HIS MAJESTY'S GOVERNMENT OF NEPAL

FEASIBILITY REPORT ON SAPT GANDAKI HYDROELECTRIC POWER DEVELOPMENT PROJECT

VOL. I

MAIN REPORT

JANUARY 1983

JAPAN INTERNATIONAL COOPERATION AGENCY

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LIST OF REPORTS

PREFACE

In response to the request of His Majesty's Government of Nepal, the Government of Japan decided to conduct a feasibility study on the Sapt Gandaki Hydro-electric Power Development Project and entrusted the study to the Japan International Cooperation Agency (JICA). The JICA sent to the Kingdom of Nepal a study team headed by Mr. Masashi YAMAGUCHI, 8 times during the period from February 1st, 1981 to October 10th, 1982.

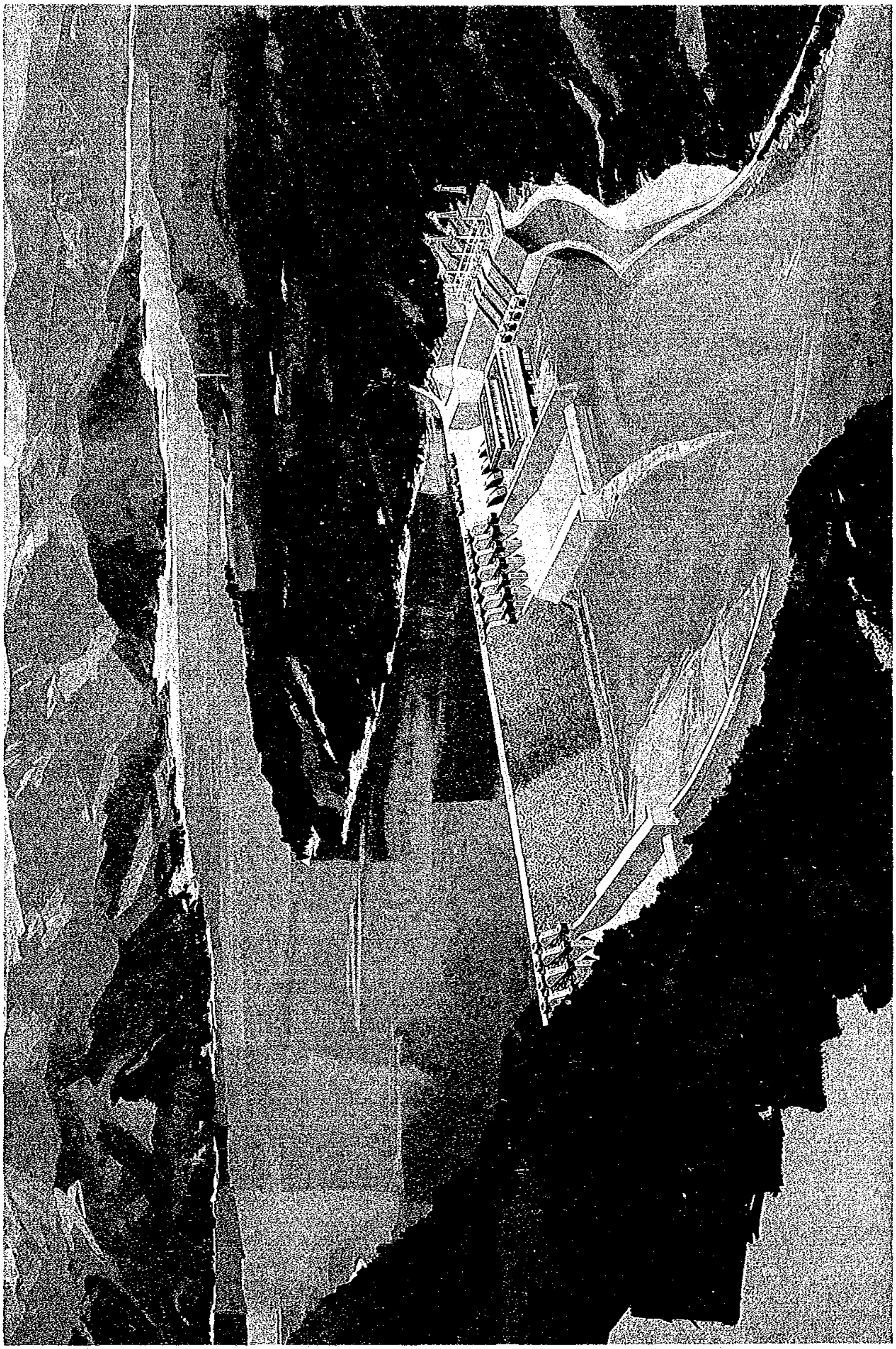
The team conducted the study and had a series of discussions with the officials concerned of His Majesty's Government of Nepal. After the team returned to Japan, further studies were made and the present report has been prepared.

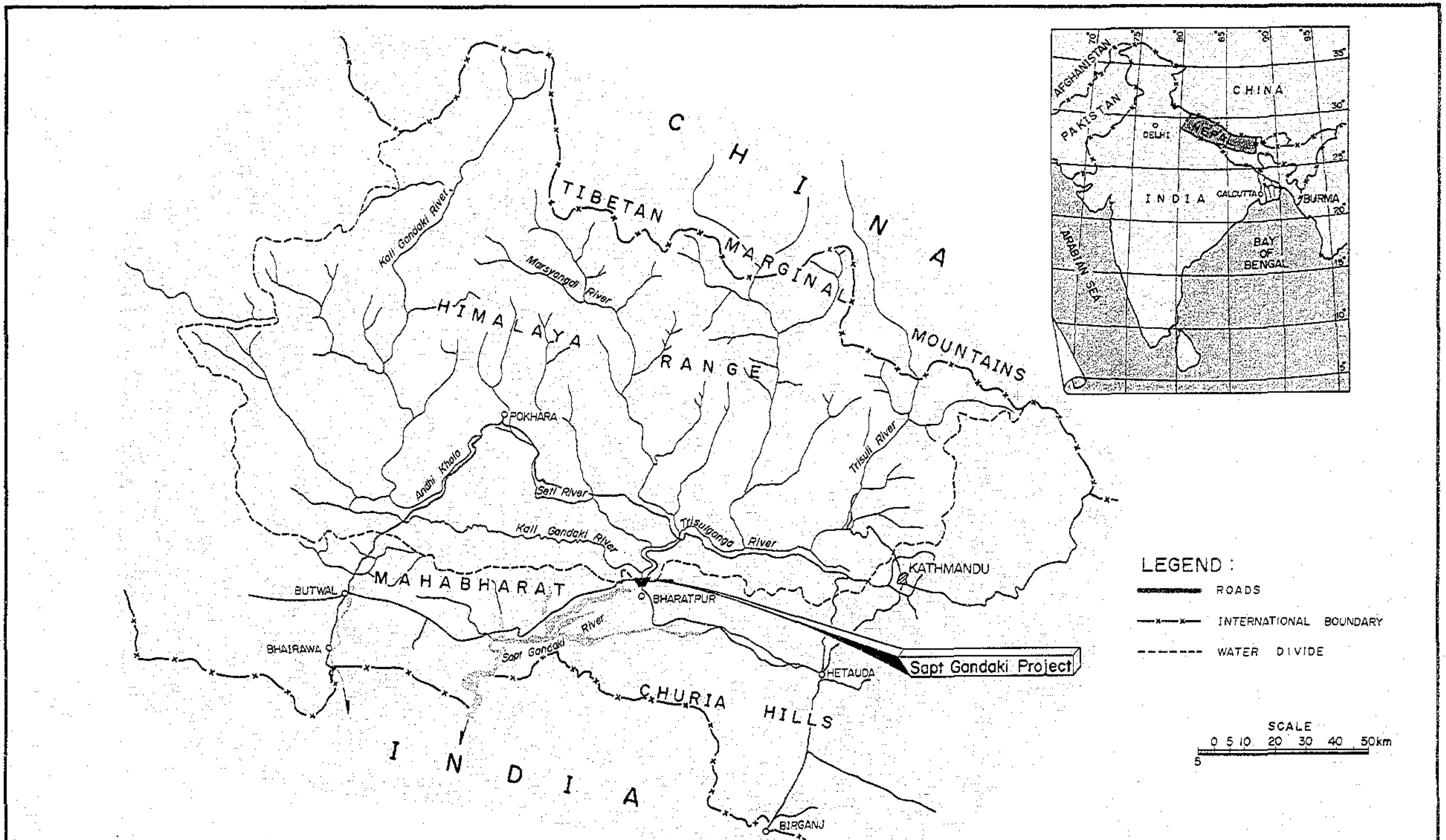
I hope that this report will be useful as a basic reference for the Sapt Gandaki Hydro-electric Power Development Project and contribute to the promotion of the friendly relations between the two countries.

I wish to express my deep appreciation to the officials concerned of His Majesty's Government of Nepal for their close cooperation extended to the study team.

January, 1983

Keisuke Arita
President
Japan International
Cooperation Agency
(JICA)





LOCATION MAP

SUMMARY, CONCLUSION AND RECOMMENDATION

PROJECT BACKGROUND

1. The Sapt Gandaki River drains a basin of about 31,100 km^2 in the central part of Nepal above the confluence of the two major tributaries, the Kali Gandaki and the Trisulganga. The river enters into the Inner Terai Plain about 3 km downstream therefrom. It has an abundant stream flow. Its annual average runoff amounts to about 1,500 m^3/sec. The Sapt Gandaki Hydroelectric Project site is located just downstream of the confluence and about 4 km north of Narayangar.

   In the wide area south of Narayangar in the Chitwan Valley of the Inner Terai Plain, a number of new projects are being developed including highway, transmission line and irrigation. A new north-south highway connecting with the Kathmandu-Pokhara road runs near the Project site. Such a situation makes the development of the Sapt Gandaki River more attractive in view of its accessibility and regional development.

2. The power and energy demand will be narrowly met until 1988/89 by the stagewise development in series of the hydropower of the Kulekhani No.1, Devighat, Kulekhani No.2 and Marsyangdi Projects. To meet the demand thereafter, a new hydroelectric project is needed to be put in service.

   In view of such situation and of the future growth of power demand, the Electricity Department (ED) of His Majesty's Government of Nepal (HMG) intends to develop the Sapt Gandaki Project, following the projects now under implementation stage.

3. HMG decided to carry out the Feasibility Study of the Sapt Gandaki Project and officially requested the Government of Japan to provide a technical cooperation for the Feasibility Study in December 1980.

The Government of Japan agreed to the request and decided to send a JICA Survey Team for the Feasibility Study. The Feasibility Study of the Sapt Gandaki Project started from the beginning of February, 1981 to assess the economic and technical soundness of the Project.

INVESTIGATION AND STUDY

4. The Feasibility Study of the Sapt Gandaki Hydroelectric Power Development Project has been carried out in three stages, namely Stage I, II and III. The investigation in the Stage I Study was made in two months from February, 1981 to roughly clarify the geological condition of the dam foundation at the proposed damsite and to collect the relevant information. Another objective was to make the preliminary technical and economic evaluation to see if it is justifiable to go into the succeeding Stage II and III Studies.

