No. 9

The Kingdom of Thailand

Electricity Generating Authority of Thailand

UPPER QUAE YAI HYDROELECTRIC DEVELOPMENT PROJECT FEASIBILITY REPORT

Volume 1

June _ 1980

Japan International Cooperation Agency

The Kingdom of Thailand

Electricity Generating Authority of Thailand

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PREFACE

It is with great pleasure that I present this report entitled FEASIBILITY REPORT OF UPPER QUAE YAI HDYROELECTRIC DEVELOPMENT PROJECT to the Government of the Kingdom of Thailand.

This report embodies the result of a feasibility survey which was carried out in the Upper Quae Yai area, Thailand from March 6 to March 29 and from July 2 to July 31, 1979 by the Japanese survey team commissioned by the Japan International Cooperation Agency following the request of the Government of the Kingdom of Thailand.

The survey team, headed by Mr. Hiroharu KISHO, had a series of close discussions with the officials concerned of the Government of the Kingdom of Thailand and conducted a wide scope of field survey and data analyses.

I sincerely hope that this report will be useful as a basic reference for development of the project.

I am particularly pleased to express my appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the Japanese team.

June, 1980

Keisuke Arita
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Mr. Keisuke Arita
President
Japan International Cooperation Agency

Dear Mr. Arita:

We submit for your attention our report on the feasibility study of the Upper Quae Yai Hydro Electric Development Project planned by the Electricity Generating Authority of Thailand (EGAT) of the Kingdom of Thailand.

The survey team of five members made a field investigation during a period from March 6 to 29, 1979 and that of ten members from July 2 to 31, 1979 concerning hydrology of the Quae Yai River in connection with rainfall, runoff, etc., topography and geology of the Project site, and dam construction materials, surveys with respect to the social and economic backgrounds connected with electric power demand, the electric power system, transmission lines, telecommunications systems, transportation plans, etc., and collected various data required for a feasibility study. During the periods of the visits to Thailand, exchanges of opinions were made with engineers of EGAT with regard to the Project.

Upon returning to Japan, the team studied based on these field investigation results, and completed this report.

The Upper Quae Yai Hydro Electric Development Project consists of Nam Chon Power Station with installed capacity of 580,000 kW and Thi Khong Power Station of 51,000 kW for a total capacity of 631,000 kW.

This report contains studies such as hydrologic analyses, determinations of layout and scale of the project, basic designs of principal structures such as dams and power stations, basic designs of electrical equipment, transmission line planning, system analysis, etc., and as a result of studies, it is clarified that this Project would be amply feasible both technically and economically.

The Upper Quae Yai Hydroelectric Development Project has been investigated and planned for a long period by EGAT as a promising hydroelectric power generation plan. It is ardently hoped that the Report would be useful for the early electric power development in the Kingdom of Thailand in near future.

In closing, it is wished to express the heartfelt gratitude to everyone who kindly provided guidance and cooperation in the carrying out of this study.

June, 1980

Yours faithfully,

Survey Team for Upper Quae Yai
Hydroelectric Development Project

Hiroharu Kisho

Hiroharu Kisho
Team Leader


Nam Choan
Reservoir
UPPER QUAE YAI PROJECT

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Nam Chon
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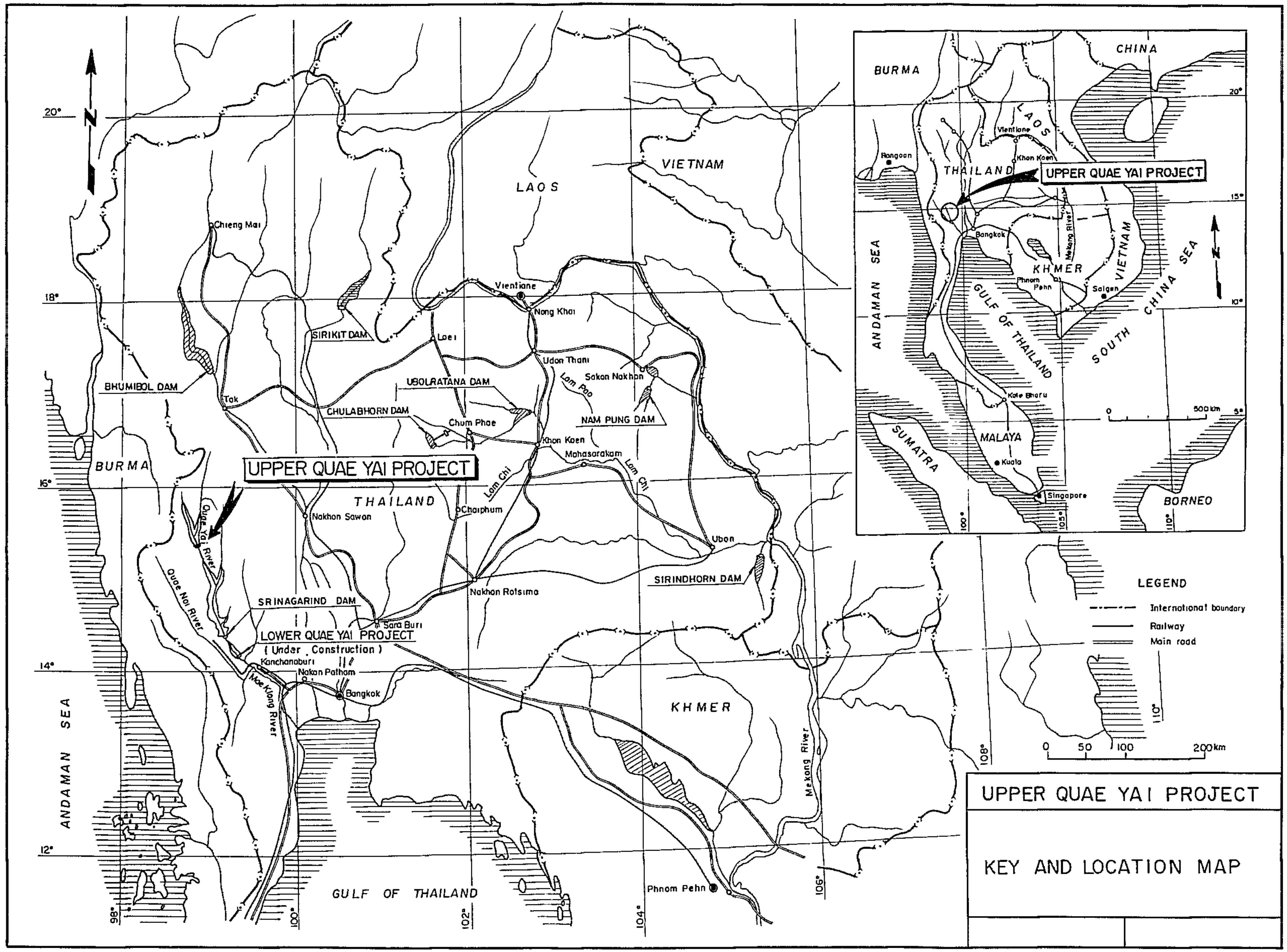
N
20°
18°
16°
14°
12°
98°
100°
102°
104°
106°
108°
LAOS
VIETNAM
BURMA
THAILAND
KHMER
ANDAMAN SEA
GULF OF THAILAND
Chieng Mai
Vientiane
Nong Khai
Loei
Udon Thani
Sakon Nakhon
Tak
Chum Phae
Khon Koen
Mahasarakam
Nakhon Sawan
Chaiphum
Ubon
Nakhon Rotsima
Sara Buri
Kanchanaburi
Nakon Pathom
Bangkok
Phnom Pehn
Lam Pao
Lam Chi
Quae Yai River
Quae Noi River
Mae Klong River
Mekong River
SIRIKIT DAM
BHUMIBOL DAM
UBOLRATANA DAM
CHULABHORN DAM
NAM PUNG DAM
SIRINDHORN DAM
SRINAGARIND DAM
UPPER QUAE YAI PROJECT
LOWER QUAE YAI PROJECT
(Under Construction)
BURMA
CHINA
LAOS
THAILAND
VIETNAM
KHMER
MALAYA
SUMATRA
BORNEO
ANDAMAN SEA
GULF OF THAILAND
SOUTH CHINA SEA
Rangoon
Vientiane
Khon Koen
Bangkok
Phnom Pehn
Saigon
Kota Bharu
Kuala
Singapore
Mekong River
UPPER QUAE YAI PROJECT
20°
15°
10°
5°
100°
105°
110°
0
500 km
LEGEND
International boundary
Railway
Main road
0
50
100
200km
UPPER QUAE YAI PROJECT
KEY AND LOCATION MAP

FORWARD

The fruits of feasibility study on the Upper Quae Yai Project are presented in 4 volumes as follows:

* Feasibility Report - Summary -

* Volume 1 Feasibility Report - Main - comprising 12 chapters

    1. INTRODUCTION
    2. NECESSITY FOR DEVELOPMENT
    3. HYDROLOGY
    4. GEOLOGY
    5. MATERIALS
    6. DEVELOPMENT SCHEME
    7. PRINCIPAL STRUCTURES
    8. ELECTRICAL EQUIPMENT
    9. POWER SYSTEM ANALYSIS, TRANSMISSION LINE AND TELECOMMUNICATION SYSTEM
    10. CONSTRUCTION SCHEDULE AND PROCEDURE
    11. CONSTRUCTION COST AND FINANCIAL PROGRAM
    12. ECONOMIC JUSTIFICATION

* Volume 2 Appendix 1. HYDROLOGY

* Volume 3 Appendix 2. GEOLOGY AND MATERIAL

    Appendix 3. DESIGN OF STRUCTURES

* Volume 4 Appendix 4. LOAD FORECAST

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- Supplementary Study on Design Flood and Spillway Capacity. Ban Chao Nen (Quae Yai No.1) Hydroelectric Project EGAT July 1973
- Reconnaissance Report Upper Quae Yai Hydroelectric Project November 1973 OTCA (EPDC)
- The Fourth National Economic and Social Development Plan (1977 - 1981) NESDB
- Load Forecast for Thailand Electric System December 1978 - Power Tariff Study Sub-Committee
- Preliminary Report Upper Quae Yai Project EGAT August 1978
- Prefeasibility Report Upper Quae Yai Project EGAT June 1979
- EGAT's Revised Power Development Plan 1979 - 1990 February 1979
- Annual Report 1978 EGAT
- Report on Inspection of Upper Quae Yai Project JB Cooke, IL Pinkerton, J. Newbery February 1978

