No. 18

HIS MAJESTY'S GOVERNMENT OF NEPAL

NEPAL ELECTRICITY AUTHORITY

FINAL REPORT
OF
FEASIBILITY STUDY
ON
ARUN-3 HYDROELECTRIC POWER DEVELOPMENT PROJECT

EXECUTIVE SUMMARY

JUNE 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

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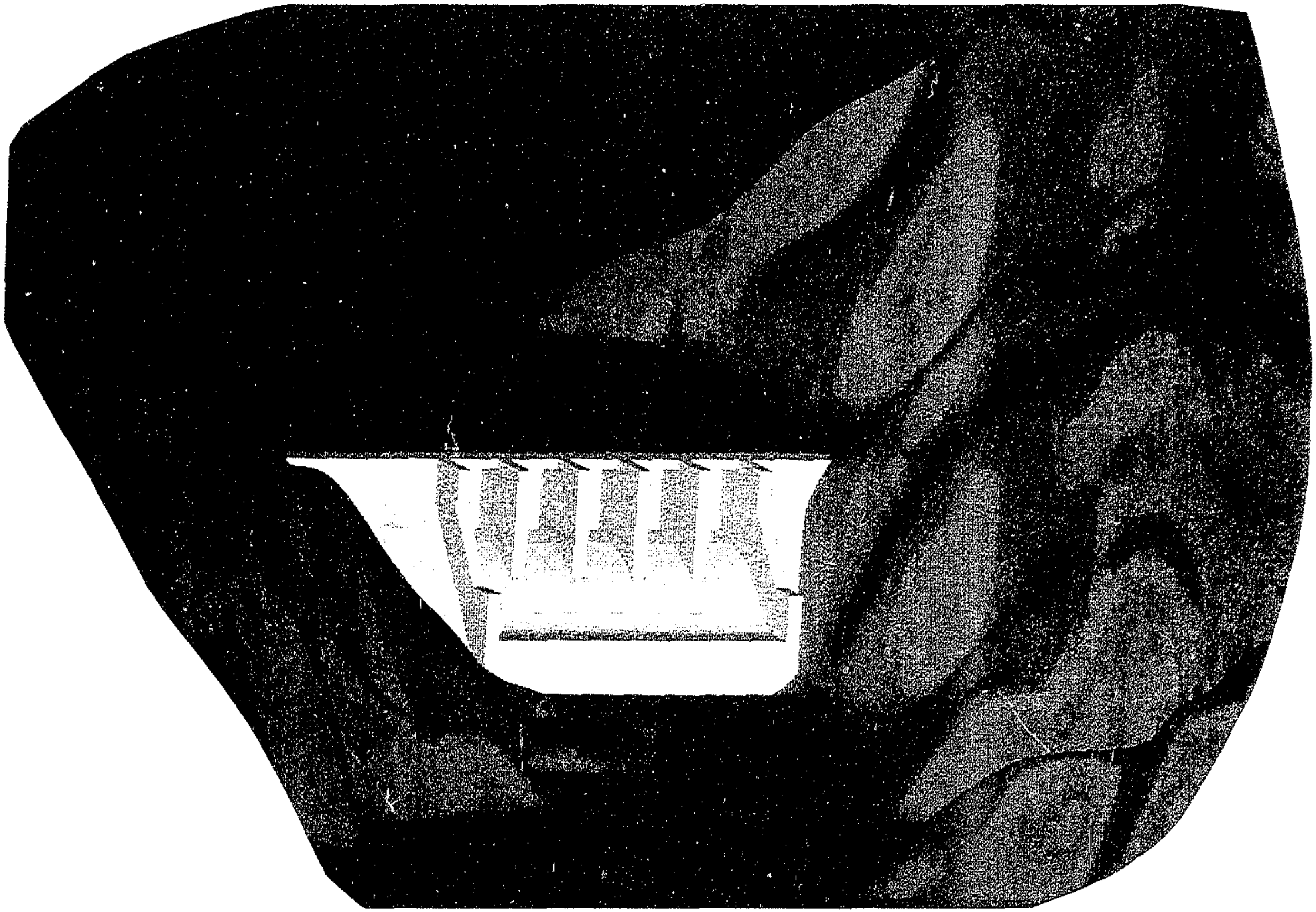
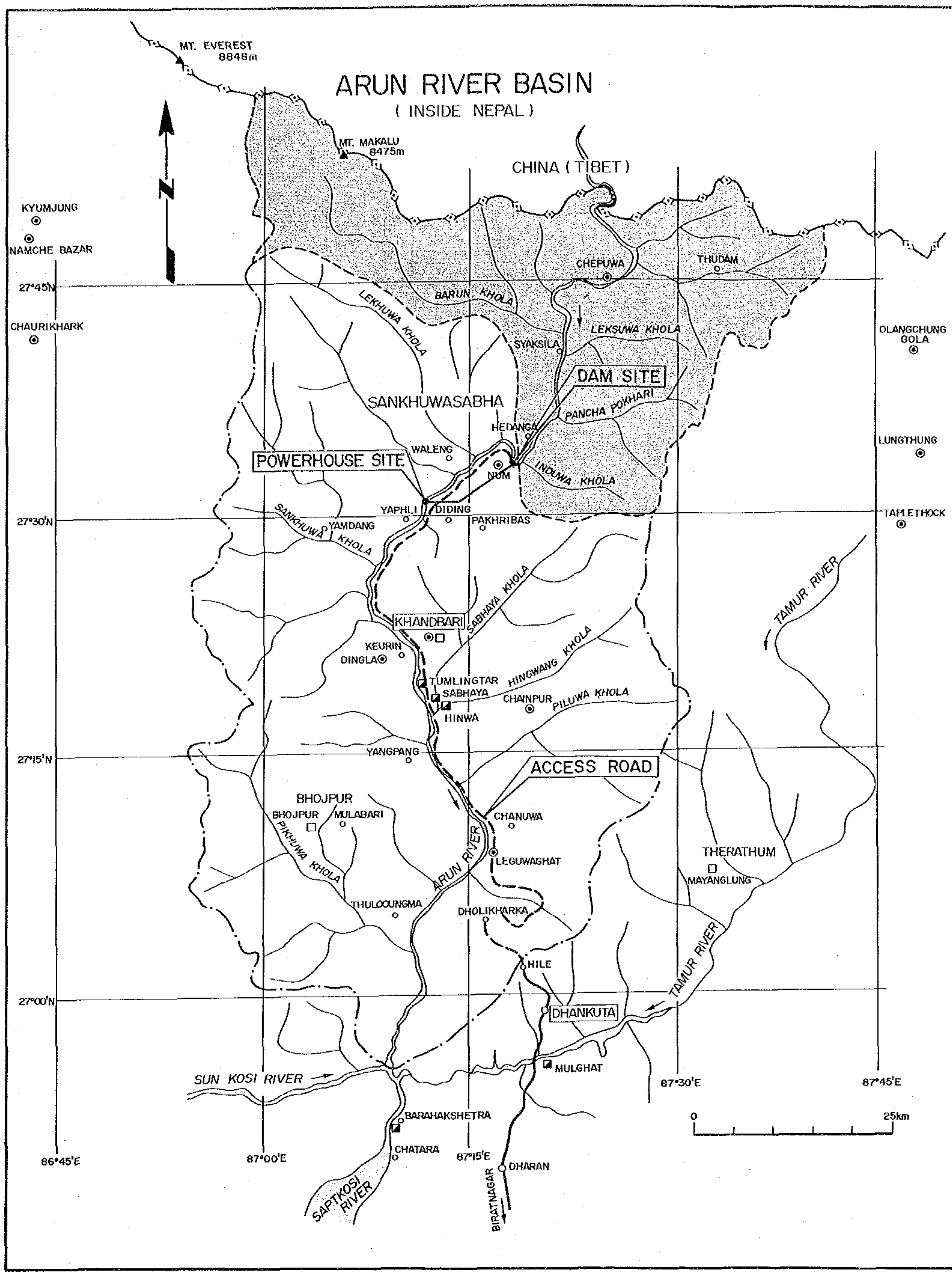


Bird eye view of Arun 3 Dam
(Drawn by Computer Aided Design System)

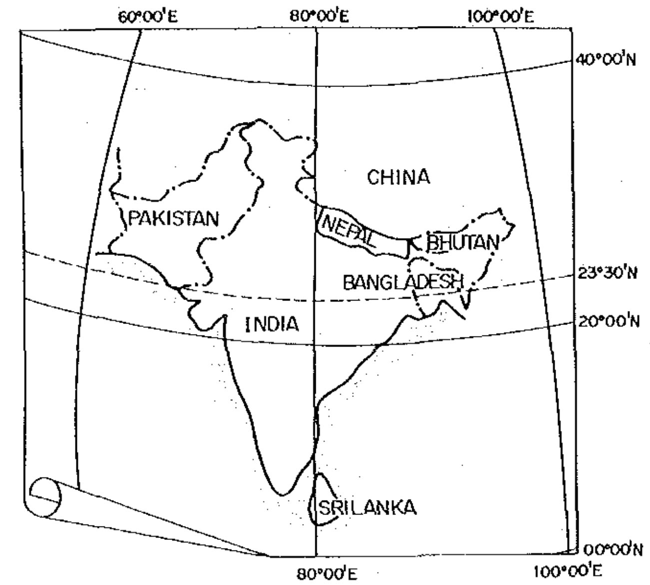
ARUN RIVER BASIN
(INSIDE NEPAL)