5. After the preliminary assessment on the technical and economic feasibility of the project was made in Stage I, the Stage II Study was proceeded with field surveys in topography, geology, construction materials, meteo-hydrology, environment and power market in more details for a period from August, 1981 to April, 1982. In the Stage III Study, the detailed study inclusive of the plan formulation, design, cost estimate and economic analysis was carried out to fully prove the feasibility of the Project.

The geological investigation in Stage I and II contained 21 core borings (942 m in total length), 17 traverses seismic prospecting (9.8 km in total length), in-situ rock tests in the two adits, etc.

POWER DEMAND FORECAST

6. The total installed capacity of power in Nepal is 85.1 MW as of 1981 out of which the available output in the dry season is 63.2 MW. However, the power supply condition was getting worse as seen in the fact that the annual increase rate of power supply was drastically down from 9% of 1977/78 to 1.1% of 1978/79 in the central

system, while the average increase rate in 7 years before 1977/78 was 16.2%.

7. The future increase of power and energy demand was forecasted by the following two different approaches;

   (i) Global demand forecast based on the past trend of demand growth, inclusive of those made by ED and the JICA Team.

   (ii) Sectoral demand forecast based on the economic growth in the non-agricultural sector and the development of potential projects projected in the 6th and 7th Five Year Plans in addition to the recorded past demand of the respective sector.

   The demand forecasts by the above approaches indicated an approximate concurrence. Further, reviewing the sectoral demand forecast in detail, the total projected amount of the energy requirement was judged reasonable. (The demand forecast in the industrial sector seems to be overestimated to some extent, while those in the commercial and domestic sectors to be rather conservative, offsetting each other.)

8. For the feasibility study of the Sapt Gandaki Project, the global demand forecast made by ED was adopted.

   In this forecast, the maximum power and energy demands were estimated to reach 113 MW and 416 GWh in 1984/85, and 286 MW and 1,078 GWh in 1989/90, respectively.

SITE CONDITION

9. The Sapt Gandaki Project site is characterized by the deep river gravel deposit, weak foundation rock, big river run-off and large sediment transportation, all of which are the elements to increase the cost of the project implementation.

10. The dam foundation is composed of alternating sandstones, mudstones, conglomerates and intraformational breccias of Neogene Siwalik Formation. Gray massive sandstones are predominant.

The river gravel deposit was found to be around 30 m to 40 m in depth in the middle part of the river channel, while the depth is around 15 to 20 m in the both sides. A more than 40 m thick and 400 m wide terrace gravel deposit exists on the left bank in the originally proposed damsite-A, while it is 130 m to 150 m wide in the downstream alternative sites (B and C). As such, it was judged that the originally proposed damsite-A would not necessarily be the most advantageous and that a comparative study with the downstream sites be required.

In-situ rock mechanical test revealed the shear strength of the foundation sandstones to be approximately 8 kg/cm^2 in cohesion and 40° in internal friction angle. These are the marginally low values for design of a concrete dam with a considerable height.

11. The annual average run-off at the damsite is about 1,500 m^3/s. The average monthly run-off ranges from about 4,200 m^3/s in August to about 280 m^3/s in March. The maximum discharge of 16,350 m^3/sec was recorded on August 5, 1974. The discharge of 90% firmness in time is found to be 290 m^3/s.

The flood frequency analysis indicated that the probable flood magnitude of 200, 1,000 and 10,000 years recurrence interval are about 19,000, 23,000 and 28,000 m^3/sec respectively. The sediment transportation of the Sapt Gandaki was estimated at a very large quantity of 2,800 $m^3/km^2/year$ (2.8 mm in terms of the depth for the basin) or 87.1 x 10^6 $m^3/year$ at the damsite.

12. Sufficient concrete coarse aggregate of acceptable quality are available from the river gravel deposits in the upstream and downstream reaches of the damsite. The fine aggregate can be obtained from the sand bars spreading in the Khageri Khola about 7 to 8 km far from the damsite.

The clayey soil material covering the tableland with a depth of 3 to 4 m in the left bank of the damsite is considered the most suitable source of the core material for the possible fill type dam scheme, while the quality will have to be improved by mixing some coarser materials. The rockfill materials are also available from the quarry located at 7 to 10 km north of the damsite or the gravel deposits spread in the Sapt Gandaki, the Trisulganga and the Kali Gandaki rivers.

PLAN FORMULATION

13. In order to find out the optimum project scheme, comparative studies of various conceivable project schemes were carried out. The basic factors involved in the study are the damsite-A and -B, the dam type - concrete gravity type and fill type, the development scale-full supply level EL.210, 220, 230 and 240 m, and the installed capacity - 75 MW, 112.5 MW, 150 MW, 187.5 MW, 225 MW, 262.5 MW and 300 MW. (Installation consists of 3 units with the provision of additional one future unit.) A total of 64 alternative schemes with various combinations of the basic factors were selected for comparison.

14. The benefit in each schemes was estimated by simulating the plant operation with the computer, using the stream flow data. The cost was estimated through the preliminary design made for each case, incorporating all the field investigation results.

The optimum project scheme which is defined as one to yield the maximum net benefit is indicated below:

Optimum Project Scheme

Damsite	Damsite-B
Dam type	Fill type dam
Development scale	F.S.L. 230.0
Installed capacity	225 MW
Firm peak power output	174 MW
Primary and secondary energy	757 GWh & 852 GWh

PROJECT DESIGN

15. The selected project scheme has to be designed as a run-of-river type since the reservoir will be filled up to the spillway crest with sediment in several years.

The main dam is designed as a zoned rockfill dam of center core type. The dam crest level was set at EL.238 with 8 m freeboard above the reservoir full supply level. The center core does not reach the bed rock. The treatment of the riverbed deposit, about 30 to 40 m deep in the center of the river channel, to intercept underseepage is designed to be done by the construction of a cut-off concrete wall instead of a core trench usually adopted.

16. Two large diversion channels (one on each bank) are provided for handling the big river run-off during construction and because of the construction procedure. The design flood for the river diversion system is the recorded maximum flood of 16,350 m^3/sec.

17. Two spillways (one in each of the right and left bank diversion channel portions) are provided, separately from the rockfill dam. The spillway consists of a gated concrete dam and a 100 m long stilling basin. Three radial gates (15 m wide and 19 m high) are set in the 52 m wide right bank spillway and 7 radial gates of the same type are set in the 126 m wide left bank spillway. The spillway has a capacity to pass the design flood of 23,000 m^3/sec (1.2 times of 200 year recurrence flood) with a freeboard of 5.8 m. The spillway also has a capacity to handle 10,000 year flood of 27,400 m^3/sec which is considered nearly corresponding to the probable maximum flood with a freeboard of 3.0 m.

Thus, a sufficient allowance of the freeboard is given in consideration of hydrological uncertainties involved in the huge catchment basin and unexpected troubles in the spillway gate operation. Further, 2 sets of emergency diesel generator and a device for the automatic gate operation are provided in view of the risk that no electricity or operator is available at the flood time.

18. The power waterway and power station are provided in the left bank adjacent to the left bank spillway. 3 units of the generator, 75 MW each, with Kaplan type turbines are to be set in the power house.

The heaviest part of the generating equipment for transportation will be about 30 tons of the rotor (about 35 tons including the trailer weight). A few bridges between Birganj and Hetauda can not sustain the above load and will have to be strengthen.

Taking into consideration sedimentation and suspended load during the flood period, an intake wall to protect the inflow of sediment is provided in front of the power intake. Its crest level is set 10 m higher than the spillway overflow crest level. The sediment will be effectively discharged out together with the spillway discharge without settling in front of the intake wall.

19. An alternative layout provided with a desilting basin instead of the proposed intake wall was examined. However, it was concluded that such costly structure would not be essential for the reasons that the life of turbine blades will be extended up to around 10 years by using 13 Chromium Hi-Nickel steel which is durable against abrasion and that in case the damage of turbine blades by abrasion occurs, it will be possible to repair the damaged blades by the build-up-welding at very low expense.

20. The intake and penstock (only the portion embedded in the dam body) for the installation of additional unit in future are provided. A space for the additional unit is left open in the river side of the power house for convenience of the operation of the first 3 units.

CONSTRUCTION PLAN

21. The construction plan is prepared based on the preliminary design of the project components. It will take about 5 years (61 months) from the contract award for the civil works to the commissioning of the first 75 MW unit of the generator. In addition to the above construction period, two years are necessary for the financial arrangement, supplemental investigation, tender and contract awarding.

22. Assuming that the financing for further investigation and design for tendering is achieved by the end of March, 1983, the power commissioning of the project could be made by the beginning of the 1989/90 dry season, i.e. by the end of October, 1989. It is recommended to successively start the installation of the second and third 75 MW so that its installation can be completed at the beginning of the dry seasons in 1990/91 and 1992/93 respectively.

PROJECT COST

23. The total project cost of the selected scheme is estimated at U.S.$354.7 x 10^6 which consists of Foreign Currency of U.S.$299.8 x 10^6 and Local Currency of U.S.$54.9 at 1982 July price level excluding the cost of the price escalation.

24. The investment disbursement schedule is prepared as shown below, assuming that the price level rises at an annual rate of 6% and L.C. is financed from the Government budget, while F.C. is financed by a foreign loan with an interest rate of 4%.

(Unit: 10^3 US$)

Fiscal Year	Total of present-day construction cost		Price contingency		Interest on F.C.	Total
	F.C.	L.C.	F.C.	L.C.		
1982/83	3,585	1,663	215	100	152	5,715
1983/84	3,046	1,565	376	193	289	5,469
1984/85	14,936	3,873	2,853	740	1,000	23,402
1985/86	28,370	6,293	7,446	1,652	2,433	46,194
1986/87	59,725	11,127	20,201	3,763	5,630	100,446
1987/88	63,544	11,170	26,594	4,675	9,236	115,219
1988/89	72,449	11,780	36,488	5,933	13,593	140,243
1989/90	32,513	4,756	19,308	2,824	2,073	61,474
1990/91	10,702	1,318	7,379	909	723	21,031
1991/92	7,223	895	5,712	708	1,241	15,779
1992/93	3,707	460	3,330	413	1,522	9,432
	299,800	54,900	129,902	21,910	37,892	544,404
	354,700		151,812		(75,783)	(582,295)

Remarks: Figures in parenthesis show the amount with an interest rate of 8%.

25. The power and energy output is classified to the firm power, primary energy and secondary energy. The firm power is defined as the power output which can be guaranteed with 90% firmness and with a capacity factor of 50% in operational duration even in drought years. The estimated firm power to be generated in the Sapt Gandaki power plant is 174 MW.

The primary energy is defined as the energy to be produced with the firm power at 50% capacity factor. The secondary energy is any surplus energy other than the above primary energy to be generated beyond 50% capacity factor in the high river flow season.

The power and energy output depends upon the demand of the system and calculated as shown below.

