. The diversion tunnel is a 430 m long horse shoe shaped concrete lined tunnel with inside diamter of 6.6 m. The discharge capacity is 580 m^3/sec, which corresponds to about 20-year flood.

The tunnel will be excavated by the top heading-bottom bench method.

Immediately after completion of the diversion tunnel, the Kulikhani river will be diverted through the diversion tunnel.

The diversion tunnel will be plugged with concrete after completion of the main dam works.

7.3.3 Main Dam Works

Following the river diversion, the upstream and downstream cofferdams will be constructed within one dry season.

The foundation excavation of main dam in the river bed portion will be started also after river diversion and carried out along with the construction of cofferdams, while, the excavation in the both abutment portions can be started before the river diversion.

After completion of foundation excavation, the curtain grouting work will be carried out prior to the core embankment.

The total embankment volume of the dam including the cofferdams is about 3,500,000 m^3. The embankment work of the main dam will be carried out in about 27 months. The monthly progress is estimated at 130,000 m^3 on an average and 250,000 m^3 at the peak.

The foundation excavation and dam embankment will be carried out in conventional way. The major construction machineries will be 2 m^3 class power shovels, 30 ton class heavy dump trucks, 32 ton class bulldozers. 20 ton class tamping rollers and 22 ton class tire rollers will be used for compaction of core zone and filter zone.

The impervious core material will be hauled by dump trucks from several borrow area located 200 to 1,000 m from damsite. The filter and rock material will be hauled also by dump trucks from the quarry site located about 500 m to 1,500 m from the damsite.

The spillway will be constructed on the left abutment of the main dam. The construction work will be proceeded in parallel with the construction of main dam and completed by the time of the completion of the main dam. The concrete work of the spillway will be started from the weir section and proceeded downward to the flip bucket portion.

Common and weathered rock will be excavated by bulldozer with hydraulic ripper where necessary. The fresh rock will be excavated by bench cut blasting method using crawler drills. The concrete placing for the crest, pier, deck and side walls will be made by truck crane and/or crawler crane with concrete buckets, and centipede conveyor or chute will be used for the slab and chuteway.

7.3.4 Headrace tunnel

The total length of headrace tunnel is 5,800 m. In order to shorten the construction period, the tunnel construction will be performed by dividing the whole length into two sections with construction of working adits. The length of the longest section is 4,200 m.

The tunnel will be excavated by full-face attack method using leg drills and locker shovels. Tunnel muck will be hauled out by battery locomotives and trolleys. After excavation, concrete lining, mortar grouting and pressure grouting will be followed.

7.3.5 Penstock Line

The penstock line consists of the three portions, i.e., the upper horizontal tunnel portion, open portion and lower inclined tunnel portion. The construction of the upper horizontal tunnel portion will be made in the similar way to that for the headrace tunnel. The excavation work for the open portion will be performed mainly by power shovels and bulldozers. The excavation of the lower inclined tunnel portion will be carried out from both upper and lower end. The excavation from the upper end will be made by ordinary way with leg-drill, winch, muck cars etc., the excavation from the lower end will be performed with an electric-driven raise climber, loader and dump truck. Concrete placing in the open portion will be made by the combination of truck crane, winch and agitator truck, and that for inclined tunnel portion by concrete placer. The penstock pipes will be installed by the combination of truck crane and winch.

7.3.6 Power House

For construction of the underground power station, an access tunnel of about 500 m in length and a working adit which branches off from the access tunnel to the arch portion of power house will be constructed first.

The construction of the power house main body will be started with the excavation of the arch section which will be followed by concrete placing of the section. After that, the construction will be proceeded downward by repeating the excavation and concrete placing alternately to the floor base. During the period all the excavated material will be hauled out and all construction material carried in by dump truck through the access tunnel.

The major construction machineries for the work will be power leg drill, shovel, locker shovel, dump truck, concrete placer and air compressor.

7.3.7 Tailrace

Construction of tailrace will be made from both outlet sides and power house side in the similar way to that for the headrace tunnel.

7.4 Construction Machinery and Plant

The project requires concrete aggregate of about 70,000 m^3, besides the sand and gravel of about 420,000 m^3 are required as filter material for the rockfill dam. Those sand and gravel cannot be obtained from river deposit as stated in the foregoing section 7.2. They will be produced from the rock material obtained from the quarry site located about 500 m downstream from the damsite and the weathered rock obtained on the north-eastern slope of Deorali located about 1.5 km from the damsite.

A crushing plant with a capacity of 400 ton/hr will be provided on the left bank about 500 m downstream from the damsite, which will produce the concrete aggregate for the whole project and filter material for the dam. A concrete plant with a capacity of about 30 m^3/hr will be provided adjacent to the crushing plant to supply concrete to the dam, spillway, intake, Chakhel intake and connecting tunnel, upstream portion of headrace tunnel, etc. Another mixing plant with capacity of about 15 m^3/hr will be provided at the power station site to supply concrete to power house, penstock line, lower portion of headrace tunnel, tailrace, etc.

The major plant and equipment required for the construction of the project are listed in Table 7-1.

TABLE 7-1 REQUIRED MAJOR PLANT AND EQUIPMENT

No.	Description	Capacity	Quantity
1.	Crushing plant	400 t/h	1 set
2.	Concrete plant	28 cft x 2	1 "
3.	- do -	28 cft x 1	1 "
4.	Power shovel	2 m^3	5 nos.
5.	- do -	1.2 "	4 "
6.	Dozer shovel	2 "	2 "
7.	Bulldozer w/ripper	27 t	5 "
8.	Bulldozer	17 t	10 "
9.	Sheeps foot roller	20 "	2 "
10.	Dump truck	30 "	30 "
11.	- do -	15 "	10 "
12.	Ordinary truck	10 "	15 "
13.	Crawler drill	5 "	8 "
14.	Rocker shovel	0.4 m^3	8 "
15.	Battery locomotive	4 t	5 "
16.	Air compressor	160 ps	5 "
17.	- do -	200 "	5 "
18.	Concrete pump	20 m^3/h	6 "
19.	Boring machine	$100^m.65^{\phi}m/m$	15 "
20.	Crawler crane	30 t	1 no.
21.	Truck crane	25 "	1 "
22.	Raise climber	200 m	1 set
23.	Tire roller	22 t	1 no.
24.	Tractor & trailer	30 "	1 "
25.	Motor grader	12 "	3 nos.

7.5 Construction Material

The quantities of main materials required for the construction works are estimated as follows. These material will be purchased abroad.

Cement	:	25,000 ton
Steel bar	:	4,500 "
Steel support	:	1,000 "
Steel pipe	:	1,000 "
Trash rack	:	20 "
Gates	:	260 "
Explosives	:	1,200 "
Fuel	:	15,000 kl

7.6 Construction Schedule

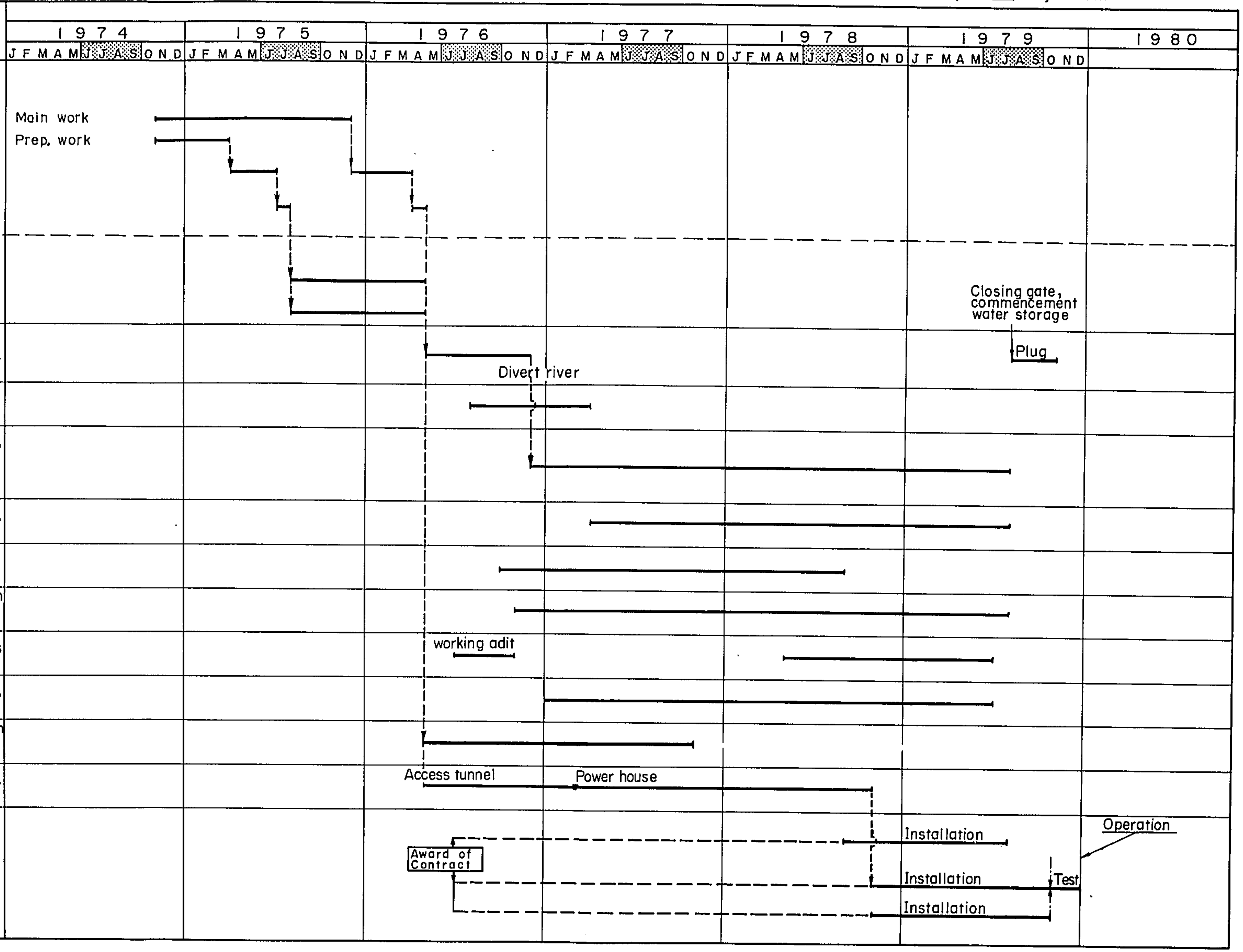
The proposed construction schedule will extend over a period of five and a half years including detailed design and project mobilization as shown in Fig. 7-1. The construction activities on the field will require about four years for completion of the works.

The detailed design and the preparation of tender documents for the main work will require about one year because further geological investigations are necessary at such sites as dam, surge tank, underground power house, etc. While the construction of the preparatory work will be started earlier under a separate contract so as to make the construction period as short as practicably possible.

FIG. 7-1 CONSTRUCTION TIME SCHEDULE FOR THE KULIKHANI NO.1 POWER STATION PROJECT

Note : ▒ Wet season, ☐ Dry season

DESCRIPTION	QUANTITY
Tender document & detailed design	
Award of tender	
Mobilization	
Preparatory works	
Access road	
Buildings and Water and power supply	
Diversion tunnel	D=7m, L=430m
Excavation	21,000 m^3
Concrete	7,600 〃
Coffer dams	H=30m,
Excavation	26,000 〃
Embankment	155,000 〃
Main dam	
Excavation	527,000 m^3
Embankment, Rock	2,470,000 〃
〃 , Filter	420,000 〃
〃 , Core	450,000 〃
Spillway	
Excavation	513,000 m^3
Concrete	16,000 〃
Intake	
Excavation	61,000 m^3
Concrete	1,400 〃
Headrace tunnel	Ø=2.5m, L=5,800m
Excavation	44,000 m^3
Concrete	15,300 〃
Surge tank	
Excavation	5,000 m^3
Concrete	1,000 〃
Penstock	
Excavation	36,000 m^3
Concrete	4,500 〃
Tailrace tunnel	R=1.65m, L=1,000m
Excavation	9,000 m^3
Concrete	2,700 〃
Power house	
Excavation	32,000 m^3
Concrete	9,300 〃
Metal works	
Gates & penstock	
Power generating equipment	
Sub-station & transmission line	



CHAPTER 8

COST ESTIMATE

8.1 Construction Cost

The total construction cost of the Kulikhani No.1 power station is estimated to be US$53 million. Out of the total cost, about US$43 million will be needed in foreign currency and the rest of US$10 million in domestic currency. The interest during the construction period is not included in the above estimate.

Followings are the conditions on which the cost estimate is based.

- Prices are based on those prevailing as of July 1974.
- The following exchange rates are assumed.

  1.0 US Dollar = 10.56 Nepali Rupees
  = 300 Japanese Yen
- Work quantities are estimated from a preliminary design as shown in the attached drawings.
- The construction is assumed to be carried out by a competitive contract basis to be awarded to foreign contractors. Unit prices for each work item include direct costs such as personnel and labour expenses, material costs, operating and depreciation costs of construction equipment, etc. and indirect costs such as the contractor's overhead and administrative expenses.
- Domestic currency will be required for the land compensation cost, the labour cost, purchase of domestically furnished materials such as timber, bricks, fuels, etc., and the transportation charge in the territory of Nepal.
- Taxes and duties to be levied by the Government of Nepal are assumed to be exempted from the imported goods and services.
- General administrative expenses of the Government of Nepal and the engineering services for detailed design and construction supervision to be rendered by a foreign consultant is estimated to be about 10 % of the total of the direct construction cost.

- As the contingency and reserve to cover a possible quantity increase of the project works and to allow price escalation, about 20 % of the construction cost is counted.

The summary of the construction costs is shown in Table 8-1.

TABLE 8-1 SUMMARY OF CONSTRUCTION COST

(1,000 US$)

Item	Foreign currency	Domestic currency	Total amount
Preparatory works	1,950	850	2,800
Access road (20 km), buildings and service utilities			
Dam and spillway	16,880	2,640	19,520
Diversion tunnel (L=430 m, D=6.6m), cofferdams, main dam (inclined core type rockfill dam, 107 m high), spillway (open chute with flip bucket)			
Waterway	4,960	1,130	6,090
Intake, headrace tunnel (L=5.8 km, D=2.5 m), Surge tank, penstock (L=1.3 km, single lane)			
Power house	1,500	500	2,000
Access tunnel, underground power house			
Tailrace	410	110	520
Generating equipment	5,580	620	6,200
2 units x 30,000 kW			
Transmission line (0.2 km) and Extension of substation (70 MVA)	1,220	300	1,520
Tributary intakes	780	170	950
Weirs and connecting tunnel (2.3 km)			
Sub-total	(33,280)	(6,320)	(39,600)
General expense and engineering service including compensation	2,770	1,800	4,570
Sub-total	(36,050)	(8,120)	(44,170)
Contingency and reserve (about 20 %)	7,250	1,580	8,830
Grand total	43,300	9,700	53,000

8.2 Annual Fund Requirement

Construction funds will be disbursed over a period of 4 years to complete the project works. The annual fund requirement is estimated as shown in Table 8-2, based on the construction schedule as described in Section 7.6.

TABLE 8-2 ANNUAL DISBURSEMENT SCHEDULE

(Thousand US$)

Year	Foreign currency	Domestic currency	Total amount
1st year	3,900	1,000	4,900
2nd year	6,500	1,300	7,800
3rd year	18,800	4,200	23,000
4th year	14,100	3,200	17,300
Total	43,300	9,700	53,000

8.3 Operation, Maintenance and Replacement Cost

The Electricity Department of the Ministry of Water and Power, which is responsible for planning and implementation of the electric power development in Nepal, will be responsible for the operation and maintenance of the Kulikhani No.1 power station.

The annual operation, maintenance and replacement cost (OMR cost) will include the average annual expenditure for administration, operating personnel, equipment, supplies and other cost necessary to keep the Kulikhani No.1 power station in efficient operating conditions. The OMR cost is estimated to be US$360,000 in terms of annual equivalent cost, as discussed below, and summarized in Table 8-3.

(a) Personnel expense

The following operational and maintenance staffs are considered necessary and the required personnel cost is estimated to be US$150,000. No additional personnel will be required for the maintenance of the existing 66 kV transmission line to which the Kulkhani No.1 power station is to be connected. Some operators, however, will be required to be added at the existing substation at Kathmandu which will be extended by 70 MVA under the project.

Several expatriate guidance engineers may be necessary for the initial one or two years to give operation and maintenance guidance services and the training of the personnels.

Personnel Requirement Schedule

1 - Manager
1 - Deputy manager

(General affairs and accounting)

1 - Chief
4 - Clerks
1 - Typist
2 - Warehouse keepers
4 - Drivers
3 - Watchmen

(Operation)

Power Station : 3 shifts, 1 reserve
4 - Chief (Electrical)
12 - Operators (Electrical)
12 - Operators (Mechanical)
Dam and Intake
2 - Operators (Gate)
Substation
6 - Operators (Additional to the existing substation at Kathmandu)

(Maintenance)

1 - Chief (Electrical)
1 - Chief (Mechanical)
1 - Chief (Civil)
10 - Workers

---

66 persons in total US$150,000

(b) Maintenance and repairing cost

The maintenance and repairing cost of gates, penstock pipes, generating equipment and others are estimated to be US$90,000 annually as shown below.

Dam, spillway and reservoir	US$30,000
Powerplant	US$50,000
Transmission line and substation	US$10,000
Total	US$90,000

(c) Replacement cost

The economic life of generating equipment, transmission line to connect with the existing 66 kV transmission line and the transformers to be added in the existing substation at Kathmandu is 35 years. The replacement cost of such equipment, US$7,720,000, is duly counted after 35 years from the initial operation of the project. The annual equivalent cost of replacement is calculated at US$40,000, under the annual discount rate of 8 % and the evaluation period of 50 years.

(d) Other expenses

Other expenses such as insurance, OMR office maintenance, etc. are estimated to be US$80,000 annually.

TABLE 8-3 OPERATION, MAINTENANCE AND REPLACEMENT COST

Personnel expense	US$150,000
Maintenance and repair cost	US$ 90,000
Replacement cost	US$ 40,000
Other expenses	US$ 80,000
Total	US$360,000

CHAPTER 9

ECONOMIC AND FINANCIAL ANALYSIS

9.1 General

The project is formulated primarily for the purpose of power generation to cope with the increasing power demand in the load center of Nepal covered by the Central Nepal Power System. The project will produce the primary energy of 165×10^6 kWh and the secondary energy of 46×10^6 kWh per annum. The dependable peak output will be secured at 60,000 kW, equal to the installed capacity, since the reservoir water level is kept above the rated water level during the months of January and February when the annual peak demand is expected to occur.

In addition to the energy to be produced by the project, the potential energy of the run-of-river type hydro plants wasted in the off-peak time at present will become consumable in the system by the peaking operation of the Kulikhani No. 1 power station. The amount of such energy is estimated to be 97×10^6 kWh per annum, as explained in Section 6.5.

The economic and finantial analysis is presented in this chapter, solely based on the power benefit of the project. As a matter of fact, the project will probably be associated with such benefits other than power generation as road improvement between Kathmandu and Indian border, further power generation on the course of the Rapti river, water supply for irrigation and industrial use in the downstream Rapti basin, fish farming in the Kulikhani reservoir. These conceivable benefits, however, cannot be taken as a real benefit countable immediate after the project completion but a potential benefit depending largely upon the future regional development. It is also noted that the project will contribute to the saving of fuel consumption resulting in the saving of foreign currency to a considerable extent as compared with the case of power supply by the alternative coal-fired thermal plant.

The economic feasibility of the project is assessed by comparing the project cost with the power benefit based on the cost of the alternative thermal plant. The financial feasibility is assessed by the loan repayment capability of the project based on the net revenue from energy sale and repayment liability.

9.2 Economic Analysis

9.2.1 General

The discount rate for the economic evaluation of a project is usually be taken at around 8 %. The discount rate of lower than 8 % might be justifiable for the project, taking it into account that the opportunity cost of capital seems to be low in Nepal compared with other Asian countries and most of the capital intensive projects in Nepal have been financed on a grant or semi-grant base. However, the discount rate of 8 % is taken for the economic analysis of the project for the conservative sake.

The life of the project for the economic analysis is taken at 50 years from the initial operation of the project.

9.2.2 Unit Power Values

It is generally accepted that the power benefit of a hydropower development project is evaluated based on the cost of the most competitive thermal plant alternative. The most likely thermal alternative in Nepal will be a coal-fired thermal plant being widely practiced in India, with unit capacity of 30,000 kW. Based on the alternative thermal plant as stated above, the capacity value and the energy value of the power output of the project are estimated to be US$ 73/kW and US mill 20/kWh, respectively, as shown in Table 9-1.

9.2.3 Power Export to India

Power market in India is large, growing at an annual rate of more than 10 %. If the energy produced in Nepal is offered to be sold at an attractive rate compared with the cost of power generation in India, India is expected to be willing to import it.

At present, exchange of small power is being made between Nepal and India under the agreement of both governments, at an agreed rate of US mill 20/kWh. Some adjustment of the rate would be in order owing to the current global oil crisis.

TABLE 9-1 UNIT POWER VALUES

(Coal-fired thermal plant of unit capacity of 30,000 kW)

(1) Capacity value (kW value)

Unit construction cost:	US$500/kW
Discount rate:	8 %
(i) Amortization for 25-year life time:	9.4 %
(ii) Operation and maintenance cost:	2.5 %
(iii) Others	0.5 %
Total of (i) to (iii)	12.4 %
Capacity adjustment factor:	1.173 /1
Capacity value: US$500/kW x 0.124 x 1.173 =	US$73/kW

(2) Energy value (kWh value)

Coal consumption:	0.645 kg/kWh /2
Cost of coal:	Rs.300/ton (US$30/ton)
Energy adjustment factor:	1.028 /1

Energy value: US$0.030/kg x 0.645 kg/kWh x 1.028 =US mill 20/kWh

/1: Adjustment factor:

	Hydro	Steam
Loss at primary substation	5.0 %	2.0 %
Auxiliary power use	0.3	6.0
Forced outage	0.5	5.0
Overhaul	2.0	10.0

Capacity adjustment factor

$$= \frac{(1 - 0.05)(1 - 0.003)(1 - 0.005)(1 - 0.02)}{(1 - 0.02)(1 - 0.06)(1 - 0.05)(1 - 0.100)} = 1.173$$

Energy adjustment factor

$$= \frac{(1 - 0.05)(1 - 0.003)}{(1 - 0.02)(1 - 0.06)} = 1.028$$

/2: Based on average value recorded in Seventh Annual Electric Survey of India published by the Central Electricity Authority, 1972.

As the primary energy produced by the Kulikhani No.1 power station will be fully consumed in Nepal except for the initial few years of maturity period,/1 only the secondary energy will be exportable to India. This kind of energy is considered to be sold at fuel replacement value at most and probably at lower rate than it. It is noted that cheap coal is available in eastern and western regions of India and the capacity of whole coal-fired thermal plants occupies a greater part of the total generating capacity in the regions. The fuel replacement cost is estimated to be US mill 14.5/kWh, assuming the price of coal at US$22.5/ton at Indian thermal plants near the border to Nepal and the unit coal consumption at 0.645 kg/kWh.

With reference to the above, power export rate is taken at US mill 12/kWh/2 and a half of the surplus energy is assumed to be exportable to India.

9.2.4 Project Benefit

The project benefit in a full benefit stage, after the maturity period, is calculated at US$ 7,960,000 per annum, as shown below.

Capacity benefit		
	60,000 kW x US$ 73/kW =	US$ 4,380,000
Energy benefit		
Primary	165×10^6 kWh x US$ 0.020 =	US$ 3,300,000
Secondary	46×10^6 kWh x 0.5 x US$ 0.012 =	US$ 280,000
Total annual benefit		US$ 7,960,000

/1: It is possible to export firm energy to India for the initial few years of maturity period at much higher export rate than the assumed power rate for secondary energy. But in this report this effect is not included to make the economic and financial analysis reasonably conservative.

/2: Export rate for secondary energy may be around US mill 12 - 15/kWh. The power rate of US mill 12/kWh is tentatively taken in this report.

The power benefit for an initial few years of maturity period is estimated as shown in Table 9-2, in comparison with the alternative thermal plant with 30,000 kW unit capacity.

TABLE 9-2 GROWTH OF PROJECT BENEFIT

	Capacity (kW)	Primary energy (x 10^6 kWh)	Energy exportable to India (x 10^6 kWh)	Total benefit (x 10^3 US$)
1st year	30,000	50	81	4,160
2nd year	30,000	80	66	4,580
3rd year	30,000	108	52	4,970
4th year	60,000	138	37	7,580
5th year	60,000	162	25	7,920
6th year (full)	60,000	165	23	7,960

From the above, the annual equivalent benefit is calculated at US$ 7,220,000 at the discount rate of 8 % and the evaluation period of 50 years.

9.2.5 Project Cost

The project cost consists of the annual capital recovery cost and OMR cost.

The annual capital recovery cost is calculated at US$ 4,690,000, as shown in Table 9-3.

The OMR cost is US$ 360,000, as estimated in Section 8.3. Then the annual project cost is calculated at US$ 5,050,000.

TABLE 9-3 ANNUAL CAPITAL RECOVERY COST

	Initial investment cost ($\times 10^3$US$)	Interest ($\times 10^3$US$)	Cost including interest ($\times 10^3$US$)
1st year	4,900		4,900
2nd year	7,800	390	5,290
3rd year	23,000	1,050	14,140
4th year	17,300	2,970	40,110
Total	53,000		57,410

Total cost including interest : US$ 57,410,000

Capital Recovery Factor

at 8% discount rate and

50 year evaluation period : 8.174 %

Annual capital recovery cost : US$ 4,690,000

9.2.6 Benefit-Cost Ratio and Internal Rate of Return

The benefit-cost ratio is calculated at 1.43, which proves economic feasibility of the project.

For the purpose to know the internal rate of return, the same procedures as stated in the foregoing subsections are followed, applying different discount rates. The results are shown in Table 9-4. The economic feasibility of the project is also demonstrated by the internal rate of return of 12.9 %, as read from the Fig. 9-1 showing the results of the project benefit and cost at different discount rates.

FIG. 9-1 INTERNAL RATE OF RETURN

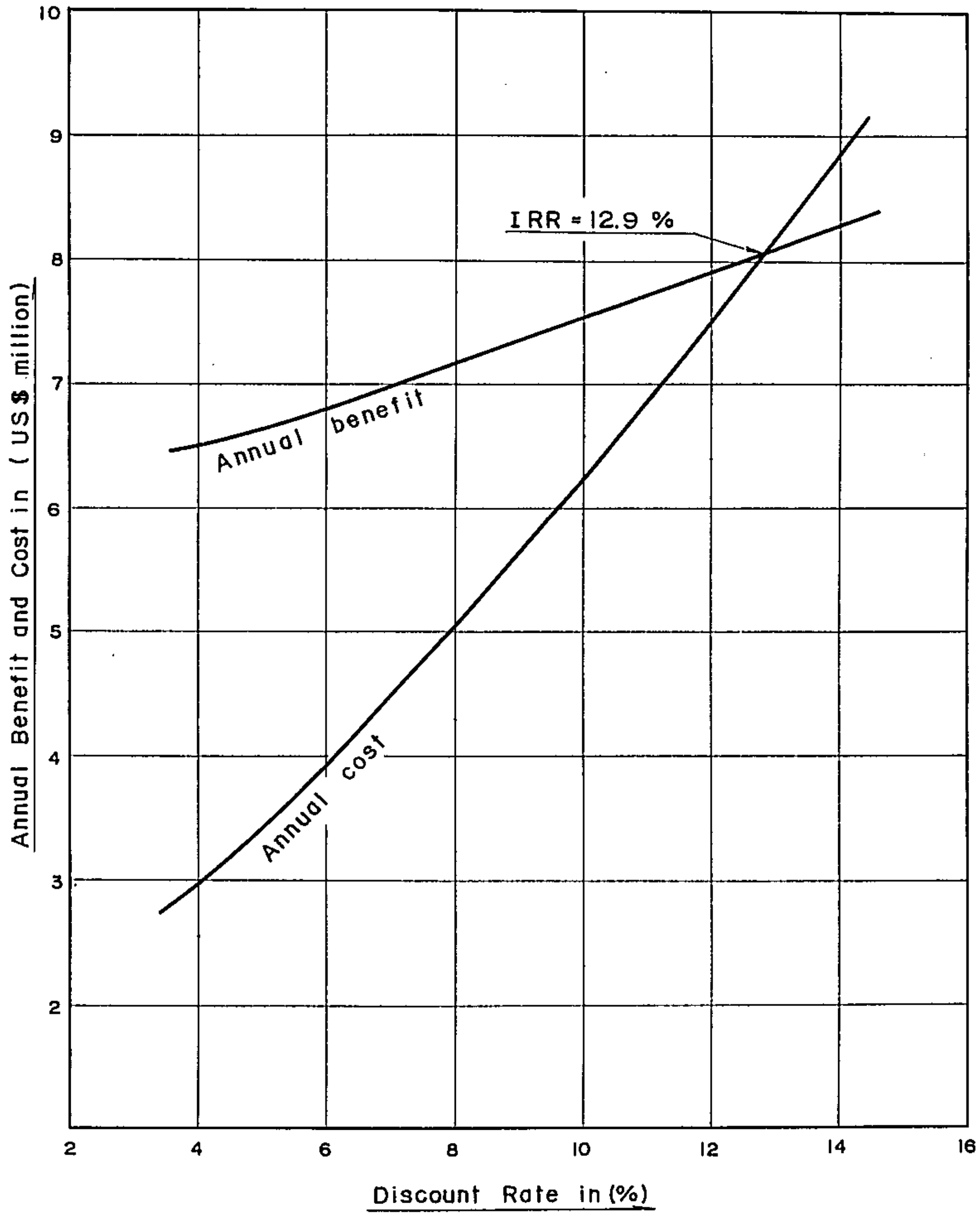


TABLE 9-4 PROJECT BENEFIT AND COST FOR VARIED DISCOUNT RATES

Discount rate (%)	4	6	8	10	12	14
Capacity value (US$/kW)	55	63	73	82	93	103
Capacity benefit ($\times 10^3$US$)	3,090	3,460	3,920	4,310	4,760	5,170
Energy benefit ($\times 10^3$US$)	3,400	3,350	3,300	3,240	3,190	3,140
Total ($\times 10^3$US$)	6,490	6,810	7,220	7,550	7,950	8,310
Capital recovery cost ($\times 10^3$US$)	2,570	3,570	4,690	5,910	7,170	8,530
OMR cost ($\times 10^3$US$)	410	380	360	350	340	330
Total ($\times 10^3$US$)	2,980	3,950	5,050	6,260	7,510	8,860
Surplus benefit ($\times 10^3$US$)	3,510	2,860	2,170	1,290	440	- 550
Benefit-cost ratio	2.18	1.72	1.43	1.21	1.06	0.94

9.2.7 Energy Cost

The Kulikhani No.1 power station will produce the primary energy of 165 x 10^6 kWh and in addition will make the potential energy of 97 x 10^6 kWh to be generated at the run-of-river type hydropower plants consumable in the system. Therefore the total annual energy output attributable to the project is considered to be 262 x 10^6 kWh. The energy saleable in the system is 253 x 10^6 kWh at the existing Kathmandu substation allowing the averaged transmission loss of 3.5 %. Taking the low demand for a few years from the initial operation into consideration, the annual equivalent energy output is calculated at 222 x 10^6 kWh. Then the energy cost at the Kathmandu substation averaged throughout the project life of 50 years is calculated at US mill 22.7/kWh, dividing the annual project cost of US$ 5,050,000 by the annual equivalent energy output. If the secondary energy is taken into consideration as evaluated in the foregoing subsections, the energy cost will become US mill 20.7/kWh, under the discount rate of 8 % and the evaluation period of 50 years.