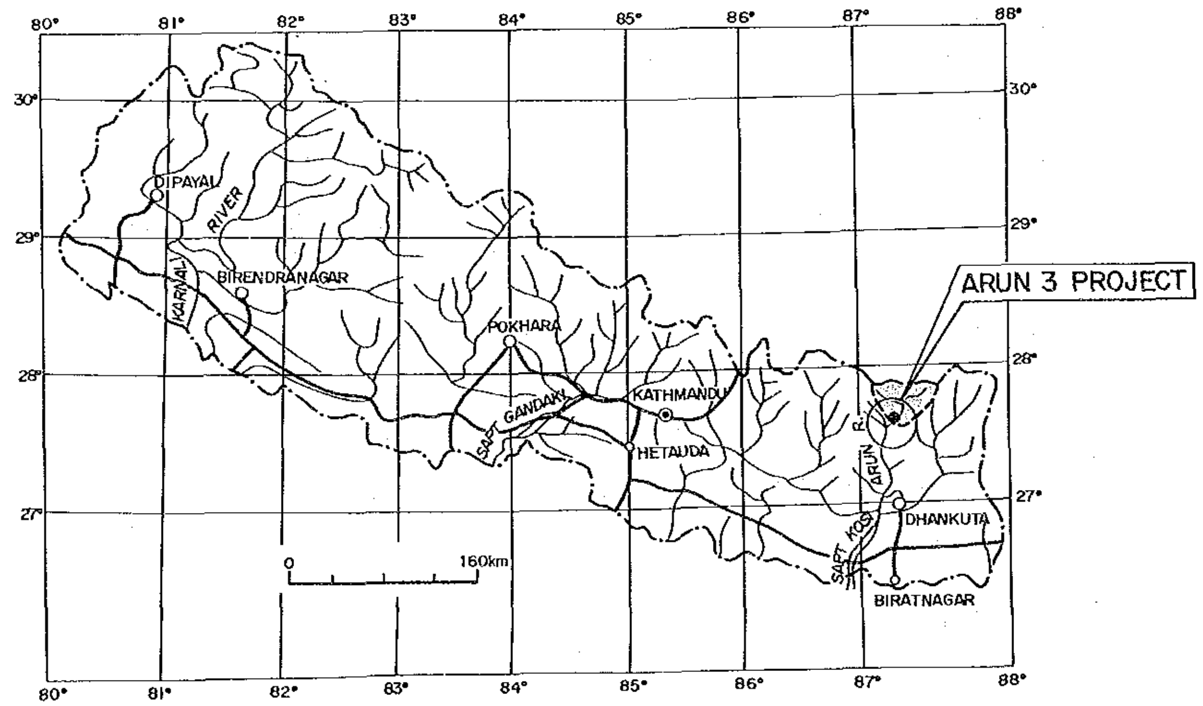
LEGEND

- PROJECT SITE
- REGIONAL HEADQUARTER
- DISTRICT HEADQUARTER
- TOWN / VILLAGE
- TRIBUTARY
- ARUN-3 DRAINAGE BASIN (INSIDE NEPAL)
- HYDROMETEOROLOGICAL STATION
- RAINFALL GAUGE STATION
- DRAINAGE BASIN
- HIGHWAY
- PROPOSED ACCESS ROAD
- ARUN RIVER BASIN

KEY PLAN



LOCATION MAP



ARUN 3 HYDRO POWER PROJECT
FEASIBILITY STUDY

KEY AND LOCATION MAP

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1. INTRODUCTION

This Final Report includes the results of the feasibility study works undertaken in the period from February 1986 to April 1987 on the Arun 3 hydroelectric power development project in Nepal as a part of technical cooperation of the Japan International Cooperation Agency (JICA).

The Arun 3 hydroelectric project was identified in the course of the "Master Plan Study on the Kosi River Water Resources Development" conducted with the JICA's technical assistance from 1983 to 1985 and was accorded the highest priority for future further study. Recognizing the attractiveness of the project, NEA immediately carried out the prefeasibility study of the project and issued the report in October 1985. The findings of this study reconfirmed the technical and economical attractiveness of the project which led to the HMG's request to the Government of Japan in May 1985 to assist in carrying out the feasibility study of the project.

The Government of Japan agreed to provide assistance and instructed JICA immediately to duly consider the above. Upon careful investigations of the status of preliminary studies performed so far by NEA and the draft report of NEA's prefeasibility study, JICA dispatched to Nepal the preliminary study team composed of five (5) experts headed by Mr. H. Suzuki (then Head of Natural Resources Division, Mining & Industrial Planning and Survey Department, JICA) in November 1985. After their arrival in Nepal, the team undertook site reconnaissance, data collection, etc. and also had discussions with NEA. The Scope of Work (S/W) and appurtenant Minutes of Meeting (M/M) for the feasibility study on the Arun 3 hydroelectric power development project were then prepared, agreed finally on their contents and signed on December 12, 1985. In order to promote the study works contemplated in the above S/W and M/M, JICA proceeded in selection of the consultant firm and awarded the works to the joint venture of the Electric Power Development Company (EPDC) and the Chuo Kaihatsu Corporation (CKC), who subsequently transferred its service contract to the Chuo Kaihatsu Corporation, International (CKCI) on January 27, 1987, through prescribed documentary examination.

The study team organized in accordance with the above consultancy contract and headed by Mr. S. Nojiri immediately started the home study of the project background and was dispatched to Nepal for approximately one month from February 23 to March 25, 1986 to carry out the first site investigation works which include data collection indispensable for further studies in various fields, site reconnaissance and drafting of topographical, geological field investigation works. The study team was again dispatched for approximately three months from May 4, 1986 to carry out the second site investigation works which include further data collection, execution of the topographical, geological field investigations previously drafted, investigation of the existing power generation, transmission line and substation facilities, and aerial reconnaissance by helicopter of probable routes of access road and transmission line for this project.

All reference data collected during the above site visits and topographical and geological data obtained by the field investigation works were brought back to Japan and have been used for the succeeding study works in Japan. The study team has intensively executed various works such as analyses of these data and other study works indicated in the Scope of Work.

2. SUMMARY OF THE STUDY

The study results carried out in the feasibility study on the Arun 3 hydroelectric power development project are summarized as below.

2.1 Field Investigation

The extensive programme of field investigation was made in order to identify the geological condition of the project area, hydrology of the river at the dam site and to prepare the topographical map of the project area. The investigation programme including a total of 558 m of core drilling and 3.99 km of seismic prospecting at the related structures, ground survey covering an area of 593,000 m^2 was conducted and 1:500 scale maps of dam and powerhouse areas were produced. 1:5,000 scale map of the project area including headrace tunnel and reservoir areas and 1:10,000 scale map of access road linking the project area with the nearest road terminal Hile were also prepared on the basis of the existing aerophotographs of 1:20,000 scale. Rock mechanical test was carried out to acertain the mechanical properties of foundation rock. A geological map in the scale of 1:500 for dam and powerhouse areas and 1:5,000 map for headrace tunnel area were also prepared.

2.2 Geology

The geological formation of the entire project area consists of gneiss and micaschist with gneiss predominating. The proposed dam is located on the competent foundation rock composed of augen gneiss. Thickness of river deposit at the dam site is confirmed to be about 13 m. The rock foundation at the desanding basin is composed of augen gneiss with a low velocity zone across the central portion of the basin. The headrace tunnels pass through metamorphic rocks (augen gneiss and mica schist) with intrusion of granite.

At the Pikhuwa site, augen gneiss is widely distributed in the area including the surge tank and penstock route sites. Intrusion of deeply weathered granite formation occurs around the surge tanks of the Kaguwa site. Augen gneiss of good quality is distributed at both the Pikhuwa and Kaguwa powerhouse sites.

2.3 Hydrology

The Arun river has a catchment area of 29,310 km^2 at the dam site about 90% of which lies in the Tibetan region. Numerous glaciers and snow packed mountains serves as the source of feeding of this river, giving the river a high firm discharge throughout the year. The flood is usually generated by the monsoon rain which occurs from late June to late September, which does not coincide with the snow melting period.

The high base flow and comparatively low flood discharge create a favorable condition for designing the structure and yielding the benefit. The long term annual average discharge is calculated as 321 m^3/s. While the diversion discharge calculated on the basis of dry flood flows is estimated at 490 m^3/s. Owing to the fact that limited information is available for the greater part of the Tibetan catchment basin and also proper hazard potential of glacier lake outburst flood (GLOF) be presumed, it is considered proper to take the value of the probable maximum flood (PMF) instead of usual flood of 1,000 year return period for the design of structures such as spillway. The PMF discharge estimated at 7,700 m^3/s is considered enough for taking care of the uncertainties in the upper reach of the river.

In connection with GLOF, past records, mechanism, glacier lake distribution in the Arun river basin, etc. were investigated. Considering that the GLOF assumed at the Barun Khola would have the largest impact on the downstream structures compared with others in the Arun river basin, simulation analysis of prescribed GLOF was examined and the maximum flood discharge was estimated at approximately 7,200 m^3/s at the dam site.

2.4 Load Forecast

In the case that the Arun 3 project be implemented in succession to the Marsyangdi project which is being under construction, its optimum scale and development program shall agree with the trend of load demand in Nepal after 1994. The latest load demand forecast prepared by NEA and released in July 1986 is adopted as the basic condition for the study. The said load demand forecast for future twenty years is made by disaggregate method for the first five years forecast and trend method for the succeeding medium to long term forecast taking into consideration the industrial, agricultural and commercial development plan of Nepal, expansion plan of transmission and substation facilities, recent economic movement, etc. The above forecast is also cross-examined macrographically based on the growth rates of GDP and energy consumption per captia, the population growth rate, etc. and found to be adequate.

2.5 Comparative Studies on Alternative Layout

Different alternative schemes of the project are studied. In particular, two dam locations: upstream and downstream of the junction of the Khoktak Khola and Num Khola with the Arun river, two power systems: one with one intake, one headrace tunnel, one surge tank and another with two intakes, two headrace tunnels and two surge tanks, desanding basin of outdoor and underground types, and powerhouse of outdoor as well as underground types at two locations of Pikhuwa and Kaguwa are analyzed. The final scheme that came out of the study on the alternative schemes includes a dam of 65 m in height, two sets of intakes, desanding basins, headrace tunnels, surge tanks, penstocks and tailrace tunnels, and a powerhouse of underground type at the Pikhuwa site which are to be developed in two stages.

2.6 Optimization Study

Upon preparation of the cost estimates based on the preliminary designs in which all topographical and geological information obtained by the field investigations are fully incorporated and also the development program meeting the domestic load growth, the optimum scheme is examined with parameters such as the maximum power discharge, intake water level corresponding to the dam height and tailwater level corresponding to the powerhouse site. The results induced therefrom for two cases; single stage development to cope with domestic power demand only and two stage development in consideration of power export also, are as tabulated below.

