ELECTRICITY GENERATING AUTHORITY OF THAILAND
KINGDOM OF THAILAND

RECONNAISSANCE REPORT
UPPER QUAE YAI HYDRO-ELECTRIC PROJECT

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การไฟฟ้าฝ่ายผลิตแห่งประเทศไทย

NOVEMBER 1973

Overseas Technical Cooperation Agency
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Preface

The Government of Japan, in response to the request of the Government of the Kingdom of Thailand, entrusted the Overseas Technical Cooperation Agency with a study on the Hydro-electric Development Project in Upper Quae Yai, Thailand.

Being fully aware of the importance of the power development in the socio-economic aspects of the country, the agency dispatched a survey team comprising five technical experts, headed by Mr. Tsutomu Nishida, senior engineer of the Electric Power Development Co., Ltd. from Feb. 1973 to Thailand.

Thanks to the kind cooperation of the government of Thailand and Electricity Generating Authority of Thailand, the study including the field investigation and data collection on Huai Nam Chon Project and Huai Khlong Ngu Project located upper stream of Ban Chao Nen hydro-electric power plant which is now under preparation, has been carried out for a period of 18 days from February, 6, 1973.

After returning Japan, the team, by virtue of cooperation with the experts of the E. P. D. C., made a comprehensive study on the results of the field investigation, compiled data and information, and thus, this reconnaissance study report has been completed for presentation here.

Nothing would be more gratifying to our agency than if this report could be of any help for the power development in Thailand, also for promoting closer relationships as well as economic interchange between Thailand and Japan.

In closing, I, on behalf of the O. T. C. A., would like to take this opportunity to express my sincere gratitude to the officials of the government of Thailand and Electricity Generating Authority of Thailand for the wholehearted cooperation and assistance extended to us during the time of the team's study in Thailand.

October 1973.

Keiichi Tatsuke,
Director General
Overseas Technical Cooperation Agency

LETTER OF TRANSMITTAL

Mr. Keiichi Tatsuke, Director General
Overseas Technical Cooperation Agency
Tokyo, Japan

Dear Sir:

Submitted herewith is a reconnaissance report on the Upper Quae Yai Hydroelectric Development Project in the Kingdom of Thailand.

The Survey Mission, in a joint effort with the Electricity Generating Authority of Thailand, carried out reconnaissance of the sites of the Project and investigation of related areas, collected data and information on hydrology, topography, geology, demand forecast and start-up plans, while exchanging opinions on the Project with engineers of the Authority.

After returning to Japan, the Survey Mission with the cooperation of the engineering staff of the Electric Power Development Co., Ltd. prepared this Report based on the data and information gathered in Thailand.

The Upper Quae Yai Hydroelectric Development Project consists of the 600-MW Huai Nam Chon Project (conventional type) located approximately 90 km upstream of the Ban Chao Nen Hydroelectric Power Station (First Stage, 360 MW), which is on a schedule to start construction work at the beginning of 1974, and of the 1,000-MW Huai Klong Ngu Project (reversible type) also located about 40 Km upstream of the Power Station.

In this Report, a general study was made on hydrologic analysis, optimum scale of development and start-up plans for the two projects, with a conclusion that the projects are both advantageous and worth proceeding with a feasibility study.

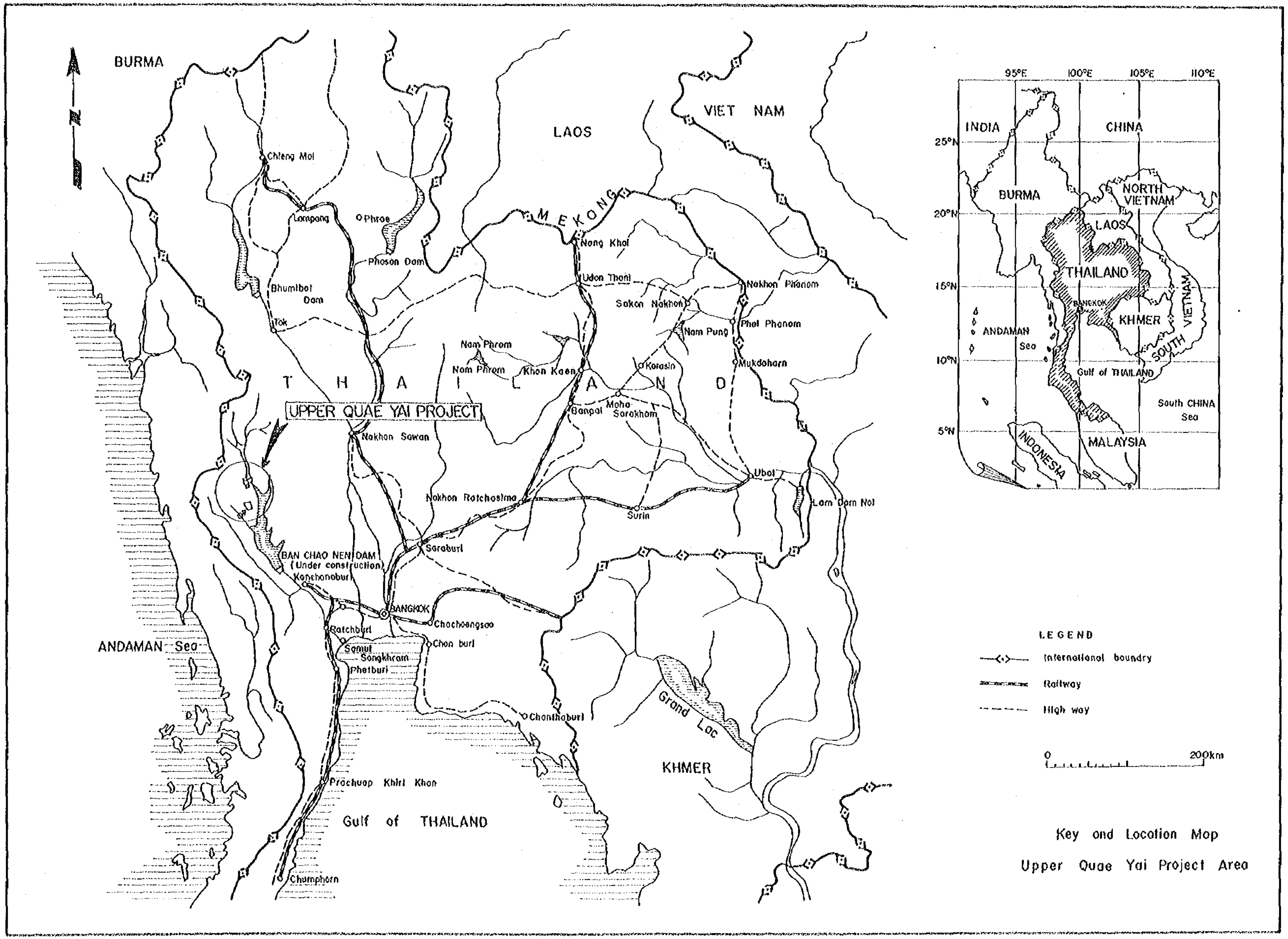
Although more detailed surveys and preparations over a long period would be necessary before the hydroelectric projects can reach the stage of actual development, it is expected that the characteristics of the two projects will be recognized in future and they will be expedited as promising projects which will contribute to the electric power supply of Thailand.

On the occasion of submitting this Report I sincerely express heartfelt gratitude to all persons concerned for their generous assistance and cooperation in performing the studies.

Yours respectfully,

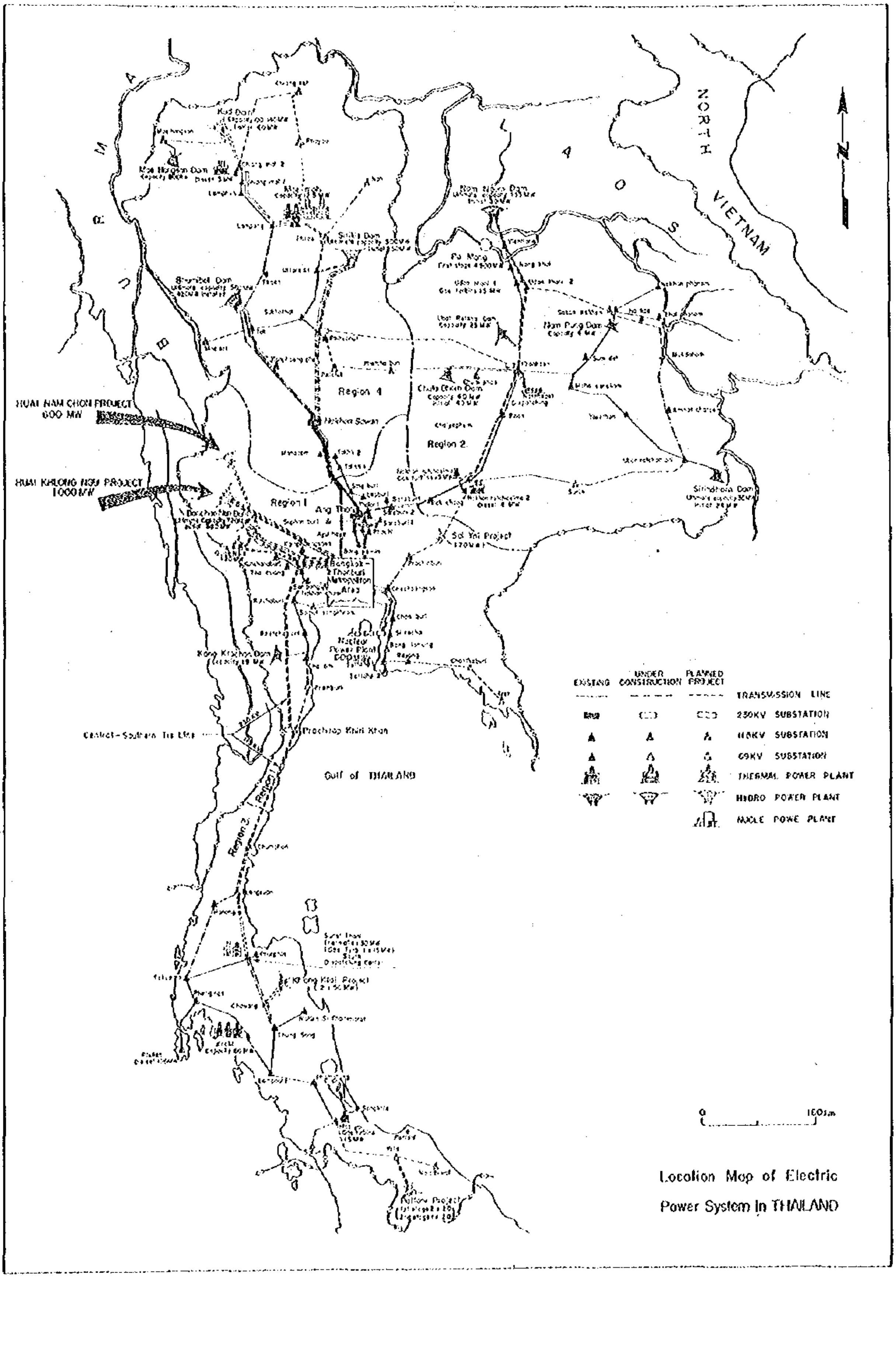
Tsutomu Nishida

Tsutomu Nishida, Chief
Upper Quae Yai Hydro-electric
Development Project
Survey Mission



Key and Location Map

Upper Quae Yai Project Area



Location Map of Electric Power System in THAILAND

Unit and Conversion

mm	: Millimeter
cm	: Centimeter
m	: Meter
km	: Kilometer
sq.mm	: Square millimeter
sq.cm	: Square centimeter
sq.m	: Square meter
sq.km	: Square kilometer
ha	: Hectare
cu.m	: Cubic meter
mg	: Milligram
gr.	: Gram
kg	: Kilogram
ton	: Metric ton
m/sec.	: Meter per second
cu.m/sec.	: Cubic meter per second
kW	: Kilowatt
kWh	: Kilowatt hour
MW	: Megawatt
kV	: Kilovolt
kVA	: Kilovolt-Ampere
MWh	: Megawatt hour
MkWh	: Millions of kWh
rpm	: Revolutions per minute
Hz.	: Hertz (cycles per second)
EL	: Height above means sea level
^{o}C	: Centigrade
p.p.m.	: Parts per million
%	: Percentage
1 ha	: 10,000 sq.m.
1 MW	: 1,000 kW

Definitions of Thai Terms

Rai	Unit of land area equal to 1,600 sq.m = 0.16 ha = 0.395 acre
Baht (฿)	Unit of currency equal to 100 Satang
Changwat	A political subdivision of the Kingdom of Thailand; the English equivalent is province.
Amphoe	A political subdivision of a province (Changwat): The English equivalent is district.
Ban	A village
Huai	A rivulet
Khlong	A stream
Khao	A mountain, a hill

CONTENTS

CHAPTER 1

INTRODUCTION

CHAPTER 1. INTRODUCTION

A) Authorization

The Electricity Generating Authority of Thailand (hereinafter called EGAT) has been contemplating numerous electric power development plans in order to cope with electric power demand which has been increasing at an extremely high rate in recent years.

The Quae Yai River is a large river with one of the greatest hydroelectric potentials in Thailand having a catchment area of approximately 14,800 sq.km. and annual runoff of approximately 6,000 million cu.m.

EGAT planned the Ban Chao Nen Project for the downstream part of the Quae Yai River as the first stage of development of the river and earnest preparations have been expedited and nearly all of these preparations have been completed to start construction work at the beginning of 1974.

To follow the Ban Chao Nen Project, EGAT has established the Upper Quae Yai Hydroelectric Development Project consisting of two projects, at Huai Klong Ngu site and the Huai Nam Chon site, with the purpose of effective utilization of the water resources of the upstream part of the Quae Yai River.

In 1972, the Government of Thailand requested the Government of Japan to carry out a preliminary survey for the Upper Quae Yai Hydroelectric Development Project. Upon receiving this request, the Government of Japan commissioned the Overseas Technical Cooperation Agency (hereinafter called OTCA) to carry out the survey.

OTCA, dispatched a Survey Mission consisting of 5 persons headed by Mr. Tsutomu Nishida of the Electric Power Development Co., Ltd. (hereinafter called EPDC) to Thailand in February 1973. The roster of the Survey Mission is given in 1-E.

B) Purpose and Scope of Report

The purpose of this Report is to examine the various development schemes for the two projects which had been already conceived by EGAT in the Upper Quae Yai Basin and to prepare the most advantageous development schemes, and upon carrying out general studies of the technical and economic aspects of the schemes, to clarify items of investigation and study required for a feasibility study which would be conducted in the future.

1) Huai Klong Ngu Project

This project is located on a tributary of the Quae Yai River 40 km north of the Ban Chao Nen site. A pumped-storage type power station will be constructed under the project utilizing the Ban Chao Nen Reservoir as the lower pondage.

2) Huai Nam Chon Project

This project is located on the main Quae Yai River 90 km north of the Ban Chao Nen site. A conventional dam and reservoir type power station will be constructed under the project taking advantage of the abundant water flow from the broad catchment area.

The scope of study of this Report covers the abovementioned two power generating schemes and the power transmission facilities proposed between the power stations and substation to be built in the Bangkok area.

C) Contents of Survey Operations

1) Field Survey

The Survey Mission conducted, from February 6 to February 23, field surveys of the project areas and related areas and gathered necessary information, while exchanging opinions and discussing on the Project with EGAT engineers. Regretfully, during the field reconnaissances, it was impossible to obtain access to the damsite of the Huai Nam Chon Project due to abnormal low water so that the Mission was obliged to limit the investigation of topographical and geological conditions to general reconnaissances by means of airplanes and helicopters provided by EGAT.

2) Works in Japan

After returning to Japan, the Survey Mission with the cooperation of EPDC prepared this Report in about 7 months from March 30 to October 16, 1973 based on the information and data gathered in Thailand. The major items of study are as follows:

a) Examination of development plan,

b) Hydrologic analysis,

c) Examination of geological conditions,

d) Load forecast and examination of start-up plans, and

e) Examination of power generation and transmission plans.

D) Basic Data

Basic data such as hydrologic data, topographical maps, geological maps, data of power supply and demand, data for cost estimate, etc., which are necessary for the study of the Projects were furnished by EGAT.

These data are as shown in the list of data attached to Appendix A.

E) Organization of Survey Mission

The Survey Mission was comprised of the following persons:

Chief	Tsutomu Nishida, Chief, Toyone Construction Section, Shintoyone Construction Office, EPDC
Member	Takashi Yoshida, Design Office, EPDC
Member	Tsuyoshi Hanada, Thermal Power Generation Section, Thermal Power Department, EPDC
Member	Jiro Inoue, Design Office, EPDC
Member	Norio Otomura, Foreign Activities Department, EPDC

(Positions of Mission members are as of February 1973)

CHAPTER 2

SUMMARY AND RECOMMENDATIONS

CHAPTER 2. SUMMARY AND RECOMMENDATIONS

A) General

In regard to the Upper Quae Yai Hydroelectric Development Scheme planned by EGAT, field reconnaissances of the Upper Quae Yai Basin and surveys of related areas were carried out, and various studies were made in Tokyo after returning to Japan based on fundamental data furnished by EGAT, and as a result, it was possible to obtain a general outlook on the basic concept of the development scheme, economic features of the scheme and the appropriate timing for start-up as described in the following chapters.

However, in establishment of the present development plan, the basic data obtained and gathered were found to be insufficient. Especially, with respect to geology, the Mission unavoidably relied only on the results of surface reconnaissance for the Huai Klong Ngu Project (reversible type) and mainly on interpretation of aerial photographs for the Huai Nam Chon Project (conventional type) since for the latter it was not possible to approach the projected damsite due to abnormally low water.

Nevertheless, from the outlook on the two projects at the present stage, it is considered that the economics of the projects are good and they are promising for development. Therefore, it is desirable as a first step to carry out a prefeasibility study to reconfirm the fundamental matters pertaining to the Projects, and as a second step to proceed with necessary preparatory work and various formalities in order to conduct a detailed feasibility study. However, there will be conceived some hopeful sites for pumped storage power station other than Huai Klong Ngu site and so the comparative studies among the sites shall be conducted before the pre-feasibility study of the Huai Klong Ngu Project.

The outlines of the two projects are given below.

B) Power Generation Development

(1) Huai Klong Ngu Project (Reversible Type)

This Project is a pumped storage power generation scheme located approximately 240 km west-northwest of Bangkok which would use Ban Chao Nen Reservoir (under construction) as the lower reservoir. A new regulating pond will be excavated as the upper reservoir, which pond is to be completely lined with asphalt, to obtain an effective head of 466 m for power generation of maximum output of 1,000 MW (250 MW x 4 units).

The electric power demand of Thailand is expected to continue to grow in the future at a rate of 10% or higher. Consequently, electric power development, both hydro and thermal, has been taken up as an urgent problem, and EGAT is planning construction of large-capacity thermal and nuclear power plants as part of the development. Therefore development of pumped storage power stations utilizing surplus nighttime power of these thermal and nuclear stations will be necessary for peak supply capability.

Since the Huai Klong Ngu Project is located at a site providing a high head rarely found in Thailand and will utilize an existing reservoir, the economics of the Project are excellent. There is an exceedingly great possibility that it will become one of the most promising site for pumped storage power station in the country.

The roughly calculated total construction cost at this time including the construction cost of related power transmission lines is 4,310 million Baht (฿4,310 per kW) and the benefit-cost ratio is 1.13.

(2) Huai Nam Chon Project (Conventional Type)

This Project is located approximately 45 km north of the Huai Klong Ngu site described above and is near the end of the Ban Chao Nen Reservoir which is under construction on the main stream of the Quae Yai River.

The essence of the Huai Nam Chon Project is to construct a rockfill dam with a height of 195 m across the Quae Yai River to build a reservoir with a high water surface level of 360 m and effective storage capacity of 2,680 million cu.m to nearly completely regulate the river flow and to generate an annual energy production of 1,158 million kWh at a maximum output of 600 MW (150 MW x 4 units).

The roughly calculated total construction cost at this time including the construction cost of related power transmission lines is 3,874 million Baht and the benefit-cost ratio is 1.20.

The Huai Nam Chon Project, as a key development of the Quae Yai River which has one of the greatest hydroelectric potentials in Thailand, is located at a site that is one of the few remaining in Thailand where large scale development is possible, and since the economics of the Project are quite good, if it should be developed in succession to the downstream Ban Chao Nen Power Station, it would play a large role in the power supply system as a leading peak supply capability.

C) Power Transmission Plan

It is assumed that the electric power generated by the two projects would be transmitted to Bangkok, the load center, and that power generated at the power stations would be transmitted as follows taking into account timing of start-up, transmission voltages presently adopted and other factors:

		Huai Klong Ngu	Huai Nam Chon
Transmission distance	:	Approx. 240 km	Approx. 226 km
Transmission voltage	:	230 kV	230 kV
Number of circuits	:	4 cct	2 cct Huai Nam Chon - Ban Chao Nen 3 cct Ban Chao Nen - Bangkok
Cycles	:	50 Hz	50 Hz
Conductor	:	ACSR 610 mm^2 (1272 MCM)	ACSR 610 mm^2 (1272 MCM)

It should be noted that transmission for the Huai Nam Chon Project is in common with the Ban Chao Nen Second Stage Project (360 MW) at the section between the Ban Chao Nen and Bangkok.

D) Demand Forecast and Timing of Development

The demand forecast for Thailand prepared by EGAT is based on the past record and real economic growth rate is assumed around 7%. According to the forecast, the annual growth rate of maximum electric power is approximately 12.4% averaged for 1971 through 1980 and approximately 8.5% averaged for 1980 through 1990, and the maximum power of 1,029 MW (actual) in 1972 is expected to increase to 2,720 MW in 1980 and 6,180 MW in 1990, while electric energy is expected to increase from the 5,711 million kWh (actual) in 1972 to 36,550 million kWh in 1990.

In order to meet this rapidly increasing power demand, EGAT has established a plan to add hydroelectric power stations centered around the Ban Chao Nen Project and large-scale thermal and nuclear power stations from 1975 to 1985, and if this plan were to be executed as scheduled, it would be desirable for the Huai Nam Chon Project (600 MW) to start operation around 1988 and the Huai Klong Ngu Project (1,000 MW) around 1994 or 1996. Since materials and equipment for construction of two projects will have to be delivered utilizing Ban Chao Nen Reservoir, and considering that completion of the Ban Chao Nen First Stage Project (360 MW) will be in 1979, the earliest start of operation of Huai Nam Chon Power Station could be around 1986 or 1987 from the standpoint of construction.

E) Recommendations

(1) Huai Klong Ngu Project

As previously stated, this Project is a promising pumped storage power generation plan and it is considered worth conducting a prefeasibility study hereafter as a first step. However, for example, as indicated in Appendix B, a promising pumped storage site can be considered to exist downstream of the Ban Chao Nen site, while it is imagined there would be other promising pumped storage sites in Thailand. Therefore, it is recommended that selection of a pumped storage site be based on detailed surveys to be executed hereafter by carrying out reconnaissance studies on the other pumped storage sites at least to the same degree as for the Huai Klong Ngu Project and by making comparisons of the sites.

(2) Huai Nam Chon Project

As previously stated, this Project is considered to be extremely promising and it is therefore recommended that a feasibility study be carried out. However, since the scheme is of an exceedingly large scale and there is allowance in time until start of development, it would be desirable for a prefeasibility study to be made as a first step to reconfirm basic matters.

It is recommended that the following be carried out for the prefeasibility study:

1) Provide a base camp and make it possible to approach the projected damsite at all times.

2) Conduct field reconnaissances of the projected damsite by experts in civil engineering and geology.

3) Compile hydrologic and meteorological data, prepare topographical maps and conduct geological surveys (see Appendix C).

CHAPTER 3

OUTLINE OF PROJECT

CHAPTER 3. OUTLINE OF PROJECT

A) Huai Klong Ngu Project

This Project is a scheme for pumped storage power generation utilizing the head of approximately 500 m between the karstic plateau running north and south on the right bank of Ban Chao Nen Reservoir and the Huai Klong Ngu River, a Quae Yai River tributary which cuts down through this plateau. In other words, a regulating pond lined completely with asphalt and having a high water surface level at 680 m and an effective storage capacity of 6 million cu.m is to be constructed on the karstic plateau of elevation of 600 to 700 m on the left bank of the Huai Klong Ngu River approximately 8 km upstream from the confluence with the Quae Yai River. This regulating pond and Ban Chao Nen Reservoir under construction are to be connected by a headrace tunnel, penstocks, powerhouse and tailraces, and utilizing the effective head of 466 m obtained, pumped storage power generation of maximum output of 1,000 MW (250 MW x 4 units) is to be carried out with maximum discharge of 258 cu.m/sec.

The construction cost per kW of this pumped storage power station including the construction cost of a related transmission line would be ฿4,310/kW. As for the economics of the Project, in case of 1,000 hours of operation annually, the surplus benefit [(B) - (C)] would be 73 million Baht (with tax on fuel) and the benefit-cost ratio [(B)/(C)] would be 1.13.

The general outline of the Project is indicated in Fig. 3-1 and Table 3-1.

B) Huai Nam Chon Project

This Project consists of building a rockfill dam with a height of 195 m on the main stream of the Quae Yai River near the end of the backwater of Ban Chao Nen Reservoir immediately upstream of the junction with the Huai Nam Chon River to provide a reservoir with high water surface level at 360 m, available drawdown of 25 m and effective storage capacity of 2,680 million cu.m to regulate the seasonal and annual fluctuation of the runoff of the Quae Yai River, and with an underground power station constructed at the left bank, power generation of maximum output of 600 MW (150 MW x 4 units) and annual energy production capability of 1,158 million kWh is to be carried out.

The economics of this power station shows surplus benefit [(B)-(C)] would be 70 million Baht (with tax on fuel) and benefit-cost ratio [(B)/(C)] would be 1.20.

The general outline of the Project is indicated in Fig. 3-2 and Table 3-2.