It is reported that the energy cost of the proposed Devighat project is about US mill 18/kWh under the discount rate of 6 % and the evaluation period of 50 years. It is understood therefore that the Kulikhani No.1 power station can bear a fullest comparison with the Devighat power station, which is of a run-of-river type and scheduled to be implemented prior to the Kulikhani No.1 power station.

9.2.8 Sensitivity Analysis

A sensitivity analysis is made for the following or the combination of the following three cases.

(a) In case of possible cost increase by 15 %

(b) In case of further cost increase by 30 %

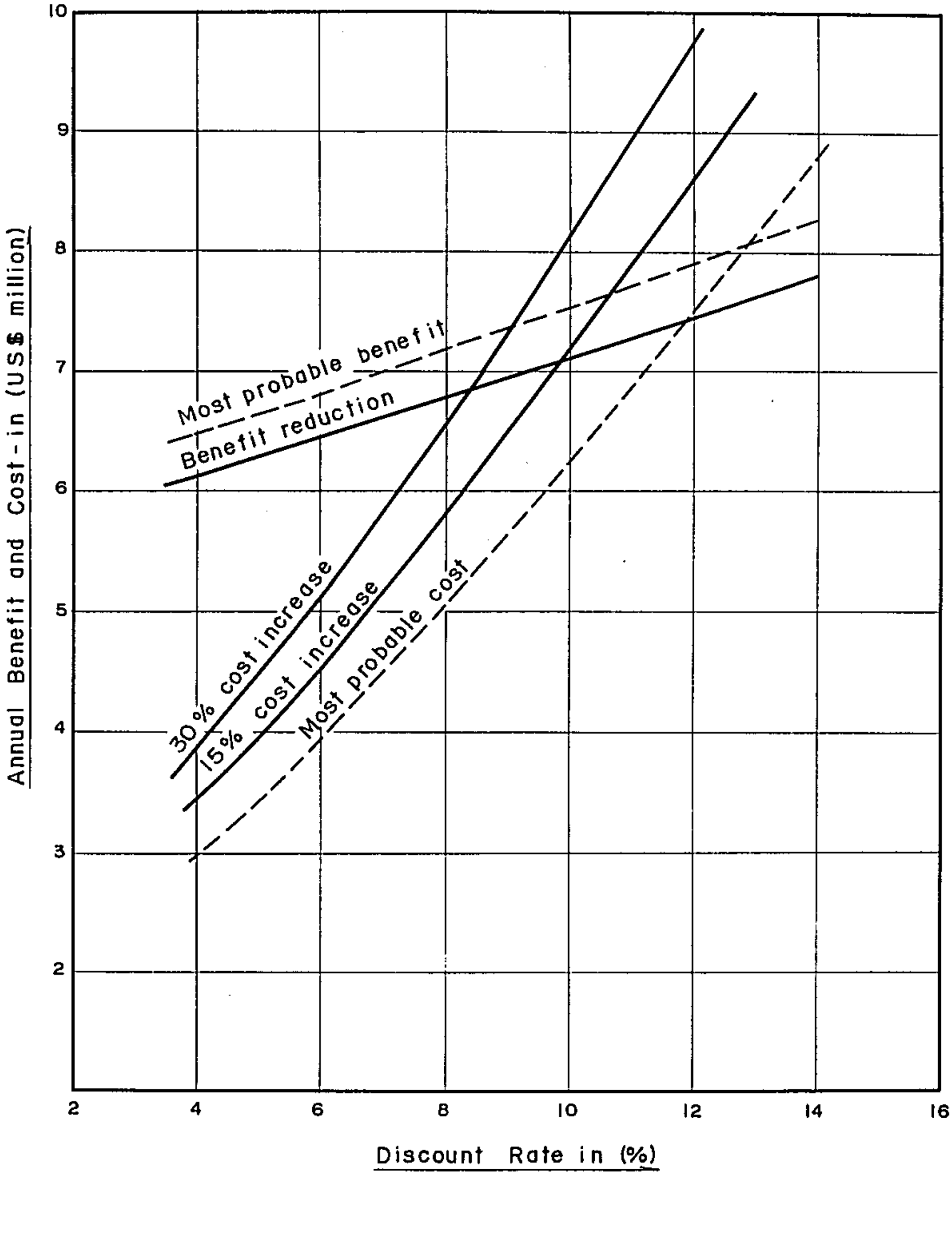
(c) In case that India rejects to import surplus energy

The results of the sensitivity test are summarized in Table 9-5 and also graphically shown in Fig. 9-2. The benefit-cost ratio in the worst case, the combination of case (b) and (c) above, is determined at 1.04, which shows that the project is still economically feasible.

TABLE 9-5 SENSITIVITY ANALYSIS

Discount rate (%)	4	6	8	10	12	14
Cost ($x10^3$US$)						
Normal	2,980	3,950	5,050	6,260	7,510	8,860
(a) 15% increase	3,430	4,540	5,810	7,200	8,640	10,190
(b) 30% increase	3,870	5,140	6,570	8,140	9,760	11,520
Benefit ($x10^3$US$)						
Normal	6,490	6,810	7,220	7,550	7,950	8,310
(c) Surplus energy wasted	6,140	6,430	6,820	7,130	7,500	7,840
Benefit-cost ratio						
Normal	2.18	1.72	1.43	1.21	1.06	0.94
Case (a)	1.89	1.50	1.24	1.05	0.92	0.82
Case (b)	1.68	1.32	1.10	0.93	0.81	0.72
Case (c)	2.06	1.63	1.35	1.14	1.00	0.88
Case (a) & (c)	1.79	1.42	1.17	0.99	0.87	0.77
Case (b) & (c)	1.59	1.25	1.04	0.88	0.77	0.68

FIG. 9-2 SENSITIVITY ANALYSIS



9.3 Financial Analysis

9.3.1 General

The construction cost of the project is estimated on the basis of the price level of July 1974.

The actual construction, on the other hand, is scheduled to be executed during 4 years from mid 1975 to mid 1979. Considering the current worldwide inflation, a price contingency is included in the item of contingency and reserve as shown in Table 8-1, to cover the anticipated price increase especially for the imported goods and services. This allowance for price escalation is also made for the estimation of the construction cost of the alternative coal-fired thermal power plant.

The financial arrangement should be made for US$ 53 million as estimated in Table 8-1 and Table 8-2.

9.3.2 Loan Conditions

As the loan conditions have not been settled yet at the moment, the probable range of loan conditions is assumed for the financial analysis of the project.

It is tentatively assumed that both the foreign and domestic currency portions of the construction cost will be financed under the same loan conditions of an annual interest rate ranging from 2 % to 7 % and a repayment period of 30 years including 5-year grace period.

9.3.3 Power Rate

The power tariffs in Kathmandu established by the National Electricity Corporation are US mill 20/kWh for domestic use, US mill 8 to 15/kWh for industrial use and US mill 15 to 18/kWh for commercial use. The tariffs in Hitaura and Birganj area set by the same Corporation are about 50 % to 100 % higher than those in Kathmandu, US mill 35/kWh for domestic use, US mill 15 to 25/kWh for industrial use and US mill 25 to 30/kWh for commercial use.

The prevailing power tariffs as described above are considered to be much lower than the power tariffs adopted in other countries. The Government of Nepal seems to have an intention to keep the low power tariff to expedite and promote the regional electrification, and as a result to save the consumption of fuel or oil for domestic, industrial and commercial uses.

It is to be noticed that most of the power plants in Nepal were constructed by a foreign aid on a grant or semi-grant base. It is easily imagined that such low power tariffs are made possible by the fact that power supply authorities in Nepal are almost free from the liability of capital recovery for the initial investment cost of the power plants.

If the present level of power tariff is intended to be maintained in future, the price of power at a primary substation will have to be about US mill 14/kWh, assuming the distribution loss at 15 % and the additional cost for administration and distribution service at around US mill 7/kWh.

For a sound development of future power projects in Nepal, it will be worthwhile to review the present power tariff policy and to search for the optimum level of power tariff.

9.3.4 Conditions for Financial Analysis

The annual saleable energy at a primary substation attributable to the project is the primary energy of 159×10^6 kWh from the Kulikhani No.1 power station and the energy of 94×10^6 kWh from the run-of-river type hydro plants to be made consumable by the introduction of the Kulikhani No.1 power station, making total of 253×10^6 kWh.

The growth of the saleable energy during the maturity period is estimated as shown in Table 9-6. The saleable energy during the maturity period includes the energy of diesel plants which will be replaced by the project due to the high operation cost of diesel plants.

TABLE 9-6 GROWTH OF SALEABLE ENERGY

Year		Saleable energy	
Calendar	Sequential	Domestic ($x 10^6$ kWh)	Export to India ($x 10^6$ kWh)
1979/80	1	77	111
80/81	2	122	89
81/82	3	165	67
82/83	4	211	44
83/84	5	249	25
84/85	6 (full)	253	23

A half of the surplus primary energy during the maturity period and the secondary energy is considered to be exportable to India at the rate of US mill 12/kWh, as assumed in Section 9.2.3.

The annual cost is the sum of the amortization cost and operation, maintenance and replacement cost. The amortization cost is dependent on annual interest rate and the repayment period of loan. The OMR cost is estimated to be US$ 540,000 per annum, comprising US$ 320,000 of operation and maintenance cost as estimated in Section 8.3 and US$ 220,000 of replacement cost. The replacement cost for the financial analysis is calculated applying a linear depreciation method for generating equipment, transformers, etc., the life of which is estimated at 35 years from their initial operation.

9.3.5 Loan Repayment Capability

A financial power cost is calculated for the interest rates ranging from 2 % to 7 %, under the repayment period of 30 years. A financial power cost may be defined as the power rate at a primary substation, which makes the total net revenue from energy sale to be exactly the same as the total repayment liability, during the repayment period of 30 years. If the power rate is taken at the financial power cost, the project will produce no profit and no loss during the repayment period.

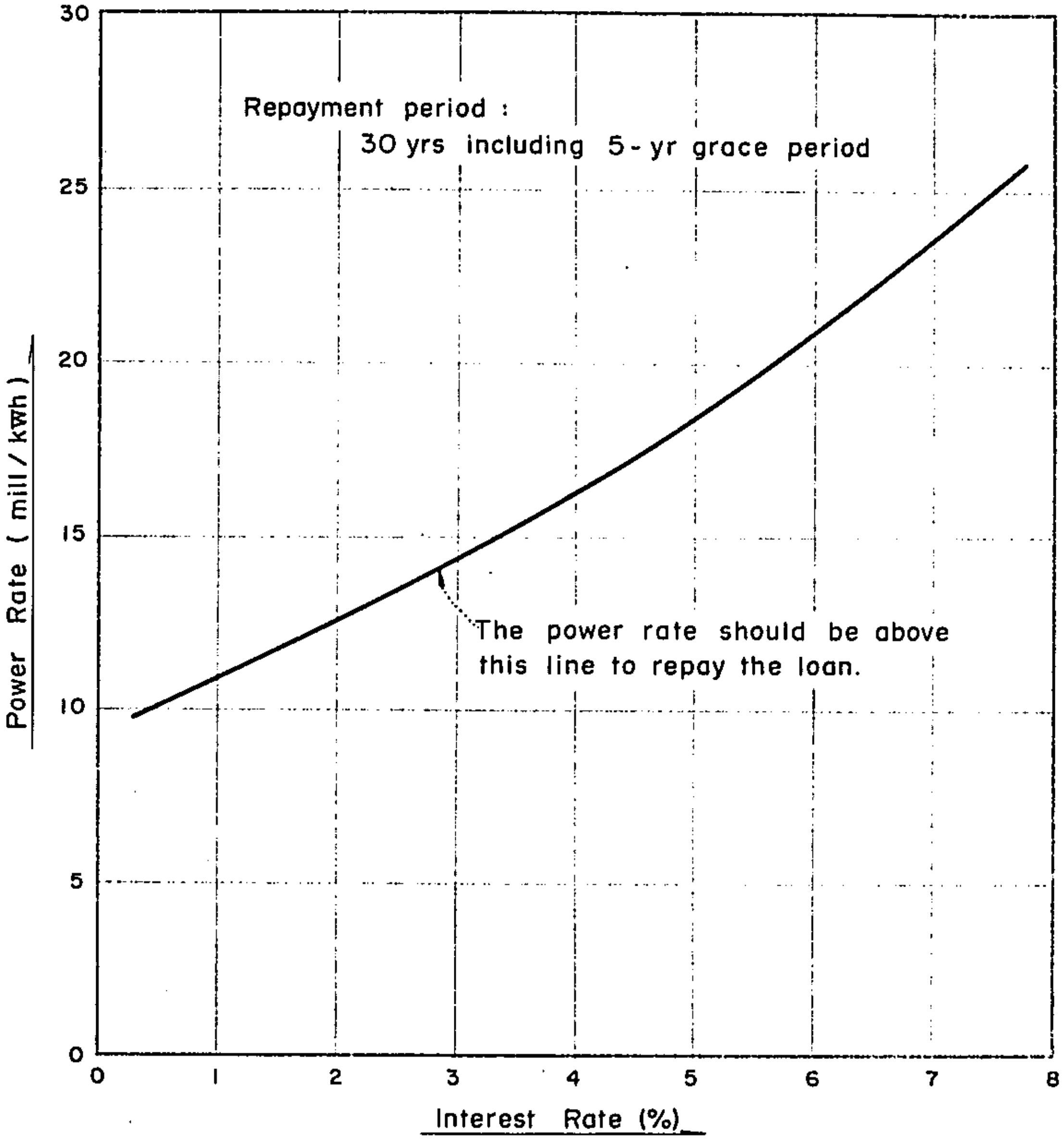
The financial power costs are US mill 12.5/kWh, US mill 17.3/kWh and US mill 23.5/kWh for the interest rates of 2 %, 4.5 % and 7 %, respectively, as shown in Fig. 9-3.

9.4 Feasibility of Combined No.1 and No.2 Power Stations

The Kulikhani No.1 power station project, which is the first stage development of the overall Kulikhani project, is proved to be economially feasible as described in the preceding sections. In the case that the Kulikhani No.2 power station, which is planned to be constructed in the future on the course of the Rapti river as discussed in Chapter 10, is taken into consideration, the combined No.1 and No.2 power station project will become even more feasible as explained below.

The No.2 power station will be installed with 35,000 kW, producing an annual firm energy output of 123×10^6 kWh and a secondary energy of 20×10^6 kWh. Since the No.2 power station is planned with the run-of-river type, the dependable peak output will be reduced to 32,100 kW. Then the power benefit will be US$ 4.92 million annually. The total construction cost is estimated at US$ 17.0 million excluding the interest during

FIG. 9-3 REPAYABLE LOAN CONDITION



the construction period. The annual cost is estimated at US$ 1.84 million, comprising the annual capital recovery cost of US$ 1.52 million at the discount rate of 8 % and a project life of 50 years and the OMR cost of US$ 0.32 million. The benefit-cost ratio of the combined Kulikhani No.1 and No.2 power station project is roughly estimated at 1.82 as shown in Table 9-7. The remarkably high benefit-cost ratio of the No.2 power station is attributable to the large master reservoir to be created by the Kulikhani dam of 107 m in height.

The power cost at a primary substation also reduces from US mill 19.6/kWh to US mill 18.0/kWh if the energy output of the No.2 power station is taken into account, as shown in Table 9-8.

If it is allowed to take other benefits expected from water supply for irrigation and industrial use in the downstream Rapti basin, fish farming in the Kulikhani reservoir, etc. as described in Section 9.5, say US$ 500,000 per annum by rough estimation, the combined power cost will be further reduced from US mill 18.0/kWh to US mill 16.6/kWh.

Though the above discussion is made for the full benefit stage of the combined No.1 and No.2 power stations, it should be understood that the Kulikhani No.1 power station project, which is feasible by itself, will provide a lot of opportunities for further promising development projects as described above, and will surely contribute greatly to the economic and social development of the Central region of Nepal.

9.5 Associated Benefit

Such associated benefits will be contemplated from the project as the saving of foreign currency, water supply for irrigation and industrial use, improvement of road between Kathmandu and Indian border and fish farming in the Kulikhani reservoir.

(1) Saving of foreign currency

Nepal is poor in mineral resources and has to import most of fuels and oils. If the energy to be generated by the Kulikhani No.1 power station were produced by the alternative coal-fired thermal plant, the annual consumption of coal would amount to 106,000 tons. This would

TABLE 9-7 BENEFIT-COST RATIO OF COMBINED NO.1 AND NO.2 POWER STATIONS

		No.1 P.S.	No.2 P.S.	Total
Benefit				
Installed capacity	(kW)	60,000	35,000	95,000
Dependable peak output	(kW)	60,000	32,100	92,100
Annual energy output	(x 10^6 kWh)			
Primary		165/6	123	288
Secondary		46	20	66
Capacity benefit/1	(x 10^3 US$)	4,380	2,340	6,720
Energy benefit/2	(x 10^3 US$)	3,580	2,580	6,160
Total	(x 10^3 US$)	7,960	4,920	12,880
Cost	(x 10^3 US$)			
Construction cost/3		53,000	17,000	70,000
Annual cost				
Capital cost/4		4,890	1,520	6,410
OMR cost		360	320	680
Total		5,250	1,840	7,090
Benefit-cost ratio/5		1.52	2.67	1.82

/1: Unit capacity value is US$ 73/kW.

/2: Unit energy value is US mill 20/kWh for primary energy and US mill 6/kWh for secondary energy assuming that a half of the secondary energy will be exportable to India at US mill 12/kWh.

/3: Construction cost excluding interest during construction.

/4: Derived from annual interest rate of 8 % and project life of 50 years.

/5: Benefit-cost ratio at the discount rate of 8 %. If the discount rate of 10 % is taken, the benefit-cost ratio will be 1.30 for No.1 P.S., 2.34 for No.2 P.S. and 1.56 for combined No.1 and No.2 P.S.

/6: The plant factor of No.1 P.S. is low to use efficiently the potential energy of the run-of-river type hydro plants. The primary energy attributable to No.1 P.S. is 262 x 10^6kWh including such potential energy to be made consumable.

TABLE 9-8 POWER COST OF COMBINED NO.1 AND NO.2 POWER STATIONS

		No.1 P.S.	No.2 P.S.	Total
Annual energy output	(x 10^6 kWh)			
From Kulikhani P.S.		165	123	287
From run-of-river powerplants /1		97	-	97
Total		262	123	385
Transmission loss /2		9	4	13
Energy output at primary S/S		253	119	372
Annual cost	(x 10^3 US$) /3	5,250	1,840	7,090
Secondary energy	(x 10^6 kWh) /4	46	20	66
Value of secondary energy /5		280	120	400
Net annual cost /6	(x 10^3 US$)	4,970	1,720	6,690
Energy cost	(US mill/kWh)	19.6	14.5	18.0

/1: Potential energy of the run-of-river plants will be fully recovered by the peaking operation of the Kulikhani No.1 power station as described in Section 6.5.

/2: Transmission loss is taken at 3.5 %.

/3: Refer to Table 9-7.

/4: Refer to Table 9-7.

/5: Refer to the remark /2 of Table 9-7.

/6: Net annual cost is the annual cost deducted by the value of secondary energy.

require a foreign currency of US$ 3.2 million at the unit cost of US$ 30/ton. The construction of the thermal plant would also require a considerable amount of foreign currency, which is estimated at US$ 1.2 million and US$ 2.1 million as an annual amortization cost, assuming the annual interest rate at 2 % and 7 % respectively and the repayment period of 25 years from the initial operation of the power-plant. On the other hand, the annual repayment liability in foreign currency in case of the Kulikhani power station project is US$ 2.2 million and US$ 3.7 million, assuming the same loan condition as stated above and total annual requirement of foreign currency is estimated to be US$ 2.5 million and US$ 4.0 million for the interest rates of 2 % and 7 % respectively, including the required foreign currency for operation, maintenance and replacement. Therefore, the annual saving of foreign currency of US$ 1.9 million and US$ 1.3 million will be expected for the first 25 years of operation for the interest rate of 2 % and 7 % respectively. It is noted that the Kulikhani power station has the economic life of about 50 years. During the period of about 25 years after the first 25 years, the Kulikhani power station will require only US$ 0.3 million annually, while the alternative thermal plant will continue to require US$ 4.4 million to US$ 5.3 million of foreign currency annually.

(2) Water supply for irrigation and industrial use

Water increased by the project in the Rapti river will also have a potential to be utilized for irrigation and industrial purpose. The project will increase the run-off of the Rapti river from about 3.0 m^3/sec to about 8 m^3/sec in the lowest run-off period.

The Hitaura area located at the middle reach of the Rapti river is designated as an industrial center by the Government and the irrigable area of about 15,000 ha extends on the right bank of the lower reach of the Rapti river. It is roughly estimated that the annual benefit attributable to the additional water will be US$ 300,000 when these development projects are realized.

(3) Improvement of road

The existing highway called "Tribubhan Rajpath" road between Kathmandu and Hitaura runs in the hilly part with steep slopes and sharp curves. The high altitude of nearly 3,000 m in the vicinity of Daman is a bottleneck of this route causing a reduction of truck loading capacity.

The Government contemplates to construct a bypass to avoid the bottleneck of the existing road. There are two alternatives. One is to pass along with the Bagmati river and the other is to pass via Kulikhani, the southern part of which coincides with the route of the proposed access road for the construction of the project works. It is expected that the latter alternative will be taken for implementation taking advantage of the access road of about 20 km in length.

(4) Fish farming in the reservoir

In Nepal, researches and studies have been made on the possibility of inland fish production in rivers and lakes. The Kulikhani reservoir to be created by the project will offer a good opportunity for fish farming.

Subject to thorough investigations and studies to be made on water quality, temperature, effect of seasonal water level fluctuation on fish growing, etc., fish farming in the reservoir, if successful, will contribute greatly to the inhabitants' diet in the surrounding areas and the improvement of the regional economy.

CHAPTER 10

FURTHER DEVELOPMENT PLANS

10.1 General

The Rapti river course is so steep that it falls down by 430 m for a distance of 18 km from Bimphedi to the confluence of the Simri river. Following the Kulikhani No.1 power station project, two successive hydro-power stations, Kulikhani No.2 and No.3 power stations, can be developed on the course of the Rapti river, utilizing the increased discharge and steep river gradient.

The No.2 power station will be of a run-of-river type to take advantage of the tailwater discharge from the No.1 power station in addition to the natural runoff of the Rapti basin. The No.3 power station will be of a dam-and-conduit type to further regulate the runoff of the Rapti river in addition to the tailwater from the No.2 power station.

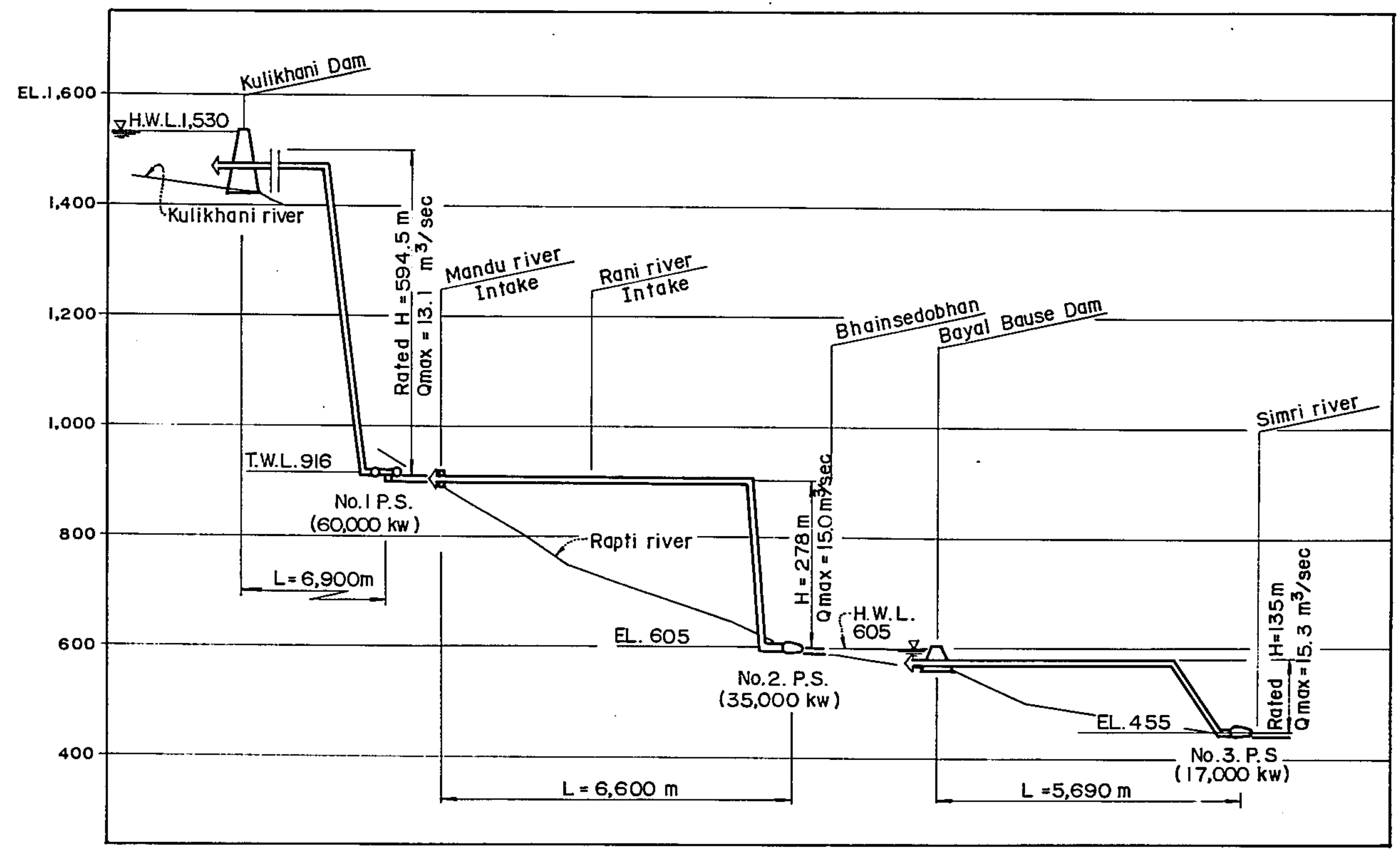
Though much more investigations and studies are needed before arriving at the final plan of these two power stations, the preliminary concept of these further development schemes are outlined in the following sections. The skelton scheme of the overall Kulikhani hydropower development is shown in Fig. 10-1.

10.2 No.2 Power Station

The No.2 power station will be located on the right bank of the Rapti river near Bainse Dobhan. The tailwater of the Kulikhani No.1 power station and the natural runoff of the Rapti river will be conveyed to the No.2 power station through a tunnel of about 6 km in length. In the midway of the tunnel, additional discharges from the tributaries of the Rapti river, the Mandu and the Rani, will be collected into the tunnel. Through the intake of water in the Rapti basin, the available annual mean and maximum discharges are expected to increase from 4.93 m^3/sec to 6.61 m^3/sec and from 13.1 m^3/sec to 15.0 m^3/sec respectively. An effective head of 278 m will be available from the head tank to the power plant.

The power station will generate the annual primary energy of 123 x 10^6 kWh and the secondary energy of 20 x 10^6 kWh. The dependable peak output

Fig. 10-1 SKELTON SCHEME OF POWER GENERATION



will be 32,100 kW with an installed capacity of 35,000 kW.

The project mainly consists of such structures as Rapti intake, water leading open channel of 1 km in length from the Rapti intake to intake site of the tailwater from the Kulikhani No.1 power station, tributary intakes on the Mandu and the Rani, non pressure tunnel of 6 km in length, head tank, penstock of 850 m in length, open power house and open tailrace channel of 100 m in length. The waterway tunnel passes mainly through siliceous sandstone beds and partly through the sandstone-slate alternation. In tunnelling work, any noticeable difficulty will not be encountered, though the route is crossed by some minor faults. The power station at Bainse Dobhan will be rested on the alternately sandstone and slate or mica schist.

A new transmission line of 132 kV will be constructed in parallel with the existing 66 kV line between Kathmandu and Hitaura. Transformers with 25 MVA and 30 MVA will be added to the Kathmandu and the Hitaura substations, respectively.

The total construction cost excluding the interest during construction is estimated to be US$ 17 million and the annual project cost US$ 1,840,000 at an annual interest rate of 8 %. The mean energy cost will be around US mill 14.5/kWh. The power benefit is calculated at US$ 4,920,000 per annum and the benefit-cost ratio will be as high as 2.67 owing to the master reservoir to be created by the Kulikhani No.1 power station project.

The power generation plan of the No.2 power station is summarized in Table 10-1.