	1st Stage (Without Export)	1st & 2nd Stages (With Export)
Intake water level (m)	840	840
Max. power discharge (m^3/s)	80	160
Max. output (MW)	201	402

Eventually, the optimum scheme of this project is the Pikhuwa power plant (1) with intake water level at EL. 840 m, the maximum power discharge of 160 m^3/sec and the maximum output of 402 MW, (2) to be developed in two stages.

Annual generating energy for the optimum scheme are summarized below.

Scheme	Installed Capacity (MW)	Generating Energy (GWh)		
		Firm	Secondary	Total
1st stage	201	1,721.6	0	1,721.6
1st & 2nd stages	402	1,863.2	1,097.1	2,960.3

The scheduled times of starting commercial operation of respective units are as shown below.

1st stage development scheme

Unit No. 1 (67 MW)	Jun. 1994
Unit No. 2 (67 MW)	Sep. 1994
Unit No. 3 (67 MW)	Sep. 1998

2nd stage development scheme

Unit No. 4 (67 MW)	Dec. 1998
Unit No. 5 (67 MW)	Mar. 1999
Unit No. 6 (67 MW)	Jun. 1999

2.7 Feasibility Design

The feasibility designs are undertaken based on every topographical and geological information obtained by the field investigations as well as the latest technical standard. Basic project features applied to the designs are intake water level at EL. 840 m, max. power discharge of 160 m^3/s and max. output of 402 MW as well as two headrace tunnels and 6 units of electrical equipment for facilitating two stage development. Both types of powerhouse construction; outdoor and underground types at both the Pikhuwa and Kaguwa sites, are studied and the underground type powerhouse at the Pikhuwa site is adopted from technical and economical point of view. As the type of the water turbine affects greatly on the design of powerhouse structure, the economic comparison between Francis and Pelton turbines is examined and the Francis turbine is finally adopted.

The main features of the Project are as shown below.

General Project Features

(1) Reservoir

Catchment area	29,310 km^2
Annual inflow	10,123 $x10^6$ m^3
High water level	EL. 842.00
Low water level	EL. 838.00
Flood water level	EL. 844.00
Available drawdown	4.00 m
Effective storage capacity	2.0 x 10^6 m^3
Dead storage capacity	4.5 x 10^6 m^3

(2) Diversion Tunnel

Length	354.50 m
Diameter	7.00 m (horseshoe)
No. of unit	1
Maximum discharge	490 m^3/s

(3) Dam (1st & 2nd Stages)

Type	Concrete gravity
Height	65 m
Volume	160,700 m^3

(4) Spillway

Gate type	Radial Gate
No. of gates	5
Size of gate	Width 12.0 m x Height 14.5 m
Discharge capacity	7,700 m^3/s

(5) Intake (1st & 2nd Stages)

Type	Vertical tower
No. of units	2

(6) Desanding Basin (1st and 2nd Stages)

Type	Underground (continuous flushing type)
No. of chambers	2
Width	20.00 m
Height	32.00 m
Length	110.00 m

(7) Headrace Tunnel

Type	Pressure tunnel
Length	11.354 km each
Excavated Diameter	7.00 m (circular for TBM)
"	" (horseshoe for CMB)
No. of units	1 (1st stage)
	1 (2nd stage)

(8) Surge Tank

Type	Orifice
Shaft diameter	14.00 m
Height	70.00 m
No. of units	1 (1st stage)
	1 (2nd stage)

(9) Penstock

Type	Embedded steel pipe
Length	376.74 m
Diameter	5.80 m - 2.30 m
No. of unit	1 (1st stage)
	1 (2nd stage)

(10) Powerhouse (1st and 2nd Stages)

Type	Underground
Width (Cavern size)	16.00 m
Length (")	120.00 m
Height (")	41.50 m
No. of units	3 (1st stage)
	3 (2nd stage)
Turbine	Francis (69 MW)
Generator	Vertical shaft, synchronized (79 MVA)
Main transformer	Indoor, oil immersed, water cooled (79 MVA, 13.8/220 kV)

(11) Tailrace Tunnel

Type	Pressure tunnel
Diameter	3.50 m (circular) - 5.80 m (horseshoe)
Length	272.00 m
No. of units	1 (1st stage)
	1 (2nd stage)

(12) Power Generation

Max. power discharge	80 m^3/s (1st stage)	
	160 m^3/s (1st & 2nd stages)	
Gross head	302 m	
Effective head	288 m	
Max. output	201 MW (1st stage)	
	402 MW (1st & 2nd stages)	
Annual energy	firm	secondary
1st stage	1,721.6 GWh	0.0 GWh
1st & 2nd stages	1,863.2 GWh	1,097.1 GWh

(13) Access Road

Length	115 km (Hile - Leguwa Ghat - Tumlingtar - P/H - D/S)

2.8 Transmission Line and Substation

The optimum scheme of transmission and substation facilities to be developed in stages corresponding to construction sequence of the Arun 3 power station, has been made up and outline of the facilities are summarized below.

The transmission line voltage has been selected as 220 kV, however, the operational voltage is to be provisionally 132 kV before No. 3 unit will have been put in service in September, 1998.

(1) Transmission Line

Arun 3 Switchyard - Dubi Substation	220 kV, 2 cct, 120 km
Dubi Substation - Dhalkebar Switchyard	220 kV, 2 cct, 146 km
Dhalkebar Switchyard - New Kathmandu Substation	220 kV, 2 cct, 120 km

(2) Substation/Switchyard

Dubi Substation (Expansion)	70 MVA x 3 (Transformer)
Dhalkebar Switchyard (Expansion)	25 MVA x 2 (Shunt Reactor)
New Kathmandu Substation (New Construction)	100 MVA x 3 (Transformer)

2.9 Total Construction Cost

The total construction cost estimated for the Arun 3 project is as shown below. The unit prices of materials and equipment are made up for the price level at June 1986.

	Foreign currency portion (US$)	Local currency portion (US$)	Total (US$)
1st stage scheme (201 MW)	328,561,000	55,830,000	384,391,000
1st & 2nd stage schemes (402 MW)	445,872,000	72,607,000	518,479,000

2.10 Construction Schedule

The Arun 3 project is to be constructed in two stages; the 1st stage development scheme and the 2nd stage development scheme. The 1st stage scheme is to develop the maximum output of 201 MW to cope with the domestic power demand, while the 2nd stage is to develop succeedingly another 201 MW taking also power export into consideration. The construction schedule of the 1st stage development scheme is set up aiming the start of commercial operation of unit No. 1 at June 1994 and the construction of the 2nd stage development scheme is to be started 4 years after commencement of construction of the 1st stage development scheme. The critical path of the project runs along the construction works of access road and headrace tunnel. The construction periods of the major works are as shown below.

(1) Supporting Facilities

Access road	Nov. 1987 - Oct. 1989 (1st phase)
	Nov. 1989 - Oct. 1991 (2nd phase)
Preparatory works	Nov. 1989 - Oct. 1990

(2) Reservoir Storage Facilities

Diversion tunnel	Nov. 1989 - Oct. 1990
Dam & spillway	Nov. 1990 - Feb. 1994

(3) Waterway

Desanding basin	Jan. 1991 - May 1994
Headrace tunnel	Nov. 1989 - May 1994 (No. 1)
	Jan. 1994 - Sep.1998 (No. 2)

(4) Powerhouse

Civil works	Jan. 1990 - May 1994

Electromechanical equipment

1st stage

Nov. 1990 - Jun. 1994 (No. 1)

Feb. 1991 - Sep. 1994 (No. 2)

Feb. 1997 - Sep. 1998 (No. 3)

2nd stage

May 1997 - Dec. 1998 (No. 4)

Aug. 1997 - Mar. 1999 (No. 5)

Nov. 1997 - Jun. 1999 (No. 6)

(5) Transmission Line

1st stage

Schedule 1 (Jun. 1994) 132 kV provisional operation

- Arun 3 P/S - Dubi S/S (220 kV, 120 km, 2 cct towers with 2 cct stringing)
- Dubi S/S - Dhalkebar S/Y (220 kV, 146 km, 2 cct towers with 1 cct stringing)
- Dhalkebar S/Y - New Kathmandu S/S (220 kV, 120 km, 2 cct towers with 1 cct stringing)

Schedule 2 (Sep. 1998) 220 kV operation of above schedule 1

2nd stage

Schedule 3 (Dec. 1998) 220 kV operation, power export is considered.

- Dubi S/S - Dhalkebar S/Y (220 kV, 146 km, 1 cct stringing)
- Dhalkebar S/Y - New Kathmandu S/S (220 kV, 120 km, 1 cct stringing)
- Dubi S/S - Importing country (220 kV, 2 cct towers with 2 cct stringing)

(6) Substations and Switchyard

1st stage

Schedule 1 (Jun. 1994) 132 kV provisional operation

- Dubi S/S (expansion of 220 kV equipment)
- Dhalkebar S/Y (expansion of 220 kV equipment)
- New Kathmandu S/S (New installation of 132 kV, 220 kV equipment)

Schedule 2 (Sep. 1998) 220 kV operation

- Dubi S/S (expansion of 220 kV equipment)
- New Kathmandu S/S (expansion of 220 kV equipment)

2nd stage

Schedule 3 (Dec. 1998) 220 kV operation, power export is considered.

- Dubi S/S (expansion of 220 kV equipment)
- Dhalkebar S/Y (expansion of 220 kV equipment)
- New Kathmandu S/S (expansion of 220 kV equipment)

2.11 Access Road

Two proposed routes are studied; Alternative A running through the populated centers such as Chainpur, Khandbari, and Alternative B running along the Arun river with the shortest length to the dam site from the end of the nearest motable road, i.e., Hile. Geological conditions along Alternative B is better in general, however, it has disadvantage that the bridge spans crossing the tributaries are comparatively long. In consideration of the requirement to complete the access road as early as possible, Alternative B having shorter length is selected also taking into account that Alternative B will serve for the rural development by construction of feeder roads to the populated centers.

2.12 Environmental Impact

The construction of the large sized project and long access road as involved in the Arun 3 project exerts, in general, a great influence on health and welfare of the inhabitants in the related area. According to the results of environmental assessment, however, it is judged that no harmful effects on the inhabitants as well as ecology in the project area will be produced. However, a limited amount of compensation and resettlement of the inhabitants will be necessary.

2.13 Project Evaluation

Results of the project evaluation for two stage development scheme are summarised below.

