The Kingdom of Thailand
National Energy Administration
Ministry of Science, Technology and Energy

MASTER PLAN
FOR
THE MAE PAI AND MAE CHAEM RIVERS
HYDROELECTRIC POWER DEVELOPMENT PROJECT

Volume 1

JULY 1981

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request of the Government of The Kingdom of Thailand the Japanese Government decided to conduct a survey on the Mae Pai River and Mae Chaem River Hydroelectric Power Development Project and entrusted the survey to the Japan International Cooperation Agency. The J.I.C.A. sent to Thailand a survey team headed by Mr. Yutaka NARITA from November 11, 1980 to January 19, 1981.

The team exchanged views with the officials concerned of the Government of The Kingdom of Thailand and conducted a field survey in northern Thailand area. After the team returned to Japan, further studies were made and the present report has been prepared.

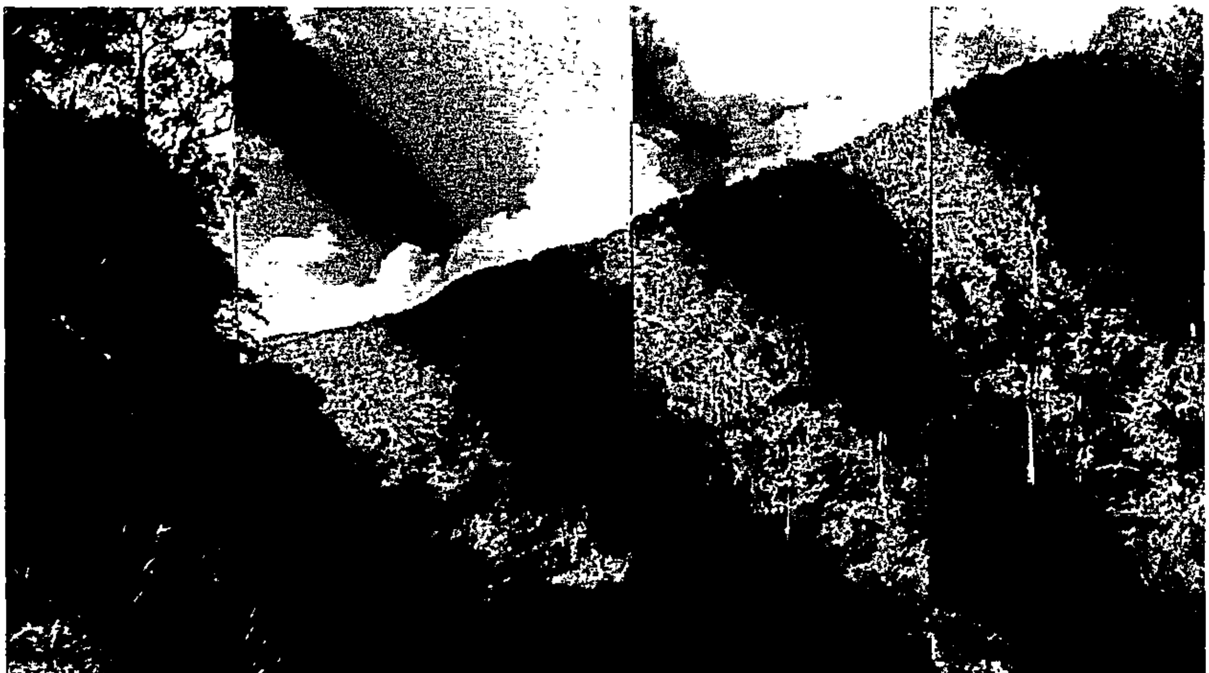
I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of The Kingdom of Thailand for their close cooperation extended to the team.

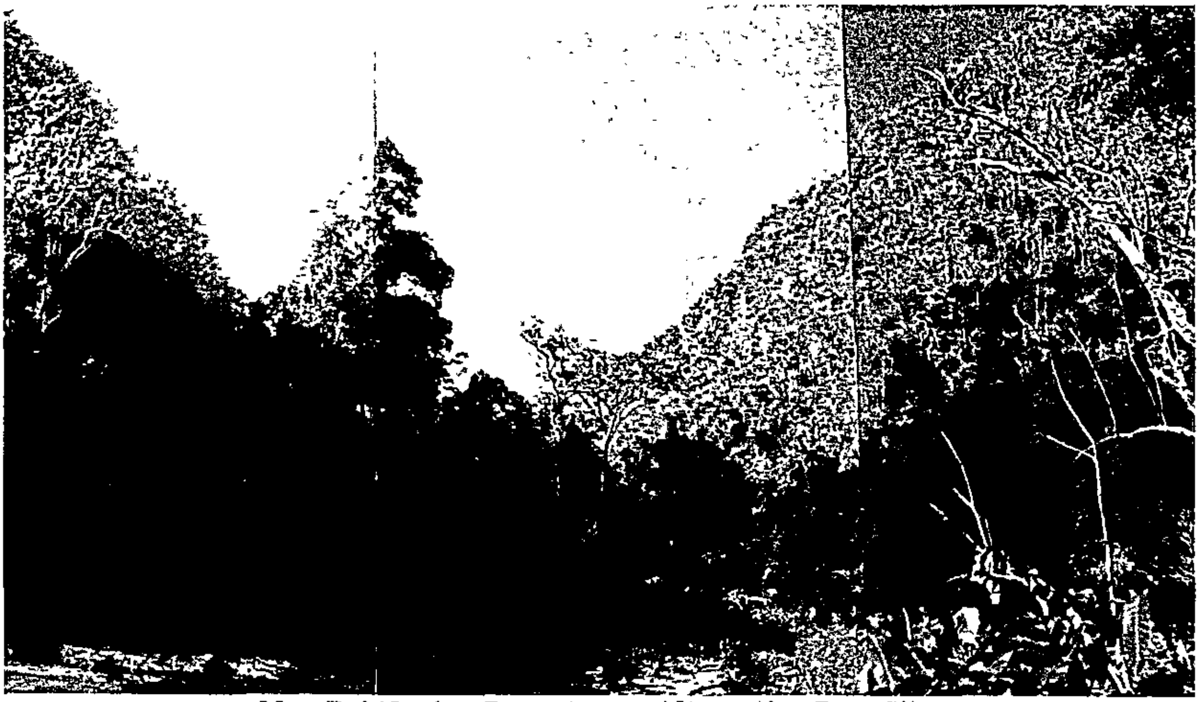
July, 1981

Keisuke Arita
President
Japan International
Cooperation Agency

Mae Pai No.6　Dam Site
View from downstream



Mae Pai No.1　Upstream Alternative Dam Site
View from upstream

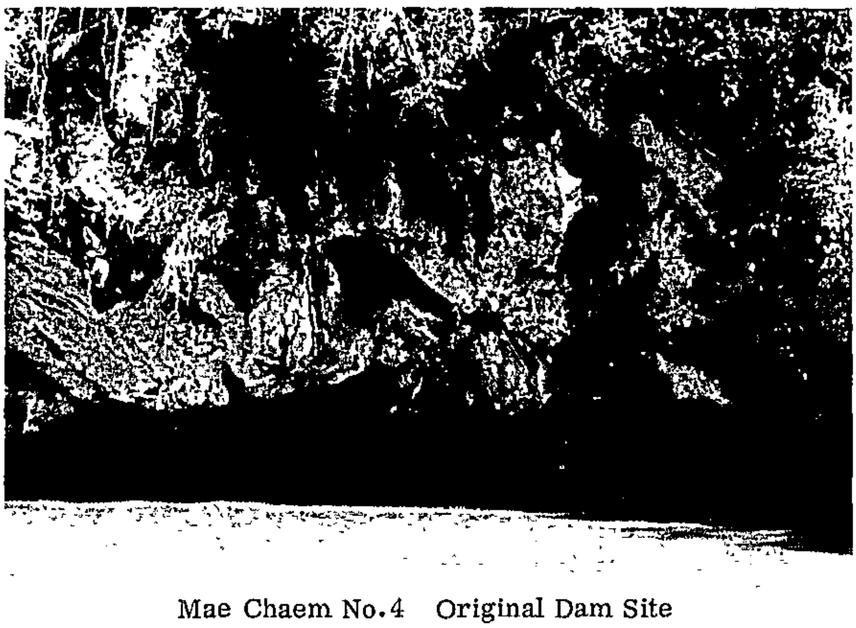

Mae Pai No. 1 Downstream Alternative Dam Site
View from upstream

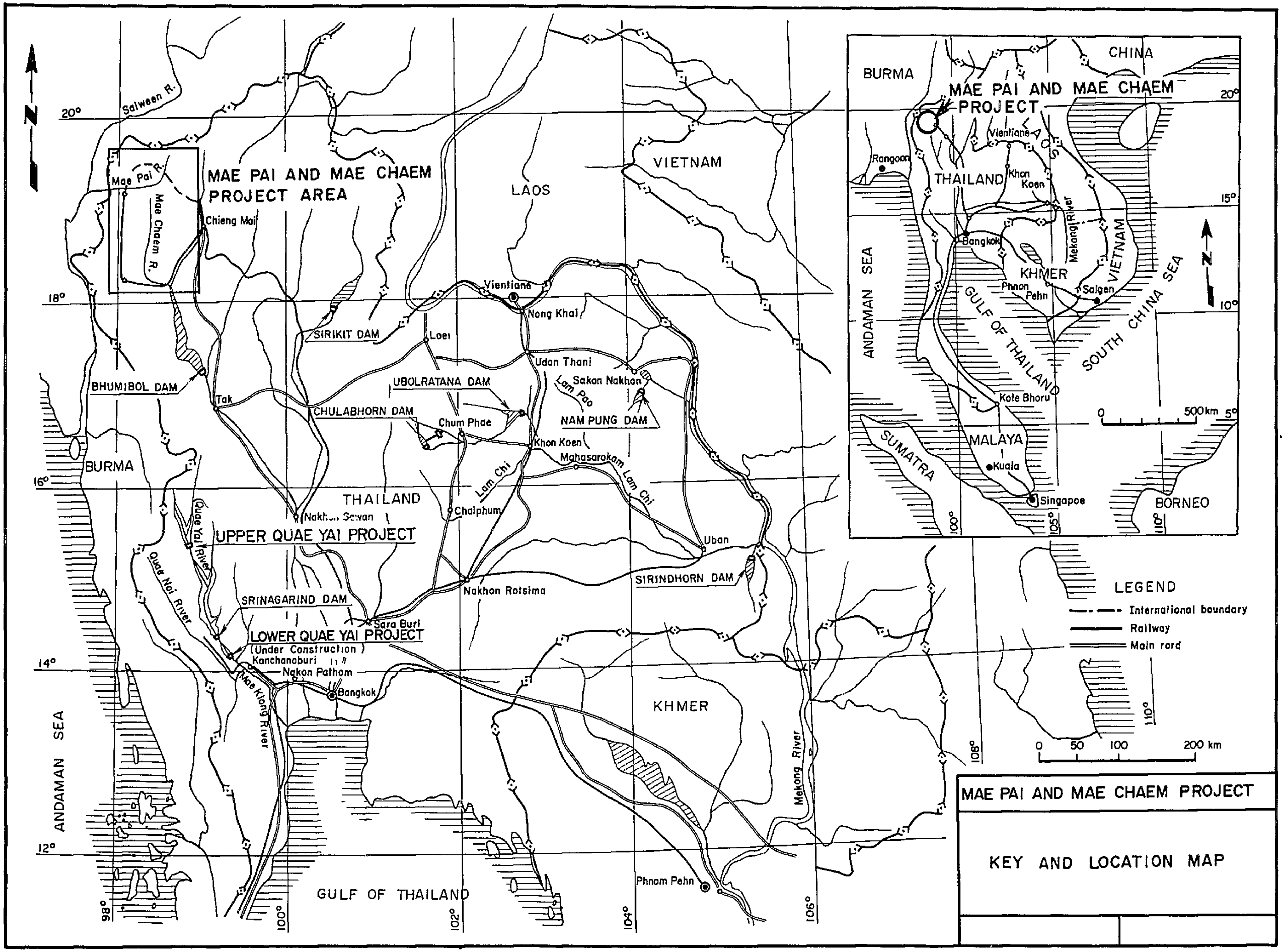

Mae Pai No. 1 Downstream Alternative Dam Site
Lime stone on right bank with Cave and Stalactite

Mae Chaem No.5　Dam Site
View from upstream

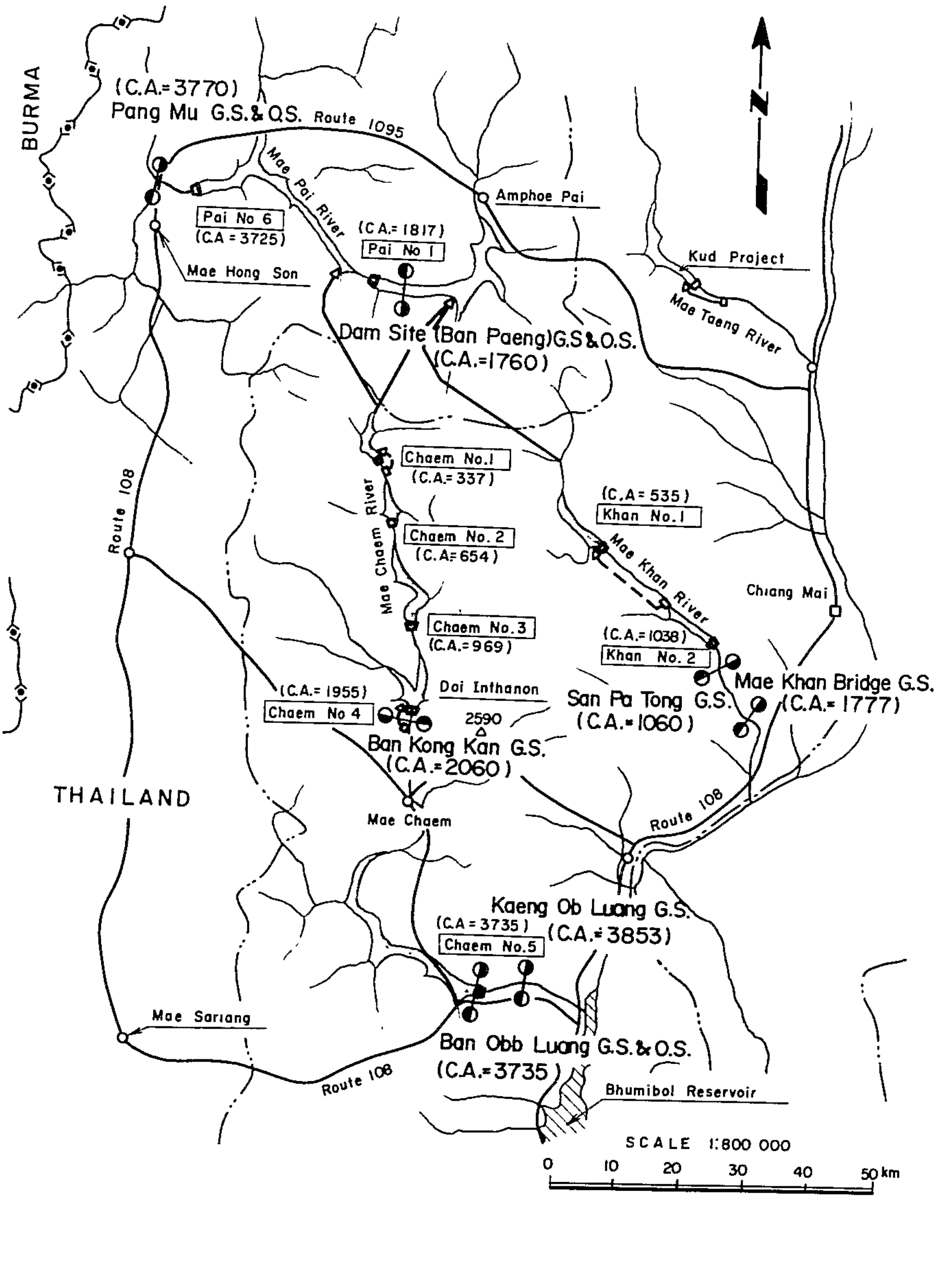
Mae Chaem No.4　Upstream Alternative Dam Site
View from upstream


Mae Chaem No.4 Original Dam Site
View from downstream


Mae Chaem No.4 Original Dam Site
Outcrop of Lime stone on left bank


MAE PAI AND MAE CHAEM PROJECT AREA
Salween R.
Mae Pai R.
Mae Chaem R.
Chieng Mai
BURMA
LAOS
VIETNAM
THAILAND
KHMER
ANDAMAN SEA
GULF OF THAILAND
SIRIKIT DAM
BHUMIBOL DAM
UBOLRATANA DAM
CHULABHORN DAM
NAM PUNG DAM
SIRINDHORN DAM
UPPER QUAE YAI PROJECT
SRINAGARIND DAM
LOWER QUAE YAI PROJECT
(Under Construction)
Vientiane
Nong Khai
Loei
Udon Thani
Sakon Nakhon
Lam Pao
Tak
Chum Phae
Khon Koen
Mahasarokam
Lam Chi
Chaiphum
Nakhon Sawan
Uban
Nakhon Rotsima
Sara Buri
Kanchanoburi
Nakon Pathom
Bangkok
Quae Yai River
Quae Noi River
Mae Klong River
Mekong River
Phnom Pehn
20°
18°
16°
14°
12°
98°
100°
102°
104°
106°
108°
110°
N
CHINA
MAE PAI AND MAE CHAEM PROJECT
Rangoon
Vientiane
Khon Koen
Mekong River
Bangkok
Phnon Pehn
Saigon
GULF OF THAILAND
SOUTH CHINA SEA
Kote Bhoru
MALAYA
Kuala
Singapoe
SUMATRA
BORNEO
0 500km
15°
10°
5°
105°
LEGEND
International boundary
Railway
Main rord
0 50 100 200 km
MAE PAI AND MAE CHAEM PROJECT
KEY AND LOCATION MAP

GENERAL FIGURE OF THE PROJECT AREA



CONTENTS

CHAPTER 1

CONCLUSION AND RECOMMENDATION

CHAPTER 1 CONCLUSION AND RECOMMENDATION

Following conclusion and recommendation have been reached respectively for the proposed hydro power development projects on Mae Pai River and Mae Chaem River after review of published survey reports, relevant data furnished by NEA and other concerned authorities in Thailand and the outcome from desk study works including site survey results.

1.1 Conclusion

1.1.1 Earliest Necessity of Feasibility Study

As a result of review performed as a pre-feasibility study, it is considered appropriate that feasibility study should be launched as soonest as possible on the two proposed project sites of Mae Pai River No. 6 and Mae Chaem River No. 5. In particular, with regard to high-water level, maximum turbine discharge and maximum power output, feasibility study should require investigation were in detail by due reference to the figures as given in the following Table as basic standard.

Project Name	HWL m	Dam Height m	Qmax m^3/S	Pmax MW	Cost 10^6฿
Mae Pai River No. 6	400	185	202	291	7,647
Mae Chaem River No. 5	440	140	116	102.6	4,669

Main design factors are as specified in Table 6-18.

1.1.2 Project Outline

(1) Mae Pai River Individual Development Scheme

Geology at No. 1 site consists mainly of limestone, for which geological survey must be conducted to make sure of technical feasibility on dam construction. If it is assured to be feasible after survey, it is then appropriate to enter into feasibility study on a basis of 475 m of high-water level. In this instance, the basic standard is given respectively as 85.4 m^3/sec for maximum turbine discharge and as 48.9MW for maximum power output.

As for No. 6 site, study has been made on four alternative cases between 350 m high-water level and 400 m high-water level. The study result indicates $(B - C)_{max}$ in the case of 400 m high-water level, though the project at No. 6 site is economically feasible in each case. The geological condition as observed at the site provides nothing abnormal which may cause any serious obstruction to the main civil work structures.

(2) Mae Chaem River Individual Development Scheme

Out of all proposed five (5) sites, three of No. 1, No. 2 and No. 3 are below the economic feasibility.

With regard to No. 4 site, the dam site originally proposed is covered with limestone expanding in a wide range over its left bank and reservoir area. No prospect for a development plan with sufficient economical advantages has been yet achieved from the present survey result on the alternative site situated 6 km upstream. However, since there still remains a possibility of economic upturn depending upon interest and the estimated benefit cost of the alternative thermal power, it is considered appropriate that the project should be further examined by execution of geological surveys at both of originally proposed and alternative-sites.

With regard to No. 5 site, the study result on each case between 410 m and 450 m high-water level has shown that the surplus benefit (B - C) at the power-generating site is positive, indicating the economical feasibility, in each case except the case of 450 m water level. Thus the case of 440 m water level which is the highest one in all economically feasible cases has been selected considering energy situation in Thailand.

(3) No economic feasibility is observed on the Mae Kham River Development Scheme.

(4) Pumped-up Diversion Channel Scheme

As a result of comparative study on the pumped-up diversion scheme from Mae Pai River into any one of three rivers such as Mae Chaem, Mae Khan and Mae Taeng, conclusion has been reached that the Mae Pai - Mae Chaem River diversion channel plan would be relatively preferrable but, even if so, still with very low economic advantage. The reasons are relatively small benefit expectancy from power generation and irrigation as compared with the estimated sum of investment, as well as high lift and long diversion distance. Therefore, it can be concluded that this project would not take shape unless and until the benefit from irrigation is increased significantly corresponding to remarkable uprise of the benefit unit price.

1.1.3 Time Schedule for Development

When consideration is given to the present power situation in Thailand, in particular stabilized supply of electric power by effective utilization of domestic potential resources and also by reduction of heavy dependency upon imported primary energy resources, it is no doubt that development of hydro power projects should be urgently proceeded with the top priority. Although the time schedule for each project should be necessarily determined by comparative study on the economic advantage with other proposed hydro power projects, it is most advisable that feasibility study is to be conducted on both projects of Mae Pai No. 6 and Mae Chaem No. 5 which shall be developed independently in each river system, aiming at a commencement of operation in near future as soon as possible.

1.2 Recommendation

It has been finally concluded that as stated in the preceding item 1.1.2), feasibility study should be launched for both proposed sites of Mae Pai No. 6 and Mae Chaem No. 5 and continuous survey should be preferrably required for feasibility of Mae Pai No. 1 and Mae Chaem No. 4 sites.

In accordance with the conclusion above, it is recommended thereby that necessary investigation works for future feasibility study should be carried out as specified in Tables 1-1 and 1-2.

Table 1-3 shows the outlined implementation time schedule of projects.