10.3 No.3 Power Station

For the purpose of regulating the runoff of the Rapti river as well as the tailwater from the No.2 power station, a 65 m high dam will be constructed at Bayal Bauss on the Rapti river about 2 km downstream from the No.2 power station. The water regulated by the reservoir will be conveyed to the No.3 power station through a pressure tunnel and penstock of about 6 km in total length passing through the left bank along the Rapti river. The power station will be located near the confluence of the Simri river with the Rapti river.

TABLE 10-1 POWER GENERATION PLAN OF KULIKHANI NO.2 POWER STATION

Available discharge		
Tailwater of No.1 power station		
Wet season (Jun. - Nov.)	firm discharge	2.1 m^3/sec
Dry season (Jan. - Apr.)	"	6.2 m^3/sec
Transition period (May, Dec.)	"	4.2 m^3/sec
Maximum discharge		13.1 m^3/sec
Rapti river		
Monthly maximum (Aug.)		5.2 m^3/sec
Monthlyminimum (Apr.)		0.3 m^3/sec
Annual mean		1.6 m^3/sec
Tributaries (Mandu and Rani)		
Monthly maximum (Aug.)		3.8 m^3/sec
Monthly minimum (Apr.)		0.2 m^3/sec
Annual mean		1.2 m^3/sec
Maximum discharge		15.0 m^3/sec
Head		
Inlet elevation		EL. 910 m
Tailwater level		EL. 605 m
Gross head		305 m
Maximum loss head		27 m
Rated head		278 m
Power generation		
Type		Run-of-river type
Installed capacity		35,000 kW
Dependable peak output		32,100 kW
Annual energy output		
Primary		124 x 10^6 kWh
Secondary		20 x 10^6 kWh
Total		144 x 10^6 kWh

The foundation of the proposed damsite is in the province of white siliceous sandstone and quartzite, hard and cracked, which will be suitable for dam construction with an ordinary foundation treatment. The waterway tunnel will pass through sandstone and stable slate, and through the weathered sandstone-slate alternation of the Tertiary Siwaliks, crossing a thrust fault in between. The foundation of the penstock line and the power house is covered with weathered soft zone and some deep excavation will be required.

The catchment area of the Rapti river above the damsite is 122 km^2 and yields an average annual runoff of 7.4 m^3/sec. Since the water diverted from the Kulikhani river basin is added by the average flow of 3.8 m^3/sec, the total inflow of the Bayal Bauss reservoir will be 11.2 m^3/sec. A 65 m high rockfill dam is envisaged to create a gross storage capacity of about $14 \times 10^6 m^3$.

The installed capacity will be in the order of 17,000 kW under the available effective head of 135 m and the maximum discharge of 15.3 m^3/sec. The power station will generate the annual gross energy of 97×10^6 kWh of which the annual firm energy is 75×10^6 kWh. The power will be transmitted through the 132 kV line to be constructed at the time of the No.2 power station development. Transformers with 12 MVA and 7 MVA will be added to the Kathmandu and the Hitaura substations.

The total construction cost excluding the interest during construction is estimated to be US$ 22,000,000 and the annual project cost to be US$ 2,330,000 at an annual interest rate of 8 %. The energy cost is calculated to be around US mill 29.3/kWh. The annual power benefit is US$ 2,840,000 and the benefit-cost ratio is calculated at 1.22 under the discount rate of 8 % and evaluation period of 50 years.

For the implementation of the No.3 power station project, due consideration should be given to the relocation of the existing highway, transmission line and ropeway to be inundated by the creation of the reservoir.

The power generation plan of the No.3 power station is summarized in Table 10-2.

TABLE 10-2 POWER GENERATION PLAN OF KULIKHANI NO.3 POWER STATION

Available discharge

Kulikhani river diversion (156 km^2)	3.8 m^3/sec
Rapti river (122 km^2)	7.4 m^3/sec
Total	11.2 m^3/sec

Discharge for power generation

Dam	65 m high rockfill dam	
Reservoir capacity	14 x $10^6 m^3$ (Gross)	
	10 x $10^6 m^3$ (Net)	
Mean discharge		9.3 m^3/sec
Maximum discharge		15.3 m^3/sec

Head

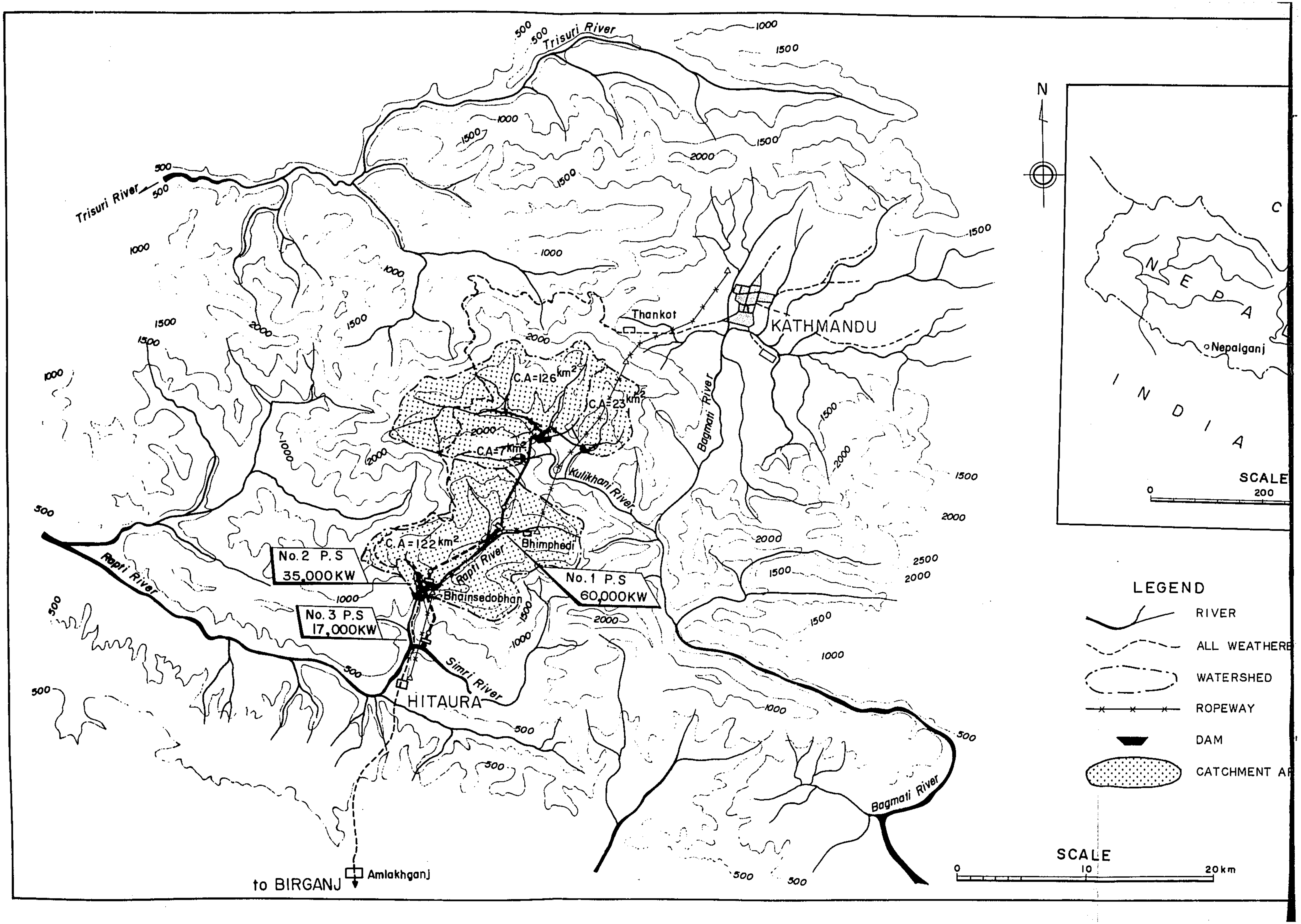
High water level	EL. 605 m
Low water level	EL. 597 m
Tailwater level	EL. 455 m
Gross head	150 m - 142 m
Maximum loss head	12 m
Rated head	133 m

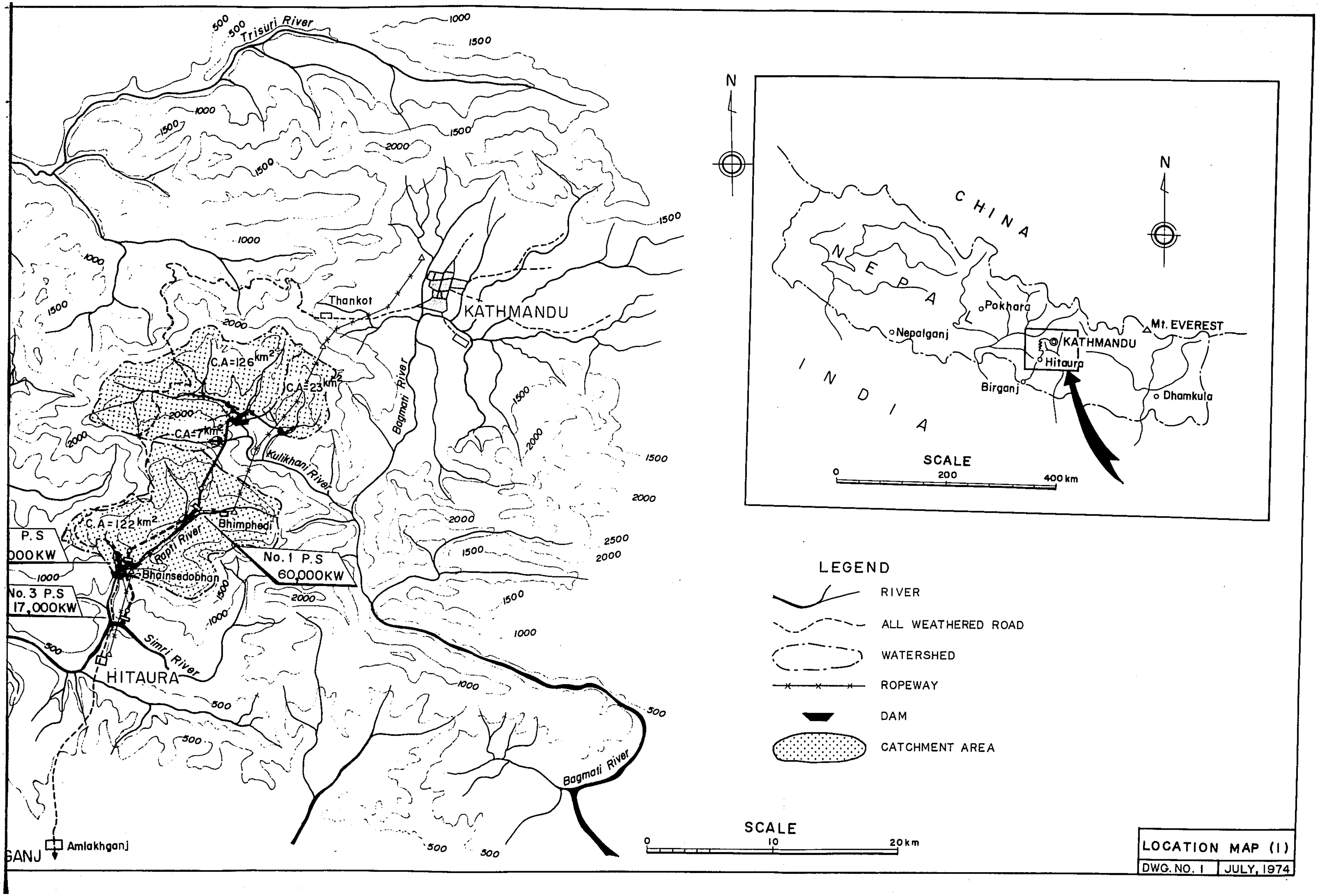
Power generation

Installed capacity	17,000 kW
Dependable peak output	16,500 kW
Annual energy output	
Primary	75 x 10^6 kWh
Secondary	22 x 10^6 kWh
Total	97 x 10^6 kWh

DRAWINGS

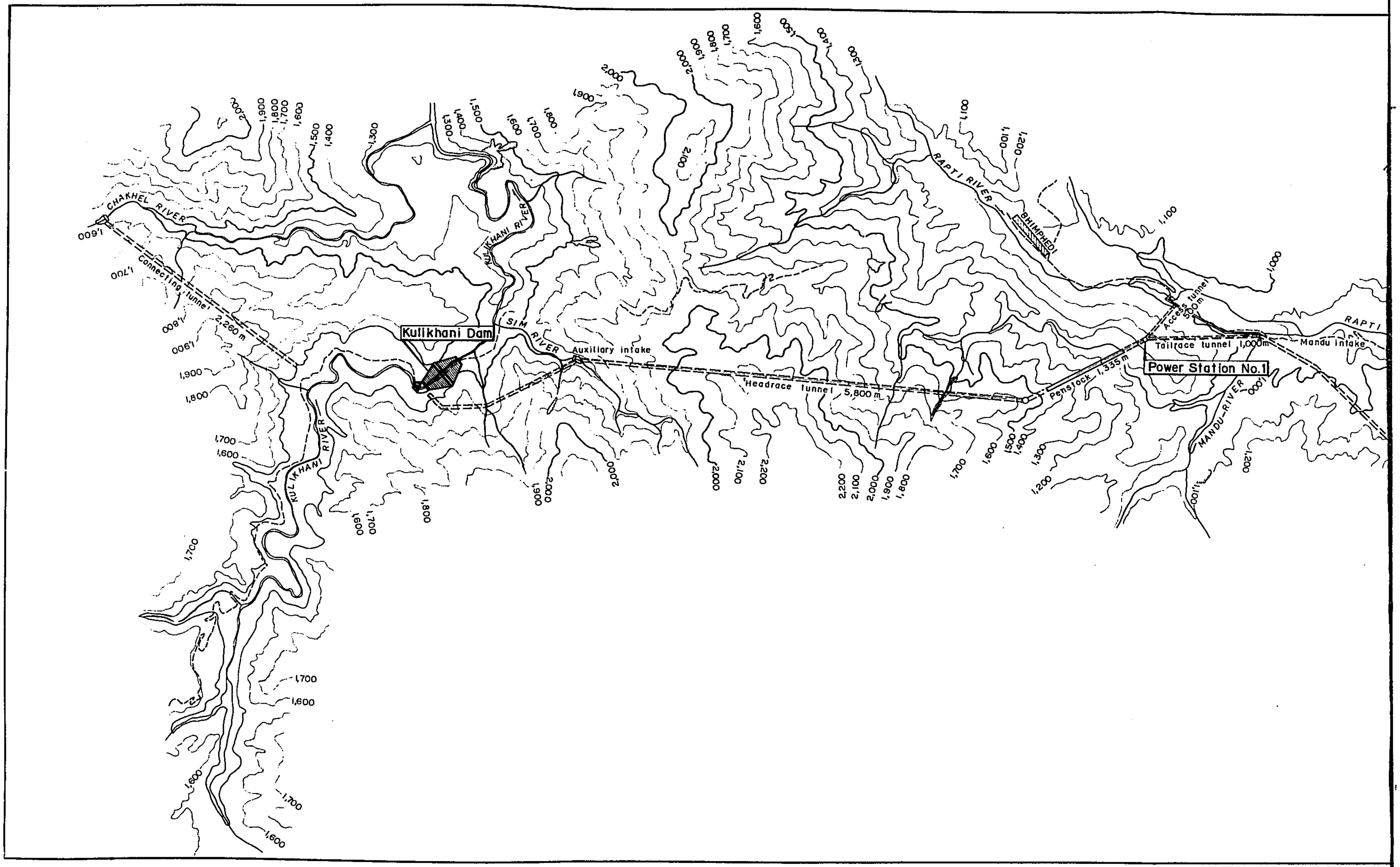
Drawing No.	Title
1	Location Map (1)
2	Location Map (2)
3	General Layout of No.1 Project
4	Geological Map in Project Area
5	General Plan
6	Typical Section and Profile of Dam, Spillway and Diversion Tunnel
7	Geological Map of Dam Site
8	Geological Profile of Dam Site (1)
9	Geological Profile of Dam Site (2)
10	Plan and Profile of Intake and Auxiliary Intake
11	Plan and Profile of Waterway
12	Plan and Profile of Surge Tank, Power House and Switch Yard
13	Detail of Power House


Trisuri River
KATHMANDU
Thankot
Bagmati River
Kulikhani River
C.A=126 km²
C.A=23 km²
C.A=7 km²
C.A=122 km²
Bhimphedi
Rapti River
No.2 P.S
35,000KW
No.1 P.S
60,000KW
No.3 P.S
17,000KW
Bhainsedobhan
Simri River
HITAURA
to BIRGANJ
Amlakhganj
NEPAL
INDIA
Nepalganj
N
LEGEND
RIVER
ALL WEATHER
WATERSHED
ROPEWAY
DAM
CATCHMENT A
SCALE
0
10
20km

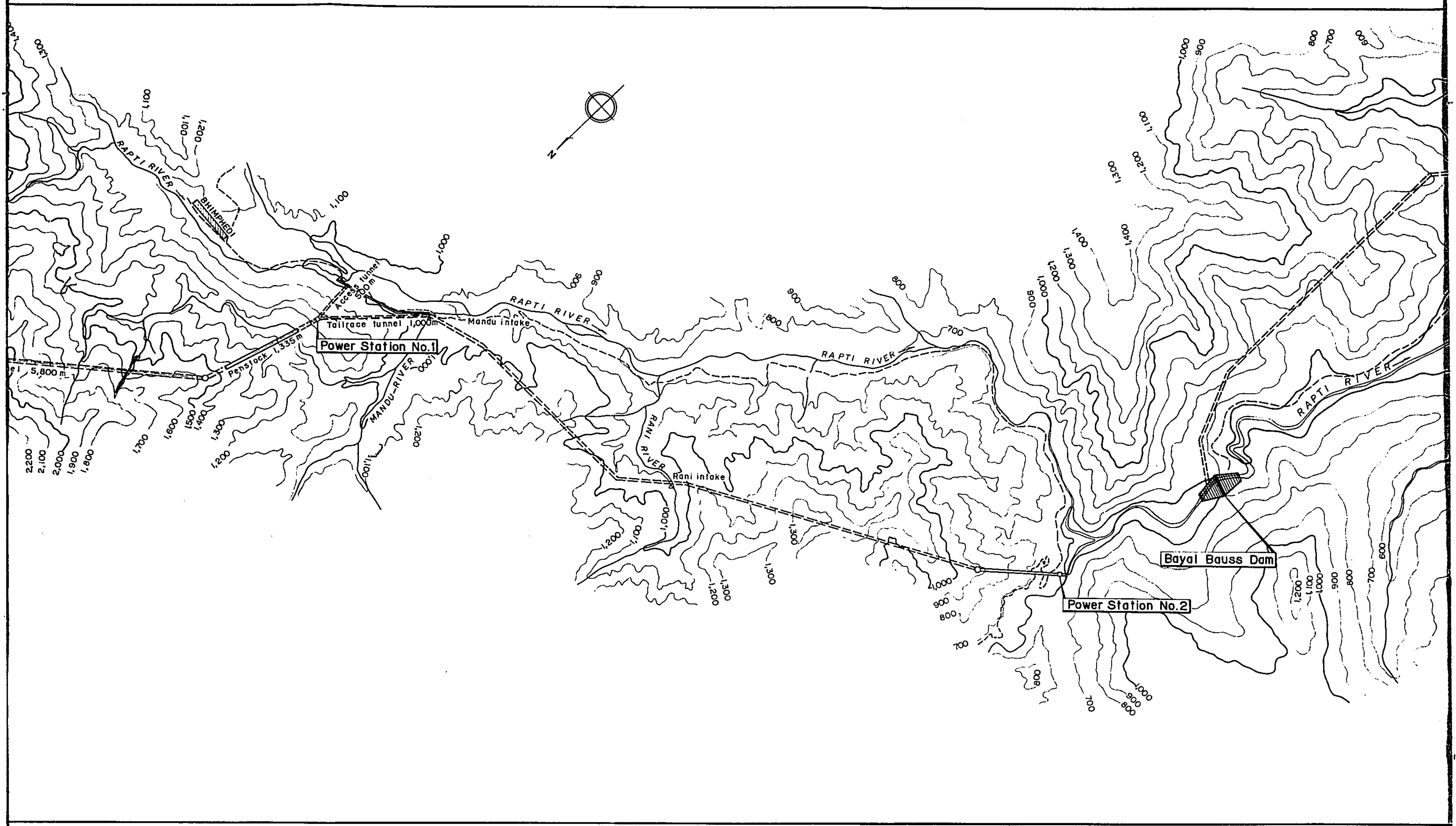


LOCATION MAP (1)

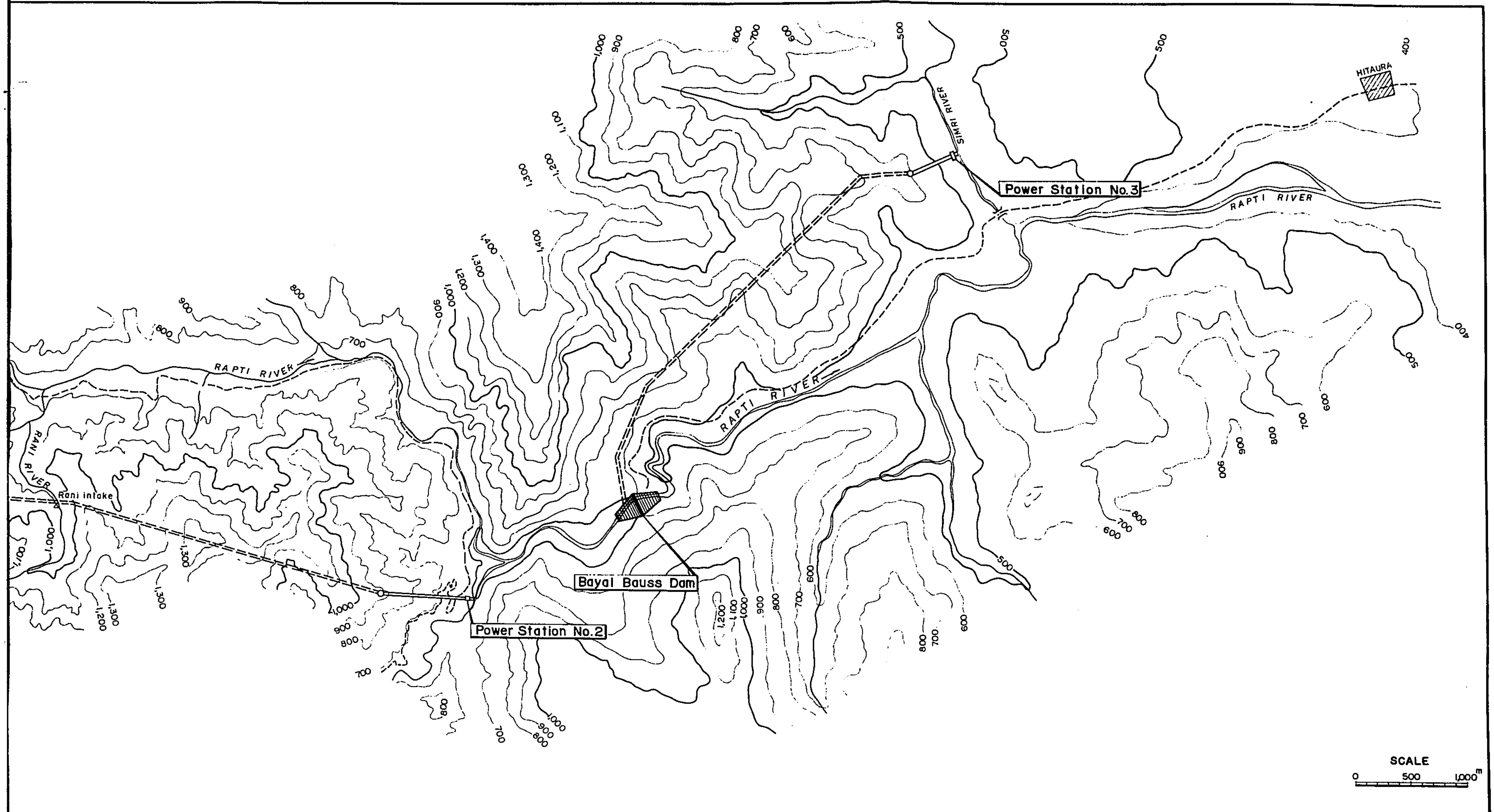
DWG. NO. 1 | JULY, 1974



CHAKHEL RIVER
Connecting tunnel 2,260 m
KULIKHANI RIVER
Kulikhani Dam
SIM RIVER
Auxiliary intake
Headrace tunnel 5,800 m
Penstock 1,335 m
Access tunnel 500 m
Tailrace tunnel 1,000 m
Mandu intake
Power Station No.1
MANDU RIVER
RAPTI RIVER
RAPTI
BHIMPHEDI

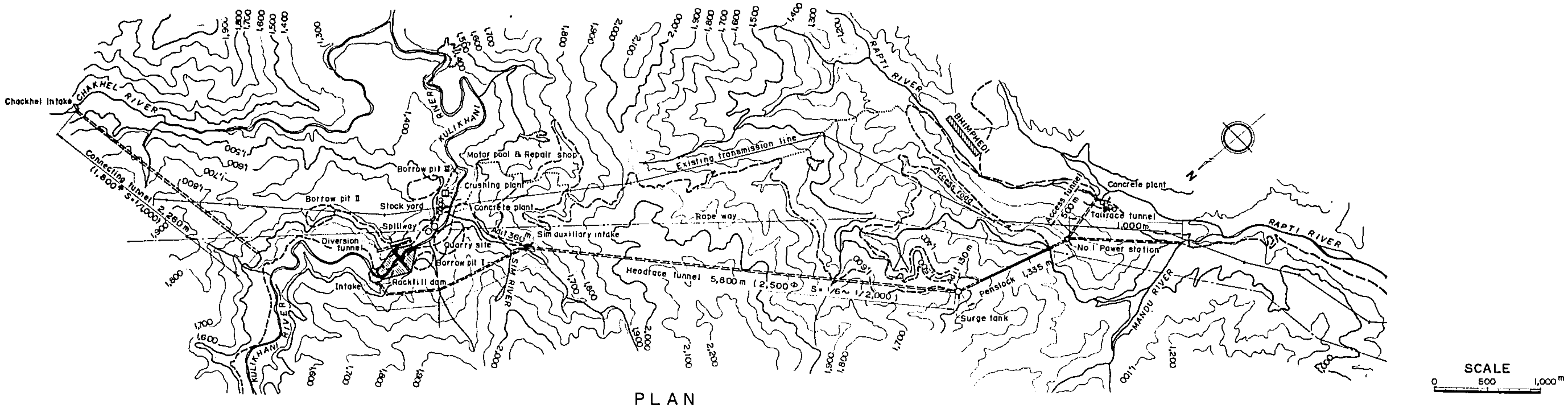


RAPTI RIVER
BHIMPHEDI
Access tunnel 500m
Tailrace tunnel 1,000m
Mandu intake
Power Station No.1
Penstock 1,335m
5,800m
MANDU RIVER
RAPTI RIVER
RANI RIVER
Rani intake
RAPTI RIVER
Bayal Bauss Dam
Power Station No.2
RAPTI RIVER
N

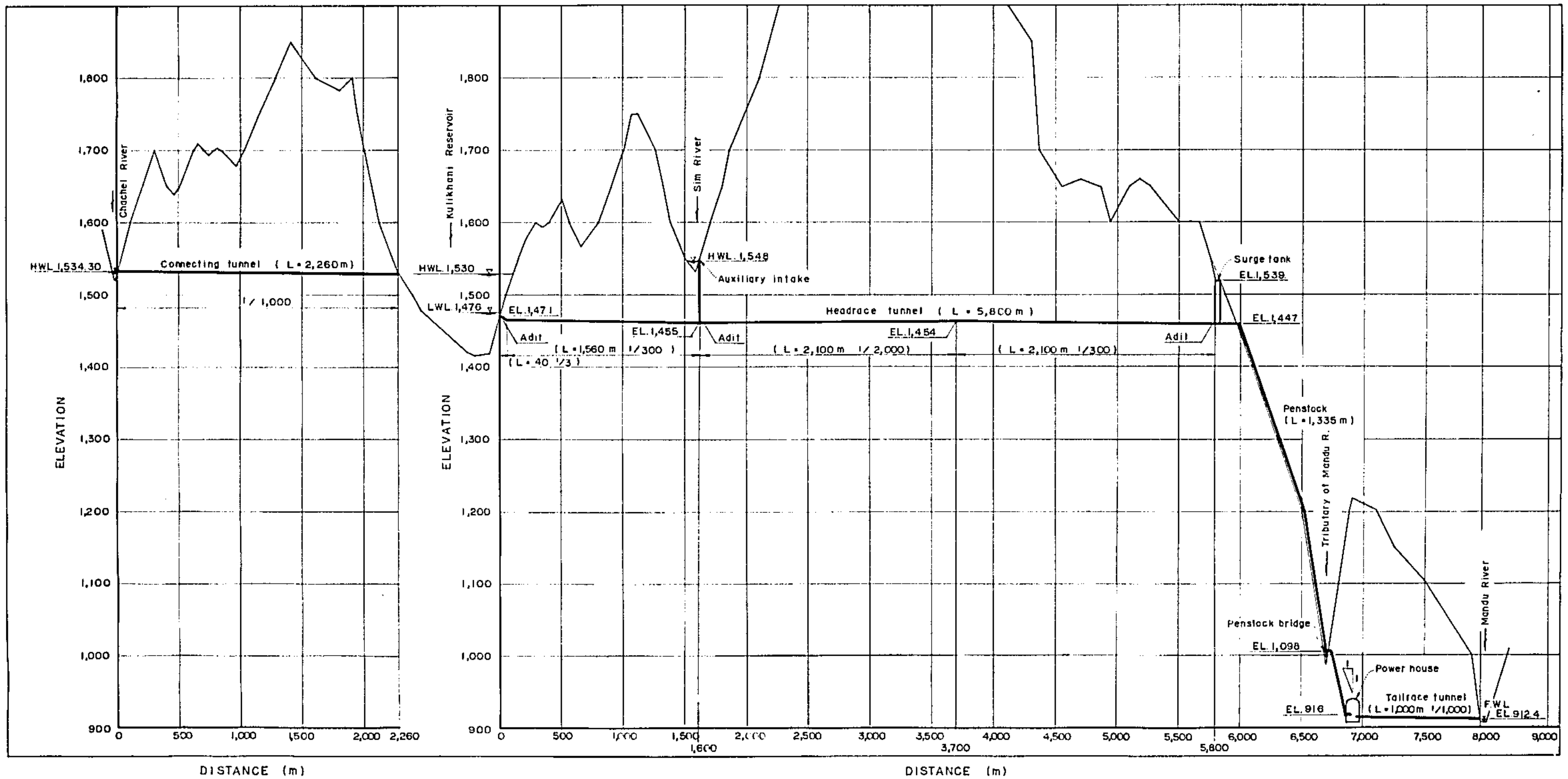


LOCATION MAP(2)