(1) Energy Cost

	Receiving End		Generation End	
	1st stage (201 MW)	1st & 2nd stages (402 MW)	1st stage (201 MW)	1st & 2nd stages (402 MW)
Construction Cost (10^6 US$)	384.4	518.5	280.9	392.0
Generated Energy (GWh)	1,635.5	2,816.2	1,721.6	2,960.3
Energy Cost (US Cent/kWh)	3.1	2.4	2.1	1.7

(2) EIRR and B/C

	EIRR	B/C
1st stage scheme (201 MW)	15.5%	1.5
1st and 2nd stage schemes (402 MW)	19.5%	2.1

(3) FIRR

	FIRR
1st stage scheme (201 MW)	10.8%
1st and 2nd stage schemes (402 MW)	14.9%

3. CONCLUSION

(1) The total installed capacity of generating facilities of Nepal is 182 MW as of March, 1987. According to the load demand forecast released in July, 1986, the growth rate of future load demand is estimated at an average of 11.4 percent upto F.Y. 1993/94 and then 6.3 percent upto F.Y. 2005/ 06. In despite of rather low estimate mentioned above, it is still anticipated that the power supply capacity will come short in 1993/94, even the additional capacity of 113 MW to be generated by the projects under construction including the Marsyangdi power station (69 MW) being expected to be put in service in 1989 is taken into account. Since Nepal is endowed with abundant hydropower resources viable of economical construction, it is necessary to select the next hydropower development project urgently and proceed to construction of the same in order to avoid a situation of shortage in power supply capacity.

(2) Since the Arun 3 hydroelectric power development project is capable of producing power of big capacity at low cost owing to abundant river discharge as well as high head available at the site, it can cope with the increasing domestic power demand over long period and also contribute to the national economy by possible power export of large scale. Further, it will serve with its stable power supply capability for promotion of light industries and for breakaway from dependance on wood as the domestic energy source, thus having considerable effects on the important national energy policies.

While, it is indispensable to construct the access road over 115 km for implementation of the Arun 3 hydroelectric power development project and once this road is open for traffic service, it will produce immeasurable benefit for the local economy and welfare. Also it will provide apparently the favorable conditions for the future development of the projects existing in the upper Arun basin in series.

(3) According to the load demand forecast of Nepal, additional capacities should be installed by June 1994. The way to fully and

economically utilize the hydropower potential endowed to this project is to carry out the large scale development considering power export. As the necessary arrangements related to power export are, however, not made yet at this time on both sides of the exporting and importing countries, the most realistic plan is to develop this project in two stages; the 1st stage development scheme to cope with the domestic load demand and the 2nd stage development scheme being the extension scheme considering power export.

The Arun 3 project mainly includes a concrete dam of 65 m in height, two headrace tunnels of 11.4 km in each length, underground type powerhouse, transmission lines of 386 km in total length, etc. and its development scale is 201 MW (3 units, 67 MW each) as the 1st stage development scheme and additional 201 MW (3 units, 67 MW each) as the 2nd, totalling 402 MW. The total energy production is estimated at 1,721.6 GWh and 2,960.3 GWh after completion of the 1st and 2nd stage development schemes, respectively.

(4) The geological condition in the project area is favorable. Sound gneiss rock is widely distributed at the dam and powerhouse sites. Though the project involves desanding basin and powerhouse of underground type, there will be no particular technical problems in construction of these large sized caverns. While, mica schist distributing at the central part of headrace tunnel route is observed and it is important to identify its character for the future detailed designs and construction planning.

(5) It must be well recognized that the construction schedule aiming at the start of commercial operation of the Arun 3 power station at June 1994 is considerably tight. Especially, the precondition for meeting the above schedule is that the access road should be open for transportation of construction materials and equipment by November, 1989 as the 1st phase work. The special considerations are needed in order to start the construction of access road at the end of rainy season, i.e., November 1987. It is considered that the access road can be completed within the above-stated period (1st phase) by advanced construction of pilot road followed by simultaneous works at 4 subdivided sections.

(6) As to the construction schedule, unit No.1 of the 1st stage development scheme is to be operated in June 1994 being 4.5 years after the access road is open to traffic. Unit No.2 is also to be operated successively in order to secure the stability of power supply system, however, unit No.3 will be operated in September 1998 in line with the growth of domestic load demand.

While, construction of the 2nd stage development scheme is to be commenced 4 years (that will be sufficient for negotiation and fund arrangement) after commencement of construction of the 1st stage development at the end of 1989. The completion dates of the 1st and 2nd stage development schemes are scheduled to be September 1998 and June 1999, respectively.

In the event of stagewise development stated above, a part of facilities in the 2nd stage development scheme will be necessarily constructed simultaneously with execution of the 1st stage development. Namely, the respective structures of intake, desanding basin, powerhouse (excluding installation of equipment) and tailrace outlet are to be constructed as the unified ones to secure the safety of works and to avoid the increase in cost that will be further required when they are constructed separately.

(7) The construction cost at the price level on June 1986 is as shown below.

	Foreign currency portion (US$)	Local currency portion (US$)	Total (US$)
1st stage scheme (201 MW)	328,561,000	55,830,000	384,391,000
1st & 2nd stage schemes (402 MW)	445,872,000	72,607,000	518,479,000

(8) According to the project evaluation, economical internal rate of return (EIRR) and financial internal rate of return (FIRR) are calculated as shown below.

(a) Energy Cost

	Receiving End		Generation End	
	1st stage (201 MW)	1st & 2nd stages (402 MW)	1st stage (201 MW)	1st & 2nd stages (402 MW)
Construction Cost (10^6 US$)	384.4	518.5	280.9	392.0
Generated Energy (GWh)	1,635.5	2,816.2	1,721.6	2,960.3
Energy Cost (US Cent/kWh)	3.1	2.4	2.1	1.7

(b) EIRR and B/C

	EIRR	B/C
1st stage scheme (201 MW)	15.5%	1.5
1st and 2nd stage schemes (402 MW)	19.5%	2.1

(c) FIRR

	FIRR
1st stage sceme (201 MW)	10.8%
1st and 2nd tage schemes (402 MW)	14.9%

(9) The construction of the large sized project and long access road as involved in the Arun 3 project exerts, in general, a great influence on health and welfare of the inhabitants in the related area. According to the results of environmental assessment, however, it is judged that no harmful effects on the inhabitants as well as ecology in the project area will be produced. However, a limited amount of compensation and resettlement of the inhabitants will be necessary.

(10) It is concluded that 1st stage development (201 MW) is technically and economically feasible. If the project is further developed into 2nd stage (402 MW in total), the project will become much more economically attractive.

4. RECOMMENDATIONS

(1) As Arun 3 project is found to be economically and technically attractive the proceeding with immediate implementation of the project is highly recommended.

(2) Since it is essential to strictly observe the construction schedules of access road and headrace tunnel (which are on the critical pass) in order to start the commercial operation of unit No.1 in June 1994, the related preparatory proceedings and detailed designs have to be actively promoted.

(3) In order to obtain the further detailed information that will be incorporated in the future detailed designs and construction activities, the following investigations have to be made as soon as possible.

(a) Driving of exploratory adit along work adit in headrace tunnel

Since mica schist is distributed widely in this area, further investigations are needed in order to obtain geological features at the place of tunnel route and also to obtain geotechnical information for detailed construction planning.

(b) Additional test drillings around surge tanks

In order to check the adequacy of surge tank locations and also to obtain the supplementary information for detailed designs, it is required to survey the geological conditions in more detail.

(c) Driving exploratory adit reaching powerhouse cavern

This exploratory adit is for obtaining detailed geotechnical information of rock around powerhouse and transformer caverns and the results are to be incorporated in the stability analysis of caverns as well as study on construction procedure.

(d) Other investigation works

Test drilling, seismic prospecting and topographic survey of 1/500 scale around the dam site, desanding basin, headrace tunnel, tailrace outlet, etc. are to be carried out to obtain the geological information in more detail, where deemed necessary.

(4) In order to collect the additional hydrological data to be referred to the construction planning, it is necessary to make continuous measurement of river discharge at the upstream dam gauging station. Suspended load survey at this station is also required.

Further, it will also be necessary to augment the weather observations at the existing meteorological stations in the Arun river basin to obtain weather conditions to be referred especially during construction. New construction of meteorological stations in the area upstream of the dam site is desired.

(5) To make further studies on GLOF, site reconnaissance at the glacier lake on the Barun Khola and data collection related to distribution and sizes of glacier lakes in Tibet are necessary.

(6) It is necessary to actively undertake the studies on transmission, substation and telecommunication systems, especially of those itemized below, so that the schedules of these work components will be reasonably set out in line with the construction schedule of the Arun 3 project.

(a) Transmission line route between the Dhalkebar switchyard and the New Kathmandu substation.

(b) Location of the New Kathmandu substation and connection of same with the existing substations and expansion programme of the existing power supply system.

(c) Expansion plan of 132 kV transmission line in the western region.

(d) Formation of Supervisory Control and Data Acquisition (SCADA) system of NEA's power supply facilities including the Arun 3 power station.

(e) Formation of telecommunication system including its route between the Arun 3 power station and Kathmandu.

(f) Further studies on power supply system to set up, on the premise of the development of the Arun 3 project, the optimum overall system including transmission and subtransmission networks around Kathmandu and in the western region, SCADA system and telecommunication system.