Unit and Conversion of Unit

mm	:	Millimeter
cm	:	Centimeter
m	:	Meter
km	:	Kilometer
cm^2	:	Square centimeter
m^2	:	Square meter
km^2	:	Square kilometer
m^3	:	Cubic meter
kg	:	kilogram
t	:	Metric ton
m^3/sec	:	Cubic meter per second
kw	:	Kilowatt
kWh	:	Kilowatt hour
MW	:	Megawatt
MWh	:	Megawatt hour
GWh	:	Gigawatt hour
kV	:	Kilovolt
kVA	:	Kilovolt-Ampere
MVA	:	Megavolt-Ampere
MCM	:	Thousands of circular mils
rpm	:	Revolutions per minute
Hz.	:	Hertz (cycles per second)
El	:	Elevation
°C	:	Degree in Centigrade
mb	:	Millibar
%	:	Percentage

US$	:	U.S. dollar
฿	:	Baht
Lu	:	Lugeon value (rate of water loss from a drillhole)
hrs	:	Hours
yr	:	Year
ea	:	Each
Max.	:	Maximum
Min.	:	Minimum
cct	:	Circuit
ℓ	:	Liter
1 MW	:	1,000 kW
1 GW	:	1,000 MW
1 barrel	:	159 ℓ
1 rai	:	1,600 m^2

GLOSSARY OF NAMES

Agencies

AIT : Asian Institute of Technology

EGAT : Electricity Generating Authority of Thailand

EPDC : Electric Power Development Co., Ltd.

JICA : Japan International Cooperation Agency

MEA : Metropolitan Electricity Authority

NEA : National Energy Authority

NESDB: National Economic and Social Development Board

OPEC : Organization of Petroleum Exporting Countries

PEA : Provincial Electricity Authority

YEA : Yanhee Electricity Authority

Terms

a.c. : Alternative current

ACSR : Aluminum Conductor Steel Reinforced

ASTM : American Society for Testing and Materials

CA : Catchment Area

FY : Fiscal Year

GDP : Gross Domestic Product

IRR : Internal Rate of Return

MF : Maximizing Factor

PAX : Private Automatic Exchanger

PMF : Probable Maximum Flood

PMP : Probable Maximum Precipitation

UHF : Ultra High Frequency

VHF : Very High Frequency

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The power generating facilities presently existing in the Kingdom of Thailand amount to approximately 2,900 MW. Growth in electric power demand is predicted to be at an annual rate of 10 - 15% for about the next 10 years, after which, although there will be some decline in the rate, annual increases will be at least 8 - 9% up to about 1995.

The Upper Quae Yai Hydroelectric Power Development Project which is to have a large-scale reservoir indicates an economic superiority over alternatives as a facility corresponding with the increasing demand for electric power. It should also be fully realized that a hydroelectric power station will be advantageous for the national economy in that petroleum imports will be suppressed.

As a result of electric power demand forecasts, the start of operation of this Project should be in 1987.

This Project consists of the main power station of Nam Chon Power Station of output of 580,000 kW and Thi Khong Power Station of output of 51,000 kW utilizing the head between Nam Chon Power Station and the downstream Srinagarind Power Station. The general features of the Upper Quae Yai Project consisting of the above are as indicated below.

Nam Chon Power Station

Catchment area	4,908 km^2
Annual mean inflow	2,975 x $10^6 m^3$

Reservoir normal high water level	El. 370 m
Reservoir min. water level	El. 331 m
Total storage capacity	5,975 x $10^6 m^3$
Effective storage capacity	4,100 x $10^6 m^3$
Reservoir surface area (at El. 370 m)	137 x $10^6 m^2$
Power generation	
Max. output	580,000 kW
Annual energy production	1,095 x 10^6 kWh
Dam	
Type	Rockfill dam with center core
Height	185 m
Volume	12.7 x $10^6 m^3$
Main electrical equipment	
Turbine and generator capacities	145,000 kW
Number of units	4
Transmission line	
Route	Upper Quae Yai to Sai Noi Substation
Length	277 km

Thi Khong Power Station

Catchment area	5,145 km^2
Annual mean inflow	3,090 x $10^6 m^3$
Regulating pond normal high water level	El. 197 m
Regulating pond min. water level	El. 196.8 m (El. 193.5 m during one unit drop)
Total storage capacity	10 x $10^6 m^3$
Effective storage capacity	0.3 x $10^6 m^3$
Pond surface area	1.45 x $10^6 m^2$
Power generation	
Max. output	51,000 kW
Annual energy production	93 x 10^6 kWh

Dam	
Type	Concrete gravity
Height	32 m
Volume	$46 \times 10^3 m^3$
Main electrical equipment	
Turbine and generator capacities	25,500 kW
Number of units	2

Since limestone is distributed in the catchment area, the Nam Chon damsite, where a large-scale reservoir is to be provided, was carefully selected upon consideration of geological conditions so that leakage from the reservoir will not be a problem. The size of the reservoir was also determined upon economic studies fully taking the geological conditions into account.

Regarding the type of the dam, a rockfill dam having an impervious core was selected as appropriate for this site upon technical and economic studies including concrete dams. The power station is to be provided at the left bank immediately downstream of the dam.

Thi Khong Dam is to be a concrete gravity dam with the power station provided at the right bank side of the dam.

Regarding construction periods, approximately 6 years will be required for the Nam Chon Project and approximately 4 years for the Thi Khong Project. The time of execution of works for the latter should be scheduled so that care of river can be done during the impoundment of Nam Chon Reservoir.

The construction cost of the Project including all expenses such as interest during construction, import duties, etc., will be the following in terms of 1980 prices.

Nam Chon Project US$570.4 million (Bahts 11.694 million)

Thi Khong Project US$56.4 million (Bahts 1,156 million)

The economic evaluation of the Upper Quae Yai Project was analyzed according to cost and benefit (B/C, B - C) and internal rate of return (IRR).

As a result, at discount rate of 10%, B/C = 1.45, B - C = US$152.9 million, and IRR = 15.2%.

Recommendations

In order to start operation of the Upper Quae Yai Project by 1987, the various investigation works such as geological investigations on the damsite, investigations and laboratory tests of materials energetically being carried out by EGAT at present should be continued to be expedited for the purpose of detail design. The detailed concerned is stated in Chapter 4.

Based on the investigation results, it will be necessary to immediately commence detail design, and also preparation of tender documents and specifications.

Facilities required for construction such as access roads to project sites and buildings should be prepared as early as possible in order to meet planned construction schedules.

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

The installed capacity for electric power generation owned by EGAT as of 1979 was approximately 2,900 MW for hydro and various types of thermal combined. The growth in power demand since 1970 up to the present, although dropping to 5% in 1974 immediately after the oil crisis, has shown annual rates between 8 and 15%. It is forecast that for the period from 1979 through 1990 the demand for entire Thailand, including MEA and PEA, will increase at 8 - 15%, with extreme growth anticipated particularly for PEA.

EGAT is actively constructing power stations, both thermal and hydro, to meet the increase in power demand. The Upper Quae Yai Project has been taken up as a promising hydroelectric scheme and studies such as various field investigations starting with geological investigations, project planning, etc. have been vigorously pushed forward for early development.

1.1 Antecedents

The Quae Yai River, which is one of the main streams of the Mae Klong River, because of its abundant runoff and favorable topographic conditions, has been studied as one of the most promising streams in Thailand suited to hydroelectric development.

EGAT has been thoroughly aware of the importance of water power development of the Quae Yai River, and in 1965 requested the Japanese Government through the Thai Government for technical cooperation to expedite basic studies of the water power energy of the entire Quae Yai River basin.

In 1967, based on a contract with YEA (reorganized as EGAT in 1969), EPDC prepared a feasibility report on the Quae Yai No.1 Hydroelectric Project. EGAT started development of the Quae Yai River in earnest based on this feasibility report. The first to be developed were Srinagarind Power Station, and downstream of it, Lower Quae Yai Power Station.

The second-stage development is the Upper Quae Yai Project located upstream of the end of the backwater of Srinagarind Reservoir. The Thai Government requested the Japanese Government in 1972 for a reconnaissance study in order to promote this Project. Subsequently, responding to the request of the Thai Government, the Japanese Government provided the following technical cooperation up to 1976 for the Upper Quae Yai Project.

- Dispatch of Reconnaissance Study Team in 1972 and preparation of report
- Dispatch of a technical expert from 1974 to 1976. During this time, the Thai Government incorporated this Project in the Fourth National Economic Development Plan (1977-1981).

Meanwhile, in order to speed up field investigations for this Project, EGAT has energetically made preparations such as construction of access roads to the site and a base camp for carrying out investigations. Still more, to accelerate the field investigations, EGAT requested the Japanese Government to dispatch one civil engineer and two geologists from 1978 to 1980 through the Thai Government.

The works completed by EGAT up to 1979 were the following:

- Provision of a base camp for investigation of the Project site in 1977
- Improvements of road between Srinagarind and the investigation base camp in 1977 - 1979
- Preparation of Preliminary Report in August 1978
- Geological investigations of candidate damsites and reservoirs, and materials investigations from April 1978 to June 1979
- Preparation of Pre-feasibility Report in June 1979

Taking into account the state of progress in investigations at the damsite selected in preliminary studies, EGAT requested through the Thai Government in January 1979 for a feasibility study team to be dispatched. In response, the Japan International Cooperation Agency (JICA), on behalf of the Japanese Government, dispatched the Feasibility Study Team in March and July 1979 for the field investigations.

1.2 Scope of Work and Field Investigation

The objective of the work was to carry out an economic and technical feasibility study of the Upper Quae Yai Hydroelectric Power Development Project.

Field investigations for the Study were carried out twice, from March 6 to 29, 1979 the first time, and from July 2 to 31, 1979 the second time. Items such as the following were included in the investigations.