DWG. NO. 2 | JULY, 1974

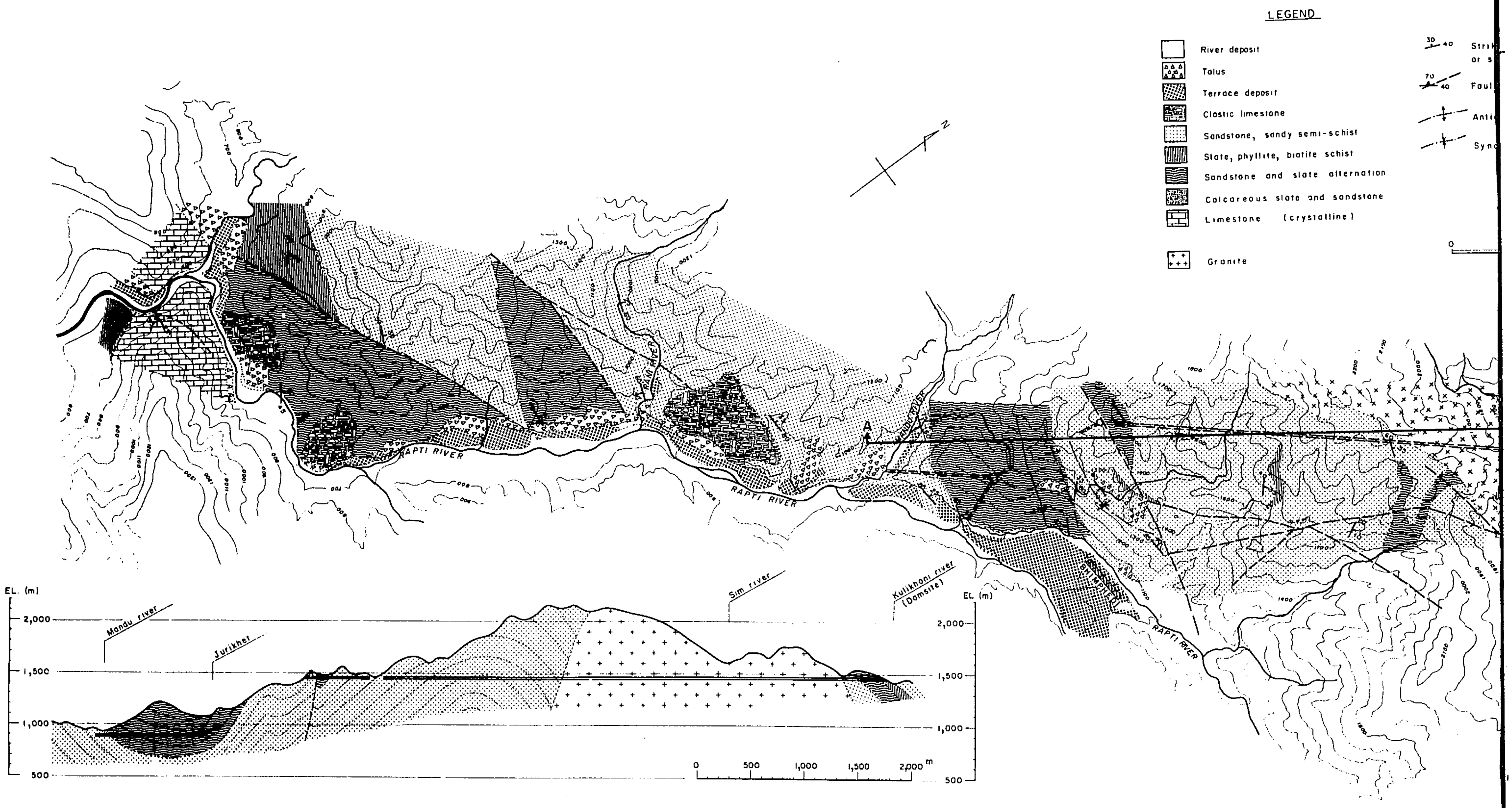


PLAN

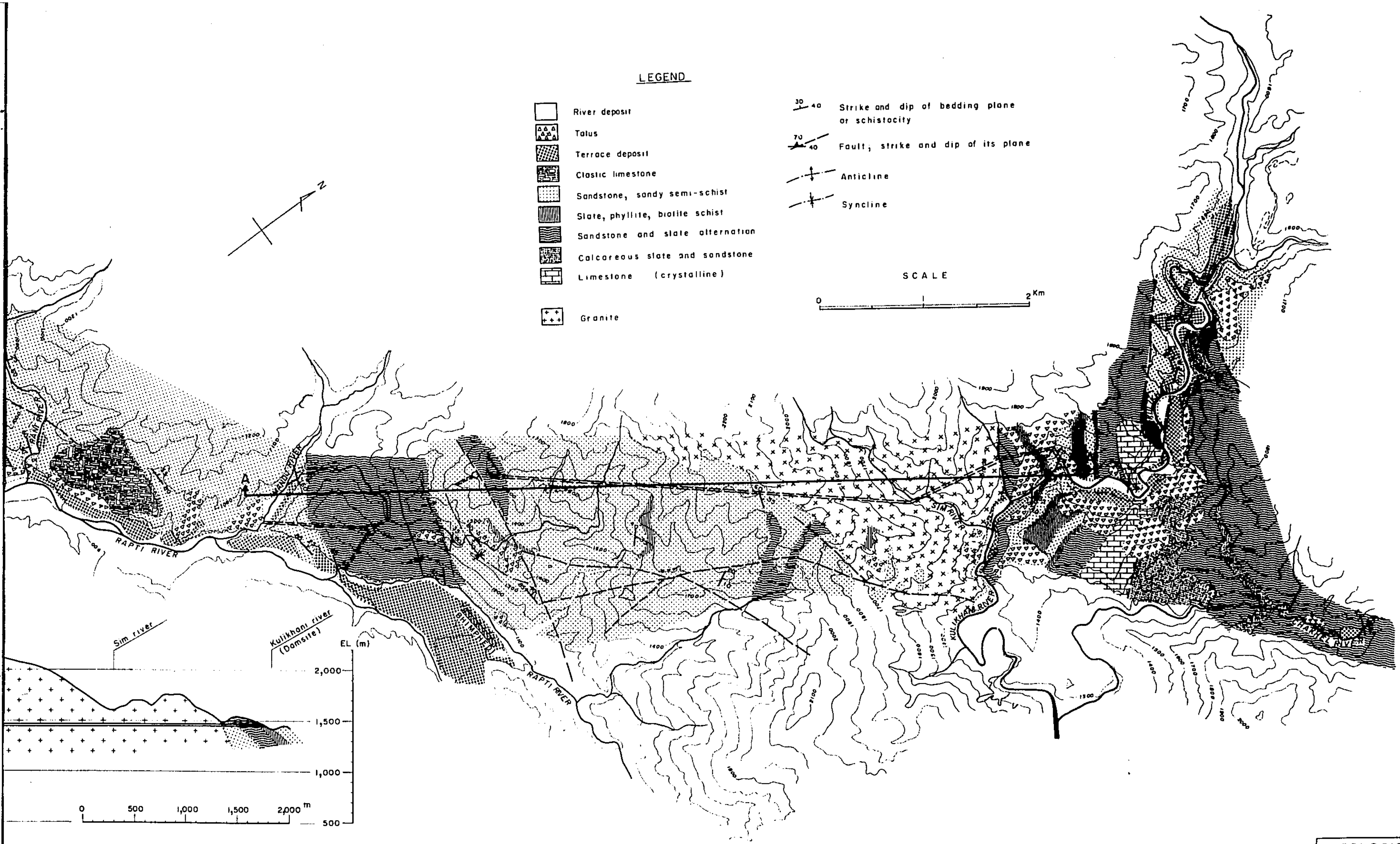


PROFILE

GENERAL LAYOUT OF No.1 PROJECT	
DWG. No. 3	JULY, 1974

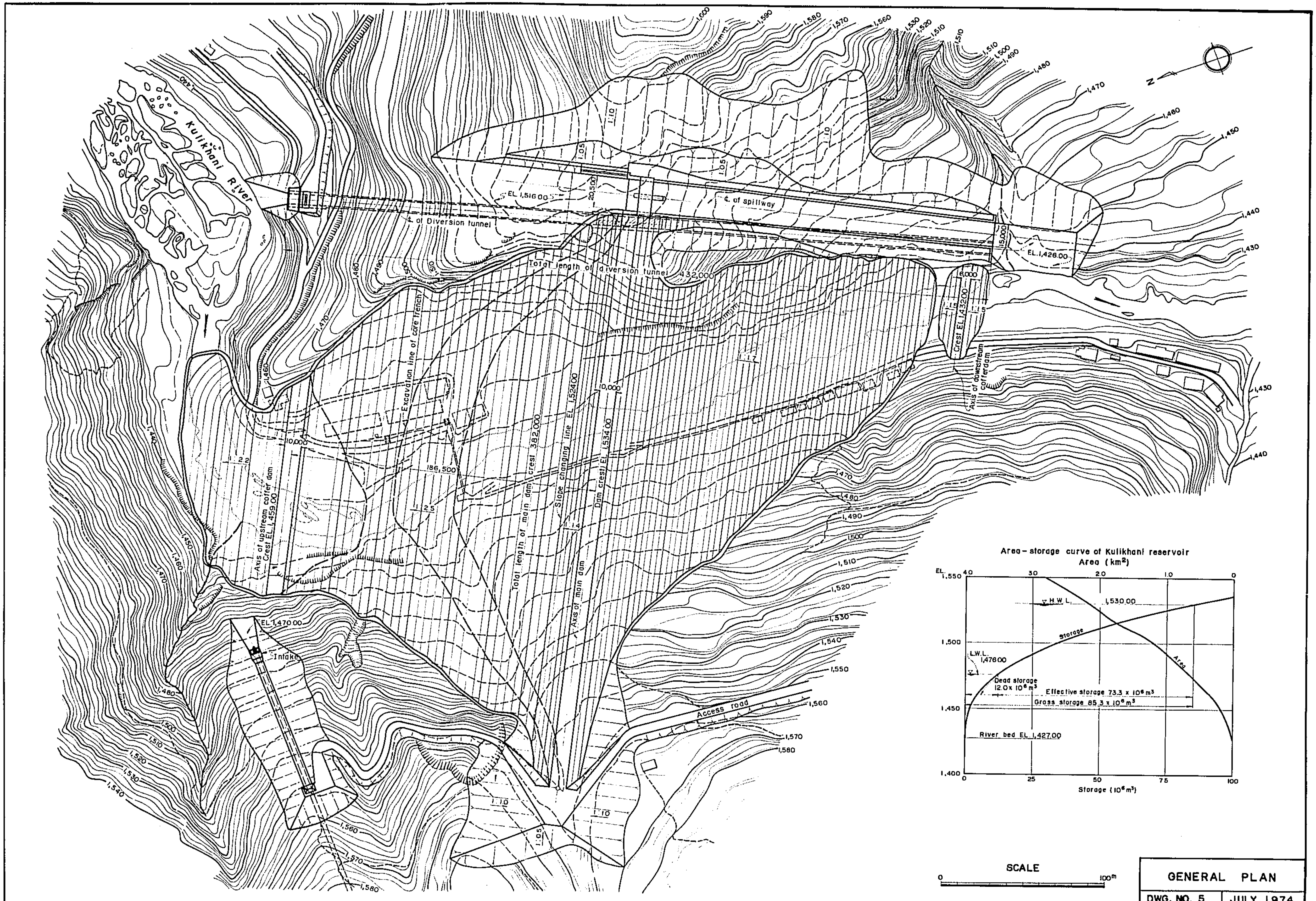

LEGEND
River deposit
Talus
Terrace deposit
Clastic limestone
Sandstone, sandy semi-schist
Slate, phyllite, biotite schist
Sandstone and slate alternation
Calcareous slate and sandstone
Limestone (crystalline)
Granite
RAPTI RIVER
RAPTI RIVER
RAPTI RIVER
EL. (m)
2,000
1,500
1,000
500
Mandu river
Jurikhet
Sim river
Kulikhani river (Damsite)
0
500
1,000
1,500
2,000 m

SECTION A — A



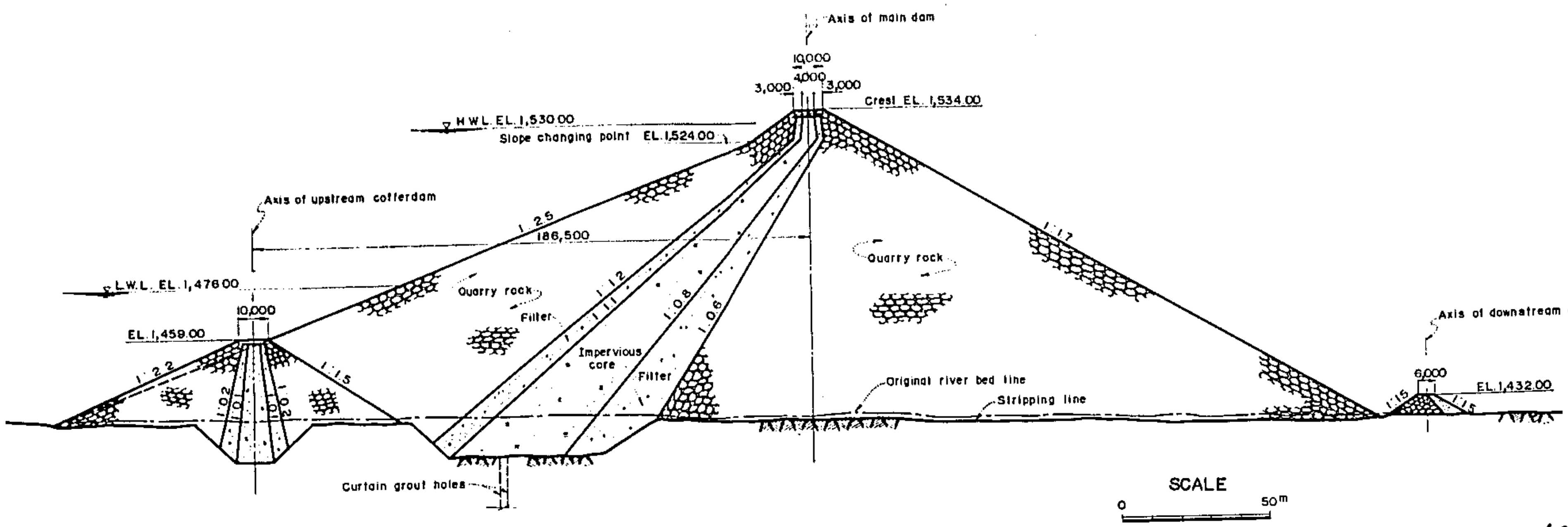
GEOLOGICAL MAP IN PROJECT AREA

DWG. No. 4	JULY, 1974

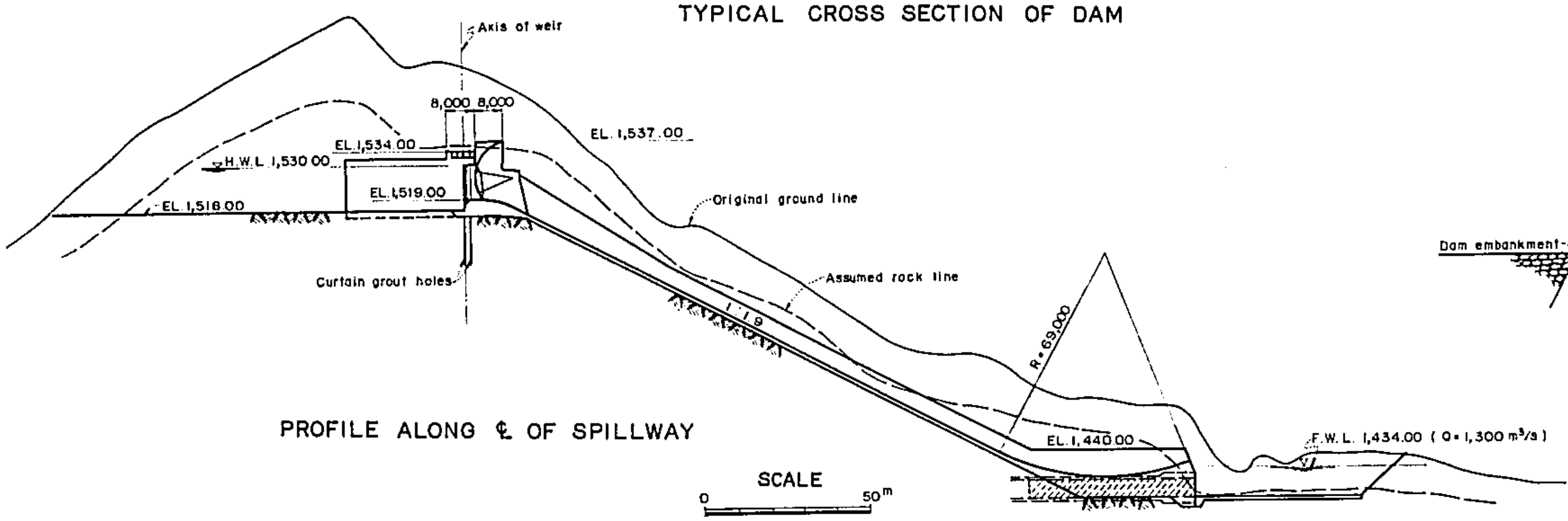


GENERAL PLAN

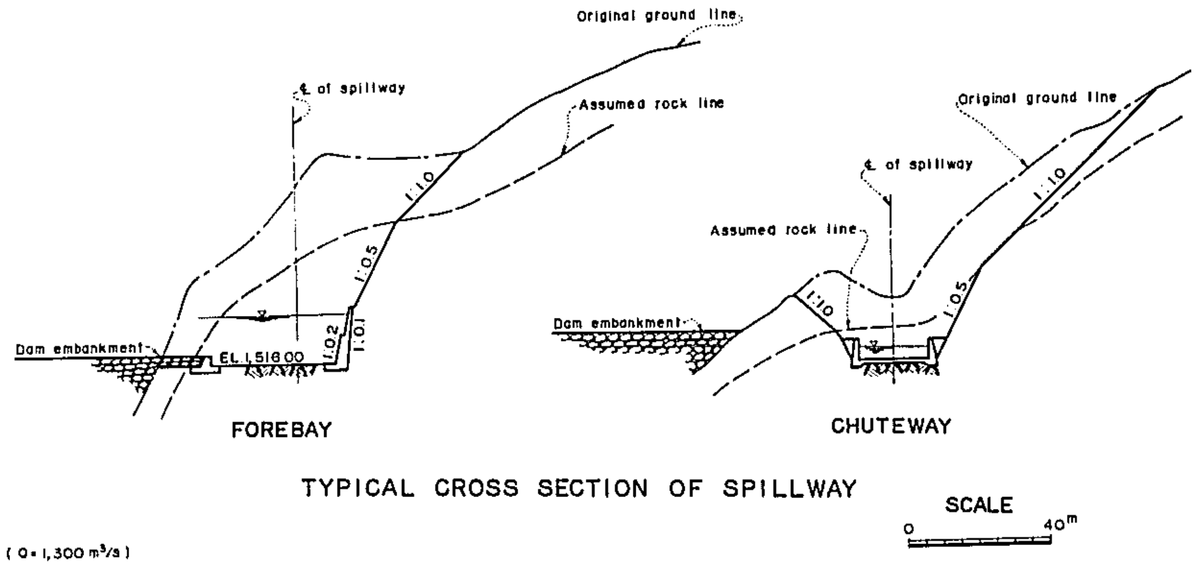
DWG. NO. 5 | JULY, 1974



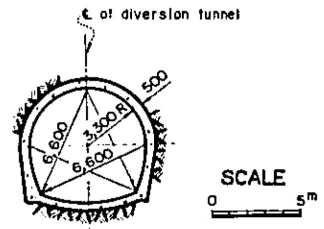
TYPICAL CROSS SECTION OF DAM



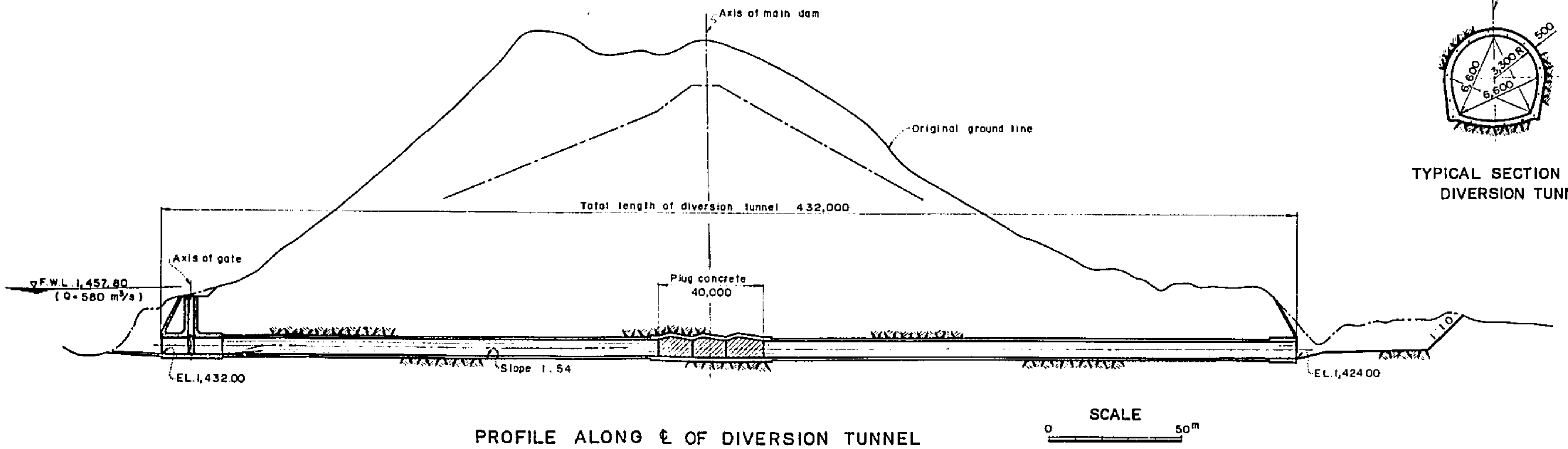
PROFILE ALONG ℄ OF SPILLWAY



TYPICAL CROSS SECTION OF SPILLWAY

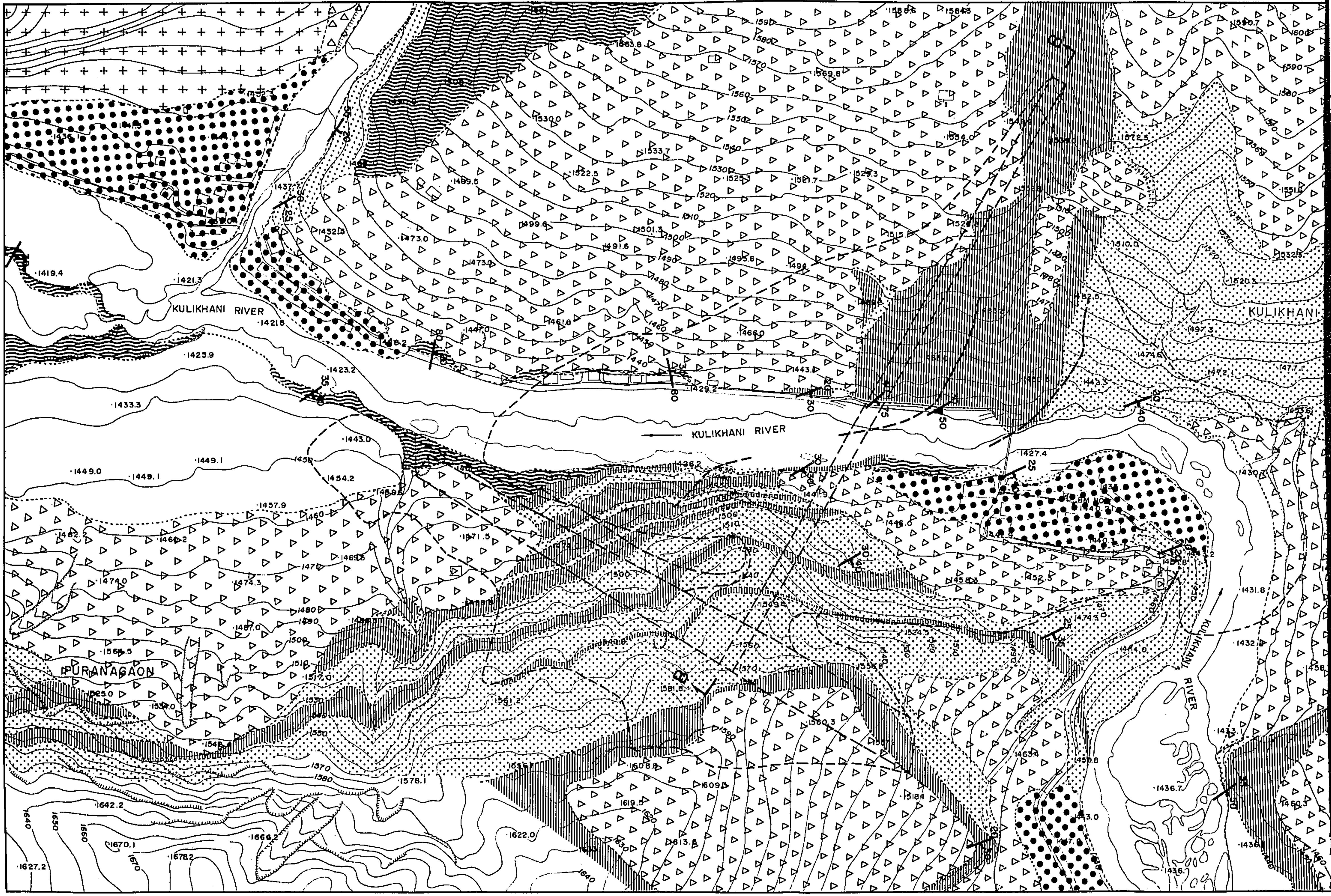


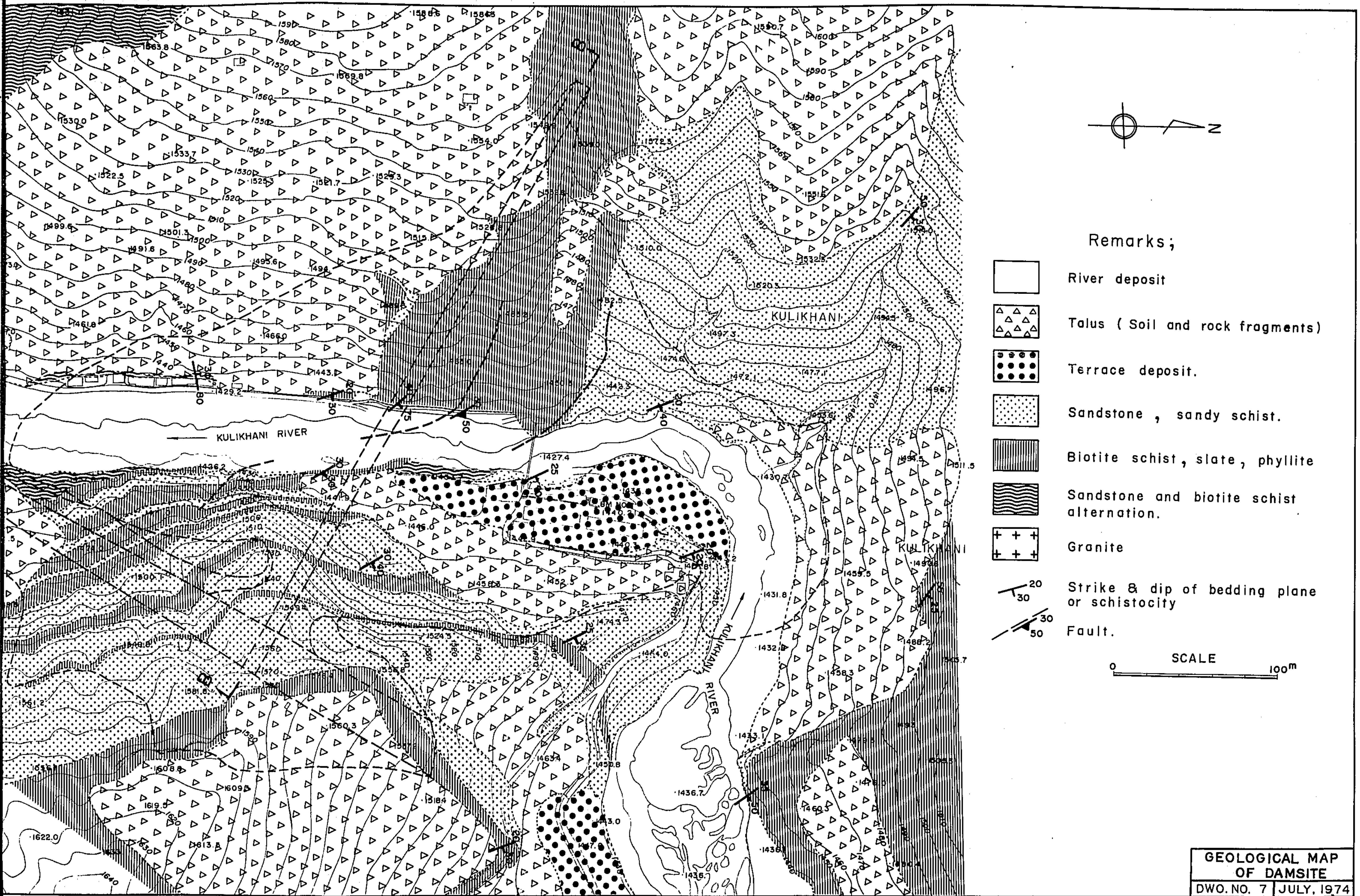
TYPICAL SECTION OF DIVERSION TUNNEL



PROFILE ALONG ℄ OF DIVERSION TUNNEL

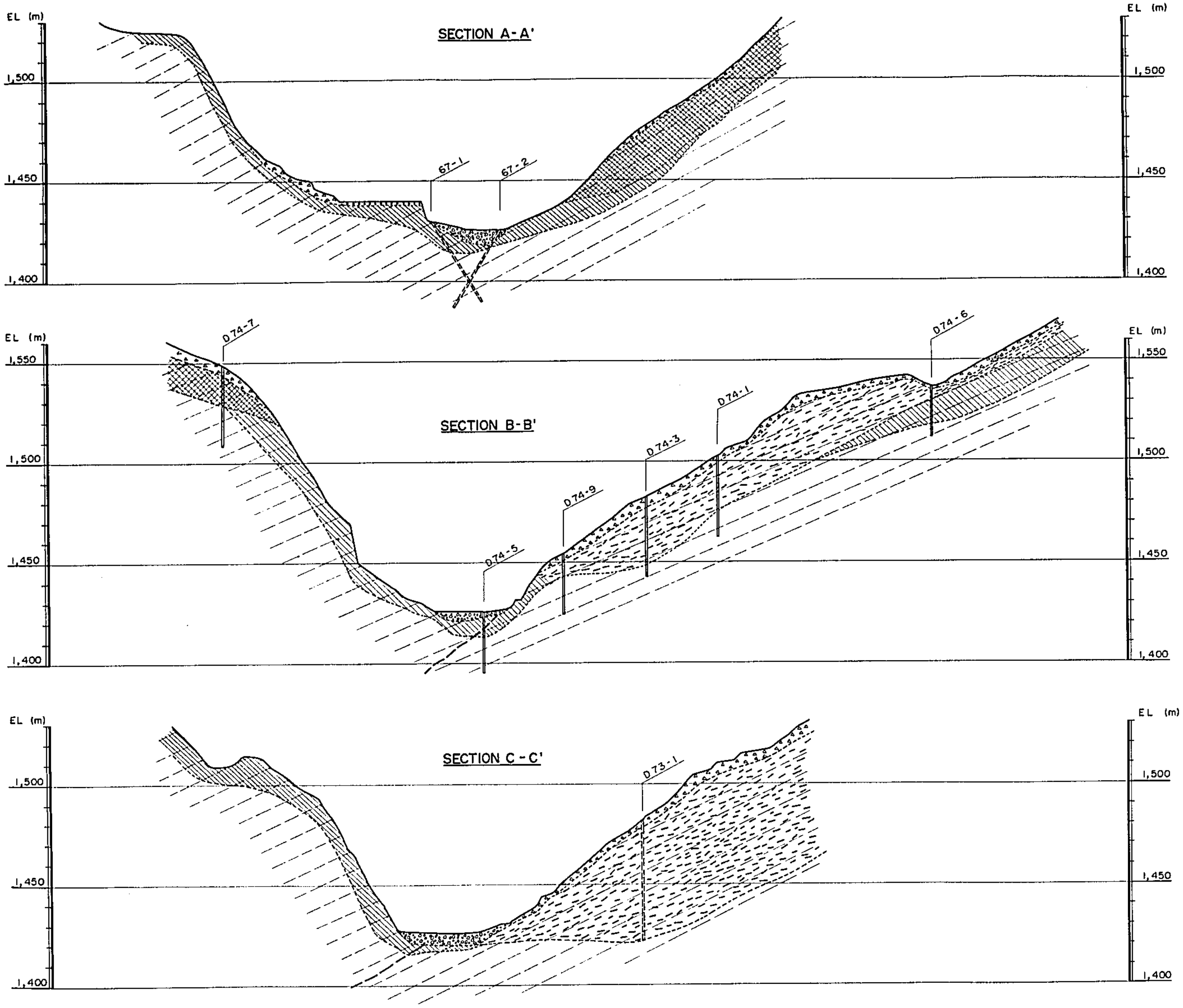
TIPICAL SECTION AND PROFILE OF DAM, SPILLWAY AND DIVERSION TUNNEL	
DWG. No. 6	JULY, 1974