Fig. 1 Projection of Load Resources Balance (kW)

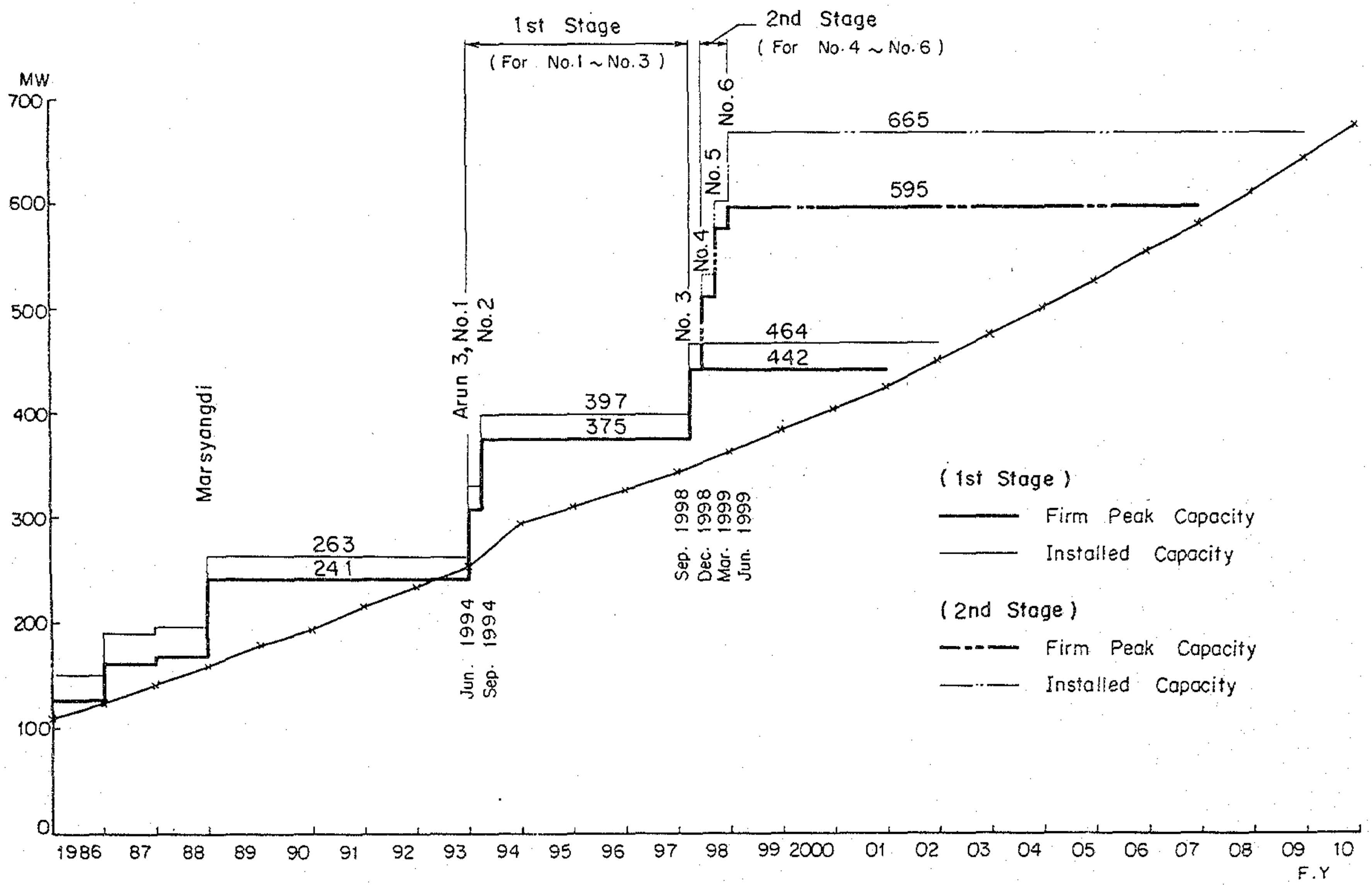