Fiscal Year	Installed Capacity (MW)	Firm Power (MW)	Energy (GWh)		
			Primary	Secondary	Total
1989/90	75	75	322	322	644
1990/91	150	104	456	750	1,206
1991/92	150	142	621	585	1,206
1992/93	225	174	757	852	1,609

26. The project benefit is the power benefit which is estimated with the cost of the most likely alternative power plant in the absence of the project. The alternative in this case is the 100 MW coal-fired thermal plant.

The power benefit is divided into the capacity benefit and the energy benefit. The capacity benefit consists of the installation cost, operation and maintenance cost and replacement cost of the alternative thermal plant with the same capacity as the project. The capacity benefit is estimated as follows:

Capacity Benefit

	Estimated Unit Cost	Adjustment Factor	Firm Power	Amount (10^3 US$)
Installation Cost	U.S.$1,000/kW	1.173	174 MW	204,102
Replacement Cost	U.S.$ 900/kW	1.173	174 MW	183,692
Annual O & M Cost	U.S.$ 30/kW	1.173	174 MW	6,090

27. The energy benefit consists of the primary energy benefit and the secondary energy benefit. The primary energy benefit is considered to be the fuel cost required in the alternative thermal plant for generating the same amount of the primary energy as the project. It is valued at U.S.$0.042/kWh based on the coal price of U.S.$63/ton. The secondary energy is considered not consumable in the system but is assumed to be exportable to India with an energy loss of 40%. The revenue from India (U.S.$0.024/kWh) is considered as the secondary energy benefit. The estimated energy benefit is as follows:

Energy Benefit

(Unit: 10^3 U.S.$)

Fiscal Year	Primary Energy	Secondary Energy	Total
1989/90	13,524	4,632	18,156
1990/91	19,152	10,800	29,952
1991/92	26,082	8,424	34,506
1992/93 onward	31,794	12,264	44,058

28. The value of the economic internal rate of return (EIRR) is calculated at 16.2% for the evaluation period of 50 years. The benefit-cost ratio (B/C) is calculated to be 1.28 at 12% discount rate. This value is high enough for the implementation of the hydropower project in Nepal. The EIRR of the project is not very sensitive to the deviation in cost and benefit, its value being 11.4% even if the cost is increased by 20% and the benefit is reduced by 10% concurrently.

The value of the financial internal rate of return (FIRR) is calculated at 9.2% for the evaluation period of 30 years. This value shows that the project is financially viable even if the project costs are financed by international financing agencies.

29. The loan repayment analysis indicates that the accumulated surplus will be turned into a positive figure only one year after the project reaches its final development stage in 1992/93. Afterwards, the project yields the annual profit of about U.S.$37 million after deducting the loan repayment from the net revenue. The accumulated surplus at the end of the repayment period, 2011/12, will reach about U.S.$670 millions. This amount exceeds the total required financial cost of the project and makes it possible to reconstruct a same kind of project at the end of the project life. Thus, the project is also justifiable from the viewpoint of loan repayability.

ALTERNATIVE PROJECT SCHEME (SECOND CHOICE)

30. In case financing difficulty becomes the major constraint for the project implementation, a smaller alternative scheme may have to be chosen as a second choice even at the sacrifice of the economic advantage. The following scheme is recommendable as the second choice in view of the less cost and reasonable profitability.

Recommendable Alternative Scheme

Damsite	Damsite-A
Dam type	Fill type dam
Full supply level	EL.220
Installed capacity	150 MW
Firm power output	134 MW
Primary and secondary energy	580 GWh & 544 GWh

31. The total project cost of the alternative sheme is estimated at U.S.$276.5 x 10^6 which consists of F.C.234.5 x 10^6 and L.C.42.0 x 10^6 at 1982 July price level. The total necessary fund including the cost of price escalation (annual rate 6%) up to 1990/1991 and interest during construction is estimated at U.S.$423.5 x 10^6.

32. The economic internal rate of return (EIRR) is calculated at 16.3% for the evaluation period of 50 years. This value is still high enough for the implementation of a hydropower project in Nepal.

The financial internal rate of return (FIRR) is calculated at 8.8% for the evaluation period of 30 years. The alternative project scheme will be financially viable if the project cost is financed with an interest rate less than 8.8%.

The loan repayment analysis indicates that the alternative scheme is also justifiable from the viewpoint of loan repayability.

EI IRONMENT

33. It was judged that the effect of the project on the riverine fishery can not be ignored, since about 10% of the nearby inhabitants are exclusively engaged in riverine fishery, getting cash income by selling fish in nearby communities. Thus, it was determined to provide a fish passing facility. The fish passing facility is provided on the slope of the right bank.

34. The area of agricultural lands and the number of residential houses to be submerged by the proposed reservoir will amount to about 440 ha and 490 nos. in total, respectively. In addition to the above, three traditional temples, four schools, two suspension bridges crossing the river and about 8 km of the existing Mugling Road will also be inundated, assuming the reservoir water level of EL.230. The total compensation cost required for the above is approximately estimated at U.S.$9,000,000.

EXTENSION SCHEME

35. If some storage reservoirs to regulate the seasonal variation of the river run-off are created in the upstream reaches of the Sapt Gandaki Project, the firm discharge into the Sapt Gandaki Project will increase, making it possible to expand the installed capacity of the Sapt Gandaki Project. The study thereof indicated that the possible increase of the firm discharge would be from 290 m^3/sec to more than 750 m^3/sec. With this increase of the firm discharge, the final installed capacity of the Sapt Gandaki Project can be extended up to a range of 400 MW to 600 MW. The definite final installation will depend on the magnitude of the daily peak discharge released from the immediate upstream hydroelectric power station of storage scheme. The facilities for extension (addition of 100 MW to 300 MW) will be constructed on the right bank.

IRRIGATION WATER SUPPLY

36. The Sapt Gandaki Project will make it possible to supply irrigation water by gravity flow from the reservoir to the Chitwan Valley irrigation project, instead of pumping up by the pumping station which is being constructed at about 4 km downstream from the Project site. It, however, will be accompanied with a loss of energy of the Sapt Gandaki Project due to the supply of irrigation water and the necessary construction cost of the intake facilities and canal, etc.

The study revealed that the full utilization of the pumping facilities in the downstream would be more profitable for the time being and that the plan of the irrigation water supply by gravity flow from the Sapt Gandaki Project should be considered at the time when the replacement of the pumping facilities becomes necessary after about 25 years.

DEVELOPMENT PLAN OF HYDROPOWER PROJECTS

37. There are several hydropower projects for which the technical and economic feasibility has been confirmed through the feasibility studies already made. Those are the Kali Gandaki Project

(Scheme A), the Kankai Multipurpose Project, the Mulghat Project and the Sapt Gandaki Project. The Kankai scheme is of the storage type and has the capacity to regulate the seasonal variation of the run-off. The others are of the run-of-river type.

To meet the future growth of power demand, the most desirable or beneficial development order of these hydropower projects was sought by carrying out the comparative study of several conceivable cases.

The most beneficial one appeared in the case that the Kankai Project is firstly developed in 1989/90 when the pwoer demand will reach the supply capacity of the system. However, examining the implementation of the above development plan, it was found that the construction works of two projects will mostly overlap since the successive project ha to be completed two years after the completion of the Kankai Project. Considering the financial difficulty due to the above overlap will become a major constraint for the implementation, the following development order, which is the second advantageous, was recommended as the most recommendable from the practical viewpoint.

Sapt Gandaki (Nov. 1989) - Kankai (Oct. 1993) - Kali Gandaki (Feb. 1996) - Mulghat (Feb. 1997)

Note: ( ) shows the commissioning time of each project.

FURTHER INVESTIGATION

38. In addition to the data and information so far obtained, the following further investigation and tests will be required for the tender and detailed designs of the components involved in the Sapt Gandaki Project.

- Additional geological investigation to confirm more accurately the surface of the bedrocks under the river deposits and the terrace deposits.

- Additional investigation of the construction materials to confirm the mechanical strength of the embanked quarry rock, necessary mixing ratio of the coarser material with the fine soil material to obtain the proper core and filter materials.

- Detailed topographic survey for the design and cost estimate of the Mugling relocation road.

- Survey of the exact suitable route of the transmission line.

- Hydraulic model test of the spillway and the intake related with the sedimentation inflow problems.

RECOMMENDATION

39. In consideration of the necessary commissioning time and construction period, the detailed engineering works for the Sapt Gandaki Project, including the detailed investigations, design and preparation of tender document, should be started at the early stage of 1983. The necessary detailed geological investigations required in the river channel are recommended to be carried out during the 1982/83 dry season.

40. Taking into consideration the time required for negotiating international contracts, the commencement of construction by the contractor will be at the end of 1984 at the earliest. To avoid the delay of the commissioning of the project targeted at the beginning of the 1989/90 dry season, the preparatory works such as the main access roads in both banks and the power supply system up to the damsite are recommended to be completed beforehand by HMG.

41. The excessive deforestation in the basin causes severe erosion and landslides, a large amount of sediment transport, and a big magnitude of the flood discharge, etc. In view of the keen necessity of mitigation of the above, it is recommended to push forward the afforestation in the basin.

PROJECT PRINCIPAL FEATURES

(1) Reservoir

Catchment area	31,100 km^2
Fully supply water level	EL.230 m
Minimum operation water level	EL.226 m
Flood water level	EL.232.2 m
Drawdown	4 m
Gross storage capacity (at FSWL)	450×10^6 m^3
Effective storage capacity for daily regulation	8.5×10^6 m^3

(2) Diversion system

Design flood inflow	16,350 m^3/sec
Type	Open channel
Right bank channel,	
Width and length	52 m and 820 m
Left bank channel,	
Width and length	126 m and 950 m
Crest elevation of upstream cofferdam	EL.196 m
Crest elevation of downstream cofferdam	EL.195.5 m

(3) Dam

Type	Rockfill with center core
Crest level	EL.238 m
Dam height above river bed	60 m
Crest length (Rockfill dam section)	338 m
Crest width (Rockfill dam section)	10 m
Upstream and downstream slopes	1:2.5 (1:1.9 above F.S.L.) & 1:1.9

Embankment volume,	
Core	346,600 m^3
Filter	161,000 m^3
Quarry rock	1,500,000 m^3
Total	2,007,600 m^3

(4) Spillway

Type	Gated chuteway with stilling basin
Gage,	
Right side	19 m(H) x 15 m(W) x 3 sets
Left side	19 m(H) x 15 m(W) x 7 sets
Crest level	EL.211.5 m
Design flood	23,000 m^3/sec
Design flood for stilling basin	17,800 m^3/sec
Concrete volume	624,000 m^3

(5) Waterway and powerhouse

Intake;	
Type	Gated conduit type provided in the gravity dam
Center level of intake conduit	EL.214.5 m
Gate	7.6 m(H) x 7.6 m(W) x 3 sets
Penstock;	
Length	72 m
Diameter	7.6 m
Powerhouse;	
Type	Above-ground
Width, length and height	35.1 m x 104 m x 53.9 m

(6) Generating equipment

Turbine;	
Type	Vertical shaft, Kaplan type with an elbow type draft tube

Elevation of casing center	EL.179.4 m
Net head at rated water level	42.315 m
Rated discharge	617 m^3/sec
Installed capacity	75,000 kW x 3 units
Turbine rated speed	136.3 rpm
Average annual energy output	1,609 GWh (Primary: 757/Secondary: 852)
Tailwater level at max. discharge	EL.184.60 m

Generator;

Type	Vertical shaft, revolving field umbrella type
Capacity	83,300 kVA x 3 units
Voltage	11,000 V
Cycle	50 Hz
Power factor	0.9

Main transformer;

Type	Oil immersed fan cooled outdoor type
Voltage	10.5 kV/126-129-132-135 kV
Capacity	83,300 kVA x 3 units

(7) Transmission line

Transmission line;

Voltage	132 kV double or single circuit lines
Conductor	264 mm^2 ACSR

	Section	Route Length	Circuit No.
(i)	Sapt Gandaki - Hetauda	75 km	Double
(ii)	" - Bharatpur	5 km	Single
(iii)	" - Dumkibas	55 km	Single (Double in future)
(iv)	Dumkibas - Butwal	45 km	Single (Additional)

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CHAPTER 1 INTRODUCTION

1.1 Master Plan and Prefeasibility Study

Master Plan: In 1973 to 1974, the master planning of hydroelectric power development for the whole of Nepal was executed by the Japan International Cooperation Agency (JICA). Its study is presented in the report, "MASTER PLAN OF HYDROELECTRIC POWER DEVELOPMENT IN NEPAL, September 1974, JICA".