- Social and economic backgrounds and power demand

- Topography, geology and stream flows of the Quae Yai River basin
- Topography and geology of construction site of structure such as dam and powerhouse
- Construction for dam embankment and concrete aggregates
- Availability of local construction materials and construction cost
- Transportation of construction materials, turbines, generators, etc.
- Transmission line and telecommunication system
- Collection of data

The followings were included in the study in Japan. As for preparation of topographic maps of the Project sites, and boring of drillholes and excavation of test adits for geological investigations, these were all carried out by EGAT. Basic data needed for the study were also furnished by EGAT.

- Selection of project scale and layout
- Basic design of structures such as dam and powerhouse
- Basic designs of electrical equipment
- Transmission line planning, power system analysis and telecommunication system designing
- Construction cost and financial program
- Economic analysis

With respect to environmental assessment for the Project, it is being made separately by EGAT.

The members of the feasibility study team and the personnel of EGAT who cooperated in the investigations are as listed below.

- First Study Team

Hiroharu Kisho	Chief
Setsuo Takemoto	JICA, Coordinator
Yoshihiro Mitsui	Electrical Engineer, Power Transmission
Takeshi Takeno	Electrical Engineer, Telecommunications
Yukiyoshi Ozaki	Civil Engineer, Planning

Experts, dispatched from the Japanese Government, Cooperating with Study

Yozo Fukutake	Geologist
Kunio Watanabe	Civil Engineer
Mamoru Yamada	Geologist

- Second Study Team

Hiroharu Kisho	Chief
Setsuo Takemoto	JICA, Coordinator
Tateshi Murai	Economist, Load Forecasting, Economic Analysis
Kunio Watanabe	Civil Engineer, Designing
Katsuo Goda	Civil Engineer, Planning
Hiroo Miyairi	Civil Engineer, Construction Cost
Ryozo Kobayashi	Civil Engineer, Materials
Kunio Kitamura	Civil Engineer, Designing
Takuya Takaoka	Electrical Engineer, Electrical Equipment, Economic Analysis
Mitsuhiro Omori	Electrical Engineer, System Analysis

Experts, dispatched from the Japanese Government, Cooperating with Study

Yozo Fukutake	Geologist
Yoshihiro Nakazawa	Civil Engineer

- EGAT Personnel Concerned

Mr. Srid Aphaiphuminart	Director, Planning Department
Mr. Sommart Boonpirugsa	Assistant Director, Planning Department
Mr. Somkiet Phalaprakarn	Chief, System Planning Division
Mr. Vijit Somponpun	Chief, Survey Division
Mr. Payak Ratnarathorn	Chief, Water Resources Planning and Development Division
Mr. Prasit Niratsayakul	Chief, Environmental Division
Mr. Narongsak Vichetpan	Assistant Chief, Project Division
Mr. Kitti Naparaxawong	Chief, Hydrology Section, Survey Division
Mr. Annop Kaovichagon	Chief of Survey Section, Survey Division
Mr. Danit Suvarnsiri	Chief, Geological Section, Survey Division
Mr. Surin Karchanopas	Chief, Laboratory Section, Survey Division
Mr. Opas Kietsrikul	Survey Division
Mr. Peel Chitakarn	Survey Division

1.3 Acknowledgements

This Feasibility Report could not have been prepared without the cooperation of all the gentlemen concerned in EGAT, and it is wished to hereby express the sincerest gratitude of the Study Team. Profound thanks are also owed to those concerned at the Royal Thai Government agencies who assisted in coordination of work performed by the Feasibility Study Team in Thailand.

CHAPTER 2

NECESSITY FOR DEVELOPMENT

CHAPTER 2 NECESSITY FOR DEVELOPMENT

2.1 Electric Power Situation of Thailand

The Government of Thailand, in its Fourth National Economic and Social Development Plan (1977 - 1981), has set the target for the annual average growth rate of GDP at 7% (performance during the Third Development Plan period: approximately 6%), with approximately 6% of the total development budget allocated to the electric power sector. This takes into account development of large-scale hydro and modern thermal projects to cope with the electric power demand expected to increase sharply in the future, expansion and strengthening of the electric power system, and development of the possibility for utilization of domestic energy resources to replace power generating facilities burning imported oil which has become extremely expensive in recent years.

Approximately 80% of the total energy consumption of Thailand is of petroleum products and gas, of which 40 percentage points are for the transportation sector, and about 20 percentage points each for industry, electricity and residential/commercial. Approximately 70% of the total electric energy production depends on petroleum fuels, with the greater part of the crude oil purchased coming from the Middle East where the political situation is uncertain.

In Thailand, more than half of the electric energy production is consumed centered at the Bangkok Area. Growth in demand recorded an annual average 14% during the Third Development Plan period (1972 - 1976), and is projected to be an annual average of approximately 11% for the period of the Fourth Development Plan.

The demand for electricity in 1978 was 2,110 MW at maximum power, and 12,372 GWh in electric energy production. Against this demand, the total installed generating capacity as of the end of December 1978 was 2,936 MW. This capacity consisted of 33% of hydro, 53% of oil-fired, 7% of lignite-burning thermal, and 7% of others (see Table 2-1).

The power transmission system consists of 230 kV outer loop line connecting thermal power stations located in the outskirts of Bangkok and substations in the load center, 230 kV trunk transmission line connecting large-scale hydroelectric power stations located in Region-4 and the load center, 115 kV transmission lines connecting hydroelectric power stations scattered in Region-2 and the load center, and an independent 115 kV system in Region-3 (scheduled to be interconnected in 1980). Other than the above there are high-voltage transmission lines (230 kV) being constructed or planned to connect a group of large-scale hydroelectric power stations being realized in Region-1 with the load center. The circuit length of transmission line as of the end of December 1978 totalled 9,172 km.

2.2 Load Forecast

Long-range load forecasts for entire Thailand are made by the Load Forecast Working Group, Power Study Sub-Committee, consisting of representatives from the National Economic and Social Development Board (NESDB), National Energy Authority (NEA), EGAT, MEA and PEA. The forecast figures are utilized for formulating power generation, transmission and distribution system plans, studies of tariff rates, setting up of budgets and carrying out financial analysis. In making load forecasts, a method of correlative checking of microscopic and macroscopic forecasts is adopted, the contents being as described below.

In microscopic forecasts, the energy sales by type of consumer for the MEA and PEA service areas are estimated based on time series analysis. Besides the above, for PEA areas, concrete phenomena such as trends in the economic growth rate, checks by correlation curves between GDP per capita and electric energy consumption per capita, start-ups of new industrial projects, regional increases or decreases in population, and the state of progress in housing development plans are taken into consideration. For consumers directly supplied by EGAT, analytical forecasts are made for the individual consumers.

Macroscopic forecasting described below is done in order to check these microscopic forecast figures. Customers are classified according to the five categories of residential, commercial, industrial, street lighting, and others, and the correlation between GDP per capita and energy consumption per capita is analyzed for each category (1963 - 1977) to forecast total demand up to 1987. The results of microscopic and macroscopic forecasts are extremely close to each other (see Fig. 2-1). Based on these load forecasts, EGAT recently made load forecasts up to 1995 for evaluation of the Project.

As a result of referring this forecast made by EGAT to a world global model and an Asiatic countries model, it is seen that Thailand belongs to a group of countries in a so-called growth period with there being a possibility of future growth in power demand by leaps and bounds. Accordingly, the load forecast by EGAT in which the growth in power demand during the 17 years up to 1995 is estimated to be approximately 11.7% in the first half (1979 - 1986) and approximately 7.5% in the second half (1987 - 1995) is judged to be reasonable, and it was decided with

EGAT's consent to adopt the forecast figures of EGAT for this Report. (see Table 2-2, Fig. 2-2)

2.3 Electric Power Development Program

In order to meet the power demand anticipated based on the load forecast described above, it will be necessary to develop approximately 12,000 MW of new electric power plants by 1995. In effect, construction of power generating facilities amounting to approximately 4 times the present installed capacity will be required during the next 17 years, which corresponds to a development tempo of an annual average of approximately 700 MW.

Since it is expected that future power sources will be diversified with increases in coal-fired and lignite-fired thermal plants and nuclear plants in order to conserve on petroleum fuels, large-scale hydroelectric projects which can immediately cope with peak loads will become increasingly important. At present, the largest-scale candidate site for hydroelectric power development in Thailand is the objective of the present Study, the Upper Quae Yai project site. It is scheduled for this Project to be completed in October 1987, and the aim is to contribute to stability of supply capability as a peaking power station.

The shifts in the power source structure according to principal years are shown in Table 2-3.

2.4 Demand and Supply Balance

Demand and supply balances from 1979 to 1995 were studied predicated on the load forecast and electric power development program described above. The results are as indicated in Tables 2-4 and 2-5.

Besides the above, duration balances on representative days were studied for the years 1985, 1987, 1988, 1990, 1992 and 1995. The results are as indicated in Fig. 2-3. These typical daily duration balances were prepared with the purpose of allocation of energy supply by type of generating units and to detect the adequate capacity of Upper Quae Yai Project, and are not proper to match the actual operation of power plants in daily load curve. Main factors considered in the balances were as follows.

(1) Taking into consideration of rapidly increasing oil prices and difficulties of its acquisition in the world market, energy produced in nuclear, lignite and hydro power plants is to be fully consumed in order to save energy from conventional thermal power plants. An attention should be paid not to be down the operational efficiency of the thermal power plants.

(2) A part of the hydroelectric power plants should continuously be operated for 24 hours for the purpose of irrigation, etc.

(3) The reserve capacity is to be equivalent to a total capacity of the first and second largest units of nuclear and or thermal in the entire system.