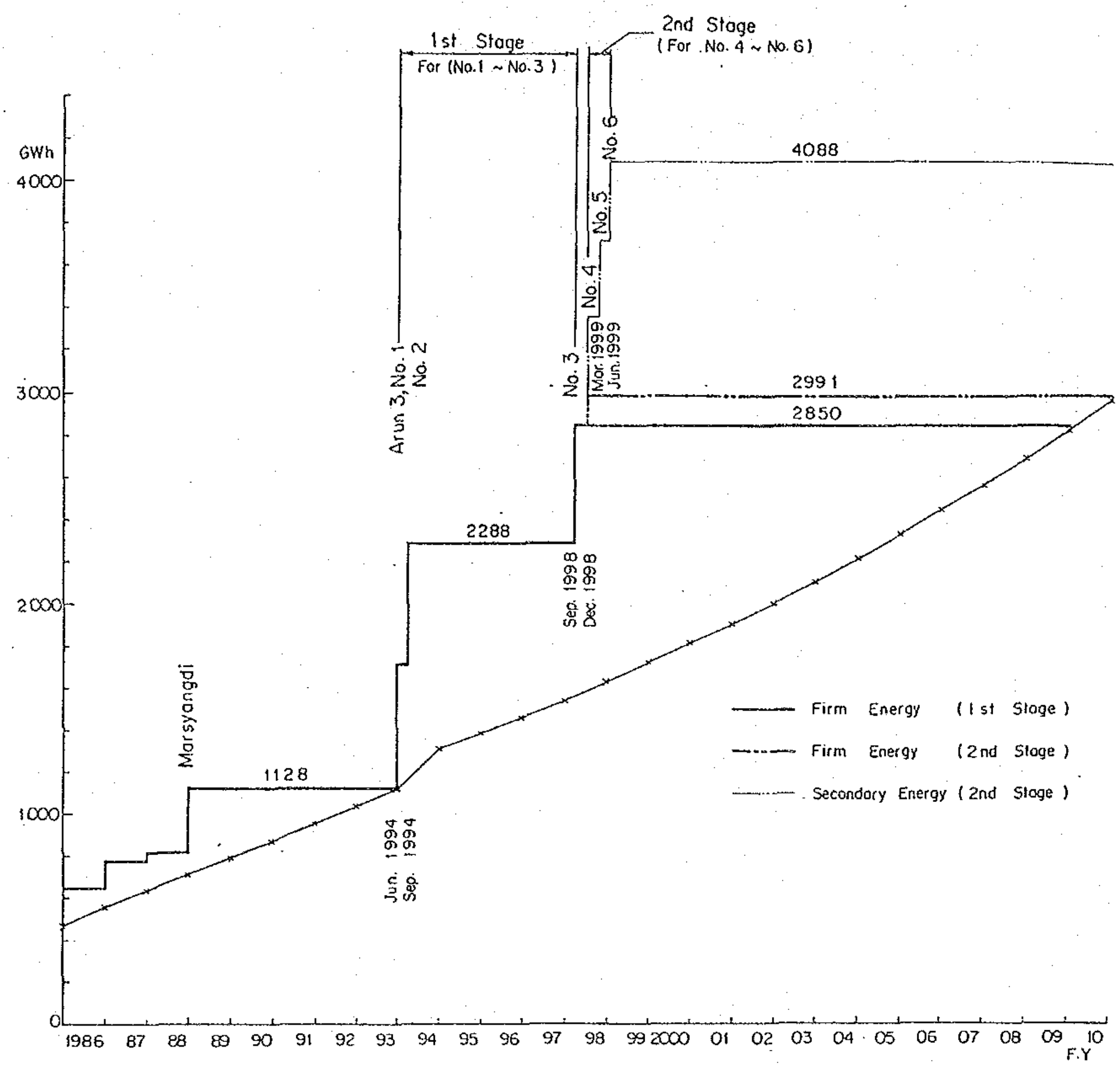
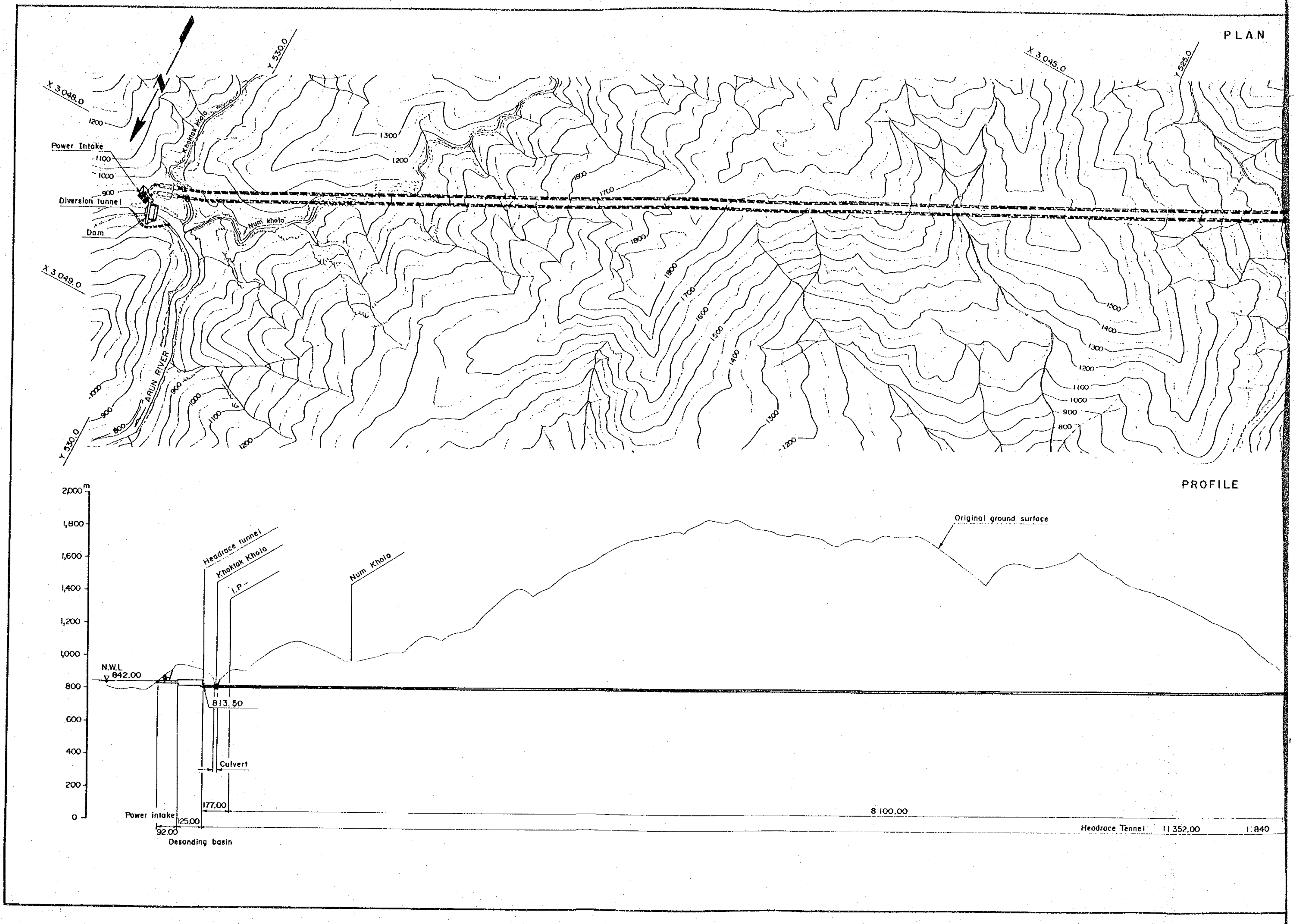
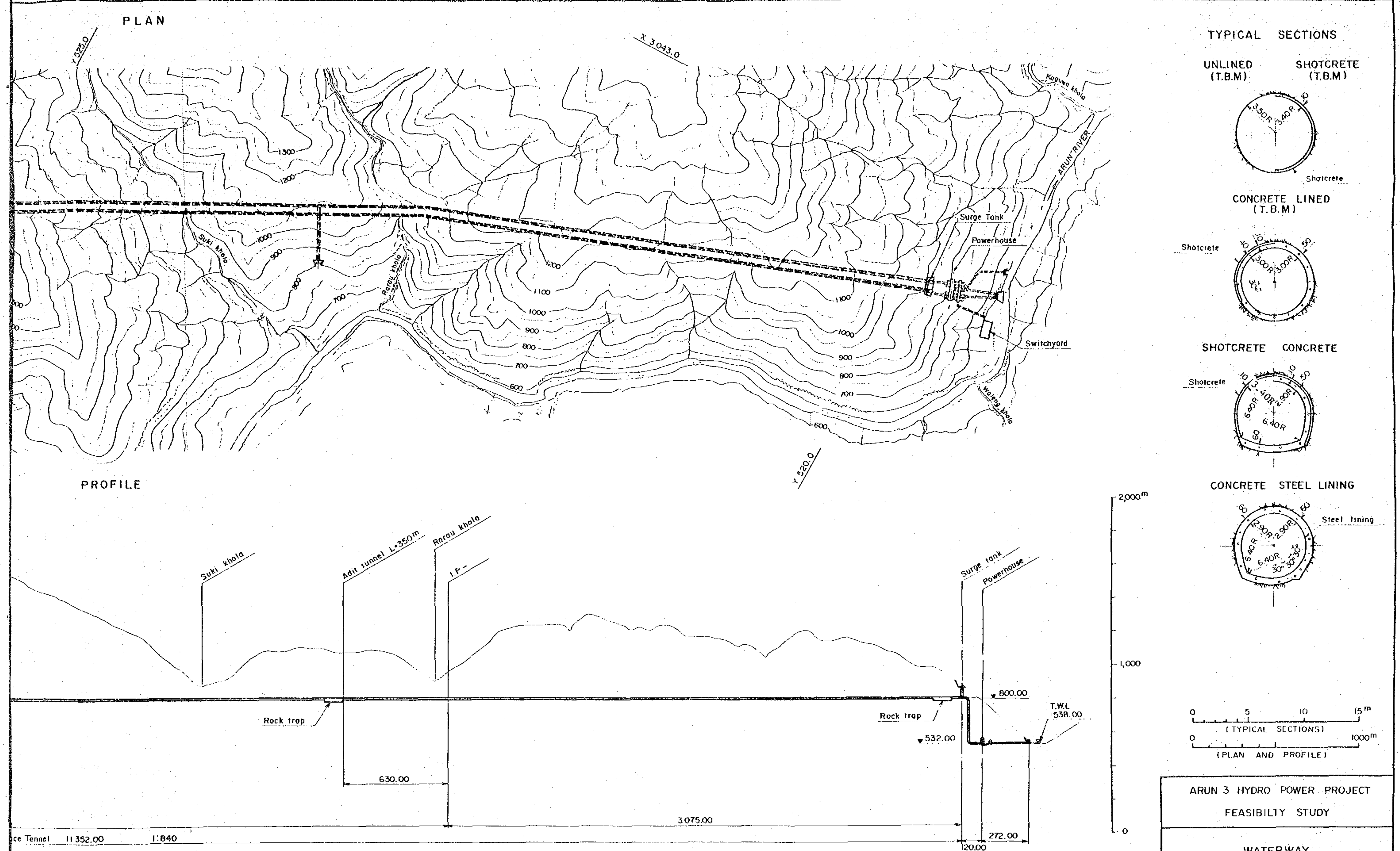