The master plan revealed that, theoretically, the hydropower potential of the Gandaki River basin is approximately 21 million kW as compared to 83 million kW for the whole of Nepal. The development of existing large scale hydroelectric power sites was judged premature for the time being although they may become economically justifiable in the future.

Instead, the master plan recommended the development of medium-small size hydropower Projects to meet the pressing domestic power demand. In the sequence to harness the Sapt Gandaki River, the Sapt Gandaki Project with an installed capacity of 150 MW was proposed as a medium size hydropower scheme to be constructed, following the Kulekhani No.1 and No.2 hydropower projects.

Following the above Master Plan for the whole country, a master planning of hydropower development in the Gandaki River basin was carried out from 1977 to 1979 by the Snowy Mountain Engineering Corporation (SMEC) under a Contract with the United Nations Development Programme (UNDP). The results of its investigation are presented in the report "GANDAKI RIVER BASIN POWER STUDY, BASIN STUDY, BASIN MASTER PLAN, July 1979, UNDP".

In the UNDP master plan, the following hydroelectric power projects were recommended so as to meet the increasing power demand in Nepal.

Projects	Installed Capacity	Year of Completion
Kulekhani No.1	1 unit x 30 MW	1980
"	"	1981
Dev Ghat	3 unit x 4.7 MW	1983
Kali Gandaki	1 unit x 30 MW	1984
"	"	1985
"	"	1986
Kankai	2 unit x 19 MW	1986
Marsyangdi	2 unit x 25 MW	1988
Kulekhani No.2	2 unit x 35 MW	1990
Sapt Gandaki	1 unit x 37.5 MW	1991
"	"	1992
"	"	1993
"	"	1994

Prefeasibility Study: The mentioned master plan was based on the site reconnaissance and no detailed site survey was made in the project area. To promote the Sapt Gandaki Project, SMEC carried out a prefeasibility study in 1979, based on the field investigations performed under a contract with UNDP, and prepared the "Prefeasibility Report for the Sapt Gandaki Hydroelectric Project". It was stressed in this report that further investigation, especially for geological condition of the dam foundation, is needed to fully assess the economic and technical soundness of the project.

1.2 Feasibility Study

In December, 1980, His Majesty's Government of Nepal (HMG) requested the Government of Japan to render technical cooperation to carry out the feasibility study of the Sapt Gandaki Project. This request was made in consideration of the increasing power demand and the necessity to further develop hydropower after the completion of projects presently in progress. The Government of Japan agreed to the above HMG's request and appointed the JICA team to carry out the feasibility study of the project.

The feasibility study of the Sapt Gandaki Project was planned to be performed in three stages, i.e. Stage-I, Stage-II and Stage-III, each consisting of the following;

Stage-I : To carry out the geological investigation of the proposed damsite,

To collect the relevant data and information for the project,

To make preliminary technical and economic assessment of the project based on the obtained data, and

To see if it is justifiable to advance to the detailed investigation (Stage-II) for the feasibility study.

Stage-II : Provided that it is justified by the Stage-I study to enter the Stage-II study,

To carry out the detailed field survey of topography, geology, construction materials, hydrology, economics and environment, etc.

Stage-III : To carry out the feasibility study of the project based on the data obtained by the detailed field survey at Stage-II.

The geological investigation and collection of the relevant data and informations of the project at Stage-I were carried out during February and March in 1981 by the JICA Survey Team. The Interim Report I was submitted to HMG as the result of the Stage-I study. The Stage-I study revealed that the project is expected to be technically and economically feasible and that proceeding with the successive studies is fully justifiable.

Thus, the detailed field survey of Stage-II was executed during the period from August, 1981 to April, 1982. Its results were all reported in the Interim Report II which was submitted in May, 1982.

The feasibility study at Stage-III was successively commenced from May, 1982 on the basis of the detailed field survey result at Stage-II.

This report provides all findings from the above feasibility study at Stage-III.

CHAPTER 2 GENERAL GEOGRAPHY AND ECONOMY

2.1 General Geography

Geography: The Kingdom of Nepal lies along the southern slopes of the Himalayan Ranges. The country extends between India and the Tibetan Plateau of China from North-West to South-East. Its rectangular-shaped land covers an area of 141,059 km^2 with about 800 km length from East to West and about 130 km to 240 km width from North to South. The land is situated between the latitudes of 26°30' N to 30°15' N and the longitudes of 80°00' E to 88°15' E.

Topography: The land of Nepal of which 83% is mountainous and 17% is in the Terai plains, comprises six topographic zones; they include, from the south to the north, the Terai Belt, Siwalik Hills, Mahabharat Mountain Range, Mid-land zone, Himalayan Range and the Tibetan Plateau.

The Terai Belt extends from the left bank of the Ganges River and lies between the Indian border and the foot of the Siwalik Hills. It has an altitude ranging from about 60 m to 300 m and a width from about 15 km to 40 km.

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

The Mahabharat Range rises to an altitude of some 3,000 m. Geologically, it is a front of the big overthrusted nappes, the breakers against the Siwaliks. In general, the Mahabharat Range forms a large syncline which covers nearly the whole length of the country.

The Midlands of Nepal covers a zone of about 65 km to 100 km in width between the Mahabharat Range and the Himalayas. The Midlands zone has a terrain of very gentle slopes lying at altitudes ranging from about 600 m to 2,000 m. The Midlands is very fertile. All kinds of fruits, vegetables and grains of subtropical and moderate climate are grown.

The main range of the Himalayas is divided by the big traversal rivers into different groups. The main range of the Himalayas forms the border line between Nepal and Tibet in its eastern part.

In the western part, Nepalese territory extends far beyond the main range of the Himalayas into the Tibetan Plateau. The Tibetan Plateau in Nepal consists of a mountain desert between 3,000 m and 5,000 m in altitude. With irrigation, barley and other grains are raised besides potatoes.

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

2.2 General Economy

Administration: Nepal is administratively divided into 14 zones and subdivided into 75 districts. In the execution of economic development policy, Nepal is divided into 4 Development Regions of Central (Kathmandu), Eastern (Dankuta), Western (Pokhara) and Far Western (Surkhet) as shown in Fig.-2.1. The capital of Nepal, Kathmandu, is located in the Bagmati Zone in the Central Development Region. The so-called Kathmandu-Hetauda-Birganj corridor along the Kathmandu-Culcutta Highway is the center of the nation's economic activity.

Recently, the Kathmandu-Mugling-Narayangar-Hetauda-Birganj Highway was opened by the completion of the highway between Mugling and Narayangar. This route is longer than the Kathmandu-Hetauda-Birganj route but does not have such steep slopes as in the Kathmandu-Hetauda-Birganj route. The above new route has become the main transportation artery.

Most of the major towns in Nepal are linked by a wireless network and/or telephone line operated by HMG. HMG also plans to introduce a microwave network to cover the entire country.

Population: The population in Nepal was estimated at 14 million in 1980. It comprises various races and tribes deriving from the Tibeto-Burmese group, the pure Tibetan group and the Indo-Aryan group. The population is growing at a rate of 2.1 to 2.2% per annum as indicated in Table-2.1. Two-thirds of the population lives and engages in agriculture on the mountains and hilly areas, where the fertility of land is depleted and deforestation is common. Consequently, mass migration to the southern plain of the Terai is being made under the resettlement programme of the government. During the Fifth Five Year Plan, about 25,000 families were resettled in the southern plain.

Employment: According to the National Planning Commission of HMG, unemployment including underemployment in rural and urban areas is respectively 63% and 45%. The problem of employment is a serious one, and the government has put a high priority in promoting various development programmes to absorb labour and induce more employment opportunities.

GDP: Gross Domestic Product (GDP) of Nepal has risen at an annual rate of 2.2% during 1965/66 to 1974/75. GDP in 1974/75 amounted to Rs.16,571 million (= U.S.$1,381 million) at current market price. After that, the GDP is growing at the annual rate of 3.0% to 4.5% under the Fifth Five Year Plan which planned to increase the GDP at a rate of 4% every year. Agriculture is the main contributor to the GDP contributing two-thirds of the total followed by the service sector with 20%. The manufacturing sector contribution to the GDP is only 3 to 4%. Recent record of the GDP of Nepal is as shown in Table-2.2.

Foreign Trade: The main export items are rice, maize, oil seeds, hides and skins, butter, tea, jute, timber, carpet and handicrafts. The main import tiems are machineries, semi-processed raw materials, construction materials and vehicles, etc.

Recent record of import and export is as indicated in Fig.-2.2. During the fiscal year 1979/80, exports earned Rs.1,305.7 million and imports cost Rs.3,053.2 million, resulting in a deficit of Rs.1,747.5 million (U.S.$145.6 million) in the balance of payments. Trade statistics for the first half of the fiscal year 1980/81 already indicated a trade deficit of Rs.1,657.5 million (U.S.$138.1 million) as compared with a deficit of Rs.899.3 million (U.S.$74.9 million) during the corresponding period of last year. This is due to the swelling of imports.

The foreign exchange holdings of Nepal has steadily increased. It amounted to Rs.2,133.2 million (U.S.$177.8 million) in 1979/80, by which imports for four months can be paid.

Agriculture: Agriculture is the principal economic activity in Nepal. It employs 90% of the labour force including workers in the agro-based industries, and supports 80% of the export earnings and two-thirds of the GDP. In addition, it provides raw materials for industries.

Industry: Industry in Nepal is in an infant stage of development with less than 60,000 persons employed in about 3,500 firms and its contribution to the GDP is only 4%. However, the industry is growing faster than the other sectors under the industrial policy of the government which focused on the promotion of import-substituting industries and the expansion of employment opportunities. This is reflected in the recent establishment of cement and textile industries, expansion in the sugar and cigarette factories, etc.