Table 3-1 General Description of Huai Klong Ngu Project

1. Upper Pond	
Normal High Water Surface Level	680 m
Effective Storage Capacity	6.0 million cu.m.
Available Drawdown	30 m
2. Dam	
Type	Asphalt facing rockfill dam and concrete gravity dam
Elevation of Crest	685 m
Height	60 m
Length	600 m
Volume	2,600 thousand cu.m.
3. Lower Reservoir (Ban Chao Nen Reservoir)	
Normal High Water Surface Level	180 m
Effective Storage Capacity	4,550 million cu.m.
Available Drawdown	12 m
4. Intake (outlet for Pumping)	
Type	Morning Glory Type
Number	1
5. Headrace	
Type	Circular Pressure Tunnel
Number of Line	1
Inner Diameter	7.2 m
Total length	670 m
6. Surge-tank	
Type	Orifice Chamber Type
Number	1
Riser Inner Diameter	8 m

7. Penstock

Type	Steel Lined Tunnel Type
Number of Lines	2 ~ 4
Total Length	2,660 m
Inner Diameter	5.5 m, 4.4 m, 2.9 m.
Virtical Angle	50 degree

8. Powerhouse

Type	Underground Type
Dimension	H = 43m, W = 22m, L = 190m

9. Tailrace

Type	Circular Pressure Tunnel
Number of Lines	4, 2
Length	620 m
Inner Diameter	3.9 m, 5.1 m

10. Outlet (Intake for Pumping)

Type	Side Intake Type
Number	2

11. Power Generating

Installed Capacity	1,000 MW
Unit Capacity	250 MW
Number of Units	4
Rated Head	466 m
Max. Discharge	258 cu.m/sec.

12. Transmission Line

Voltage	230 kV
Number of Circuits	4 cct.
Length	240 km

13. Construction Cost

Preparation Works	62 million Baht
Civil Works	1,509 million Baht
Hydraulic Equipment	312 million Baht
Electrical Equipment	1,260 million Baht
Engineering Fee	110 million Baht
Interest during Construction	487 million Baht
Sub-total	3,740 million Baht
Transmission Line	570 million Baht
Total	4,310 million Baht

14. Annual Energy Production — 1,000 million kWh (1,000 hour operation per year)

15. Surplus Benefit

Import Duty on Fuel included	73 million Baht
Import Duty on Fuel not included	89 million Baht

16. Benefit-Cost Ratio

Import Duty on Fuel included	1.13
Import Duty on Fuel not included	1.15

Table 3-2 General Description of Huai Nam Chon Project

1. Catchment Area	5,100 sq.km.
2. Annual Inflow	3,000 million cu.m.
3. Reservoir	
Normal High Water Surface Level	360 m
Total Storage Capacity	5,380 million cu.m.
Effective Storage Capacity	2,680 million cu.m.
Available Drawdown	25 m
Maximum Water Surface	364 m
4. Dam	
Type	Rockfill with Center Impervious Core
Elevation of Crest	367 m
Height	195 m
Crest	485 m
Volume	15,300 thousand cu.m.
5. Spillway	
Type	Open Channel Chute Type
Capacity	3,000 cu.m./sec.
6. Intake	
Type	Side Intake Type
Number	1
7. Headrace	
Type	Circular Pressure Tunnel
Number of Lines	2
Total Length	420 m
Inner Diameter	78 m

8. Penstock	
Type	Steel Lined Tunnel
Number of Lines	4
Total Length	1,210 m
Inner Diameter	4.8, 4.1 m
9. Powerhouse	
Type	Underground Type
Dimension	H = 38 m, W = 20 m, L = 104 m
10. Tailrace	
Type	Circular Pressure Tunnel
Number of Lines	2
Length	600 m
Inner Diameter	7.8 m
11. Power Generating	
Installed Capacity	600 MW
Unit Capacity	150 MW
Number of Units	4
Rated Head	168.5 m
Max. Discharge	420 cu.m/sec.
12. Transmission Line	
Voltage	230 kV
Number of Circuits	2 cct. (PS. to Ban Chao Nen)
	3 cct. (Ban Chao Nen to Bangkok)
Length	286 km

13. Construction Cost	
Preparation Works	144 million Baht
Civil Works	1,785 million Baht
Hydraulic Equipment	211 million Baht
Electrical Equipment	770 million Baht
Engineering Fee	100 million Baht
Interest during Construction	540 million Baht
Sub-total	3,550 million Baht
Transmission Line	324 million Baht
Total	3,874 million Baht
14. Annual Energy Production	1,158 million kWh
15. Unit Construction Cost	6,460 Baht per kW, 3.35 Baht per kWh
16. Surplus Benefit	
Import Duty on Fuel included	70 million Baht
Import Duty on Fuel not included	59 million Baht
17. Benefit-Cost Ratio	
Import Duty on Fuel included	1.20
Import Duty on Fuel not included	1.17

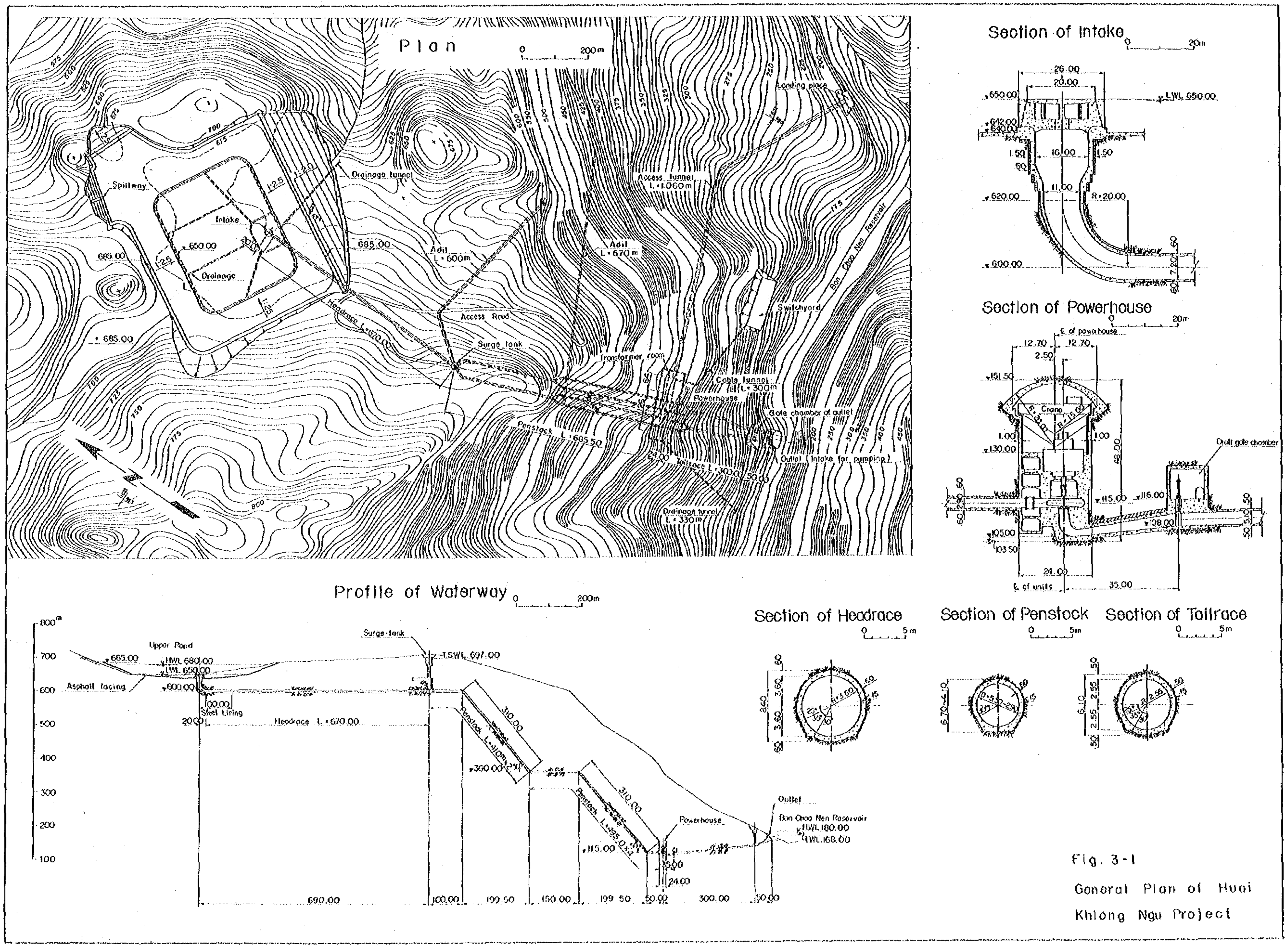


Fig. 3-1 General Plan of Huai Khlong Ngu Project

CHAPTER 4

DEVELOPMENT SCHEME

CHAPTER 4. DEVELOPMENT SCHEME

A) Basic Conditions for Planning

The studies of the development scheme were made based on the following conditions:

1) The basic features of the Ban Chao Nen Project are as given below in accordance with the feasibility report of the Project.

Ban Chao Nen Reservoir		
Normal high water surface level	180 m	
Available drawdown	12 m	
Effective storage capacity	4,550 million cu.m	
Power Generation		
Maximum discharge	732 cu.m/sec.	
Effective head	114 m	
Installed capacity	720 MW	1st stage 360 MW 2nd stage 360 MW

If the basic features of the Ban Chao Nen Project will be modified, restudy of the present development scheme is necessary, accordingly.

2) The dependable output and annual energy production to be used for the study of the Huai Nam Chon Project were calculated by the method described in Chapter 4, C-2) using a mass curve obtained from runoff converted from the 20-year runoff data at Ban Chao Nen Gaging Station.

3) Determination of the effective storage capacity of the reservoir and normal discharge for the Huai Nam Chon Project was done by mass curve.

4) Calculations of the catchment area and the storage capacity of the Huai Nam Chon Project were made using topographical maps of 1/250,000-scale and 1/50,000-scale respectively, both published by the Department of Royal Thai Survey.

5) The installed capacity of the Huai Nam Chon Project was determined taking a plant factor of approximately 21% (5 hours of peak duration time). The dependable output was taken to be the output when the reservoir is at its lowest level.

6) Construction costs were estimated as of the present time and rises in commodity prices were not taken into account.

Rough designs were made based on aerial photographic survey maps furnished by EGAT, 1/10,000-scale for the Huai Klong Ngu Project and 1/5,000-scale for the Huai Nam Chon Project upon which the construction costs were calculated.

Further, it was considered that transportation of all materials and equipment for the construction of the two projects would be accomplished utilizing Ban Chao Nen Reservoir assuming that the projects would be developed after completion of the Ban Chao Nen Project. Taxes were included in the cost estimates for equipment and materials.

7) Interest was taken to be 7.5%.

8) The values given in Table 4-1 for the respective structures are equalized cost factors which are used in calculations of annual costs for economic evaluation. For the calculation of annual costs of the Huai Klong Ngu Project, costs of power for pumping-up corresponding to the annual energy production was added to the annual costs for the investment amount.

For the unit price per kWh of the pumping-up power cost, the following values obtained by dividing the additional fuel cost for extra operation of a thermal power plant by the overall efficiency of pumping-up were used:

Without tax on fuel	฿ 0.149/kWh
with tax on fuel	฿ 0.166/kWh

The annual operating time for the pumped storage power station was taken to be 1,000 hours as stated in Chapter 5, D).

Table 4-1 Equalized Annual Cost Factor for the Projects

	Generating Plant	Transmission Line
Serviceable Year	50	40
Annual Interest Rate	7.5%	7.5%
Equalized Annual Cost Factor		
(1) Interest and Depreciation	7.71%	7.94%
(2) Operation and Maintenance	0.70	2.50
(3) Administration	0.30	0.30
Total	8.71	10.74

9) It was considered that the economic evaluations of the two projects would be made based on the annual costs of an oil-burning steam power plant installed with 2 units of 600 MW.

It was assumed, in this case, that this thermal power plant would be constructed in the area surrounding Bangkok, the load center. The unit capacity of this alternative thermal power plant is identical to the maximum unit capacities for nuclear power and thermal steam power to be developed by 1985, and is of a reasonable size considering the scale of the EGAT power system and the growth of electric power demand.

The basic features and construction cost of this alternative thermal power plant are given below.

Table 4-2 Construction Cost and General Features of Alternative Thermal Power Plant

Installed Capacity	1,200 MW
Unit Capacity	600 MW
Number of Unit	2 units
Annual Capacity Factor	70%
Thermal Efficiency at Sending End	37.2%
Annual Energy Supply at Sending End	7,100 million kWh
Annual Fuel Consumption	1,664 million liters
Fuel Cost	0.40817 Baht/lit. (without taxes on fuel)
	0.45517 Baht/lit. (with taxes on fuel)
Serviceable Life	25 years
Construction Cost (taxes inclusive)	5,200 million Baht

As benefits of the hydroelectric power stations, the annual fixed cost per kW of the above alternative thermal power plant multiplied by a kW adjustment factor of 1.15 was taken to be the benefit per kW and the variable cost per kWh of the alternative thermal power plant was taken to be the benefit per kWh.

	Excluding import duty on fuel	Including import duty on fuel
Benefit per kW	550 Baht	550 Baht
Benefit per kWh	0.10 Baht	0.11 Baht

B) Huai Klong Ngu Project

1) Location (See Fig. 4-1)

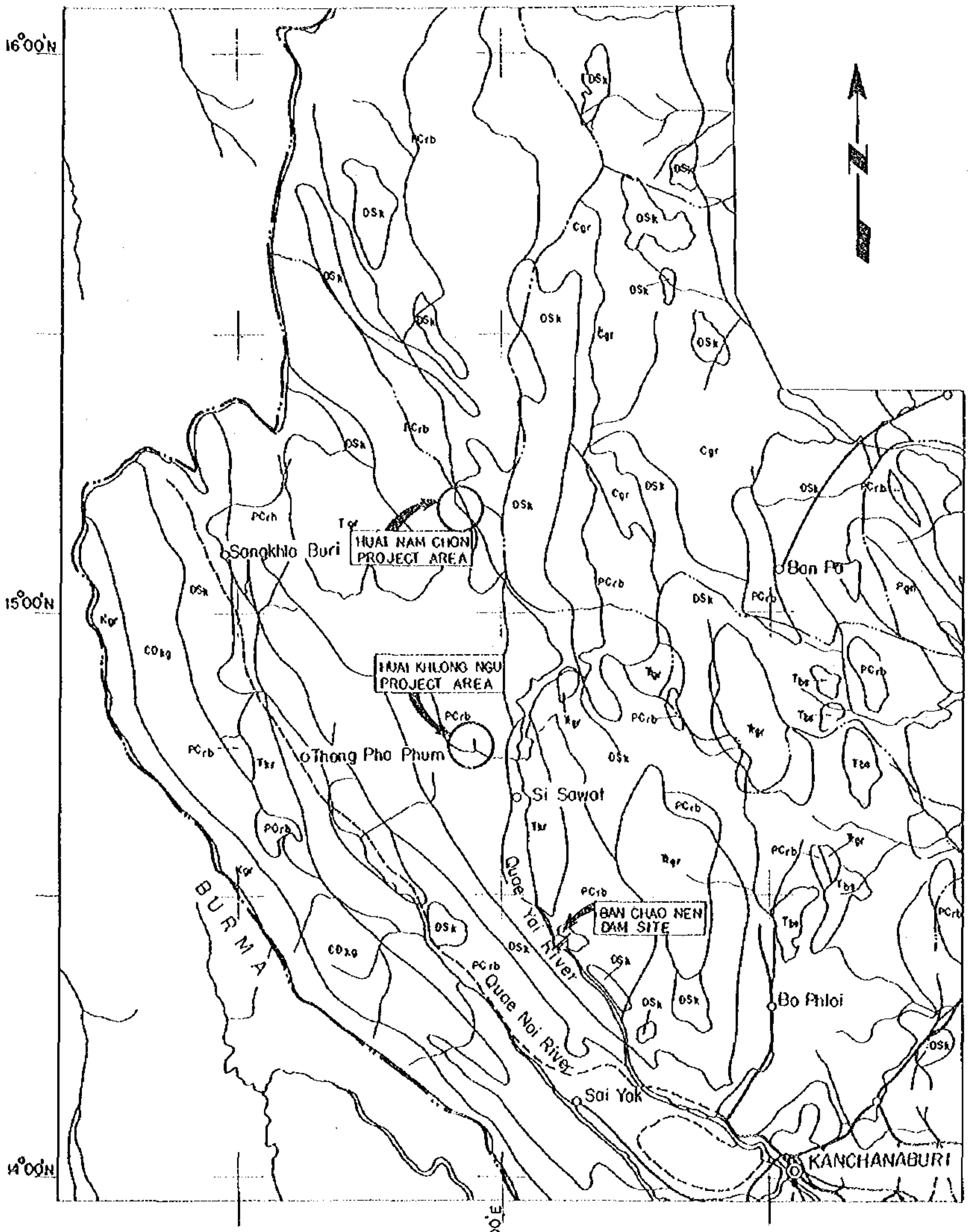
The project site is located roughly at 14°47' north latitude and 98°57' east longitude. This area belongs to the Northwest Mountain Region of Thailand and lies at distances of 240 km west-northwest from the capital city of Bangkok and 100 km northwest of the city of Kanchanaburi, approximately. For transportation to the site, a railway and a highway can be utilized between Bangkok and Kanchanaburi, while from Kanchanaburi to the Ban Chao Nen damsite there is a laterite road, but mostly beyond that point there is no other choice but to navigate up the Quae Yai River by boat.

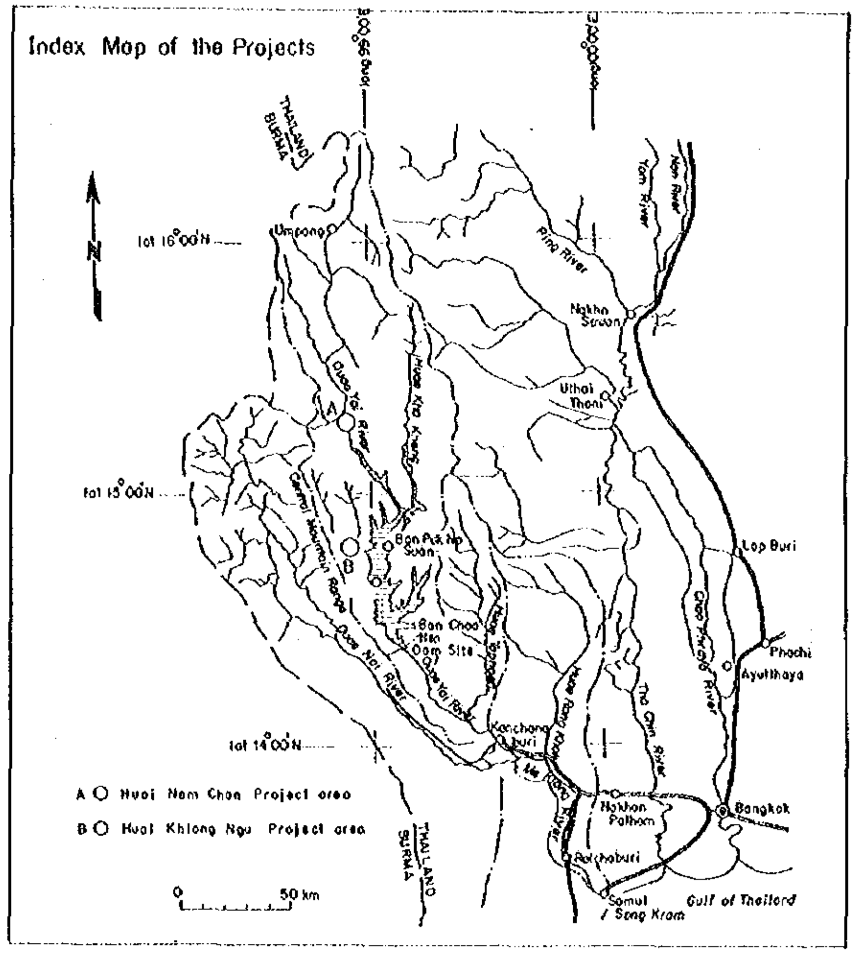
The Huai Klong Ngu River springs from the karstic plateau spread out at a high elevation on the right bank of Ban Chao Nen Reservoir under construction and after changing its course from south-southeast to east, it merges with the mainstream Quae Yai River at a point approximately 40 km upstream from the Ban Chao Nen damsite between Ban Pak Na-Suan and Si Sawat. The design high water surface level (El. 180 m) of Ban Chao Nen Reservoir goes back along this tributary approximately 10 km. Approximately 8 km upstream from the confluence point, there is a tributary feeding in from the left bank of the Huai Klong Ngu River called the Huai Khliti River and the project site occupies a part of the northwest bank of the junction point of the Huai Klong Ngu River and the Huai Khliti River, that is, the left bank of the middle stretch of the Huai Klong Ngu River.

2) Topography and Geology (See Fig. 4-2)

The project area is located approximately 10 km west of the Quae Yai River mainstream at the right bank of Ban Chao Nen Reservoir under construction and is situated from the western end of the plateau spread out to the north between the Huai Khliti River and the Huai Klong Ngu River, down to the Huai Klong Ngu River. The eastern side of the plateau is separated from the Quae Yai River by a mountain block with Mt. Khao Khliti (El. 951 m) as the main peak and drops down to the Huai Klong Ngu River at the southwestern side in a steep slope. Slopes around this plateau are eroded with steep valleys. Although parts above El. 600 m of the project area comprise a gently sloped plateau, the plateau is

Geologic Map of the Southern Part of Northwest Highlands.





Legend

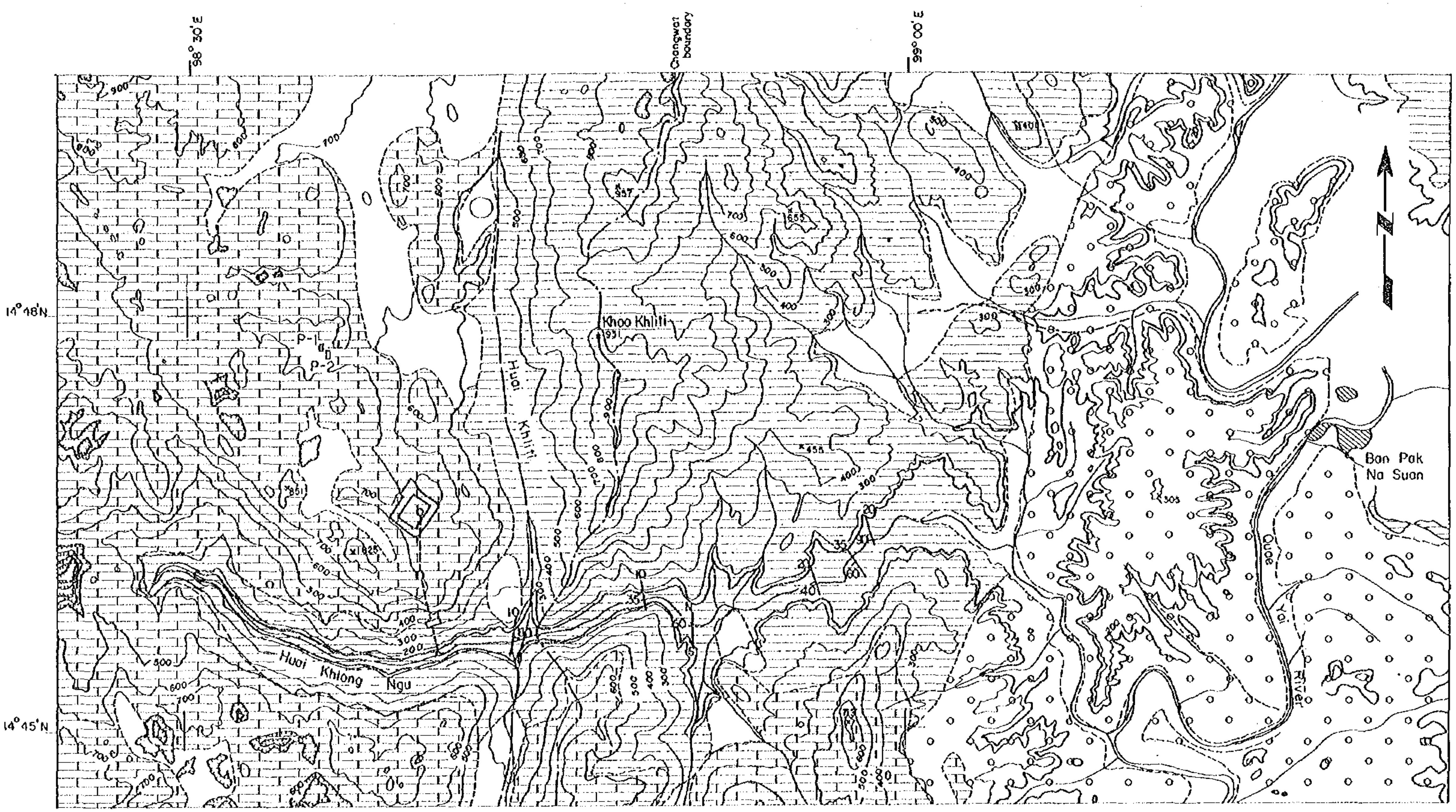
Symbol	Name	Age	Symbol	Name	Age
Qal		Quaternary to Recent	Tbs	Basalt and its equivalent	Tertiary
Tkr	Krabi group	Tertiary	Kgr	Granite and granodiorite	Cretaceous
PCrb	Ratburi group	Carboniferous and permian	Ꞇgr	do	Triassic
cDkg	Kaeng krachan formation (Tanaosi group)	Carboniferous, Devonian and Silurian	Cgr	Granite	Carboniferous
Dsk	Kanchanaburi formation (Tanaosi group)		pPgn	Gneiss and schist	Pre - Permian

Note :

From Department of Mineral Resources, Ministry of National Development, Thailand (1969) GEOLOGICAL MAP OF THAILAND, Scale 1/1,000,000

Fig. 4 - 1

Geologic Map of the Southern Part of Northwest Highlands



Legend

(blank box)	Quaternary system.	Topsoil, and terrace, flood plain, river bed and talus deposits.
(circles)	Tertiary system	Gravel, sand, silt and lime-cemented sand-gravel layer; locally with thin lignite seam.
(brick pattern)	Ratburi limestone	Pure limestone; karst in some places.
(dashed lines)	So-called Kanchanaburi series (Formation B*)	Alternation of shaly limestone, shale and calcareous sandstone; locally with thin impure limestone and sandstone bed.