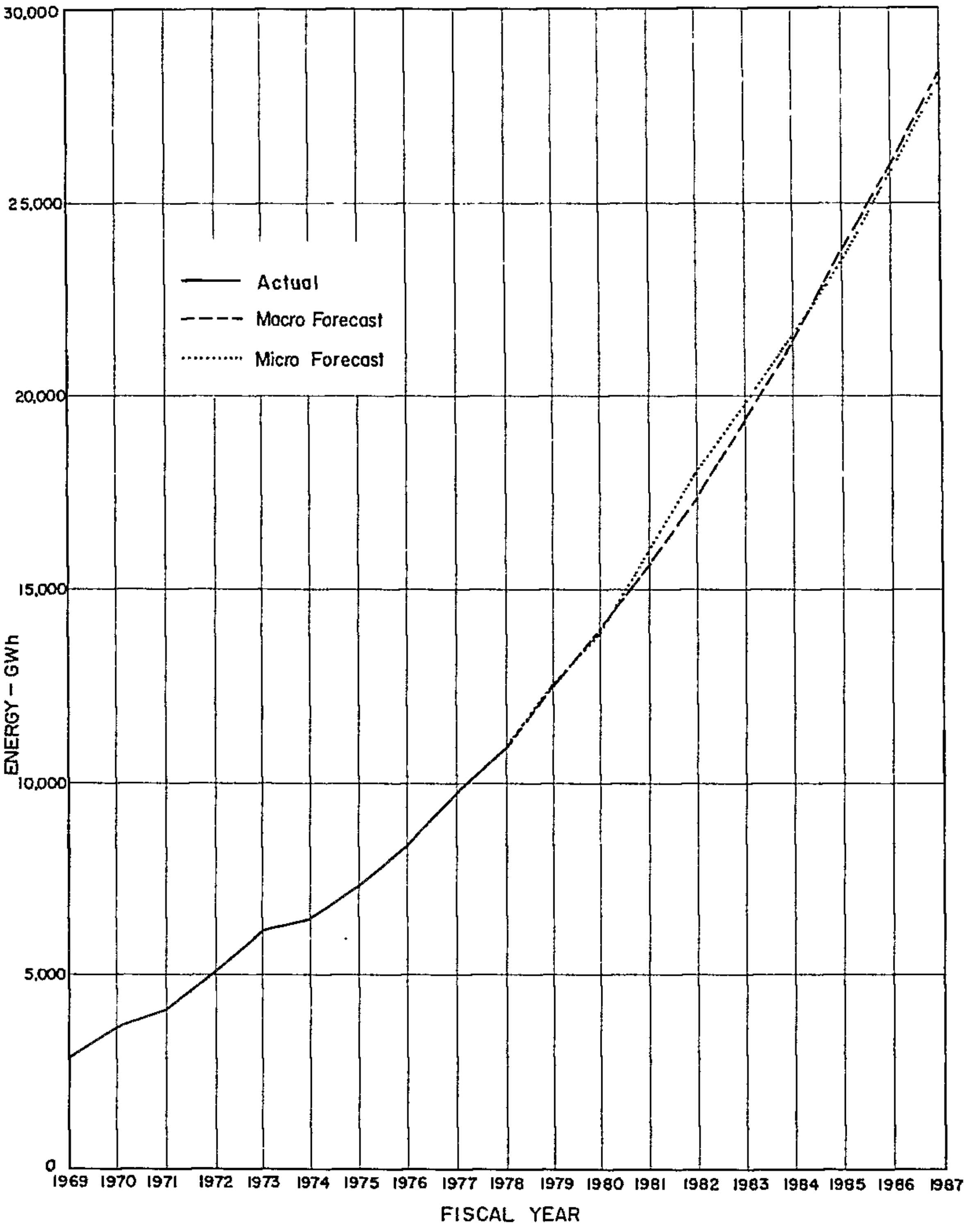
2.5 Upper Quae Yai Project

As a result of studies by year of the demand and supply balances described above and in consideration of the state of progress of the Project, it is most desirable for commissioning of the Upper Quae Yai Project to be in October 1987 as presently planned by EGAT.

The electric power demand in Thailand recently has been increasing steadily with progress made in industrialization and with rising living standards of the nation. It is anticipated that the pattern of demand will show slight peaking without abrupt changes, and from 1987, Nam Chon Power Station of the Upper Quae Yai Project will be operated continuously for about 5 hours as a peaking power station. As the scale of output, approximately 550 MW to 600 MW in terms of dependable capacity would be desirable. It is desirable for Thi Khong Power Station of the same Upper Quae Yai Project to be operated according to a pattern identical to that of Nam Chon.

The position of this Project in the long-range balance of demand and supply of electricity is as indicated in Tables 2-4 and 2-5.

Fig. 2-1 COMPARISON OF MICRO AND MACRO FORECAST



NOTE : Those figuers are given at consuming end.

Fig.2-2 RELATIONSIP OF PER CAPITA ELECTRIC ENERGY PRODUCTION TO PER CAPITA GDP BETWEEN ASIAN AND WORLD WIDE COUNTRIES (1967 — 1976)