KULIKHANI RIVER
KULIKHANI RIVER
KULIKHANI
PURANAGAON
KULIKHANI RIVER



GEOLOGICAL MAP OF DAMSITE

DWO. NO. 7 JULY, 1974



LEGEND

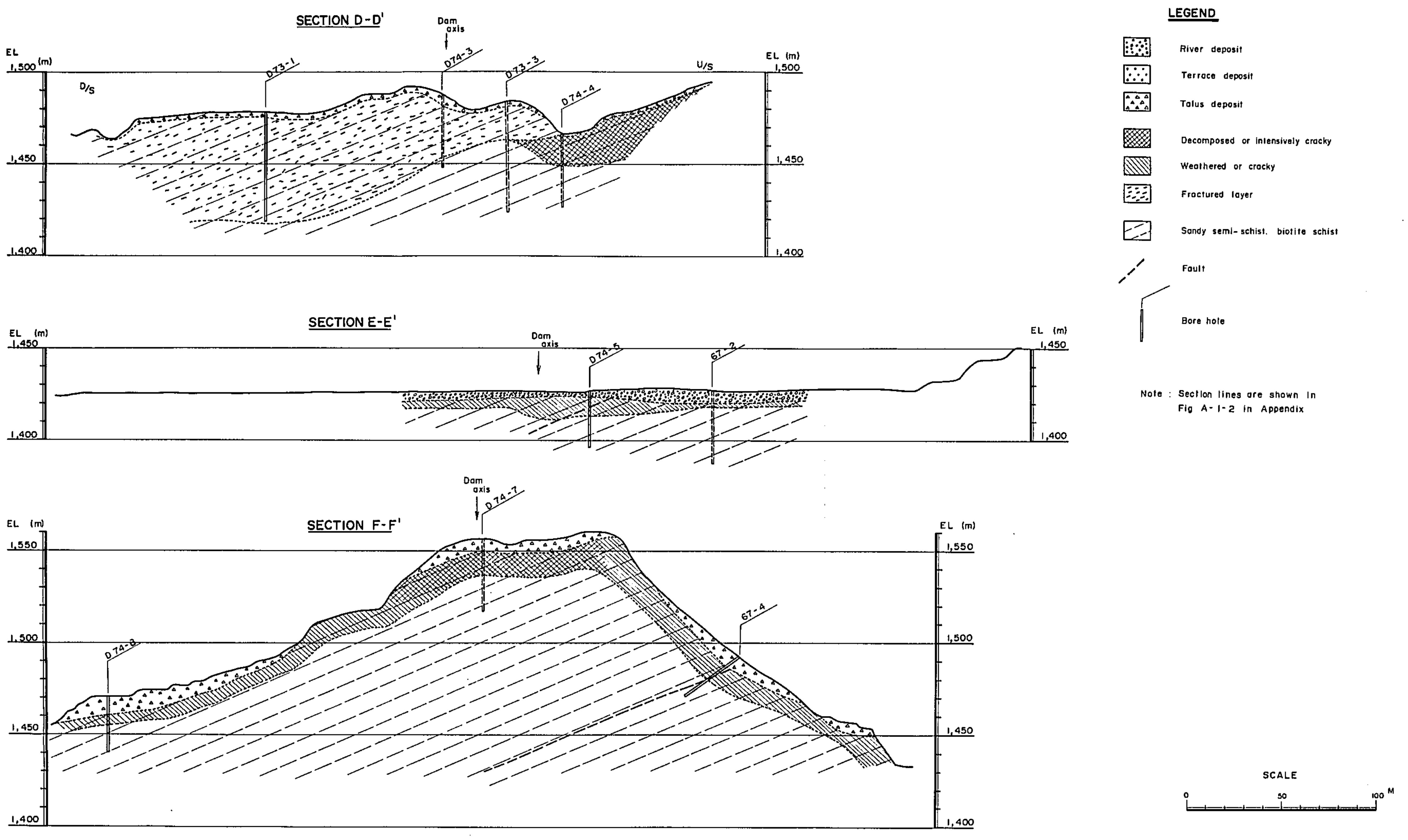
- River deposit
- Terrace deposit
- Talus deposit
- Decomposed or intensively cracked
- Weathered or cracked
- Fractured layer
- Sandy semi-schist, biotite schist
- Fault
- Bore hole

Note : Section lines are shown in Fig. A-1-2 in Appendix

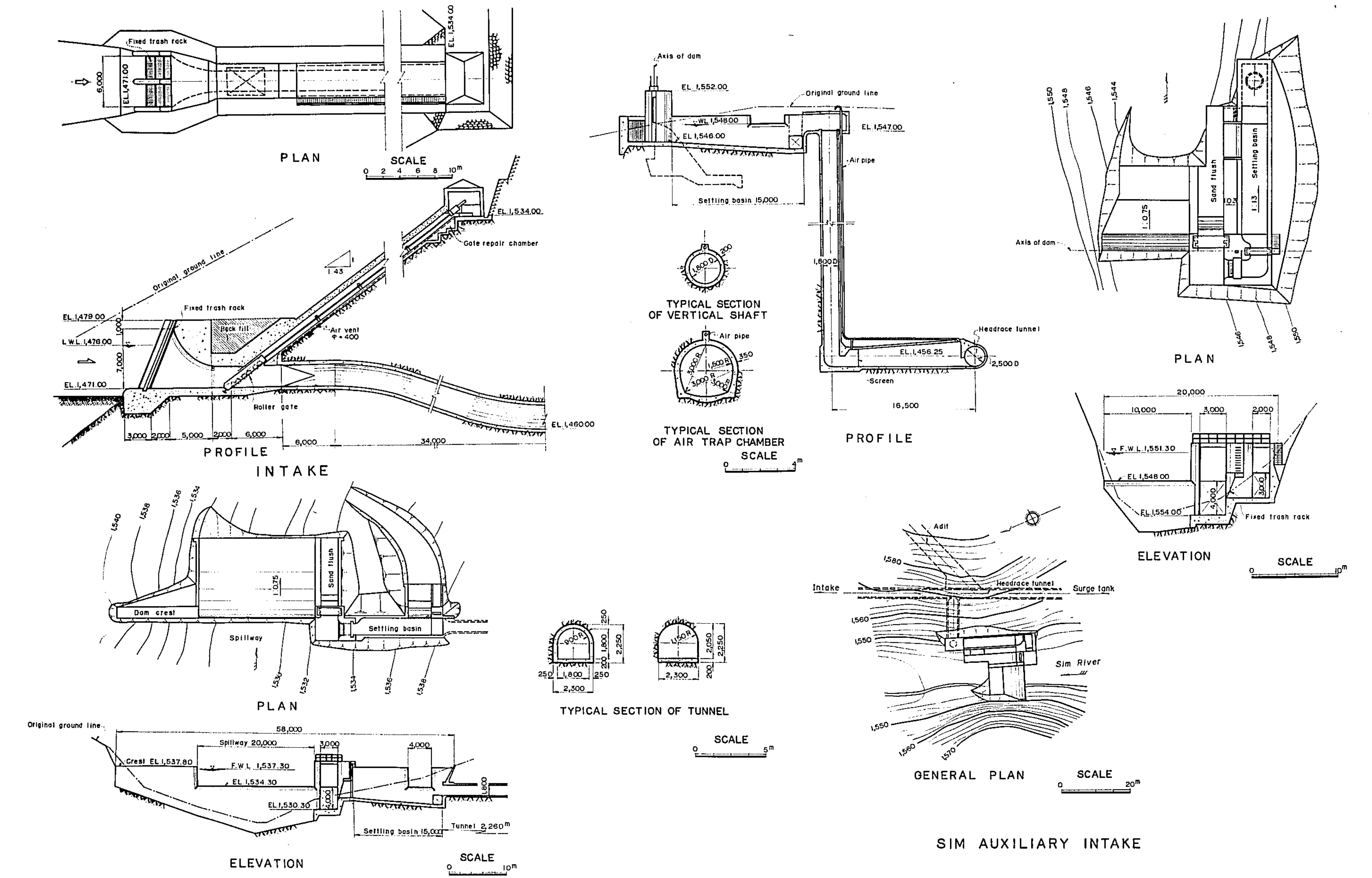
SCALE

0 50 100M

GEOLOGICAL PROFILE OF DAMSITE (1)	
DWG. NO. 8	JULY, 1974

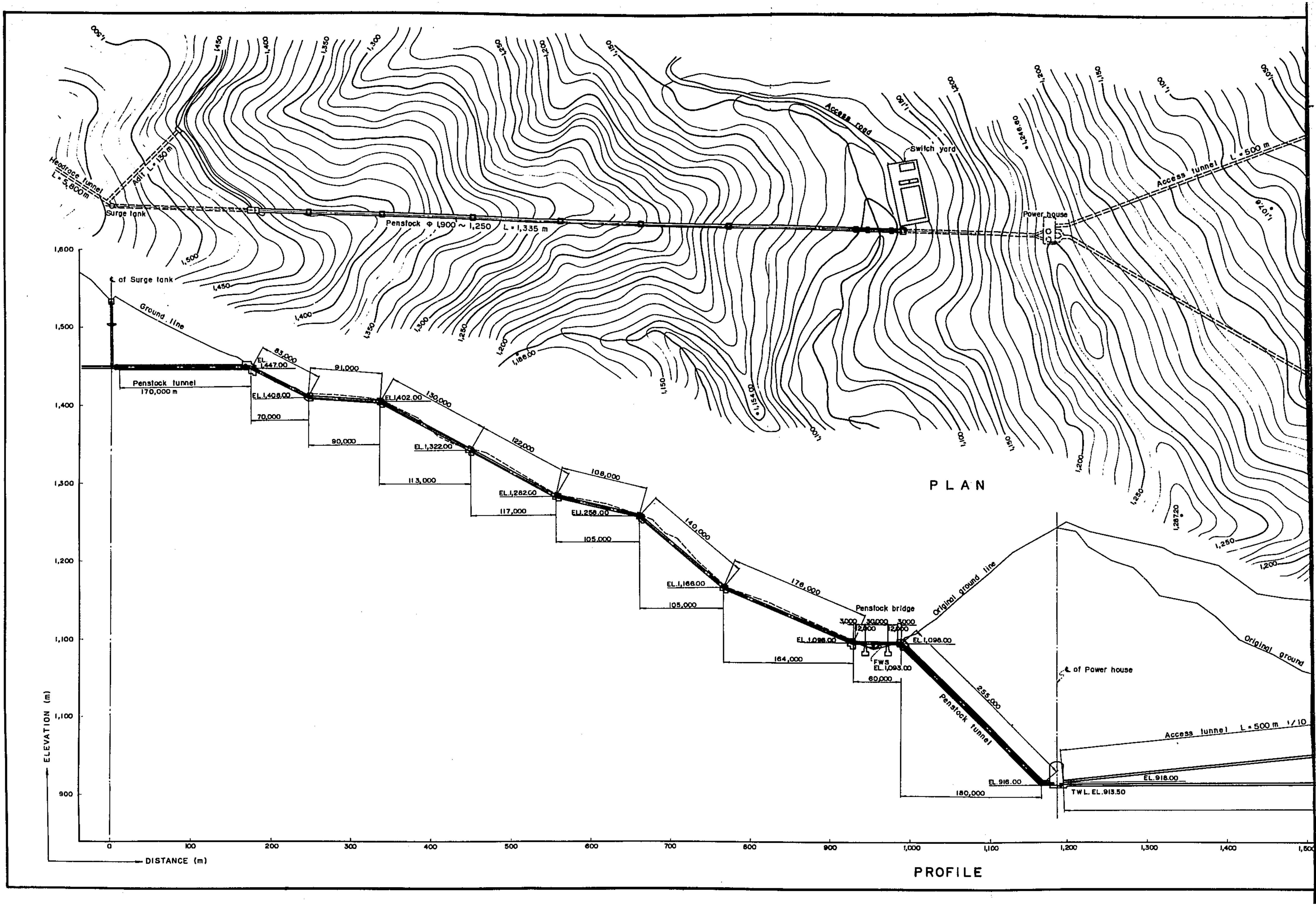


GEOLOGICAL PROFILE OF DAMSITE (2)	
DWG. NO. 9	JULY, 1974

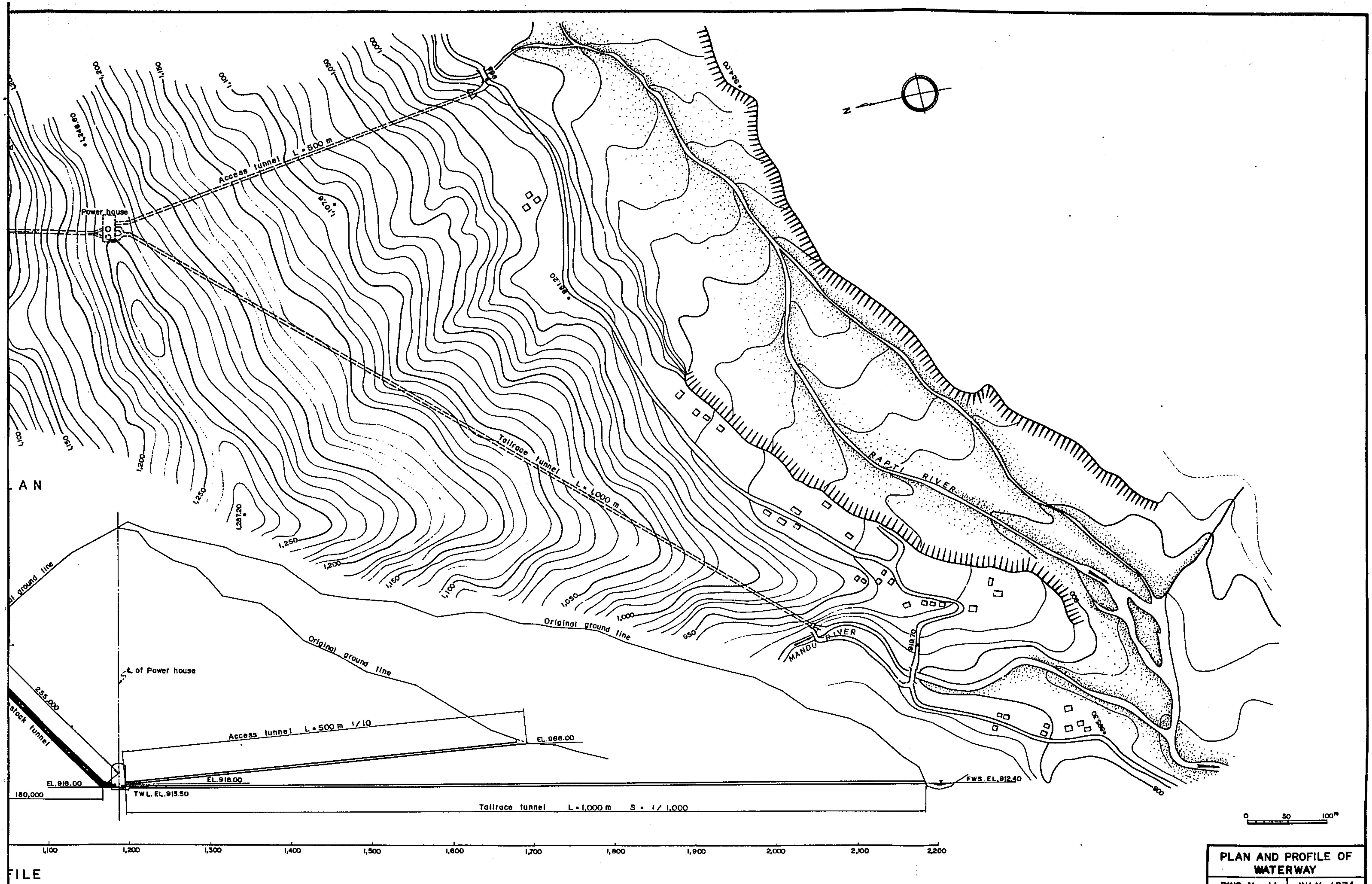


CHAKHEL AUXILIARY INTAKE

PLAN AND PROFILE OF INTAKE AND AUXILIARY INTAKE	
DWG. No. 10	JULY, 1974

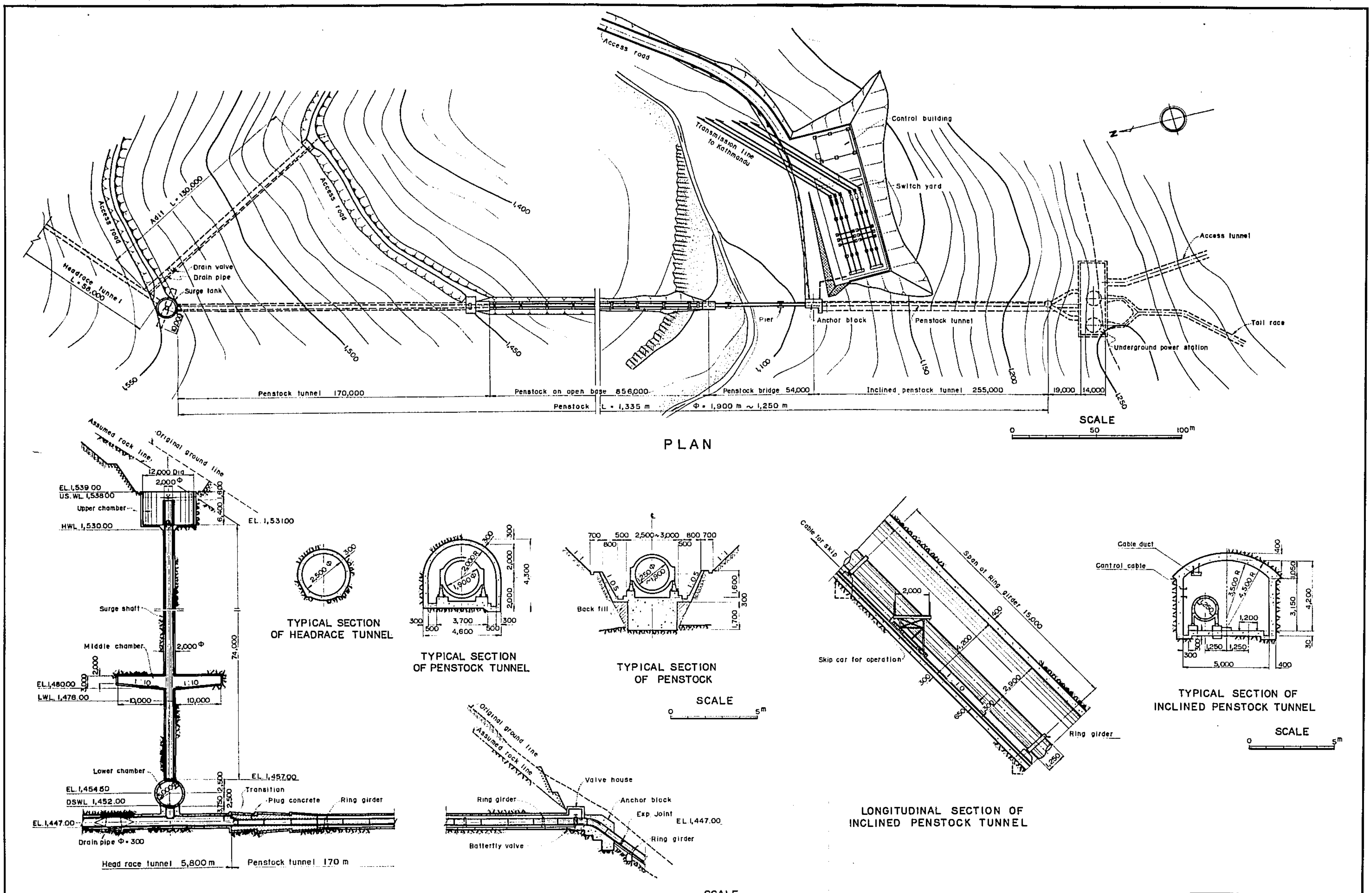


Headrace tunnel L=5,800m
Adit L=130m
Surge tank
Penstock Φ 1,900 ~ 1,250 L=1,335 m
Access road
Switch yard
Power house
Access tunnel L=500 m
PLAN
℄ of Surge tank
Ground line
Penstock tunnel
170,000 m
EL. 1,447.00
83,000
91,000
EL. 1,408.00
70,000
EL. 1,402.00
130,000
90,000
EL. 1,322.00
122,000
113,000
EL. 1,282.00
108,000
117,000
EL. 1,258.00
105,000
140,000
EL. 1,166.00
105,000
176,000
Penstock bridge
Original ground line
EL. 1,098.00
164,000
FWS
EL. 1,093.00
60,000
EL. 1,096.00
255,000
Penstock tunnel
℄ of Power house
Original ground
Access tunnel L=500 m 1/10
EL. 916.00
180,000
EL. 918.00
TWL. EL. 913.50
ELEVATION (m)
DISTANCE (m)
PROFILE