* See the description in this report.

- 70 5 — Strike and dip of beds
- Assumed fault
- Sinkhole
- P-1 — Test pit
- High water surface of Ban Chao Nen reservoir (EL. 180 m)

Note ;

This map is cited from the report of "Geological Investigation of Reservoir Area, Quae Yai NO1 Project", prepared for EGAT by EPOC in 1972. But, around this project area, some revisions are made by the collected data during present reconnaissance.

0 2 km

Fig. 4 - 2

Geologic Map of Huai Khlong Ngu Project Area and its Surroundings.

scattered with limestone buttes and sinkholes of medium and small size so that the micro-topography shows considerable variation. The upper pond is planned on this plateau.

The valley walls of the Huai Klong Ngu River cutting down the plateau and flowing east and of the tributary Huai Khliti River comprising the eastern edge of the plateau are steep slopes of 35° to 55° and at many places there are cliffs of large size with heights exceeding 100 m and slopes steeper than 70°. The powerhouse is planned as underground types at a steep slope facing the Huai Klong Ngu River.

The general geology of the project area, according to the Report* shows distributions of karstic Ratburi limestone at parts of higher elevation and non-karstic members of the so-called Kanchanaburi Formation consisting of alternations of shaly impure limestone, shale and calcareous sandstone at lower elevations. In the present survey, the distribution of rocks and the geologic structure were confirmed to be correct as it had been reported. And the flat boundary of Ratburi limestone and Kanchanaburi. Formation is generally traced along the contour line of an elevation of 400 m. (see Fig. 4-2 and Fig. 4-3). Therefore, the upper regulating pond would be provided on a karstic plateau. Thin topsoil covers the entire plateau while it seems that almost no talus deposits are distributed even at the foots of buttes. At two test pits excavated at alternative site approximately 2 km distant to the north from the proposed site, there is a existence of weathered limestone, with 2 or 3 m thick, fractured into rocks including boulders covered by topsoil of thickness less than 1 m. In many cases at limestone areas, not only there are many uneven portions of various forms at the ground surface but also the contact between the overburden and the underlying limestone usually is highly irregular, due to the agencies of solution and erosion. Therefore, it is conceivable that there are fairly thick portions of overburden locally, and thorough investigation will be necessary.

* Electric Power Development Co., Ltd. (1972) Geological Investigations of Reservoir Area, Quae Yai No. 1 Project. - prepared for Electricity Generating Authority of Thailand -

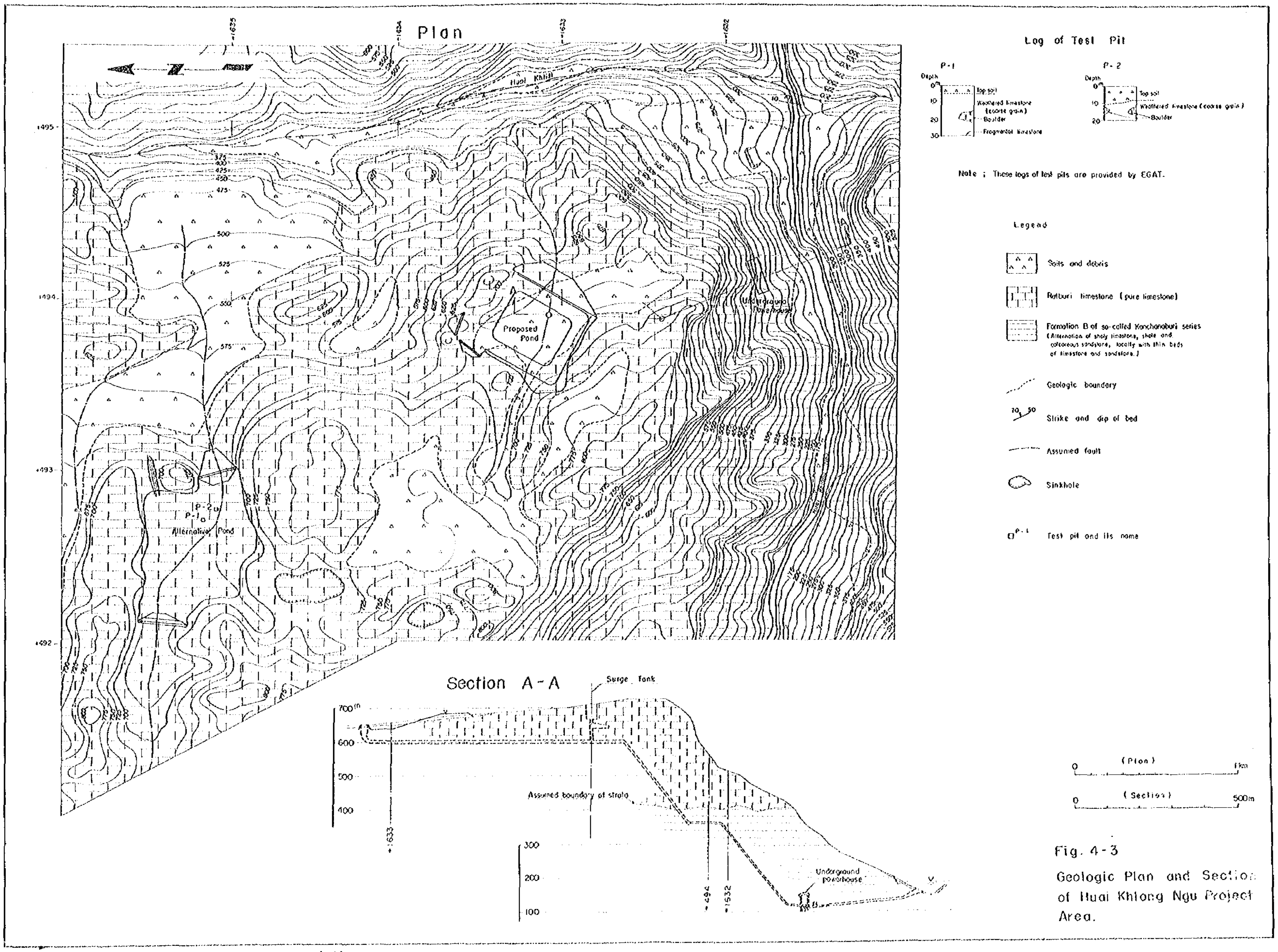


Fig. 4-3
Geologic Plan and Section of Huai Khlong Ngu Project Area.

The Ratburi limestone has sinkholes of various sizes in general, and even in the vicinity of the proposed site, there are sinkholes of about 1.5 m in diameter. This rock is fairly cracky overall. Therefore, water leakage of a degree that would not be ignored from view points of dam stability and economy of storing, might be discovered from the dam foundation, its surrounding area, and the reservoir area. Consequently, it is necessary for an appropriate countermeasure to be provided. Notwithstanding, it is considered this rock possesses sufficient bearing capacity as a foundation for low dams or asphalt and concrete pavements.

The slope of the mountain proposed to be the site of the underground powerhouse is distributed with talus deposits consisting chiefly of blocks of 5 m diameter or larger from the river bed (El. 130 m) up to around an elevation of 200 m. Most of these blocks are limestone. There are continuations of cliffs where limestone is exposed at slopes above elevation of approximately 400 m. As previously mentioned, there is a distribution of the so-called Kanchanaburi Formation below an elevation of approximately 400 m. The strata distributed in this vicinity are attributed to Formation B in the Report. The rock types of Formation B consist of alternations of shaly limestone, shale and calcareous sandstone, and is characterized by partial intercalations of thin layers of limestone or sandstone, which are non-karstic. In the vicinity of the junction between the Huai Klong Ngu River and the Huai Khliti River, there are outcrops of calcareous shale, the general strike and dip of which are N 10° W and 80° NE.

The powerhouse and the greater parts of tunnel sites are located in this Formation B. This formation, according to numerous outcrops observed, has prominent bedding, has been folded in gentle to intense states. Therefore, in construction of large-scale underground structures such as tunnels with large cross sections and underground powerhouses, careful site selection and design in accordance with results of thorough investigations will be necessary. Consequently, it should be necessary besides detailed geological reconnaissance and investigations by core boring and test adits, to carry out tests of the characteristics of rock mechanics of the bedrock, as required, to reflect the tests results in design of underground structures.

Since the upper regulating pond is presently planned to be an excavated type, the muck from this pond would be profitable to use as dam construction material. Adopting the suitable earthwork, this material could be sufficiently stable for embankment.

As for aggregate for concrete, natural aggregate cannot be expected and artificial aggregate would be used. Crushed rock from Ratburi limestone rather than from stone belonging to the so-called Kanchanaburi Formation would be better as aggregate, but it will be necessary to conduct aggregate tests before using.

3) Power Generation Plan

i) Scale of Development

The Huai Klong Ngu site which would utilize the Ban Chao Nen Reservoir under construction is one of the few sites where large-scale pumped storage power generation can be carried out.

In planning a pumped storage power plant, it is more economical to plan for high head and large capacity so far as possible technically or topographically and geologically.

Consequently, the development scale for this site was selected to be as indicated below within the range technically practicable and taking into consideration the head, lift and the scale of the power system at the time this station is put into service.

Development scale	1,000 MW
Unit capacity	250 MW
Number of units	4 units
Turbine type	Francis reversible pump-turbine

However, since there is considerable time until development is realized, the capacity of upper pondage and scale of development should be carefully determined upon the study of trend of demand for the next several years and timing of development for thermal and nuclear power stations.

ii) Study of Development Plan

For the upper regulating pond of Huai Klong Ngu Project there had been two sites considered by EGAT as shown in Fig. 4-4. Consequently, for the pumped storage power generation plan for this Project, there would be two alternative schemes in which pumped storage power generation would be accomplished utilizing the heads of approximately 500 m obtained between the respective upper regulating ponds and Ban Chao Nen Reservoir, but regarding the structures from surge tank down to tailrace outlet, single locations were selected in consideration of topography and accessibility, and the two alternative schemes were compared connecting these structures with the respective upper regulating ponds by headrace tunnels (see Fig. 4-4).

The studies of these alternative schemes were made based on a 1/10,000-scale topographical map and field reconnaissance, to obtain the results for the various structures as described below.

The upper regulating pond would be built on a karstic plateau. Because it seems that various size of sinkholes exist in the limestone which comprises this karstic plateau and since the limestone is cracky, it is anticipated that troublesome leakage will be encountered for a regulating pond that would be created merely by embanking or excavating. Therefore, a surface water-tight regulating pond with its entire inner surface lined with asphalt was selected. In planning the regulating pond, the balance of amounts for excavation and embankment was considered as much as possible. The capacity of the regulating pond was selected to be 6 hours in terms of maximum output taking allowance for the present daily load and the available drawdown was selected to be 25 m and 30 m.

The intake is to be a morning glory type since the upper regulating pond is a surface water-tight type linned with asphalt, while the headrace is to be a single line with inner diameter of 7.2 m taking the easiness of construction and economy into account.

The surge tank is to be a restricted orifice water chamber type, while all penstocks are to be embedded lines, and in consideration of easiness of work, they will be made inclined shafts at an inclination of 50°. The penstocks will be branched into two lines immediately downstream of the surge tank and then again branched into four lines at the middle of the penstock. As steel for the penstocks, extra-high tensile steel will be used since the internal pressure will be extremely high.

Since the centers of the pump-turbines would be 63 m below the low water level of Ban Chao Nen Reservoir, the powerhouse is to be an underground type. The main transformers will also be installed underground next to the assembly hall, while switching equipment and the control building for the power station will be above ground.

The length of a tailrace tunnel would be around approximately 400 m, and on referral to past performance and experiences, it is considered influence of water pressure of the lower reservoir (Ban Chao Nen Reservoir) on the underground powerhouse can be avoided so that a surge chamber will not be provided. The number of tailrace tunnels will be two lines immediately downstream of draft gates, namely, one tailrace tunnel for two turbines.

The outlets are to be of horizontal type and since they would be built underwater in Ban Chao Nen Reservoir, it was considered special construction techniques would be used.

The outlines of project components, construction costs and economic justifications based on the above consideration are as given in Table 4-3. According to this table, due to its short waterway, Plan A results in more advantageous in construction cost per kW and benefit-cost ratio, in spite of its high cost for construction of regulating pond.

Table 4-3 Outline of Alternative Schemes of Huai Klong Ngu Project

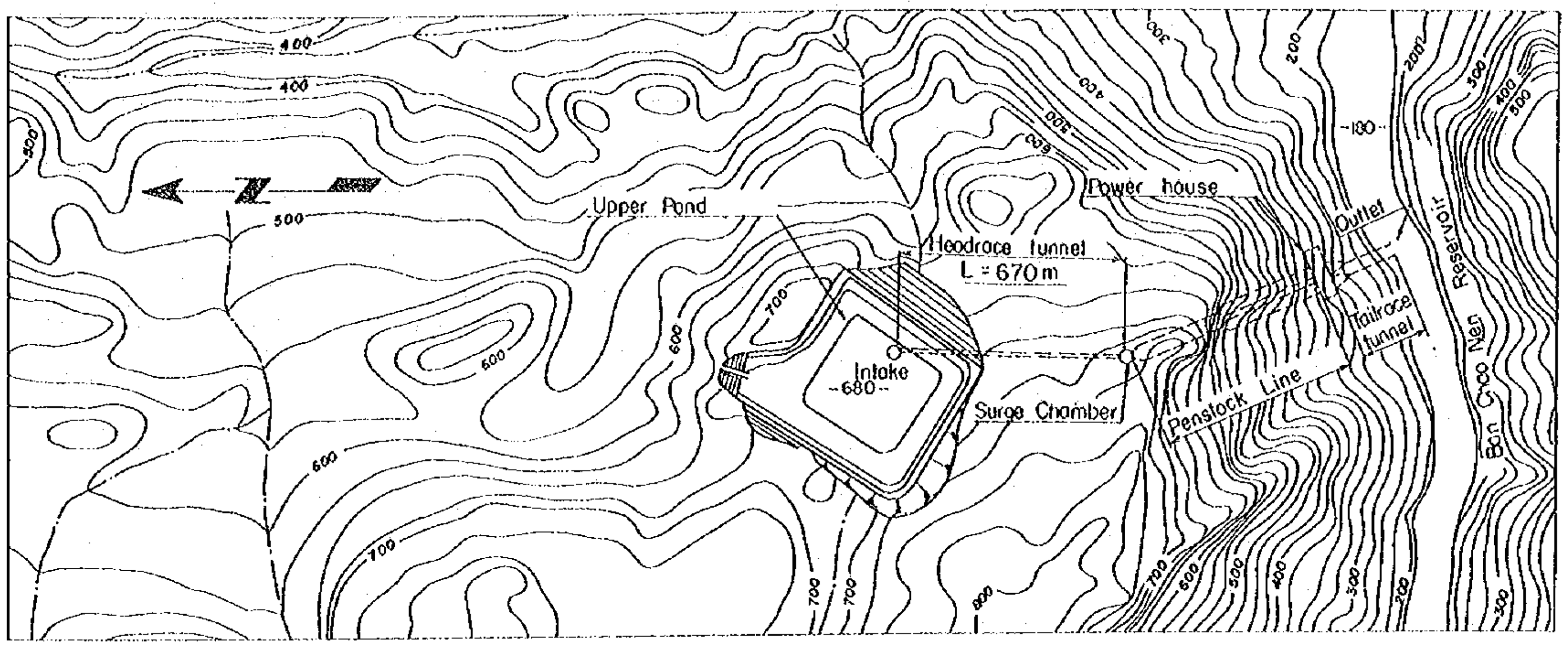
	Unit	Plan - A	Plan - B	Remarks
Upper Pond				
High Water Level	m	680	670	
Available Drawdown	m	30	25	
Effective Storage	10^6 cu. m	6	7	6 hour operating per day
Dam Height	m	60	50	
Dam Volume	10^3 cu. m	2,700	1,000	
Lower Reservoir				Ban Chao Nen Reservoir
High Water Level	m	180	180	
Available Drawdown	m	12	12	
Headrace Tunnel				
Number		1	1	
Length x Diameter	m	670 x 7.2	2,900 x 7.2	
Penstock				
Number		2 - 4	2 - 4	
Diameter	m	2.9 - 4.4 - 5.5	2.9 - 4.4 - 5.5	
Length	m	2,660	2,660	
Tailrace Tunnel				
Number		4 - 2	4 - 2	
Length x Diameter		620 x 3.9 - 5.1	620 x 3.9 - 5.1	

(Continued)

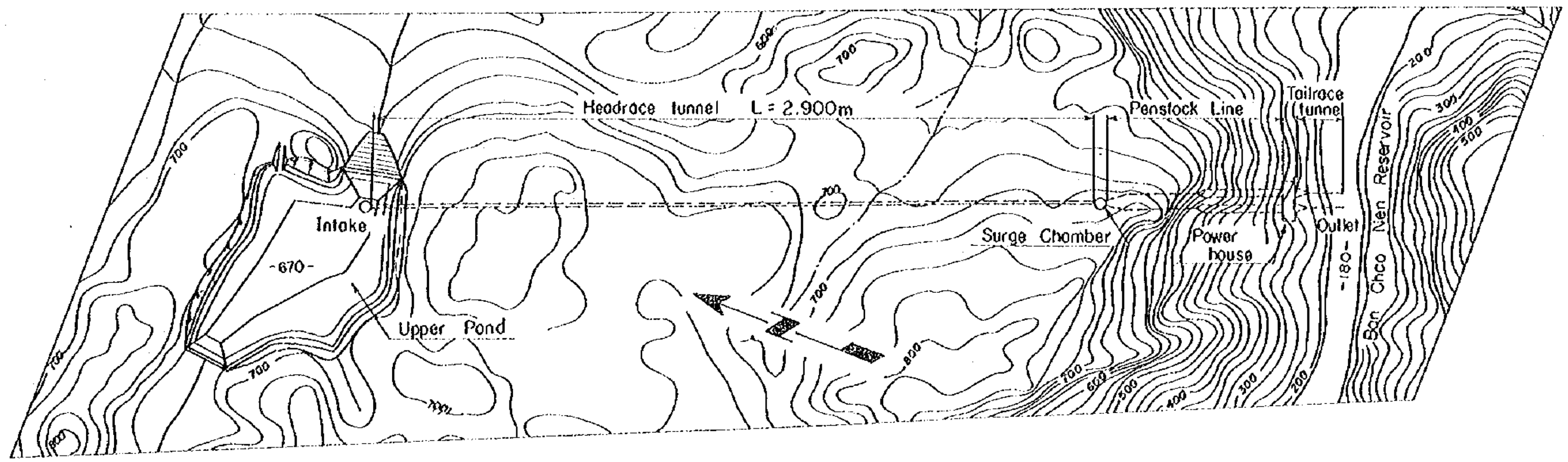
	Unit	Plan - A	Plan - B
Power Generation			
Installed Capacity	MW	1,000	1,000
Max. Discharge	cu.m/sec.	258	266
Effective Head	m	466	453
Unit Capacity	MW	250	250
Transmission Line			
Voltage	kV	230	230
Circuit	cct	4	4
Length	km	240	240
Construction Cost			
Generating Facilities	10^6 ฿	3,740	4,000
Transmission Line	10^6 ฿	570	570
Total	10^6 ฿	4,310	4,570
Economic Justification *			
Benefit (B)	10^6 ฿	626	626
Cost (C)	10^6 ฿	553	576
Surplus Benefit (B) - (C)	10^6 ฿	73	50
Benefit Cost Ratio		1.13	1.09

* 1,000 hour operating per year

Plan – A



Plan – B



0 500 1000m

Fig. 4 - 4

General Layouts of Huai Khlong Ngu Project and its Alternative Scheme.

C) Huai Nam Chon Project

1) Location (See Fig. 4-1)

The damsite of this Project is on the main stream of the Quae Yai River and is located at about 15°15' north latitude and 98°55' east longitude. This site is situated approximately 110 to 120 km upstream of the Ban Chao Nen damsite, or the end of the backwater of Ban Chao Nen Reservoir under construction.

For this area, besides the proposed dam axis described in this report, six alternative ones have been chosen by EGAT. These axes are numbered one to six in order from downstream to upstream while proposed site is located in the middle of No. 4 and 5. There is a distance of approximately 5.5 km and a difference in river-bed elevation of approximately 7 m between the uppermost and lowermost dam axes.

2) Hydrology

The locations of runoff gaging stations and rainfall observatory stations in the Quae Yai River Basin and its surrounding area are indicated in Fig. 4-5.

The periods for which runoff and rainfall records at these stations exist are as shown in Table 4-4.

River runoff of the Quae Yai River, was studied in Basic Study of Quae Yai No. 1 Hydroelectric Project, Volume 1 using the specific runoff ratio and catchment area based on Kang Rieng Gaging Station in the feasibility studies of the Project.

The runoff at the project site is calculated by the following formula:

$$Q_x = Q_K \cdot \frac{Ax}{A_K} \cdot \alpha \qquad (1)$$

where

- Q_x : Runoff at x site with catchment area of A_x
- Q_K : Runoff at Ban Chao Nen (Kang Rieng) Gaging Station
- A_x : Catchment area at x site
- A_K : Catchment area at Ban Chao Nen (Kang Rieng) = 10,800 sq. km
- α : Specific runoff ratio obtained from Fig. 4-6

According to topographic maps, the catchment area of the Huai Nam Chon damsite is 5,100 sq.km. Runoff gaging stations near the project site are located at Had Pana (C.A. = 5,644 sq.km) and Khao Chod (C.A. = 5,530 sq.km) with observation periods of 4 years and 7 years respectively.

The runoff gaging station with the longest period of observation on the Quae Yai River is Ban Chao Nen (Kang Rieng) Gaging Station from which runoff data for approximately 20 years are available.

Adding runoff data obtained after the Quae Yai No. 1 Feasibility Report (hereinafter in this report, merely called the Feasibility Report) and determining the specific runoff ratio between Ban Chao Nen Gaging Station and Khao Chod Gaging Station from the cumulative correlation (Fig. 4-7), it is 1.55 and more or less the same result as the specific runoff ratio of 1.6 for the same gaging stations in the Feasibility Report.

Therefore, it was decided to use Formula (1) in calculation of the runoff of the project site.

Substituting the catchment area of the project site and the specific runoff ratio obtained from Fig. 4-6 in Formula (1), the equation for converting runoff at Ban Chao Nen Gaging Station to that of the project site will be the following:

$$Q_X = Q_K \cdot \frac{A_X}{A_K} \cdot \alpha = 0.68\ Q_K \qquad (2)$$

where

Q_X : Runoff at Huai Nam Chon site

Q_K : Runoff at Ban Chao Nen (Kang Rieng) Gaging Station

A_X : Catchment area at Huai Nam Chon site = 5,100 sq.km.

A_K : Catchment area at Ban Chao Nen (Kang Rieng) Gaging Station = 10,800 sq.km.

α : Specific runoff ratio at 5,100 sq.km obtained from Fig. 4-6 = 1.45

The 20-year (from April 1952 to March 1972) monthly average runoff obtained for the project site by the above formula are as shown in Table 4-5. Annual rainfall at the site amounts to about 1,000 mm.

The design flood discharge of the project site was determined from the design flood discharge of 7,500 cu.m/sec of Ban Chao Nen Dam studied in Supplementary Report for Quae Yai No. 1 Project, Volume 1, using the conversion factor 0.68 in Formula (2). According to this calculation, the design flood discharge of the project site is estimated to be 5,100 cu.m/sec. The flood hydrograph is as shown in Fig. 4-8.

Regarding evaporation, net evaporation loss was taken to be 500 mm/yr. as in the Feasibility Report.

Table 4-4 Rainfall, Runoff Gaging Stations and Existing Data.

Rainfall Observatory Station and Existing Data. (Daily and Monthly Record)

NO.	ANPHUR	NAME OF STATION	'50	'51	'52	'53	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72
1	SANGKHLABURI	PILOP MINE										—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	SANGKHLABURI	SANGKHLABURI			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
3	THONG PHAPHUM	THONG PHAPHUM			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	SAI YOK	WANG PO						—	—	—	—	—	—	—	—	—	—	—	—						
5	UMPHANG	UMPHANG			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	SRI SAWAT	BAN NASUAN								—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7	SRI SAWAT	SRI SAWAT						—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	SRI SAWAT	KANG RIENG			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
9	BO PHLOI	BO PHLOI						—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
10	PANOM TUAN	PANOM TUAN			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—				
11	PANOM TUAN	KANCHANABURI	from 1911		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12	THA MUANG	THA MUANG			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
13	THA MAKA	THA MAKA			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14	MUANG	LAM SOI LAM PAO									—	—	—	—	—	—	—	—	—						
15	BANGKOK	BANGKOK	from 1911		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Runoff Gaging Station and Existing Data. (Daily Reoord)

NO.	NAME OF RIVER	NAME OF STATION	CATCHMENT AREA (Sq.km)	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72
①	MAE NAM QUAE NOI	HUAI MAE NAM NOI														—	—	—	—	—	—	—
②	MAE NAM QUAE NOI	WANG PO	6,500									—	—	—	—	—	—	—	—	—	—	—
③	MAE NAM QUAE NOI	LUM SUM	7,008												—	—	—	—	—	—	—	—
④	MAE NAM QUAE YAI	KHAO CHOD (Main Stream)	5,530												—	—	—	—	—	—	—	
⑤	MAE NAM QUAE YAI	KHAO CHOD (Tributary)	2,350													—	—	—	—	—	—	
⑥	MAE NAM QUAE YAI	HAD PANA	5,644																—	—	—	—
⑦	MAE NAM QUAE YAI	ONGKLA	8,320													—	—	—	—	—	—	—
⑧	MAE NAM QUAE YAI	KANG RIENG	10,802	from 1952 —	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
⑨	MAE NAM QUAE YAI	KAO WANG MASUNG	11,963													—						
⑩	HUAI TA POEN	LAM TA PHERN													—			—	—	—	—	
⑪	MAE NAM MAE KLONG	BAN THAM	(till Mar '63) 25,466 (till Mar '63) 27,200				—	—	—	—	—	—	—	—	—							
⑫	MAE NAM MAE KLONG	BAN WANG KHASAI	27,300												—	—	—	—	—		—	—

Table 4-5 Monthly Average Discharge at Huai Nam Chon Site
(Catchment Area: 5,100 sq. km)

Unit: Cu.m/sec.