In the Sixth Five Year Plan, the government gave the first priority to the development of import-substituting industries, i.e. cement, textile, paper, iron and steel etc., and to the development of cottage and small-scale industries in view of expanding employment opportunities. Thus, a remarkable growth in the industry sector is expected.

Tourism: Tourism, which is one of the major sources of foreign exchange earnings, has been playing a significant role in the Nepalese economy. Foreign visitors are continuously increasing. The number of foreign visitors in 1975 was 92,000. It increased up to more than 162,000 in 1979. Foreign exchange earnings from tourism increased from Rs.120.7 million in 1974/75 to Rs.518.7 million in 1979/80. The construction of new hotels and the extension of the existing ones is also being promoted by the government. The record of tourist arrival and available hotel beds is as shown in Table-2.3.

Development Plan: The Fifth Five Year Plan (1975/76-1979/80) ended in June 1980 and the Sixth Plan (1980/81-1984/85) came into operation in July 1980. The first and foremost aim of the Sixth Plan is to get agriculture moving and building on the basis of past investments in infrastructure, agriculture, transportation and communications and looking to more directly productive investments, better utilization of manpower and increasing productivity.

The total outlay during the Sixth Plan is projected as Rs.33.94 billion, of which Rs.20.49 billion is to be invested in the public sector, Rs.11.65 billion in the private sector, and Rs.1.8 billion in the Panchayat sector (Local bodies). Allocation of the total development expenditure for the Sixth Plan is given in Table-2.4.

Water Resources: Nepal, a mountainous country, is rich in water resources. The total hydropower potential in the whole country is estimated at 83,000 MW of which less than 0.1% is exploited at present. Water resources development will greatly contribute to the economy of the country by the development of agriculture, industry and electrified transportation system, and by exporting the hydroenergy produced.

Consumer Prices: The national urban consumer price has been increasing as shown below. It has risen at the average rate of 9.4% per year during the period from 1972 to 1981.

Year	1972/73	73/74	74/75	75/76	76/77	77/78	78/79	79/80	80/81	1972/81 Average
Price Index	100	118.2	138.0	137.0	140.7	156.4	161.8	177.6	202	-
Annual Increase (%)	-	18.2	16.8	-0.7	2.7	11.2	3.5	9.8	13.7	9.4

Table-2.1: POPULATION OF NEPAL (1971 - 1980)

Year	Millions	Growth Rate (%)
1971	11.56	
1972	11.81	2.2
1973	12.06	2.1
1974	12.32	2.2
1975	12.59	2.2
1976	12.86	2.1
1977	13.14	2.2
1978	13.42	2.1
1979	13.71	2.2
1980	14.01	2.2

Source: Monthly Bulletin of Statistics, April 1981.
Vol. XXXV, United Nations

Table-2.2: RECENT GDP AND ITS SECTORAL COMPOSITION a/

	1974/75	1975/76	1976/77	1977/78	1978/79	1979/80
	(In Million Rupees at Current Prices)					
Agriculture b/	11,435	11,493	10,389	11,616	12,118	12,782
Mining	22	23	26	25	27	28
Manufacturing	440	459	499	531	542	553
Cottage Industry	224	231	237	263	274	282
Construction	583	718	1,020	1,338	1,494	2,092
Electricity, Gas & Water	34	38	39	42	48	52
Transport, Storage & Communications	690	805	852	1,093	1,306	1,767
Trade, Restaurant & Hotels	540	603	636	707	789	996
Finance, Insurance & Real Estate	1,095	1,171	1,412	1,534	1,785	2,198
Services	873	1,046	1,145	1,277 c/	1,350	1,555
Pbulic	(648)	(811)	(901)	(989)	(1,055)	(1,160)
Private	(225)	(235)	(244)	(269)	(295)	(395)
Gross Domestic Product at Factory Cost	15,936	16,589	16,255	18,426	19,733	22,305
Net Indirect Taxes	635	805	1,025	1,306	1,419	1,562
Gross Domestic Product at Market Prices	16,571	17,394	17,280	19,732	21,152	23,867
	(In Million Rupees at Constant 1974/75 Prices)					
Agriculture d/	11,550	11,615	11,141	11,141	11,480	10,933
Non-agriculture d/	5,021	5,685	6,681	7,070	7,285	7,577
Gross Domestic Product at Market Prices	16,571	17,300	17,822	18,211	18,765	18,510
Population (000)	12,439	12,704	12,979	13,265	13,557	13,855
GDP per Capita Rupees	1,346	1,362	1,373	1,373	1,384	1,336
" " " US$	103	104	105	105	104	102

a/ New series begun in 1974/75. Data for 1977/78 to 1979/80 are preliminary estimates.
b/ Includes fishing and forestry.
c/ Includes "extraterritorial" services item of Rs.19 million.
d/ Constant price series available at market prices only.

Sources: Central Bureau of Statistics and National Planning Commission.

Table-2.3: TOURIST ARRIVAL AND HOTEL BED

	1975	1976	1977	1978	1979
1. Number of Tourist	92,440	105,108	129,329	156,123	162,276
2. Number of Hotel Beds	1,663	2,099	4,600	4,888	5,018

Note : Calendar year

Source: Department of Tourism thru "Economic Survey" 1979/80, Ministry of Finance, 1980

Table-2.4: ALLOCATION OF THE TOTAL DEVELOPMENT EXPENDITURE, 1980 - 85

(At 1979/80 Prices)

Rs. in million

	Public Sector 1/	Panchayat Sector	Private Sector	Total	%
Agriculture, Irrigation and Forest	6,260	490	3,820	10,570	31.1
Industry, Mining and Power	5,280	30	3,500	8,810	26.0
Transport and Communications	4,230	540	1,106	5,870	17.3
Social Services 2/	4,720	740	3,230	8,690	25.6
Total	20,490	1,800	11,650	33,940	100.0

Notes: 1/ Of the total development expenditures of Rs.21.75 billion to be incurred in the public sector, the sum of Rs.1.26 billion which is to go to other sectors as financial assistance, has been included in the sectors concerned instead of lumping it up with the public sector expenses. Of the net development outlay of Rs.20.49 billion, 60 percent or Rs.12.30 billion, is estimated to be spent in the form of investment.

2/ The amount shown under the head social services also includes expenses relating to residential housing construction and other miscellaneous development expenditures also.

Source: The Sixth Plan (1980 - 85), A Summary, Part 1, National Planning Commission, January 1981.

CHAPTER 3 POWER SUPPLY AND DEMAND

3.1 Organization and System of Power Supply

The Ministry of Water Resources (MWR) administratively controls the power development and supply in Nepal. MWR, assisted by Water and Energy Commission (WEC), formulates water and power development policy and coordinates and supervises the operations of the other power sector agencies. The organization chart of the Ministry of Water Resources is shown in Fig.-3.1.1.

The Electricity Department (ED), which is a department of the Ministry of Water Resources and of which an organization chart is given in Fig.-3.1.2, is the sole agent responsible for the planning and construction of the power generation facilities and transmission lines in Nepal. Once power facilities are completed by ED, they are transferred to an electricity corporation for commercial operation.

The Nepal Electricity Corporation (NEC) is responsible for the operation of all power facilities in the "Central and Western Nepal Power System". NEC also provides power supply from India in the Central and Western Region.

The Eastern Electricity Corporation (EEC) is responsible for power supply in Eastern Nepal. EEC also distributes power imported from India in the Eastern Region.

The Butwal Power Company (BPC) which is a private company is in charge of power supply in Butwal of the western region, cooperating with ED.

3.2 Present Power Situation in Nepal

3.2.1 Generating Facilities

The present situation of power generating facilities in Nepal is as seen in Table-3.2.1 and Table-3.2.2. The total installed capacity in 1975 was only about 65 MW.

Recently, it has remarkably increased by the completion of Gandaki in 1980 (15 MW) and the additional installation of a diesel plant at Hetauda in 1981 (10 MW), although some old diesel plants went out of use.

The present total installed capacity reached 85.1 MW as of 1981, of which 52.1 MW is hydroelectric, 28.5 MW diesel and 4.5 MW is steam generated. Public service accounts for 77.1 MW or 90.1%; the remaining 8 MW are owned and operated by various self-generating industries and institutions.

The largest installations are 21 MW hydro. in Trisuli, 14.5 MW diesel in Hetauda and 1.4 MW steam in Biratnagar.

The monthly peaking capacity fluctuates seasonally due to the seasonal variation of the hydroelectric power stations as calculated in Table-3.2.3. The total monthly peaking capacity changes from 63.2 MW in the driest month (in March) to 75.6 MW in the rainy season (July to October) as seen in the Table.

3.2.2 Records of Power Demand and Supply

Past record of the power and energy supply in Nepal up to 1979 is shown in Table-3.2.4 to Table-3.2.6. Table-3.2.4 gives the past record of supply for the whole Nepal. Table-3.2.5 and Table-3.2.6 give those for each development region.

As seen in Table-3.2.4, the power demand in Nepal has grown at an average annual rate of 16.5% per year. However, the annual increase rate of power supply was drastically down from 11.1% of 1977/78 to 3.4% of 1978/79 in the whole of Nepal due to the drastic lowering of the one in the Central Nepal Power System (CNPS) which occupies a major part of the power supply. In the Central Region, it was down from 9.0% of 1977/78 to 1.1% of 1978/79, notwithstanding a rather normal increase of energy supply. The load factor which has ranged from 40 to 44% indicated an improvement of 47.5% in 1978/79 as seen in Table-3.2.5.

The above is understood to indicate that the power demand in the Central Nepal Power System exceeded the power supply capacity in 1978/79 and the power supply was limited to its supply capacity.

The fact that the power demand in the Central Nepal Power System exceeded the power supply capacity is also understood by the following;

The daily load curves of the Central Nepal Power System for summer and winter are shown in Fig.-3.2.1 and Fig.-3.2.2 respectively. The load factors of summer and winter are indicated as 56.3% and 75.0% repsectively. Considering that electric heaters are used in winter, the power and energy demands in winter are expected to be higher than those in summer. However, the peak power supply in winter is actually less than that in summer, showing a higher load factor, as shown in Fig.-3.2.1 and Fig.-3.2.2. Thus, it is considered that the power supply capacity of the system in winter is far short for the peak demand due to insufficient capacities of the hydropower plants. A load shedding program was imposed on a continuous rotation basis and application of new consumers were also suspended. The serious shortage on the system in winter was also recognized by the above fact.

3.2.3 Power Transmission System

Fig.-3.2.3 shows the power transmission system in Nepal envisaged up until 1984/85.

The existing 66 kV transmission system in Central Nepal was first constructed to send the generated power of the Trisuli power station to Kathmandu, Hetauda and Birganj, delivering power to the areas along the line by substations connected to the system. The surplus power has been exported to India from Birganj.

The 66 kV system was extended by the construction of the Siuchatar substation to receive power from the Kulekhani No.1 power station which is connected to the 66 kV system. The 66 kV line from the Sunkosi power station to the Patan substation, which had been operated separately, will also be connected to the above 66 kV system by the line extended from Siuchatar to Patan under the Kulekhani Project.