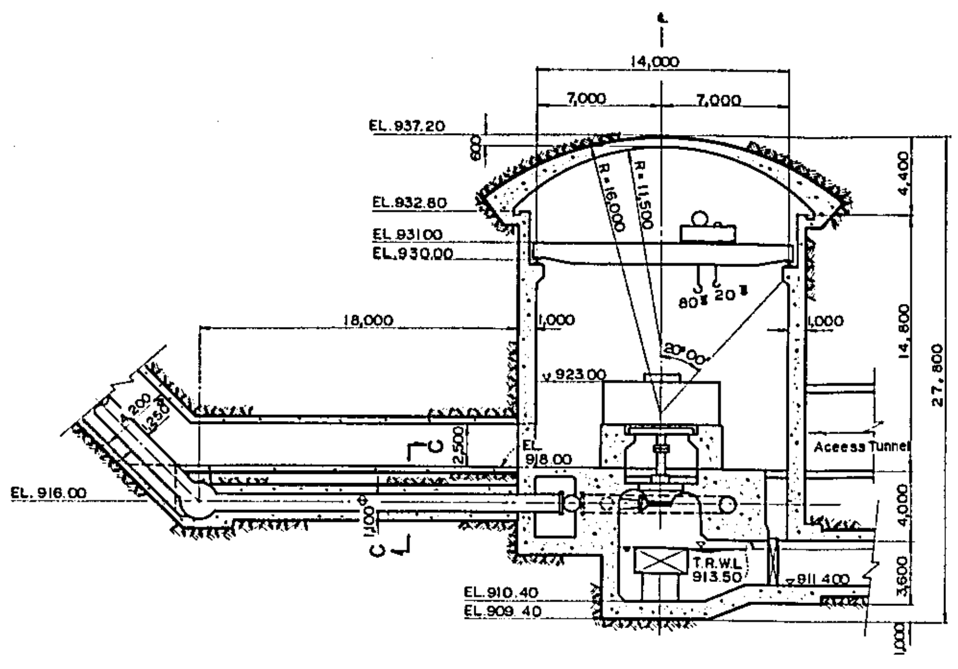
PLAN AND PROFILE OF WATERWAY

DWG. No. 11	JULY, 1974

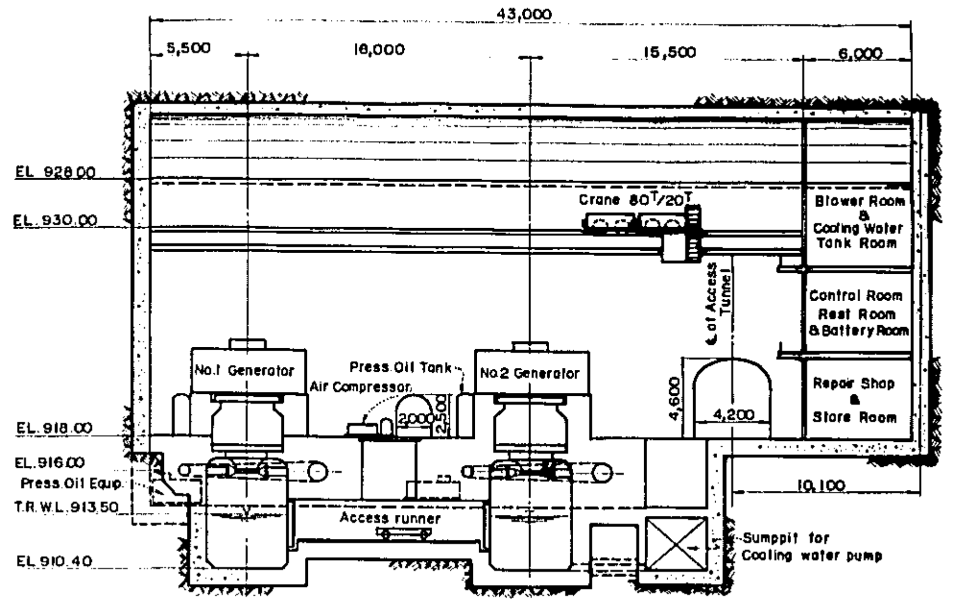


PLAN AND PROFILE OF SURGE TANK, POWER HOUSE AND SWITCH YARD

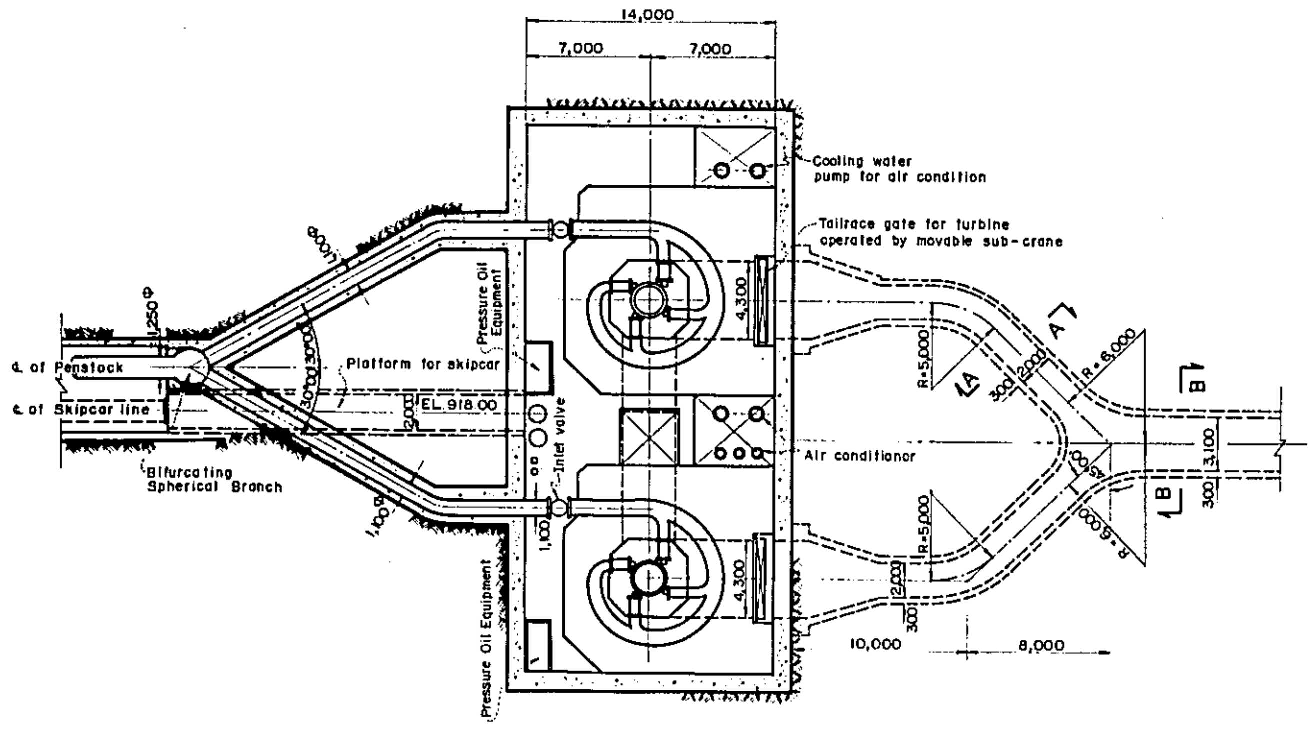
DWG. No. 12	JULY, 1974



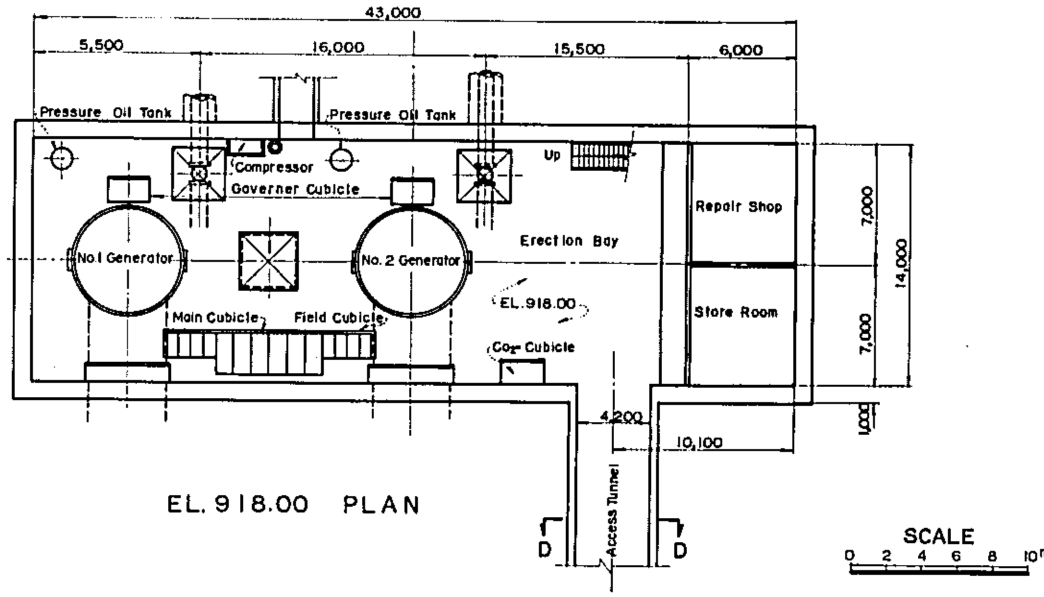
STANDARD SECTION



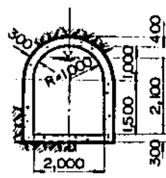
LONGITUDINAL SECTION



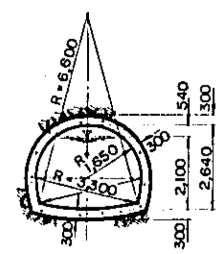
EL. 916.00 PLAN



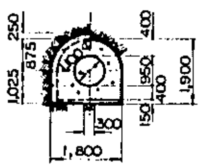
EL. 918.00 PLAN



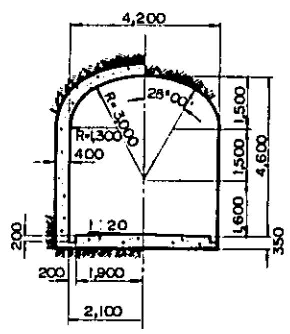
SECTION A-A



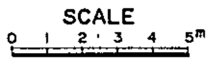
SECTION B-B
(TAILRACE TUNNEL)



SECTION C-C



SECTION D-D
(ACCESS TUNNEL)



DETAIL OF POWER HOUSE

DWG. No. 13 | JULY, 1974

APPENDIX - I

GEOLOGICAL INVESTIGATION DATA

LIST OF FIGURES

Fig. A-1-1 Location of Bore Holes

Fig. A-1-2 Location of Bore Holes and Seismic Exploration Lines

Fig. A-1-3 Record of Core Boring at Damsite

Fig. A-1-4 Record of Core Boring at Power Station Site

Fig. A-1-5 Seismic Profile Line No.1

Fig. A-1-6 Seismic Profile Line No.2

Fig. A-1-7 Seismic Profile Line No.3

Fig. A-1-8 Seismic Profile Line No.4

Fig. A-1-9 Seismic Profile Line No.5

Fig. A-1-10 Seismic Profile Line No.6

Fig. A-1-11 Seismic Profile Line No.7

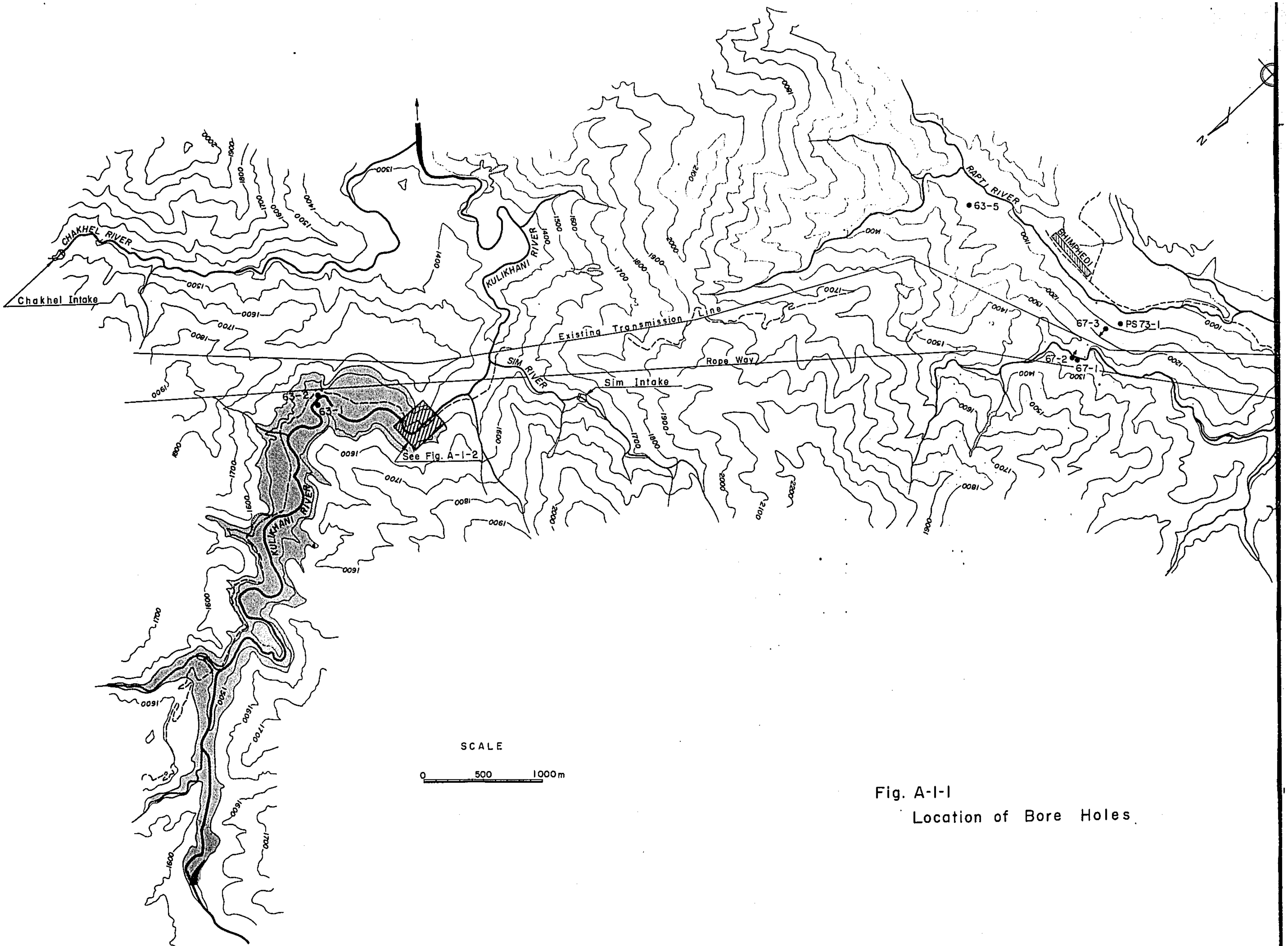


Fig. A-1-1
Location of Bore Holes

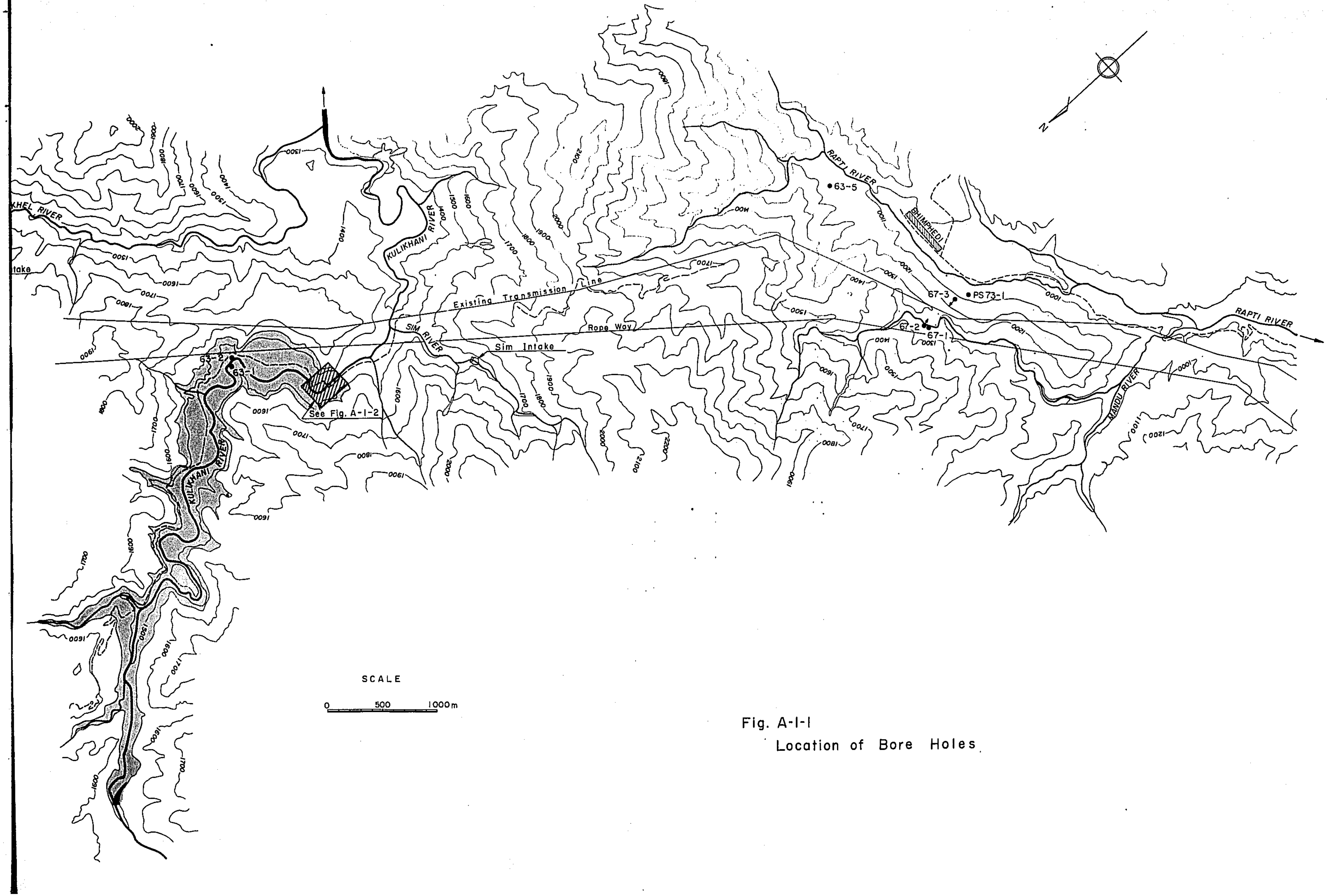
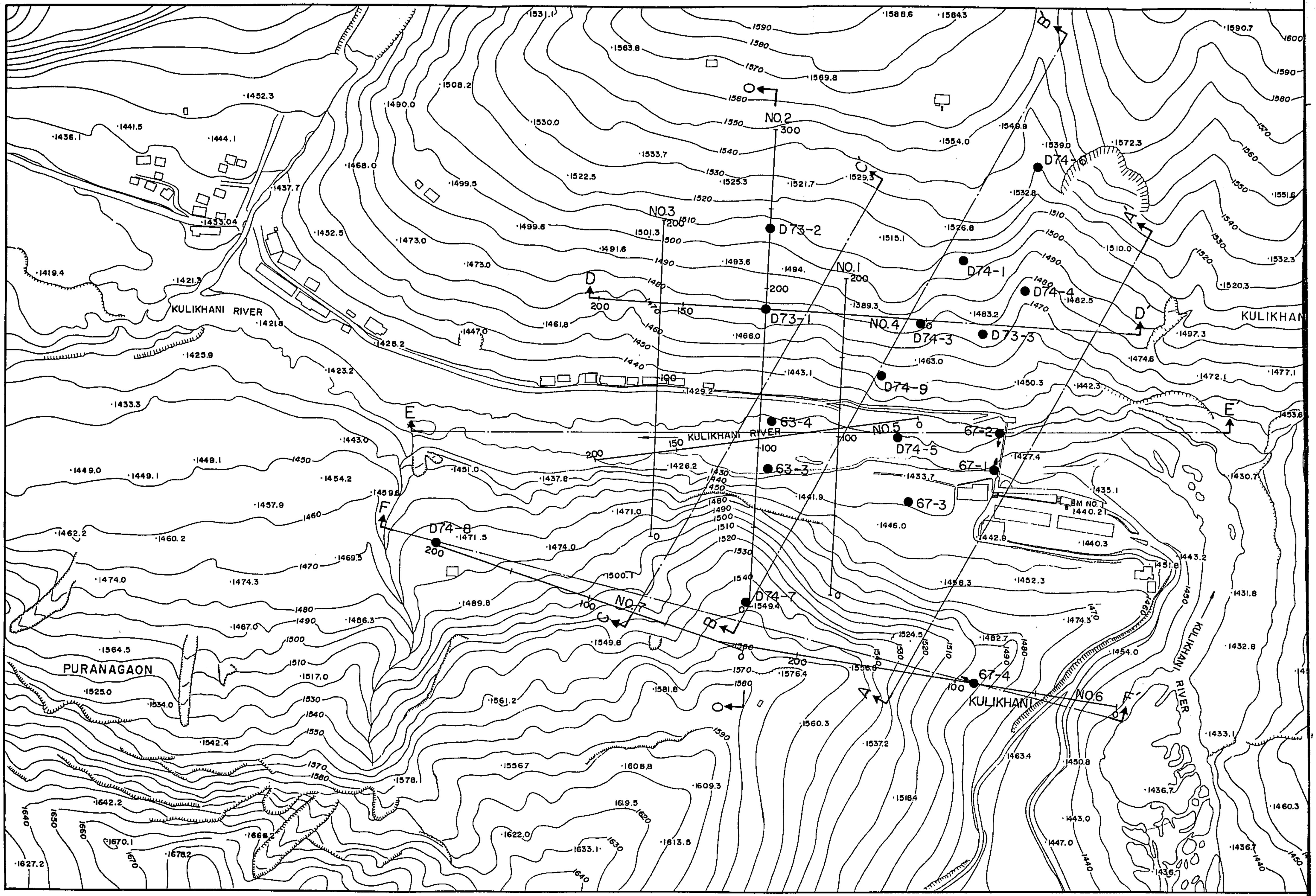


Fig. A-1-1

Location of Bore Holes


KULIKHANI RIVER
KULIKHANI RIVER
KULIKHANI RIVER
KULIKHANI
KULIKHANI
PURANAGAON
NO.1
NO.2
NO.3
NO.4
NO.5
NO.6
NO.7
D73-1
D73-2
D73-3
D74-1
D74-3
D74-4
D74-5
D74-6
D74-7
D74-8
D74-9
63-3
63-4
67-1
67-2
67-3
67-4
BM NO.1
1440.21
A
A'
B
B'
C
C'
D
D'
E
E'
F
F'

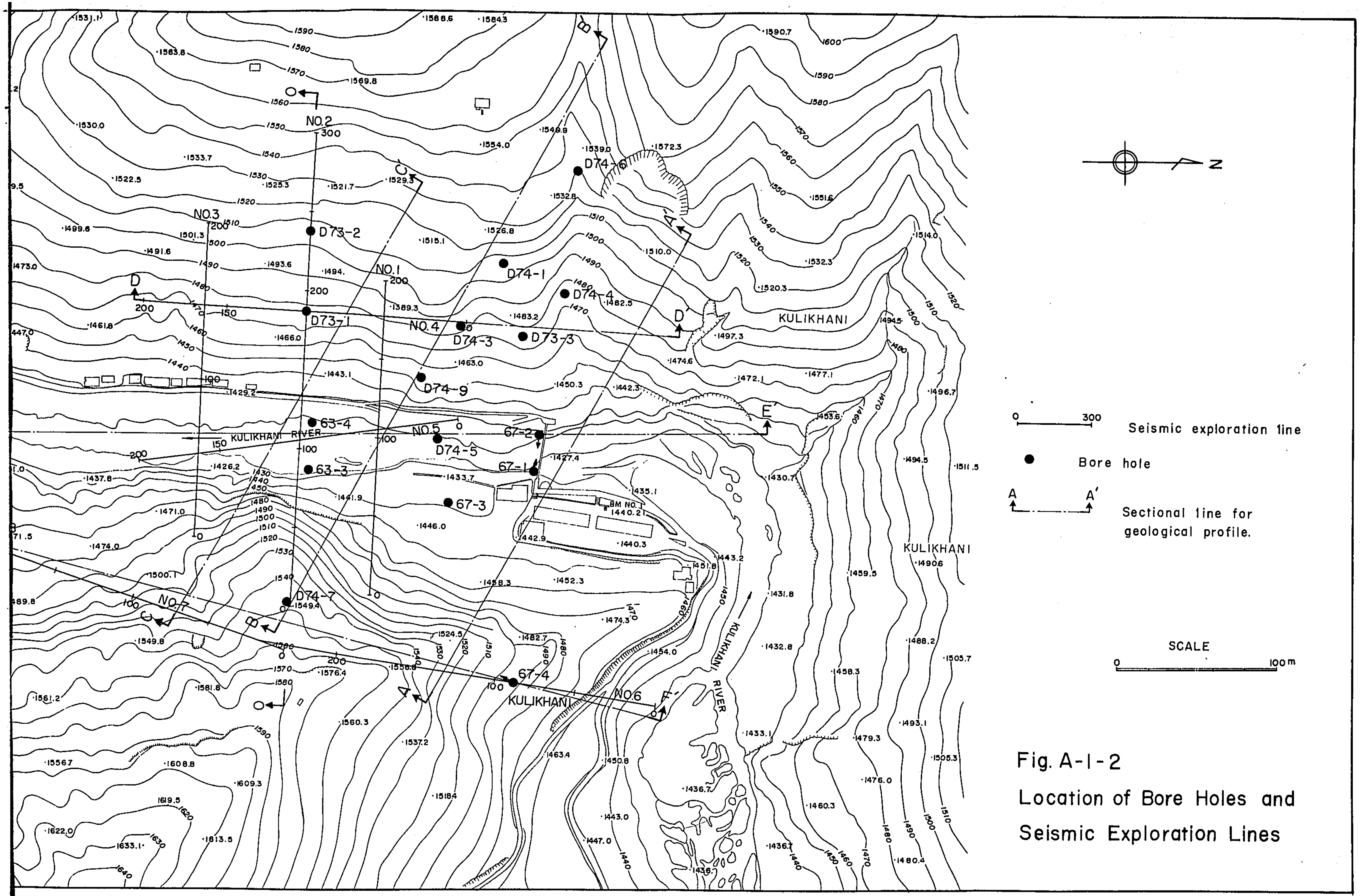


Fig. A-1-2
Location of Bore Holes and
Seismic Exploration Lines

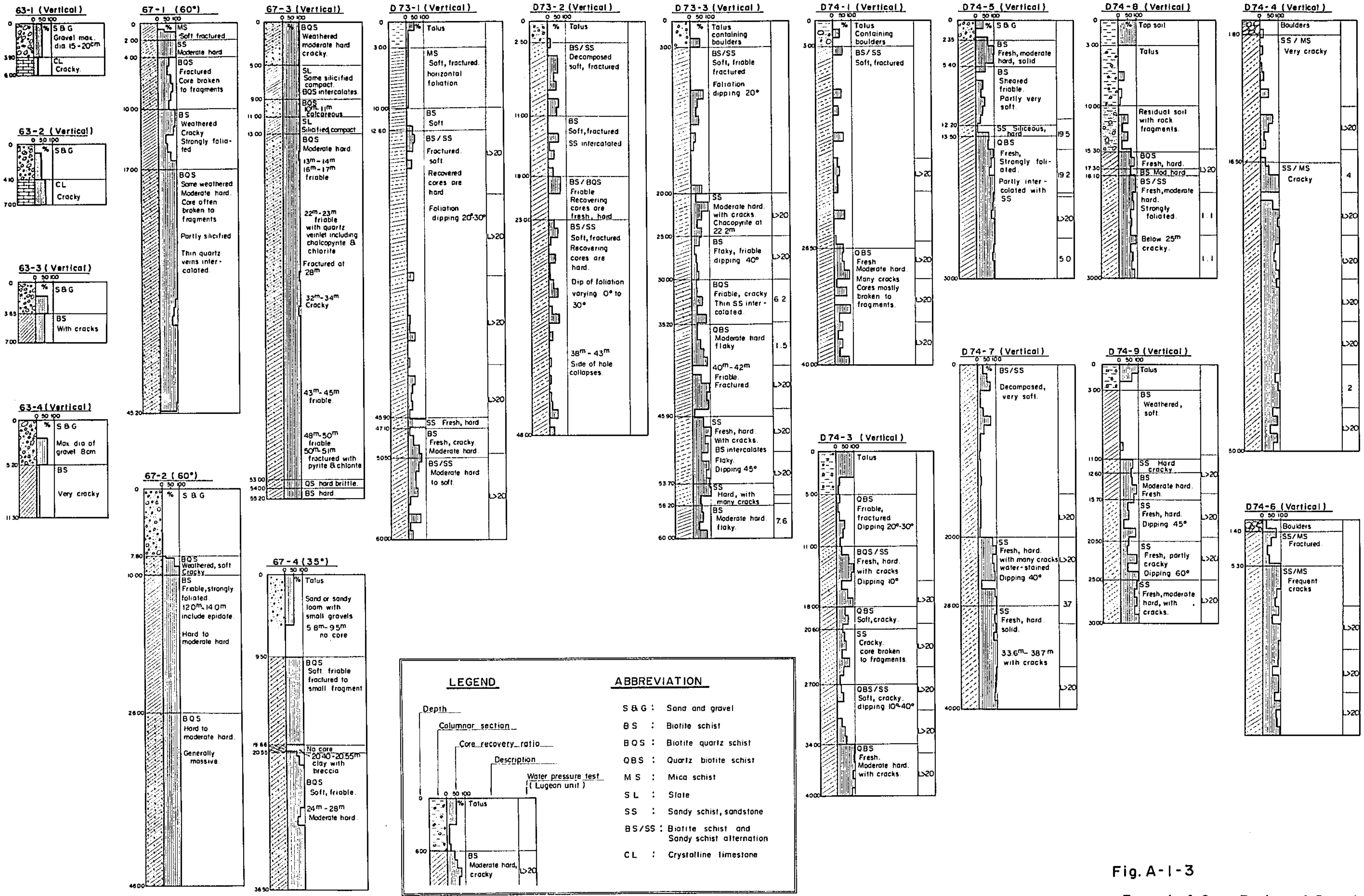


Fig. A-1-3

Record of Core Boring of Damsite

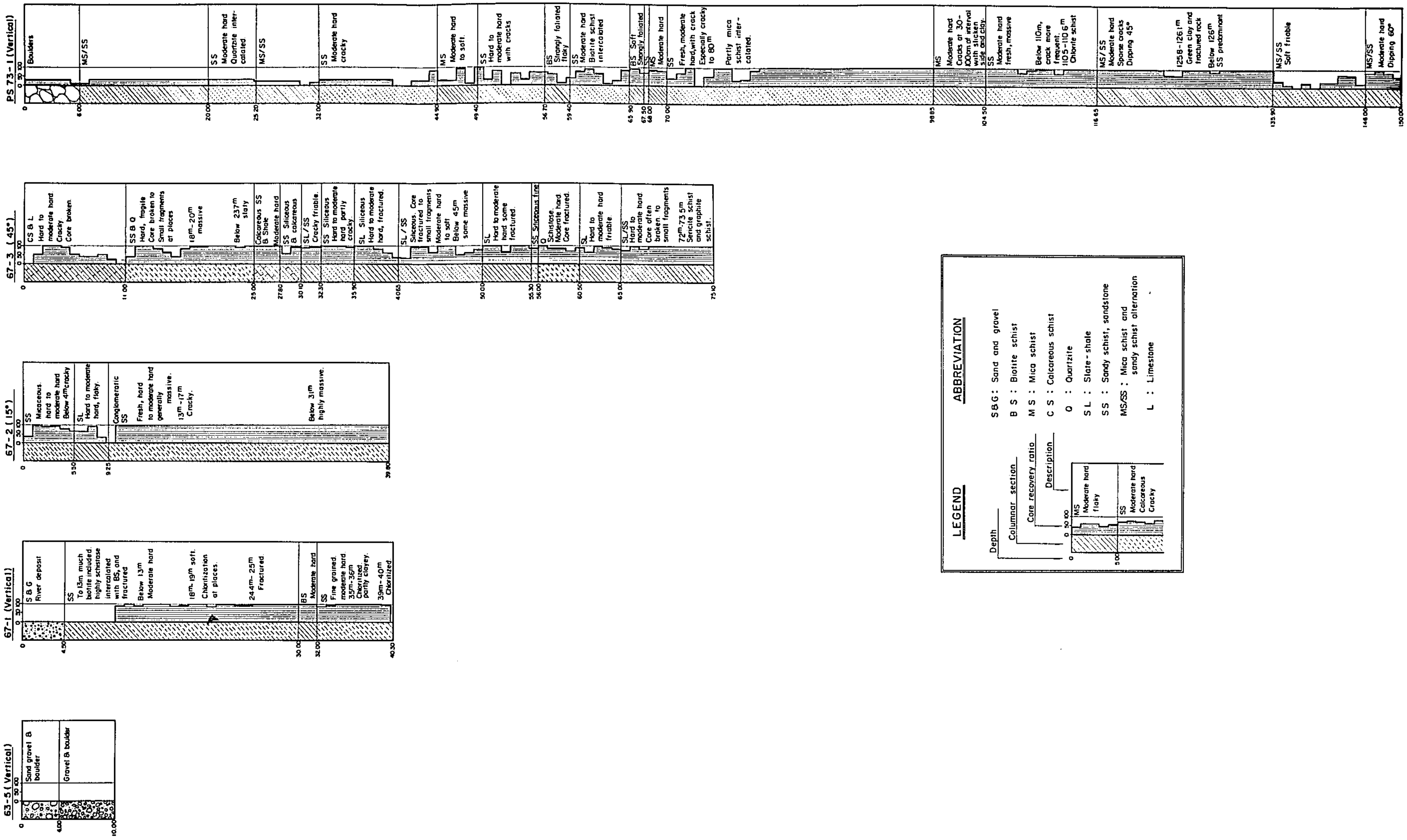
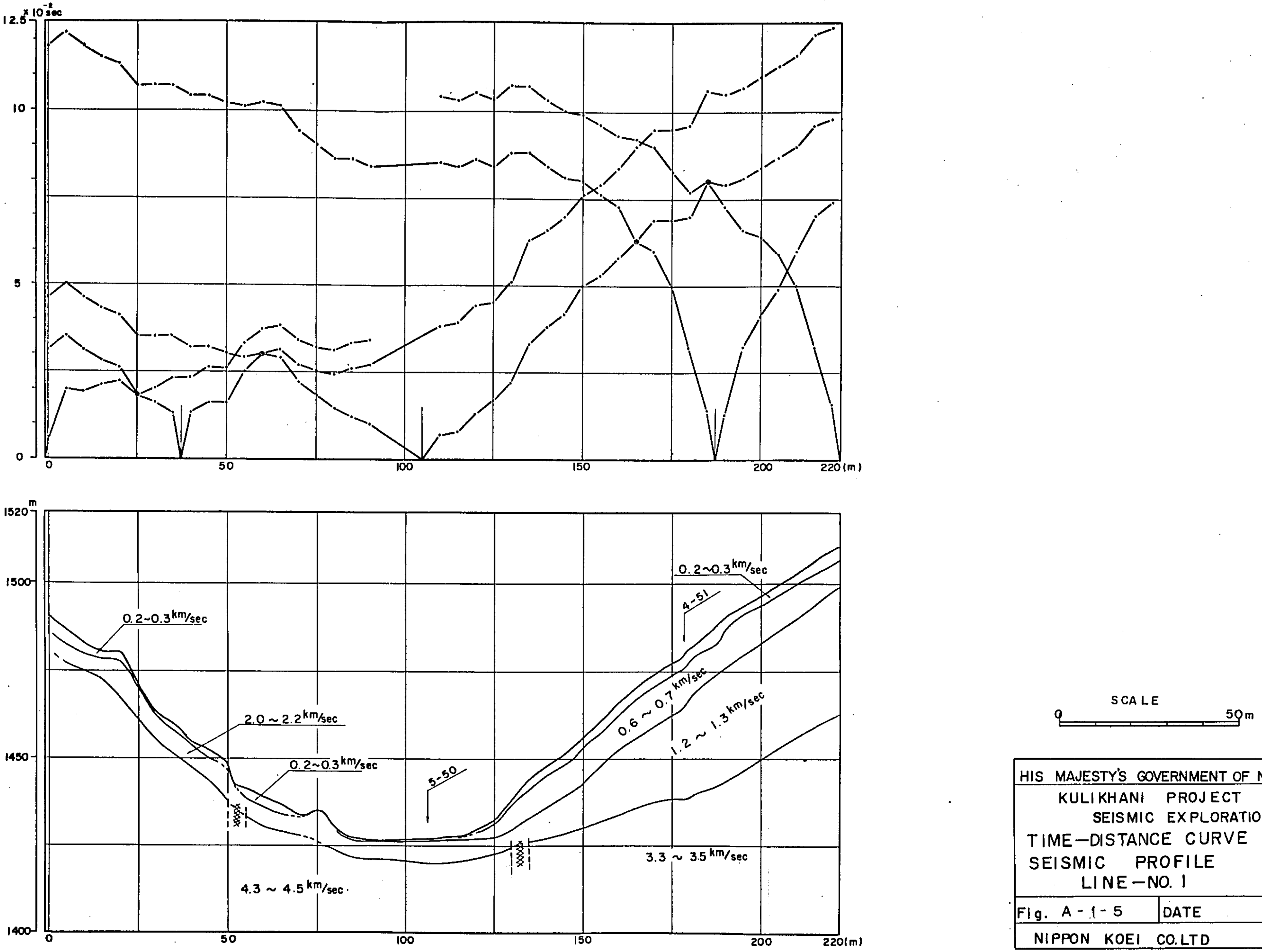