Table 1-1 Additional Investigation Works for Feasibility Study

Items	Mae Pai No.6	Mae Pai No.1	Mae Chaem No.5	Mae Chaem No.4
1) Hydrology				
• New gaging station	Downstream of Mae Kong	-	-	-
• Suspended sediment	Pan Mu G.S	Dam Site G.S	Ban Ob Luang G.S	Ban Kong Kan G.S
• Flood observatory	"	"	"	"
• Hourly rainfall intensity	"	"	"	"
2) Survey				
• Leveling	By setting of bench mark	Same as left	Same as left	Same as left
• Topographical survey	Supplementary survey on 1 : 2,000 scale with coverage up to 1,000 m on both up and down stream sides from dam axial line and up to EL 450 Supplementary survey on 1 : 10,000 scale to cover planned HW level up to EL of HWL plus 20 m	Topographical mapping on 1 : 2,000 scale of upstream site with coverage up to 1,000 m to both up and down stream sides from dam axial line and up to EL 650 Supplementary survey on 1 : 10,000 scale to cover planned HW level up to EL of HWL plus 20 m	Supplementary survey on 1 : 2,000 scale with coverage up to 1,000 m on both up and down stream sides from dam axial line and up to EL 300 to 550 Supplementary survey on 1 : 10,000 scale up to 3,000 m down stream from dam axial line and EL 300 to 400, to cover planned HW level up to EL of HWL plus 20 m	Check of contour lines on 1 : 2,000 and 1 : 10,000 scale Topographical mapping on 1 : 2,000 scale of upstream alternative site with coverage of 1,000 m to both up and down stream sides from dam axial line and up to 1,500 m from river course center on both left and right banks Supplementary survey on 1:10,000 scale map with full coverage of planned HW level up to EL of HWL plus 20 m
3) Access road	New construction of vehicle-trafficable access to dam site	New construction of access from gauging station to dam site	-	New construction of access to dam site
	Provision for river crossing	Provision for river crossing	-	Provision for river crossing

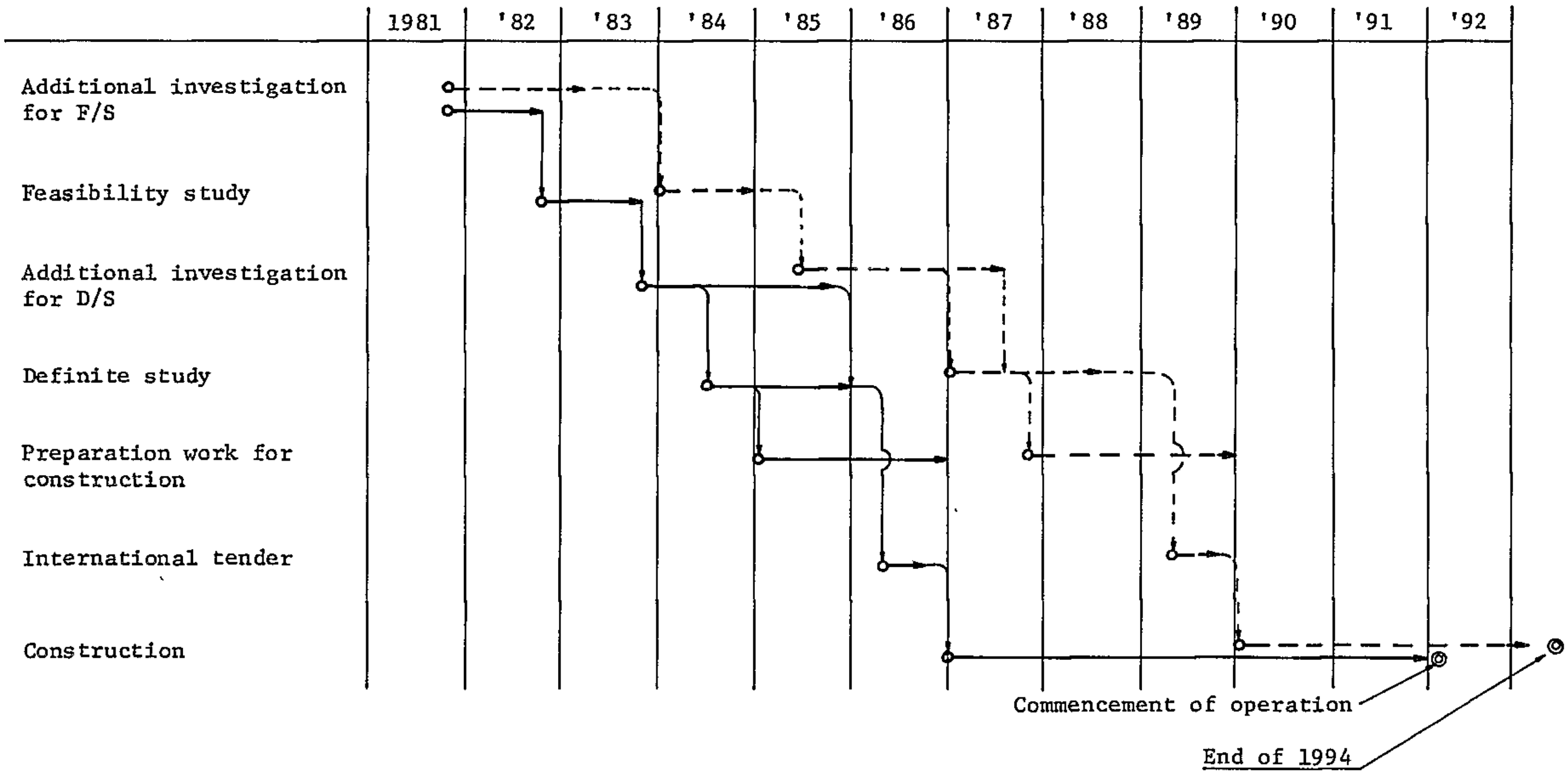
Table 1-2 Additional Investigation Works

Items	Mae Pai No. 6				Mae Pai No. 1				Mae Chaem No. 5				Mae Chaem No. 4 Alternative Site				Mae Chaem No. 4 Original Site			
	No.	Elevation (m)	Length (m)	Direction	No.	Elevation (m)	Length (m)	Direction	No.	Elevation (m)	Length (m)	Direction	No.	Elevation (m)	Length (m)	Direction	No.	Elevation (m)	Length (m)	Direction
4) Geology Drill hole Dam	R-1* L-1* L-2*	365 230 330	100 100 100	90° N6°W,60° 90°	R-1* R-2* L-1* L-2*	405 475 500 560	70 70 100 150	S13°W,60° 90° 90° 90°	R-1* R-2* R-3* L-1* L-2* L-3*	330 360 328 365 332 360	100 70 50 70 50 50	N15°W,60° 90° 90° 90° 90° 90°	R-1* L-1* L-2*	580 510 580	80 80 80	90° W,60° 90°	L-1* L-2**	500 700	70 200	S82°W,60° 90
	Total: 3 holes 300 m				Total: 4 holes 390 m				Total: 6 holes 390 m				Total: 3 holes 240 m				Total· 2 holes 270 m			
Spillway	S-1 S-2	350 260	40 40	90° 90°					S-1 S-2	350 338	40 40	90° 90°								
	Total: 2 holes 80 m								Total: 2 holes 80 m											
Power-house	PH-1	230	40	90°																
	Total: 1 hole 40 m																			
Surge tank	S-1	415	50	90°																
	Total: 1 hole 50 m																			
Intake	I-1	390	40	90°																
	Total: 1 hole 40 m																			
Saddle													RS-1* LS-1*	635 625	100 100	90° 90°				
Test adit Dam	RA-1 RA-2 LA-1 LA-2	235 300 275 375	60 60 60 60	N6°W N6°W S36°E S36°E					RA-1 LA-1	400 400	60 60	S5°W N5°E								
	Total: 4 adits 240 m								Total: 2 adits 120 m											
Others					•Geological mapping on 1:2000 scale in adjoining area of dam site. •Reconnaissance of construction material sites, candidated sites as shown in Fig. 5.								•Geological mapping on 1:2000 scale in adjoining area of dam site. •Reconnaissance of construction material sites, candidated sites as shown in Fig. 5.				•Clarification of distribution and characteristic of ordovician limestone •Survey on river discharge (riverbed water or spring water, etc.) and water quality analysis by survey.			

Note:

- The location of the additional investigation works described in the preceding tables are shown in the Fig. 5-18 to Fig. 5-22.
- At the drill holes marked by *, water pressure tests are to be performed.
- At the drill holes marked by **, water pressure tests are to be performed, and further they are utilized as water level observation holes by inserting strainers after completion of the excavation.
- Water level is to be measured and recorded at each drill hole every day during the excavation.

Table 1-3 Implementation Schedule



* Legend: o——→ Mae Chaem No. 5

o- - -→ Mae Pai No. 6

Note: The relation between both projects in the schedule can be changed as the progress of the investigation works.

CHAPTER 2

INTRODUCTION

CHAPTER 2 INTRODUCTION

2.1 Historical Circumstances

The National Energy Administration (NEA) of the Kingdom of Thailand is making special efforts regarding the various electric power development projects, in order to cope with the remarkable increase of demand of electric power (annual rate of 12% through 15%) occurring recently in the country.

However, the various projects, like those referring to nuclear power generation, fuel oil burning thermal power generation and so forth are facing a quite difficult situation, in view of problems related to the procurement of fuel, environmental detereolation and so forth.

In view of the situation described above, the Thai government is actively promoting development plans referring to natural resources available in the country, i.e., water power, natural gas, lignite, etc.

The hydroelectric power development projects in the basin of the Mae Pai River, a tributary of the Salawin River, and in the basin of the Mae Chaem River, a tributary of the Chao Phraya River, has been mentioned as a part of the said plans for utilization of the domestically available resources.

Aiming at materializing the said plan for utilization of domestically available resources, the Government of Thailand has prepared a master plan based upon the hydroelectric power development project, and asked for cooperation of the Japanese Government in order to carry it out.

Based upon the mentioned request, the Japanese Government (Japan International Cooperation Agency - JICA) sent a Preliminary Survey Team to Thailand in February of 1980, and the said team carried out field survey and collected data related to the matter. The survey described in the present report was carried out as a consequence of the discussions between the Japanese and Thai sides referring to the Scope of Works regarding this project, based upon the results of the Preliminary Survey.

The Survey Team stayed in Thailand during the period of 11th of November of 1980 through 19th of January of 1981, and carried out the collection of data and information in Bangkok, discussions with the various organizations related to the matter and field survey at the basins of the Mae Pai and Mae Chaem Rivers and other related areas.

The results of the field survey are summarized in the "Field Investigation Report", which was presented to the NEA prior to the return of the Survey Team to Japan.

After the return of the Survey Team to Japan, the studies required for preparation on the Master Plan of this project were carried out with full support of the Electric Power Development Company. The results of the said studies are reported in the "Master Plan for the Mae Pai and Mae Chaem Rivers Hydroelectric Power Development Project".

Descriptions referring to the principal studies carried out in the past with regard to the matter are presented in the Chapter 6 of the present report.

2.2 Scope of the Report

The present report refers to the field reconnaissance covering the areas related to the hydroelectric power development project of the Mae Pai, Mae Chaem and Mae Khan Rivers planned by the Thailand Government (NEA), to the analysis of data and information carried out in Japan and to the preparation of the Master Plan including the plans referring to the water pumping and diversion of the Mae Pai - Mae Chaem and Mae Khan Basins.

The surveying activities carried out by the Survey Team refers to the following fields.

(1) Civil engineering, geological and electrical fields related to the power generation.

(2) Irrigation and water supply aiming at utilizing the water at the downstreams areas, regarding the water pumping and diversion plans.

(3) Economical field, referring to the economical analysis and evaluation of the whole project.

Followings are the various sub-items composing each one of the items mentioned above.

(1) Civil engineering, geological and electrical fields related to the power generation.

1. Study of the project layout
   According to the various studies carried out so far, the present project has as a substance the plan referring to the pumping and

diversion of water from the Mae Pai River to the Ping River, which is a tributary of the Chao Phraya River, crossing the city of Bangkok, based upon the projects referring to the individual development of the Mae Pai, Mae Chaem and Mae Khan Rivers. With regard to the reports referring to the studies mentioned above, the Preliminary Survey Team presents the following advices.

- The reports referring to the studies carried out previously do not make clear mentions to the irrigation benefit in the downstream areas and to the benefits of the potable and industrial water supply, and consequently the evaluation of the project itself is difficult.
- The project area presents a complicate topographic and geological characteristics, and in addition presents many problematic points. Accordingly, it is required to prepare an adequate master plan by making a comprehensive arrangement of the conditions referring to aspects like the dam site, location of the water ways and various facilities and so forth, based upon studies covering the whole area to be developed.

The present Survey Team prepared the master plan by taking into consideration the advices mentioned above, by carrying out a careful analysis of the project layout and by taking globally into consideration the results of the various survey items.

2. Geological survey

- Aero photograph interpretation of the project area and its results
- Topography and geology of the whole basins
- Geology of the planned reservoirs
- Geological characteristics of the sites proposed for construction of the main structures
- Concrete aggregate, embankment materials

3. Hydrological survey

- Collection of meteorological data and information

  Collection of data and information referring to meteorological aspects like rainfall, temperature, humidity, etc. in the northern Thailand area

- Collection of data and information relating to the discharge rates

  Survey of the various water gauging stations usable for measuring of inflow into each site and collection of the data and information

- Collection of information and data referring to sedimentation

  Survey mainly of the sedimentation in the presently existing Bhumibol storage reservoir

4. Development scheme

   – Comparative study of the various alternatives –

- Scheme of individual development of the Mae Pai River
- Scheme of individual development of the Mae Chaem River
- Scheme of individual development of the Mae Khan River

- Mae Pai - Mae Chaem water pumping and diversion scheme
- Mae Pai - Mae Khan water pumping and diversion scheme

With regard to the Mae Taeng River, which was also object of the master plan in initial stage, the KUD project is being promoted by the RID and the EGAT, and the relevant Feasibility Report has been already presented. There is no margin for planning of any other project in case of enforcement of this KUD project. On the other hand, with regard to the water diversion from the Mae Pai River to this river, the length of the waterway will be extremely long, therefore the water diversion alternative will not be worth of analysis. Accordingly, the Mae Taeng River is not taken into consideration as object of the Master Plan as a consequence of the facts mentioned above.

5. Load forecast

The NEA, EGAT, MEA and PEA have organized a committee, and are studying load forecast on a medium and long term basis. The estimation of the ultra-long term load forecast required in this master plan was calculated based upon the presently existing data and by taking into consideration the development projects.

6. Power system analysis, transmission lines and substations

The analysis of the power system based upon the long-term planning referring to the electricity is indispensable for preliminary design of electric equipment and transmission facilities. The transmission lines and substations are planned by carrying out the necessary analysis for the preliminary design such as examination of transient stability, voltage regulation and short circuit capacity, etc.

7. Actual state and demand of water in the irrigation areas
   - Survey of the actual conditions prevailing in the Chainat Irrigation Project, Chom Thong area and Kamphaeng Phet area

     Monthly requirement of water for agricultural purposes, quantity of due water discharged to downstream areas, hydraulic structures in the Chainat beneficiary area, cost of irrigation project and cultivated crops, agricultural proceeds, etc.
   - Analysis of the impacts of the project upon the irrigated agriculture related to the water pumping and diversion project

     Estimation of the average planting system, estimation of the evapotranspiration rates, effective rainfall, etc. Analysis of the relation between planting system and water consumption, analysis of the irrigation scale corresponding to the diverted quantity of water, estimation of the factors required for the cost-benefit study for purpose of economical evaluation, etc.

8. Actual situation of the water supply and demand of water in the cities
   - Survey of the actual situation prevailing in the metro Bangkok area including the Thomburi area

     Presently existing facilities like water-intake, water purification station, water distribution station, etc., water distribution and supply area, water supply population, daily water consumption, etc.

- Relation between the future expansion plan and the water diversion project.

9. Preliminary design

A preliminary design is prepared, with reference to the optimum alternative derived as a result of the comparative study of the various possible alternatives. The design items are the dam and appurtenant structures, waterways, power station, electrical equipment, transmission lines, substation, etc.

10. Construction cost

The construction cost at present is calculated by taking into consideration such quantity and unit costs that have been experienced in hydroelectric power projects in Thailand.

11. Economical evaluation

- Analysis of factors like annual cost, power generation cost, cost-benefit ratio, etc.
- Criteria for selection of alternative thermal power
- Assumption of multi-purpose benefits

12. Advices on additional investigation items

Investigation on hydrological, topographical, material, compensation and environmental aspects

2.3 Field Survey

The purpose of the present Survey Team was to carry out field survey, including the collection of basic data, required to prepare the master plan of the hydroelectric power development project of the Mae Pai, Mae Chaem and Mae Khan Rivers, proposed by the Thai Government.

In order to attain the mentioned goals, the Survey Team carried out collection of data, field survey activities in the project area and discussions with the various Thai organizations related to the matter.

The results of the activities carried out by the Survey Team are described in the "Master Plan for the Mae Pai and Mae Chaem Rivers Hydro-electric Power Development Project in the Kingdom of Thailand - Field Investigation Report", which was presented to the NEA. The said report contains the opinion of the Survey Team on the field survey and the basic items required for preparation of the master plan.

The members of the JICA Survey Team and the NEA staff who participated and offered their contribution in the field survey activities are as follows.

Members of the JICA Survey Team

Mr. Yutaka Narita	Chief	EPDC
Mr. Kazuhiro Yoneda	Coordinator	JICA
Mr. Akiyoshi Noda	Irrigation Engineer	EPDC
Mr. Yoshihiro Nakazawa	Civil engineer	EPDC
Mr. Shiro Miyashita	Civil engineer	EPDC
Mr. Kiyoshi Ishikawa	Geologist	EPDC

Mr. Takao Chaishi	Geologist	EPDC
Mr. Takuya Takaoka	Electric Engineer	EPDC
Mr. Hirofumi Sato	Economist	EPDC

NEA

Mr. Suvat Saguanwongse	Director, Investigation and planning division
Mr. Mohar Singh Monga	Civil Engineer
Mr. Winya Sinjermsiri	Civil Engineer
Mr. Vijit Sirichoti	Civil Engineer
Mr. Sompong Sripyak	Geologist
Mr. Inthon Sapata	Civil Engineer
Mr. Chartdanai Chatpolruk	Mechanical Engineer
Mr. Aram Supakarn	Surveying Engineer
Mr. Thanee Montrivade	Planning Engineer
Mr. Lek Suwanthada	Agronomist
Mr. Preecha Seniwong	Economist
Mr. Thirayuth Viraphan	Geologist
Mr. Manit Rodphai	Geologist
Mr. Samran Tusgate	Geologist
Mr. Kamol Karunamit	Geologist

2.4 View on the Site

2.4.1 Outline of the Topography and Geology

Granite severely weathered is distributed throughout a wide area, in the upstream region of the Mae Pai River. The topography in this area has a gentle mountainous configuration. In view of these facts, it is not possible to find any adequate dam site upstreams of the No. 1 site.

The topography downstreams of the No. 1 site has a very steep mountainous configuration, and is adequate as a dam site. However, various places with large scale landslided configuration are found in the area comprised between the No. 1 site and the No. 4 site, and accordingly the adequate dam sites are restricted.

The geology in the basin is formed chiefly of quartzite, argillite, shale, sandstone, limestone (Ratburi and Thung Song group) and granite. The Ratburi limestone is accompanied by a prominent karstic topography, and is widely distributed throughout the northern side of the Mae Pai River and at the East and West sides of the Khong River, which is a tributary of the Mae Pai River. However, this limestone is distributed in a shale zone at places with more than 400 m in elevation in the basin. Accordingly, it is expected that no water leakage will occur from the storage reservoirs, if the high-water level of the No. 6 dam is planned around that elevation.

Several karstic topographies are observed also in the Thung Song limestone area, and there are many caves of various sizes on the outcrops. Making a judgement based upon local condition of geology in the area, there is possibility, although small, of leakage of water from the storage reservoir of the No. 6 dam to other basins.

On the other hand, in the No. 1 dam site there is posibility of water leakage to the downstream side.

The topography of the basin of the Mae Chaem River is generally represented by a gentle mountainous configuration. In addition, the river presents also a considerable meandering.

The geology of the basin is composed chiefly of gneiss, granite, shale and limestone (Thung Song group). The weathering phenomenon is generally very pronounced in the granite and in the shale. The steep cliffs existing between limestone and other layers, especially shale, compose the boundary between them. However, the upper part of these cliffs presents a flat plateau topography. Some karstic topopgraphy is found within the limestone mentioned above, according to the analysis of the air photographs, but many caves of various sizes are found on the outcrops.

The geology of the basin of the Mae Khan River is composed chiefly of gneiss, granite and shale. The topography within a distance of 1.5 km to the downstream of the No. 2 site presents locally some narrow valleys, and the outcrops of gneiss in the river bed are very hard. However, the topography within the basin of the Mae Khan River is generally gentle, and is characterized by low mountains. Accordingly, it is not possible to construct high dams in the basin of the Mae Khan River.

2.4.2 Judgement of the Various Dam Sites from the Point of View of Civil Engineering

Special considerations regarding to the hydrological characteristics of the project area should be made when the matter is analyzed from the point of view of hydroelectric power development. There are two seasons, i.e. wet and dry, lasting about 6 months each in the project area. Accordingly, the storage reservoir should be able to control the inflow throughout one or several years, and then a stable generation of electric power will be possible throughout the year as a consequence of that control. On the other hand, the project scale should be determined as a result of an economical evaluation.

(Mae Pai River)

a. According to the past reports, 6 dam sites have been proposed so far. According to the reports presented so far and the results of the aero photographs interpretation, the No. 2 and No. 3 dam sites are considered inadequate. This rejection is due to the possibility of occurrence of landslides at the said dam sites. The No. 4 and No. 5 sites were concluded to be adequate for construction of medium scale dams. However, from the topographical and geological points of view these sites are worse compared with the No. 6 site, and also from the geographical point of view they are located within a distance of less than 10 km from the No. 6 site. Accordingly, the No. 4 and No. 5 sites are not taken into consideration as object of dam construction, and the present Survey Team carried out field reconnaissance at the No. 1 and No. 6 sites.

b. Mae Pai No. 1

The catchment area at this point is 1,817 km^2, and the average run-off is 23 m^3/s. The field survey was carried out at the site originally proposed by the NEA and at an alternative site located approximately 1 km downstreams. The latter point is more advantageous from the topographical point of view. Both sites are characterized by outcrops of limestone with many caves, but at the right bank of the site originally proposed by the NEA the presence of shale is observed scattering in the limestone. A detailed geological survey is required in order to judge if the construction of the dam at that site is actually possible.

Two cases should be taken into consideration at the occasion of the analysis of the master plan. In other words, the 1st case is that assuming that the construction of the dam at the No. 1 site is possible, and the 2nd case is that assuming that the construction of the dam at the No. 1 site is impossible. Even when the construction of the dam at the No. 1 site is possible, it is desirable to design the storage reservoir in such a way that the influence upon the nearby plains is neglible, and in such a way to make possible the control of the discharge of the Mae Pai River throughout several years. From the point of view mentioned above, the Survey Team determined the full water level of the above mentioned storage reservoir at an altitude of 475 m.

c. Mae Pai No. 6

At this point the catchment area is 3,725 km^2 and the average run-off is 50 m^3/s. This site is adequate for construction of a large scale dam, and a fill type dam is taken into consideration in the present master plan.

If the development of the Mae Pai River is carried out with a 2 step configuration, composed of the No. 1 and No. 6 dams, the head occurring between the 2 dams can be utilized in practically full if the reservoir normal high water level of the No. 6 reservoir is assumed to be at an altitude of 400 m. On the other hand, the large area extending over the East and West sides of the Khong River is covered with a conspicuous karstic topography, and accordingly, the occurrence of water leakage is expected at places with altitudes exceeding approximately 400 m. Consequently, various cases of dams having storage reservoirs with altitudes below 400 m will be studied in the master plan.

(Mae Chaem River)

a. Five dam sites can be taken into consideration in the development of the Mae Chaem River. In the scheme for diversion of water from the Mae Pai River the controlled discharge flows from the reservoir to be constructed in the Mae Pai River to the Mae Chaem River. Consequently, it is assumed that the reservoir capacity on the Mae Chaem River required in the water diversion project will be identical to the capacity required in case of the project for individual development of the Mae Chaem River.

However, the waterway capacity and the power station will be modified according to the case.

b. Mae Chaem River No. 1

The catchment area at this site is 337 km^2 and the average run-off is 4.2 m^3/s. Consequently, the construction of a large scale dam is not required in this case. In addition, the analysis of the aero photographs interpretation has revealed the existence of many faults in this area, and this is another factor making this area inadequate for construction of a large scale dam. The construction of a dam with a scale suited for this site will be studied in the master plan, by taking into consideration the facts mentioned above. The dam waterway type will be also studied in addition to the dam system, because the river presents various places with a steep gradient at the neighboring of this site.

c. Mae Chaem River No. 2

The catchment area of this site is 654 km^2 and the average run-off is 7.9 m^3/s. The optimum scale for this site will be analyzed.

d. Mae Chaem River No. 3

The catchment area at this site is 969 km^2 and its average run-off is 11.6 m^3/s. The dam site has a relatively large width, and the foundation rock bed is extremely deep. This place can not be considered an adequate dam site, but the construction of the dam is possible. The geology of this area is formed of limestone containing many caves, and consequently, the high water level of the reservoir should be kept below 750 m.

e. Mae Chaem River No. 4

The topography of the originally proposed site is adequate for construction of the dam. However, the left bank side is composed of limestone containing large caves. Accordingly, a survey of water permeability at the periphery of the dam site and in the reservoir is required, in order to make a judgement of the possibility of construction of the dam.

An alternative dam site is proposed 6 km upstream of the originally proposed one. The catchment area of this dam site is 1,955 km^2, and the average run-off is 22 m^3/s. The both banks of the dam site present a saddle shaped topographical configuration, and the foundation rock bed is relatively deep. However, there is not any adequate alternative site except this one, and this alternative site still be studied in the master plan. In this case, the normal high water level of the storage reservoir should be restricted to a maximum of 580 m altitude, by taking into consideration the topography of the both banks. The dam type and the dam waterway type will be studied at the occasion of the determination of the optimum scale.

If the results of the geological survey evidence that the originally proposed dam site makes possible the construction of the dam, further analyses should be carried out in the future with regard to this site.

f. Mae Chaem River No. 5

At this site the foundation rock is an extremely hard gneiss, a sedimentation layer with a thickness of approximately 20 m is accumulated in the river bed, and the width of the valley at both banks is large.

By assuming that the normal high water level of the reservoir will be located at an altitude of 425 m, the dam height will be 105 m with regard to the river bed and 125 m with regard to the foundation rock, and under such circumstances the dam crest length will be approximately 550 m. In view of the facts mentioned above, this is not topographically an ideal site. However, this site is located at the downstream extremity of the Mae Chaem River, having a catchment area of 3,735 km^2 and an average run-off of 38 m^3/s, which is a relatively large value. In addition, since it presents few problems from the geological point of view, it can be considered that most promising site within the Mae Chaem River development project.

With regard to the compensation problem, it is required to replace for part of the National Highway Route No. 108 (total width of 10 m, asphalt paved width of 6 m) which is located at the right bank of the dam site and makes the connection with the Mae Sariang, and for part of the road to Amphoe Mae Chaem (total width 8 m, not paved) which branches from that highway. The route of the National Highway should be replaced prior to starting the dam construction, and the Amphoe Mae Chaem road should have the alternative route constructed in accordance with the planned reservoir water level.

The study in the master plan will be carried out by assuming a fill type dam.

g. Mae Khan River No. 1 and No. 2

The catchment areas of these sites are 535 km^2 and 1,038 km^2 respectively, while the average run-off are 5.3 m^3/s and 10.2 m^3/s, respectively.

It is thought that the dam construction at the No. 1 site is possible. On the other hand, the topographical and geological characteristics at the No. 2 site are relatively good. Accordingly, the study will be carried out for these 2 sites.

h. Mae Taeng River

The KUD Project is being planned by the RID and the EGAT in the Mae Taeng River, and its Feasibility Report is scheduled to be prepared by the Electro Consult.