As the Gandaki Power Station was developed, a single circuit of 132 kV transmission line was constructed up to Hetauda through Bharatpur, to send power to load centers in the Kathmandu valley. The 132 kV system is connected to the 66 kV system by 132 kV/66 kV interconnecting transformers at the Hetauda substation.

3.3 Power Demand Forecast

3.3.1 Present Situation

As explained in the preceding Section, the annual increase rate of peak demand of the entire country was drastically down from 11.1% in 1977/78 to 3.4% in 1978/79, though it showed an average increase of 18.5% for the period from 1970/71 to 1977/78. On the contrary, the yearly load factor increased from 42% in 1977/78 to 46.2% in 1978/79. These showed that the power requirement in 1978/79 exceeded the power supply capacity to a considerable extent, especially in the winter season. Such a serious power shortage of the system led to the imposition of a load shedding program in the load center of Nepal, Kathmandu area and the suspension of new consumer's applications until the Kulekhani No.1 hydropower station was put into service in 1982.

Judging from the said power situation in the system, the demand is expected to increase remarkably within the initial several years if the supply capacity can be expanded to meet the power requirement (power demand in CNPS jumped up from 35 MW to 56 MW after the completion of the Kulekhani No.1). The distribution system will be successively improved after the completion of the Kulekhani No.1 with the reinforcement of the Kathmandu distribution system. In addition, various industrial and irrigation projects are planned in the 6th and 7th Five Year Plans. These increments of load are needed to be incorporated in the power demand forecast.

3.3.2 Demand Forecast by HMG

For the purpose of planning investment, HMG has made the demand forecast by using two different methodologies, namely the global and the sectoral approaches. The former was based on the historical data on the global power demand, while the latter took into consideration the sectoral economic growth and the development of potential projects projected in the Sixth and Seventh Five Years Plan (hereinafter called 6th and 7th Plan, respectively) in addition to the data on the historical power demand broken down by respective sector. The results of the above forecasts are presented below.

(1) Global demand forecast

Taking into consideration the above power situation in Nepal, ED has prepared the power demand forecast in August 1981 which covers the period up to 1999/2000. The expected power demand was estimated based on the records of past demands.

The procedures and assumptions adopted to predict the above power demand are explained below.

(i) The annual mean increase rate will decrease gradually in the following range.

Growth rate for the period 1977/78 to 1999/2000 (%)			
Eastern	Central	Western	Far western
25 to 10 (23.6)	15 to 9 (15.6)	25 to 10 (44.1)	30 to 10 (113.0)

Remark: Figures in parenthesis are the annual mean increase rate from 1970/71 to 1977/78.

(ii) The energy demand for the year of 1977/78 was taken as the base for the purpose of the power demand estimation. The energy demand indicated in 1977/78 is deemed as close to the actual demand while the power supply condition in the Central Region for 1978/79 showed a drastic power shortage.

(iii) The energy demand and load factor in 1977/78 of the base year are assumed to be 186.6 GWh and 42% respectively, as indicated in the power supply record shown in Table-3.2.4.

(iv) The annual load factor is assumed to gradually increase from 42% in 1977/78 to 45% in 1999/2000.

(v) The requirement only in the interconnected system is counted as the real demand, while the requirement in the non-interconnected area is deemed as potential demand. Then, in the forecast, an abrupt increase in the demand will occur concurrently with the completion of the system interconnection to the new area.

The estimated power and energy requirement by region were tabulated in Table-3.3.1 and Table-3.3.2 and those in the interconnected system are summarized below.

Fiscal Year	Energy Requirement (GWh)	Power Requirement (MW)	Load Factor (%)
1977/78	144.2	39.2	42
1978/79	165.8	45.1	42
1979/80	190.7	51.8	42
1980/81	218.7	59.4	42
1981/82	250.2	68.0	42
1982/83	297.0	80.8	42
1983/84	338.9	92.1	42
1984/85	416.0	113.1	42
1985/86	590.2	156.7	43
1986/87	710.2	188.5	43
1987/88	810.5	215.1	43
1988/89	920.8	244.4	43
1989/90	1,077.5	286.1	43
1990/91	1,212.6	314.6	44
1992/93	1,511.5	392.2	44
1994/95	1,847.3	479.3	44
1996/97	2,236.5	567.4	45
1998/99	2,689.6	682.4	45
1999/2000	2,942.2	746.4	45

(2) Sectoral damand forecast

Aiming to prove the authenticity of the power demand forecast by the global forecast method mentioned in the previous paragraph, HMG carried out the sector by sector power demand forecast, based on the historical data in the respective sector, the economic growth projected and potential projects planned in the 6th and 7th Plans covering the period from 1980/81 to 1989/90.

The above sectoral demand forecast is briefed below, and its details and supporting data are presented in ANNEX (D) together with the JICA Team's view. The view endorses the reasonableness of the forecast as a whole, although it is considered that there is an overestimation in the industrial sector that will be offset by the underestimate in the domestic sector.

i) Industrial demand

The industrial demand forecast was made by the macro-economic method, using the logarithmic model. It was established based on a historical relationship between non-agricultural GDP and electricity sales to the industrial sector for the last ten years, the annual growth rates of non-agricultural GDP projected in the 6th Plan (5.6%) and 7th Plan (7.0%) and the gradual decrease of the energy loss ratio from 40% in 1980/81 to 30% in 1989/90. The analysis idnicated that the energy sales to the industrial sector will increase at an annual growth rate of 17.8% and 22.5% for the 6th and 7th Plan periods respectively, and that the energy requirement will reach around 489 GWh in 1989/90. It showed a good agreement with the figure derived by another approach in which the forecast was made by relating the energy requirement to the total investment on the industrial projects planned to be implemented in the 6th and 7th Plans.

ii) Commercial demand

Since a high correlation between the historical energy sales to the commercial sector and the number of tourist arrival was observed, the commercial demand forecast was made based on the annual growth rate of the number of tourist arrival projected in the 6th and 7th Plans. The projected rate was 15% throughout the periods which corresponded to the mean annual growth rate for the period from 1971/72 to 1979/80. This resulted in 82.0 GWh of commercial energy requirement in 1989/90.

iii) Irrigation demand

HMG is planning to develop new irrigated areas of 23,750 ha in the 6th Plan and 86,000 ha in the 7th Plan by groundwater or lift irrigation schemes. The energy requirement in the irrigation sector was estimated based on the power requirement and implementation schedule of eleven irrigation projects on-going or to be implemented in the 6th and 7th Plans and assumed load factor (50%), coincidence factor (35%) and energy loss ratio (20%). The energy requirement was expected to reach 183.4 GWh in 1989/90.

iv) Domestic demand

The domestic demand forecast was also made by the macro-economic method same as that was used for the industrial demand. With the logarithmic model established and the growth of non-agricultural GDP projected in a same manner, the energy requirement in the domestic sector was forecasted at 186.3 GWh in 1984/85 and 325.0 GWh in 1989/90.

The domestic demand forecast was made by another approach, assuming that the number of domestic consumers will increase at an annual growth rate of 8.2% for the periods both in the 6th and 7th Plans and that the present annual average consumption per consumer of around 800 kWh which was suppressed by the load shedding will grow at an annual increase rate of 20 kWh. On the basis of these assumptions, the energy requirement in 1989/90 was derived to be 300.2 GWh.

v) Street lighting, water supply and other requirement

As energy requirments other than those in the said four sectors, the requirements for street lighting, water supply, self consumption of the utilities and export to India were considered. For the former two sub-sectors, it was assumed that the annual consumption in terms of per consumer of domestic sector will be respectively 20 kWh and 10 kWh for street lighting and water supply over the period from 1980/81 to 1989/90. The self consumption of the utilities was assumed to be constantly equivalent to 1.5% of the total energy requirement which corresponds to the average rate during the period of the last 5 years. The energy exported to India is assumed to maintain the same average amount of the last 5 years, 6 GWh/year. Thus, the energy requirement in the above sub-sectors was expected to totally amount to 32.2 GWh in 1989/90.

The results derived by the above sectoral demand forecast are summarized in Table-3.3.4.

3.3.3 Demand Forecast Made in Interim Report I by JICA Team

The JICA Team has independently predicted the power demand up to 1990/91 in the course of preparing the Interim Report I which was submitted to HMG in July 1981. The annual growth rate of peak demand was estimated to be 17.9% during the 5 years period from 1980/81 to 1985/86 and 10.5% during the 5 years period from 1985/86 to 1990/91. The power and energy demands are tabulated in Table-3.3.3.

3.3.4 Adopted Demand Forecast

Three forecasts of the energy requirement, i.e. the forecasts made by the global demand forecast method, sectoral demand forecast method and the JICA Team, are graphically shown in Fig.-3.3.2 for comparison. As seen in the Figure, it is understood that there is no significant difference among the three forecasts, because an approximate concurrence in the energy requirements is seen in the later stage of the decade. Especially in 1989/90 when the Sapt Gandaki Project is to be put into service, the results by three different approaches have nearly coincided, and it is judged that the energy demand forecast in the later stage of the decade is reasonable.

For the purpose of the feasibility study of the Sapt Gandaki Project, it is determined to adopt the energy demand forecast by the global demand forecast method (shown with a thick line in Fig.-3.3.2), which resulted in relatively lower figures.

The peak power demand forecast is derived from the projected energy requirement by assuming the future load factor. In Nepal, there was no particular increase of load factor during the past ten years indicating the annual load factor of around 41 to 42% (although the load factor in 1978/79 indicated an abrupt improvement of 46.2%, it is due to the limitation of power supply capacity in the year). With such past trend in consideration, the annual load factor was assumed to gradually increase from 42% in 1977/78 to 45% in 1999/2000.

The peak power demand forecast worked out is shown in Fig.-3.3.1. The forecast shown in thick line in Fig.-3.3.1, which was derived from the energy demand projected by the global method, is adopted for the feasibility study of the Sapt Gandaki Project.

3.4 Expansion Schedule

3.4.1 Power Generating Facilities

By the addition of the installed capacity of Gandaki (15 MW) in 1980 and Hetauda diesel plant (10 MW) in 1981, the total installed capacity in the Nepal Power System has prominently increased recently. Kulekhani No.1 (60 MW) just commenced its power operation in the beginning of 1982, and thereby, the total peaking capacity has reached 123.2 MW in the dry season. This peaking capacity exceeds the present peak power demand estimated at about 70 MW and the power supply condition has been much improved.

However, the power demand in Nepal is projected to indicate a rapid increase as seen in Fig.-3.3.1. The peak power demand in the interconnected system is projected to increase up to 113 MW in 1984/85, 286 MW in 1989/90 and 479 MW in 1994/95. Thus, the peak power demand will reach the power supply capacity of 123.2 MW obtained by the addition of Kulekhani No.1 in 1984/85.