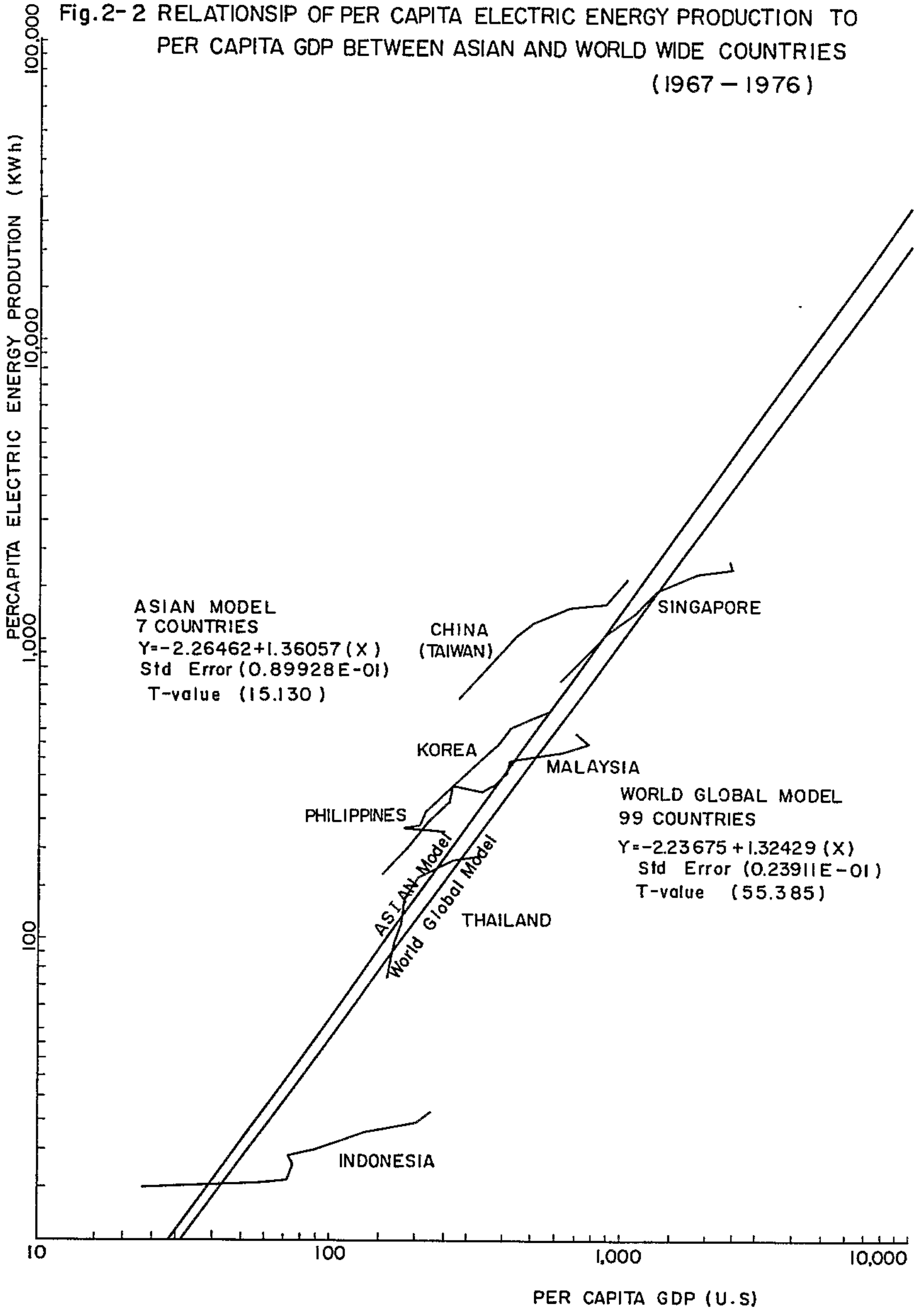


Fig. 2-3 TYPICAL DAILY DURATION CURVE

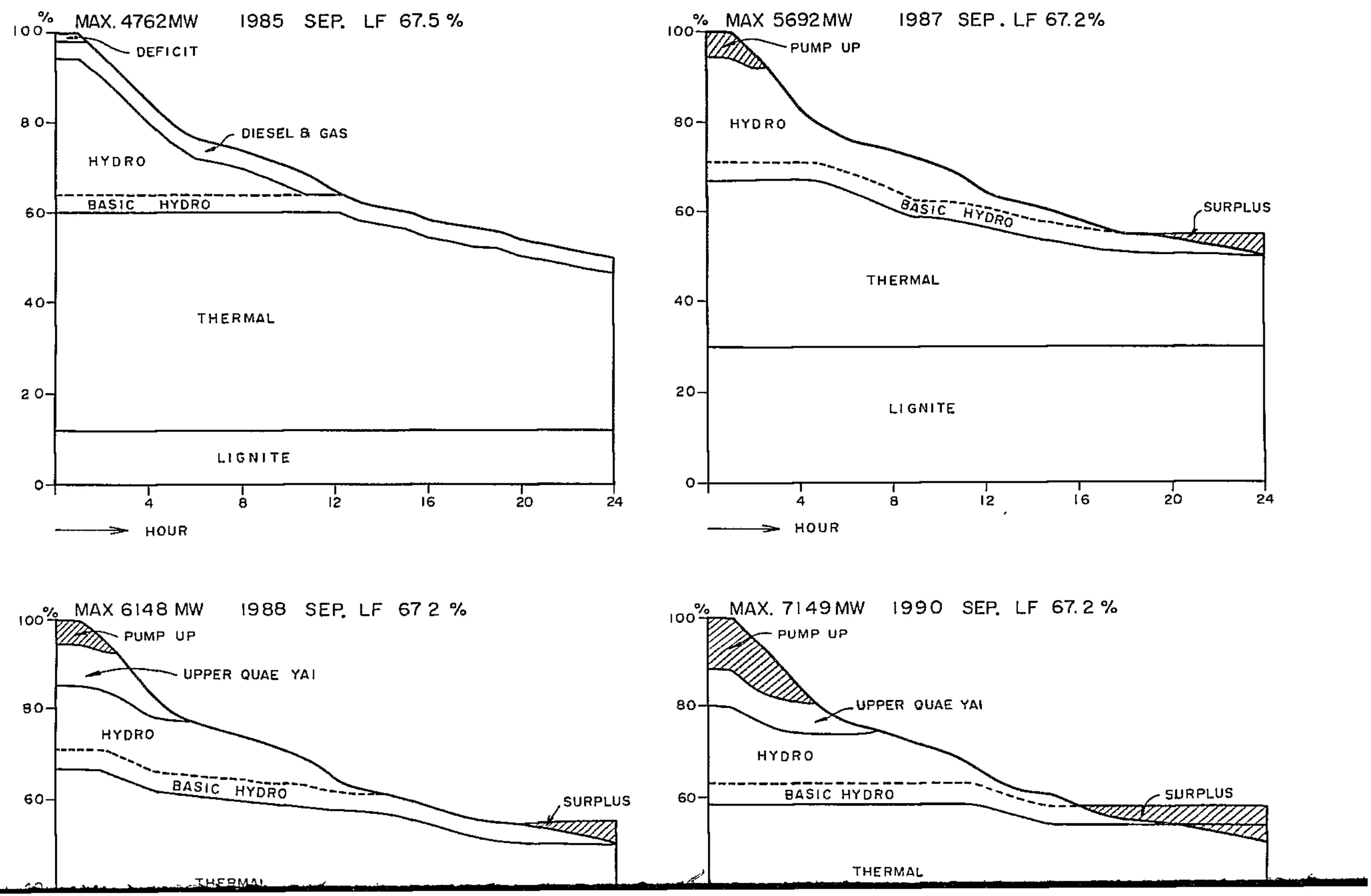


Fig. 2-3 TYPICAL DAILY DURATION CURVE

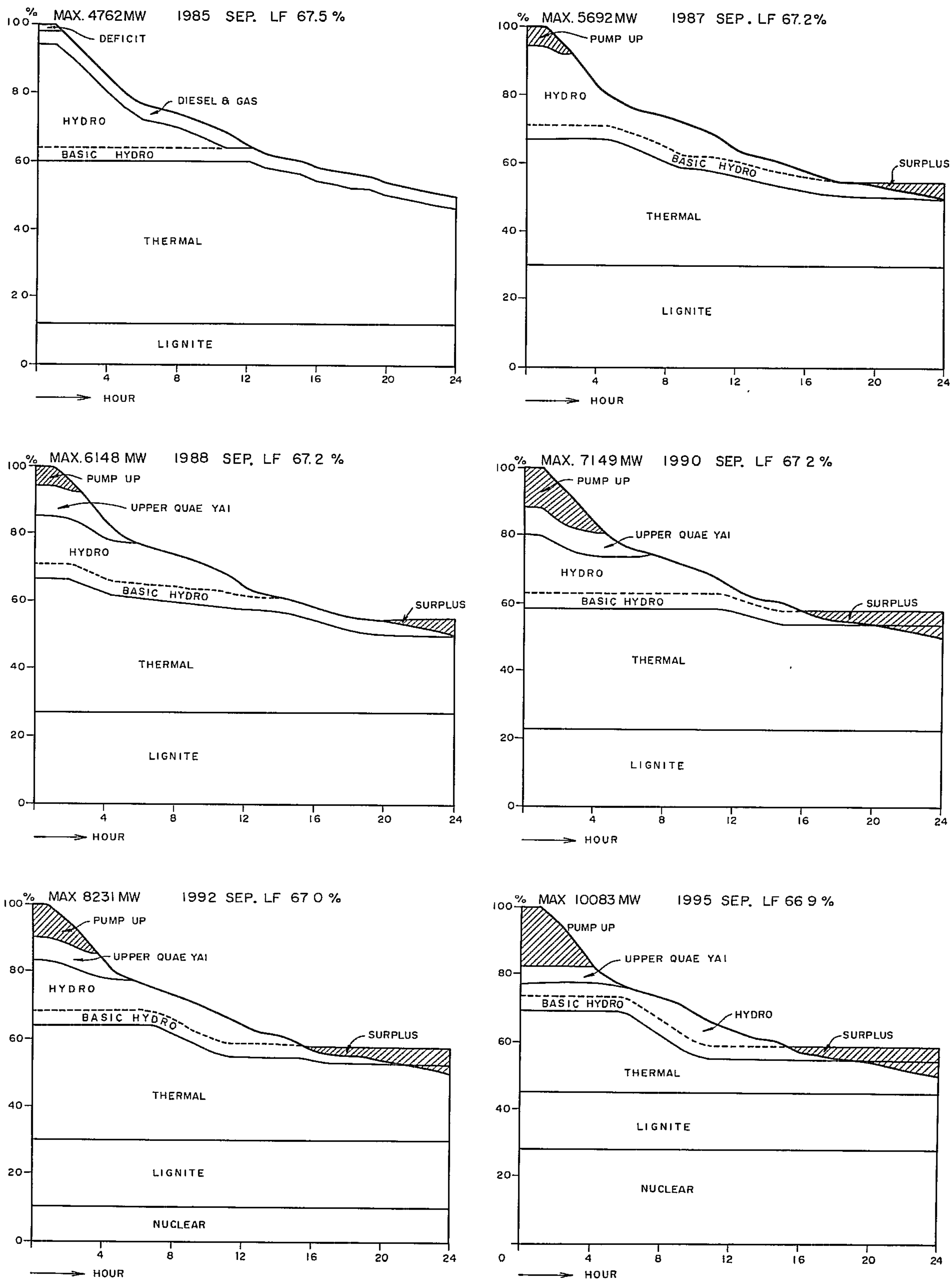
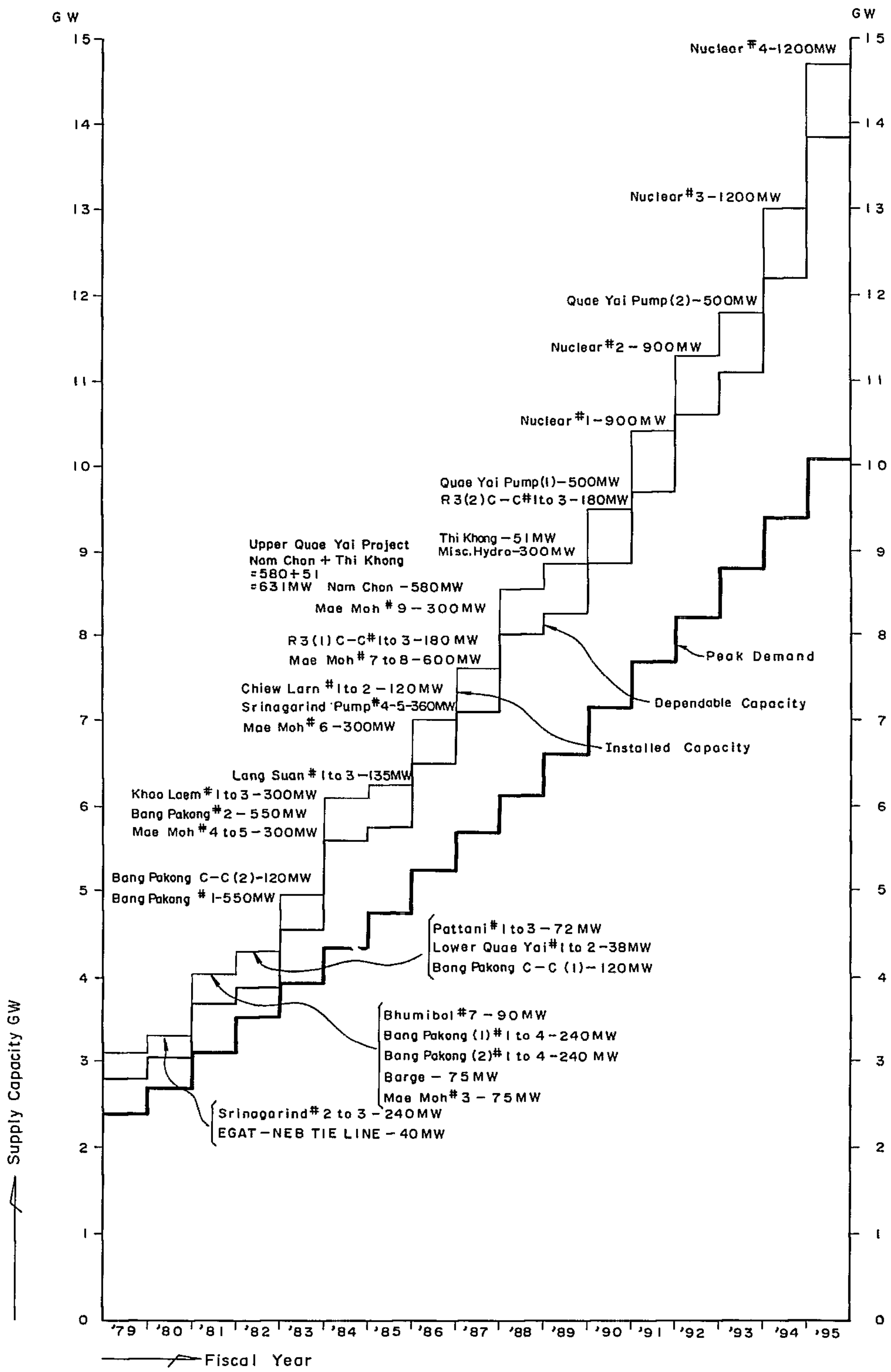
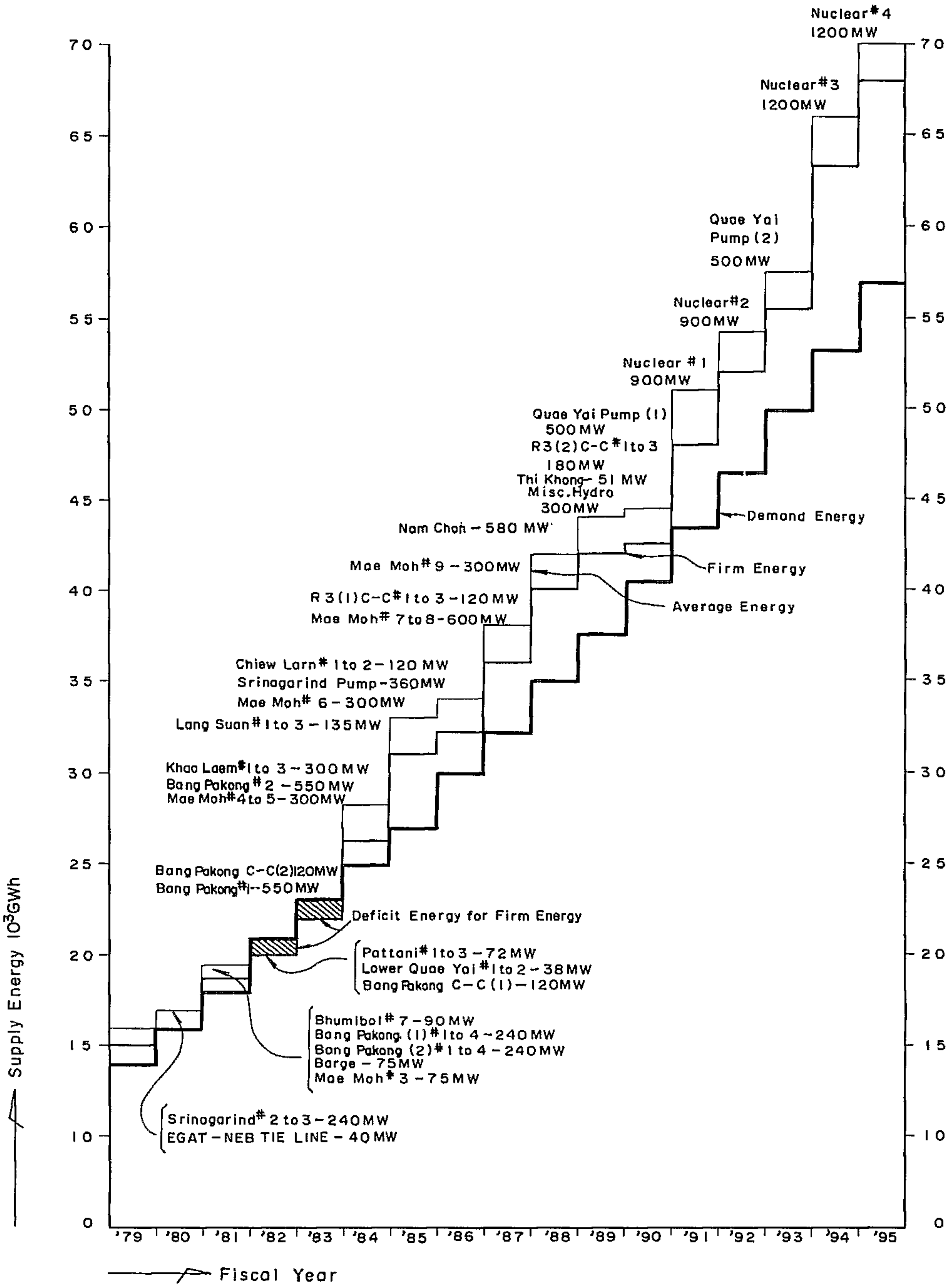