Fig. A-1-4

Record of Core Boring of Power Station Site



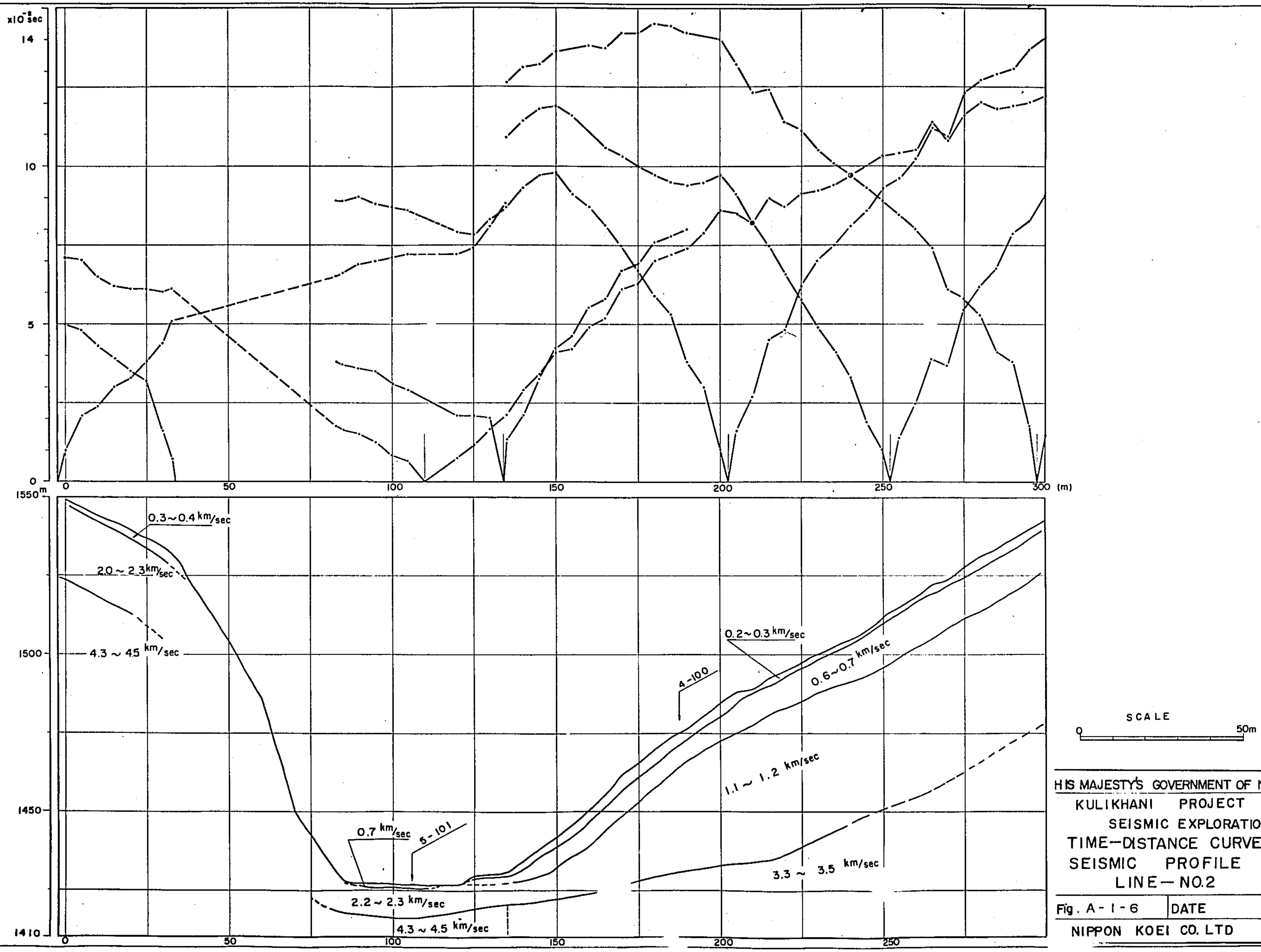
HIS MAJESTY'S GOVERNMENT OF NEPAL

KULIKHANI PROJECT
SEISMIC EXPLORATION

TIME—DISTANCE CURVE
SEISMIC PROFILE
LINE—NO. 1

Fig. A-1-5	DATE

NIPPON KOEI CO.LTD



HIS MAJESTY'S GOVERNMENT OF NEPAL

KULIKHANI PROJECT

SEISMIC EXPLORATION

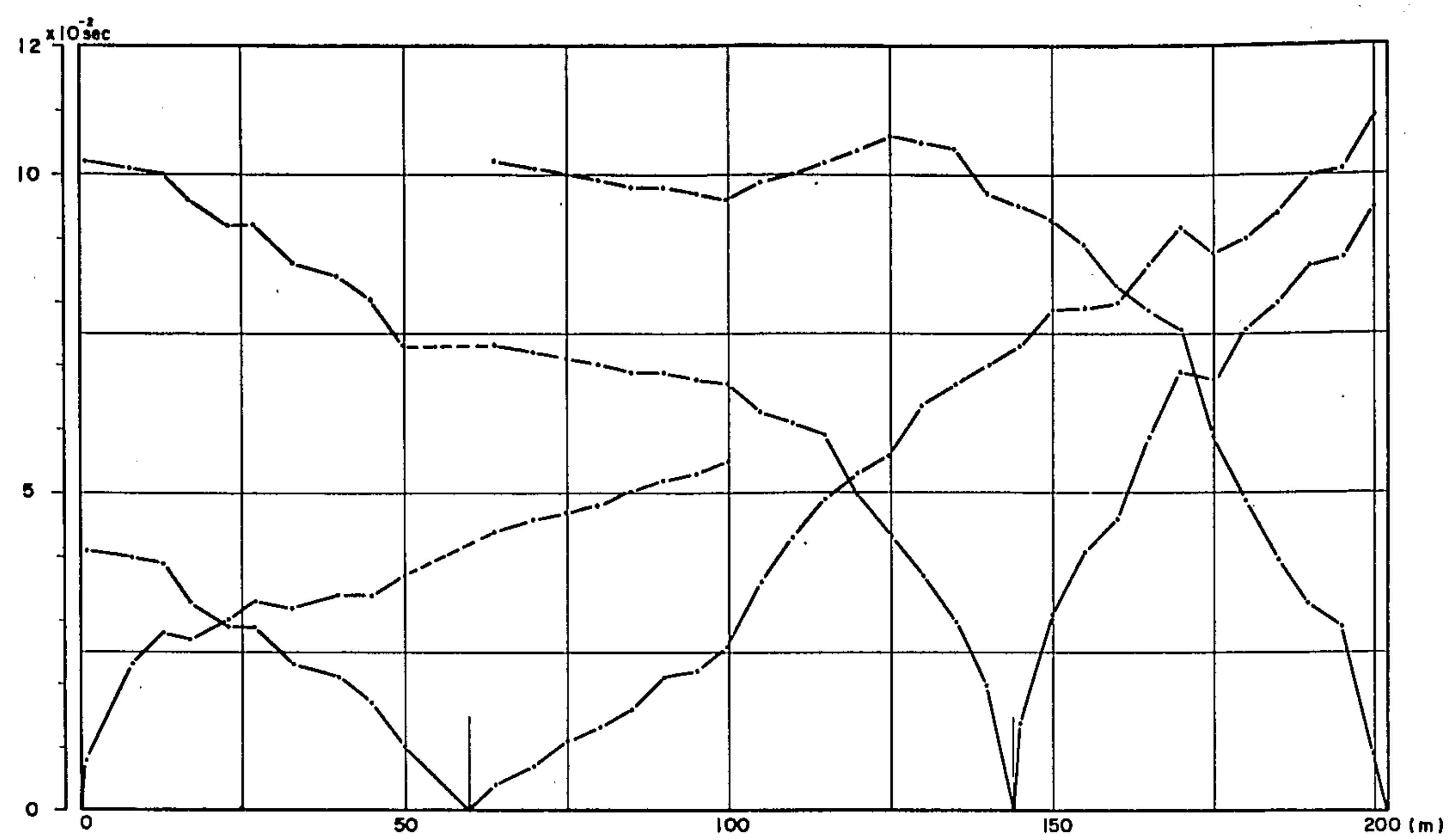
TIME—DISTANCE CURVE

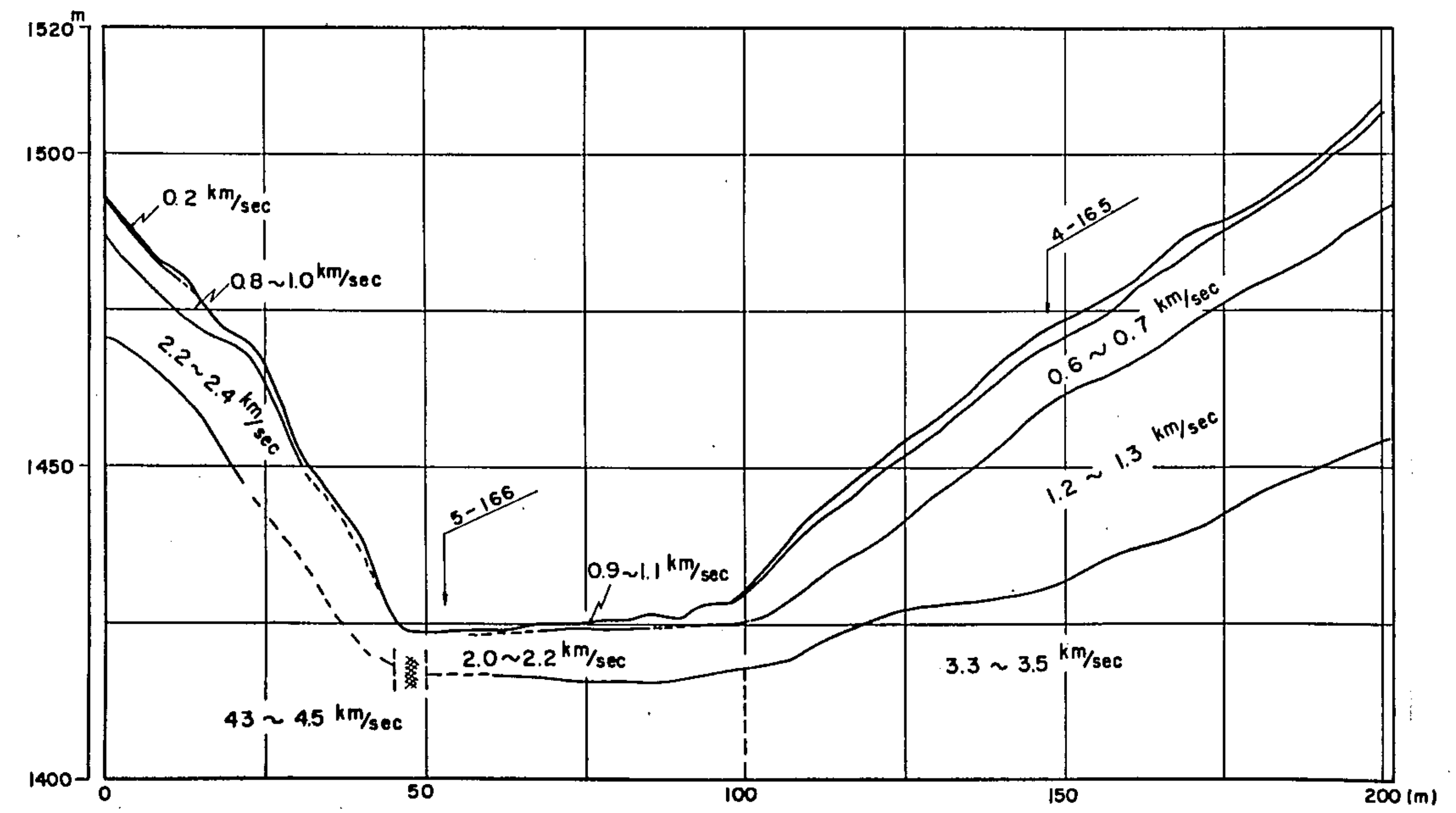
SEISMIC PROFILE

LINE — NO.2

Fig. A - 1 - 6	DATE

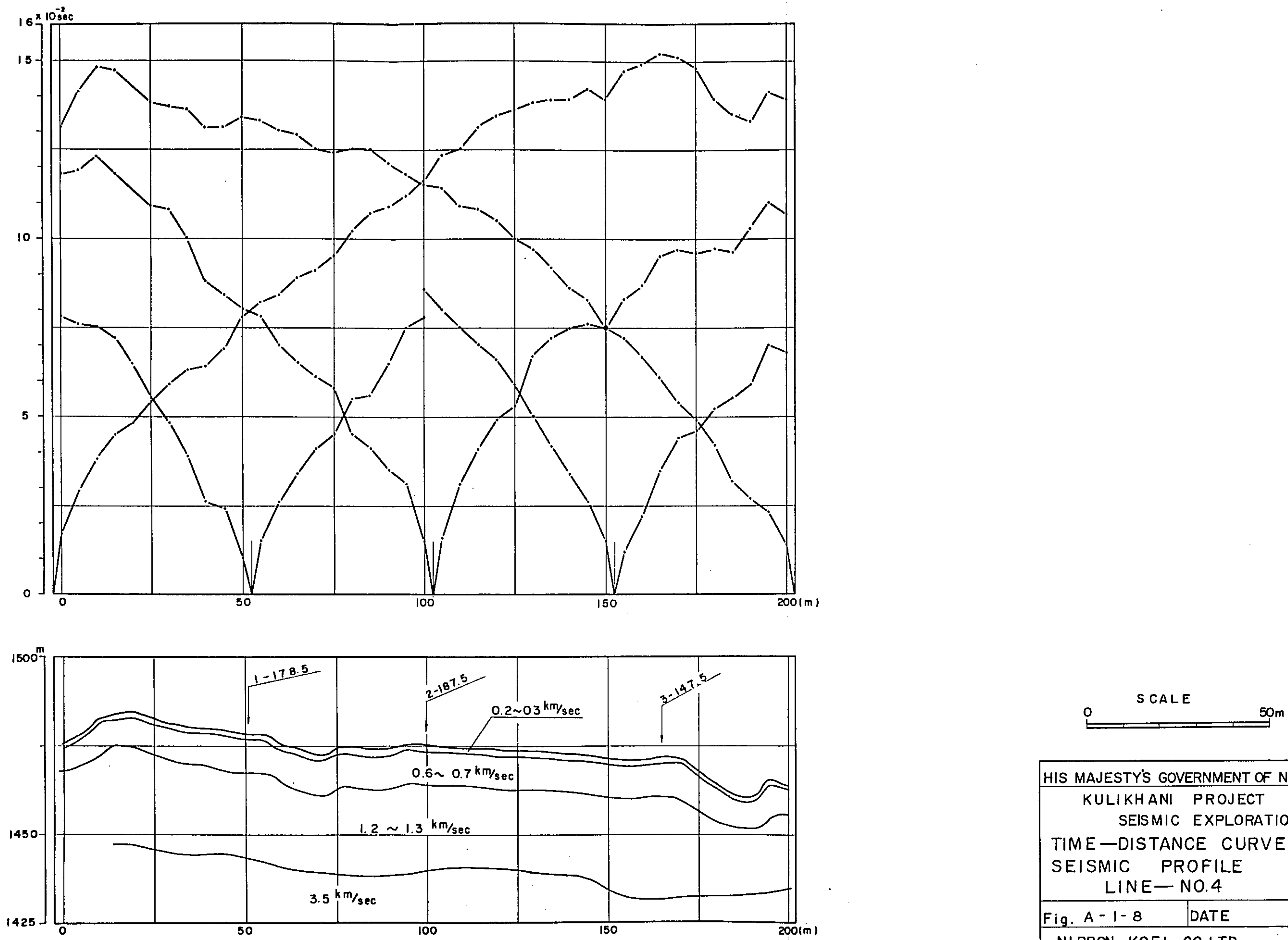
NIPPON KOEI CO. LTD





SCALE
0 50 m

HIS MAJESTY'S GOVERNMENT OF NEPAL	
KULIKHANI PROJECT SEISMIC EXPLORATION TIME—DISTANCE CURVE SEISMIC PROFILE LINE—NO. 3	
Fig . A - 1 - 7	DATE
NIPPON KOEI CO. LTD	



HIS MAJESTY'S GOVERNMENT OF NEPAL

KULIKHANI PROJECT

SEISMIC EXPLORATION

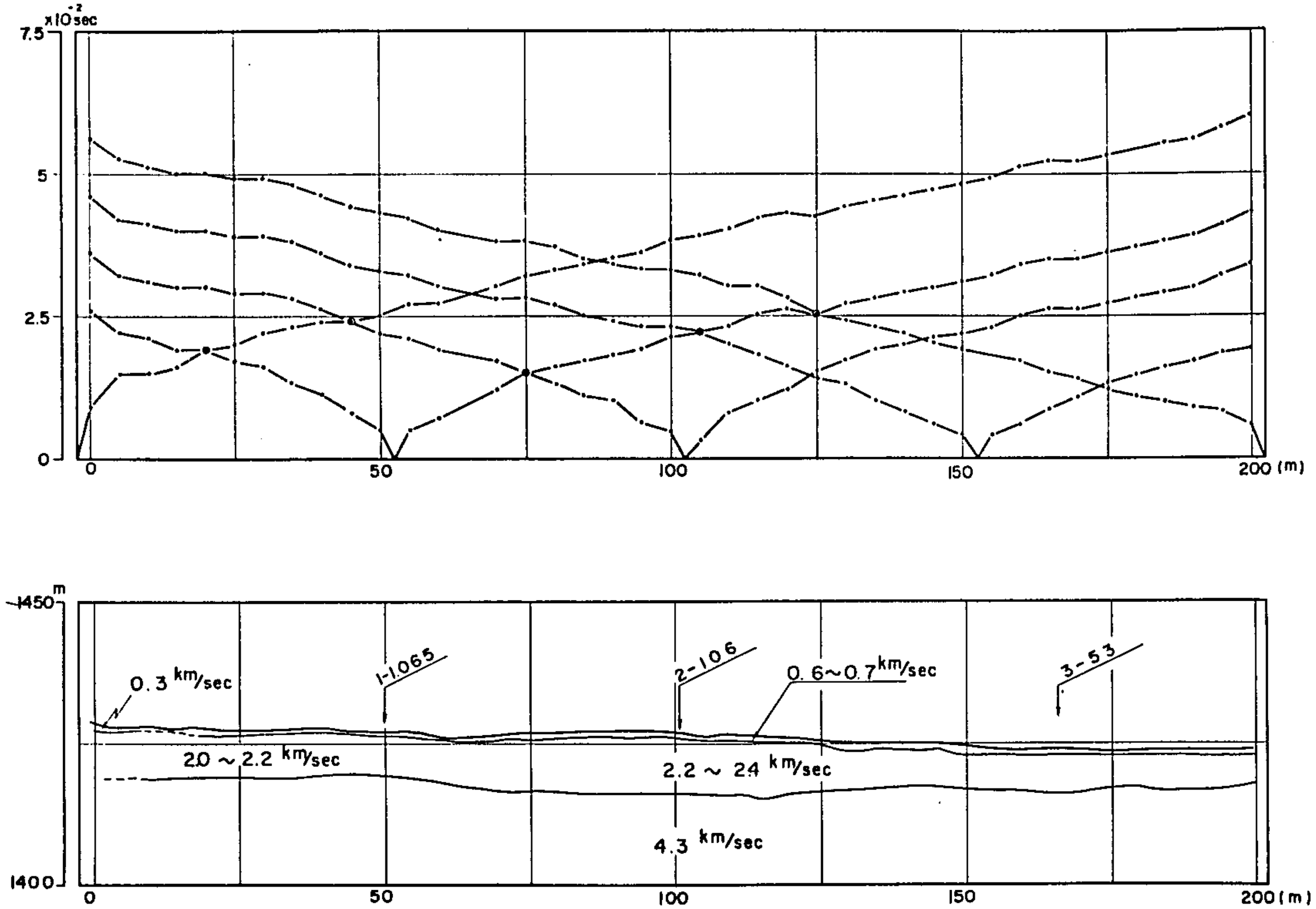
TIME—DISTANCE CURVE

SEISMIC PROFILE

LINE— NO.4

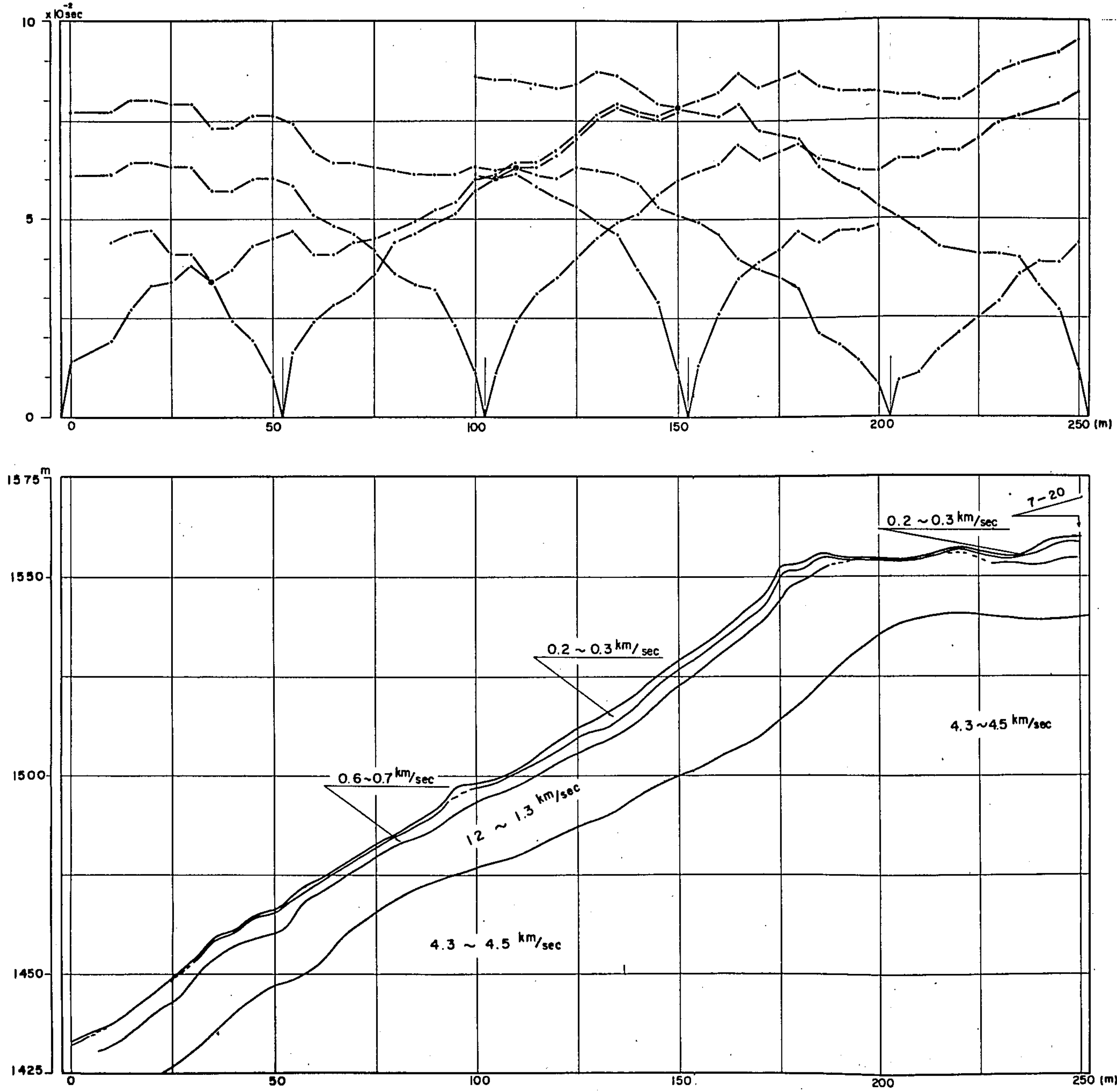
Fig. A-1-8	DATE

NIPPON KOEI CO.LTD



SCALE
0 50m

HIS MAJESTY'S GOVERNMENT OF NEPAL	
KULIKHANI PROJECT SEISMIC EXPLORATION TIME—DISTANCE CURVE SEISMIC PROFILE LINE—NO. 5	
Fig. A-1-9	DATE
NIPPON KOEI CO.LTD	