In order to meet the power demand after that, HMG planned to reinforce the power supply capacity as follows;

- 132 kV Bharatpur - Pokhara transmission line of 86 km in length to be constructed in 1982/83. Thus, Pokhara hydroelectric power station (1.0 MW) will be incorporated into the system.
- Intake of Trisuli hydroelectric power station to be rehabilitated by 1982/83, intending to increase its peaking capacity from 18 MW to 20 MW.
- Devighat hydroelectric power station (14.1 MW) to be completed in 1984/85.
- Kulekhani No.2 hydroelectric power station (32 MW) to be completed in 1986/87.
- Marsyangdi hydroelectric power station (66 MW) to be completed in 1986/87.

With the above reinforcement, the total peak power supply capacity will be about 238 MW which can meet the power demand up to 1988/89. To response to the subsequent power demand increase, the necessity of developing new projects is keenly felt. HMG took up the Sapt Gandaki Project, Mulghat Project, Kankai Project or Kali Gandaki Project and so on to subsequently reinforce the supply capacity, for which the feasibility study is being conducted.

The mentioned HMG's expansion plan of the power generating facilities and peaking power supply capacity to be acquired are as tabulated in Table-3.4.1. It is also shown graphically in comparison with the peak power demand in Fig.-3.4.1.

3.4.2 Transmission Lines

The expansion plan of the power transmission system in addition to the existing system as described in the preceding section 3.2.3 is as follows;

A single circuit of 132 kV transmission line is constructed from the Gandaki Power Station to Hetauda through Bharatpur, to send power to the load center in the Kathmandu Valley. The 132 kV system is connected to the 66 kV system by 132 kV/66 kV interconnecting transformers at Hetauda substation.

Extending the above 132 kV system, it was planned to establish 132 kV trunk line system in Central Nepal with extension of interconnection lines to Biratnagar in Eastern Nepal and to Nepalganj in Far Western Nepal. Under the master plan for the 132 kV system, the following lines are under construction or planned to be constructed keeping pace with the development of the respective power plants.

Marsyangdi	-	Kathmandu		1 cct
"	-	Bharatpur		1 cct
Dumkibas	-	Butwal		1 cct (2 cct in future)
Butwal	-	Nepalganj		2 cct
Hetauda	-	Janakpur	- Biratnagar	2 cct

Under the Kulekhani No.2 Project, one circuit of 132 kV line supported on double circuit steel towers is planned to be constructed between Hetauda and Kathmandu (Siuchatar).

Considering the above-mentioned system configuration, it is proposed to connect the Sapt Gandaki Power Station to the 132 kV power system by the construction of the following three lines.

(1) Double circuit line, direct to Hetauda

(2) Single circuit line to Bharatpur

(3) Single circuit line to Dumkibas
(Double circuit in future)

(4) Additional one circuit line from Dumkibas to Butwal on the existing towers, which is designed for double circuit but carrying only one circuit conductors at present.

Most of the power generated by the Sapt Gandaki power station will be sent to Hetauda to be delivered to load centers in the Kathmandu Valley and East Nepal.

The details of the line sections to be constructed under this Project is stated in Section 6.7.

Table-3.2.1: EXISTING INSTALLED CAPACITY IN NEPAL AS OF 1981

Location	Type	Ownership	Installed Capacity (MW)
Eastern Region:			
Ilam	Diesel	NEC	0.200
Bhadrapur	"	"	0.346
Dhankuta	Hydro	"	0.240
Biratnagar	Diesel	"	2.934
"	"	Private	2.579
"	Steam	"	1.400
	Sub-total:		7.699
Central Region:			
Godawari	Hydro	Agril. Dept.	0.030
Janakpur	Diesel	NEC	0.032
Bharatpur	"	"	0.600
Sunkosi	Hydro	"	10.050
Trisuli	"	"	21.000
Panauti	"	"	2.400
Sundarijal	"	"	0.600
Pharping	"	"	0.400
Patan	Diesel	"	1.490
Kathmandu	"	"	1.728
Hetauda	"	"	14.470
Various	Steam	Private	2.400
	Sub-total:		55.200

Location	Type	Ownership	Installed Capacity (MW)
Western Region:			
Pokhara	Hydro	NEC	1.000
"	Diesel	"	1.068
Tansen	"	"	0.224
Bhairawa	"	"	0.500
Taulihawa	"	"	0.050
Bahadurgunj	"	"	0.025
Krishnanagar	"	"	0.112
Gandaki	Hydro	GOI	15.000
Butwal	"	Butwal Power Co.	1.280
"	Diesel	"	0.225
Various	"	Private	0.330
"	Steam	"	0.750
	Sub-total:		20.564
Far Western Region:			
Chorahi	Diesel	ED	0.050
Tulsipur	"	"	0.075
Surkhet	Hydro	"	0.345
"	Diesel	"	0.020
Nepalgunj	"	"	0.528
Dhangadhi	"	"	0.025
Mahendrangar	"	"	0.025
Various	"	Private	0.534
	Sub-total:		1.602
	Grand total:		85.065

Table-3.2.2: EXISTING INSTALLED CAPACITY AND AVAILABLE OUTPUT IN DRY SEASON AS OF 1981

(Unit: MW)

Region	Hydro P/S	Diesel P/S	Steam P/S	Total	Available Output in Dry Season
Eastern Reg.	0.240	6.059	1.40	7.699	
Central Reg.	34.480	18.320	2.40	55.200	
Western Reg.	17.280	2.534	0.75	20.564	
Far Western Reg.	0.345	1.257	-	1.602	
Total:	52.345	28.170	4.55	85.065	63.202*

*: Reference is made to Table-3.2.3.

Table-3.2.3: MONTHLY POWER OUTPUT OF EXISTING POWER STATIONS IN NEPAL

Power Stations	Installed Capacity (MW)	Month											
		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
- Hydro. P/S													
Sundarijar	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Pharping	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Panauti	2.40	2.24	2.16	2.10	2.00	2.09	2.40	2.40	2.40	2.40	2.40	2.40	2.36
Sunkosi	10.05	6.07	5.13	5.03	6.04	8.90	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Trusuli	21.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
Tinau (Butwal)	1.28	1.00	1.06	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Pokhara (Phewa)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Gandaki	15.00	11.20	6.87	6.71	6.47	9.30	12.60	13.50	13.50	13.50	13.50	12.44	11.72
Others	0.615	0.492	0.492	0.492	0.492	0.615	0.615	0.615	0.615	0.615	0.615	0.492	0.492
Sub-total	52.345	41.002	35.652	35.392	36.282	42.185	46.895	47.795	47.795	47.795	47.795	46.612	45.852
- Total Diesel P/S	28.17	23.94	23.94	23.94	23.94	23.94	23.94	23.94	23.94	23.94	23.94	23.94	23.94
- Total Steam P/S	4.55	3.87	3.87	3.87	3.87	3.87	3.87	3.87	3.87	3.87	3.87	3.87	3.87
Grand Total	85.065	68.812	63.462	63.202	64.092	70.000	74.705	75.605	75.605	75.605	75.605	74.422	73.622

Note: Capacity utilization of diesel and steam power plants is assumed as 85% of the installed capacity.

Table-3.2.4: RECORD OF POWER AND ENERGY SUPPLY IN NEPAL

	Energy Supply								Available Energy			Max. Demand		Yearly
Year	Domes-tic	Indust-rial	Comm-ercial	Street Light & Others	Total Utilized Energy	Loss	Total Supplied Energy	Yearly Rate of Increase	Gene-rated	Impor-ted	Expor-ted	Power	Rate of In-crease	Load Factor
	MWH	MWH	MWH	MWH	MWH	MWH	MWH	%	MWH	MWH	MWH	kW	%	%
1970/71	24,866	8,732	4,599	2,713	40,910	19,139	60,049	-	60,049	-	-	15,520	-	44.2
71/72	32,918	10,714	5,143	2,816	51,591	23,350	74,941	24.8	74,941	-	-	20,100	29.5	42.6
72/73	38,775	13,908	5,962	3,024	61,669	28,414	90,083	20.2	92,021	386	2,324	24,590	22.3	41.8
73/74	47,710	15,757	6,514	3,218	73,199	33,885	107,084	18.9	109,890	896	3,702	29,810	21.2	41.0
74/75	54,090	21,397	7,897	3,816	87,200	36,995	124,195	16.0	126,020	2,796	4,621	36,165	21.3	39.2
75/76	61,787	32,128	9,173	4,173	107,261	42,965	150,226	21.0	148,162	8,004	5,940	40,245	11.3	42.6
76/77	65,768	39,036	10,405	4,382	119,591	45,789	165,380	10.1	159,638	11,858	6,116	45,580	13.3	41.4
77/78	71,348	42,751	13,068	4,488	131,655	54,724	186,579	12.7	178,586	13,763	5,970	50,630	11.1	42.0
78/79	77,221	47,827	18,020	5,895	148,963	62,998	211,961	13.7	201,426	16,695	6,160	52,360	3.4	46.2

Source: "Electric Power Statistics of Nepal, Planning Evaluation Section, ED, 1980".

Table-3.2.5: RECORD OF POWER AND ENERGY SUPPLY IN FOUR REGIONS (1)

Region	Year	Energy Supply								Available Energy			Max. Demand		Yearly Load Factor
		Domes-tic	Indust-rial	Comm-ercial	Street Light & Others	Total Utilized Energy	Loss	Total Supplied Energy	Yearly Rate of Increase	Gene-rated	Impor-ted	Expor-ted	Power	Rate of Incr-ease	
		MWH	MWH	MWH	MWH	MWH	MWH	MWH	%	MWH	MWH	MWH	kW	%	%
Eastern Region	1970/71	1,630	2,804	19	362	4,815	603	5,418	-	5,418	-	-	1,300	-	47.6
	71/72	1,849	3,489	17	315	5,670	731	6,401	18.1	6,401	-	-	1,550	19.2	47.1
	72/73	2,155	3,535	22	360	6,072	998	7,070	10.5	7,070	-	-	1,770	14.2	45.6
	73/74	2,626	4,252	21	387	7,286	1,170	8,456	19.6	8,456	-	-	2,070	16.9	46.6
	74/75	3,322	5,744	-	430	9,496	1,675	11,171	32.1	10,975	196	-	2,960	43.0	43.1
	75/76	4,080	11,091	-	504	15,675	2,890	18,565	66.2	17,834	731	-	4,400	48.6	48.2
	76/77	5,958	12,453	-	464	18,875	403	19,278	3.8	17,903	1,375	-	5,680	29.1	38.7
	77/78	6,846	11,986	-	694	19,526	2,642	22,168	15.0	20,437	1,731	-	6,830	20.2	37.1
	78/79	7,812	15,890	-	805	24,507	2,665	27,172	22.6	25,193	1,979	-	7,500	9.8	41.4
Central Region	1970/71	22,826	5,749	4,567	2,310	35,452	18,197	53,649	-	53,649	-	-	13,860	-	44.2
	71/72	30,131	6,939	5,090	2,323	44,483	22,096	66,579	24.1	66,579	-	-	17,720	27.8	42.9
	72/73	35,205	10,049	5,910	2,475	53,639	26,488	80,127	20.3	82,412	39	2,324	21,650	22.2	42.2
	73/74	42,495	10,928	6,394	2,504	62,321	31,678	93,999	17.3	97,360	341	3,702	25,970	20.0	41.3
	74/75	47,734	14,112	7,778	2,808	72,432	33,929	106,361	13.2	110,268	714	4,621	30,780	18.5	39.4
	75/76	52,888	18,631	8,951	2,411	82,881	37,745	120,626	13.4	124,865	1,701	5,940	32,560	5.8	42.3
	76/77	53,823	23,139	10,133	2,210	89,305	42,139	131,444	9.0	135,017	2,543	6,116	35,790	9.9	41.9
	77/78	56,197	26,515	12,792	1,906	97,410	49,417	146,827	11.7	150,534	2,263	5,970	39,000	9.0	43.0
	78/79	60,465	26,388	17,987	6,100	110,940	53,321	164,261	11.9	167,757	2,664	6,160	39,440	1.1	47.5

Source: "Electric Power Statistics of Nepal, Planning Evaluation Section, ED, 1980".