In the Mae Taeng River there is not any other adequate dam site with exception of the KUD Project one. On the other hand, the project for water diversion from the Mae Pai River requires an extremely long waterway, and it is evidently unfeasible.

Accordingly, the Mae Taeng River Project is excluded from the Master Plan in view of the facts mentioned above.

i. Water pumping and diversion project

- The Mae Pai River double step development project

  The economical advantage of the project will be improved in direct proportion to the volume of water diverted from the

Mae Pai River, provided that it will be possible to obtain the required water pumping power, when the transbasin project is assumed to bring economical benefits.

Accordingly, the master plan assumes that the volume of water diverted to the Mae Chaem River or to the Mae Khang River will be approximately equal to the total run-off of the Mae Pai No. 1 site, i.e., 23 m^3/s.

- The Mae Pai River single step development project

  The transbasin project will be analyzed by assuming the normal high water level at an elevation of 400 m for the Mae Pai No. 6 storage reservoir. In that case the volume of diverted water is assumed to be 23 m^3/s or more. The run-off of the Mae Pai No. 6 site is approximately 50 m^3/s, but the diversion of that volume seems to be excessive from the point of view of pumping power and from the point of view of utilization of water at the downstream areas.

CHAPTER 3

NECESSITY OF DEVELOPMENT

CHAPTER 3 NECESSITY OF DEVELOPMENT

3.1 The Economy in General

3.1.1 Foreword

During the last 20 years the Thai economy has shown a stable and rapid growth, and the GDP is presenting an annual average growth rate of 7.5%. Especially in the '60s the infrastructure of the country was expanded and reinforced thanks to the introduction of foreign aids and foreign capital, and with regard to the agriculture it was considerably diversified from the conventionally prevailing rice monoculture, while the industrialization progressed rapidly after the enforcement of the Industrial Investment Promotion Act in 1962, and during the period of 1965 through 1970 the growth rate of the GDP recorded an annual average of 8.6%. However, in the '70s the country faced various problems like the abrupt inflation rate triggered by the reduction of foreign investments in the country due to the worldwide economical recession resulting from the 1st Petroleum Crisis, the soaring prices of the imported commodities, etc. The situation presented a temporary improvement from 1976, but in the period of 1979 through 1980 the production of the chief agricultural products like rice, sugar and so forth declined due to the influence of the drought, resulting into a recession of the exports, and as a consequence of the concurrent increase of the import of raw material and capital goods required to upkeep the production of the domestic industry, the balance of international payments evidenced a tendency of pronounced deficit. Especially with regard to the import of crude oil, which corresponds to 85% of the energy consumption in Thailand, it came to share 30% of the total value of the imports in 1979 and became a large factor oppressing the international payments, as a consequence of the successive increases of price by the oil exporting countries.

Accordingly, in order to ensure the future economical growth of Thailand, efforts have been made to promote the development of domestically available energy resources like natural gas, water power, etc., making possible the reduction of the dependency of the country upon petroleum, so that the demand of energy can be coped with, which is expected to increase year by year along with the process of promotion of industrialization, besides, that the improvement of the agricultural productivity.

3.1.2 Actual Situation

As can be seen from the fact that approximately 70% of the employed population of the country is working in the agriculture and fishery, the economy of Thailand is based upon the agriculture even now. However, the agriculture comprises aspects of considerable instability, i.e., the dependency of the crop upon the weather conditions prevailing during the year and the dependency of the prices upon the situation of the international market and, as a consequence, from 1960 on the share occupied by the agriculture within the GDP tends to reduce year by year.

On the other hand, the share of the manufacturing industry within the GDP tends to increase gradually, and it is expected that within a few years these two items will share almost even percentages (refer to Table 3-1).

The facts mentioned above can be interpreted as an evidence of the tendency of take-off of the country from the agriculture-based economy and the tendency of materialization of the economical independency through the industrialization, based upon the Socio-Economic Development Plan (1st Plan started in January of 1961 and 4th Plan being enforced presently and expected to be completed in September of 1981) planned and drafted by the National Economic Development Board.

As mentioned in the preceding paragraph, the GDP of Thailand presented during the last 20 years an effective growth rate of 7.5%, and factors like the relatively stable political situation of the country, the expansion and reinforcement of the infrastructure, the diversification of the agriculture and the promotion of industrialization thanks to the establishment of the Industrial Investment Promotion Act can be mentioned as causes of that noteworthy growth.

Next, with regard to the international trade, the exports are composed chiefly of primary commodities such as rice, raw rubber, tapioca, maize, sugar, tin, etc., and in 1960 only two items, i.e., rice and raw rubber shared approximately 60% of the total value of the exports of the country, but recently that monocultural tendency seems to fade out, and the two items mentioned above share just 25% of the total values of the exports, and a wide variety of other export commodities are presenting a gradual growth.

As for the imports, the country is importing capital goods like machinery, steel and iron, etc., in addition to industrial raw materials, and especially the crude oil and petroleum products are evidencing recently a remarkable increase of the weight shared among the total value of the imports.

The international balance of payments is presenting recently a tendency of severe deficit, due chiefly to the reduction of the export of the main agricultural products caused by the drought occurred in 1976 and to the inversion of the balance of international trade caused by the 2nd petroleum crisis occurred from 1978 through 1979, etc.

3.1.3 Socio-Economical Development Plan

The Socio-Economical Development Plan of the Kingdom of Thailand, which has been carried out for a period of approximately 20 years since 1961 has the 4th Plan (October of 1977 through September of 1981) nearly ended. The chief targets of that 4th Plan are listed below, and are similar to those of the 3rd Plan (October of 1971 through September of 1976).

(1) Promotion of the recovery of the economy
(2) Elimination of the differences of income levels
(3) Restriction of the demographic growth, improvement of the skill of the workers and increase of employment
(4) Control of the basic natural resources and preservation of the environment
(5) Reinforcement of the security of the nation

However, the Thai authorities are now making reflections about the conversion of forests into arable land carried out during the 3rd Plan aiming at attaining the increase of production of crops like rice and maize, because it implies the risk of a disorderly exploitation of natural resources. In order to prevent the occurrence of such noxious situation, the said authorities are carrying out a survey of the natural resources, and are making efforts to control the basic natural resources and to preserve the environment, based upon the Local Development Plan (Table 3-5). The chief target of the 4th Plan is to make even the shares of the agriculture and manufacturing industry within the GDP, by adopting the policy of introduction of an export-oriented industry in the industrialization of the country.

The main points of the 5th Plan being prepared presently and having its enforcement scheduled for the period of 1982 through 1986 are as follows.

(1) To restrict the growth rate to less than 5% through 6%, by attributing special attention to the even distribution of the income and taking a serious view of the growth pattern instead of the high levels of the growth rate.

(2) To improve the efficiency of the production, by coping with the restrictions imposed to aspects like land, water, energy, forests, etc. To stimulate the exploitation of natural gas.

(3) To promote a careful and detailed production stimulation policy for the agriculture, because it shares 60% of the exports and 75% of the employed workers of the country, and is in addition characterized by the small consumption of energy.

(4) To reduce the import of raw materials and parts required by the industry, and to promote the light industry through its dispersion

to the local districts. To study carefully the investments of large enterprises.

(5) To reinforce the tax income of the nation by measures to cope with tax evasion and by increasing the types of direct taxes, in addition to measures to stimulate the saving and elimination of economical monopoly.

3.2 Power Supply Situation

3.2.1 Foreword

The consumption of electric power in the Kingdom of Thailand is recently presenting a remarkable increase, and the growth rate occurred during the last 10 years have been of the order of 16% in average, with exception of the 2 or 3 years immediately after the petroleum crisis. That remarkable increase can be attributed to the rapid development of the Thai economy and to the active suburban development policy of the government. On the other hand, the increase of the consumption due to the tourism was also very pronounced, and 20% of the 12% increase of demand occurred in the Bangkok area compared with a year before can be attributed to the tourism.

Presently, the power generation facilities of the EGAT have a capacity of approximately 3,250MW, but according to the Annual Report of 1979 the total capacity of 2,886MW is composed of 61.6% of thermal electric plants, 31.5% of hydroelectric station, 5.7% of gas turbines and 1.2% of Diesel motor-generator groups. However, Thailand is also facing serious problems of outflow of hard currency due to the soaring prices of the petroleum, and efforts to convert the fuel of the thermal electric power stations, which occupy a large percentage of the power sources of the country, into domestically available fuels like natural gas or lignite are indispensable at the actual state of things.

The natural gas recently discovered at the Gulf of Thailand is expected to become the main fuel at the South Bangkok Thermal Electric Power Station, which is the largest power plant existing in the Metro-Bangkok area, and works aimed at making the petroleum-gas conversion in the said plant are progressing presently. The utilization of the said natural gas is expected to start in 1981, and the fuel to be utilized in the Bang Pakong Thermal Electric Power Station (2,920MW) which is being presently constructed by the EGAT is expected to be composed 100% of natural gas.

Survey on the reserves of lignite are being carried out presently in the neighbouring of Chiang Mai, in the northern region of the country, and simultaneously, the EGAT is carrying out the expansion of the Mae Moh Thermal Electric Power Station.

In addition to the measures described above aimed at reducing the dependency upon petroleum, efforts to develop the water power resources are also progressing in the country. Recently the construction of the Srinagarind Hydroelectric Power Station (360MW, final capacity of 720MW), which has the largest scale in the basin of the Quae Yai River, has been completed, and in addition other hydroelectric power stations like Pattani (72MW), Lower Quae Yai (39MW), Quae Noi (300MW), etc., are presently under construction.

3.2.2 Actual Situation

Presently, the supply of electric power in Thailand is under the responsibility of the EGAT, which is in charge of a wide variety of activities including construction, operation and maintenance of power plants, transmission lines and substation, and the transmission of power up to the demand centers. The transmitted power is distributed to the consumers by the MEA and by the PEA, and in addition, in case of some specific industries and facilities, power is directly transmitted by the EGAT. Besides the cases above, in areas not covered by the transmission networks, power can be supplied by small sized hydroelectric power stations under the control of the NEA.

In 1979 the power generation facilities under the control of the EGAT were 5 thermal electric power stations totaling 1,777.5MW, 7 hydroelectric power stations totaling 909.2MW, 6 Diesel power generator units totaling 34.6MW and 5 gas turbine power generation units totaling 165MW, and the electric energy generated during the year was 15,539MKWH. For further details refer to the Table 3-6.

The electric power supply system of the EGAT is divided into the 4 areas listed below.

- First area covering the Bangkok Metropolitan area
- Second area covering the North-East region of the country
- Third area covering the Southern region of the country
- Fourth area covering the Northern region of the country

Power of the first area and fourth area is supplied by the North Bangkok and South Bangkok Thermal Electric Power Stations, and by the Mae Moh

Lignite Thermal Electric Power Station located in the northern region of the country. At the occasion of the peak power consumption, there is also supply of current from the Bhumibol, Sirikit and Srinagarind Hydroelectric Power Station. Besides the facilities mentioned above, gas turbine and diesel power plants have been installed at the power demand centers, aiming at both improving the reliability of the system, and coping with situations of abnormal power demand peaks.

In the second area, located in the North-Eastern Thai region, power is generally supplied by hydroelectric power stations, and gas turbines are utilized as auxiliary means at the occasion of peaks of power demand. In this area part of the consumed power is purchased from the Nam Ngum power station of the PDR of Laos. In case of insufficiency of power even with that purchase, there is supply of complementary power from the first area, by a 115kV transmission line.

In the third area, corresponding to the Southern Thailand, power is supplied by the Krabi Lignite Thermal Electric Power Station and by the Surat Thani Oil Thermal Electric Power Station, together with some auxiliary diesel and gas turbine generator units. Refer to Fig. 3-1. As for the transmission lines, 3 voltage classes, namely, 230kV, 115kV and 69kV are used, and the frequency is 50Hz. In 1979 the extension of the various types of transmission lines were 2,547km/230kV, 5,584km/115kV and 1,023km/69kV.

3.2.3 Load Forecast

As can be seen in the Table 3-7, the increase of demand of electric power in the period of 1970 through 1978 presented an average of 14.25% in terms of KW and 15.77% in terms of KWH, which are quite high rates. Only in 1974 the growth rate attained a very low value of 4.75%, due to the influence of the petroleum shock and due to the energy saving policy adopted by the government.

In December of 1978 was announced the new load forecast referring to all power systems. That forecast was presented to the Power Tariff Study Sub-committee as a result of the joint work carried out by the Load Forecast Working Group. The said Working Group was composed by representatives dispatched from the organizations listed below.

NESDB: National Economic and Social Development Board

NEA : National Energy Administration

EGAT : Electricity Generating Authority of Thailand

MEA : Metropolitan Electricity Authority

PEA : Provincial Electricity Authority

The forecasting work was started in September of 1978, and the relevant report was prepared after 8 meetings carried out at the NESDB. The summary of the said report is presented in the Table 3-7. According to that report, during the period of 12 years from 1979 through 1990, the average growth of demand is expected to be 10.7% in terms of KW and 10.0% in terms of KWH, where the minimum growth is expected to be 7.76% in terms of KW and 7.74% in terms of KWH occurring in 1990. However, in case of implantation of new industries in the power distribution areas of the PEA as a result of the future electrification of the local districts, the figures mentioned above will naturally require corrections.

3.2.4 Development Plan

According to the demand forecast described in the paragraph 3.2.3, the power generation facilities which will be required anew in Thailand will be approximately 4,500MW in 1990. Aiming at coping with that demand, the NEA and the EGAT are with close coorporation preparing the plan for development of new power resources like water power resources and thermal power resources, and are making efforts in order to materialize them. The Development Plans prepared by the EGAT and their order of priority are summarized in the Figs. 3-2 and 3-3 and in the Table 3-8.

The various projects studied in the present Master Plan are not taken into consideration in the said development plan. However, in the Inventory of Hydropower Potential in Thailand, they are taken into consideration with the denominations listed below, in the desk study level or as potential projects.

Mae Pai River	Nam Pai No. 3	97.6MW
Mae Chaem River	Nam Chaem No. 1	10.0MW
Mae Chaem River	Nam Chaem No. 2	37.3MW
Mae Chaem River	Nam Chaem No. 3	50.7MW
Mae Chaem River	Nam Chaem No. 4	109.0MW
Mae Chaem River	Nam Chaem No. 5	219.0MW

In the present Master Plan the projects listed above, which are at the desk study level, are pushed up to the pre-feasibility or feasibility Study Level.

As for the hydropower potential in Thailand, it is estimated to reach a total output power of 20,000MW and 92 sites, in accordance with the Fourth Five-year Plan announced by the NESDB in 1977. After that, in 1978 the NESDB, NEA, EGAT and the RID joined together the plans of each organization and made a new estimation based upon unified criteria. The conclusions obtained at that occasion are summarized in the

"Inventory of Hydropower Potential in Thailand Volume I
- Main Report".

The main points of the conclusions of that report are as follows.

- Existing Projects including those under construction : 11 sites 2,099.1MW
- Pre-feasibility Study Level or Higher : 21 sites 6,516.9MW
- Desk Study Level or Potential Projects : 72 sites 15,009.6MW

The total of the cases mentioned above is 104 sites and 23,625.6MW. However, the actual potential is presumed to be approximately 20,500MW, because the cases listed above include 7 water pumping storage projects, with a total of approximately 3,100MW. On the other hand, with regard to the Pa-Mong Project (4,800MW) planned in the Mekong River flowing on the border with Laos, it is not possible to say when the project will be developed, because of the international situation.

3.3 Necessity of Development and Its Time to Be Set up

3.3.1 Necessity of Development

As mentioned in the paragraph 3.2, the consumption of electric power in Thailand is presenting a remarkable growth, but on the other hand, with regard to the supply of power, the power generation cost is presenting a pronounced increase due to the repeated increases of petroleum prices occurred recently, because the fuel of thermal electric power plants being main sources of energy depends upon imported petroleum, consequently the Thai authorities in charge of the matter have practiced the increase of the electric charges twice a year. Aiming at coping with the mentioned electricity crisis, the authorities responsible for the subject is making efforts like the restriction of supply of power, large increase of the electric charges, revision of the electric charge system (adoption of progressive charges proportional to the power consumption), restriction of the business hours of the restaurants and similar activities, and so forth.

According to the 5th Five-year Development Plan which will be enforced from October of 1981, the annual growth rate of power demand which used to be approximately 15% so far will be restricted to less than 10%, the import of petroleum will be reduced, and the effective utilization of the domestically available energy resources (hydropower resources, lignite, natural gas, oil shell, etc.) and imported coal thermal electric projects and so forth will be promoted as much as possible.

The power potential development plan of the EGAT covers the period up to 1993, but the last item progressing toward the materialization is the 9th Generator (300MW) of the Mae Moh thermal electric power plant by lignite scheduled for 1989, and all other items are subject to changes, because they are at the level of desk plans.

For example, with regard to nuclear power plants, they are far from being materialized, because there are too many problems to be solved. As for natural gas burning thermal electric power plants, the gas generated at the presently existing wells are expected to be utilized in the Bang Pakong Power Station and in the South Bangkok Power Station, and new power plants utilizing natural gas have not been planned yet. As for lignite burning thermal electric power plants, the presently available lignite of the Mae Moh area is scheduled to be utilized in the Mae Moh thermal electric power plant, thus there is no rest for other new plants constructed anew.

The thermal electric power plants to be constructed anew in the future will have their operation depending upon lignite and natural gas to be discovered or upon coal to be imported from foreign countries. Among the mentioned alternatives, the thermal electric power plants burning imported coal seem to be of the highest grade of feasibility. There is a quantity of coal in the world sufficient to cope with the demand expected to occur in the future, and in addition, since the reserves of coal are widely distributed throughout the world, a continued import is expected to be possible also in the future. In countries like Japan, Taiwan, Korea and Hong Kong the first thermal electric power plant burning imported coal is expected to start the operation in 1981, and the same will occur in the various countries of the Eastern Asia area. Accordingly, the imported coal burning thermal electric plants are expected to replace the petroleum burning ones.

In view of the considerations above, the hydroelectric power stations projects offered to basic survey, which do not present technical problems and are considered economically feasible can be materialized at any time, as soon as the raising of the required funds is available.

Under such circumstances, the Nam Pai No. 6 Power Generation Project and the Chaem No. 5 Power Generation Project are ones of a few which have the survey and works in progress, and it is desirable to go forward to the next steps, i.e., the feasibility study and the detailed design, if no technical problems are found. Even when the project does not present high degree of economical advantages at the present time, we consider it recommendable to bring forward from the point of view of the national interest, by taking into consideration the increase of the prices of imported energy resources expected to occur in the future and its stable supply, in addition to the saving of hard currency required to import the fuel for operation of the thermal electric power plants.

Especially in case of national enterprise like the electric power industry, the decision referring to the relevant projects should be made by taking carefully into considerations aspects like the future operation and maintenance, stable supply of fuel, increase of the prices of fuel, interruption of supply (import) of fuel due to a temporary worsening of the international relations, and so forth, besides the optimistic principles of the free economy.

In addition, with regard to the Nam Pai No. 1 Power Generation Project and Mae Chaem No. 4 Power Generation Project, which do not have yet the survey and works in progress, it is recommendable to bring them forward to the next stage, because of their possibility to have developing merit in the future.

As for the water pumping projects, the results from various studies carried out so far suggest that the plan referring to the diversion of the water of the Pai River to the Chaem River is the most advantageous one from the economical point of view. However, in view of the large pumping head, the benefits brought to the agriculture and the benefit resulting from the increase of the power and energy output generated at the downstream power station of the Pai River are small, and thus the project is economically a whole disadvantageous comparing with the investment.

3.3.2 Development Time

As can be seen from the electric power supply situation prevailing in Thailand described in the preceding paragraph, the exploitation of the hydropower resources is a theme of utmost urgency, from the points of view of utilization of the domestically available natural resources and the stable supply of power by reducing the dependency of the power generation upon foreign sources, etc.

On the other hand, with regard to the power supply system existing presently in Thailand, it is expected to be connected to the Ban Pakong Thermal Electric Power Plant which has an individual generator capacity of 550MW, and to the Mae Moh Thermal Electric Power Plant which has a capacity of 300MW. The connection to the power supply system is possible without any restriction in particular regarding the individual generator capacity.

As for the time of the actual start of operation, it should be determined after making a comparative study of the priority with regard to the other hydroelectric power generation projects. However, in view of the actual situation in the country, which is requiring an urgent development of the hydropower resources, it is recommendable to continue the survey and to prepare the plan referring to the individual development of the river, aiming at starting the generation of power in order of the readiness for development, by taking into consideration the time required to carry out the construction work.