Fig. 2-4 Yearly Peak Balance in G W



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

Fig. 2-5 Yearly Energy Balance in GWh



Note : Fiscal Year '79 : '79 Oct. to '80 Sep.

: GWh = 10^9 Wh

Table 2-1 EGAT'S INSTALLED GENERATING CAPACITY AS OF DECEMBER 1978

Plant Type	No. of Units	Installed Capacity (MW)	In-Service Date (First Unit)
A. Hydroelectric Plant			
Bhumibol	6	420	May 1964
Sirikit	3	375	Jan 1974
Ubolratana	3	25	Oct 1966
Sirindhorn	2	24	Nov 1971
Chulabhorn	2	40	Nov 1972
Nam pung	2	6	Oct 1965
Kang Krachan	1	19	Aug 1974
Sub-Total	19	909	
B. Thermal Paint			
North Bangkok	3	237.5	Mar 1961
South Bangkok	5	1,300	Apr 1969
Surat Thani	1	30	Feb 1973
Mae Moh	2	150	May 1977
Krabi	3	60	Jun 1964
Sub-Total	14	1,777.5	
C. Gas Turbine Plant			
South Bangkok	3	45	Dec 1970
Nakhon Ratchasima	1	15	Jun 1968
Udon Thani	1	15	Jun 1969
Hat Yai	3	45	Aug 1971
Surat Thani	3	45	Nov 1977
Sub-Total	11	165	
D. Diesel Plant			
Mae Moh	9	9	May 1972
Chiangmai	3	3	Jul 1968
Phuket	4	10.6	Nov 1967
Nakhon si Thammarat	2	2	Jul 1973
Srinagarind	5	5	These old plants were removed from other places for temporary use according to the construction work
Bang Lang	5	5	
Sub-Total	28	34.6	
E. Nam Ngum Surplus		50	Dec. 1977
Grand Total	72	2,936 1	

Note: Data is given by EGAT.

Table 2-2 EGAT'S TOTAL GENERATION REQUIREMENTS

Year	Peak Generation		Energy Generation		Load Factor
	MW	% Increase	GWh	% Increase	%
ACTUAL					
1969	638	22.59	3,376	28.95	60.25
1970	748	17.28	4,095	21.62	62.47
1971	873	16.62	4,793	17.03	62.69
1972	1,029	17.89	5,711	19.16	63.37
1973	1,199	16.57	6,873	20.34	65.42
1974	1,256	4.75	7,259	5.61	65.96
1975	1,407	11.96	8,212	13.13	66.64
1976	1,652	17.45	9,414	14.65	65.05
1977	1,873	13.40	10,951	16.32	66.73
1978	2,110	12.63	12,372	12.98	66.94
FORECAST					
1979	2,405	13.98	14,188	13.62	67.34
1980	2,709	12.64	15,914	12.17	67.06
1981	3,151	16.32	18,355	15.34	66.50
1982	3,567	13.20	20,714	12.85	66.29
1983	3,961	11.05	22,715	9.66	65.46
1984	4,356	9.97	24,828	9.30	65.07
1985	4,762	9.32	27,025	8.85	64.78
1986	5,260	10.46	29,782	10.20	64.63
1987	5,692	8.21	32,230	8.22	64.64
1988	6,148	8.01	34,843	8.11	64.70
1989	6,634	7.91	37,620	7.97	64.74
1990	7,149	7.76	40,533	7.74	64.72
1991	7,678	7.40	43,532	7.40	64.72
1992	8,231	7.20	46,667	7.20	64.72
1993	8,807	7.00	49,933	7.00	64.72
1994	9,423	6.99	53,429	7.00	64.73
1995	10,083	7.00	57,169	7.00	64.72

NOTE : Data was given by EGAT.

Table 2-3 ELECTRIC POWER DEVELOPMENT PLAN

Unit : MW,(%)

End of F.Y.	Installed Capacity				
	Hydro	Thermal	Lignite	Nuclear	Total
1985	1954 (31)	3702 (60)	585 (9)		6241 (100)
1987	2434 (32)	3717 (49)	1485 (19)		7636 (100)
1988	3014 (35)	3717 (44)	1785 (21)		8516 (100)
1990	3865 (41)	3897 (41)	1725 (18)		9487 (100)
1992	3865 (34)	3897 (35)	1725 (15)	1800 (16)	11.287 (100)
1995	4865 (33)	3897 (27)	1725 (12)	4200 (28)	14.687 (100)

Note Thermal capacity includes gas turbine and deisel plants

Table 2-4 PEAK BALANCE

Unit: MW, %

FY	Peak Demdnd A	Total Installed Capacity							Total Dependable Capacity							Reserve Capacity B-A	Reserve Capacity Ratio B-A/A %	Ist &2nd Largest Units	Reserve Capacity Less Largest Unit
		Hydro	Thermal	Lignite	G/T	Diesel	Nuclear	Total	Hydro	Thermal	Lignite	G/T	Diesel	Nuclear	Total B				
1979	2405	1079	1567	210	165	35	0	3056	912	1489	197	148	28	0	2774	369	15.4	570	−201
1980	2709	1319	1607	210	165	35	0	3336	1151	1529	197	148	28	0	3053	344	12.7	570	−226
1981	3151	1409	2162	285	165	35	0	4056	1226	2056	268	148	28	0	3727	576	18.3	570	6
1982	3567	1519	2282	285	165	35	0	4286	1318	2170	268	148	28	0	3932	365	10.2	570	−205
1983	3961	1519	2952	285	165	35	0	4956	1318	2807	268	148	28	0	4569	608	15.3	1045	−437
1984	4356	1819	3502	585	165	35	0	6106	1554	3329	553	148	28	0	5612	1256	28.8	1045	211
1985	4762	1954	3502	585	165	35	0	6241	1689	3329	553	148	28	0	5747	985	20.7	1045	−60
1986	5260	2434	3502	885	165	35	0	7021	2159	3329	838	148	28	0	6502	1242	23.6	1045	197
1987	5692	2434	3682	1485	0	35	0	7636	2159	3500	1408	0	28	0	7095	1403	24.6	1045	358
1988	6148	3014	3682	1785	0	35	0	8516	2706	3500	1693	0	28	0	7927	1779	28.9	1045	734
1989	6634	3365	3682	1785	0	35	0	8867	3030	3500	1693	0	28	0	8251	1617	24.4	1045	582
1990	7149	3865	3862	1725	0	35	0	9487	3530	3671	1639	0	28	0	8868	1719	24.0	1045	674
1991	7678	3865	3862	1725	0	35	900	10387	3530	3671	1639	0	28	855	9723	2045	26.6	1378	667
1992	8231	3865	3862	1725	0	35	1800	11287	3530	3671	1639	0	28	1710	10578	2347	28.5	1710	637
1993	8807	4365	3862	1725	0	35	1800	11787	4030	3671	1639	0	28	1710	11078	2271	25.8	1710	561
1994	9423	4365.0	3862	1725	0	35	3000	12987	4030	3671	1639	0	28	2850	12218	2795	29.7	1995	800
1995	10083	4865	3862	1725	0	35	4200	14687	4530	3671	1639	0	28	3990	13858	3775	37.4	2280	1495