Fig. 2 Projection of Load Resources Balance (kWh)




PLAN
X 3 048.0
Y 530.0
X 3 045.0
Y 525.0
X 3 049.0
Y 530.0
Power Intake
Diversion tunnel
Dam
Khoktak Khola
Num khola
ARUN RIVER
1300
1200
1100
1000
900
800
1600
1700
1800
1500
1400
PROFILE
2,000 m
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Original ground surface
Headrace tunnel
Khoktak Khola
I.P.
Num Khola
N.W.L
842.00
813.50
Culvert
177.00
8 100.00
Power intake
125.00
92.00
Desanding basin
Headrace Tennel
11 352.00
1:840



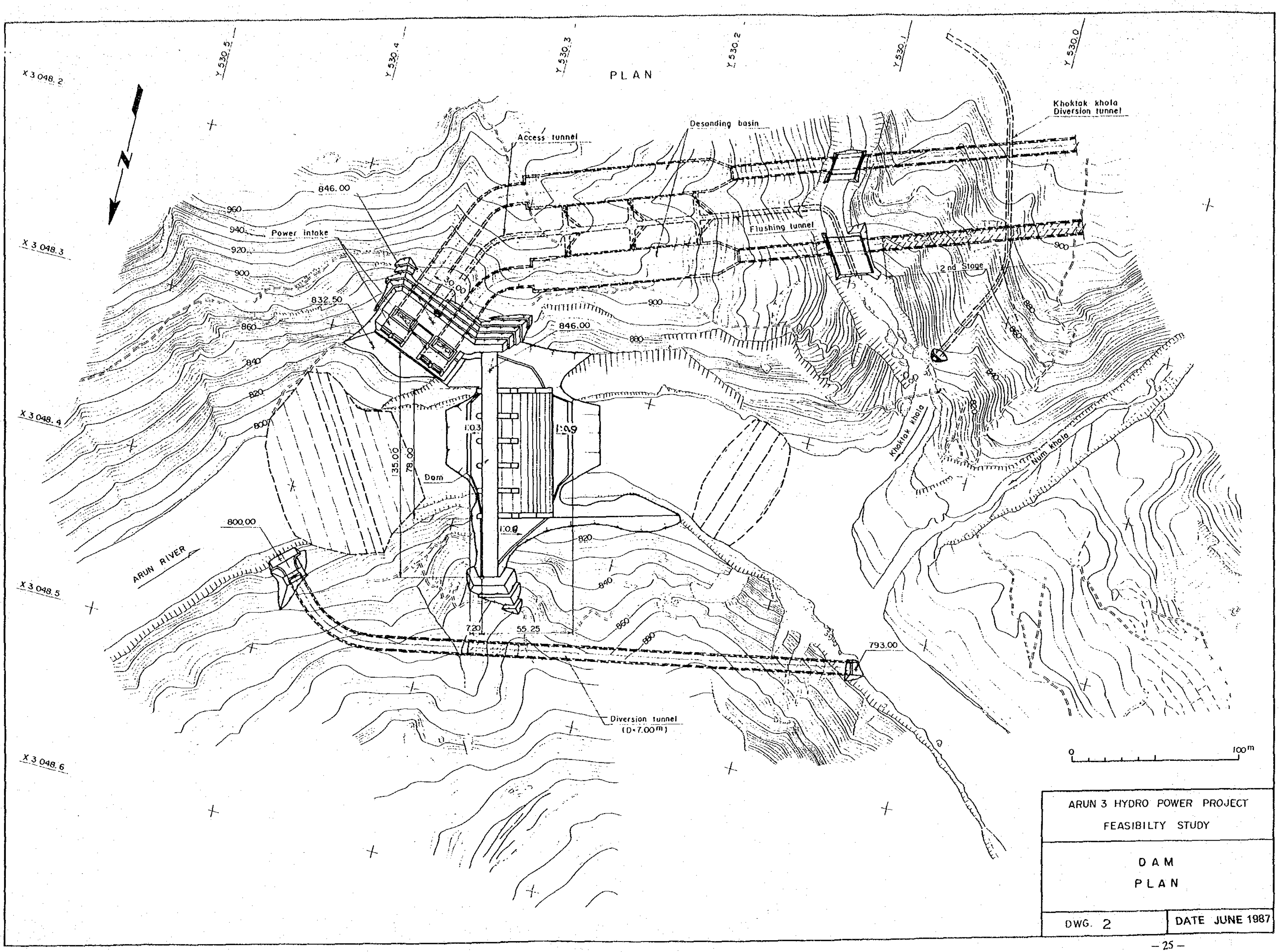
ARUN 3 HYDRO POWER PROJECT

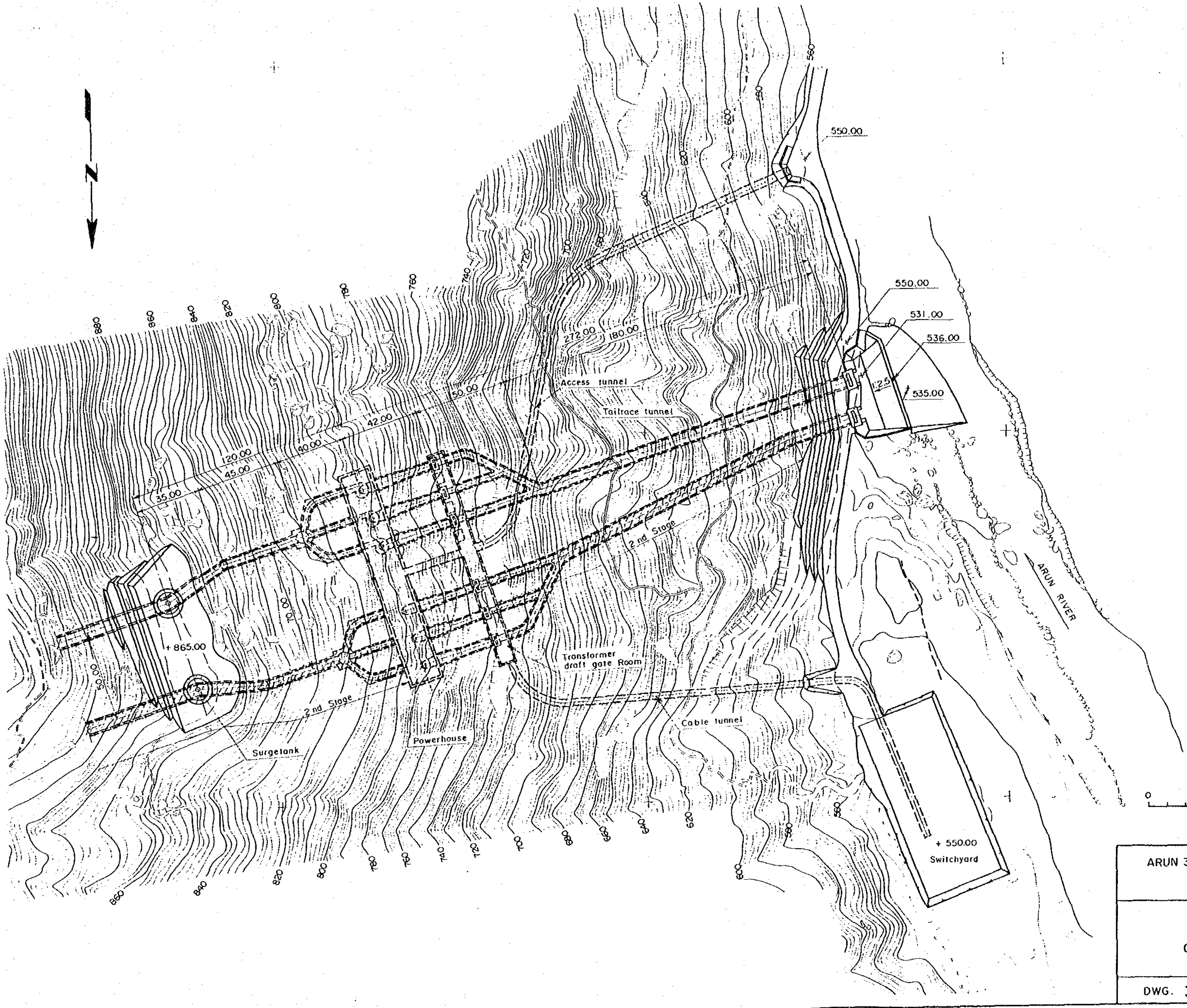
FEASIBILTY STUDY

WATERWAY

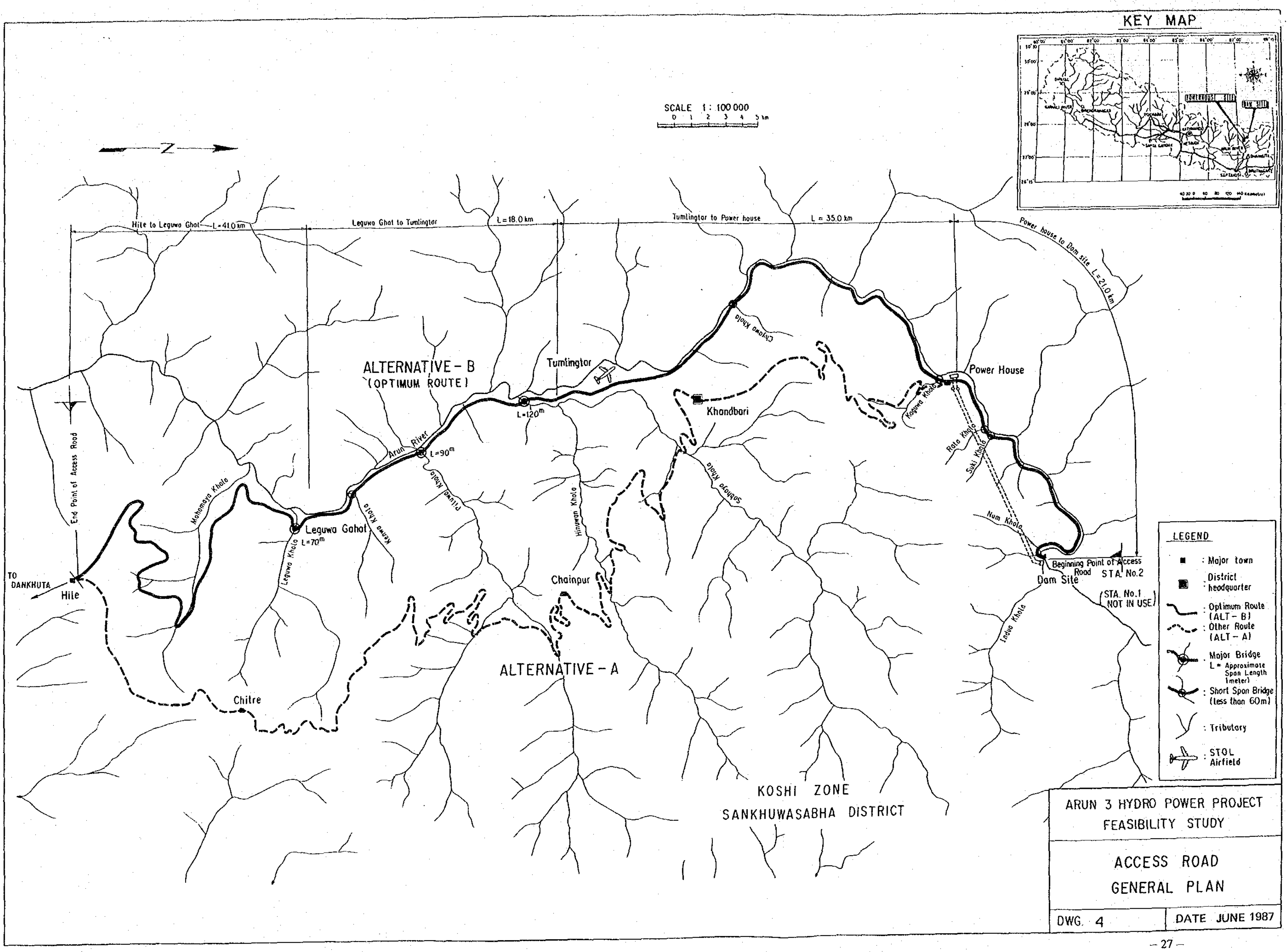
GENERAL PLAN AND PROFILE

DWG. 1 | DATE JUNE 1987


PLAN
X 3 048.2
X 3 048.3
X 3 048.4
X 3 048.5
X 3 048.6
Y 530.5
Y 530.4
Y 530.3
Y 530.2
Y 530.1
Y 530.0
N
Access tunnel
Desanding basin
Khoktak khola
Diversion tunnel
Flushing tunnel
2 nd Stage
Power intake
846.00
832.50
846.00
800.00
793.00
Dam
ARUN RIVER
Khoktak khola
Num khola
Diversion tunnel
(D=7.00m)
135.00
78.00
7.20
55.25
0
100m
ARUN 3 HYDRO POWER PROJECT
FEASIBILTY STUDY
DAM
PLAN
DWG. 2
DATE JUNE 1987



ARUN 3 HYDRO POWER PROJECT	
FEASIBILTY STUDY	
POWERHOUSE GENERAL PLAN	
DWG. 3	DATE JUNE 1987


KEY MAP
SCALE 1 : 100 000
0 1 2 3 4 5 km
Z
Hile to Leguwa Ghat L = 41.0 km
Leguwa Ghat to Tumlingtar L = 18.0 km
Tumlingtar to Power house L = 35.0 km
Power house to Dam site L = 21.0 km
ALTERNATIVE - B
(OPTIMUM ROUTE)
Tumlingtar
Power House
Khandbari
Chiyawa Khola
Kogawa Khola
Rata Khola
Suki Khola
Num Khola
Sabhaya Khola
Hinuwan Khola
Piluwa Khola
Kasuwa Khola
Leguwa Khola
Mahamaya Khola
Induwa Khola
Arun River
L = 120m
L = 90m
L = 70m
Leguwa Gahat
End Point of Access Road
TO DANKHUTA
Hile
Chainpur
Chitre
ALTERNATIVE - A
Beginning Point of Access Road STA. No.2
Dam Site
(STA. No.1 NOT IN USE)
KOSHI ZONE
SANKHUWASABHA DISTRICT
LEGEND
: Major town
: District headquarter
: Optimum Route (ALT - B)
: Other Route (ALT - A)
: Major Bridge L = Approximate Span Length (meter)
: Short Span Bridge (less than 60m)
: Tributary
: STOL Airfield
ARUN 3 HYDRO POWER PROJECT
FEASIBILITY STUDY
ACCESS ROAD
GENERAL PLAN
DWG. 4
DATE JUNE 1987