Year	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual
'52-'53	18.5	19.6	42.0	89.5	190.8	133.7	337.1	137.3	50.6	34.3	33.3	27.3	92.8
'53-'54	24.0	36.5	70.4	188.1	600.7	329.9	255.4	206.8	92.7	58.3	42.8	32.9	161.7
'54-'55	26.4	47.5	73.5	103.5	153.8	235.4	232.4	77.2	46.5	25.6	21.2	16.5	88.3
'55-'56	19.9	22.5	36.7	72.7	79.0	217.5	144.9	93.0	40.9	26.5	19.2	14.6	65.6
'56-'57	20.4	54.9	52.0	83.8	161.5	237.1	214.2	80.0	47.7	35.2	23.3	16.7	85.6
'57-'58	15.4	11.1	43.4	82.6	224.8	278.1	338.5	82.1	41.4	28.4	20.2	15.0	98.4
'58-'59	15.8	19.7	44.7	63.7	135.1	303.2	185.1	70.1	38.0	25.6	27.4	14.2	78.6
'59-'60	14.5	20.8	38.3	57.9	146.5	221.8	370.6	75.9	39.6	26.0	19.4	12.9	87.0
'60-'61	12.1	16.0	21.1	25.7	148.3	118.7	210.0	60.6	47.5	24.5	18.2	13.6	59.9
'61-'62	11.6	32.6	66.6	239.0	499.8	514.1	271.8	111.5	56.9	39.0	27.9	21.7	157.7
'62-'63	19.4	24.2	46.1	111.4	224.9	425.2	242.8	75.6	41.8	27.0	18.4	14.7	106.0
'63-'64	10.7	8.7	25.8	134.7	200.3	321.2	464.2	143.1	59.9	37.0	25.6	18.5	120.8
'64-'65	19.2	44.4	43.4	84.8	150.5	267.8	369.8	115.8	61.2	37.6	28.7	28.3	104.3
'65-'66	22.0	33.2	121.8	169.6	205.3	166.5	182.7	73.0	39.3	29.4	25.1	17.5	90.5
'66-'67	16.9	28.9	54.0	107.2	160.8	272.7	148.2	64.8	42.1	29.1	20.9	15.6	80.1
'67-'68	16.9	25.7	39.9	62.1	229.3	225.7	208.5	69.1	40.1	27.7	22.2	18.2	82.1
'68-'69	15.7	32.2	28.4	67.5	211.3	159.6	113.1	45.0	27.2	21.0	14.5	10.7	62.2
'69-'70	9.3	7.0	48.9	100.6	323.2	315.5	177.8	94.8	41.5	28.5	20.8	15.9	98.7
'70-'71	14.0	20.5	33.5	92.5	167.0	197.4	193.7	104.6	63.5	31.8	20.5	15.8	79.6
'71-'72	19.8	25.8	72.0	176.7	162.6	171.8	120.9	70.2	35.5	25.8	19.1	14.9	76.3
Average	17.1	26.7	50.1	105.7	218.8	255.6	239.1	92.6	47.7	30.9	23.4	17.8	93.8

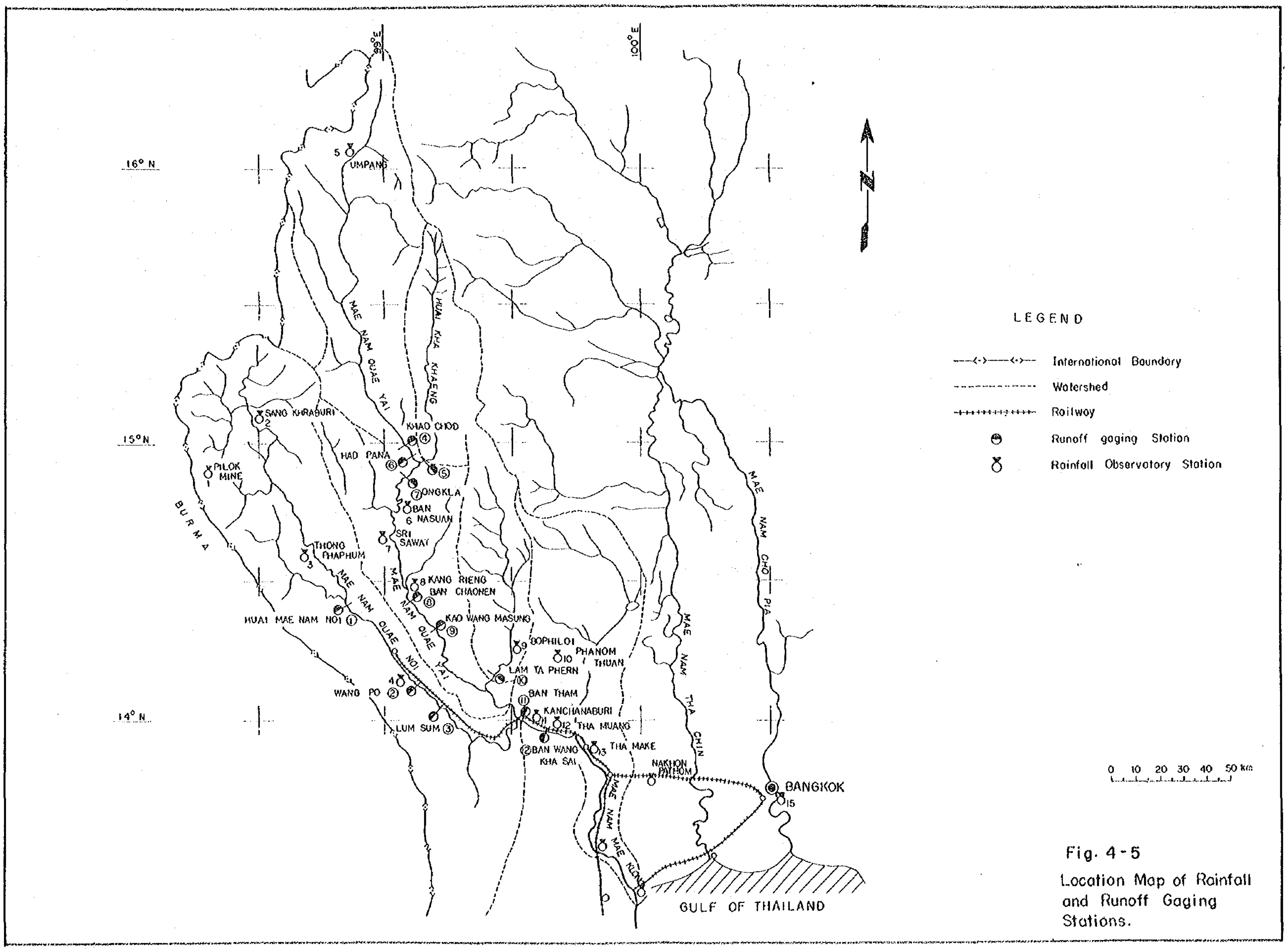


Fig. 4-5
Location Map of Rainfall and Runoff Gaging Stations.

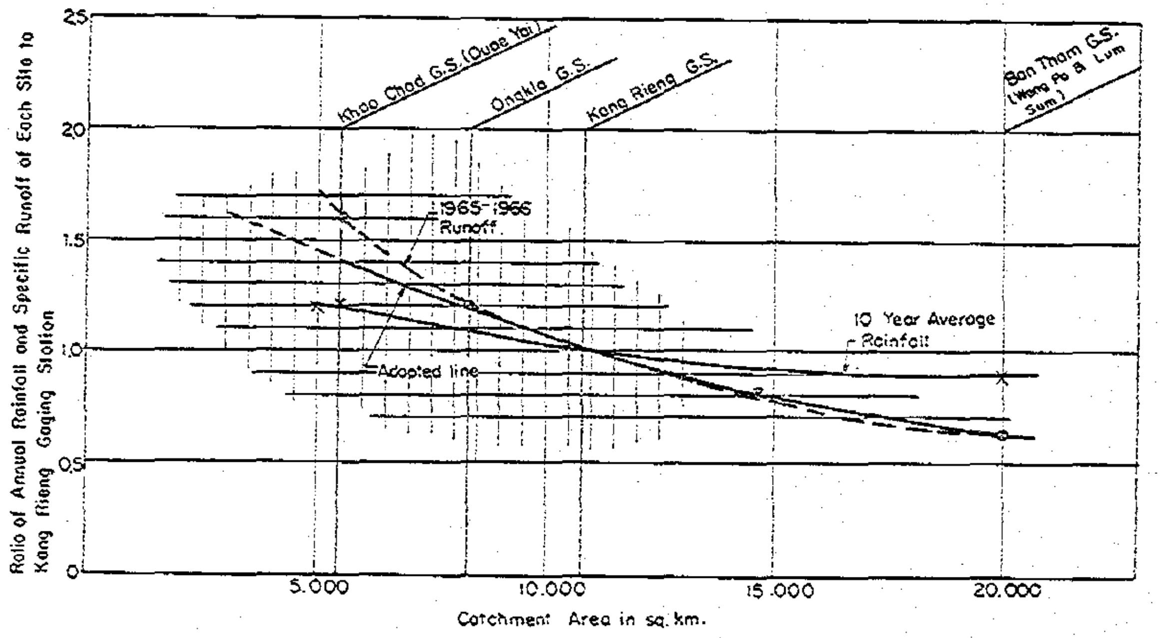


Fig. 4 - 6

Ratio of Annual Rainfall and Specific Runoff of Each Site to Ban Chao Nen.

Fig. 4-7 Correlation of Specific Runoff between Ban Chao Nen and Khao Chod.

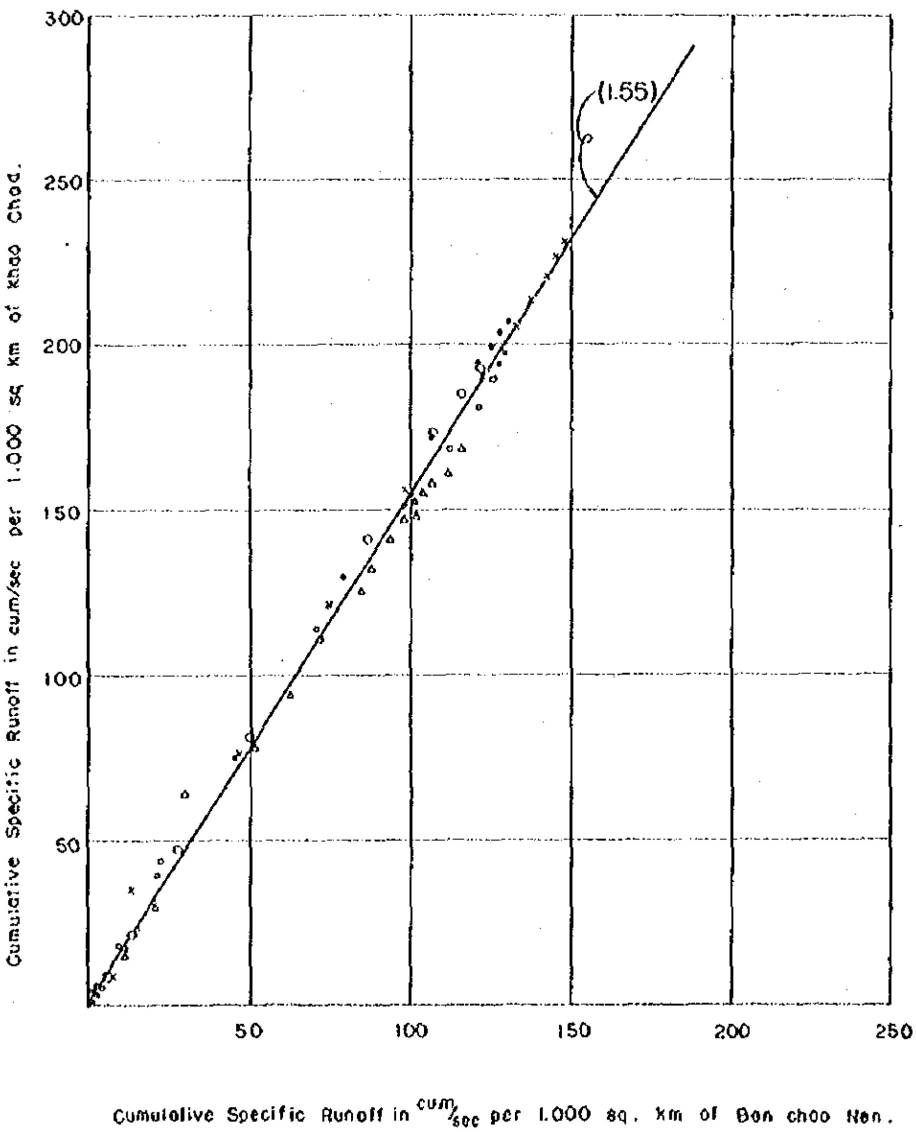
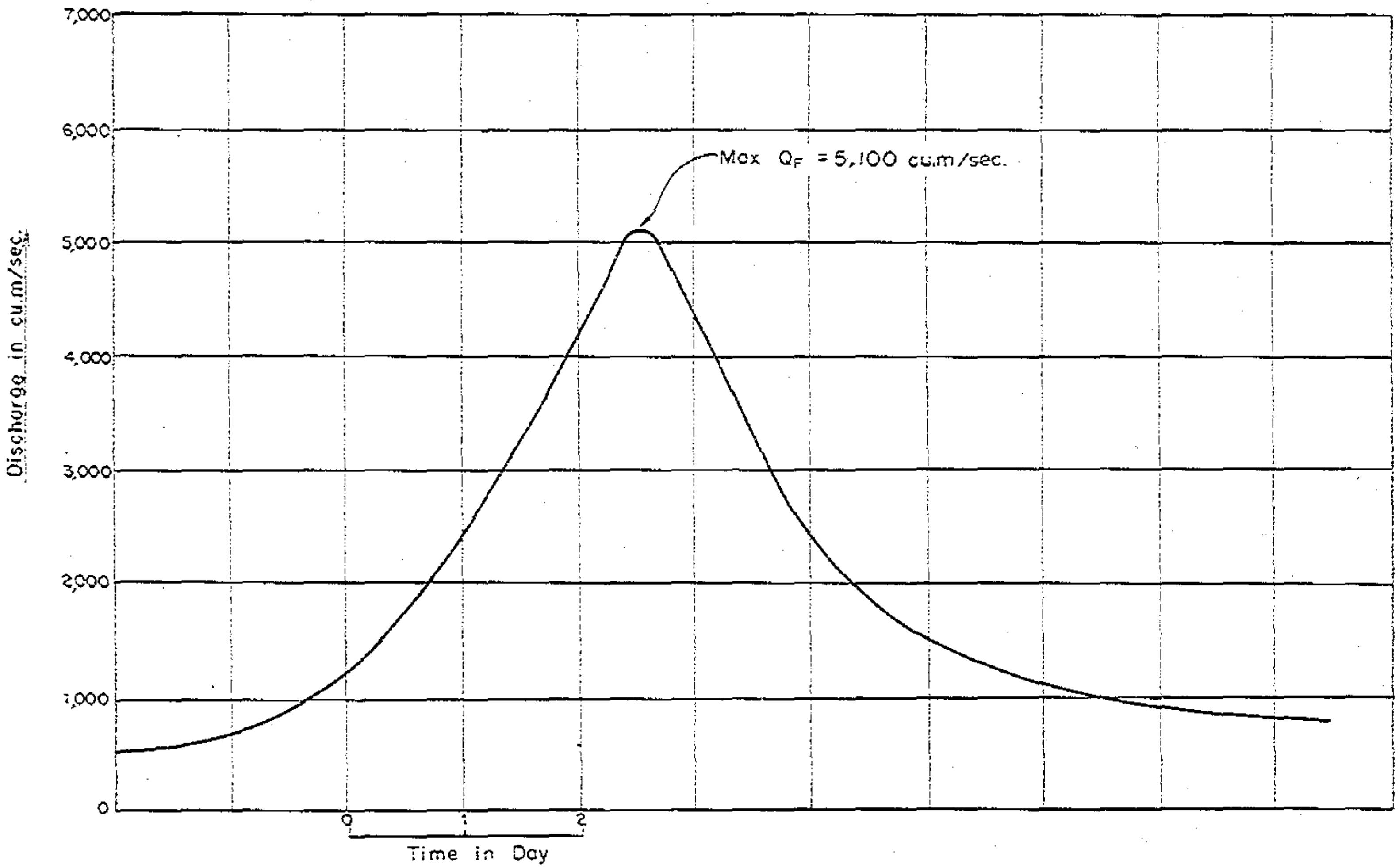


Fig. 4-8 Flood Hydrograph at Huai Nam Chon Site



3) Topography and Geology

The Project site is extremely close to and north of the surveyed area where, in 1971 and 1972, EGAT and EPDC jointly carried out the investigation for the Ban Chao Nen reservoir and for which EPDC completed a Report * in February 1972, compiling the results.

Since the present reconnaissance was made during the lowest water season in the end of February 1973, it was only possible to reach a point approximately 10 km downstream from alternative damsite No. 1, because an accessibility to the project site is only available by boat through the river. Therefore, the outlines of topography and geology described in this report are summary of aerial inspections by helicopter, interpretations of aerial photographs, judgement of data including topographic maps furnished by EGAT, and information from Colombo Plan Expert and EGAT geologist.

The topographic and geologic features of the project sites composing the proposed site in this report and six former alternative sites are more or less similar and may be outlined as described below. (See Fig. 4-9)

The Quae Yai river meanders somewhat in the project area, but the river between the uppermost alternative damsite and the lowermost site is flowing almost straight and has a rather gentle gradient. The width of the river bed is 30 to 50 m in the abovementioned sites.

There are no flat areas such as flood plains and terraces near the river side, and valley walls rise directly from both banks of the river channel. These valley walls have average inclinations between 35° and 55°, but at various places there are large-scale cliffs with height of 70 m to 150 m sloped at 70° or steeper.

Although the shape of the valley presents a precipitous topography as described above, the mountain-land on the right bank higher than EL. 600 m is spread out in a gently-sloped plateau-like terrain. From the fact that karstic topography are indicated to exist at many places on the 1/50,000 scale topographic map, it is thought this broad and gentle slope is a karstic plateau consisting of calcareous rocks.

* Electric Power Development Co., Ltd. (1972) Geological investigation of reservoir area, Quae Yai No. 1 Project - prepared for Electricity Generating Authority of Thailand.

The geologic structure of this area, viewed macroscopically, is governed by the Burmese-Malaya geologic movement and the structure is generally prominent in the NW-SE direction, that is, roughly being parallel to the Quae Yai river.

Taking into consideration the location of the project area which is close to the end of the Ban Chao Nen reservoir, macroscopically speaking, it should naturally have a continuation of the geology distributed in the Ban Chao Nen reservoir area.

The rocks of the project area seem to consist of Ratburi limestone at higher elevations and, at lower elevations, probably Formation B of so-called Kanchanaburi series composing of alternations of shaly limestone, sandstone and shale, sandstone beds with considerable thickness and intercalated thin layers of limestone. Although the boundary between Ratburi limestone and Formation B is not yet confirmed in the field, it appears to be more or less horizontal from the data of topographic considerations, interpretations of aerial photographs and reconnaissance by helicopter, and it is assumed Ratburi limestone is distributed (approximately above 600 m). But there were some small scale hollows were observed at an elevation between 325 m and 350 m around No. 1 alternative damsite by helicopter.

Formation B which underlies Ratburi limestone, according to the previously mentioned Report, has sustained severe folding at many places, but a variation of geologic structure in this formation is rather remarkable in a place.

Overburden is thin as a whole. But, at the foot of steep cliffs there is considerable thick deposit of debris. In general, talus deposit of left bank is thicker than that of right bank.

For preparing this report, geological interpretations of 1/25,000 scale aerial photographs covering the project area which were in the possession of EGAT were made. The results which are given in Fig. 4-9 may be outlined as follows:

1) Line patterns which are thought probably to be boundaries of strata are recognizable.

2) Judging from the continuation of line patterns, it is estimated there exists a synclinal axis in the NW-SE direction crossing the Quae Yai river midway between dam axis No. 3 and dam axis No. 4.

3) Numerous characteristic lineaments assumed to be faults running in various directions are recognizable.

4) At higher elevations on the left bank downstream of the project area, there can be observed distinguishing factors which differ from those of other areas and this portion is thought to be intrusive rock consisting of granitic rock.

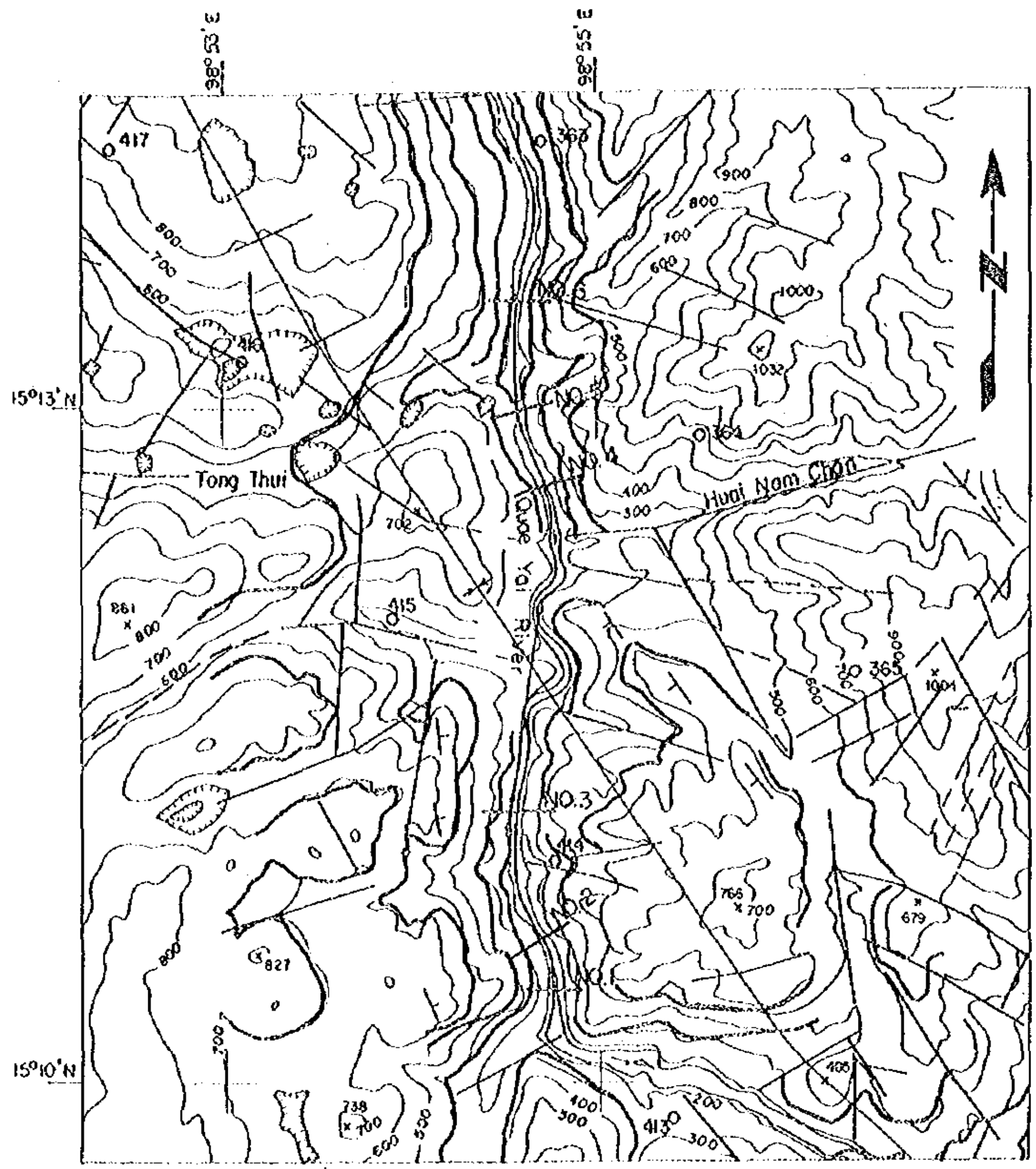
As described above, extremely generalized information has been obtained, but it is not possible to determine everything about the geologic features such as differences in rock type and geologic structure from only information gathered from interpretation of photographs.

The following is a general description which must be performed at this project area in the future to make clear a geologic condition of a reservoir and to decide a final damsite.

The distribution of karstic rock with the risk of presenting leakage paths for reservoir water is not clearly known, but as the karstic rock is surely distributed in the project area and it cannot be clearly denied that there is no possibility such paths may spread out from the damsite to downstream areas and even from the reservoir area to the adjacent basins. Therefore, it is necessary for geological field reconnaissance to be carried out over a wide range, and as a supplementary measure, for interpretations of aerial photographs to be made for the whole project area including its surrounding area to study the distribution and corroded condition of karstic rocks.

Next, after finishing the abovementioned geological investigation, a detail field geological investigation by using a large scale maps such as 1:500 or 1:1,000 is required to confirm a geologic condition of foundation at proposed damsite, to select a final damsite comparing with alternative damsites and to decide a location of drill hole, adit and other prospecting.

In regard to dam construction materials, it appears natural aggregate cannot be counted on since river deposits are shallow. It is assumed from the topographic conditions of this area that obtaining large quantities of core material for construction of rockfill dam will not be easy. Thorough investigations in the future are also necessary in this connection.



Legend

- Assumed boundary of rock facies
- Assumed strike and dip of bed
- Assumed axis of syncline
- Linear feature
  do (deducible image)
- Lineation (joint system)
- Sinkhole
- No.1 Proposed or alternative dam axis and its name
- o417 Principal point of No. 417 photograph

Note ;
The geologic features are interpreted by the view of stereoscope.

0 2 km

Fig. 4-9

Geological Interpretation Map of Aerial Photographs Covering Huai Nam Chon Project Area and its Surroundings.

4) Power Generation Plan

i) Selection of Damsite

For the site of Huai Nam Chon Dam, EGAT has suggested 6 candidate locations as shown in Fig. 4-10. Since it was not possible to carry out a surface reconnaissance in the present field survey, sufficient material for deciding on the damsite from among the abovementioned 6 locations could not be collected.