Table 2-5 ENERGY BALANCE

Unit · GWh, %

FY	Energy Demand A	Annual Load Factor %	Firm Energy					Average Energy		Reserve Energy for Firm		Reserve Energy for Average	
			Hydro	Nuclear	Thermal & Lignite	Gas & Die	Total B	Hydro	Total C	B-A	(%)	C-A	(%)
1979	14 188	67.34	2 341	0	12 519	145	15005	3 396	16 060	817	(5.8)	1 872	(13.2)
1980	15 914	67.06	3 155	0	12 660	145	15960	4 476	17281	46	(2.9)	1 367	(8.6)
1981	18 355	66.50	3 155	0	14988	145	18288	4 476	19609	-67	(-3.7)	1 254	(6.8)
1982	20 714	66.29	3 295	0	16403	145	19843	4713	21261	-871	(-4.2)	547	(2.6)
1983	22 715	65.46	3 412	0	18 336	145	21893	4856	23337	-822	(-3.6)	622	(2.7)
1984	24 828	65.07	3 679	0	22943	145	26767	5 302	28390	1939	(7.8)	3562	(14.3)
1985	27 025	64.78	4 095	0	27221	145	31461	5 955	33321	4436	(16.4)	6296	(23.3)
1986	29782	64.63	4 470	0	27385	145	32000	6 378	33908	2218	(7.4)	4126	(13.9)
1987	32 230	64.64	4 594	0	31 452	13	36059	6 516	37983	3829	(11.9)	5 753	(17.8)
1988	34 843	64.70	5 558	0	34245	0	39803	7 628	41 873	4960	(14.2)	7030	(20.2)
1989	37620	64.74	6 215	0	36051	0	42266	8 285	44336	4646	(12.3)	6716	(17.9)
1990	40533	64.72	6 215	0	36218	0	42433	8285	44503	1 900	(4.7)	3970	(9.8)
1991	43 532	64.72	6 215	6 307	36577	0	49099	8 285	51169	5 567	(12.8)	7637	(17.5)
1992	46 667	64.72	6 215	9 461	36577	0	52253	8 285	54323	5 586	(12.0)	7656	(16.4)
1993	49 933	64.72	6 215	12 614	36577	0	55406	8 285	57476	5473	(11.0)	7543	(15.1)
1994	53 429	64.73	6 215	21 024	36577	0	63816	8 285	65886	10 387	(19.4)	12 457	(23.3)
1995	57 169	64.72	6 215	25229	36577	0	68021	8 285	70091	10 852	(19.0)	12 922	(22.6)

CHAPTER 3

HYDROLOGY

CHAPTER 3 HYDROLOGY

3.1 Outline of Basin

The Quae Yai River having a length of approximately 450 km and a catchment area of approximately 14,800 km^2 rises in Umphang District, Tak Province, from a mountain range near the border with Burma. The Quae Yai River flows down southward and is merged by the Mae Chan River from the downstream of Ban Hom, and keeps flowing down southward. In the vicinity of Thi Khong, the river flows into Srinagarind Reservoir which is presently being filled up. The inflow, after regulation by Srinagarind Reservoir, is effectively utilized at Srinagarind Power Station and Lower Quae Yai Power Station.

The discharged water flows down still as the Quae Yai River, and after being merged by a tributary, the Huai Taphoen River, it is joined at Kanchanaburi by the Quae Noi River flowing in from the right bank, after that it changes its name to the Mae Klong River, and ultimately, the river flows into the Gulf of Thailand at Samuth Songkhram Province approximately 100 km southwest of Bangkok.

Most of the mountainous part of the basin of this river is covered by dense forest. The longitudinal profile of the river, as seen in Fig. 3-1, shows the river gradient to be steep at about 1:400 in the upstream part where a gorge is formed.

Near the confluence with the tributary Huai Kha Khaeng the gradient is approximately 1:700. The river gradient gradually becomes milder downstream from this confluence and becomes approximately 1:1,000 in the vicinity of Sri Sawat and approximately 1:3,000 in the vicinity of Kanchanaburi.

The mean annual rainfall in the basin is approximately 1,000 ∿ 2,000 mm, being approximately 1,400 mm in the upstream part and approximately 1,000 mm in the midstream part.

At first Vajiralongkorn Diversion Dam, located approximately 14 km south of Kanchanaburi, irrigation water for about 1 million rais of agricultural area is being used and after completion of the upstream Khao Laem Project on the Quae Noi River and the Upper Quae Yai Project, it is scheduled for the irrigated area to be expanded to about 2.4 million rais. Moreover the water utilization of Mae Klong River with the increased demand for many purposes such as domestic and metropolitan water use, river pollution and sanitary controls is under schedule.

3.2 Climate

The climate of Thailand is influenced by that of Asian Continent to which it belongs. The climate is greatly influenced by seasonal winds and a year is divided into the rainy season brought by the southwest monsoon and a dry season accompanying the northeast monsoon.

The southwest monsoon normally starts blowing gradually from the middle of May. It is a southeast wind at the beginning, but in June it completely becomes a southwest wind which continues to blow until around the middle of October. During this period, temperature and humidity are high, the weather tends to be cloudy, and heavy rainfalls occur frequently. The heaviest rainfall occurs generally in August and September.

At the beginning of November, the rainfall decreases rapidly with retreat of the southwest monsoon, and a dry season continues until April of the following year.

Annual temperature variations are affected by the monsoons and the dry or rainy season. The high-temperature period is from the final third of March to the first third of May immediately before the rainy season begins, and when the rainy season is entered, the temperature is gradually lowered. The low-temperature period is in the dry season with minimums mostly in January and February.

3.3. Rainfall

Rainfall in the Quae Yai River basin is mostly at the western slope of the mountain range lying north-south in the path of the southwest monsoon, whereas rainfall at the eastern slope of the mountain range is comparatively light.

Tropical cyclones occur frequently from August to October in the rainy season and bring rains and floods.

The annual rainfall of the Quae Yai River basin is roughly 1,000 ∿ 2,000 mm at the northwest part, approximately 1,000 mm at the Quae Yai River on the eastern side of the mountain range, and approximately 2,000 mm at the Quae Noi River on the western side.

The average annual rainfalls at the various observatory stations are as indicated in Table 3-1.

The monthly rainfalls are as indicated in Fig. 3-2, showing that approximately 85% of the annual rainfall is concentrated in the period from May to October.

3.4 Humidity

The humidity in the river basin is influenced mainly by monsoons. The humidity is approximately 70 to 85% during May to October when the southwest monsoon blows, and drops to about 50 to 70% from November to April, the period of the northeast monsoon.

3.5 Temperature

The temperature in the river basin is generally high except during the period of the northeast monsoon when cold air masses are generated above China Continent.

Mean temperatures during the rainy season which is high-temperature period are 25° to 32°C, while those in the dry season which is low-temperature period are 20° to 25°C.

3.6 Evaporation

Evaporation is generally high in March and April when humidity is low and temperature high, and low during the rainy season. The results of measurements by pan are as indicated in Table 3-2.

Evaporation from the reservoir surface replaces the evapotranspiration from vegetation prior to construction of the reservoir.

The evapotranspiration from vegetation in the reservoir area was obtained by the Blaney-Criddle Formula, as shown in Table 3-3, while the evaporation from the reservoir surface was obtained from measured values at Hard Pana Observatory Station. The net evaporation losses are estimated as the difference between the evapotranspiration from vegetation and the evaporation from the reservoir surface.

The result of computations, as shown in Table 3-4, is net evaporation loss from the reservoir of approximately 350 mm annually.

3.7 Runoff Gaging Stations and Meteorological Observatory Stations

The number of runoff gaging stations in the Quae Yai River basin consists of 9 stations on the Quae Yai including those presently closed, 3 stations on the Quae Noi River, and 2 stations on the Mae Klong River downstream of the confluence with the Quae Noi River, or a total of 14 stations.

With regard to rainfall observatory stations, there is a total of 17 stations on the Quae Yai River, the Quae Noi River, and the Mae Klong River basin, including those presently closed.

The meteorological observatory stations concerned with this Project are those of Kanchanaburi, Don Muang, and Bangkok, where temperature, humidity, atmospheric pressure, etc., have been observed over long periods.

However, at the upstream part of the Quae Yai River where this Project is located, there is only the rainfall observatory station of Umphang, while the only runoff gaging station is Nam Chon where observations were started from July 1978.

The locations of runoff gaging stations and rainfall observatory stations are indicated in Fig. 3-3. The periods of observation are shown in Tables 3-5 and 3-6. Fig. 3-4 shows relation between rainfall and runoff in the basin.

3.8 Estimation of Runoff

(1) Gaging Stations used for Runoff Estimation

In estimations of runoffs, it is desirable to use the closest runoff gaging stations to the proposed damsites for estimating reliable inflow.

The runoff gaging station usable closest to the Upper Quae Yai Project is Hard Pana, but since the period of observation is short (1970 ∿ 1978), supplementing for Hard Pana, Khao Chod (mainstream) and Kang Rieng gaging stations at relatively next to Hard Pana are selected.

(2) Runoff Calculation Period

Runoff data are available for April 1952 ∿ January 1979, and rainfall data for January 1911 ∿ December 1978. As a result of study, it was judged advisable for data after April 1978 not to be used.