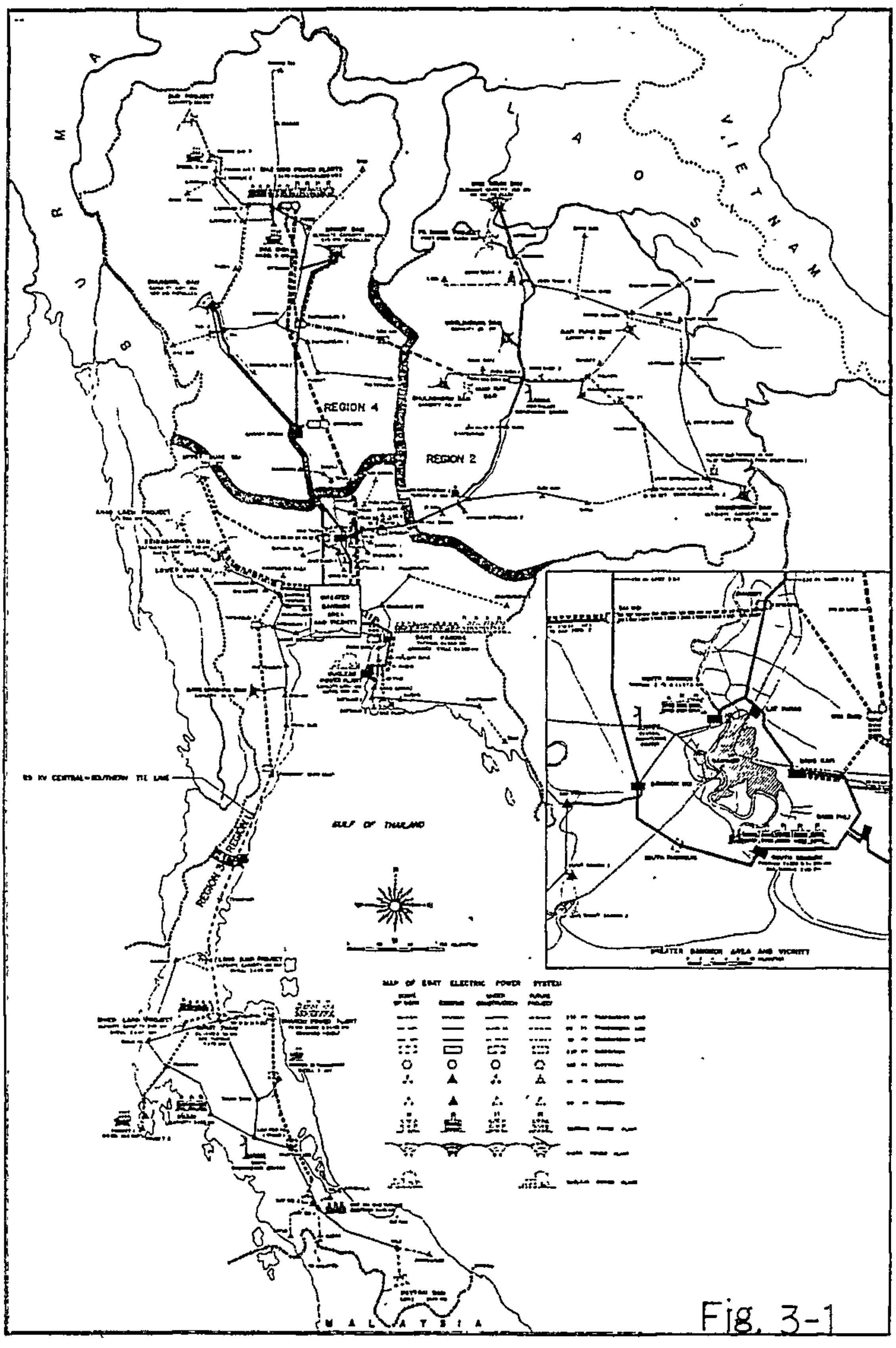
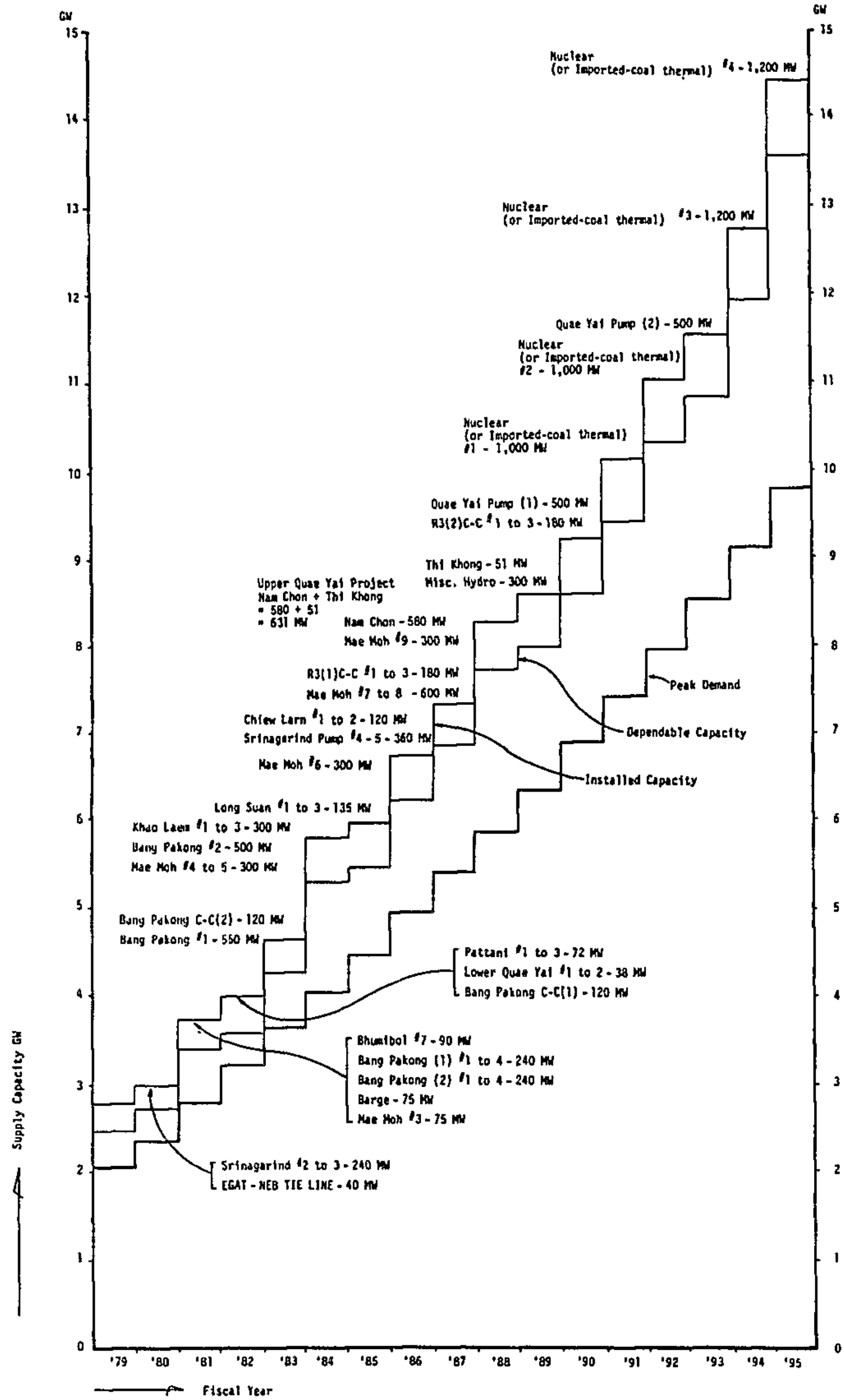
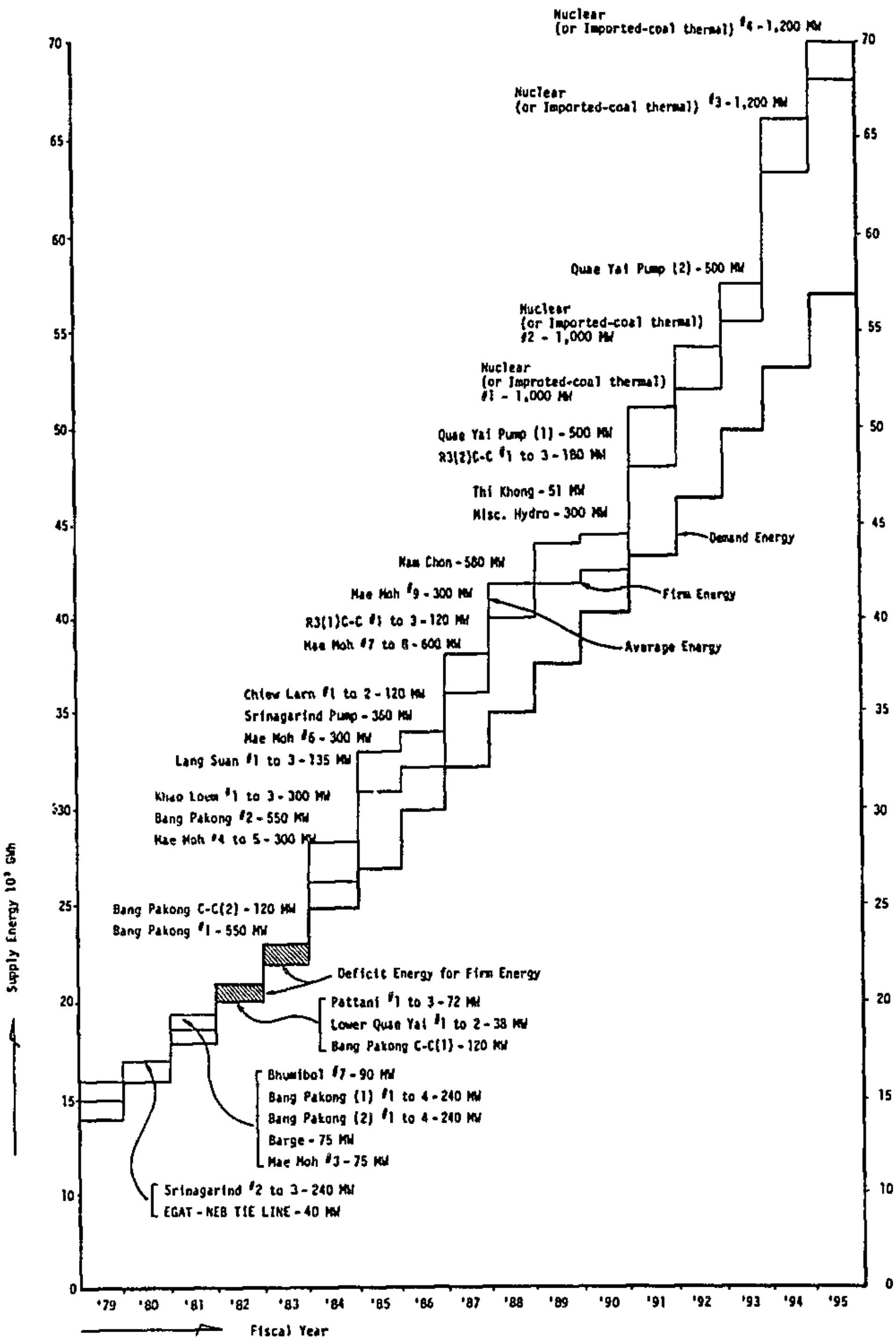

B U R M A
L A O S
V I E T N A M
REGION 4
REGION 2
REGION 3
GULF OF THAILAND
M A L A Y S I A
GREATER BANGKOK AREA AND VICINITY
MAP OF EGAT ELECTRIC POWER SYSTEM

Fig. 3-1



Note: Fiscal Year '79:'78 Oct. to '79 Sep.

Fig. 3-2 Yearly Peak Balance in GW



Note: Fiscal Year '79: '79 Oct. to '80 Sep.
: GWh = 10⁶ Wh

Fig. 3-3 Yearly Energy Balance in GWh

Table 3-1 Gross Domestic Product at 1972 Prices 1/

Unit: 10^6 Baht

	1975	1976	1977	1978	1979 2/
Agriculture	62,081 (30.5)	65,898 (29.6)	65,537 (27.4)	75,059 (28.1)	72,800 (25.5)
Mining and quarrying	2,485 (1.2)	2,906 (1.3)	3,526 (1.5)	4,101 (1.5)	4,700 (1.7)
Manufacturing	36,787 (18.1)	42,529 (19.1)	48,071 (20.1)	52,756 (19.8)	59,200 (20.8)
Construction	8,514 (4.2)	10,022 (4.5)	11,996 (5.0)	14,141 (5.3)	15,400 (5.4)
Electricity and water supply	3,181 (1.6)	3,642 (1.6)	4,144 (1.7)	4,500 (1.7)	5,100 (1.8)
Transportation and communications	13,445 (6.6)	14,650 (6.6)	16,142 (6.8)	18,434 (6.9)	20,900 (7.3)
Wholesale and retail trade	35,774 (17.6)	38,821 (17.5)	41,213 (17.3)	43,452 (16.3)	47,200 (16.6)
Banking, insurance and real estate	9,629 (4.7)	10,208 (4.6)	11,574 (4.9)	13,833 (5.2)	15,400 (5.4)
Ownership of dwellings	3,555 (1.7)	3,664 (1.6)	3,823 (1.6)	4,081 (1.5)	4,400 (1.5)
Public administration and defence	8,359 (4.1)	8,893 (4.0)	9,555 (4.0)	10,166 (3.8)	10,900 (3.8)
Services	19,704 (9.7)	21,276 (9.6)	23,260 (9.7)	26,317 (9.9)	29,200 (10.2)
Gross Domestic Product (GDP)	203,514 (100.0)	222,509 (100.0)	238,841 (100.0)	266,840 (100.0)	285,200 (100.0)

Source: Office of the National Economic and Social Development Board

1/ Revised

2/ Preliminary figures

Note: Figures in brackets denote percentage of the GDP.

Table 3-2 Export Value of the Chief Commodities

Unit: 10^6 Baht

Item \ Year	1960		1965		1970		1975		1976		1977		1978		1979	
	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%
1. Rice	2,570	29.8	4,334	33.5	2,516	17.0	5,852	13.0	8,603	14.2	13,382	18.8	10,425	12.6	15,602	14.3
2. Crude rubber	2,579	29.9	1,999	15.4	2,232	15.1	3,474	7.7	5,297	8.7	6,164	8.7	8,030	9.7	12,342	11.4
3. Tapioca products	288	3.3	676	5.2	1,223	8.3	4,597	10.2	7,527	12.4	7,720	10.8	10,892	13.1	9,523	8.8
4. Tin	537	6.2	1,166	9.0	1,618	11.0	2,247	5.0	2,972	4.9	4,541	6.4	7,229	8.7	9,252	8.5
5. Maize	551	6.4	1,004	7.8	1,969	13.3	5,705	12.7	5,676	9.3	3,345	4.7	4,275	5.1	8,957	8.3
6. Sugar	8	0.1	100	0.8	94	0.6	5,696	12.7	6,843	11.2	7,445	10.4	3,969	4.8	5,567	5.1
Others	2,087	24.2	3,662	28.3	5,120	34.7	17,436	38.7	23,879	39.3	28,601	40.2	38,245	4.6	47,164	43.5
Total	8,612	100.0	12,941	100.0	14,772	100.0	45,007	100.0	60,797	100.0	71,198	100.0	83,065	100.0	108,406	100.0

Source: Bank of Thailand

Table 3-3 Imports per Commodity

Unit: 10^6 Baht

Type of commodity / Year	1960	1965	1970	1975	1976	1977	1978	1979
I. Consumption goods	3,365 (35.0)	4,113 (26.7)	5,229 (19.4)	8,455 (12.7)	9,418 (12.9)	11,114 (11.8)	12,942 (11.9)	15,992 (10.9)
1. Non durable goods	2,258	2,919	3,486	5,148	5,586	6,346	7,544	9,327
2. Durable goods	807	1,244	1,743	3,307	3,832	4,768	5,398	6,665
II. Raw materials and semi-finished products	1,746 (18.1)	3,210 (20.8)	6,725 (24.9)	16,105 (24.1)	20,216 (27.7)	26,921 (28.6)	29,598 (27.2)	43,462 (29.7)
1. Consumption goods	1,030	2,128	4,139	10,318	12,530	16,060	16,937	26,086
(part of) Textile materials	60	319	602	1,902	2,475	3,134	2,236	3,183
2. Capital goods	716	1,082	2,586	5,787	7,686	10,861	12,661	17,376
(part of) Steel and iron	568	763	1,647	3,236	4,669	6,352	7,765	10,029
III. Capital goods	2,367 (24.6)	4,775 (30.9)	9,371 (34.7)	22,239 (33.3)	19,405 (26.6)	24,393 (25.9)	31,317 (28.8)	39,835 (27.3)
(part of) Machines (with exception of electrical machines)	1,021	2,103	4,723	11,973	9,681	12,592	15,894	18,627
(part of) Electrical machinery and parts	334	588	1,419	2,730	3,085	3,555	5,836	7,314
IV. Others	2,144 (22.3)	3,335 (21.6)	5,684 (21.0)	20,036 (30.0)	23,838 (32.7)	31,749 (33.7)	35,042 (32.2)	46,841 (32.0)
(part of) Automobiles and parts	-	1,454	2,204	4,542	5,174	7,958	7,550	7,030
(part of) Crude oil and petroleum products	-	1,353	2,329	14,233	16,695	20,889	22,851	32,650
Total	9,622 (100.0)	15,433 (100.0)	27,009 (100.0)	66,835 (100.0)	72,877 (100.0)	94,177 (100.0)	108,899 (100.0)	146,151 (100.0)

Source: Bank of Thailand

Table 3-4 Evolution of the International Balance of Payments

Unit: 10^6 US$

	1972	1973	1974	1975	1976	1977	1978	1979
A. Balance of International Trade								
Export (FOB)	1,046	1,532	2,472	2,218	3,068	3,523	4,113	5,343
Import (CIF)	1,473	2,062	3,165	3,226	3,572	4,803	5,540	7,696
Balance	-427	-530	-693	-1,008	-554	-1,280	-1,427	-2,347
B. Invisible Balance of Trade								
Transportation insurance	22	27	45	52	55	61	42	78
Travel	69	95	133	85	5	71	195	287
Investment proceedings	-16	-21	-1	6	-42	-74	-156	-314
Government transactions	237	225	196	161	80	32	41	81
(Military area)	(212)	(206)	(170)	(117)	(15)	(-)	(-)	(2)
Others	5	9	32	4	-16	32	106	-11
Net balance	317	335	405	308	82	120	228	121
C. Transfer Balance								
Private remittances	30	118	194	57	5	22	6	25
Government transactions	29	28	81	25	18	18	34	38
Net balance	59	146	275	82	23	40	40	63
Ordinary balance (A - B - C)	-51	-49	-13	-618	-449	-1,120	-1,159	2,163
D. Capital Balance								
Direct investment	69	79	138	87	81	108	51	52
Loans (long-term)	99	-30	191	176	126	281	293	908
(State-owned enterprises)	(16)	(18)	(50)	(59)	(92)	(238)	(258)	(609)
(Private enterprises)	(67)	(-59)	(132)	(66)	(34)	(43)	(35)	(299)
International trade credit, etc.	15	31	2	120	148	270	96	178
Government transactions	-5	32	4	5	108	39	303	536
Net balance	175	112	335	388	463	698	743	1,676
E. Errors and Omissions	68	-21	79	87	18	45	-249	79
(A - E) Total Balance	192	42	401	-143	-4	-377	-665	-418

Source: Monthly Report of the Bank of Thailand

US$ exchange rate 1970-1972 US$1 = 20.80 Baht (IMF evaluation)
1973 US$1 = 20.40 Baht (Average exchange rate)
1977-1978 US$1 = 20.00 Baht (IMF evaluation)

Table 3-5 GDP Targets (Effective Value Base)

Unit: 1962 prices, 10^6 Baht and %

	3rd Plan (Attained Results)					4th Plan			(Reference)
	1971		1976			1981 (Target)			Results of 1979
	Value	%	Value	%	Average Growth Rate	Value	%	Average Growth Rate	%
Agriculture	38,145	29.4	46,113	26.4	3.9	58,706	23.9	5.0	25.9
Manufacturing industry	23,569	18.2	35,575	20.3	8.6	56,277	22.9	9.6	20.4
Mining	1,879	1.4	1,762	1.0	Δ0.5	2,066	0.8	3.2	1.6
Construction	6,210	4.8	6,951	4.0	2.4	8,059	3.3	3.0	5.4
Electricity & roads	2,934	2.3	5,737	3.3	14.4	9,794	4.0	11.3	1.8
Communication & transportation	7,981	6.2	11,780	· 6.7	8.1	16,857	6.9	7.4	7.3
Wholesale and retail	22,816	17.6	28,792	16.5	4.8	39,080	15.9	6.3	16.5
Banks, insurance & real estate	5,297	4.1	8,852	5.1	10.9	13,063	5.3	8.1	5.4
Dwelling	2,399	1.9	2,861	1.6	3.6	3,555	1.4	4.4	1.5
Official business & defence	5,647	4.3	7,546	4.3	6.0	10,331	4.2	6.5	4.0
Other services	12,740	9.8	18,897	10.8	8.2	27,470	11.2	7.8	10.2
GDP	129,617	100.0	174,866	100.0	6.2	245,258	100.0	7.0	100.0

Table 3-6 Installed Electric Generating Capacity as of December 1978

Plant Type	No. of Units	Capacity (MW)		Average Energy Generation (GWh/yr)
		Installed	Ultimate	
A. Hydroelectric Plant				
Kang Krachan	1	19	19	70
Bhumibol	6	420	560	1,550
Sirikit	3	375	500	965
Chulabhorn	2	40	40	115
Nam Pung	2	6	6	15
Sirindhorn	2	24	36	73
Ubolratana	3	25	25	65
Sub-total	19	909	1,186	2,853
B. Thermal Power Plant				
North Bangkok	2	237.5		1,900
South Bangkok	5	1,300		9,100
Mae Moh	2	150		1,000
Krabi	3	60		300
Surat Thani	1	30		210
Sub-total	14	1,777.5		12,510
C. Gas Turbine				
South Bangkok	3	45		40
Nakhon Ratchasima	1	15		13
Udon Thani	1	15		13
Hat Yai	3	45		40
Surat Thani	3	45		40
Sub-total	11	165		146
D. Diesel Power Plant				
Chiang Mai	3	3		3
Mae Moh	9	9		8
Srinagarind	5	5		4
Phuket	4	10.6		9
Nakhon Si Thammarat	2	2		2
Bang Lang	5	5		4
Sub-total	28	34.6		30
Total	72	2,886.1		15,539

Table 3-7 Total EGAT Generation Requirement

Fiscal Year	Peak Generation		Energy Generation		Annual Load Factor (%)
	MW	% Increase	MkWh	% Inrease	
		Actual			
1970	748.35	17.28	4,095.31	21.62	62.47
1971	872.70	16.62	4,792.88	17.03	62.69
1972	1,028.80	17.89	5,711.15	19.16	63.37
1973	1,199.30	16.57	6,872.84	20.34	65.42
1974	1,256.30	4.75	7,258.62	5.61	65.96
1975	1,406.60	11.96	8,211.57	13.13	66.64
1976	1,652.10	17.45	9,414.48	14.65	65.05
1977	1,873.40	13.40	10,950.62	16.32	66.73
1978	2,100.60	12.13	12,371.67	12.98	67.23
		Forecast			
1979	2,405.00	14.49	14,188.00	14.68	67.34
1980	2,709.00	12.64	15,914.00	12.17	67.06
1981	3,151.00	16.32	18,355.00	15.34	66.50
1982	3,567.00	13.20	20,714.00	12.85	66.29
1983	3,961.00	11.05	22,715.00	9.66	65.46
1984	4,356.00	9.97	24,828.00	9.30	65.07
1985	4,762.00	9.32	27,025.00	8.85	64.78
1986	5,260.00	10.46	29,782.00	10.20	64.63
1987	5,692.00	8.21	32,230.00	8.22	64.64
1988	6,148.00	8.01	34,843.00	8.11	64.70
1989	6,634.00	7.91	37,620.00	7.97	64.74
1990	7,149.00	7.76	40,533.00	7.74	64.72

Table 3-8 List of Power Plants in the Revised Power Development Plan (1979 ∿ 1990)

Power Plant	Fuel Type	Unit No.	Rating (MW)	Total (MW)	Proposed Commissioning Date
Mae Moh	Lignite	2	75	75	January 1979
Srinagarind	Hydro	1	120	120	September 1979
Srinagarind	Hydro	2	120	120	December 1979
Srinagarind	Hydro	3	120	120	March 1980
Bang Pakong Gas Turbine (1)	Oil/Gas	1 ∿ 4	60	240	October 1980
Barge Thermal Plant	Oil/Gas	1	75	75	January 1981
Bang Pakong Gas Turbine (2)	Oil/Gas	1 ∿ 4	60	240	April 1981
Mae Moh	Lignite	3	75	75	July 1981
Bhumibol	Hydro	7	90	90	August 1981
Pattani	Hydro	1 ∿ 3	24	72	October 1981
Bang Pakong Combined-Cycle (1)	-	1	120	120	April 1982
Lower Quae Yai	Hydro	1 ∿ 2	19	38	August 1982
Bang Pakong Combined-Cycle (2)	-	1	120	120	October 1982
Bang Paking Thermal Unit 1	Oil/Gas	1	550	550	July 1983
Mae Moh	Lignite	4	150	150	January 1984
Khao Laem	Hydro	1 ∿ 3	100	300	March 1984
Mae Moh	Lignite	5	150	150	July 1984
Bang Pakong Thermal Unit 2	Oil/Gas	2	550	550	August 1984
Lang Suan	Hydro	1 ∿ 3	45	135	October 1984
Srinagarind	Hydro	4 ∿ 5	180	360	October 1985
Chiew Larn	Hydro	1 ∿ 2	60	120	January 1986
Mae Moh	Lignite	6	300	300	September 1987
Region 3 Combined-Cycle (1)	Oil/Gas	1 ∿ 3	60	180	October 1986
Gas Turbine Retired	Oil	1 ∿ 11	15	-165	October 1986
Mae Moh	Lignite	7	300	300	March 1987
Mae Moh	Lignite	8	300	300	September 1987
Upper Quae Yai	Hydro	1 ∿ 4	140	560	October 1987
Ao Phai Nuclear	Nuclear	1	900	900	April 1989
Region 3 Combined-Cycle (2)	Oil/Gas	1 ∿ 3	60	180	July 1980
Krabi Retired	Lignite	1 ∿ 3	20	-60	July 1990

Total net additional capacity	6,315MW	9,126.1MW
Existing capacity	2,811.1MW	

CHAPTER 4

HYDROLOGY

CHAPTER 4 HYDROLOGY

4.1 The Weather

4.1.1 The Climate

The climate in the Kingdom of Thailand suffers a considerable influence of the monsoon, and broadly speaking the year can be divided into two seasons, i.e., the rainy season and the dry season.

The rainy season is influenced by the south-west monsoon, beginning in mid May and finishing in mid October. During this season the south-west monsoon blows into the Thai territory coming from the Gulf of Thailand and from the Indian Ocean accompanied with a large quantity of rain, and especially in the months of August and September take place the heaviest rains. As a consequence of that situation both temperature and humidity are high during the rainy season and the sky is normally cloudy.

The dry season begins around mid October when the rainy season ends, and lasts until mid May in next year. This dry season can be divided into 2 parts, i.e., the first period extending from mid October through mid February, when the north-east monsoon generated at the polar areas reach the Thai territory after crossing Siberia and China. During this period the weather is generally cool and the rain is scarce. Subsequently, during the period which lasts from February to mid May the Polar Pacific Airmass is replaced by the Tropical Heat, which comes from the east and south-east, and as a consequence the weather gets hot and dry.

4.1.2 Rainfall

In the dry regions located at the lee side of the Tenesserim Mountains, i.e., the areas ranging from Chiang Mai, Tak and Kanchanaburi to Prachab, the annual rainfall is generally of the order of 1,200 mm through 1,400 mm. The catchment area of the present project belongs to the area in question, and generally speaking the measured rainfall coincides with the values mentioned above. Refer to Tables 4-5 through 4-9.

The rainfall in the region around Chiang Rai, located at the north of Chiang Mai and close to the border with Burma is relatively large, and values of the order of 1,800 mm have been recorded so far.

The other dry areas are the Chaiyaphum region and the Nakhon Ratchasima region located at the east side of the Phetchabun range, and the annual rainfall is less than 1,200 mm.

At the eastern side of the country, the regions located at the south of Chantaburi have heavy rainfall, and values larger than 2,400 mm have been recorded so far.

The southern region of Thailand suffers the influence of both north-eastern and south-western monsoons, and the rainfall presents a variation from 1,400 mm through 2,400 mm.

In the region extending from Ranong, in the west coast, to the southern part of the country, there is a heavy rainfall, like in the eastern side of the country, and values larger than 2,400 mm have been observed.

4.1.3 Temperature

The annual atmospheric temperatures prevailing in the various regions of Thailand indicate that this country is evidently located in the tropical area. Generally speaking, the average temperature is 26°C through 28°C.

The central plains of the country are the areas where the temperatures are specially high, and the average atmospheric temperature exceed 28°C in those areas. The northern region of the country, around Chiang Mai is relatively cool, and the temperature is 24°C through 26°C. The atmospheric temperatures measured in the areas covered by the present project are similar to those mentioned above. Refer to Table 4-10.

April is the hottest season of the year, due to the superposition of the sun upright and the dry season. January is the coolest season due to the influence of the north-east monsoon. The minimum temperature occurring in the northern region of Thailand is of the order of 3°C through 7°C, and 1.5°C has been recorded in Chiang Rai, and the occurrence of frost is observed in some mountainous areas.

In the southern part of the country the atmospheric temperature has a constant value of the order of 26°C through 28°C, but this is due to the direct influence of the nearby ocean.