Table-3.2.6: RECORD OF POWER AND ENERGY SUPPLY IN FOUR REGIONS (2)

Region	Year	Energy Supply								Available Energy			Max. Demand		Yearly Load Factor
		Domes-tic	Indust-rial	Comm-ercial	Street Light & Ohters	Total Utilized Energy	Loss	Total Supplied Energy	Yearly Rate of Increase	Gene-rated	Impor-ted	Expor-ted	Power	Rate of Incr-ease	
		MWH	MWH	MWH	MWH	MWH	MWH	MWH	%	MWH	MWH	MWH	kW	%	%
Western Region	1970/71	410	179	13	41	643	339	982	-	982	-	-	360	-	31.1
	71/72	938	286	36	178	1,438	523	1,961	99.7	1,961	-	-	830	130.6	27.0
	72/73	1,256	324	31	154	1,865	882	2,647	35.0	2,459	188	-	1,050	26.5	28.8
	73/74	1,976	521	99	177	2,773	828	3,601	36.0	2,611	990	-	1,370	30.5	30.0
	74/75	2,093	962	119	414	3,588	988	4,576	27.1	3,054	1,522	-	1,700	24.1	30.7
	75/76	3,465	1,313	222	1,051	6,051	1,816	7,867	71.9	5,448	2,419	-	2,295	35.0	39.1
	76/77	4,311	1,963	272	1,455	8,001	2,008	10,009	27.2	6,131	3,878	-	2,820	22.9	40.5
	77/78	5,017	2,699	276	1,592	9,584	1,626	11,210	12.0	7,443	3,767	-	3,090	9.6	41.4
	78/79	5,515	3,644	33	1,616	10,808	3,016	13,824	23.3	7,960	5,864	-	3,470	12.3	45.5
Far Western Region	1970/71	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	71/72	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	72/73	159	-	-	35	194	45	239	-	80	159	-	120	-	22.7
	73/74	613	56	-	150	819	209	1,028	330.1	132	896	-	400	233.3	29.3
	74/75	941	579	-	164	1,684	403	2,087	103.0	73	2,014	-	725	81.3	32.9
	75/76	1,354	1,093	-	207	2,654	514	3,168	51.8	15	3,153	-	990	36.6	36.5
	76/77	1,676	1,481	-	253	3,410	692	4,102	29.5	40	4,062	-	1,290	30.3	36.3
	77/78	3,288	1,551	-	296	5,135	1,039	6,174	50.5	172	6,002	-	1,730	34.1	40.7
	78/79	3,429	1,905	-	374	5,708	996	6,704	8.6	516	6,188	-	1,950	12.7	39.2

Source: "Electric Power Statistics of Nepal, Planing Evaluation Section, ED, 1980".

Table-3.3.1: POWER REQUIREMENT IN WHOLE NEPAL AND INTERCONNECTED SYSTEM

Fiscal Year	Power Requirement by Region (MW)				Total (MW)	
	Central	Eastern	Western	Far Western	Whole Nepal	Interconnected System
1977/78	39.2	(6.8)	(3.1)	(1.7)	50.8	39.2
1978/79	45.1	(8.4)	(3.8)	(2.3)	59.6	45.1
1979/80	51.8	(10.5)	(4.8)	(2.9)	70.0	51.8
1980/81	59.4	(13.1)	(5.9)	(3.8)	82.2	59.4
1981/82	68.0	(16.1)	(7.3)	(4.8)	96.2	68.0
1982/83	77.6	(19.6)	3.2(5.7)	(6.0)	112.1	80.8
1983/84	88.3	(23.7)	3.8(6.9)	(7.5)	130.2	92.1
1984/85	100.2	(28.5)	12.9	(9.1)	150.7	113.1
1985/86	110.8	30.9(2.2)	15.0	(10.8)	169.7	156.7
1986/87	125.1	36.5(2.6)	17.6	9.3(3.6)	194.7	188.5
1987/88	140.9	42.7(3.0)	20.5	11.0(4.2)	222.3	215.1
1988/89	158.2	49.5(3.5)	23.9	12.8(4.9)	252.8	244.4
1989/90	177.2	61.0	27.5	20.4	286.1	286.1
1990/91	193.4	67.9	30.7	22.6	314.6	314.6
1991/92	215.4	76.8	34.7	25.3	352.2	352.2
1992/93	239.4	86.0	38.8	28.0	392.2	392.2
1993/94	265.2	95.4	43.1	30.8	434.5	434.5
1994/95	293.0	105.0	47.4	33.9	479.3	479.3
1995/96	315.8	112.9	51.0	36.4	516.1	516.1
1996/97	347.0	124.2	56.1	40.1	567.4	567.4
1997/98	380.3	136.6	61.7	44.1	622.7	622.7
1998/99	415.7	150.3	67.9	48.5	682.4	682.4
1999/2000	453.1	165.3	74.7	53.3	746.4	746.4

Note: 1. Parentheses show power demand non-interconnected to CNPS.

2. Power demand in Malangawa, Gaur and Janak-Jalesor areas are included in that of eastern Region of the above Table.

Table-3.3.2: ENERGY REQUIREMENT IN WHOLE NEPAL AND INTERCONNECTED SYSTEM

Fiscal Year	Power Requirement by Region (GWh)				Total (GWh)	
	Central	Eastern	Western	Far Western	Whole Nepal	Interconnected System
1977/78	144.2	(24.8)	(11.2)	(6.4)	186.6	144.2
1978/79	165.8	(31.0)	(14.0)	(8.3)	219.1	165.8
1979/80	190.7	(38.8)	(17.5)	(10.8)	257.8	190.7
1980/81	218.7	(48.1)	(21.7)	(13.9)	302.4	218.7
1981/82	258.2	(59.2)	(26.7)	(17.6)	361.7	250.2
1982/83	285.4	(72.2)	11.6(21.0)	(22.1)	412.3	297.0
1983/84	324.8	(87.3)	14.0(25.4)	(27.4)	478.9	338.9
1984/85	368.7	(104.8)	47.3	(33.6)	554.4	416.0
1985/86	417.4	116.5(8.2)	56.3	(40.6)	639.0	590.2
1986/87	471.2	137.4(9.8)	66.5	35.1(13.5)	733.5	710.2
1987/88	530.6	160.8(11.4)	77.7	41.4(15.9)	837.8	810.5
1988/89	595.8	186.5(13.2)	90.1	48.2(18.6)	952.6	920.8
1989/90	667.3	229.7	103.7	76.8	1,077.5	1,077.5
1990/91	745.4	261.8	118.2	87.2	1,212.6	1,212.6
1991/92	830.4	295.9	133.6	97.6	1,357.5	1,357.5
1992/93	922.6	331.4	149.6	107.9	1,511.5	1,511.5
1993/94	1,022.2	367.8	166.1	118.6	1,674.7	1,674.7
1994/95	1,129.5	404.6	182.7	130.5	1,874.3	1,847.3
1995/96	1,244.7	445.1	201.0	143.5	2,034.3	2,034.3
1996/97	1,368.0	489.6	221.0	157.9	2,236.5	2,236.5
1997/98	1,499.3	538.5	243.2	173.7	2,454.7	2,454.7
1998/99	1,638.7	592.4	267.4	191.1	2,689.6	2,689.6
1999/2000	1,786.2	651.6	294.2	210.2	2,942.2	2,942.2

Note: 1. Parentheses show energy demand non-interconnected to CNPS.

2. Energy demand in Malangawa, Gaur and Janak-Jalesor areas are included in that of Eastern Region of the above Table though they are administratively located in Central Region.

Table-3.3.3: POWER AND ENERGY DEMAND PROJECTION OF WHOLE NEPAL PROPOSED IN THE INTERIM REPORT I

Fiscal Year	Energy Requirement (GWh)	Power Requirement (MW)	Load Factor (%)
1977/78	201.17	54.24	42.3
1978/79	225.95	56.80	45.4
1979/80	254.73	64.80	44.9
1980/81	306.72	74.83	46.8
1981/82	335.23	86.17	44.4
1982/83	420.29	107.33	44.7
1983/84	511.35	126.59	46.1
1984/85	600.90	148.99	46.1
1985/86	690.00	170.81	46.1
1986/87	784.22	190.04	47.1
1987/88	870.95	211.42	47.0
1988/89	972.77	233.15	47.6
1989/90	1,076.14	260.05	47.2
1990/91	1,203.07	282.94	48.5

Table-3.3.4: SUMMARY OF ENERGY REQUIREMENT IN THE WHOLE NEPAL (SECTORAL DEMAND FORECAST)

Fiscal Year	Energy Requirement by Sector (GWh)					Total
	(1) Industrial	(2) Commercial	(3) Irrigation	(4) Domestic	(5) Street Lighting & Others	
1980/81	98.6	25.3	10.5	129.5	16.0	279.9
1981/82	115.1	28.7	15.2	142.5	17.0	318.5
1982/83	134.7	32.7	20.0	156.7	18.3	362.4
1983/84	157.4	37.3	49.9	172.2	19.5	436.3
1984/85	184.0	42.7	63.1	189.2	20.8	499.8
1985/86	223.8	48.5	82.5	207.7	22.5	585.0
1986/87	272.1	55.3	114.1	227.9	24.5	693.9
1987/88	330.8	63.1	141.4	250.0	26.7	812.0
1988/89	402.2	72.1	164.0	274.0	29.3	941.6
1989/90	488.9	82.0	183.4	300.2	32.2	1,086.7

Table-3.4.1: INSTALLATION SCHEDULE OF POWER PLANTS

Year	Project	Installed Capacity (MW)	Peaking Capacity in Dry Season (MW)	Accumulated Peaking Capacity (MW)
-				47.992
1979/80	Gandaki	15.0	6.71	54.702
80/81	Hetauda	10.0	8.50	63.202*
81/82	Kulekhani No.1	60.0	60.0	123.202
82/83	Trisuli	+3.0	2.0	125.202
84/85	Devighat	14.1	14.1	139.302
86/87	Kulekhani No.2	32.0	32.0	172.302
"	Marsyandi	66.0	66.0	238.302
89/90	Sapt Gandaki	75.0	75.0	313.302
90/91	"	75.0	75.0	388.302
92/93	"	75.0	24.0	412.302

*: Refer to Table-3.2.3.