Therefore, selection of a damsite was made by a 1/5,000-scale topographical map furnished by EGAT and the study of the development scale was carried out based on the selected damsite.

The 1/5,000-scale topographical map furnished by EGAT was not those prepared based on the field surveying, but ones mapped from 1/25,000-scale aerial photographs. Therefore, the accuracy of the map is not so reliable.

Since the river gradient in the project area is extremely gentle, a development system in which discharge is made directly into Ban Chao Nen Reservoir from a dam-type power station would clearly be of great advantage. Therefore, the damsite will be naturally decided in relation to the water level of Ban Chao Nen Reservoir.

Since there is almost no information for judging the geological conditions of the 6 candidate sites, the damsite should be decided upon various studies after future field reconnaissances, topographical surveys and geological surveys.

In the selection of the damsite based on the present 1/5,000-scale topographical map, a point immediately upstream of the Huai Nam Chon River and roughly midway between Dam Axis No. 4 and Dam Axis No. 5 was chosen in consideration of providing a site 1) where the dam spillway and structures related to power generation could be arranged without difficulty, 2) where it would be upstream enough to minimize the effect of care of river on the backwater of Ban Chao Nen Reservoir, and 3) where there would be no influence by the small tributaries at the left and right banks. (Fig. 4-10)

ii) Reservoir Capacity

For the effective storage capacity in the Huai Nam Chon Project, the following cases are conceivable judging from the relation with the Ban Chao Nen Project and the mass curve.

a) Case of Seasonal Regulation of Inflow (Fig. 4-11, Case a)

V_e = 1,720 million cu. m.

b) Case of Regulation for 6 - 8-Year Period (Fig. 4-11, Case b)

V_e = 2,680 million cu. m.

c) Case of Capacity Providing Regulating Effect Identical to Ban Chao Nen Project in accordance with Discharge from Catchment Area of Huai Nam Chon Reservoir (Fig. 4-11, Case c)

V_e = 3,090 million cu. m.

d) Case of Capacity Securing Firm Discharge Corresponding to 20-Year (April 1952 - March 1972) Average Runoff of 94 cu. m./sec. (Fig. 4-11, Case d)

V_e = 3,940 million cu. m.

The relations between high water surface levels and available drawdowns for the above 4 cases are as shown in Fig. 4-13.

It is said that the limit of variable head factor ($\alpha = \frac{\text{Minimum Head}}{\text{Maximum Head}}$) of the Francis turbine is 50%.

Assuming that the development will be with a Francis turbine, even in Case a, the dam height will be 150 m at the limit of α = 50%, while in Case d, the dam height will be close to 190 m at the limit.

This indicates that the storage efficiency at this site is not satisfactory.

Therefore, it was decided that of the 4 cases, two cases of a and b would be selected for examination of the development scale.

iii) Scale of Development

Study of the scale of development was made for the damsite selected in (1) for the two cases of effective storage capacities of V_e = 1,720 million cu.m. (Case a) and V_e = 2,680 million cu.m. (Case b) varying their respective high water surface levels.

The fundamental principles in this study are as follows:

(1) 5 cases of high water surface level of 330 m, 340 m, 360 m, and 370 m for Case a and 5 cases of high water surface level of 340 m, 350 m, 360 m, 370 m and 380 m for Case b or a total of 10 cases were studied.

(2) The rockfill dam type was adopted for study of scale of development.

(3) Although on-site reconnaissance could not be carried out, it was assumed the geological conditions and embankment material would not pose problems.

(4) The number of unit to be installed in the power station was considered to be 4 units for all cases.

(5) The increases in power and energy at Ban Chao Nen Power Station due to the Huai Nam Chon Project was considered that the low water level of the Ban Chao Nen Reservoir would be raised by the amount of the effective capacity of Huai Nam Chon Reservoir, and the corresponding increases in the power and energy from Ban Chao Nen Power Station were added to the benefit of each case.

(6) Since the dead water of Huai Nam Chon Reservoir would decrease the energy from Ban Chao Nen Power Station, at the commencement of filling reservoir the decreases in energy at Ban Chao Nen Power Station corresponding to the dead water amount of the various cases were equalized for the serviceable years and deducted from the benefits.

(7) Regarding the transmission line, from the viewpoint of transmission capacity, it was taken to be 230 kV, 2 cct in case of power plant output of below 500 MW and 230 kV, 3 cct in case of more than 500 MW.

The results of the study are as shown in Table 4-6 and Fig. 4-14. In Case a, namely, the case of effective storage capacity of 1,720 million cu.m., the surplus benefit reaches a maximum point at high water surface level of 360 m, while the benefit-cost ratio reaches a maximum point at high water surface level of 350 m. In Case b, namely, the case of effective storage capacity of 2,680 million cu.m., the surplus benefit reaches a maximum point at a level between 360 m and 370 m, and the benefit-cost ratio reaches a maximum point at high water surface level of 360 m.

When benefit-cost ratios are compared for Case a and Case b at the maximum values, they are of the same value, but as far as surplus benefit is concerned, Case b indicates a bigger value.

Therefore, in the present study, it was deemed that high water surface level of 360 m and maximum output of 600 MW in Case b would be the optimum scale. However, the development scale should be determined upon detailed examination giving full consideration to topographical and geological conditions upon carrying out topographical surveys and geological investigations in the future.

iv) Comparisons of Dam Types

A comparison was made with an arch-type dam for a development scale of high water surface level of 360 m, effective storage capacity of 2,680 million cu.m., and maximum output of 600 MW.

The site of the arch dam was assumed to be located upstream of Dam Axis No. 5, and a comparison was made based on the plan with the spillway provided at the left bank and an underground powerhouse immediately below the arch dam as shown in Fig. 4-15. The results are as shown in the Table 4-7.

As shown in Table 4-7, the results revealed that a rockfill dam would be of greater advantage, but a decision should be made only after carrying out investigations on embankment material and geological surveys to be followed by detailed comparison studies.

For the present, the plan for a rockfill dam was adopted.

Table 4-6 Outline of Alternative Schemes of Huai Nam Chon Project

Item		Unit	Case a					Case b				
Effective Storage		10^6Cu.m			1,720					2,680		
High Water Level		m	330	340	350	360	370	340	350	360	370	380
Available Drawdown		m	43	24	18	15	12	58	33	25	20	18
	Height	m	167	177	187	197	207	177	187	197	207	217
Dam	Crest Length	m	390	420	450	485	525	420	450	485	525	570
	Volume	10^3Cu.m	10,000	11,300	13,000	15,300	18,200	11,300	13,000	15,300	18,200	21,700
Installed Capacity		MW	446	500	540	577	616	490	556	600	640	680
Annual Energy		10^6kWh	919	1,008	1,078	1,146	1,212	999	1,078	1,158	1,234	1,310
Power Increase at Ban Chao Nen P.P.		MW	30	30	30	30	30	46.2	46.2	46.2	46.2	46.2
Energy Increase at Ban Chao Nen P.P.		10^6kWh	16.1	16.1	16.1	16.1	16.1	25.1	25.1	25.1	25.1	25.1
Energy Decrease at Ban Chao Nen P.P.		10^6kWh	11.5	31.2	53.6	81.6	113.3	9.7	32.1	60.1	91.8	125.1
Construction Cost		10^6B	3,222	3,386	3,586	3,815	4,071	3,440	3,660	3,874	4,149	4,419
Benefit (B)		10^6B	293	353	382	406	427	313	380	414	442	462
Cost (C)		10^6B	286	301	319	339	361	305	325	344	368	392
Surplus Benefit [(B)-(C)]		10^6B	7	52	63	67	66	8	55	70	74	70
Benefit Cost Ratio [(B)/(C)]			1.02	1.17	1.199	1.197	1.18	1.02	1.17	1.203	1.200	1.18

Table 4-7 Comparison of Dam Types

Dam Type		Rock-fill	Arch
Dam Height	(m)	197	197
Crest Length	(m)	485	577
Dam Volume	(10^3cu.m)	15,300	1,950
Construction Cost	(10^3฿)	3,874	4,399
Surplus Benefit	(10^6฿)	70	24
Benefit Cost Ratio		1.20	1.06

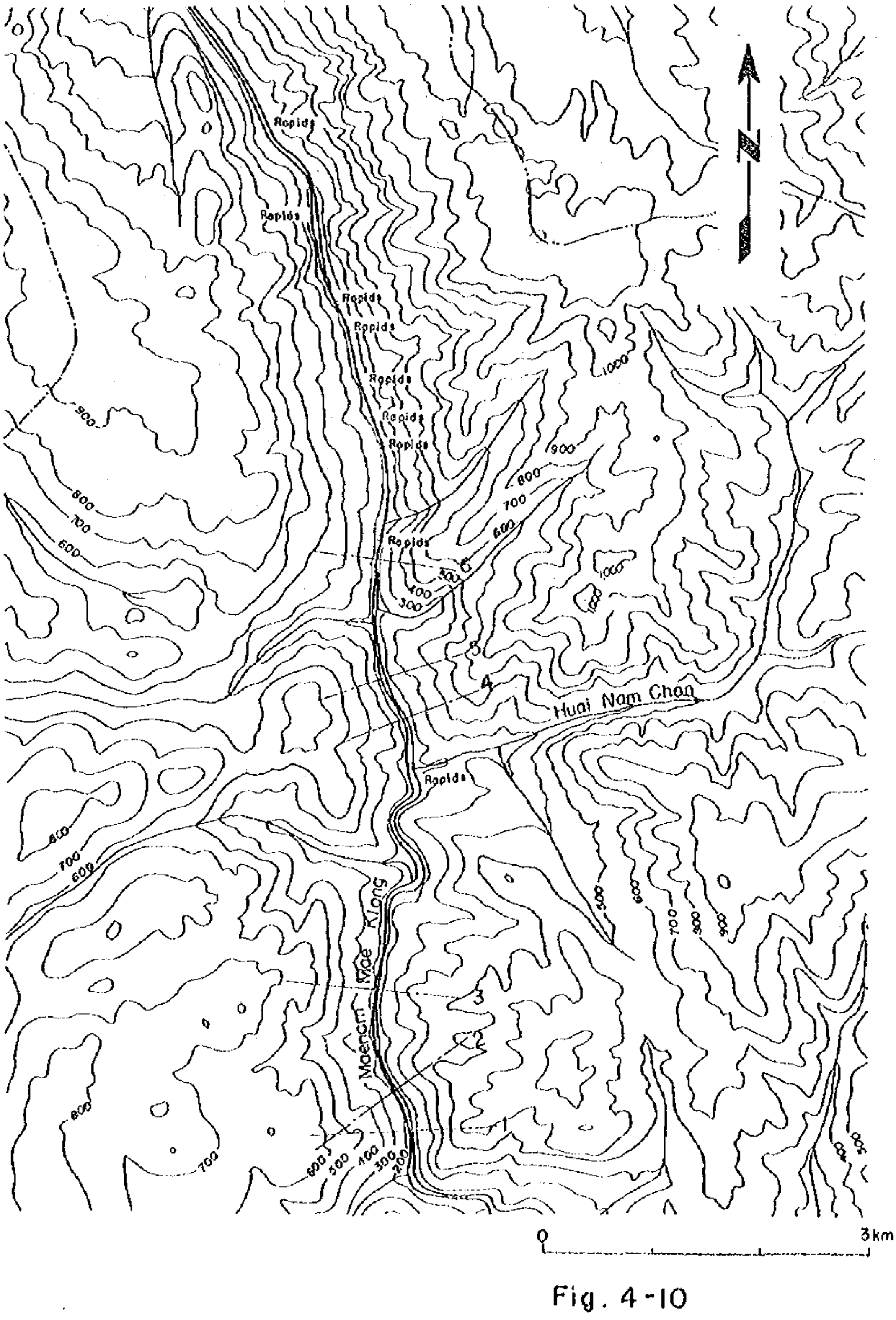
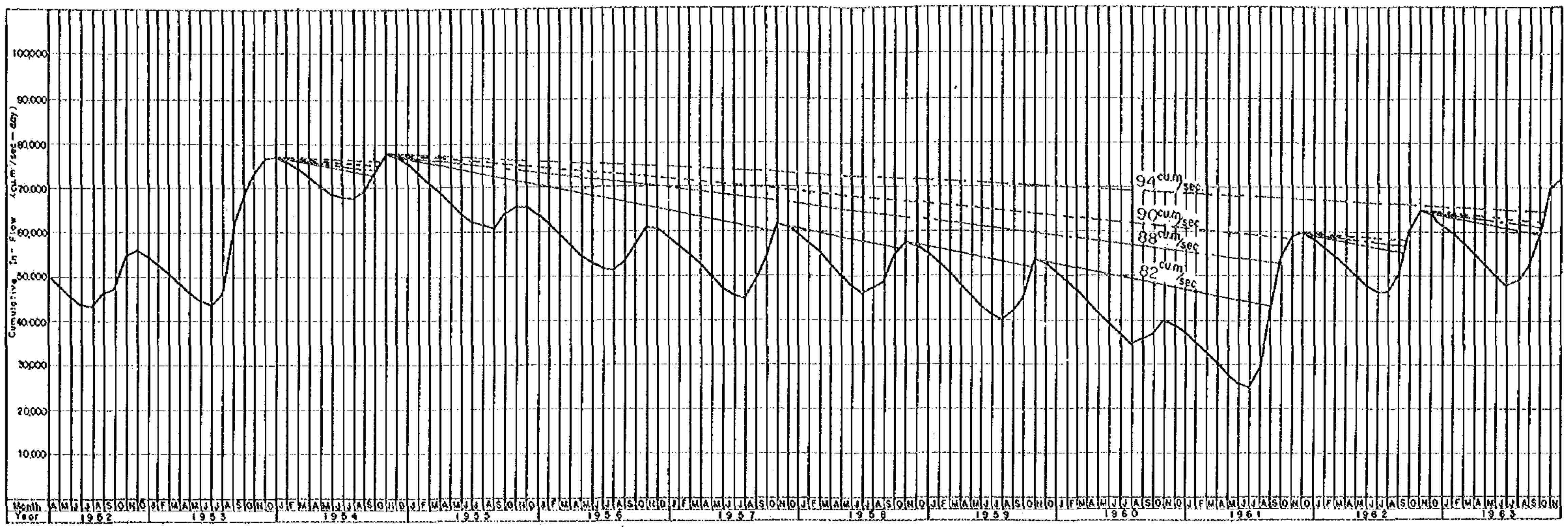
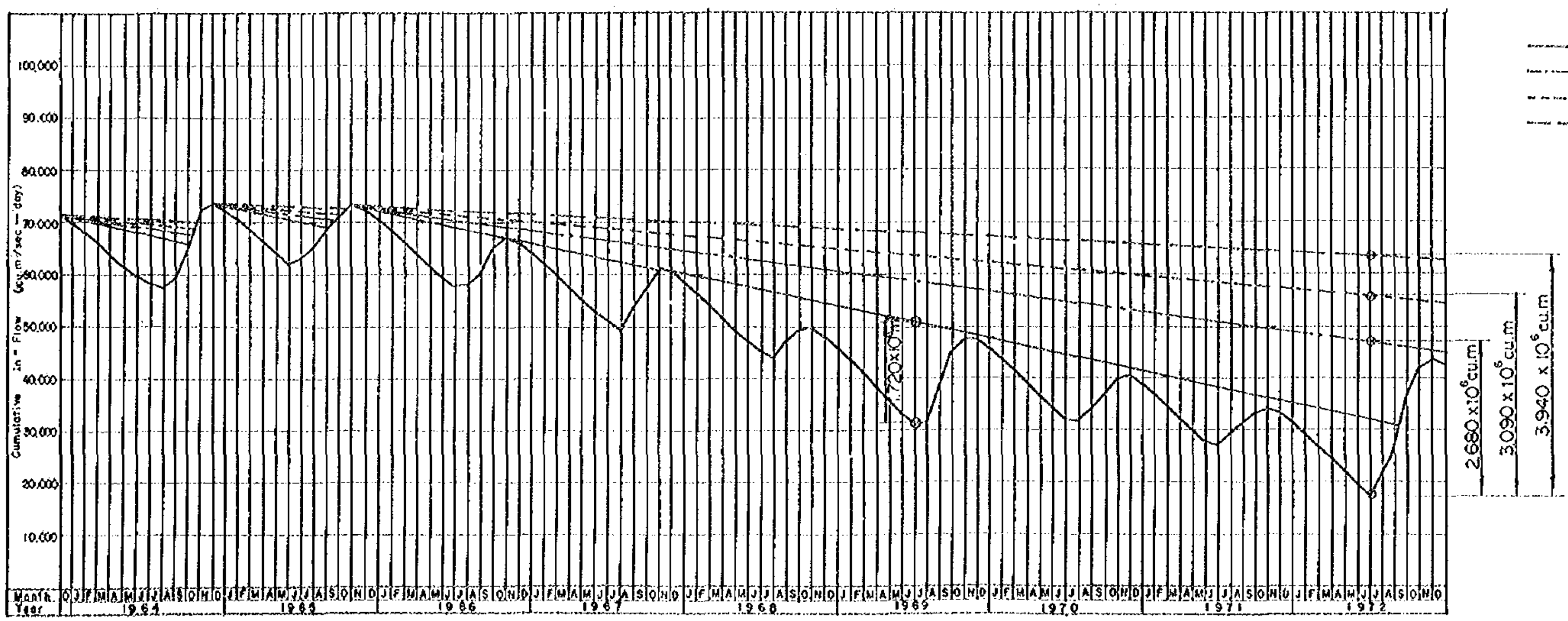


Fig. 4-10
Location of Proposed Dam Sites, for Huai Nam Chon Project.



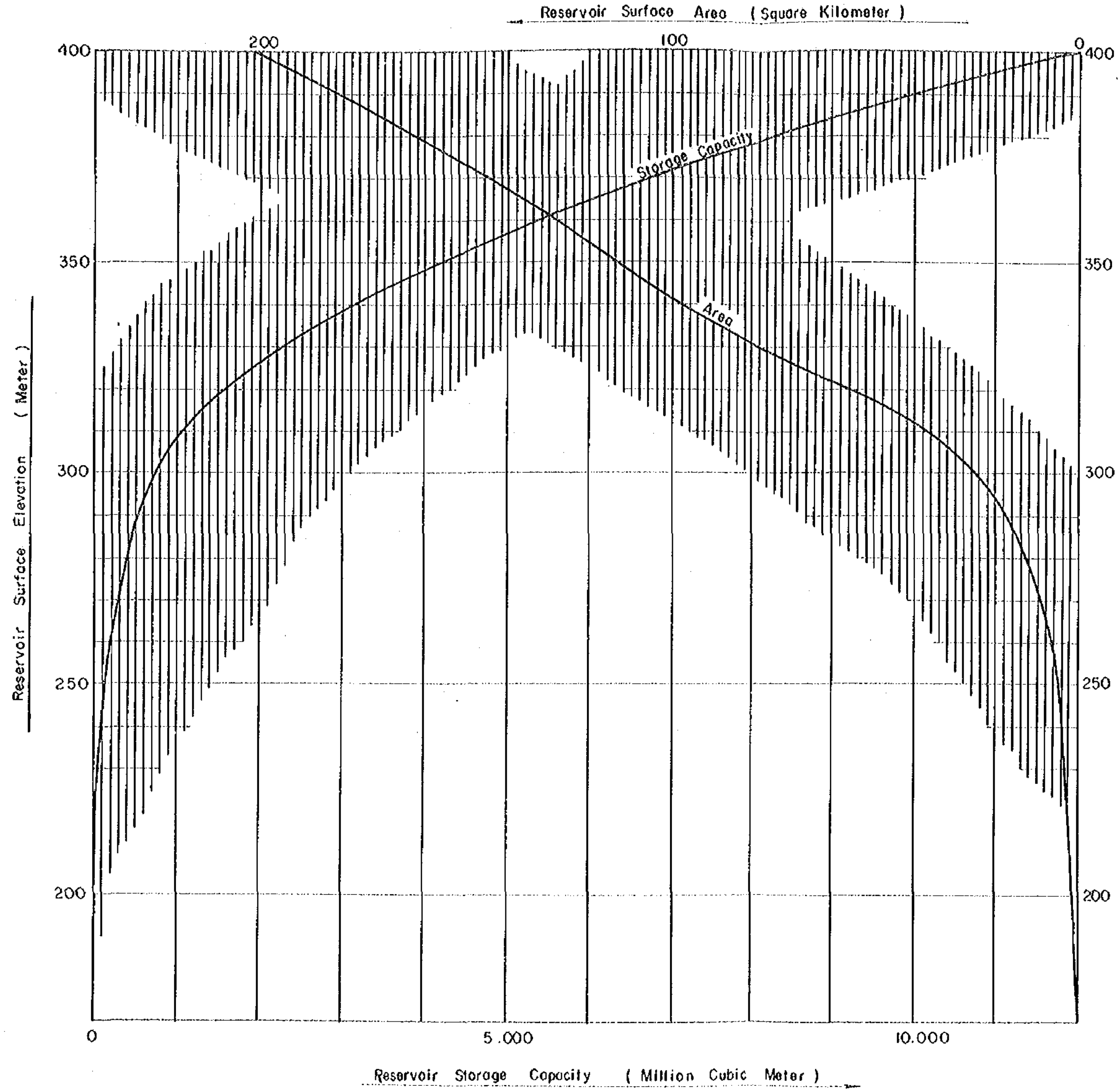


NOTE

- Case - a
- Case - b
- Case - c
- Case - d

Fig. 4-11

Mass Curve at Huai Nam Chon Site.



Elevation (m)	Area (sq. km)	Volume (10^6 cu. m)
400	202.9	11,957.3
380	163.3	8.295.0
360	128.6	5.375.7
340	97.5	3.114.9
320	56.4	1.576.0
300	25.0	762.3
280	12.4	388.3
260	6.4	199.8
240	3.8	98.0
220	2.5	36.0
200	1.1	0

Fig. 4-12
Area Capacity Curve for the Huai Nam Chon Reservoir

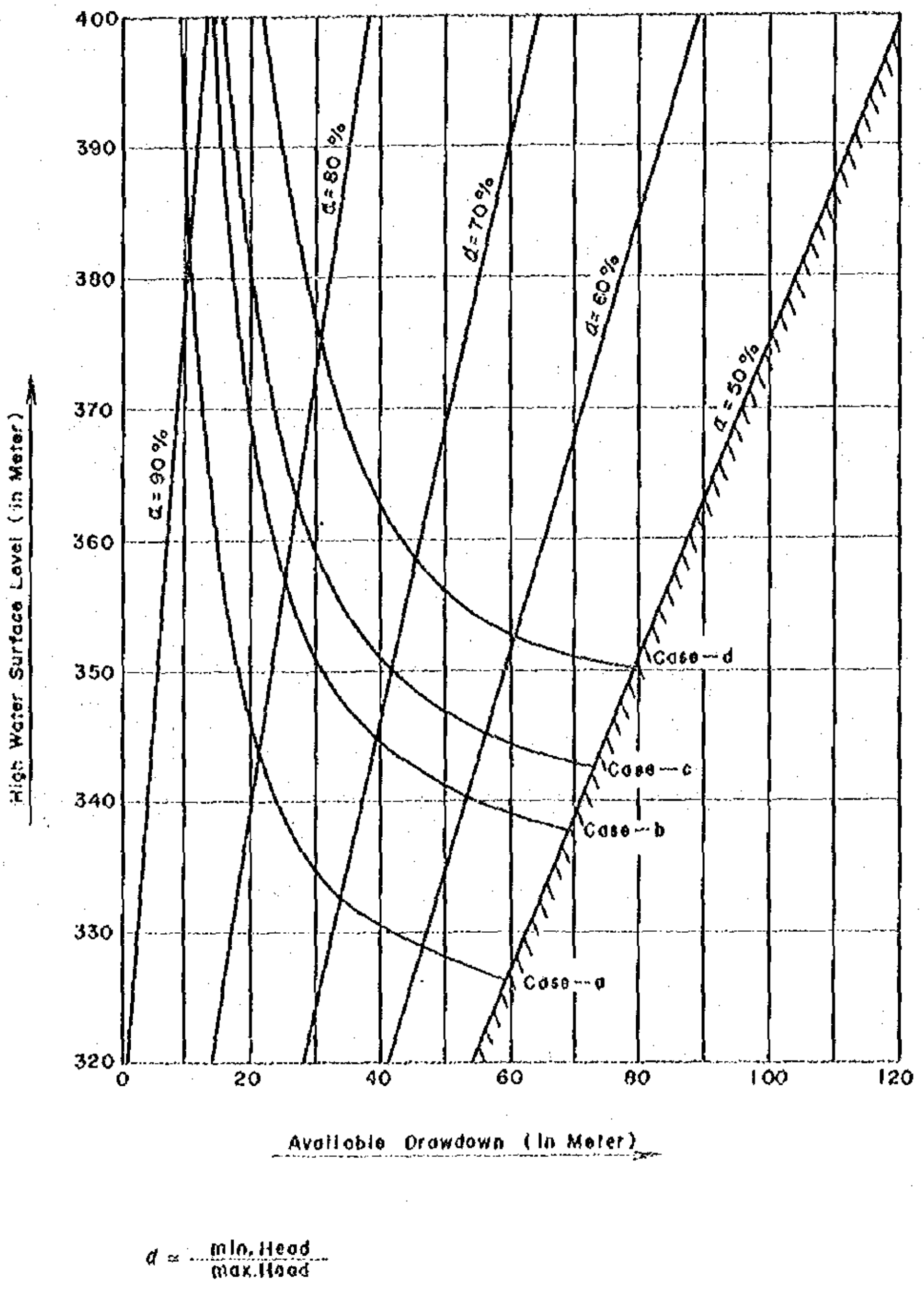


Fig. 4-13
Relation between High Water Surface Level, Available Drawdown and Storage Capacity