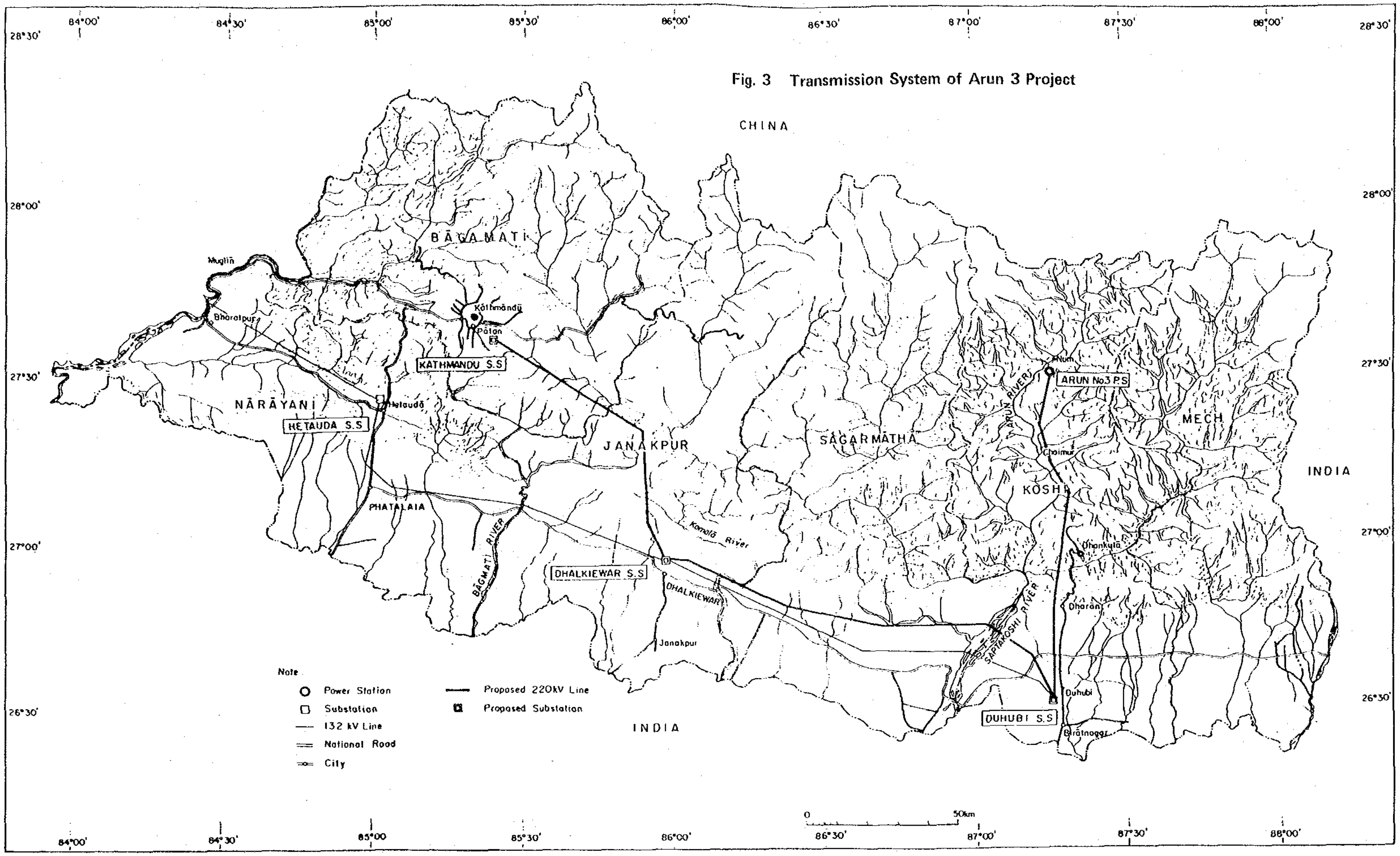


Fig. 3 Transmission System of Arun 3 Project

Fig. 4 Construction Schedule (1st & 2nd Stages)

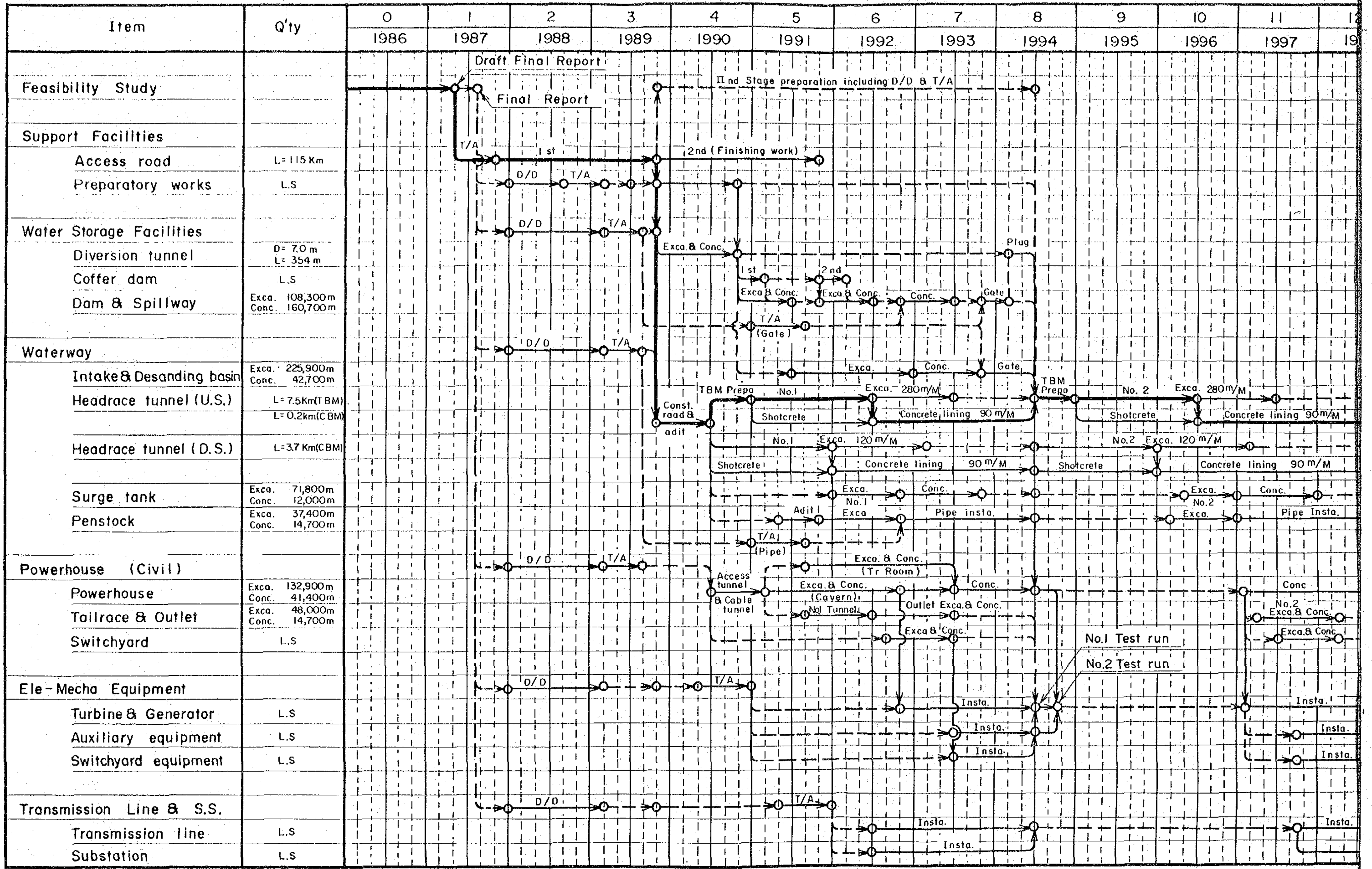
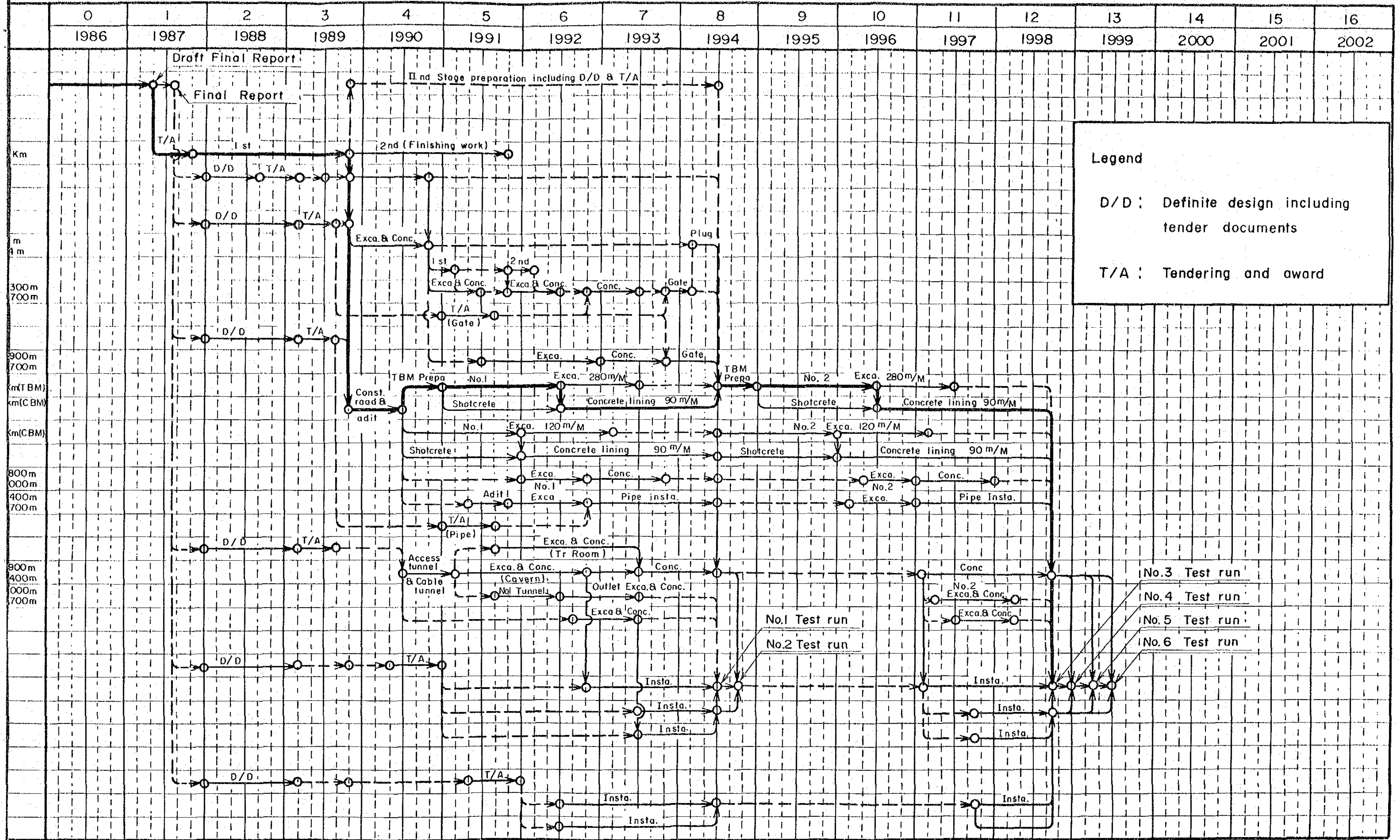


Fig. 4 Construction Schedule (1st & 2nd Stages)



JICA