SCALE
0 50 m

HIS MAJESTY'S GOVERNMENT OF NEPAL

KULIKHANI PROJECT

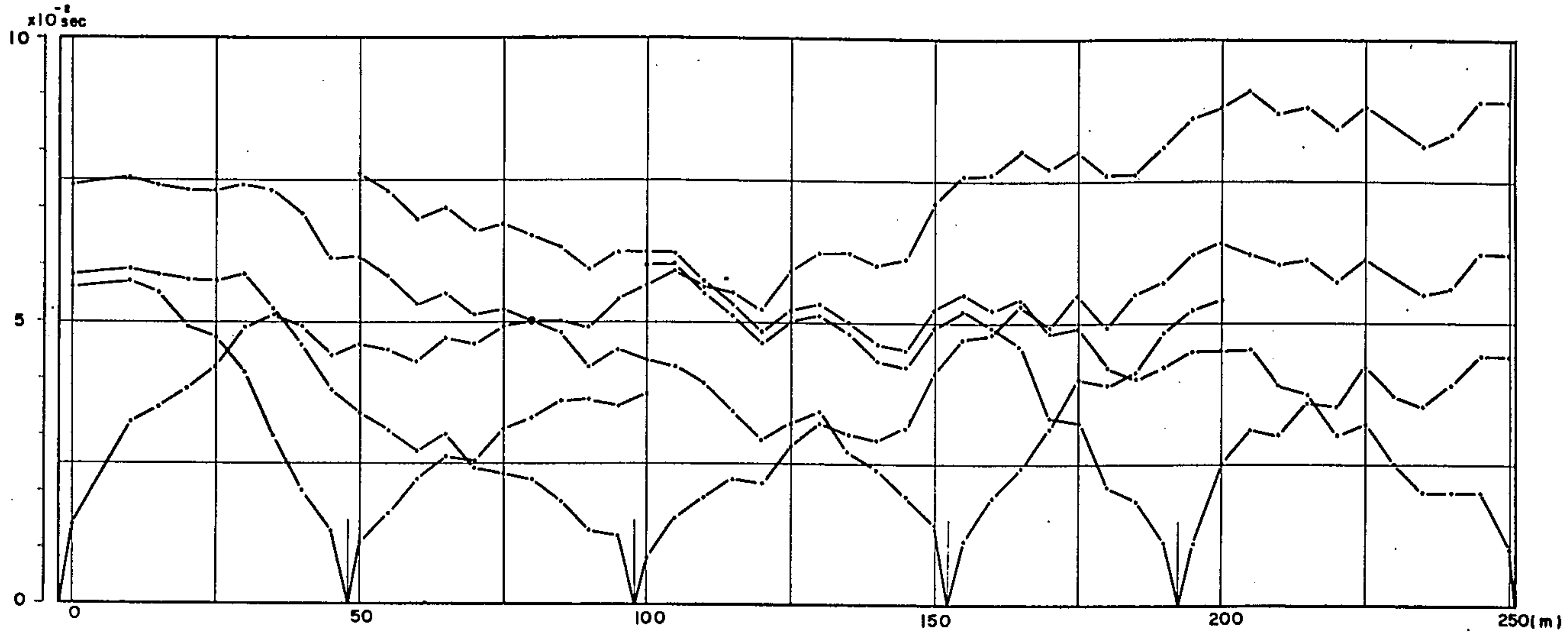
SEISMIC EEXPLORATION

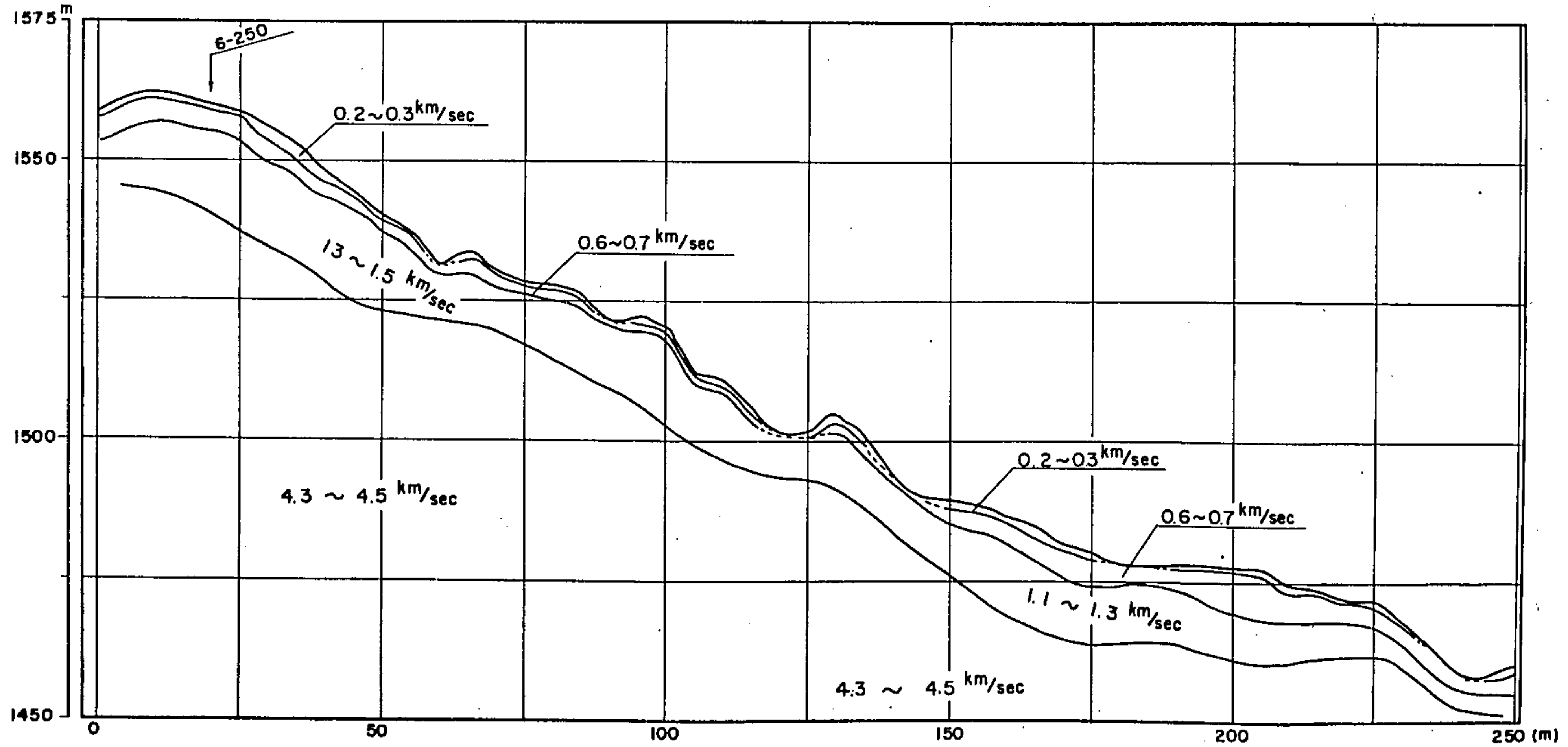
TIME-DISTANCE CURVE

SEISMIC PROFILE
LINE — NO. 6

Fig. A - 1 - 10	DATE

NIPPON KOEI CO. LTD





SCALE 0 — 50m

HIS MAJESTY'S GOVERNMENT OF NEPAL	
KULIKHANI PROJECT SEISMIC EXPLORATION TIME—DISTANCE CURVE SEISMIC PROFILE LINE—NO.7	
Fig. A - 1 - 11	DATE
NIPPON KOEI CO.LTD	

APPENDIX - II

METEO-HYDROLOGICAL DATA
AND STUDIES

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Fig. A-2-1	Air Temperature at Kathmandu
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Fig. A-2-5	Relation between Runoff at Kulikhani and Runoff at Chobhar
Fig. A-2-6	Relation between Runoff at Kulikhani and Runoff at Chakhel
Fig. A-2-7	Relation between Runoff at Kulikhani and Runoff at Sim
Fig. A-2-8	Spillway Outflow Discharge through Flood Routing

FIG. A-2-1 AIR TEMPERATURE AT KATHMANDU

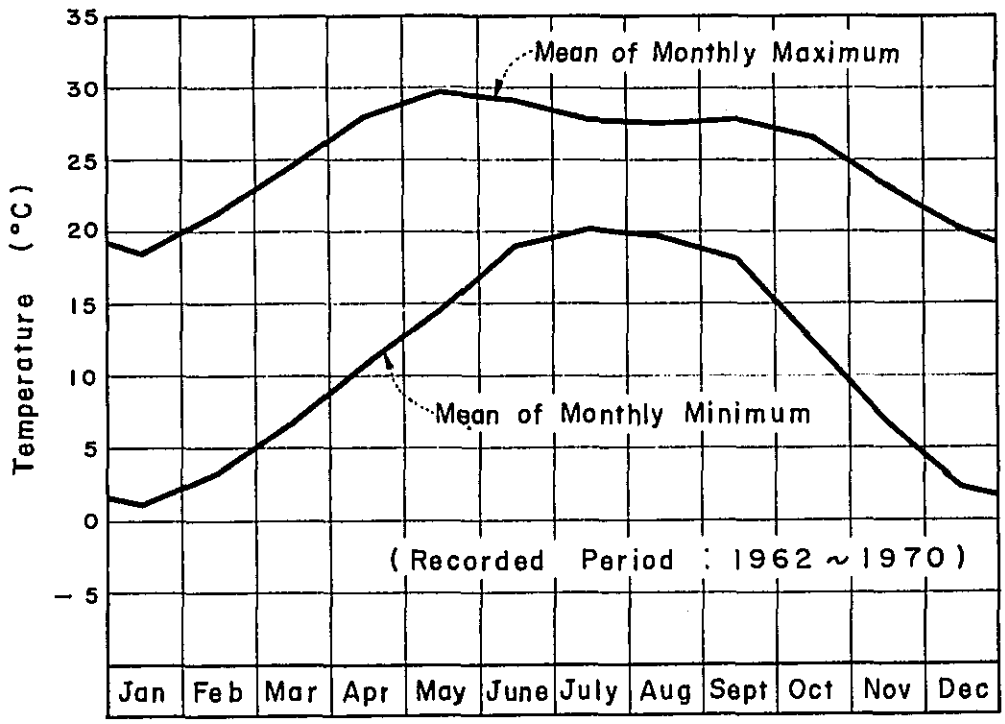

FIG.A-2-2 ANNUAL RAINFALL AT KATHMANDU

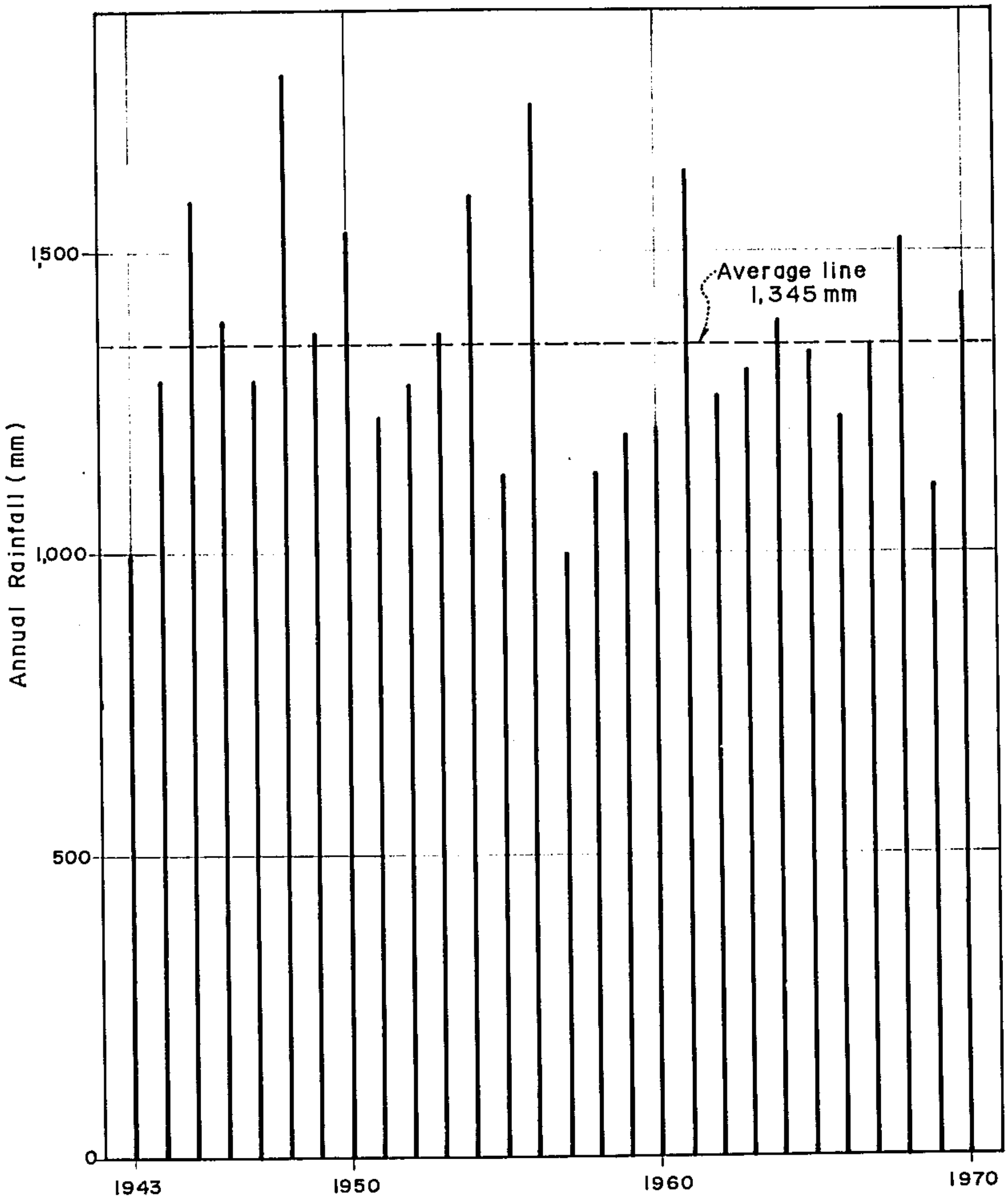

FIG. A-2-3 STAGE-DISCHARGE CURVE AT KULIKHANI GAUGE SITE

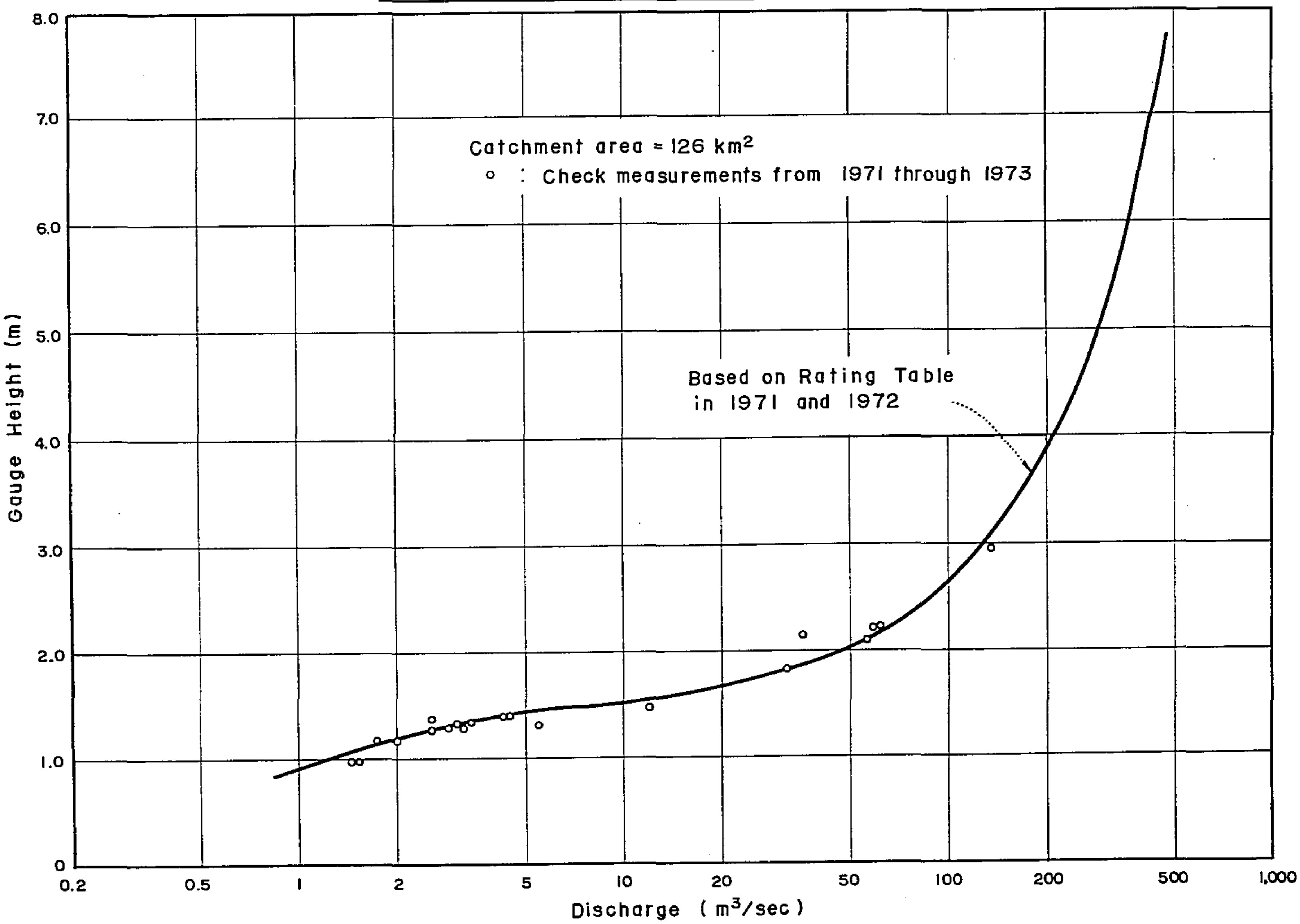

FIG. A-2-4 DURATION CURVE AT KULIKHANI DAM SITE (C.A.=126 km²)

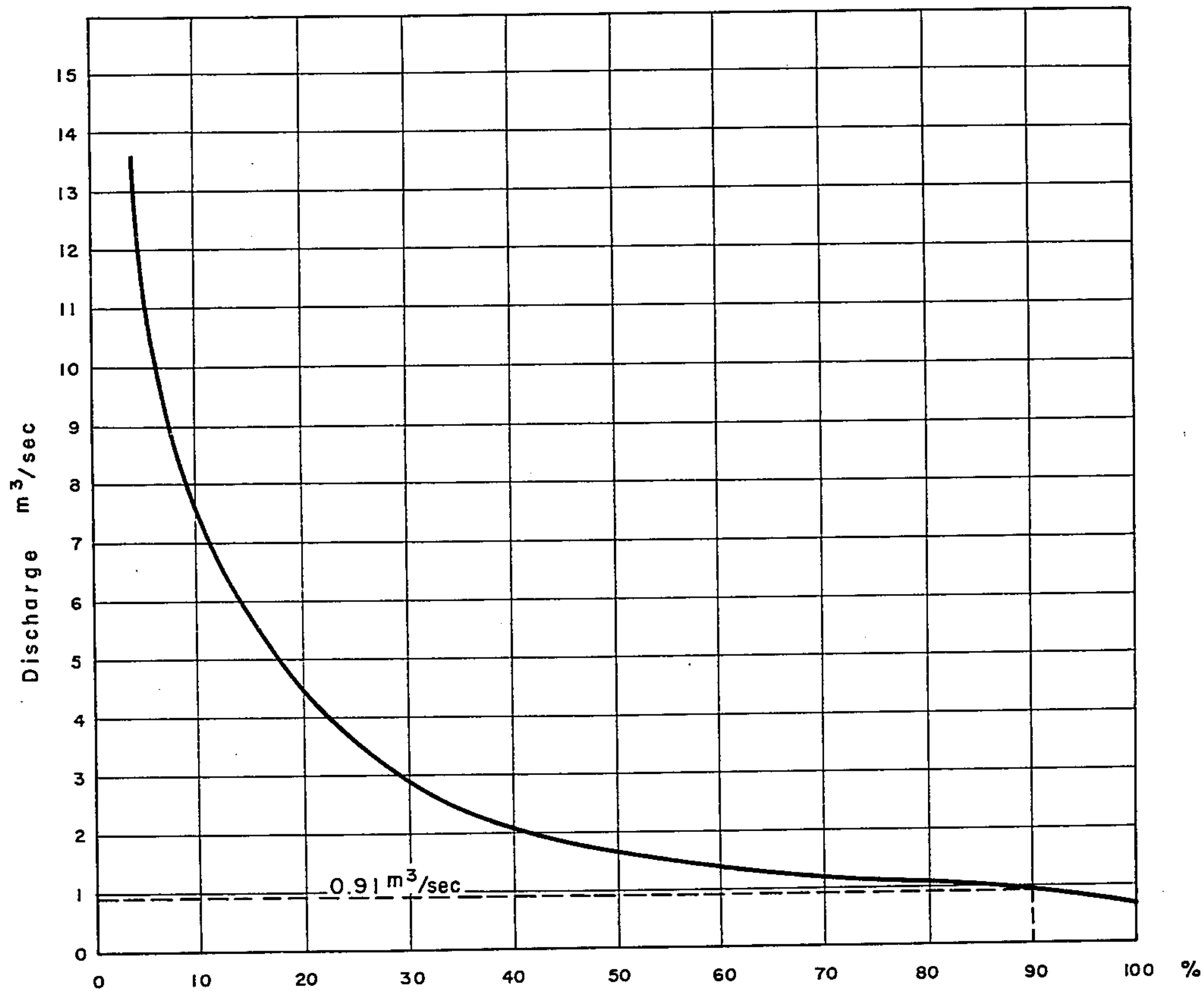

FIG. A-2-5 RELATION BETWEEN RUNOFF AT KULIKHANI AND RUNOFF AT CHOBHAR

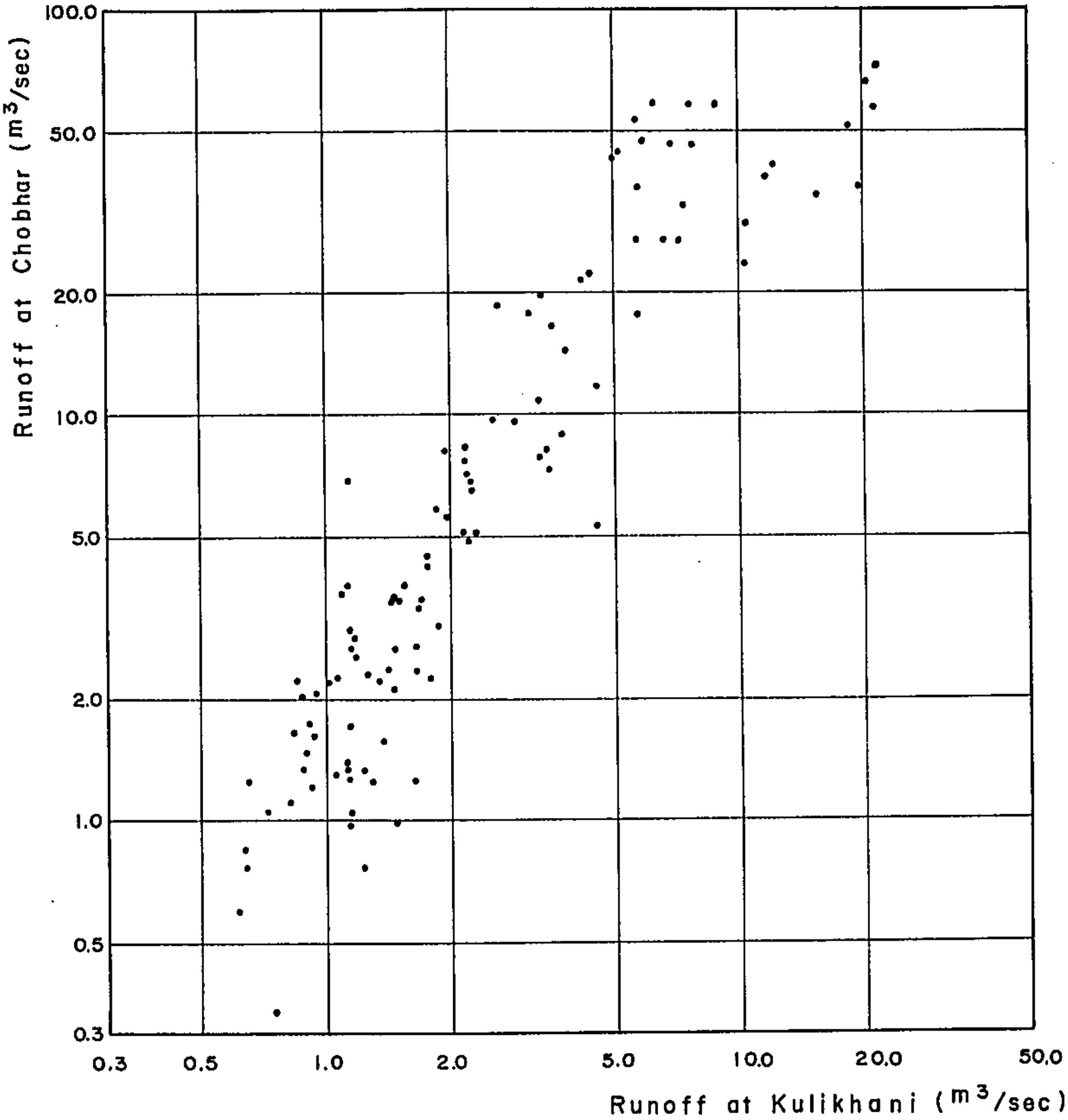

FIG. A-2-6 RELATION BETWEEN RUNOFF AT KULIKHANI AND RUNOFF AT CHAKHEL

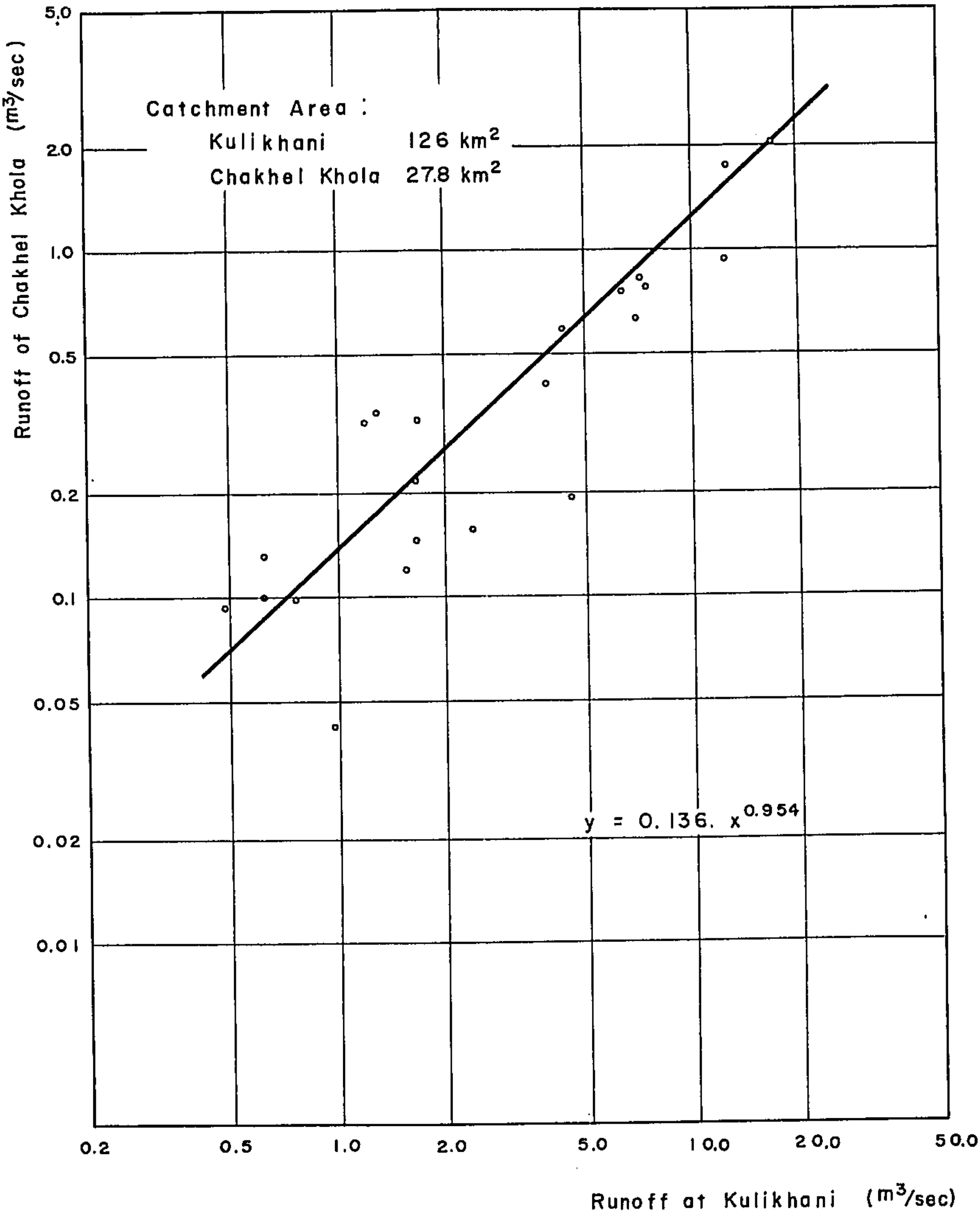

FIG. A-2-7 RELATION BETWEEN RUNOFF AT KULIKHANI AND RUNOFF AT SIM

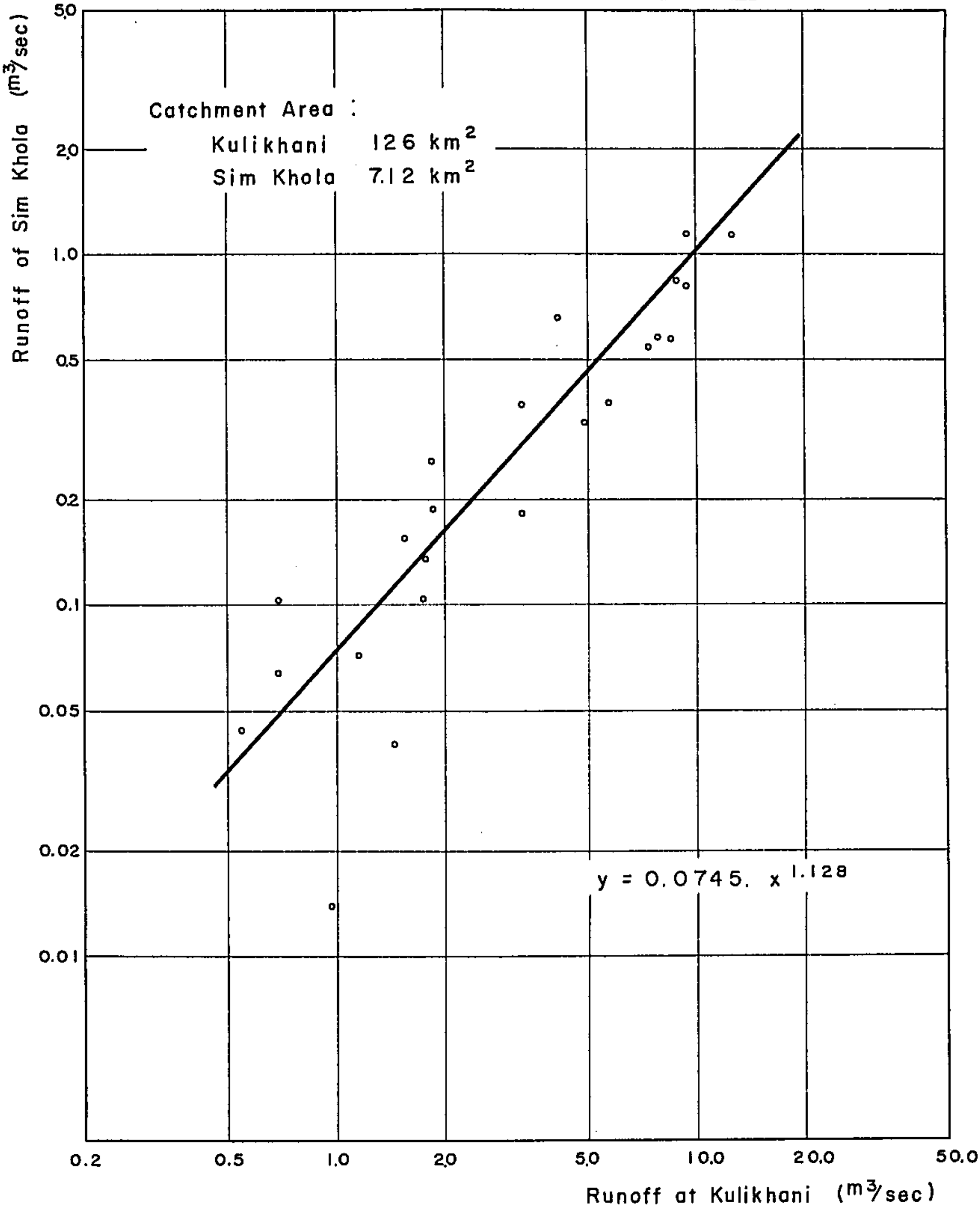

FIG. A-2-8 SPILLWAY OUTFLOW DISCHARGE THROUGH FLOOD ROUTING