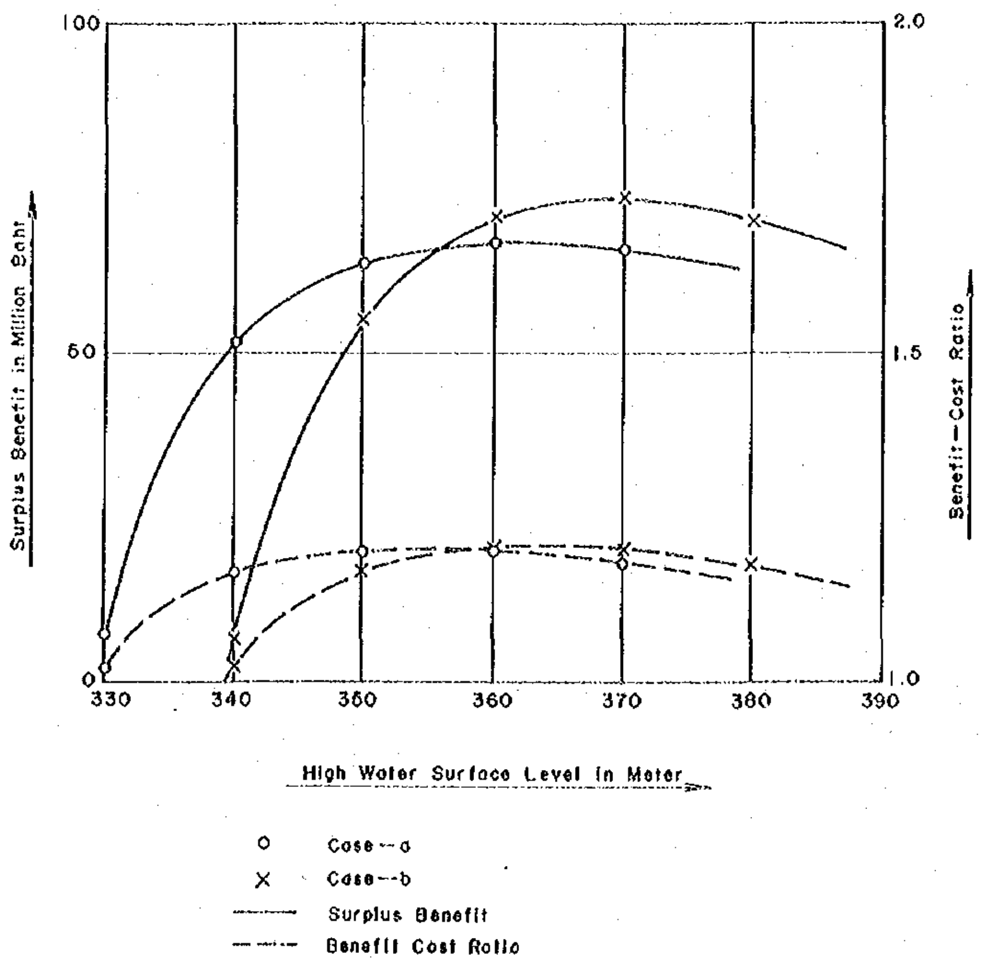


Fig. 4—14
Surplus Benefit and Benefit—Cost Ratio of Alternative Schemes of Huai Nam Chon Project

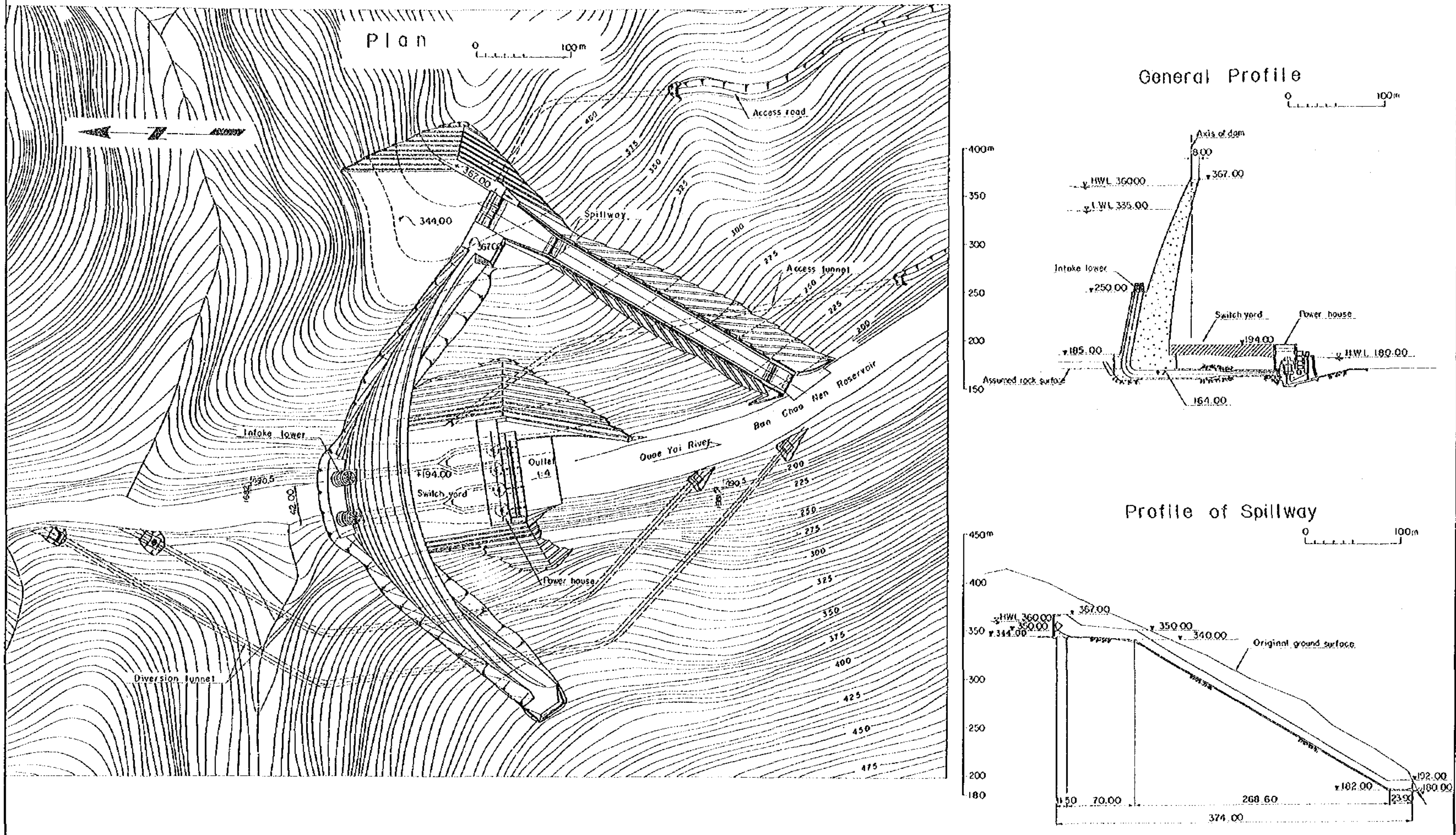


Fig. 4-15

General Plan (Arch Type) of Huai Nam Chon Project

D) Power Transmission Plan

The electric power which would be transmitted, is a maximum output of 600 MW for the Huai Nam Chon Project and a maximum output of 1,000 MW for the Huai Klong Ngu Project as described in Chapter 4.

The approximate range of the transmission voltage is determined by the electric power which should be transmitted, and in making a decision it is necessary that the following conditions be studied.

1) Voltage should be standard one,
2) Voltage should be economical one,
3) Voltage should be suitable for interconnection with the existing power system,
4) Voltage should be suitable even when considering future electric power flow.

The maximum voltage of power systems in Thailand is 230 kV and the total length per circuit as of 1970 was as much as 1,633 km. Further, when Sirikit Power Station (ultimate output, 500 MW) now under construction and Ban Chao Nen Power Station (First Stage, 360 MW) are completed, the length of the abovementioned 230-kV transmission line will be doubled. In the early 1980's, it is planned a nuclear power station with a unit capacity of 600 MW will be put into service.

Except for the Ban Chao Nen Power Transmission Plan for which the transmission voltage has already been decided as the working plan, the standard voltage after 1980 must be studied in view of the long-term electric power development of Thailand as a whole. However, for the purpose of this Report, technical and economical comparisons were made based on the following transmission voltages for the two projects.

1) 230 kV (present maximum voltage)
2) 380 kV
3) 500 kV

1) Relation to Ban Chao Nen Second Stage 360-MW Power Transmission Plan

EGAT at present has plans to construct a 2-cct, 230-kV, 196 km length transmission line from Ban Chao Nen Power Station to Rangsit Substation in order to transmit 360 MW electric power from the First Stage of Ban Chao Nen Project, and further, to construct one additional circuit at the time the Second Stage of the Project, with the installed capacity of 360 MW will be constructed.

As will be discussed in detail in Chapter 5, it is considered appropriate that the timing of development of the abovementioned Second Stage of Ban Chao Nen Project will be around 1987 while the Huai Nam Chon Project would be appropriate around 1988. It is thought suitable that the Huai Klong Ngu Project will be added to the electric power system in 1994. Therefore, technical and economic studies were made of the power transmission scheme taking the 3 power stations mentioned above into consideration.

2) Power Transmission Plan and Construction Cost

For determination of the transmission line scheme, comparative studies were made of 3 power systems as shown in Table 4-8. In this case, since there is only one-year difference in the commencement of power generation of Second Stage of Ban Chao Nen Project (360 MW) and the Huai Nam Chon Project (600 MW), it was considered that construction of transmission line for transmitting the electric power from these two power stations would be carried out simultaneously. On the other hand, Huai Klong Ngu Project would be delayed by 5 years from the above two projects.

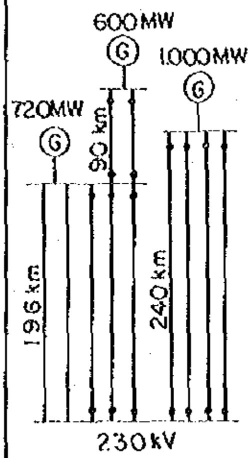
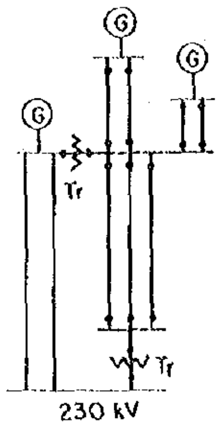
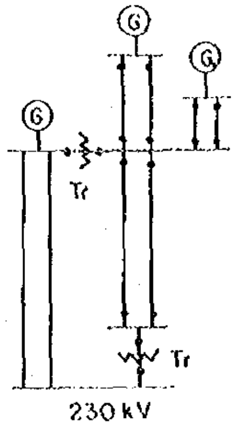
As a result of the study, the lowest construction cost would be a 230-kV transmission line as shown in Table 4-8. As seen from the table, the higher the voltage is raised, the more the construction cost will increase.

3) Transmission Voltage and Transmission Capacity

In transmission of the 720 MW of electric power from Ban Chao Nen Power Station and the 600 MW from Huai Nam Chon Power Station, or a total of 1,320 MW, the results of the studies for power circle diagram show that under the condition of 230-kV and 4 circuits (including the already decided 2 circuits), when the voltage phase angle between Ban Chao Nen Power Station and Rangsit Substation is limited to 30° (generally considered to be the limit for steady-state system stability), the power capability is 1,330 MW so that the transmission capacity is close to the limit. Therefore, it was assumed that an additional 230-kV, 3-cct line would be constructed in step with the Second Stage of Ban Chao Nen Project (360-MW) in consideration of stoppage of one circuit of the transmission line and transmission line faults due to lightning strikes or other causes. Around 1994, it would be necessary to construct a 230-kV, 4-cct transmission line of 240 km length between Huai Klong Ngu Power Station and Rangsit Substation or other substation in the neighborhood in step with construction of power station (See Fig. 4-16).

It may be added as a note that none of the power systems indicated in Table 4-8 involves any technical problem.

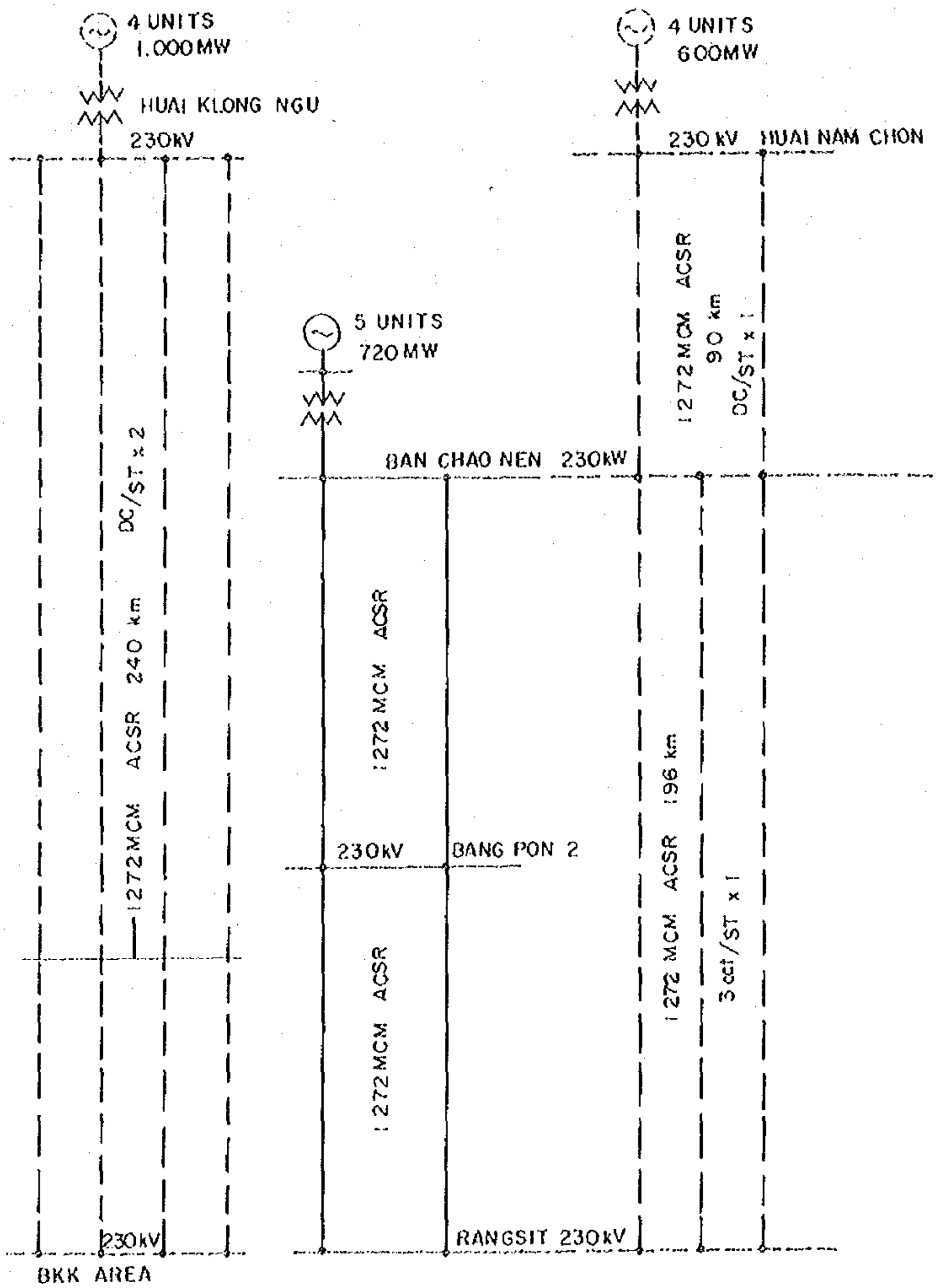
Table 4-8 Comparison of Transmission Line Schemes

Item	Unit	Case 1	Case 2	Case 3
Voltage	kV	230	380	500
Conductor		ACSR 610 mm²	ACSR 410 mm² x 2	ACSR 330 mm² x 4
Transmission Capacity ※	MVA	3.800	4.100	5.800
Outline of Power System				
Construction Cost	10^6 ∅	1.020 (100 %)	1.180 (115 %)	1.700 (166 %)

※ Note)

Transmission Capacity is Calculated Based on the Safety Current of Conductor

Fig. 4-16 Transmission Line Diagram



CHAPTER 5

LOAD FORECAST
AND
TIMING OF DEVELOPMENT

CHAPTER 5. LOAD FORECAST AND TIMING OF DEVELOPMENT

A) General

1) Present situation of electricity demand

Power demand at generating end of whole Thailand recorded 1,029 MW and 5,711 million kWh as a maximum peak load and an annual generation energy, respectively. Annual growth rate of power demand in past decade from 1962 to 1972 was 24.7% and 27.6% in term of kW and kWh, respectively.

During the period from 1964 to 1969, the economy of Thailand was remarkably developed by the influence of the Vietnam War, while at the same time, growth of power demand was also notable resulting in 40.6% of increase in 1965 in comparison with a figures recorded in the previous year. Since, the Thai Government positively carried out power development from beginning of 1960's, the total installed capacity is 1,391 MW of which hydro is 475 MW and thermal 916 MW in 1972. During the last decade, Bumibol Power Plant which was developed as a large scale hydro power station with reservoir was put in service in 1964, which has actual total installed capacity of 420 MW (Final installed capacity 560 MW) with the addition of units, while South Bangkok Power Plant which was constructed as a large scale steam power station was also put in service adding 200 MW unit each in 1970 and 1972, respectively.

2) History

The first systematic forecast of electric power demand in Thailand was made by a study team dispatched by USOM in 1966 and a report called the "Moulton's Report" was submitted. Since there were no data necessary and adequate for making demand forecast at that time, the USOM team made its forecast based on the economic indexes in the Second Social and Economic Development Plan (1967 - 1971) which was then made public. This forecast reflected the economic boom which had continued in Thailand up to 1966 and average annual growth rates of load were assumed as 22% for the 5-year period from 1966 through 1970 and 17% for the 5-year period from 1971 through 1975.

In 1969, a review of the power demand forecast for Thailand was made again by the USOM study team and a report called the "Jones' Report" was published.

In forecasting demand the USOM team classified the areas supplied by MEA, PEA and directly by EGAT into 4 to 7 categories of consumers based on statistical data which had been considerably improved by the Thai Government agencies concerned, and then estimated the number of customers and energy consumption per customer by each category, thereby obtaining the demand for entire Thailand. As a result extremely high rates were obtained for average annual growth; 24% from 1969 to 1973 and 17.5% from 1974 to 1978. These figures are apparently direct reflection of the abnormal economic boom in Thailand which had continued for several years up to 1969. However, after 1969 when the report was submitted, the growth rate of GDP dropped from 8% to 6% and the growth rate of annual government revenue dropped from 8.9% to 4.2% as shown in Table 5-1. The actual growth of power demand in 1971 fell below the forecast of Jones' Report by 447 MW or as much as 51%.

Table 5-1 Actual Record of Economic Indexes in Second Five-Year Plan

	Unit	1967 - 1969	1970 - 1971
Growth Rate of Gross Domestic Production (GDP)	%	8.0	6.0
Growth Rate of National Treasury Revenue and Expenditure	%	8.9	4.2
Growth Rate of Government Revenue	%	13.5	3.8
Growth Rate of Government Expenditure	%	15.1	8.5
Growth Rate of Private Investment	%	16.0	2.0
Foreign Currency Reserves	10^6 ฿	+848	-3,972

EGAT revises its long-term power development plans every year by incorporating the actual record of the preceding year.

Several forecasts made in the past on the maximum electric power demands and the growth rates for Thailand are as tabulated below.

(Unit: MW)

Report	1971	1980	Annual Growth Rate
Jono's Report Forecast	1,320	(7,000)	20.3%
Moulton's Projection "A"	1,180	4,150	15.0%
Moulton's Projection "B"	1,110	3,110	12.1%
EGAT Forecast	873	2,772	13.5%

B) Macroscopic Forecast

Based on the discussions with EGAT, the survey mission adopted in this report the figures of load forecast which had been prepared by EGAT.

Macroscopic forecast, as described below, was made in this report for comparison with the EGAT forecast.

1) Basic consideration for macroscopic forecast

i) Correlation between GDP and kWh

It is a well-known fact that electric power energy consumption (kWh) of any country has a very good correlation with gross domestic production (GDP) which reflects the economic activities of the country comprehensively. The trend of the future power demand of Thailand can be grasped macroscopically utilizing this relationship.

The relationship between per capita energy production are as graphically shown in Fig. 5-1 for 54 major countries of the world as of 1969.

Actual records of per capita GDP and per capita kWh of Thailand up to 1969 are shown in Fig. 5-1, which are plotted below the world average curve.

The relationship of per capita GDP and per capita kWh after 1970 is indicated with dotted line on Fig. 5-1, based on the assumption that it will grow and come closer gradually to the world average curve.

ii) Growth rate of population

According to the ECAFE Statistical Year Book, the population of Thailand in 1970 was 34,380,000 showing an average increase of 3.0% from 1960 to 1970. However, in the "Third National Economic and Social Development Plan", a policy of family planning to lower the growth rate of population to

2.5% by 1976 has been adopted, and thus it was assumed the annual rate would be decreased gradually from 3% to 2.0% in 1990.

The average annual growth rate over the period will be 2.6%.

iii) Growth rate of GDP

Actual growth rate of GDP of Thailand was 8.1% for the First Six-year Plan period (starting in 1961 and ending in 1966) and 7.2% is assumed for the Second Five-year Plan period (starting in 1967 and ending in 1971). Growth rate of 7% is established, as a target, in the Third Five-year Plan starting in 1971.

Based on these actual records and target value, it is considered that an annual growth rate of 7% would be appropriate for the present study. However, in consideration of possible fluctuation in the economic activities, growth rate of 8% and 6% were also taken in the estimation of kWh demand.

2) Forecast of Power Demand

Based on the basic consideration stated in 1) above, total energy production of Thailand as of 1980, 1985 and 1990 as well as average increase rates over the 10 year-periods from 1970 to 1980 and from 1980 to 1990 were calculated as shown in Table 5-2.

Table 5-2 Forecasted Energy Production

(in million kWh)

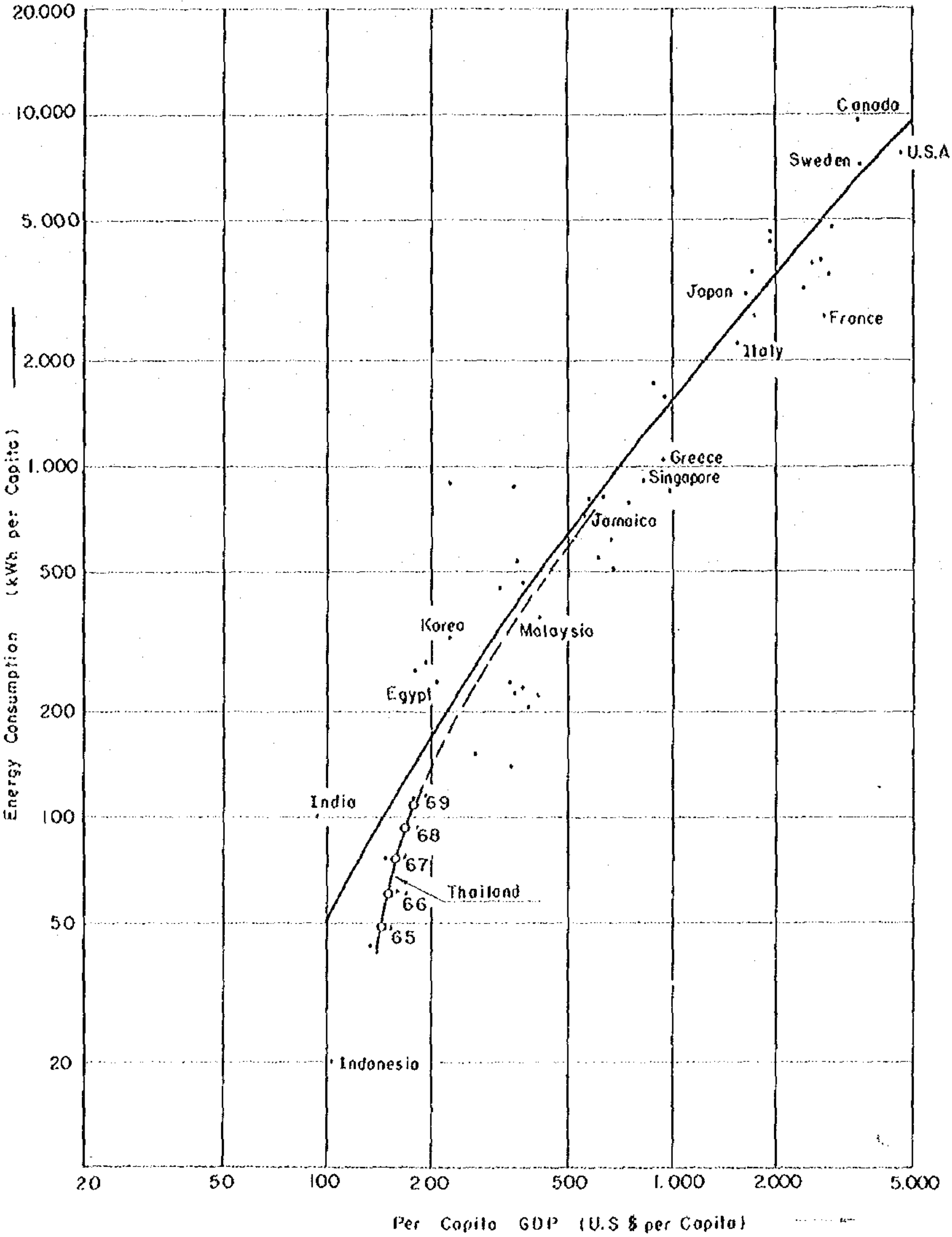
	Growth Rate of GDP (%)	1980	1985	1990
Case I	6	13,500	24,100	41,300
	-	(11.8%)1/		(11.7%)2/
Case II	7	16,310	29,900	55,300
	-	(13.9%)1/		(13.0%)2/
Case III	8	19,100	36,700	68,840
	-	(15.7%)1/		(13.8%)2/
EGAT Estimate	-	15,800	24,800	36,500
		(13.7%)1/		(8.7%)2/

Note: 1/ Growth rate of Energy demand from 1970 up to 1980.

2/ Growth rate of Energy demand from 1980 up to 1990.

The results of the calculation show the EGAT forecast well corresponds to the macroscopic forecast with annual growth rates of GDP estimated at 6% to 7%.