4.1.4 Humidity

In the northern region of Thailand the average relative humidity presents values ranging from 65% through 75%. In some areas of the northern region of the country the relative humidity may become lower than 65%.

During the season of the north-eastern monsoon the relative humidity becomes high at the morning due to the thick fog occurring early morning, and it decreases in the afternoon. However, the average value of the relative humidity is very low compared with other seasons.

The southern region of the country presents high values of relative humidity, exceeding 80%, due to the influences of the ocean and the rain which occurs all the year round.

4.1.5 Evaporation

The annual evaporation presents a variation inversely proportional to the annual rainfall. In the northern region of Thailand the evaporation is larger than that occurring in the southern region of the country, and reaches values of 1,300 mm through 1,700 mm. Refer to Table 4-11.

Generally speaking, the largest evaporation occurs during the hottest month, which is April, and the minimum evaporation occurs during the coolest months, which are December and January. In the southern region of the country the evaporation is relatively small and uniform throughout the year, and the annual average value is of the order of 1,000 mm.

4.1.6 Atmospheric Pressure

The average atmospheric pressure throughout the year is of the order of 1,005 milibar through 1,010 milibar. The atmospheric pressure begins to rise in August until reaching the maximum value in January, and after that it lowers gradually until mid June. The values of the atmospheric pressure from June to October present a considerable variation, due to the influence of the Typhoons which come from the South China Sea to the Thai territory.

4.2 Water Gauging Stations and Meteorologic Stations

There are several water gauging stations along the various rivers flowing along the project area. Although small scaled, meteorologic stations are also installed together with these water gauging stations, and they are collecting data referring to rainfall, atmospheric temperature, evaporation, etc.

After the collection of data and information and the field reconnaissance carried out by the Survey Team, the water gauging stations which can be used for the sake of preparation of the Master Plan are as follows.

Name of River	Name of Water Gauging Station	Catchment Area (km^2)
Mae Chaem River	Kaeng Ob Luang (RID)	3,853
Mae Chaem River	Ban Obb Luang (EGAT)	3,735
Mae Chaem River	Ban Kong Kan	2,060
Mae Pai River	Dam Site (Ban Paeng)	1,760
Mae Pai River	Pang Mu	3,770

Mae Khan	San Pa Tong	1,060
Mae Khan	Mae Khan Bridge	1,770

Of the 7 water gauging stations listed above, those provided with meteorological station are the following 4 places, i.e., Ban Obb Luang, Dam site, Pang Mu and San Pa Tong.

At the occasion of the calculation of the run-off at the various proposed dam sites, the gauging stations actually used for that purpose are the Dam Site Gauging Station (9 year, 1970 ∿ 1978) and the Pang Mu Gauging Station (13 years, 1966 ∿ 1978) in the Mae Pai River basin, the Kaeng Ob Luang Gauging Station (14 years, 1955 ∿ 1968), Ban Obb Luang Gauging Station (11 years, 1969 ∿ 1979) and the recently installed Bang Kong Kan Gauging Station (9 months, 1979) in the Mae Chaem River basin, and the San Pa Tong Gauging Station (7 years, 1962 ∿ 1978) in the Mae Khan River basin.

The relevant data are presented in Tables 4-1 and 4-2. The approximate locations of these water gauging stations are shown in Fig. 4-1.

The relation between the rainfall and the discharge rate in the basins of the Mae Pai and Mae Chaem Rivers is shown in Fig. 4-3, but it is necessary to keep in mind that the rainfall patterns are different in these two rivers.

4.3 Handling of the Discharge Data and Information

The points to be taken into consideration when using the discharge data and information existing presently for the purpose of calculation of the run-off at the various sites are as follows, in each basin.

4.3.1 Mae Pai River Basin

There are two water gauging stations in the Mae Pai River basin, i.e., the Dam Site Gauging Station and the Pang Mu Gauging Station. As shown in Fig. 4-1, the Dam Site Gauging Station is located slightly up-streams of the Pai No. 1 site, while the Pang Mu Gauging Station is located slightly downstreams of the Pai No. 6 site.

Data collected at the 2 gauging stations mentioned above will be utilized in the Pai River Development Project. However, the data collected at the Dam Site Gauging Station extending in a relatively short period of 9 years from 1970 through 1978, and in addition, there are some periods when the relevant data are not available. The water gauging work at the Pang Mu Gauging Station was started in 1966, and there are data referring to a period of 13 years. Accordingly, the data of the Dam Site Gauging Station are complemented based upon the correlation of the discharge rates at the 2 water gauging stations, and the discharge data referring to the period of 13 years was consolidated, like in the Pan Mu Gauging Station.

The discharge correlation formula according to the monthly discharge is as follows.

$$Q_{DS} = 0.413\ Q_{PM} + 44.79$$

where, Q_{DS} : Dam Site Gauging Station Discharge

Q_{PM} : Pang Mu Gauging Station Discharge

Refer to Fig. 4-4.

4.3.2 Mae Chaem River Basin

There are three water gauging stations in the Mae Chaeng River basin, namely the Kaeng Ob Luang Gauging Station belonging to the RID (Royal Irrigation Department), the Ban Obb Luang Gauging Station belonging to the EGAT and the newly constructed Ban Kong Kan Gauging Station.

The water gauging work in the Mae Chaem River was started by the RID since 1955, at the Kaeng Ob Luang Gauging Station, but the said gauging work was handed over to the Ban Obb Luang Gauging Station of the EGAT in 1968, which is working presently. The locations of these two gauging stations are just downstream of the Mae Chaem No. 5 site and the No. 5 site respectively, and the differences of catchment areas and specific discharge are relatively small, namely, 118 km^2 and 4%. Accordingly, the water gauging data collected at the two gauging stations mentioned above will be utilized in the project referring to the Mae Chaem River.

On the other hand, as for the Ban Kong Kan Gauging Station, the water gauging data covers a very short time, i.e., 9 months, but they are used as reference data for correction of the specific discharge of the 5 sites planned along the Mae Chaem River.

4.3.3 Mae Khan River Basin

There are 2 water gauging stations in the Mae Khan River basin, namely, the San Pa Tong Gauging Station and the Mae Khan Bridge Gauging Station. Both water gauging stations are located at the downstream area of the Mae Khan River basin. A comparison of the specific discharge of these two water gauging stations evidences that the data referring to the Mae Khan Bridge Gauging Station, located at the downstream extremity of the Mae Khan River is just approximately 1/2.3 of the data corresponding to the San Pa Tong Gauging Station, located at the upstream side.

There are two hypothesis which could explain the above mentioned difference, i.e., the river goes partially underground at some place between the two water gauging stations, or the difference mentioned above indicates the actual difference due to the volume of water utilized for irrigation purposes between the two water gauging stations. However, the tendency mentioned above did not present any change even during the rainy season, and accordingly, it was concluded that the data collected at the Mae Khan Bridge Gauging Station can not be utilized in the Mae Khan River Project.

The San Pa Tong Gauging Station is located downstream of any planned dam site, thus, only the data collected at this gauging station will be utilized in this project. The run-off data of the San Pa Tong Gauging Station refers only to a period of 7 years lasting from 1962 through 1968. Consequently, the discharge up to 1979 was calculated by utilizing both the river water level data measured after 1968 and the water level - discharge curve provided by the NEA. A comparison of the calculated values with the presently available data evidences that the said values are in average approximately 2.8 times larger than the actually measured values. The said difference can be attributed to the following causes:

- The rating curves prepared in 1968.
- No cross sectional surveying of the river has been carried out subsequently.
- The curves are not able to cope with the changes occurred in the river bed due to the facts mentioned above.

Accordingly, the calculated discharge rates are discarded for their low reliability, and only the actually measured data corresponding to the mentioned period of 7 years has been used in this project.

4.4 Run-off at the Various Sites

In the calculation of the run-off, it is recommendable to utilize data collected at the water gauging station located at the nearest position of the planned site in order to improve the relaibility of the calculated discharge rate. The water gauging stations which will be utilized for such a purpose are those mentioned in the previous paragraph.

The run-off at the various sites will be calculated by means of the following equation.

$$Q_X = Q_E \cdot \frac{Ax}{A_E} \cdot \alpha$$

where, Q_x : Discharge at the planned site

Q_E : Discharge measured at the presently existing water gauging station

A_x : Catchment area at the planned site

A_E : Catchment area at the presently existing water gauging station

α : Discharge correction coefficient of planned site referring to the presently existing water gauging station

The coefficient alpha will be taken into consideration only in the Mae Chaem River Project due to the reasons explained below.

In the Mae Chaem River there are 5 planned sites, from up- to downstream, but the water gauging station used in the project is located at the downstream extremity of the Mae Chaem River. Generally speaking, the rainfall at the mountainous areas at the upstream region of a river is larger than that occurring in the downstream regions. Consequently, the river discharge per unit area are tends generally larger at the upstream regions, when compared with downstream regions.

If data collected at the same water gauging station is utilized at the 5 sites planned along the Mae Chaem River, it is expected that the run-off calculated for the upstream sites will result smaller. However, there is not any convenient pluviometric station at the upstream area, and consequently it is not possible to use the rainfall data for the purpose of estimation of the coefficient alpha. Fortunately, the Ban Kong Kan Gauging Station has been installed anew slightly downstream of the Mae Chaem No. 4 site. Data collected at the mentioned water gauging station refers to an extremely short period of 9 months, but it is possible to compare the data of the said period with the data of the Ban Obb Luang Gauging Station located at the downstream side, which is the main water gauging station. The comparison of the specific discharge rates occurring at the two water gauging stations evidences that there is a difference of 14% between them, with the Bang Kong Kan Gauging Station located at the upstream side presenting a larger discharge per unit area. However, the discharge correction coefficient alpha between the 2 water gauging stations was modified to 10%, by taking into consideration the relatively short duration of the comparison period. The coefficient alpha referring to the 5 planned sites was analyzed based upon the value mentioned above, aiming at calculating the run-off.

The results of the said calculations of run-off are indicated in Fig. 4-5, Tables 4-12 and 4-13.

The monthly run-off at the various sites are presented in Tables 4-14 through 4-20.

4.5 Sedimentation

The estimation of the quantity of sand which will sediment in the reservoir is one of the elements required for the purpose of determination of the scale of the dam. Usually, the quantity of sand sedimented in the storage reservoir is calculated by means of the correlation between the monthly run-off of the site in question and the suspended sediment corresponding to the said discharge.

However, the measurement of the suspended sediment has not been carried out in the water gauging stations existing presently in the project area in question, and consequently this data can not be used in the present case. The sedimentation actually occurred in the presently existing storage reservoirs is used as a reference data for the purpose of solving the problem.

The Mae Chaem River is a tributary of the Mae Ping River, which on the other hand is a tributary of the Chao Phraya River, which crosses the city of Bangkok. In 1964 the Bhumibol Dam (concrete arch gravity dam, 154.0 m height, 553MW) was constructed in this Mae Ping River, and the upstream extremity of the Bhumibol storage reservoir reaches Amphoe Hod, which is the point of confluence of the Mae Ping River with the Mae Chaem River. The EGAT carried out measurements and analysis referring to the sedimentation in this storage reservoir, and the sedimentation of sand in the said storage reservoir is reported to be 12×10^6 m^3 per year, i.e., approximately 460 m^3/km^2 (Re: 251 $m^3/km^2/yr$ in the UQY Project).

In the present master plan the sedimentation area is estimated by assuming that the value mentioned above increased by 10%, i.e., 500 $m^3/km^2/yr$ is applicable in view of the peculiarities of the region in question, for the purpose of determination of the scale of the dam. The same value will also be used provisionally in the Mae Pai River and in the Mae Khan River, because these rivers are not provided with storage reservoirs, which could be used for the sake of reference. The sedimentation level is calculated for a sedimentation period of 100 years.

The measurements referring to the suspended sediment should be started as soon as possible in the various water gauging stations whose data were for the purpose of calculation of the run-off, in order to make possible the utilization of the said sedimentation data in the feasibility study and in the pre-feasibility study.

4.6 Design Flood Discharge

The design flood discharge is the basic data for design of the flood spillway, which is the main accessory facility of the dam, and there are many methods to determine it.

In view of the importance of the role which will be played by the Mae Pai No. 6 and Mae Chaem No. 5 dams after their construction, it is adequate to utilize the Probable Maximum Flood (PMF) for design purposes, like in the case of the other large scale dams constructed in the Kingdom of Thailand. The PMF is determined based upon the Probable Maximum Precipitation (PMP) and the typical unit hydrograph obtained by analyzing data like the rainfall, period of duration (number of days) and the unit hydrograph actually occurred at the occasion of the typical storms recorded in the past.

However, the detailed analysis is not carried out in the present master plan, because in the present case the design flood discharge is aimed only at determining the approximate construction cost, and the relevant calculation is carried out based upon the chart shown in the Fig. 4-6 instead. The said chart presents the classification of the flood discharges utilized for the purpose of design of the dams already constructed or being planned presently in the Kingdom of Thailand, and the data and information contained therein are considered sufficient accurate for the sake of preparation of the master plan.

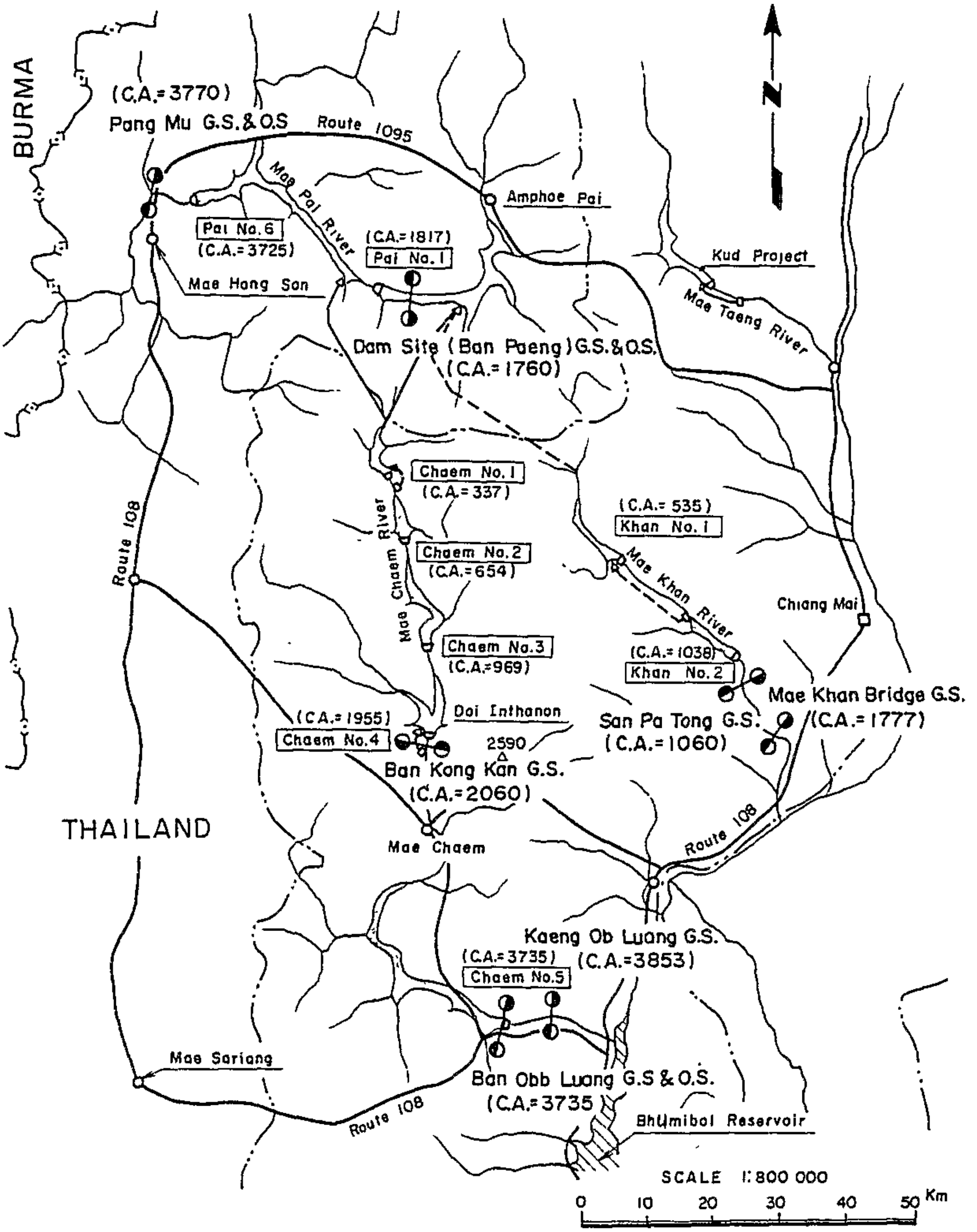
The design flood discharge of the project area in question is estimated in corresponding to the catchment area of the planned site, by assuming that it is located on the line connecting the Bhumibol Dam with the Kiu Lom Dam. The design flood discharges at the various sites are as follows:

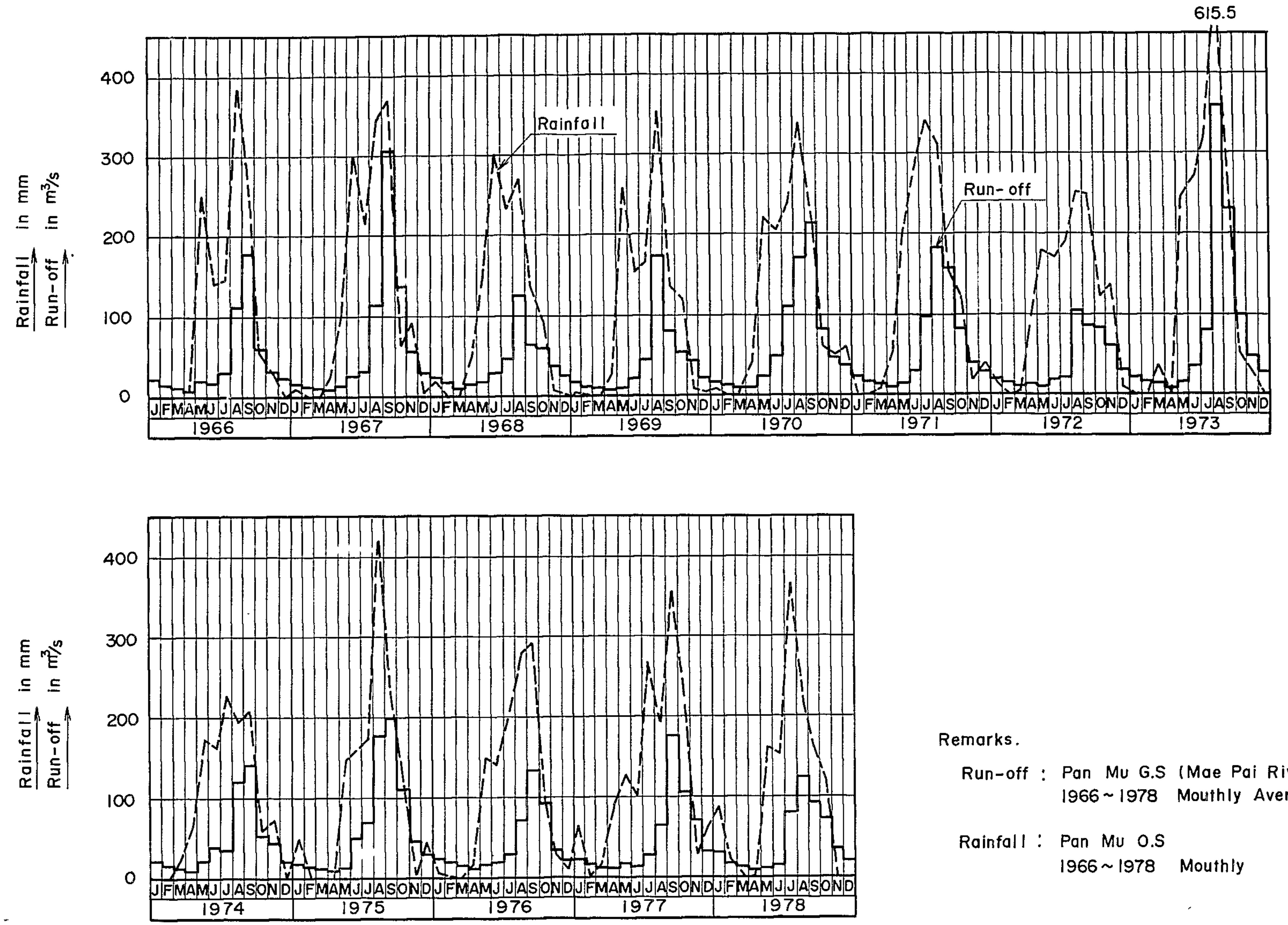
Mae Pai No. 1	2,200 m^3/s
Mae Pai No. 2	3,000 m^3/s
Mae Chaem No. 1	1,000 m^3/s
Mae Chaem No. 2	1,400 m^3/s
Mae Chaem No. 3	1,700 m^3/s
Mae Chaem No. 4	2,300 m^3/s
Mae Chaem No. 5	3,000 m^3/s
Mae Khan No. 1	1,200 m^3/s
Mae Khan No. 2	1,800 m^3/s

The figures mentioned above do not take into consideration the surcharges occurring at the occasion of operation of the dam.

In the feasibility study it is recommendable to carry out an analysis of the design flood discharge by taking into consideration the surcharge water level, in order to reduce the spillway capacity. Accordingly, it is recommendable to consolidate the actually occurring unit hydrograph by carring out the measurement of the flood flow observation in the various rivers.

Fig. 4-1 LOCATION OF RUN-OFF G.S. AND METEOROLOGICAL O.S.



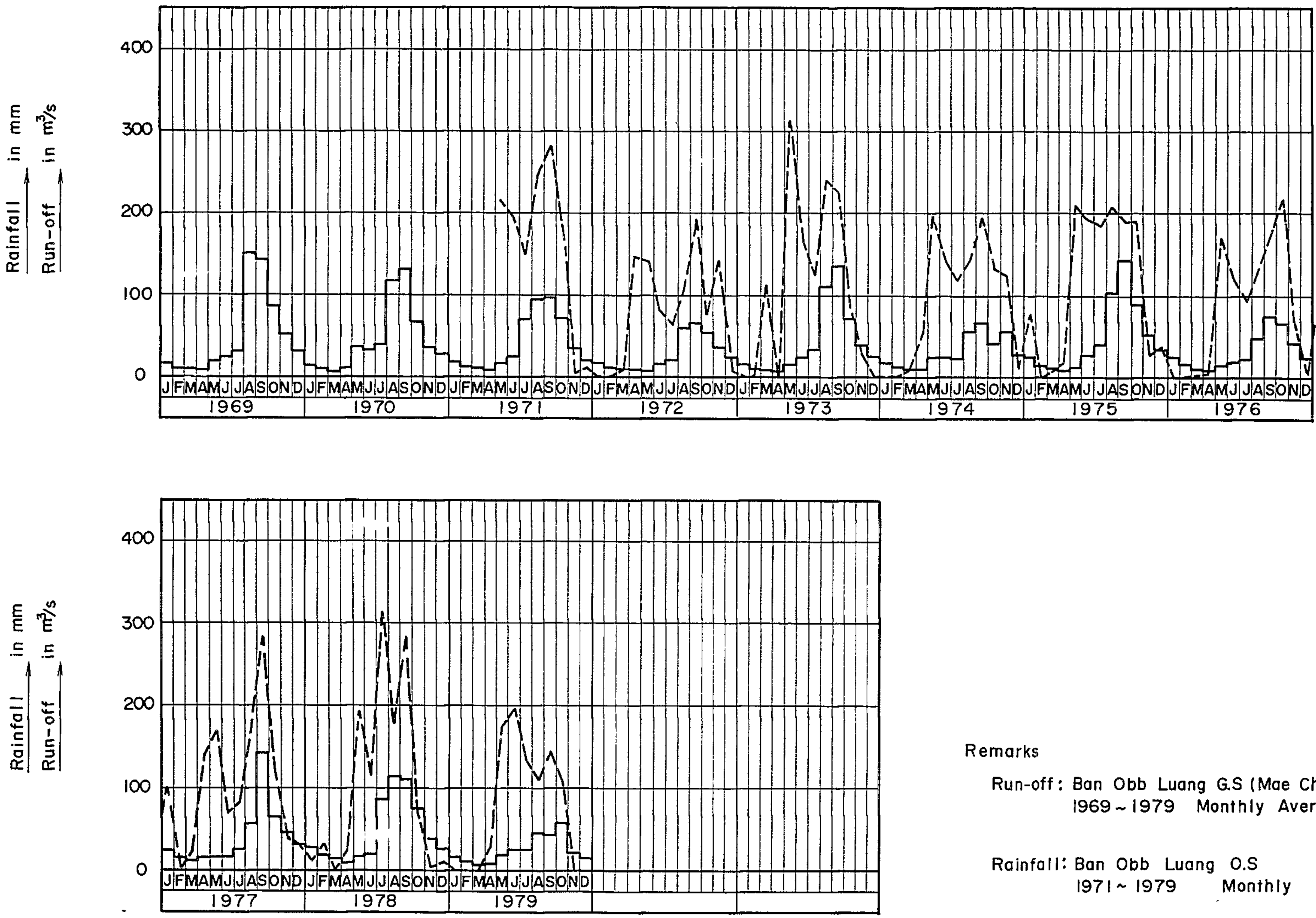


Remarks.