Fig. 5-1 Per Capita GDP and Per Capita Energy Production
Source : U.N. Year Book in 1970



C) Timing of Development

The development program for power generating facilities in Thailand for the period from 1973 to 1985 has already been prepared by EGAT, and the present study was made assuming that the development program contemplated by EGAT would be realized accordingly and that the Huai Nam Chon and Huai Klong Ngu Projects would be developed after 1985.

The major projects which will be put into service on the power system of Thailand up to 1985 are hydro-projects including Sirikit No. 1, No. 2, No. 3 (totalling 375 MW), Ban Chao Nen First Stage No. 1, No. 2, No. 3 (totalling 360 MW) and Quae Noi No. 1, No. 2, No. 3, (totalling 420 MW) and thermal projects including No. 3, No. 4 and No. 5 of South Bangkok (totalling 900 MW) and No. 1, and No. 2 of New Mae Moh (totalling 150 MW). While, the first nuclear power station in Thailand with a capacity of 600 MW will be in service at the end of 1980, which will be followed by No. 2 unit (600 MW) scheduled to join the system 4 years later. Looking at the ratio between hydro and thermal (including nuclear, gas turbine and diesel) power generating facilities, hydro comprises 34 - 43% and thermal 57 - 60%. Regarding energy supply capability, shares of hydro and thermal are 18% and 82%, respectively, on an average in terms of firm energy (See Fig. 5-2 and Fig. 5-3).

The following principles were adopted in framing up development scheme for the period after 1985.

1) Installation program for each year was established to balance the maximum power demand with the firm capacity which would be calculated by deducting maximum unit capacity from the sum of dependable peaking capacity of hydro power plants and installed capacity of thermal power plants.

2) Annual energy production of generating facilities was calculated based on the firm energy for hydro power plants and plant factors of 90% in the first year and 80% in the following years for the thermal power plants.

3) The power plants which were taken into consideration were as follows:

Name of Project	Installed Capacity MW	Dependable Capacity MW	Annual Firm Energy	Remarks
Ban Chao Nen 2nd Stage	360	360	-	Pumping up 180MW x 2 units
Huai Nam Chon	600	541	1,040 x 10^6kWh	150MW x 4 units
Huai Klong Ngu	1,000	1,000	-	250MW x 4 units
Thermal (Nuclear)	600	600	4,205 x 10^6kWh	First year 4,730 x 10^6kWh

Based on the above principles, the timing for start-up of the projects examined from only kW and kWh balance in relation to demand forecast is as shown in Fig. 5-4 and Tables 5-3, 5-4 and 5-5.

The timing for placing into service of the projects would be as follows from the standpoint of supply and demand balance:

(1) Huai Nam Chon Hydroelectric Project (600 MW) around 1988

(2) Huai Klong Ngu Pumped Storage Project, 1st Stage (500 MW) around 1994

(3) Huai Klong Ngu Pumped Storage Project, 2nd Stage (500 MW) around 1996

On the other hand, for the Huai Nam Chon Hydroelectric Project, the timing of start-up is also examined not from the standpoint of supply and demand, but from that of the construction schedule. At present the completion of the First Stage of Ban Chao Nen Project (360 MW) is scheduled at the end of 1979 according to the development program of EGAT. Since the Huai Nam Chon Project would be located upstream of Ban Chao Nen Project and it is desirable the start of construction of Huai Nam Chon Project be after completion of Ban Chao Nen Project for reasons of construction work, if construction of the Huai Nam Chon Project is to be started immediately after completion of Ban Chao Nen Project, preparatory works would require 2 to 3 years and the main works about 6 years so that the completion of the Huai Nam Chon Project would be around 1986 or 1987.

D) Pumped Storage Power Station and Power Sources for Pump-up

Pumped storage power stations utilize surplus power, during high-water seasons or during off-peak hours in the night-time and holidays, to pump up and store water which would be discharged during peak hours for power generation and consist of the following two types:

1) Stations for maintaining supply and demand balance ignoring economy because of lack of supply capability (marginal pumped storage power generation or kW pumped storage power generation).

2) Stations with economic advantage in comparison of cost reductions due to pumped storage power generation and cost increases due to pump-up (economical pumped storage power generation).

In the future, as the system capacity becomes larger with increase in demand, unit capacity of thermal (nuclear) power plants will grow as large as 600 MW, while water resources which can be developed as peak supply capability will become exhausted, and development of pumped storage power stations for peak power supply will thus become leading sources of power. However, for pumped storage power stations it will be necessary to secure electric power for pump-up, and prior to development of the pumped storage power stations a long-term outlook on sources of electric power for pump-up must be grasped.

If it is assumed that the present daily load curve in Thailand will not be changed fundamentally in the future, it is thought that operation of pumped storage power stations will be as described below.

1) Available duration of time for midnight pumping-up operation will be 5 to 6 hours.

2) Peak-hours of Thailand are 4 hours at present. As industrialization of Thailand progresses, the load pattern will change accordingly. It is estimated that peak-hours will become longer in the future.

In consideration of the above factors it is considered appropriate that the average annual operating hours of the pumped-storage power plants is 1,000 hours.

The Huai Klong Ngu Pumped Storage Project is of a large capacity as big as 1,000 MW in output. Since the power sources required for pump-up would be 550 MW x 5h in 1987 from the present development program of EGAT and the supply and demand situation, it may be said it would be impossible to put Huai Klong Ngu Project into service prior to the year taking the installed capacity of Ban Chao Nen 2nd stage into consideration. After 1987, when large capacity thermal (nuclear) power stations required from the standpoint of supply and demand are started up, power sources for pump-up calculated from the daily load curve are as follows (See Fig. 5-5).

In 1987	550 MW x 5h
1990	800 MW x 5h
1992	1,000 MW x 5h
1994	1,300 MW x 5h
1996	1,500 MW x 5h

Table 5-3 Load Forecast and kW Balance

Unit : MW

Fiscal Year	Perk Generation (A)	Installed Capacity Existing Hydro	Installed Capacity Existing Thermal	Installed Capacity Existing Gas & Diesel	Installed Capacity Existing Total (B)	Installed Capacity New Plant Hydro	Installed Capacity New Plant Thermal	Installed Capacity New Plant Total (C)	Installed Capacity New Plant ΣTotal	Total Installed Capacity Hydro	Total Installed Capacity Thermal	Total Installed Capacity Gas & Diesel	Total Installed Capacity Total D	Total Dependable Capacity (E)	Max Thermal Unit (F)	Firm Capacity (G)	Reserve Capacity (E)-(A) (H)
1972	1.029	475	710	206	1.391	—	—	—	—	475	710	206	1.391	1.352	200	1.152	323
1973	1.228	475	710	206	1.391	165	30	195	195	640	710	206	1.586	1.506	200	1.306	278
1974	1.421	475	710	206	1.391	269	300	569	764	909	1.040	206	2.155	1.989	300	1.689	568
1975	1.614	475	710	206	1.391	50	—	50	814	959	1.040	206	2.205	2.039	300	1.739	425
1976	1.840	475	710	206	1.391	12	300	312	1.126	971	1.340	206	2.517	2.349	300	2.049	509
1977	2.039	475	710	206	1.391	40	75	115	1.241	1.011	1.415	206	2.632	2.461	300	2.161	422
1978	2.265	475	710	206	1.391	—	375	375	1.616	1.011	1.790	206	3.007	2.836	300	2.536	571
1979	2.487	475	710	206	1.391	240	—	240	1.856	1.251	1.790	206	3.247	3.052	300	2.752	565
1980	2.722	475	710	206	1.391	180	—	180	2.036	1.431	1.790	206	3.427	3.211	300	2.911	489
1981	2.970	475	710	206	1.391	60	600	660	2.696	1.491	2.390	206	4.087	3.861	600	3.261	891
1982	3.240	475	710	206	1.391	420	—	420	3.116	1.911	2.390	206	4.507	4.206	600	3.606	966
1983	3.530	475	710	206	1.391	—	—	—	3.116	1.911	2.390	206	4.507	4.206	600	3.606	676
1984	3.850	475	710	206	1.391	—	600	600	3.716	1.911	2.990	206	5.107	4.805	600	4.205	955
1985	4.195	475	710	206	1.391	—	600	600	4.316	1.911	3.590	206	5.707	5.405	600	4.805	1.210
1986	4.535	475	710	206	1.391	—	—	—	4.316	1.911	3.590	206	5.707	5.405	600	4.805	870
1987	4.900	475	710	206	1.391	360	—	360	4.676	2.271	3.590	206	6.067	5.765	600	5.165	865
1988	5.295	475	710	206	1.391	—	600	600	5.276	2.271	4.190	206	6.667	6.365	600	5.765	1.070
1989	5.720	475	710	206	1.391	600	—	600	5.876	2.871	4.190	206	7.267	6.906	600	6.306	1.186
1990	6.180	475	710	206	1.391	—	600	600	6.476	1.871	4.790	206	7.867	7.506	600	6.906	1.326
1991	6.675	475	710	206	1.391	—	600	600	7.076	2.871	5.390	206	8.467	8.106	600	7.506	1.431
1992	7.210	475	710	206	1.391	—	—	—	7.076	2.871	5.390	206	8.467	8.106	600	7.506	896
1993	7.790	475	710	206	1.391	—	600	600	7.676	2.871	5.990	206	9.067	8.706	600	8.106	916
1994	8.415	475	710	206	1.391	500	600	1.100	8.776	3.371	6.590	206	10.167	9.806	600	9.206	1.391
1995	9.090	475	710	206	1.391	—	600	600	9.376	3.371	7.190	206	10.767	10.406	600	9.806	1.316
1996	9.820	475	710	206	1.391	500	600	1.100	10.476	3.871	7.790	206	11.867	11.506	600	10.906	1.686
1997	10.600	475	710	206	1.391												

Table 5-4 Load Forecast and Energy Balance

Unit : Million KWH

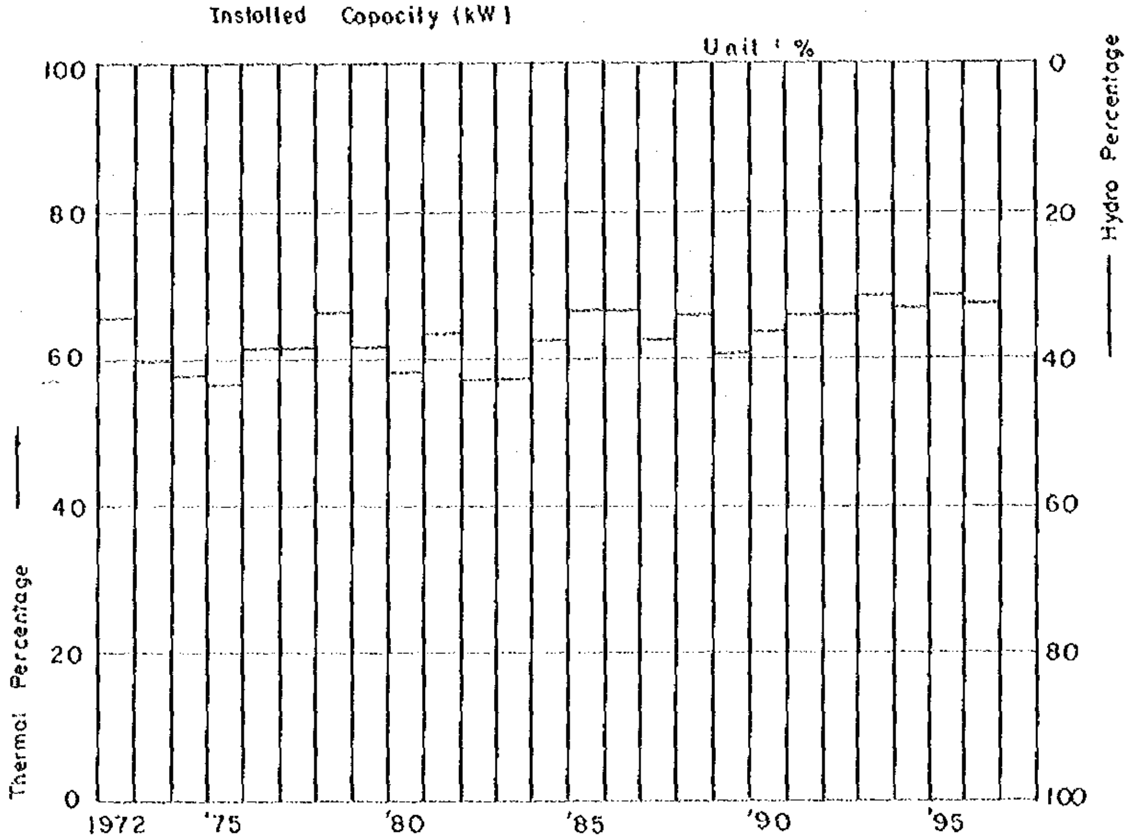
Fiscal Year	Energy Demand		Annual Load Factor %	Firm Energy Generation				Average Energy		Reserve Energy From Firm	Reserve Energy From Average
	KWH x 10^6	Increce %		Hydro	Thermal	Gas & Diesel	Total	Hydro	Total		
1972	5.711	—	63.4	994	4.965	361	6.320	1.703	7.029	609	1.318
1973	6.805	19.2	63.3	1.123	5.115	180	6.418	1.899	7.194	△ 387	389
1974	8.041	18.2	64.6	1.704	6.372	180	8.256	2.812	9.364	215	1.323
1975	9.038	12.4	63.9	1.763	7.289	180	9.232	2.886	10.355	194	1.317
1976	10.466	15.8	64.9	2.129	9.259	180	11.568	3.253	12.692	1.102	2.226
1977	11.672	11.5	65.4	2.139	9.884	180	12.203	3.269	13.333	531	1.661
1978	13.007	11.4	65.5	2.249	12.179	180	14.608	3.445	15.804	1.601	2.797
1979	14.284	9.8	65.6	2.459	12.545	180	15.184	3.735	16.460	900	2.176
1980	15.842	10.9	66.5	3.099	12.545	180	15.824	4.619	17.344	△ 18	1.502
1981	17.425	10.0	67.0	3.229	16.485	180	19.894	4.802	21.467	2.469	4.042
1982	19.080	9.5	67.2	3.469	16.750	180	20.399	5.130	22.060	1.319	2.980
1983	20.855	9.3	67.4	4.169	16.750	180	21.099	6.189	23.119	244	2.264
1984	22.730	9.0	67.4	4.169	20.288	180	24.637	6.189	26.657	1.907	3.927
1985	24.775	9.0	67.4	4.169	21.349	180	25.698	6.189	27.718	923	2.943
1986	26.800	8.0	67.5	4.169	25.160	180	29.509	6.189	31.529	2.709	4.729
1987	29.000	8.0	67.5	4.169	25.160	180	29.509	6.189	31.529	509	2.529
1988	31.300	8.0	67.5	4.169	27.525	180	31.874	6.189	33.894	574	2.594
1989	33.900	8.0	67.5	5.209	29.365	180	34.754	7.347	36.892	854	2.992
1990	36.550	8.0	67.5	5.209	31.730	180	37.119	7.347	39.257	569	2.707
1991	39.500	8.0	67.5	5.209	34.752	180	40.141	7.347	42.279	641	2.779
1992	42.650	8.0	67.5	5.209	37.780	180	43.169	7.347	45.307	519	2.657
1993	46.100	8.0	67.5	5.209	41.985	180	47.374	7.347	49.512	1.274	3.412
1994	49.800	8.0	67.5	5.209	45.518	180	50.907	7.347	53.045	1.107	3.245
1995	53.750	8.0	67.5	5.209	49.723	180	55.112	7.347	57.250	1.362	3.500
1996	58.100	8.0	67.5	5.209	53.930	180	59.319	7.347	61.457	1.219	3.357

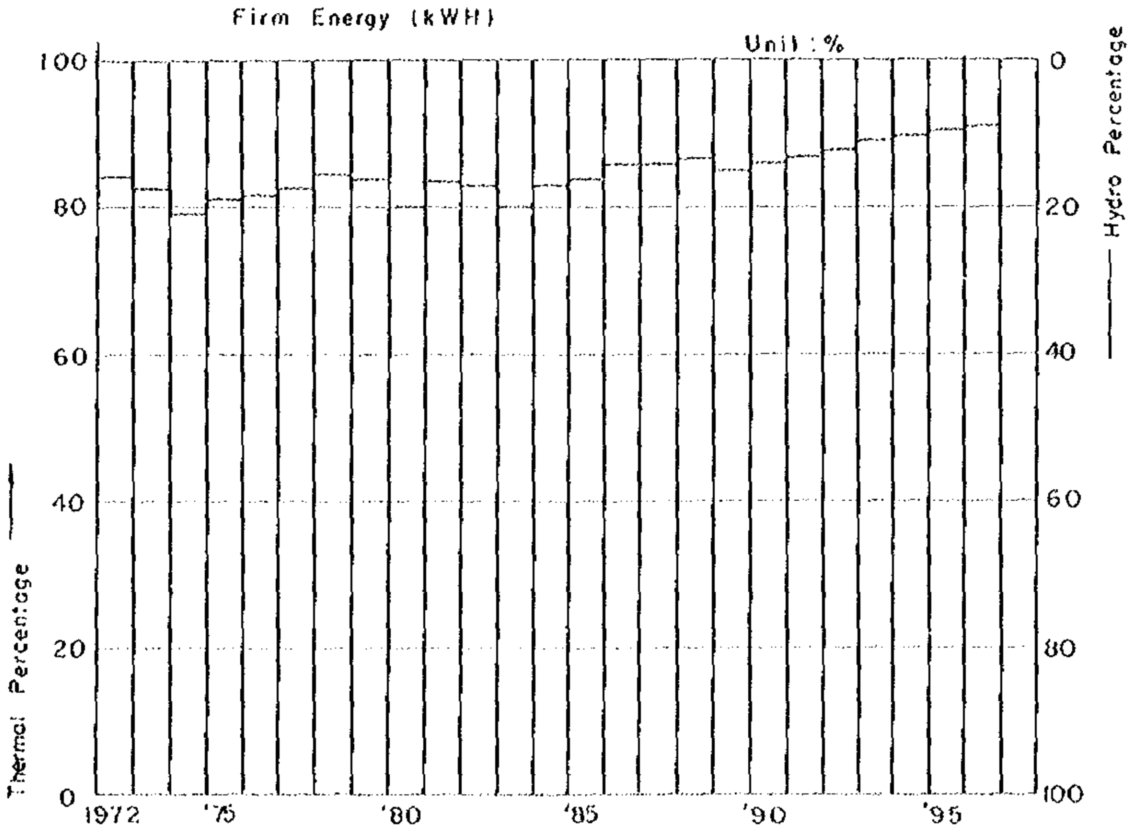
Table 5-5 Tentative Development Plan

Unit : MW

Calendr Year	Month	Project Name	Installed Capacity			Dependable Capacity		
			Hydro	Thermal	Total	Hydro	Thermal	Total
1972	OCT.	CHULA BHORN #1,#2	40		40	39		39
1973	MAR	SURAT THANI #1		30			30	
	SEP	SIRIKIT #1	125			85		
	NOV	SIRIKIT #2	125		280	85		200
1974	MAR	SIRIKIT #3	125			85		
	APR	SOUTH BANGKOK #3		300			300	
	MAY	KANG KRACHAN #1	19		444	13.3		398.3
1975	SEP	NAM NGUM SURPLUS	50			50		
	DEC	SOUTH BANGKOK #4		300	350		300	350
1976	MAR	SIRINDHORN #3	12			10		
	DEC	NEW MAE MOH #1		75	87		75	85
1977	SEP	PATTANI #1,#2	40			36.6		
	DEC	NEW MAE MOH #2		75	115		75	111.6
1978	JAN	SOUTH BANGKOK #5		300	300		300	300
1979	JUL	BAN CHAO NEN #1	120			108.3		
	SEP	BAN CHAO NEN #2	120			108.3		
	NOV	BAN CHAO NEN #3	120		360	108.3		324.9
1980	SEP	FUTURE HYDRO (R3)	60			50		
	DEC	NUCLEAR #1		600	660		600	650
1981	AUG	KUD PROJECT	60		60	50		50
1982	AUG	QUAE NOI #1,#2,#3	420		420	345		345
1984	JAN	NUCLEAR #2		600	600		600	600
1985	SEP	FUTURE THERMAL		600	600		600	600
1987	JUN	BAN CHAO NEN #4,#5	360		360	360		360
1988	APR	NEW THERMAL		600			600	
1988	OCT	HUAI NAM CHON #1,2,3,4	600		1.200	541		1.141
1990	APR	NEW THERMAL		600	600		600	600
1991	JUL	NEW THERMAL		600	600		600	600
1992	OCT	NEW THERMAL		600	600		600	600
1994	JAN	NEW THERMAL		600			600	
1994	JAN	HUAI KLONG NGU #1,#2	500		1.100	500		1.100
1995	JAN	NEW THERMAL		600	600		600	600
1996	JAN	NEW THERMAL		600			600	
1996	JAN	HUAI KLONG NGU #3,#4	500		1.100	500		1.100
		Total	3.396	7.080	10.476	3,074.8	7.080	10,154.8

Fig. 5-2 Transition of Thermal & Hydro Percentage of EGAT System





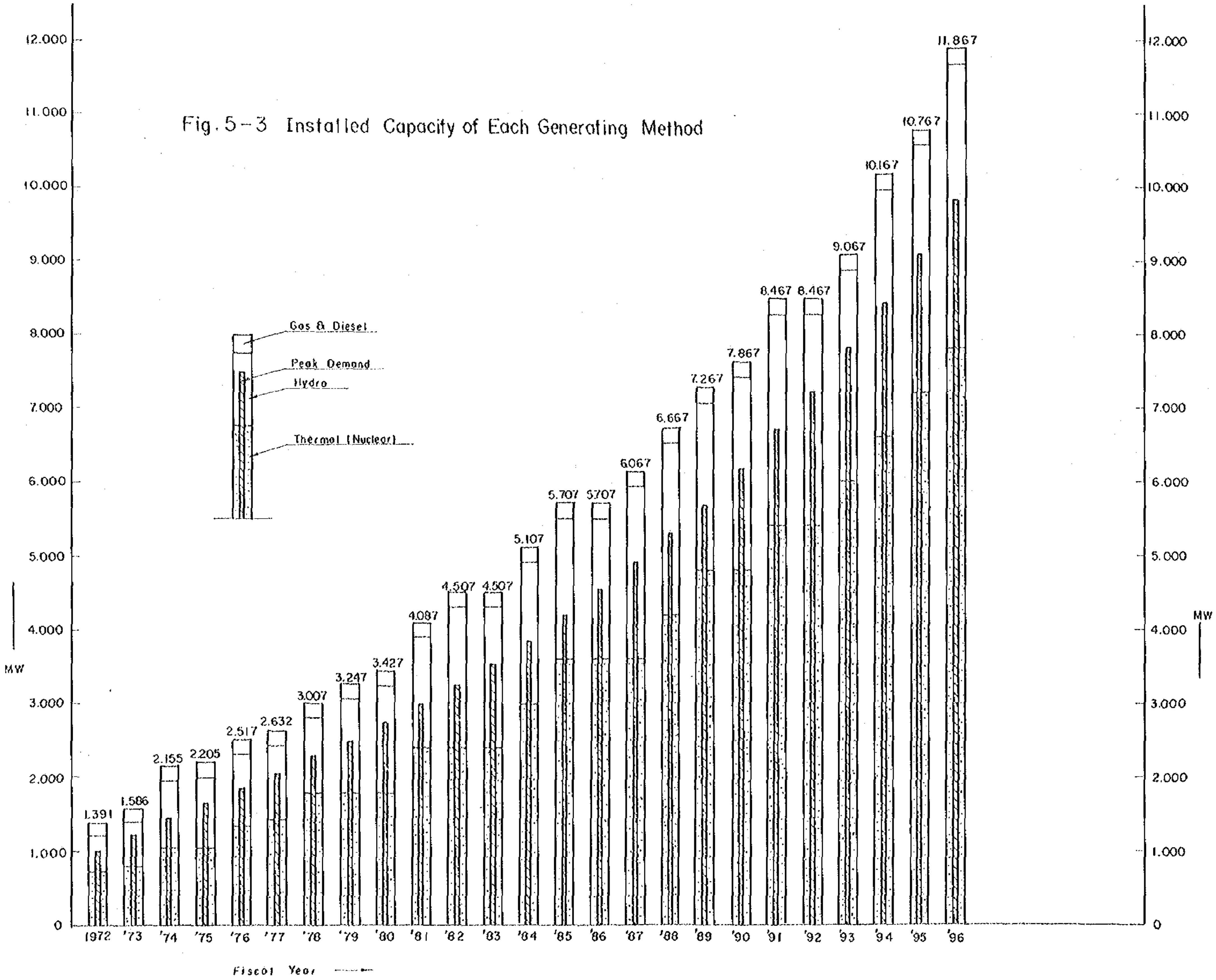


Fig. 5-3 Installed Capacity of Each Generating Method
Gas & Diesel
Peak Demand
Hydro
Thermal (Nuclear)
MW
Fiscal Year
1.391
1.586
2.155
2.205
2.517
2.632
3.007
3.247
3.427
4.087
4.507
4.507
5.107
5.707
5707
6067
6.667
7.267
7.867
8.467
8.467
9.067
10.167
10.767
11.867
1972 '73 '74 '75 '76 '77 '78 '79 '80 '81 '82 '83 '84 '85 '86 '87 '88 '89 '90 '91 '92 '93 '94 '95 '96
0 1.000 2.000 3.000 4.000 5.000 6.000 7.000 8.000 9.000 10.000 11.000 12.000