Run-off : Pan Mu G.S (Mae Pai River)
1966 ~ 1978 Mouthly Average

Rainfall : Pan Mu O.S
1966 ~ 1978 Mouthly

Fig. 4-2 Mae Pai Mae Chaem Master Plan. Run-off and Rainfall



Remarks

Run-off : Ban Obb Luang G.S (Mae Chaem River)
1969 ~ 1979 Monthly Average

Rainfall : Ban Obb Luang O.S
1971 ~ 1979 Monthly

Fig. 4-3 Mae Pai Mae Chaem Master Plan. Run-off and Rainfall

Fig.4-4 Co-Relation of Monthly Run-off at Mae Pai River

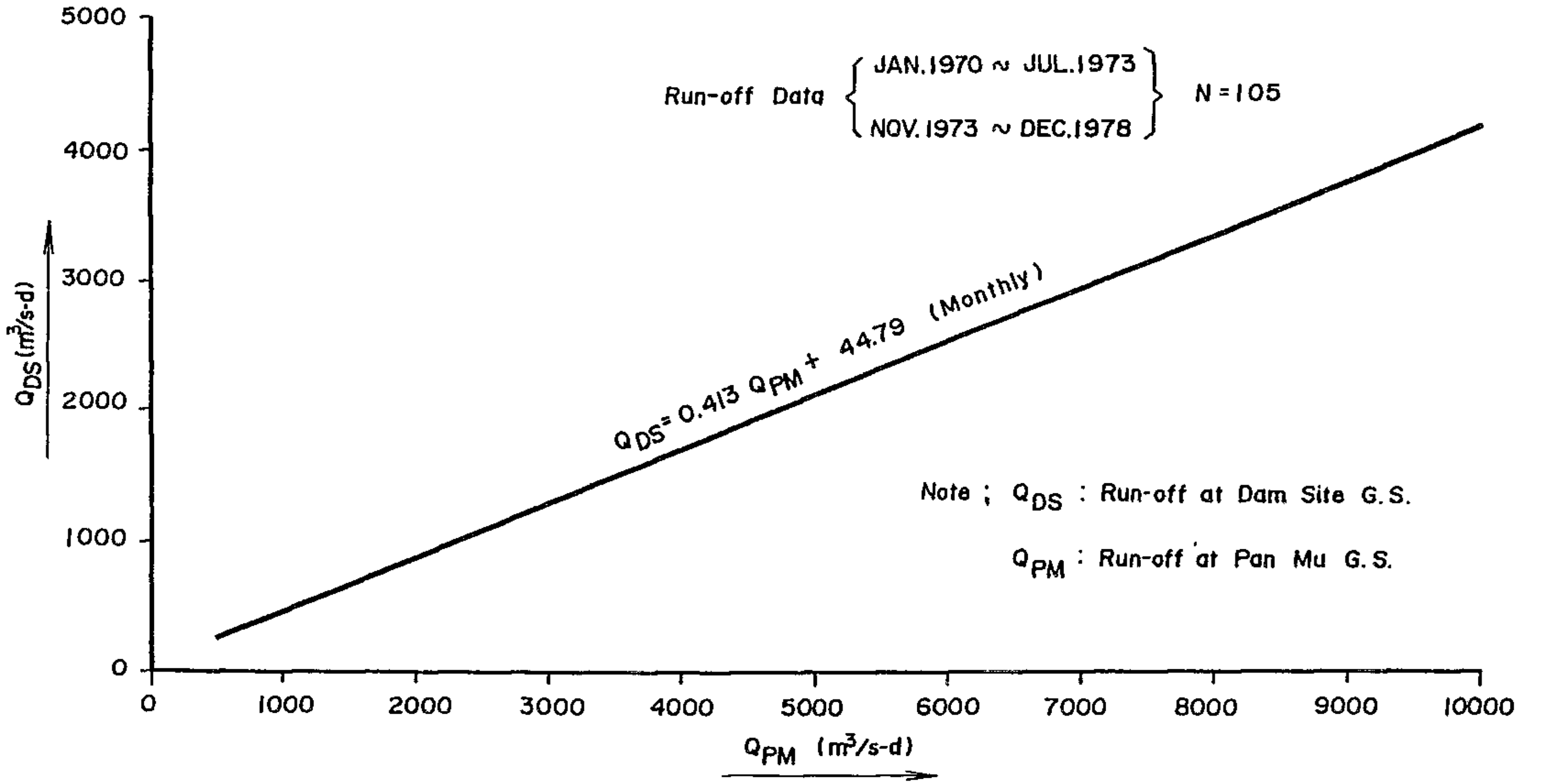


Fig. 4-5 Ca – Relation of Specific Run – off at Mae Chaem River

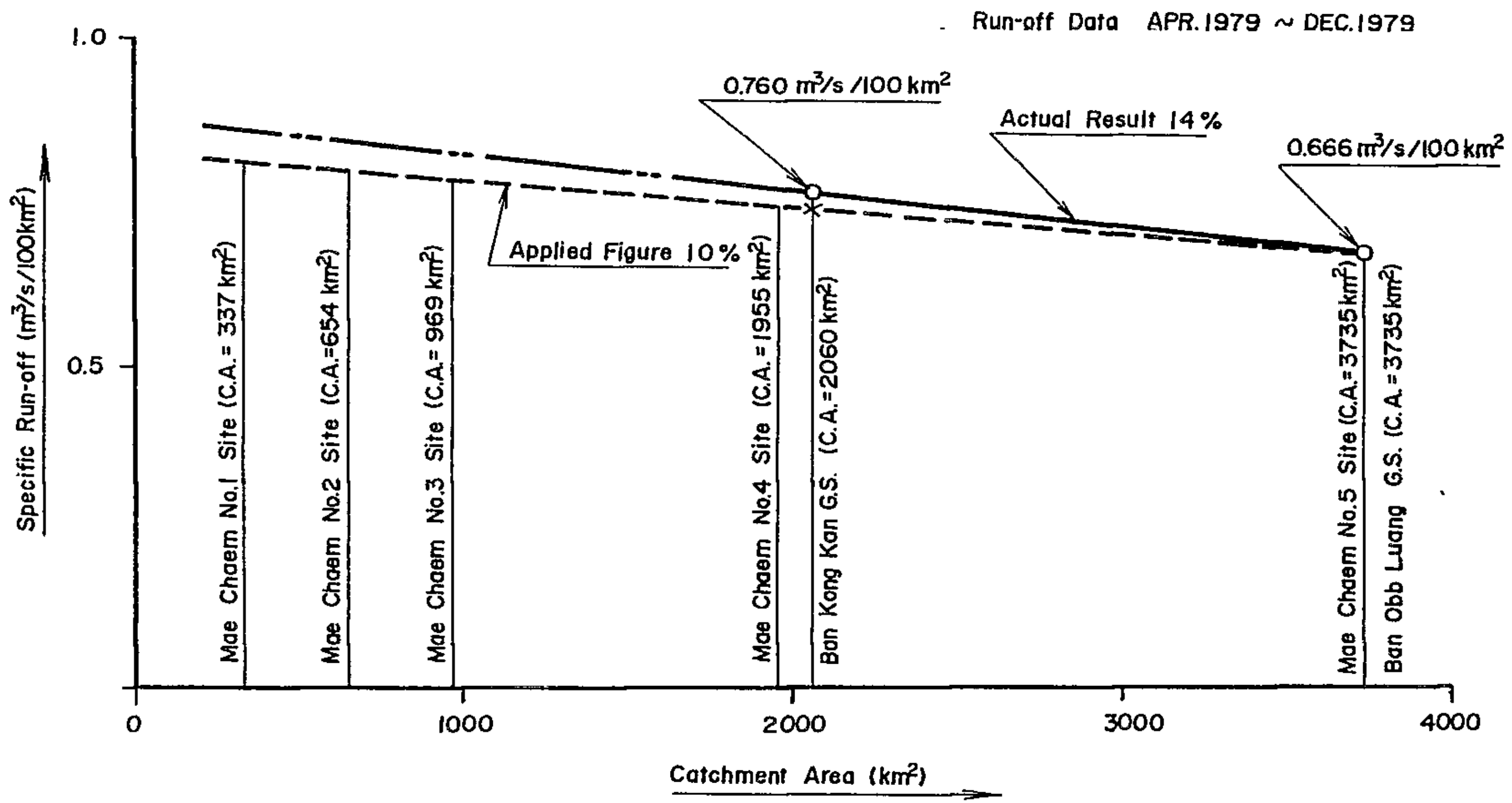
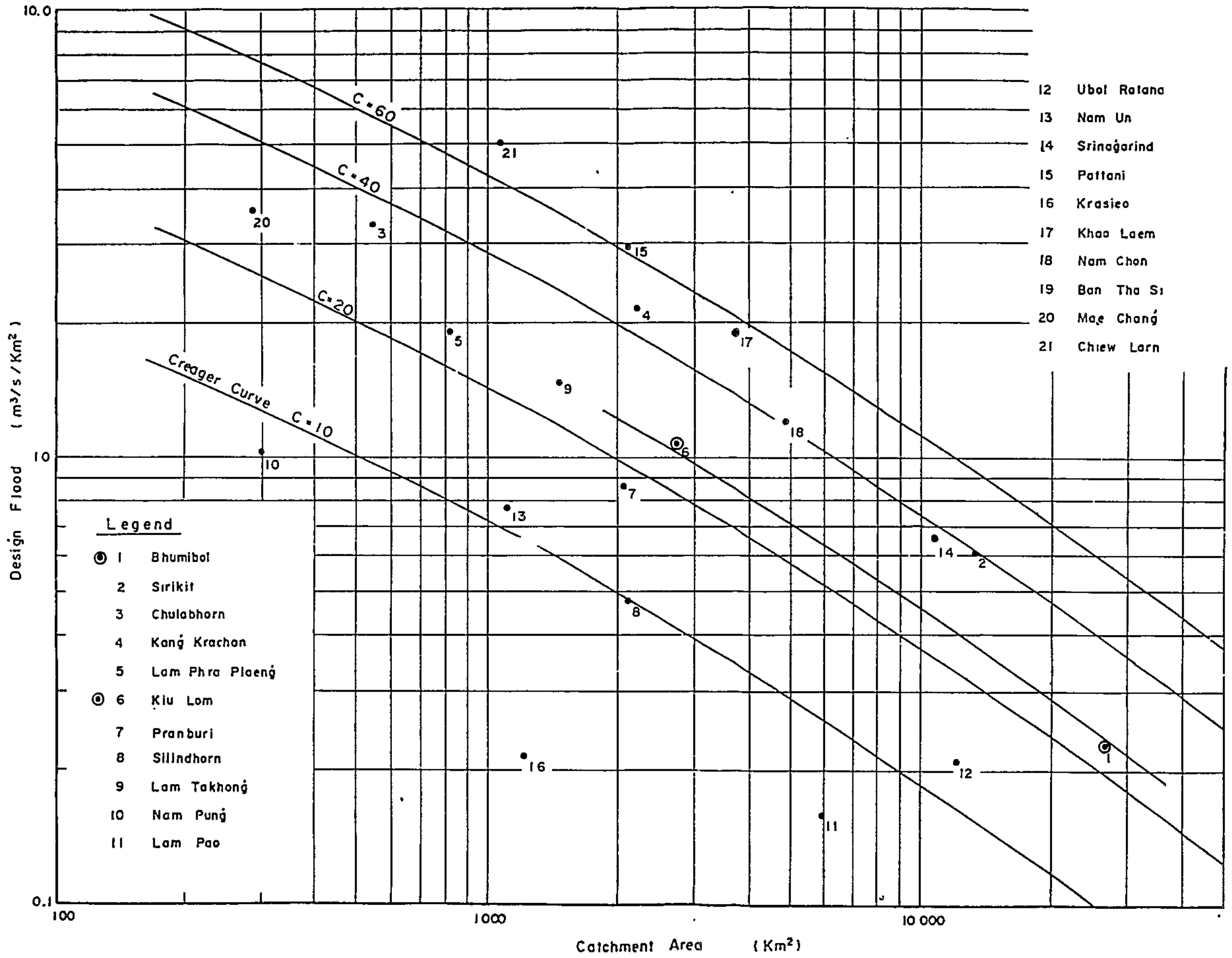
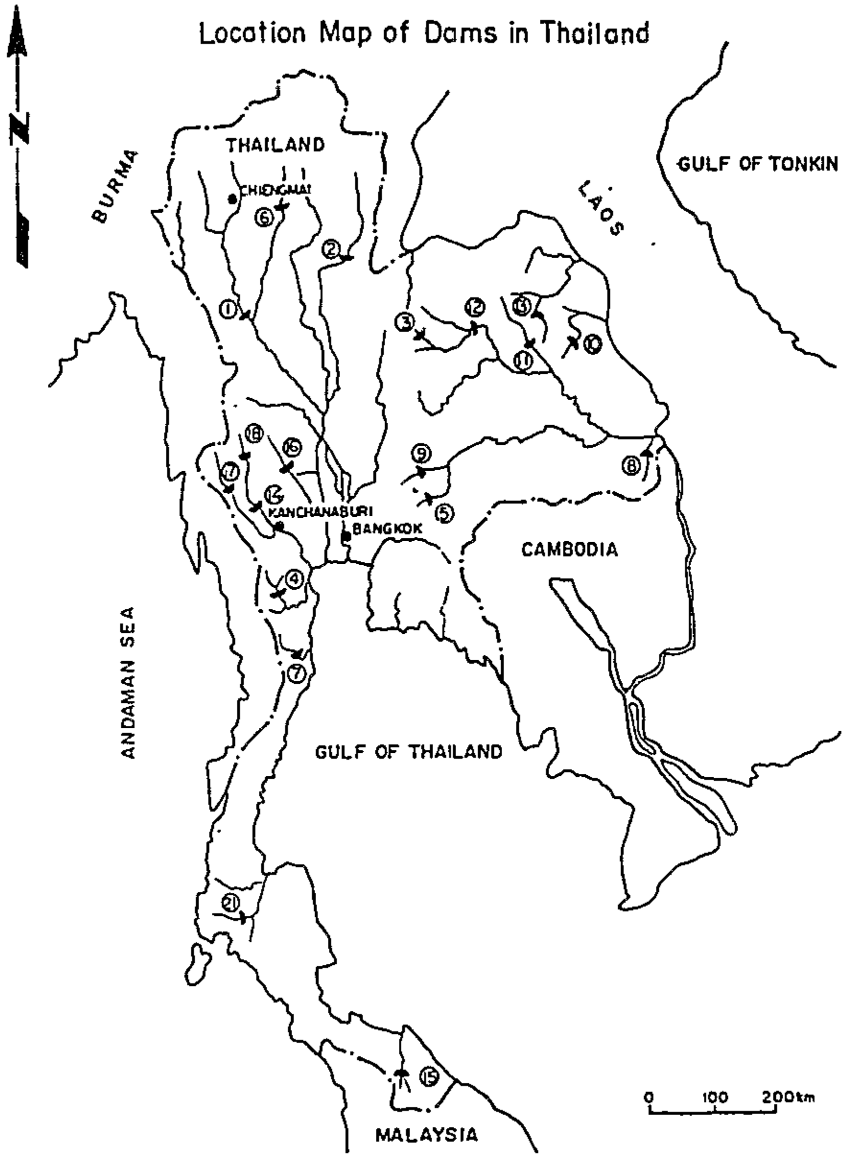


Fig. 4-6 Comparison of Design Floods in Thailand



Location Map of Dams in Thailand



Notes:

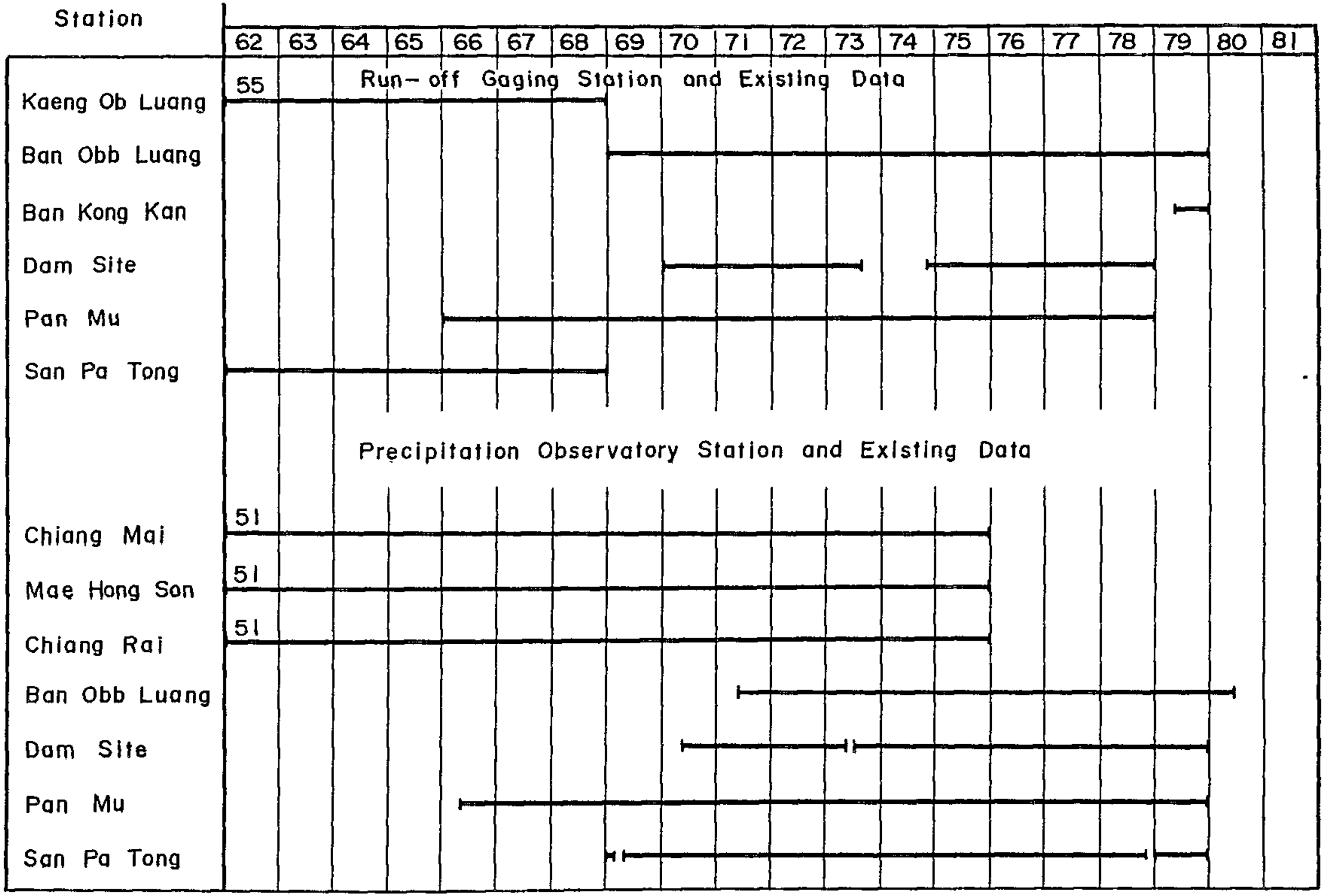
1. Creager's Eq

   (Unit in cfs - sq. Miles) $q = 46\ C.A^{(0.894 \cdot A^{-0.048} - 1)}$

   (Unit in m³/s - sq. km) $q = 0.503 \cdot C \cdot (0.3861 \cdot A)^{[0.894 \times (0.3861 A)^{-0.048} - 1]}$

2. Values in [ ] are Creager's coefficients C derived from Design PMF

Table 4 - 1


Station
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63
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77
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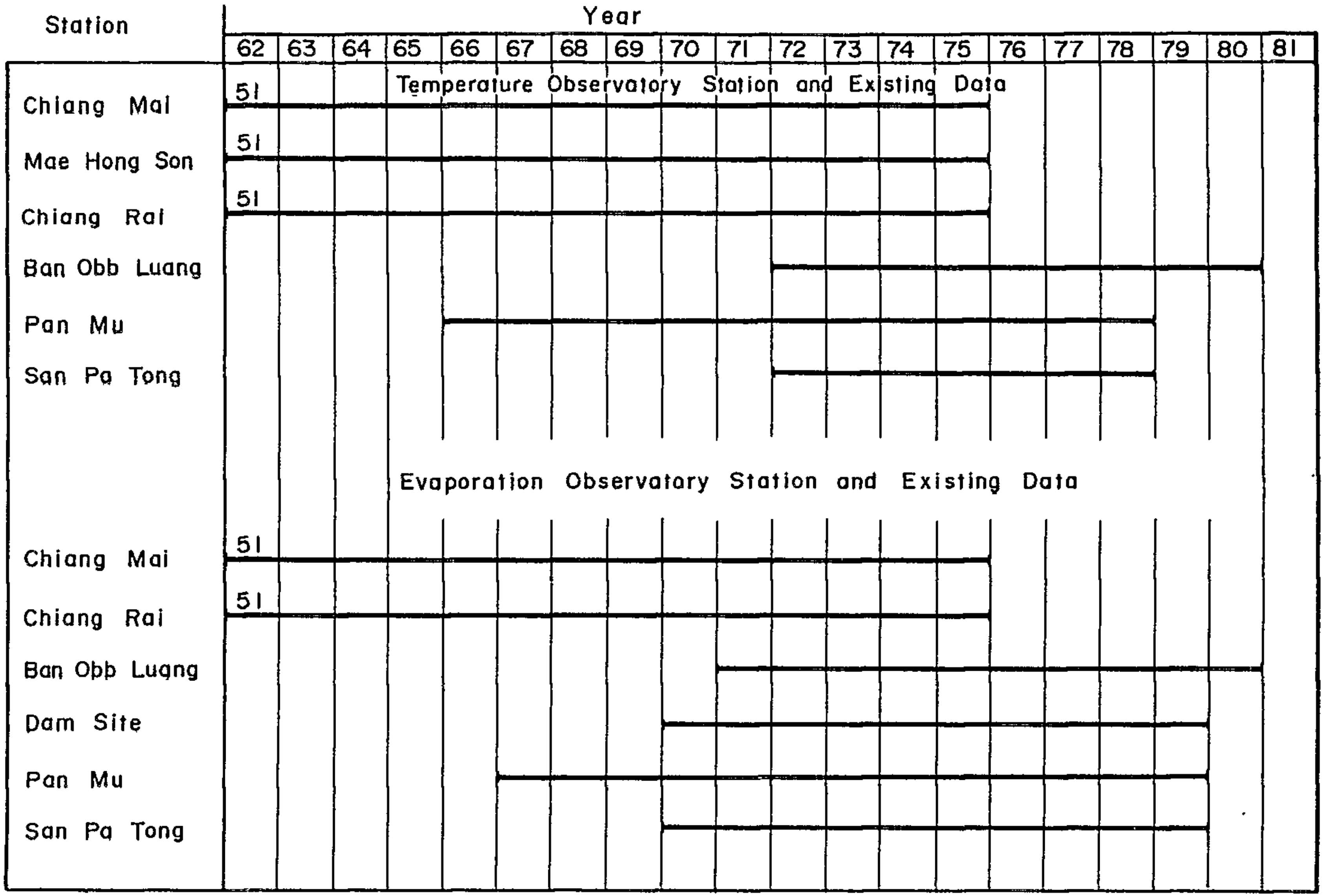
79
80
81
Run-off Gaging Station and Existing Data
55
Kaeng Ob Luang
Ban Obb Luang
Ban Kong Kan
Dam Site
Pan Mu
San Pa Tong
Precipitation Observatory Station and Existing Data
51
Chiang Mai
51
Mae Hong Son
51
Chiang Rai
Ban Obb Luang
Dam Site
Pan Mu
San Pa Tong

Table 4-2


Station
Year
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81
Temperature Observatory Station and Existing Data
Chiang Mai
51
Mae Hong Son
51
Chiang Rai
51
Ban Obb Luang
Pan Mu
San Pa Tong
Evaporation Observatory Station and Existing Data
Chiang Mai
51
Chiang Rai
51
Ban Obb Luang
Dam Site
Pan Mu
San Pa Tong

Table 4-3 Monthly Average Run-off G.S.: Pan Mu Mae Pai R.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
1966	20.3	13.7	10.0	7.2	18.9	17.4	29.7	114.7	178.2	57.9	31.0	19.2	43.3
1967	14.5	10.4	8.6	7.1	11.5	14.8	29.5	114.4	305.4	137.1	53.3	30.5	61.5
1968	22.6	15.2	10.9	12.3	15.8	28.3	46.2	124.2	62.7	60.9	36.4	24.2	38.5
1969	15.9	12.3	8.3	6.3	11.0	19.6	44.2	171.6	80.3	52.1	42.1	21.4	40.7
1970	15.5	11.0	8.4	8.5	22.7	45.1	109.6	172.0	214.9	84.6	45.3	38.0	64.9
1971	24.3	16.5	13.4	9.9	13.8	28.7	98.2	183.4	157.7	81.0	38.4	27.2	58.0
1972	18.7	13.1	9.9	10.4	8.7	15.7	17.6	101.8	82.9	81.4	58.7	31.4	37.6
1973	21.0	14.7	11.5	5.9	13.8	35.0	76.1	359.8	232.3	100.1	46.8	28.7	79.3
1974	21.4	15.4	11.6	10.1	20.1	37.4	34.4	119.8	139.7	51.4	43.3	19.4	43.8
1975	18.1	11.6	9.3	7.3	10.7	50.1	67.4	177.0	199.7	111.1	44.0	29.4	61.6
1976	22.3	17.6	12.9	9.8	14.4	17.9	27.3	69.6	133.4	94.0	36.8	21.4	39.8
1977	22.1	14.9	10.6	10.8	14.8	11.6	26.9	63.1	176.2	106.2	70.6	31.9	46.7
1978	30.6	14.8	10.8	7.5	11.6	13.4	78.5	123.7	94.4	70.8	33.0	18.9	42.6

Table 4-4 Monthly Average Run-off G.S.: Ban Obb Luang Mae Chaem R.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
1969	13.8	10.1	7.6	7.0	18.2	21.6	29.3	150.9	142.5	84.8	50.5	29.2	47.3
1970	14.3	9.2	5.8	9.8	35.8	32.2	40.0	117.9	131.1	66.9	36.9	28.7	44.2
1971	18.6	14.0	11.4	8.8	17.2	25.8	70.9	96.6	98.8	70.5	38.3	25.5	41.6
1972	17.7	12.5	9.8	11.5	8.4	15.9	20.6	60.9	66.7	52.8	38.9	24.0	28.3
1973	14.6	10.4	8.8	5.9	14.7	23.5	33.9	110.3	134.9	70.0	39.4	24.8	41.1
1974	17.6	12.3	8.5	8.8	23.6	24.7	22.9	53.7	65.2	39.9	53.7	25.3	29.7
1975	23.9	14.0	9.9	7.4	12.1	26.8	37.6	101.9	140.9	86.3	50.1	33.1	45.5
1976	23.5	16.4	11.4	9.6	14.1	16.5	21.3	44.7	73.0	64.7	41.4	22.4	29.9
1977	23.2	12.6	9.7	11.8	15.1	14.4	25.8	54.3	139.9	64.2	44.2	30.1	37.2
1978	24.9	16.8	12.6	9.7	16.7	18.9	83.4	115.5	110.4	73.5	37.7	23.7	45.6
1979	15.9	10.2	6.7	8.4	18.0	24.8	25.4	44.9	42.1	58.2	21.8	14.1	24.3

Table 4-5 Annual Average Precipitation

Observation Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Chiang Mai (1951 ∿ 1975)	10.8	7.2	20.2	51.1	162.0	152.3	172.4	248.9	262.3	128.1	40.0	15.6	1,270.9
Mae Hong Son (1951 ∿ 1975)	13.2	1.9	9.3	45.7	178.1	183.0	204.1	262.8	219.9	96.3	30.4	9.0	1,253.7
Chiang Rai (1951 ∿ 1975)	17.8	7.1	29.5	76.2	217.1	250.9	299.7	442.5	263.5	129.4	41.2	21.1	1,795.1
Ban Obb Luang (1970 ∿ 1980)	20.9	4.1	22.7	47.2	206.6	140.5	140.2	173.0	220.0	132.0	48.0	12.8	1,168.0
Dam Site (1970 ∿ 1979)	24.8	2.2	12.4	47.8	158.2	162.0	152.1	233.4	185.5	104.0	27.5	24.7	1,098.5
Pan Mu (1966 ∿ 1979)	20.2	1.7	7.3	36.5	175.9	193.5	227.4	315.5	237.0	101.6	35.8	16.8	1,369.2
San Pa Tong (1969 ∿ 1979)	23.0	2.5	23.5	56.9	197.7	136.2	179.1	267.8	274.8	139.1	42.8	21.4	1,364.8

Table 4-6 Monthly Precipitation O.S.: Ban Obb Luang Mae Chaem R.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Ave.
1971	-	-	-	-	214.3	196.5	148.3	246.7	283.6	181.4	4.1	13.9	-	-
1972	0	0	7.4	148.2	141.4	82.9	63.0	105.7	194.7	74.8	144.0	9.7	971.8	81.0
1973	0	0	115.0	0	312.4	162.4	123.2	244.4	228.9	86.7	27.0	0	1,300.5	108.4
1974	0	0	9.2	54.8	198.6	139.6	118.2	139.3	196.1	131.7	124.3	9.3	1,121.1	93.4
1975	75.5	0	5.7	16.9	211.0	189.9	185.3	207.1	189.4	190.5	26.1	37.4	1,334.8	111.2
1976	0	0.3	1.1	5.1	171.1	119.1	91.9	-	169.5	221.5	63.5	2.4	-	-
1977	101.1	2.0	26.2	136.4	172.5	67.0	81.1	156.9	284.7	121.3	39.1	31.1	1,219.4	101.6
1978	11.2	34.5	0	20.0	193.8	112.1	317.4	176.4	286.2	72.7	3.8	11.3	1,239.4	103.3
1979	0	0	0.6	34.3	174.8	198.2	133.1	107.7	147.3	107.3	0	0	903.3	75.3
1980	0	0	38.3	9.2	275.9	137.0	-	-	-	-	-	-	-	-
Ave.	20.9	4.1	22.7	47.2	206.6	140.5	140.2	173.0	220.0	132.0	48.0	12.8	1,168.0	97.3

Table 4-7 Monthly Precipitation O.S.: Dam Site (Ban Paeng) Mae Pai R.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Ave.
1970	-	-	-	36.7	235.5	201.9	234.4	183.0	188.2	80.6	10.6	56.8	-	-
1971	0	0	32.5	49.5	174.5	173.9	164.0	370.5	200.1	81.5	5.0	8.0	1,259.5	105.0
1972	2.0	0	17.0	69.9	114.2	276.0	97.3	116.0	200.0	147.0	102.0	76.0	1,216.5	101.4
1973	0	0	9.0	0	-	200.3	182.7	441.3	221.4	31.9	46.0	0	-	-
1974	0	0	24.5	81.5	208.7	148.9	74.2	232.3	234.0	108.6	59.4	3.7	1,175.8	98.0
1975	78.3	0	0	2.4	223.3	208.3	138.7	303.6	175.1	178.9	11.0	22.3	1,341.9	111.8
1976	0	6.5	0	6.1	159.5	107.9	113.9	209.3	165.2	150.3	5.0	13.1	936.8	78.1
1977	80.6	0	28.6	90.0	116.8	51.7	110.0	152.4	221.7	118.0	35.0	64.3	1,069.1	89.1
1978	62.5	13.3	0	17.0	87.1	82.2	309.5	169.1	136.0	71.8	0.6	2.5	951.6	79.3
1979	0	0	0	125.6	104.3	169.3	95.8	156.6	113.6	71.3	0	0	836.5	69.7
Ave.	24.8	2.2	12.4	47.8	158.2	162.0	152.1	233.4	185.5	104.0	27.5	24.7	1,098.5	91.6

Table 4-8 Monthly Precipitation O.S.: Pan Mu Mae Pai R.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Ave.
1966	-	-	-	13.2	253.2	143.4	146.1	385.4	249.2	50.9	37.0	0	-	-
1967	10.0	0	0	26.7	103.8	301.0	216.5	349.5	369.0	61.9	91.5	2.0	1,531.9	127.7
1968	19.8	0	0	51.3	148.7	302.7	228.3	269.9	137.4	94.2	5.0	0	1,257.3	104.8
1969	2.0	0	0	26.6	259.5	154.0	165.3	353.8	138.0	122.0	7.5	4.2	1,232.9	102.7
1970	7.0	0	4.1	41.3	222.0	205.7	237.9	342.3	221.0	61.9	50.7	60.1	1,454.0	121.2
1971	0	0	9.1	55.8	203.3	282.0	338.6	313.3	155.9	123.4	18.3	41.3	1,541.0	128.4
1972	17.0	0	4.0	102.5	181.0	169.7	189.1	253.2	250.6	122.1	137.0	9.1	1,435.3	119.6
1973	0	0	37.1	0	247.1	269.4	326.1	615.5	273.0	50.7	26.7	0	1,845.6	153.8
1974	0	0	24.5	66.5	175.3	162.8	228.1	194.4	210.0	58.0	73.2	1.0	1,193.8	99.5
1975	51.5	0	0	0	148.0	159.0	170.5	422.5	230.5	132.5	1.0	47.0	1,362.5	113.5
1976	2.0	1.8	0	15.7	151.0	139.0	199.6	279.8	288.1	96.5	27.3	9.3	1,210.1	100.8
1977	66.9	0	14.5	86.5	131.6	104.3	268.0	190.6	356.5	244.8	25.3	60.6	1,549.6	129.1
1978	86.6	20.6	1.0	1.4	161.6	151.6	364.9	218.8	164.8	119.4	0	0	1,290.7	107.6
1979	0	0	0	22.9	76.0	164.9	104.6	227.5	273.6	83.4	0	0	952.9	79.4
Ave.	20.2	1.7	7.3	36.5	175.9	193.5	227.4	315.5	237.0	101.6	35.8	16.8	1,369.2	114.1

Table 4-9 Monthly Precipitation O.S.: San Pa Tong Mae Khan R.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Ave.
1969	3.4	-	-	13.1	220.7	124.6	112.5	321.5	227.0	133.0	14.4	5.0	- -	- -
1970	5.3	0	50.3	44.8	440.3	259.5	186.9	306.1	141.4	74.1	49.9	60.4	1,619.0	134.9
1971	5.3	0	43.6	53.3	249.8	119.6	263.9	254.2	387.3	109.9	40.4	19.0	1,546.3	128.9
1972	0	0	9.1	179.4	61.7	203.1	36.6	282.4	227.4	47.0	120.9	30.5	1,198.1	99.8
1973	0	0	49.5	4.0	230.5	177.9	198.6	336.9	432.4	36.9	24.5	0	1,491.2	124.3
1974	0	0	13.4	44.7	170.0	85.3	114.7	218.2	319.0	218.2	118.6	0	1,302.1	108.5
1975	140.5	0	0	61.5	118.3	138.1	225.4	280.8	388.4	252.4	34.3	50.3	1,690.0	140.8
1976	0	6.7	25.6	26.9	128.1	65.8	109.3	224.8	182.8	279.7	16.5	4.3	1,070.5	89.2
1977	70.1	3.0	40.3	115.7	176.6	50.3	119.5	243.2	317.8	182.9	8.7	44.8	1,372.9	114.4
1978	28.2	14.0	0	6.4	202.2	80.3	417.2	307.6	208.0	72.0	-	-	-	-
1979	0	1.6	3.0	76.0	176.0	193.8	185.5	169.7	191.3	124.0	0	0	1,120.9	93.4
Ave.	23.0	2.5	23.5	56.9	197.7	136.2	179.1	267.8	274.8	139.1	42.8	21.4	1,364.8	113.7

Table 4-10 Annual Temperature

Observation Station		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
Chiang Mai (1951 ∿ 1975)	Mean	20.0	22.2	25.6	28.3	28.0	27.1	26.7	26.2	26.2	25.5	23.4	20.6	25.0
	Ext. max.	34.7	37.3	39.6	41.5	41.4	37.9	36.4	35.4	34.7	35.3	33.7	33.5	-
	Ext. min.	3.7	7.3	10.0	13.2	19.6	19.1	21.1	20.0	19.3	13.3	6.0	5.0	-
Mae Hong Son (1951 ∿ 1975)	Mean	20.6	22.2	26.1	29.7	28.7	27.1	26.6	26.2	26.5	26.2	24.3	21.4	25.4
	Ext. max.	34.5	37.0	39.5	42.4	41.4	39.4	36.0	34.5	35.5	35.4	35.2	33.9	-
	Ext. min.	6.0	8.2	11.0	15.6	20.4	20.5	21.2	20.5	19.7	15.0	9.8	7.2	-
Chiang Rai (1951 ∿ 1975)	Mean	19.6	21.8	24.7	27.5	27.6	27.1	26.7	26.2	26.2	25.1	22.7	19.6	24.6
	Ext. max.	32.1	34.8	38.0	41.3	41.2	38.0	38.6	35.2	37.0	35.0	33.6	31.7	-
	Ext. min.	1.5	6.5	9.6	11.4	17.6	18.5	19.0	18.5	18.3	11.6	5.0	2.8	-
Ban Obb Luang (1972 ∿ 1980)	Mean	20.7	24.0	26.9	30.0	28.5	28.0	27.4	26.7	26.0	25.6	23.1	21.5	25.7
	Ext. max.	36.0	39.8	40.8	43.7	43.2	39.0	37.4	37.0	37.0	35.8	35.8	35.2	-
	Ext. min.	2.8	5.9	10.3	15.0	19.0	21.0	20.0	18.8	17.0	12.2	8.8	4.9	-
Pan Mu (1966 ∿ 1978)	Mean	21.7	23.4	26.5	29.8	30.1	28.8	27.6	27.2	27.5	26.7	24.9	22.1	26.4
	Ext. max.	34.4	38.3	41.7	45.0	45.0	40.2	38.5	38.8	38.5	39.0	41.0	34.8	-
	Ext. min.	5.5	6.5	7.2	11.2	18.0	20.0	13.5	17.4	14.8	13.5	8.9	7.1	-
San Pa Tong (1972 ∿ 1978)	Mean	20.3	23.5	26.4	28.9	27.4	27.6	27.3	26.6	26.7	25.6	24.2	21.8	25.5
	Ext. max.	33.5	39.0	40.0	42.2	42.0	39.0	37.0	37.0	38.3	38.5	35.2	34.0	-
	Ext. min.	0.6	10.0	13.2	17.0	20.0	10.0	20.0	20.0	19.0	12.0	12.0	7.0	-

Table 4-11 Annual Average Evaporation

Observation Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Chiang Mai (1951 ∿ 1975)	108.4	137.0	180.6	197.2	176.2	136.7	128.5	117.8	126.4	129.1	104.4	99.7	1,642.0
Chiang Rai (1951 ∿ 1975)	108.2	134.3	171.7	202.3	166.7	125.4	112.2	94.8	107.5	117.0	105.6	101.7	1,547.4
Ban Obb Luang (1971 ∿ 1980)	116.1	158.9	210.0	222.3	160.0	134.5	129.1	112.4	110.3	116.8	103.1	100.9	1,674.4
Dam Site (1970 ∿ 1979)	76.9	104.2	166.0	186.5	176.1	134.4	118.7	111.5	112.9	116.1	89.6	77.9	1,470.8
Pan Mu (1967 ∿ 1979)	99.5	126.0	167.3	204.5	187.4	136.4	115.5	106.2	119.2	127.7	107.1	96.6	1,593.4
San Pa Tong (1970 ∿ 1979)	88.2	118.5	165.4	166.0	138.4	111.5	95.6	90.3	100.1	106.7	82.0	75.8	1,338.5

Table 4-12 Coefficient of Run-off for Mae Chaem

	Gaging Station		Dam Site				
	Ban Obb Luang	Ban Kong Kan	No. 1	No. 2	No. 3	No. 4	No. 5
Catchment area (km^2)	3,735	2,060	337	654	969	1,955	3,735
Coefficient α	1.000	1.100	1.203	1.184	1.165	1.106	1.000

Table 4-13 Estimation of Run-off

Proposed Dam Site	Catchment Area (km^2)	Average Run-off (m^3/s)	Remarks
Mae Chaem No. 1	337	4.15	Average in 25 yrs
" No. 2	654	7.92	"
" No. 3	969	11.55	"
" No. 4	1,955	22.13	"
" No. 5	3,735	38.22	"
Mae Pai No. 1	1,817	23.10	Average in 13 yrs
" No. 2	3,725	50.02	"
Mae Khan No. 1	535	5.28	Average in 7 yrs
" No. 2	1,038	10.24	"

Table 4-14 Monthly Run-off at Mae Pai River No. 1 and No. 6

Mae Pai River No. 1 C.A.: 1,817 km²

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1966	314.64	209.50	177.88	137.80	295.42	268.34	439.45	1,562.60	2,326.07	811.37	443.33	300.57	7,286.97
1967	237.65	169.97	159.65	136.66	198.45	235.49	435.56	1,558.89	3,953.04	1,857.91	728.62	449.51	10,121.40
1968	344.66	234.70	190.53	203.63	254.79	408.66	657.16	1,688.21	848.59	851.33	511.67	365.64	6,559.57
1969	256.15	192.75	156.09	126.32	191.58	296.90	630.55	2,314.90	1,073.21	734.75	584.67	329.53	6,887.40
1970	246.05	156.82	140.97	121.24	385.21	811.58	1,736.27	2,514.89	2,297.06	976.33	595.69	597.24	10,579.35
1971	469.22	354.93	179.58	173.20	336.69	424.98	1,403.94	2,457.08	1,691.36	663.41	382.40	220.99	8,757.78
1972	191.01	129.57	71.26	61.35	38.92	76.64	149.52	837.16	1,005.44	1,140.48	1,163.81	644.73	5,509.89
1973	278.26	185.67	196.13	128.53	192.21	483.05	1,034.35	4,802.59	3,017.66	1,369.71	791.32	553.46	13,038.94
1974	306.79	208.78	167.54	145.17	305.79	585.46	455.72	1,517.61	1,708.70	876.81	890.95	501.74	7,671.06
1975	356.17	186.08	148.91	99.20	197.87	904.32	1,188.17	2,694.32	2,168.73	1,679.69	900.14	701.92	11,225.52
1976	426.17	290.68	221.88	156.84	265.47	319.09	456.79	1,123.13	1,643.77	1,180.84	566.06	383.10	7,033.82
1977	357.73	181.53	134.80	144.69	260.98	186.01	438.31	908.60	1,802.34	1,256.21	769.33	415.66	6,856.19
1978	618.92	227.97	194.48	147.76	190.06	252.89	1,218.53	1,727.39	1,565.41	1,144.40	527.34	355.39	8,170.54
Total	4,403.42	2,728.95	2,139.70	1,782.39	3,113.44	5,259.41	10,244.32	25,707.37	25,101.38	14,543.24	8,855.33	5,819.48	109,698.43
Ave.	338.72	209.92	164.59	137.11	239.50	404.57	788.02	1,977.49	1,930.88	1,118.71	681.18	447.65	8,438.34

Mae Pai River No. 6 C.A.: 3,725 km²

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1966	622.02	378.36	305.08	212.16	577.43	514.68	911.20	3,513.94	5,283.18	1,773.06	920.13	589.41	15,600.65
1967	443.51	286.69	262.82	209.52	352.71	438.53	902.19	3,505.38	9,053.44	4,198.29	1,581.31	934.47	22,168.86
1968	691.61	436.71	334.37	364.74	483.31	839.86	1,415.67	3,805.00	1,859.36	1,865.68	1,078.51	740.15	13,914.97
1969	486.40	339.48	254.52	185.62	336.83	580.89	1,354.05	5,257.31	2,379.86	1,595.50	1,247.71	656.51	14,674.68
1970	476.24	303.52	256.09	251.00	696.13	1,335.45	3,357.54	5,267.74	6,369.04	2,591.87	1,341.89	1,164.70	23,411.21
1971	743.44	456.28	410.89	294.27	421.49	851.92	3,006.70	5,616.65	4,674.66	2,479.96	1,137.56	831.78	20,925.60
1972	572.66	376.18	304.30	306.92	265.04	465.14	539.01	3,116.93	2,456.73	2,493.21	1,739.65	962.29	13,598.06
1973	642.74	406.59	351.47	173.41	422.22	1,038.61	2,331.93	11,022.13	6,885.80	3,066.95	1,387.04	880.32	28,609.21
1974	655.78	425.86	355.96	300.32	615.31	1,107.92	1,054.59	3,669.31	4,139.83	1,574.72	1,282.23	595.12	15,776.95
1975	555.66	320.21	284.07	216.36	326.41	1,485.93	2,064.95	5,420.53	5,918.50	3,403.66	1,305.05	901.50	22,202.83
1976	682.75	505.00	394.34	291.75	440.50	529.80	835.51	2,132.34	3,954.63	2,877.93	1,090.43	654.49	14,389.47
1977	676.72	410.84	325.76	320.94	453.90	343.27	823.81	1,933.84	5,223.89	3,251.62	2,092.62	977.49	16,834.70
1978	938.46	409.75	329.87	222.35	355.24	398.32	2,404.35	3,789.13	2,797.11	2,169.89	977.79	579.60	15,371.86
Total	8,187.99	5,055.47	4,169.54	3,349.36	5,746.52	9,930.32	21,001.50	58,050.23	60,996.03	33,342.34	17,181.92	10,467.83	237,479.05
Ave.	629.85	388.88	320.73	257.64	442.04	763.87	1,615.50	4,465.40	4,692.00	2,564.80	1,321.69	805.22	18,267.62

Table 4-15 Monthly Run-off at Mae Chaem River No. 1

C.A.: 337 km²

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1955	47.76	28.62	24.73	30.49	43.65	124.67	89.01	153.08	253.24	144.56	96.37	63.65	1,099.83
1956	45.24	37.25	23.83	96.29	76.59	56.07	91.95	244.40	576.44	202.63	121.94	96.27	1,668.90
1957	60.28	39.14	30.57	17.09	31.14	55.66	66.24	101.95	154.34	124.57	62.60	44.26	787.84
1958	36.10	21.84	14.48	19.26	24.62	47.30	90.79	103.21	162.13	112.68	59.65	41.03	733.09
1959	31.69	16.81	13.80	12.76	28.19	48.61	106.58	223.36	482.48	237.03	92.06	57.23	1,350.60
1960	38.90	27.88	18.29	15.11	50.44	69.44	79.96	313.10	230.72	205.26	92.58	90.69	1,232.37
1961	55.97	36.61	26.84	29.27	71.49	97.32	122.88	342.35	577.17	411.78	165.60	120.36	2,057.64
1962	85.53	55.97	40.93	34.03	52.38	56.60	152.13	215.89	416.62	373.38	129.09	81.96	1,694.51
1963	61.76	40.19	30.84	29.71	48.26	154.87	233.14	327.09	326.78	442.61	258.08	168.54	2,121.87
1964	135.19	100.05	91.22	81.12	134.88	129.51	219.99	229.98	556.87	701.53	212.94	151.29	2,744.57
1965	124.04	95.32	89.95	54.71	69.02	95.53	108.26	259.44	329.93	311.52	228.62	128.77	1,895.11
1966	96.48	70.81	60.60	24.76	97.36	52.71	107.84	253.76	452.24	158.86	108.89	75.01	1,562.32
1967	53.76	33.21	30.05	27.98	56.29	46.49	79.54	174.33	375.49	227.99	116.89	77.22	1,292.24
1968	58.18	35.04	30.04	37.64	61.61	70.65	117.73	199.47	164.86	222.09	116.99	73.96	1,188.26
1969	46.43	30.57	25.50	22.84	61.26	70.23	98.61	507.80	464.01	285.36	164.36	98.41	1,875.38
1970	48.08	28.09	19.47	31.78	120.45	104.78	134.59	396.74	426.93	225.07	120.05	96.56	1,752.59
1971	62.61	42.64	38.50	28.59	57.82	84.12	238.44	325.16	321.76	237.03	124.58	85.63	1,646.88
1972	59.53	39.32	32.96	37.57	28.26	51.86	69.38	204.93	217.26	177.62	126.77	80.89	1,126.35
1973	48.97	31.75	29.68	19.36	49.59	76.35	114.09	371.11	439.21	235.59	128.30	83.33	1,627.33
1974	59.32	37.30	28.66	28.71	79.45	80.27	77.20	180.63	212.34	133.41	174.70	80.02	1,177.91
1975	80.38	42.47	33.29	24.20	40.60	87.40	126.59	342.87	458.90	290.50	163.07	111.22	1,801.49
1976	79.21	51.54	38.44	31.30	47.39	53.82	71.78	150.28	237.82	217.77	134.80	75.26	1,189.41
1977	77.94	38.27	32.77	38.45	50.83	46.88	86.71	182.85	455.61	216.15	143.89	101.17	1,471.52
1978	83.83	51.01	42.32	31.70	56.27	61.54	280.54	388.76	359.50	247.20	122.70	79.75	1,805.12
1979	53.55	30.98	22.68	27.25	60.60	80.63	85.57	150.98	136.92	195.79	70.97	47.53	963.45
Total	1,630.73	1,062.68	870.44	831.97	1,498.44	1,903.31	3,049.54	6,343.52	8,792.57	6,338.88	3,336.49	2,215.01	37,873.58
Ave.	65.23	42.51	34.82	33.28	59.94	76.13	121.98	253.74	351.70	253.56	133.46	88.60	1,514.94