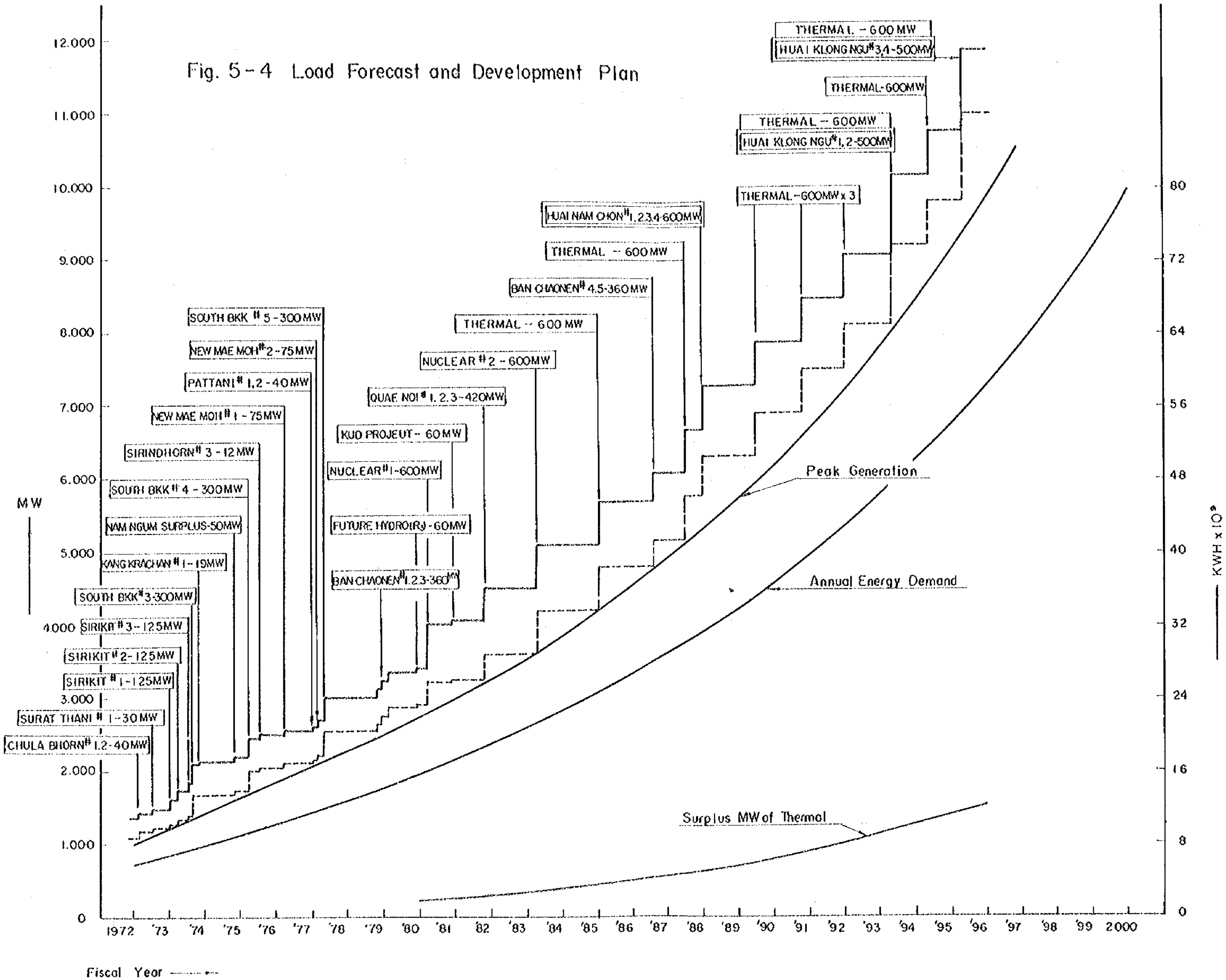
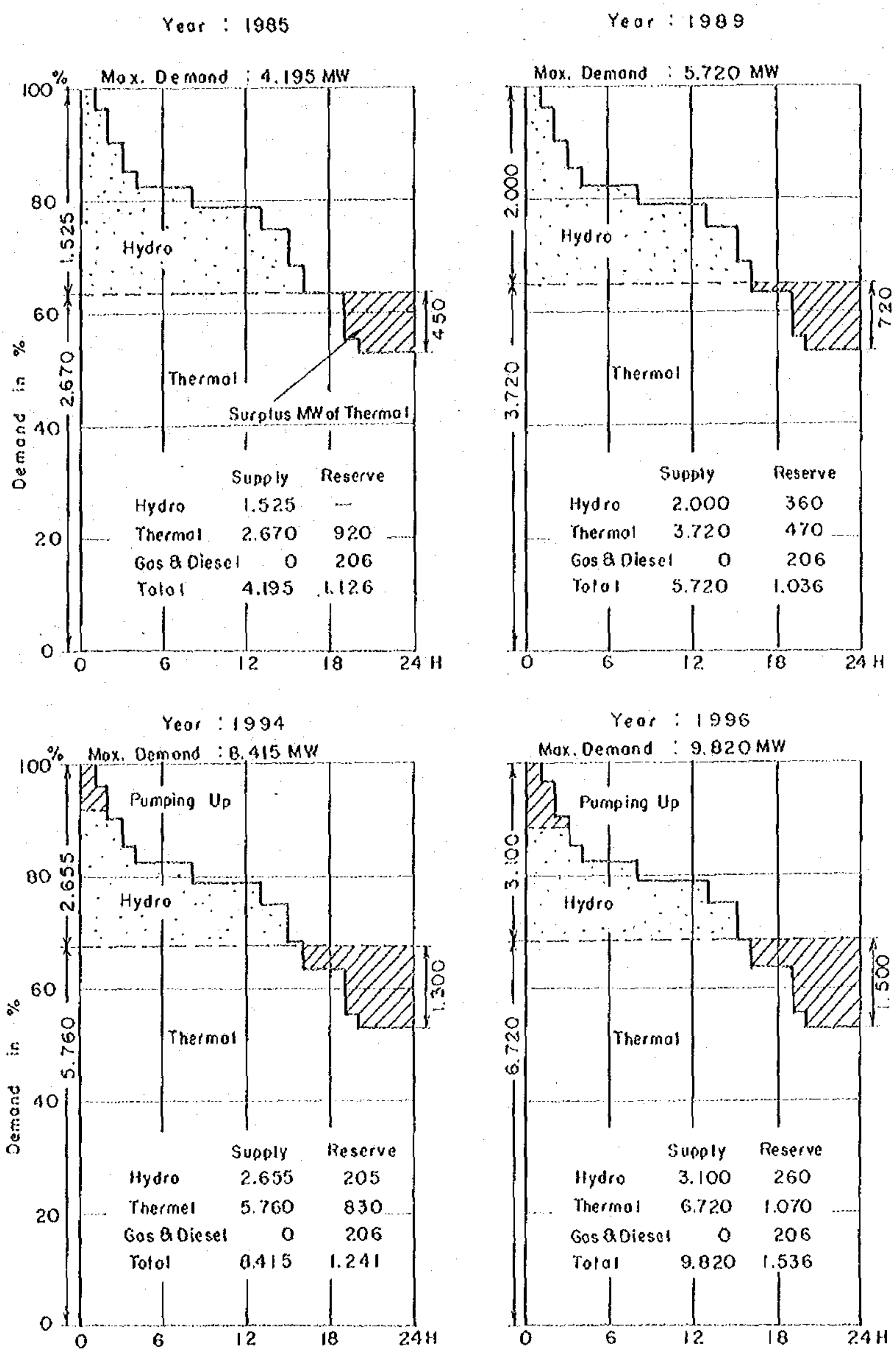


Fig. 5-4 Load Forecast and Development Plan

Fig 5-5 Supply and Demand Balance



APPENDIX

A. LIST OF BASIC DATA

APPENDIX A

LIST OF BASIC DATA

I. Topographic Map

Scale of 1: 250, 000	6 sheets	Sheet No. ND47-2, 3, 6, 7, 14, 15
Scale of 1: 50, 000	15 sheets	Sheet No. 47P/CG-20, 24 DG-9, 13, 17, 21 DH-1, CH-4, 8, 12, 15, 16, 19, 20, 24
Scale of 1: 50, 000	8 sheets	Sheet No. 47P/LH-4, 8, 12, 16, 19 20, 24 DH-1
Scale of 1: 50, 000	1 sheet	Covering Ban Chao Nen, Huai Nam Chon and Huai Klong Ngu Projects area
Scale of 1: 10, 000	2 sheets	Covering Huai Klong Ngu Project
Scale of 1: 10, 000	2 sheets	Covering a part of Ban Chao Nen Reservoir
Scale of 1: 10, 000	3 sheets	Covering downstream area of Ban Chao Nen Project
Scale of 1: 5, 000	2 sheets	Covering Huai Nam Chon Project

II. Geological Map

Scale of 1: 1, 000, 000	1 sheet	Covering Projects area
Scale of 1: 50, 000	1 sheet	Covering Huai Klong Ngu (Geologic Interpretation map aerial photograph)
1: 200, 000	1 sheet	Covering Ban Chao Nen Project area

III. Hydrological Data

(a) Daily Water Level and Discharge Record

Huai Mae Nam Noi	(RID)	70 (Apr.)	72 (Dec.)
Wang Po	(RID)	69 (Apr.)	72 (Dec.)
Lam Sum	(RID)	70 (Apr.)	72 (Dec.)
Khao Chod (main)	(NEA)	70 (Apr.)	71 (Dec.)
Khao Chod (Tributary)	(NEA)	70 (Apr.)	71 (Dec.)
Ong Kha	(RID)	70 (Apr.)	72 (Dec.)
Kang Rieng	(RID)	70 (Apr.)	72 (Dec.)
Lam Ta Phern	(RID)	69 (Apr.)	71 (Mar.)
Bang Wang Khanai	(RID)	71 (Apr.)	72 (Dec.)
Ban Chao Nen	(EGAT)	70 (Apr.)	72 (Dec.)
Ban Phu Tey	(EGAT)	70 (Apr.)	72 (Dec.)
Had Pana	(EGAT)	69 (Oct.)	72 (Dec.)

(b) Daily Rainfall Record

Umphang	70 (Jan.)	72 (Oct.)
Ban Nasuan	70 (Jan.)	72 (Dec.)
Sri Sawat	70 (Jun.)	72 (Dec.)
Kanchanaburi	70 (Jan.)	72 (Sep.)
Bangkok	70 (Jan.)	72 (Dec.)

(c) Monthly Precipitation Record

Pilk Mine	70 (Apr.)	72 (Dec.)
Sangklaburi	70 (Jan.)	71 (Dec.)
Thong Phaphum	70 (Jan.)	72 (Dec.)
Umphang	70 (Jan.)	72 (Oct.)
Ban Nasuan	70 (Jan.)	72 (Dec.)
Sri Sawat	70 (Jun.)	72 (Dec.)
Bo Phloi	70 (Jan.)	71 (Dec.)
Panom Tuan	69 (Jan.)	72 (Aug.)
Kanchanaburi	70 (Jan.)	72 (Sep.)
Tha Muang	70 (Jan.)	72 (Dec.)
Tha Maka	70 (Jan.)	72 (Dec.)
Bangkok	70 (Jan.)	72 (Dec.)

(d) Daily Upper and Surface Wind Speed at Bangkok

Surface Wind Speed	70 (Jan.)	72 (Dec.)
Upper Wind Speed (2,000, 7,000, 12,000 ft.)	70 (Jan.)	72 (Dec.)

(e) Daily Maximum and Minimum Temperature

Kanchanaburi	70 (Jan.)	72 (Sep.)
Bangkok	70 (Jan.)	72 (Dec.)

(f) Monthly Average Evaporation

Bangkok (Class A Pan)	70 (Jan.)	72 (Dec.)

(g) Monthly Rainfall and Rainy Days

Bangkok	70 (Jan.)	72 (Dec.)
Kanchanaburi	70 (Jan.)	72 (Sep.)

(h) Rating Curve (1971 - 1972) at Had Pana GS, & Ban Chao Nen G.S.

(i) Water Level of Flood Discharge at Ban Chao Nen & Head Pana G.S.

IV. Electrical Data

Energy Resources and Electric Power in Thailand

Third Five-Year Investment Program (1972 - 1976)

Annual Report of EGAT 1970 and 1971

Details of Production Cost (Fiscal Year 1971)

Installation Schedule Analysis (1972 - 1985)

Summary Report, Quae Yai No. 1 Hydro Electric Project Transmission System Study

Power Flow Charts in 1985

Daily Load Curve (at January, September and December, 1972)

Monthly Generation Data of EGAT (1972)

Single Line Diagram (R_1, R_2, R_3 and R_4)

Transmission Line Impedance Map (R_1, R_2 and R_3)

Electric Power System of Thailand

B. PUMPED STORAGE SCHEMES DOWNSTREAM OF BAN CHAO NEN PROJECT

APPENDIX B

PUMPED STORAGE SCHEME DOWNSTREAM OF BAN CHAO NEN PROJECT

At the right bank of the equalizing pond of the Ban Chao Nen Project, there is a karstic plateau of elevation of 500 m to 600 m which closes in on the pond and the topography is such that a high head can be obtained within a relatively short distance. It is naturally conceivable for a pumped storage generating scheme to be provided utilizing this high head between the karstic plateau and the equalizing pond of the Ban Chao Nen Project.

The Survey Mission selected the 3 sites indicated in Fig. B-1 on a 1/50,000-scale topographical map and carried out a general study for a 1,000-MW pumped storage power generation scheme.

The study was made based on the following conditions:

(1) The features of the equalizing pond of the Ban Chao Nen Project are planned as follows:

High water level	59.00 m
Low water level	55.50 m
Drawdown	3.5 m
Storage capacity	14,000 thousand cu.m.
Damsite	at Bang Wang Kula site

The study of the features of this equalizing pond was made on a 1/50,000-scale topographical map and is not definite one. But as the conditions for the lower reservoir of the pumped storage power station, high water level and low water level were taken to be El. 59 m and El. 55.50 m respectively. Therefore, it was assumed it would be possible to secure the capacity required for pumped storage power generation by shifting the site of the Ban Wang Kula Dam downstream.

(2) Determination of the reservoir capacity and structures was made based on the same standards as for the Huai Klong Ngu Project.

The results of the study are as given in Table B-1. A general layout is indicated in Fig. B-2 for the scheme D_A which is the most advantageous alternative.

In comparing selected scheme with the Huai Klong Ngu project, construction cost of generating facilities is lower for the Huai Klong Ngu Project, but almost the same for the Project and the scheme, when the construction cost of the transmission line is included.

Therefore, in selection of the site for a pumped storage power generation project around the Ban Chao Nen Reservoir, this scheme should be included and the selection should be made upon future detailed survey and study to be performed in consideration of the relation with the Ban Chao Nen Project.

Table B-1 Outline of Alternative Schemes

Description		Unit	DA	DB	DC
High Water Surface Level		m	560	590	440
Available Drawdown		m	30	30	30
Effective Storage		10^6 Cu. m	5.6	5.3	7.3
Effective Head		m	469	496	355
Max. Discharge		Cu. m/Sec.	257	244	340
Installed Capacity		MW	1,000	1,000	1,000
Headrace Tunnel	Number	-	1	1	1
	Length	m	600	850	1,020
	Diameter	m	7.2	7.0	8.4
Tailrace Tunnel	Number	-	2-4	2-4	2-4
	Length	m	1,080	1,360	620
	Diameter	m	3.7-5.2	3.6-5.1	4.3-6.0
Construction Cost	Generating Facilities	10^6฿	3,869	3,877	4,240
	Transmission Line	10^6฿	480	480	480
	Total	10^6฿	4,349	4,357	4,720
Surplus Benefit		10^6฿	77	76	45
Benefit-cost Ratio			1.14	1.14	1.08

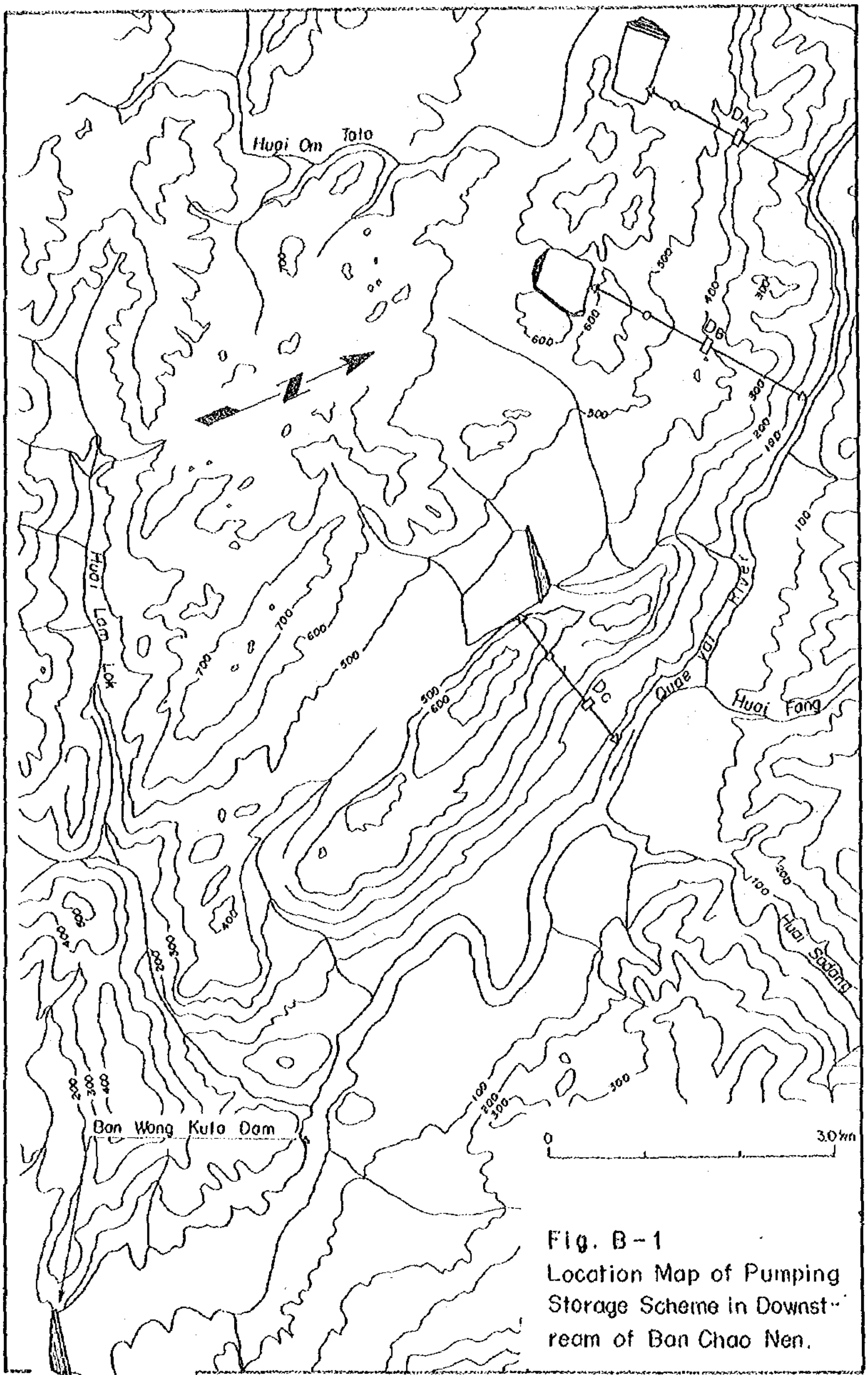


Fig. B-1
Location Map of Pumping Storage Scheme in Downstream of Ban Chao Nen.

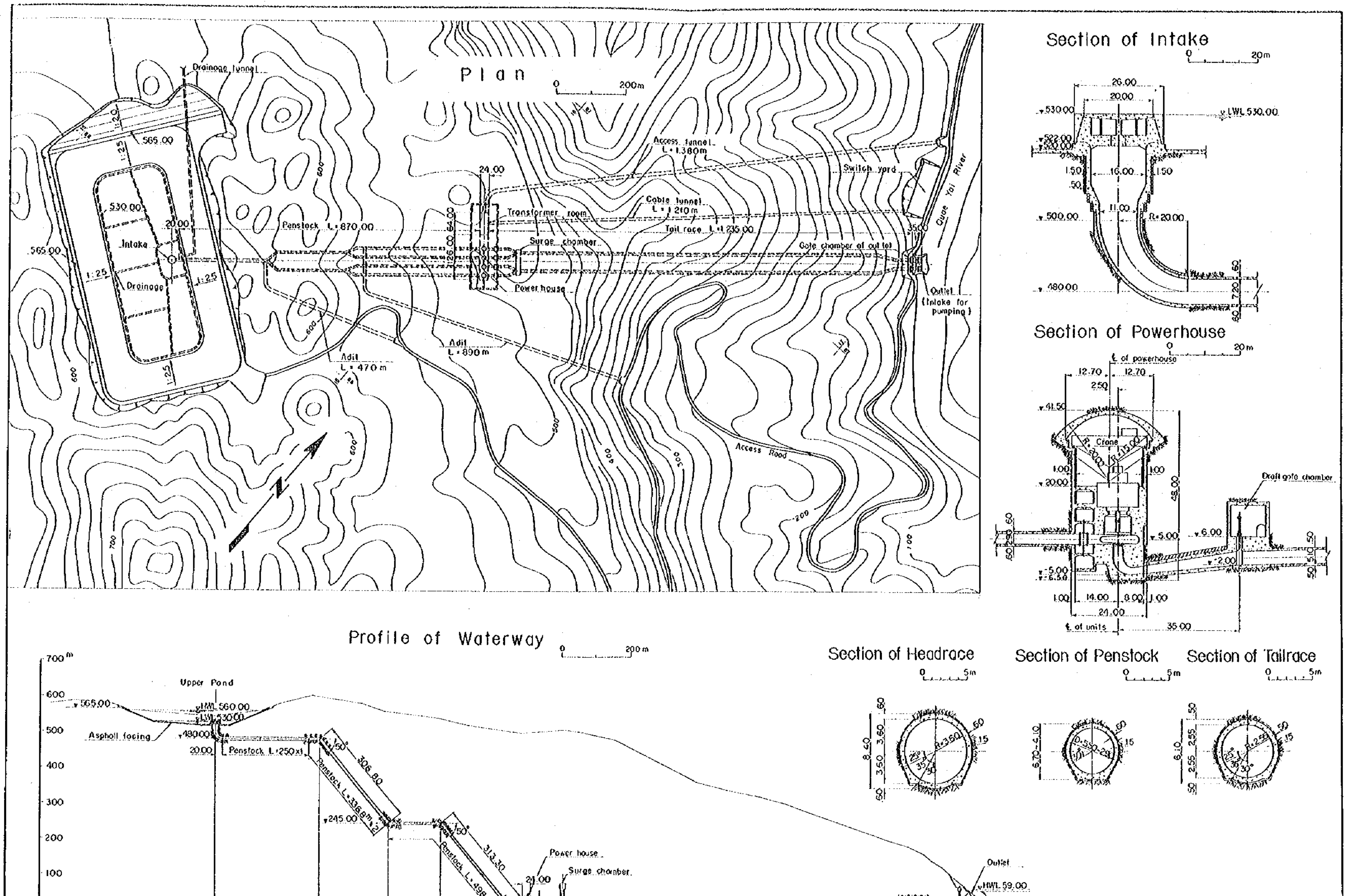


Fig. B-2

General Plan of Pumping Storage Scheme in Downstream of Ban Chao Nen

C. ITEMS OF SURVEY REGUIRED FOR FUTURE STUDY

APPENDIX C

ITEMS OF SURVEY REQUIRED FOR FUTURE STUDY

As stated in the main text, it is desirable for future examination of the Upper Quae Yai Hydroelectric Development Project to be made passing through the stages of a prefeasibility study and a feasibility study.

The schedule of studies to be made in the future for the Huai Nam Chon Project which should be developed in succession to completion of the Ban Chao Nen Project is as shown in Table C-1.

The items of survey to be discussed herein will be limited to the ones of prefeasibility study.

A) Huai Klong Ngu Project

In regard to pumped storage power generation, other projects are also conceivable, and if this site is selected upon a comparison studies with other projects, the following works will be necessary:

1) Preparation of Topographical Map

a) Preparation of 1/5,000-scale topographical maps.

These maps should be for the area covered by the existing 1/10,000-scale topographical map and should be checked through field surveying. Contour lines should be at 5-m intervals.

b) Preparation of 1/2,000-scale topographical maps for areas around structures (including alternative plan)

The maps should cover all structures sites from the upper regulating pond to the tailrace. Contour lines should be at 2-m intervals.

c) River profile of the Huai Klong Ngu

From junction with Huai Khliti Valley to waterfall approximately 0.7 km upstream.

2) Geological Survey

a) Preparation of 1/5,000-scale geological maps through field reconnaissance.

b) Preparation of 1/2,000-scale geological maps for structures sites and their surrounding areas.

c) Investigation of overburden in upper regulating pond (including alternative plan).

50 test pits, 3 to 5 m in depth.

d) Core boring for underground powerhouse site.

One hole approximately 250 m in length.

B) Huai Nam Chon Project

1) Hydrological Study

It is considered the basic runoff gaging stations for this Project will be the Kao Chod and Had Pana gaging stations which are located closest to the damsite. The observations at these gaging stations should be carefully continued to furnish adequate runoff data, while it is also necessary to carry out careful gaging operations to improve accuracy of measurements for flood observations.

It is also desirable to provide a runoff gaging station near the damsite to obtain the runoff at the location. Since there are few rainfall observation stations in the catchment area, it is desirable that the number of rainfall observation stations be increased to grasp the rainfall distribution in the catchment area.

2) Preparation of Topographical Maps

a) Preparation of 1/10,000-scale topographical maps of the reservoir area

The maps should cover the area up to an elevation of 400 m except that for the vicinity of the damsite. The maps should cover the areas up to 5 km from the river-bed on both sides of the river. Contour lines should be at 5-m intervals.

b) Preparation of 1/2,000-scale topographical maps

These maps should be for the area covered by the existing 1/5,000-scale topographical map.

c) Preparation of river profile

The coverage should be the same as for the above maps. Relation with the water level of Ban Chao Nen Reservoir must be clarified by the profile.

d) Preparation of cross section of candidate damsites

Scale must be 1/500 and up to elevation of 400 m.

3) Geological Survey

a) Preparation of 1/10,000-scale geological map of reservoir through field reconnaissance. Especially it is important to investigate karstic phenomena.

b) Geological interpretation of aerial photographs covering through reservoir area which is effective supplementary method for geological mapping and investigation.

c) Preparation of 1/2,000-scale geological maps for surrounding areas of structures sites.

d) Seismic prospecting

Approximately 4 km for each damsite.

e) Core boring

For each damsite, 3 drill holes for each bank and 3 holes for the river-bed. One drill hole for the candidate powerhouse site, approximately 150 m long, if underground type is adopted.

f) Investigations of embankment materials and aggregates.

Fig. C – I Schedule of Studies for Huai Nam Chon Project