Table 4-16 Monthly Run-off at Mae Chaem River No. 2

C.A.: 654 km^2

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1955	91.24	54.67	47.24	58.24	83.39	238.14	170.01	292.40	483.71	276.12	184.08	121.58	2,100.82
1956	86.41	71.16	45.53	183.92	146.30	107.09	175.84	466.83	1,101.05	387.05	232.91	183.88	3,187.77
1957	115.15	74.76	58.40	32.65	59.48	106.31	126.52	194.73	294.81	237.94	119.57	84.55	1,504.87
1958	68.96	41.71	27.67	36.80	47.02	90.35	173.43	197.14	309.68	215.23	113.94	78.37	1,400.30
1959	60.53	32.11	26.37	24.38	53.85	92.84	203.57	426.64	921.60	452.76	175.84	109.32	2,579.81
1960	74.30	53.25	34.94	28.86	96.34	132.63	152.73	598.05	440.70	392.07	176.84	173.23	2,353.94
1961	106.91	69.93	51.26	55.92	136.56	185.89	234.72	653.92	1,102.46	786.55	316.31	229.90	3,930.33
1962	163.38	106.91	78.17	65.01	100.05	108.12	290.59	412.37	795.80	713.20	246.58	156.55	3,236.73
1963	117.96	76.77	58.91	56.74	92.19	295.81	445.32	624.78	624.18	845.44	492.95	321.94	4,052.99
1964	258.23	191.11	174.23	154.94	257.63	247.38	420.21	439.30	1,063.68	1,340.00	406.74	288.98	5,242.43
1965	236.93	182.07	171.82	104.50	131.83	182.47	206.79	495.57	630.21	595.04	436.68	245.97	3,619.88
1966	184.28	135.25	115.75	47.28	185.97	100.68	205.98	484.71	869.55	303.45	207.99	143.28	2,984.17
1967	102.69	63.44	57.39	53.44	107.51	88.80	151.93	332.99	717.22	435.48	223.27	147.50	2,481.66
1968	111.13	66.94	57.37	71.90	117.69	134.94	224.87	381.02	314.90	424.22	223.47	141.27	2,269.72
1969	88.69	58.40	48.70	43.63	117.00	134.15	188.36	969.95	886.30	545.07	313.95	187.97	3,582.17
1970	91.84	53.66	37.18	60.71	230.08	200.14	257.08	757.81	815.49	429.92	229.30	184.44	3,347.65
1971	119.60	81.45	73.54	54.60	110.44	160.68	455.46	621.09	614.61	452.76	237.97	163.57	3,145.77
1972	113.71	75.11	62.95	71.76	53.98	99.06	132.52	391.44	414.99	339.28	242.14	154.51	2,151.45
1973	93.54	60.65	56.69	36.99	94.73	145.84	217.92	708.87	838.93	450.00	245.06	159.17	3,108.39
1974	113.31	71.24	54.75	54.83	151.76	153.32	147.46	345.02	405.60	256.54	333.70	162.41	2,249.94
1975	153.53	81.12	63.58	46.23	77.55	166.95	241.80	654.93	876.54	554.88	311.48	212.45	3,441.04
1976	151.29	98.45	73.43	59.79	90.52	102.81	137.11	287.06	454.25	415.96	257.48	143.75	2,271.90
1977	148.87	73.10	62.59	73.43	97.08	89.55	165.62	349.27	870.26	412.87	274.85	193.25	2,810.74
1978	160.12	97.43	80.83	60.55	107.48	117.56	535.87	742.58	686.69	472.19	234.36	152.33	3,447.99
1979	102.29	59.18	43.33	52.06	115.75	154.01	163.44	288.39	261.54	373.98	135.56	90.73	1,840.31
Total	3,114.89	2,029.87	1,662.62	1,589.16	2,862.18	3,635.52	5,824.95	12,116.86	16,794.75	12,108.00	6,373.02	4,230.95	72,342.77
Ave.	124.60	81.19	66.50	63.57	114.49	145.42	233.00	484.67	671.79	484.32	254.92	169.24	2,893.71

Table 4-17 Monthly Run-off at Mae Chaem River No. 3

C.A.: 969 km^2

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1955	133.03	79.70	68.88	84.93	121.59	347.23	247.90	426.35	705.30	402.61	268.41	177.28	3,063.22
1956	126.00	103.76	66.38	268.17	213.32	156.15	256.10	680.69	1,605.47	564.36	339.61	268.12	4,648.13
1957	167.90	109.01	85.15	47.61	86.72	155.01	184.49	283.94	429.86	346.94	174.35	123.28	2,194.26
1958	100.55	60.82	40.34	53.65	68.57	131.74	252.88	287.46	451.55	313.83	166.15	114.28	2,041.82
1959	88.26	46.83	38.44	35.55	78.51	135.38	296.83	622.09	1,343.80	660.18	256.39	159.40	3,761.66
1960	108.33	77.65	50.94	42.08	140.48	193.40	222.70	872.04	642.60	571.69	257.86	252.59	3,432.36
1961	155.89	101.97	74.75	81.53	199.12	271.05	342.25	953.49	1,607.52	1,146.89	461.22	335.22	5,730.90
1962	238.23	155.89	113.99	84.79	145.88	157.65	423.71	601.28	1,160.37	1,039.94	359.54	228.26	4,719.53
1963	172.00	111.93	85.90	82.73	134.42	431.33	649.34	911.01	910.13	1,232.75	718.79	469.42	5,909.75
1964	376.54	278.67	254.05	225.92	375.66	360.71	612.71	640.55	1,550.97	1,953.87	593.08	421.37	7,644.10
1965	345.47	265.48	250.54	152.37	192.22	266.06	301.52	722.59	918.92	867.64	636.74	358.66	5,278.21
1966	268.70	197.20	168.78	68.95	271.16	146.81	300.35	706.77	1,267.91	442.47	303.28	208.92	4,351.30
1967	149.73	92.51	83.69	77.92	156.77	129.49	221.53	485.54	1,045.80	634.98	325.55	215.08	3,618.59
1968	162.04	97.61	83.66	104.84	171.61	196.76	327.89	555.57	459.17	618.57	325.84	205.99	3,309.55
1969	129.32	85.15	71.01	63.61	170.61	195.61	274.65	1,414.31	1,292.34	794.78	457.77	274.08	5,223.24
1970	133.91	78.24	54.21	88.52	335.48	291.82	374.86	1,104.98	1,189.08	626.87	334.35	268.94	4,881.26
1971	174.39	118.77	107.23	79.62	161.04	234.30	664.11	905.63	896.17	660.18	346.99	238.50	4,586.93
1972	165.80	109.52	91.79	104.63	78.71	144.44	193.22	570.77	605.10	494.71	353.06	225.29	3,137.94
1973	136.39	88.44	82.66	53.93	138.12	212.65	317.76	1,033.62	1,223.27	656.16	357.33	232.09	4,532.42
1974	165.23	103.88	79.83	79.95	221.28	223.57	215.01	503.08	591.41	374.07	486.58	236.81	3,280.70
1975	223.87	118.28	92.71	67.41	113.08	243.43	352.58	954.96	1,278.10	809.08	454.18	309.78	5,017.46
1976	220.60	143.55	107.07	87.19	131.99	149.91	199.93	418.57	662.36	606.52	375.43	209.60	3,312.72
1977	217.07	106.58	91.27	107.08	141.56	130.57	241.49	509.28	1,268.94	602.02	400.76	281.79	4,098.41
1978	233.48	142.07	117.86	88.30	156.72	171.41	781.36	1,082.77	1,001.27	688.50	341.73	222.12	5,027.59
1979	149.14	86.29	63.18	75.91	168.78	224.56	238.32	420.50	381.36	545.31	197.66	132.37	2,683.38
Total	4,541.87	2,959.81	2,424.31	2,317.19	4,173.40	5,301.04	8,493.49	17,667.84	24,488.77	17,654.92	9,292.65	6,169.24	105,484.53
Ave.	181.67	118.39	96.97	92.69	166.94	212.04	339.74	706.71	979.55	706.20	371.71	246.77	4,219.38

Table 4-18 Monthly Run-off at Mae Chaem River No. 4

C.A.: 1,955 km²

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1955	254.84	152.70	131.95	162.68	232.91	665.16	474.87	816.72	1,351.09	771.25	514.17	339.60	5,867.94
1956	241.37	198.77	127.17	513.72	408.64	299.13	490.59	1,303.94	3,075.46	1,081.10	650.57	513.61	8,904.07
1957	321.63	208.81	163.12	91.20	166.13	296.94	353.41	543.91	823.45	664.60	333.99	236.16	4,203.35
1958	192.62	116.51	77.28	102.78	131.35	252.37	484.42	550.65	864.99	601.17	318.27	218.92	3,911.33
1959	169.07	89.70	73.64	68.09	150.40	259.33	568.62	1,191.68	2,574.20	1,264.65	491.15	305.36	7,205.89
1960	207.52	148.75	97.59	80.61	269.11	370.47	426.60	1,670.48	1,230.97	1,095.13	493.96	483.86	6,575.05
1961	298.62	195.34	143.19	156.19	381.44	519.22	655.62	1,826.52	3,079.39	2,196.99	883.52	642.14	10,978.18
1962	456.35	298.62	218.35	181.58	279.45	301.99	811.67	1,151.83	2,222.81	1,992.11	688.73	437.26	9,040.75
1963	329.49	214.42	164.55	158.49	257.50	826.26	1,243.88	1,745.14	1,743.45	2,361.46	1,376.91	899.23	11,320.78
1964	721.29	533.82	486.66	432.78	719.61	690.98	1,173.71	1,227.04	2,971.05	3,742.86	1,136.10	807.17	14,643.07
1965	661.79	508.55	479.93	291.88	368.22	509.67	577.60	1,384.21	1,760.29	1,662.06	1,219.74	687.05	10,110.99
1966	514.73	377.77	323.32	132.08	519.44	281.22	575.35	1,353.90	2,428.82	847.59	580.96	400.22	8,335.40
1967	286.83	177.21	160.31	149.26	300.31	248.05	424.36	930.10	2,003.34	1,216.37	623.63	412.01	6,931.78
1968	310.41	186.98	160.26	200.84	328.73	376.92	628.11	1,064.26	879.58	1,184.94	624.18	394.61	6,339.82
1969	247.72	163.12	136.03	121.86	326.82	374.70	526.13	2,709.26	2,475.62	1,522.50	876.91	525.03	10,005.70
1970	256.52	149.88	103.85	169.56	642.65	559.02	718.08	2,116.72	2,277.81	1,200.84	640.49	515.18	9,350.60
1971	334.05	227.51	205.41	152.52	308.48	448.82	1,272.18	1,734.84	1,716.71	1,264.65	664.69	456.87	8,786.73
1972	317.61	209.79	175.83	200.43	150.77	276.68	370.14	1,093.36	1,159.14	947.67	676.33	431.57	6,009.32
1973	261.27	169.41	158.35	103.31	264.59	407.36	608.70	1,980.01	2,343.30	1,256.95	684.50	444.60	8,682.35
1974	316.51	198.99	152.92	153.16	423.89	428.27	411.88	963.71	1,132.91	716.58	932.10	453.63	6,284.55
1975	428.85	226.58	177.59	129.14	216.61	466.31	675.41	1,829.34	2,448.34	1,549.89	870.02	593.41	9,611.49
1976	422.59	274.99	205.10	167.02	252.85	287.16	382.98	801.81	1,268.82	1,161.87	719.18	401.51	6,345.88
1977	415.82	204.17	174.84	205.12	271.18	250.13	462.60	975.59	2,430.80	1,153.24	767.71	539.79	7,850.99
1978	447.26	272.15	225.77	169.14	300.21	328.36	1,496.79	2,074.16	1,918.05	1,318.90	654.62	425.49	9,630.90
1979	285.70	165.30	121.03	145.41	323.32	430.18	456.52	805.52	730.53	1,044.61	378.64	253.57	5,140.33
Total	8,700.46	5,669.84	4,644.04	4,438.85	7,994.61	10,154.70	16,270.22	33,844.70	46,910.92	33,819.98	17,801.07	11,817.85	202,067.24
Ave.	348.02	226.79	185.76	177.55	319.78	406.19	650.81	1,353.79	1,876.44	1,532.80	712.04	472.71	8,082.69

Table 4-19 Monthly Run-off at Mae Chaem River No. 5

C.A.: 3,735 km^2

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1955	440.10	263.71	227.88	280.95	402.23	1,148.71	820.09	1,410.44	2,333.28	1,331.92	887.95	586.47	10,133.73
1956	416.83	343.26	219.61	887.17	705.70	516.58	847.23	2,251.86	5,311.20	1,867.02	1,123.51	886.98	15,376.95
1957	555.45	360.61	281.70	157.50	286.90	512.80	610.32	939.32	1,422.07	1,147.74	576.78	407.84	7,259.03
1958	332.65	201.20	133.46	177.49	226.83	435.83	836.57	950.96	1,493.81	1,038.20	549.64	378.06	6,754.70
1959	291.98	154.91	127.18	117.59	259.74	447.85	981.98	2,057.98	4,445.55	2,184.00	848.20	527.34	12,444.30
1960	358.38	256.88	168.53	139.21	464.74	639.79	736.72	2,884.86	2,125.84	1,891.25	853.05	835.60	11,354.85
1961	515.71	337.34	247.28	269.73	658.74	896.67	1,322.23	3,154.34	5,317.99	3,794.13	1,525.80	1,108.96	18.958.92
1962	788.10	515.71	377.09	313.59	482.60	521.52	1,401.72	1,989.16	3,838.72	3,440.31	1,189.42	755.14	15,613.08
1963	569.02	370.30	284.17	273.70	444.70	1,426.92	2,148.13	3,013.79	3,010.88	4,078.16	2,377.88	1,552.94	19,550.59
1964	1,245.65	921.88	840.45	747.39	1,242.74	1,193.30	2,026.96	2,119.05	5,130.90	6,463.79	1,962.01	1,393.96	25,288.08
1965	1,142.89	878.25	828.82	504.07	635.91	880.19	997.49	2,390.48	3,039.96	2,870.32	2,106.45	1,186.51	17,461.34
1966	888.92	652.39	558.36	228.09	897.06	485.66	993.61	2,338.13	4,194.48	1,463.76	1,003.30	691.16	14,394.92
1967	495.35	306.03	276.85	257.76	518.62	428.37	732.85	1,606.25	3,459.70	2,100.63	1,076.98	711.52	11,970.91
1968	536.06	322.90	276.76	346.84	567.71	650.93	1,084.73	1,837.93	1,519.01	2,046.35	1,077.94	681.47	10,948.63
1969	427.80	281.70	234.92	210.44	564.40	647.10	908.60	4,678.80	4,275.30	2,629.30	1,514.40	906.70	17,279.46
1970	443.00	258.84	179.35	292.83	1,109.84	965.40	1,240.10	3,655.50	3,933.70	2,073.80	1,106.10	889.70	16,148.16
1971	576.90	392.90	354.74	263.40	532.74	775.10	2,197.00	2,996.00	2,964.70	2,184.00	1,147.90	789.00	15,174.38
1972	548.50	362.30	303.65	346.14	260.38	477.82	639.22	1,888.20	2,001.80	1,636.60	1,168.00	745.30	10,377.91
1973	451.20	292.56	273.46	178.41	456.93	703.50	1,051.20	3,419.40	4,046.80	2,170.70	1,182.10	767.80	14,994.06
1974	546.60	343.64	264.08	264.50	732.05	739.60	711.30	1,664.30	1,956.50	1,237.50	1,609.70	783.40	10,853.17
1975	740.60	391.30	306.70	223.02	374.08	805.30	1,166.40	3,159.20	4,228.20	2,676.60	1,502.50	1,024.80	16,598.70
1976	729.80	474.90	354.20	288.43	436.66	495.92	661.40	1,384.70	2,191.20	2,006.50	1,242.00	693.40	10,959.11
1977	718.10	352.60	301.94	354.23	468.31	431.96	798.90	1,684.80	4,197.90	1,991.60	1,325.80	932.20	13,558.34
1978	772.40	470.00	389.90	292.10	518.46	567.06	2,584.90	3,582.00	3,312.40	2,277.70	1,130.50	734.80	16,632.22
1979	493.40	285.47	209.01	251.12	558.36	742.90	788.40	1,391.10	1,261.60	1,804.00	653.90	437.90	8,877.16
Total	15,025.39	9,791.58	8,020.09	7,665.70	13,806.43	17,536.78	28,098.05	58,448.55	81,013.49	58,405.88	30,741.81	20,408.95	348,962.70
Ave.	601.02	391.66	320.80	306.63	552.26	701.47	1,123.92	2,337.94	3,240.54	2,336.24	1,229.67	316.36	13,958.51

Table 4-20 Monthly Run-off at Mae Khan River No. 1 and No. 2

Mae Khan River No. 1

C.A.: 535 km²

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1962	79.68	48.02	36.45	32.74	44.31	39.12	111.59	188.87	346.09	532.75	108.31	67.28	1,635.21
1963	58.35	38.28	27.61	28.38	26.27	83.47	107.54	286.64	229.89	432.87	254.44	131.34	1,705.08
1964	82.13	50.00	34.86	28.30	113.82	109.47	105.53	166.60	487.71	622.01	218.29	136.72	2,155.44
1965	82.19	57.18	35.49	29.81	46.43	74.16	42.49	178.31	245.14	376.19	199.97	120.40	1,487.76
1966	81.52	68.44	27.80	19.85	94.04	60.83	132.30	322.56	434.56	262.55	144.27	96.69	1,745.41
1967	77.50	43.85	35.11	42.67	108.01	131.82	179.75	236.95	735.00	354.41	253.32	153.37	2,351.76
1968	125.42	85.16	73.50	98.41	176.19	189.43	263.99	367.74	318.83	338.67	215.51	156.37	2,409.22
Total	586.79	390.93	270.82	280.16	609.07	688.30	943.19	1,747.67	2,797.22	2,919.45	1,394.11	862.17	13,489.88
Ave.	83.83	55.85	38.69	40.02	87.01	98.33	134.74	249.67	399.60	417.06	199.16	123.12	1,927.13

Mae Khan River No. 2

C.A.: 1,038 km²

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1962	154.59	93.18	70.72	63.51	85.97	75.90	216.51	366.43	671.48	1,033.64	210.14	130.53	3,172.60
1963	113.20	74.27	53.57	55.06	50.97	161.95	208.65	556.13	446.03	839.84	493.66	254.82	3,308.15
1964	159.34	97.01	67.63	54.92	220.84	212.39	204.75	323.24	946.24	1,206.82	423.52	265.26	4,181.96
1965	159.47	110.95	68.86	57.84	90.09	143.88	82.43	345.96	475.62	729.88	387.99	233.59	2,886.56
1966	158.16	132.79	53.94	38.51	182.45	118.03	256.68	625.83	843.13	509.39	279.91	187.60	3,386.42
1967	150.36	85.09	68.13	82.79	209.56	255.76	348.76	459.73	1,426.04	687.63	491.48	297.57	4,562.90
1968	243.34	165.23	142.60	190.94	341.84	367.52	512.18	713.48	618.59	657.07	418.14	303.39	4,674.32
Total	1,138.46	758.52	525.45	543.57	1,181.72	1,335.43	1,829.96	3,390.80	5,427.13	5,664.27	2,704.84	1,672.76	26,172.91
Ave.	162.64	108.36	75.06	77.65	168.82	190.78	261.42	484.40	775.30	809.18	386.41	238.97	3,738.99

CHAPTER 5

GEOLOGY

CHAPTER 5 GEOLOGY

5.1 Introduction

The Mae Pai and Mae Chaem project contains individual development plan of Mae Pai, Mae Chaem and Mae Khan Rivers, and transbasin scheme from Mae Pai River to Mae Chaem River (for details, refer to Chapter 6).

Up to present, following dam sites have been proposed for this project:

Mae Pai River ..... 6 sites numbered as No. 1 through 6 from the upstream
Mae Chaem River ... 5 sites numbered as No. 1 through 5 from the upstream
and 1 alternative site for No. 4
Mae Khan River .... 2 sites numbered as No. 1 and 2 from the upstream

On several of these sites, geological reconnaissance and some investigation works have already been executed (refer to Clause 5.3).

The geological investigation at this time was for obtaining basic geological information required to make the master plan of this project. Since many dam sites have been proposed as mentioned in the above and since the project area was very broad, the geological investigation was carried out mainly by aerial photo geological interpretation. Field geological reconnaissance was carried out on accessible sites out of the dam sites that had been selected through the aerial photo geological interpretation. Also, the drill cores were observed and existing geological data was collected.

In this chapter the geological conditions and problems of all the selected sites are described based on the data thus accumulated. Chapter 1 has already described the project sites to be pursued in the next stage and investigation works to be conducted from now on (refer to Chapter 1).

5.2 Investigated Area and Method

Firstly, aerial photo geological interpretation was carried out on the above-mentioned proposed dam sites to select dam sites for the project prior to the field reconnaissance. As the results, it was found that large scale landslide configurations were existing in the dam sites or reservoir for No. 2 and No. 3 sites of Mae Pai River. Therefore, these sites were determined to be unsuitable and they were eliminated from the master plan. No. 4 and No. 5 sites of Mae Pai River are located very close to No. 6 and aerial photo interpretation indicated that the two sites are either same or inferior to No. 6 geologically and topographically. Therefore, No. 4 and 5 were also eliminated from the plan.

The existing plan locations for the Mae Pai No. 1 and No. 6 sites and 6 dam sites of Mae Chaem River including the alternative site were found adequate, but for the Mae Pai No. 1 site a new comparative site was selected at the downstream.

On the Mae Khan project area where aerial photos could not be taken, dam site were selected using topographical maps of 1/50,000 scale.

Investigation was made on thus selected sites in the following methods:

a) Mae Pai No. 1 and No. 6 dam sites, and all dam sites of Mae Chaem No. 3 through No. 5

- Surface geological reconnaissance along the main river using topographical maps of 1/2,000 or 1/10,000 scale
- Aerial photo geological interpretation using aerial photos of 1/50,000 scale
- Observation of drill cores of the Mae Pai No. 6 and Mae Chaem No. 5 dam sites

b) Mae Chaem No. 1 and No. 2 dam sites

- Aerial photo geological interpretation using aerial photos of 1/25,000 scale

c) Mae Khan No. 1 dam site

- Examination on the desk using topographical maps of 1/50,000 scale and existing geological maps of 1/250,000 scale (see Reference 5.1).

d) Mae Khan No. 2 dam site

- Surface geological reconnaissance along the main river using topographical maps of 1/10,000 scale prepared by enlarging topographical maps of 1/50,000 scale

e) Reservoir areas and Mae Pai - Mae Chaem Transbasin scheme site

- Aerial photo geological interpretation using aerial photos of 1/25,000 and 1/50,000 scales
- Examination on the desk using topographical maps of 1/50,000 scale and existing geological maps of 1/250,000 scale

Topographical maps of 1/2,000 and 1/10,000 scales prepared by NEA were used in these field reconnaissance but there were some discrepancies between these maps and topographical maps of 1/50,000 scale. For example, altitudes of the Mae Chaem No. 3 site and No. 4 original plan site shown in the NEA maps are higher by about 40 m and 50 m respectively than in 1/50,000 scale maps. In this master plan, topographical maps of 1/50,000 scale are used basically, but for geological plan and profile at each dam site, topographical maps prepared by NEA are used.

5.3 Previous Geological Investigations

As outline in Clause 5.1, the Mae Pai and Mae Chaem project consists of individual development project and transbasin scheme, and a number of dam sites have been proposed.

Prior to the last investigation, the following geological investigations have been carried out on these proposed sites.

Mae Pai River area

(1) A field reconnaissance was made on dam sites from No. 1 through No. 4 and No. 6 by Engineering Consultant Inc. in 1972 (see Reference 5.3). It revealed existence of unsteady landslide configurations at the right slope of the No. 2 site.

(2) NEA carried out drilling on No. 4 and No. 5 dam sites during the period of May 1973 through October 1974 (see Reference 5.5).

(3) During the period of March 1979 through April 1980, surface geological reconnaissance on the dam site and reservoir, and investigation

works on the dam site and construction material area were made on the No. 6 site (see References 5.8 and 5.10).

(4) Another investigation was made by the preliminary Survey Team dispatched by the Japanese government in March 1980 on the No. 6 site (see Reference 5.9).

Mae Chaem River area

(1) NEA carried out surface geological reconnaissance on the dam sites and reservoirs of No. 4 and No. 5 sites in 1979. NEA also carried out some investigation works on the dam site and construction material area (see References 5.6 and 5.7).

(2) The preliminary Survey Team dispatched by the Japanese government investigated the No. 3, No. 4 and No. 5 sites in March 1980 (see Reference 5.9).

(3) Drilling investigation is being conducted on the planned sites of the dam, intake and power house of No. 5 from May 1980 (see Reference 5.11 and Appendix).

No geological investigation, including field reconnaissance, had been carried out in the Mae Khan River area.

5.4 General Geology of Project Area

The project area is situated at the northwestern part of Thailand contacting with Burma with its north and west edges. The Dauna range, which is a folding mountain range in the north-south direction branched at the Shan plateau of south China and reaches the Malyan peninsular through northeast part of Burma, runs through this western border line.

The mountains of the project area are generally at the height of 1,000 to 1,800 m (MSL) and in southeastern part of the project area, Doi Inthanon, the highest mountain in Thailand (2,590 m (MSL)) stands. Generally, the mountains of this area is in the stage of latter maturity and most of the ridges are not sharp. Alongside Mae Pai River, however, the topography is in the stage of maturity and sharp ridges are observable.

In the northern part of the project area, Mae Pai River, a tributary to Salween River that runs through Burma, runs from east to west as if it cuts the north-west direction geological structure. In the southern part of the project area, Mae Chaem River and Mae Khan River, both of which are tributaries of Mae Pin River, run from north to south along the geological structure.

The project area is situated at the northwest edge of the Indochina platform formed by the Indochina orogeny during Permian to Jurassic time. The area was affected by the orogeny three times, in the Hercynian (from Precambrian to late Paleozoic time), the Indochina (from Permian to Jurassic time) and the Himalayan (from Cretaceous to Quarternary time), with the most significant influence from the Indochina orogeny. It seems that the current north-south geological structure was formed by the Indochina orogeny.