In order to judge whether the 26 year period from April 1952 to March 1978 would be adequate for study of the Project, the periodic cycle of runoff is examined by the three-point moving average method and spectral analyses based on rainfall and runoff data over long periods of time.

The results of the examinations are as shown in Figs. 3-5 and 3-6, the periodic cycle of runoff being about 10 years.

Consequently, it is sufficient if runoff calculations for this Project are made for the 26 years from April 1952 to March 1978.

(3) Runoff Estimations

(a) Supplementation for Recordless Period at Hard Pana Runoff Gaging Station

The period for estimation of runoff for this Project is taken to be the 26 years from April 1952 to March 1978 in (2) above, but the runoff measurements at Hard Pana Gaging Station closest to the Project site which are reliable are for 8 years from April 1970 to March 1978. Therefore, it is decided to obtain the runoff at the Hard Pana Runoff Gaging Station site using the runoff at Khao Chod Runoff Gaging Station from April 1965 to March 1970, and the runoff at Kang Rieng Gaging Station from April 1952 to March 1965.

Since these runoff gaging stations are not located near each other, it is thought difficult to obtain reliable runoff merely using ratio of catchment area. Therefore, it is decided that runoff of the Hard Pana site can be obtained by the equation below which takes into consideration specific runoff ratio.

$$Q_H = Q_X \cdot \frac{A_H}{A_X} \cdot \alpha$$

where,

Q_H = Hard Pana site runoff obtained from X gaging station

Q_X = measured runoff data at X gaging station

A_H = Catchment area of Hard Pana Gaging Station (5,644 km^2)

A_X = catchment area of X gaging station

α = specific runoff ratio from X gaging station to Hard Pana Gaging Station

The specific runoff ratios between each gaging station are compared and studied by the annual cumulative correlation method and the seasonal correlation method taking into consideration not only runoff correlations, but also rainfall correlations.

In seasonal correlations, one year is divided into the four seasons of February ∿ April, May ∿ July, August ∿ October and November ∿ January.

The specific runoff ratios of each gaging station to Hard Pana Gaging Station are as shown in Figs. 3-7 to 3-11 and Tables 3-7 to 3-10.

As shown in Tables 3-11 to 3-13, there are hardly any difference between the annual cumulative correlation method and the seasonal correlation method with regard to the annual inflows at the Hard Pana Gaging Station site from conversions by the before-mentioned formula using these specific runoff ratios. However, there is some difference when compared by season, it is judged more desirable to estimate by the seasonal correlation method for determining monthly runoffs at the Hard Pana Gagiong Station site.

(b) Inflows at Each Damsite

The inflows at each damsite of this Project are estimated from the Hard Pana Gaging Station site runoff supplemented by the previously mentioned seasonal correlation method using the formula below.

$$Q_X = Q_H \cdot \frac{A_X}{A_H} \cdot \alpha$$

where,

X = X Damsite

H = Hard Pana site

α = specific runoff ratio for estimating inflow at X Damsite from Hard Pana Gaging Station. Adopted values are given in Table blow.

Period	Feb. ∿ Apr.	May ∿ Jul.	Aug. ∿ Oct.	Nov. ∿ Jan.
No.9A Damsite	1.07	1.08	1.05	1.08
Nam Chon Damsite	1.04	1.05	1.03	1.06
Thi Khong Damsite	1.03	1.04	1.02	1.04

The natural inflows at each damsite obtained by the above formula are indicated in Tables 3-14 through 3-16. According to these tables the 26 year daily average natural inflows at each damsite are respectively as shown below.

No.9A site	89 m^3/sec
Nam Chon site	94 "
Thi Khong site	98 "

3.9 Sedimentation

(1) Outline

The feature of Nam Chon Reservoir is that, with the exception of the tributary Mae Chan River basin, all of it comprises a steeply-sloped stage of youth to stage of mature topography. Consequently, the river beds of the mainstream and each tributary have steep gradients. The Mae Chan River basin presents a gentle hilly topography in accordance with its geological conditions.

The geology of the basin, similarly to topography, can be divided to the mainstream area and the Mae Chan River area. The area along the mainstream making up the greater part of the reservoir is generally covered by forests and basement rocks consist of calcareous sandstone, dolomite and limestone exposed at both banks, and so-called river deposits and slope wash are scarce. The area along the Mae Chan River consists of Tertiary deposits such as sand, gravel and silt.

(2) Estimated Sedimentation

The sedimentation at the Nam Chon site was estimated basing on correlation between monthly total runoffs and monthly total suspended load quantities measured at the downstream sites of Khao Chod (1969 ∿ 1971) and Hard Pana (1973 ∿ 1977).

The inflows of the 26 year period from 1952 to 1977 were substituted in the logarithmic correlation to obtain the annual average, and the upper limit value of the specific suspended load was calculated as 209.2 $m^3/km^2/yr$.

With bed load 20% of suspended load, the total load is to be 251 $m^3/km^2/yr$.

Considering the service life of Nam Chon Reservoir as 100 years, the total sedimentation is estimated to be 123 x $10^6 m^3$. This value comes to only 6.7% of inactive storage capacity 1,850 x $10^6 m^3$.

3.10 Flood Analysis

Taking into consideration the socio-economic importance of Nam Chon Power Station, it is thought important for PMF (Probable Maximum Flood) to be the objective in design of the dam and spillway.

However, since the unit hydrograph was prepared based on limited hydrological and meteorological data, whether the design PMF obtained thereby would be appropriate was confirmed through an envelope putting together past design flood discharges used in Thailand.

(1) Rainfall and Runoff Data for Hard Pana Site

The PMP (Probable Maximum Precipitation) in the Quae Yai basin up to 1969 has already been compiled in "Supplementary Report for Quae Yai No.1 Project, Vol. 1, Feb., 1973."

Therefore, the storms since 1970 are to be examined to prepare a unit hydrograph for the Nam Chon site. The PMF for the Nam Chon site is then to be determined using this unit hydrograph and the PMP selected from comparisons of past storms.

With regard to runoff data, the daily runoff data at Hard Pana Gaging Station from April 1970 to November 1978 were used.

The average daily precipitation over the catchment area at the Hard Pana site was obtained by the Thiessen Method from daily precipitation data at the Umphang and the Hard Pana sites.

However, for the lack of precipitation data at Umphang for 1974 and 1975, the average precipitation for these two years was not considered.

(2) Preparation of Unit Hydrographs for Hard Pana and Nam Chon Sites

Daily runoff and average precipitation data over the catchment area at the Hard Pana site (hydrographs) were examined, and 9 storms, having relatively isolated peaks and distinct relations between precipitation and runoff, were selected and used as data for preparing a unit hydrograph.

Firstly, the direct runoffs and base flows were separated based on these hydrographs, and runoff coefficients were obtained from the ratios of these direct runoffs to the corresponding rainfalls. Effective rainfalls were obtained by the constant ratio method using these runoff coefficients.

The nine correlations determined by the above for the direct runoffs and effective rainfalls, in effect, the data of direct runoff-effective rainfall of the 9 storms, were processed statistically (linear analysis method) to obtain a comprehensive unit hydrograph, and upon some modification, the unit hydrograph for the Hard Pana site was determined based on the conditions below.

Unit rainfall = 10 mm/day

Time to peak = 36 hrs

Time base = 192 hrs = 8 days

The unit hydrograph for the Nam Chon site located approximately 40 km further upstream from the Hard Pana site is obtained using the conception of Snyder's "Synthetic Unit Hydrograph" as shown in Fig. 3-12.

(3) PMP at Kang Rieng (Srinagarind) Site

(a) Maximum Moisture Inflow Index

The annual maximum 12-hour persisting dew points at Kanchanaburi from 1970 to 1977 are converted to values at the 1,000 mb plane and plotted, and further, taking into account the seasonal variations (July ∿ November) in mean dew point since 1951, the envelope for the maximum 12-hour persisting dew point is drawn.

Based on these dew point values, the envelope for precipitable water corresponding to the calculation tables prepared by the U.S. Weather Bureau is obtained.

When the envelope of upper wind speed at Bangkok and the envelope of the abovementioned precipitable water are multiplied together, the maximum moisture inflow index will be approximately 1,100 (mm-m/sec).

However, in calculation of precipitable water in the previously-mentioned Supplementary Report, the 12-hour persisting temperature is employed instead of the 12-hour persisting dew point.

Therefore, upon comparisons of the cases of employing dew point and of employing temperature, this Report adopts the following value given in the Supplementary Report considering conformity.

Max. Moisture Inflow Index = 1,400 (mm-m/sec)

Further, as described in the following section, there are no effects on the design storm regardless of whether temperature or dew point is used.

(b) Moisture Inflow Index and PMP during Major Storm

Moisture inflow indices were obtained for the 6 major storms out of the 9 storms used in preparation of unit hydrograph.

The data used in the calculations were the 12-hour persisting temperatures at Kanchanaburi to obtain precipitable water. However, the temperatures used were those of days of greatest rainfalls in the respective storms.

The moisture inflow index in each of the storms is obtained by multiplication by the wind speeds corresponding to the above-mentioned precipitable water quantities.

Next, the maximizing factor (MF) was obtained by the equation defined below, and the MF and the total rainfall were multiplied together to obtain the required PMP.

$$MF = \frac{\text{Maximum Moisture Inflow Index}}{\text{Moisture Inflow Index during Storm}}$$

Recorded Storm and PMP

Storm & Flood	Total Rainfall (mm)	Peak Discharge (m^3/sec)	MF	PMP (mm)
Jul. 23 ∿ Jul. 29, 1971	66.5	737	1.4	90
Jul. 10 ∿ Jul. 17, 1972	73.3	558	1.1	80
Sep. 6 ∿ Sep. 9, 1972	69.4	881	1.6	110
Sep. 18 ∿ Sep. 21, 1972	60.1	916	1.5	90
Aug. 17 ∿ Sep. 3, 1973	143.2	702	1.2	170
Aug. 6 ∿ Aug. 15, 1978	126.2	1,270	1.3	160

In contrast with the above, the storm from September 29 to October 10, 1963 was of PMP = 350 mm, and considered comprehensively, it was found to be the storm which should be considered for design flood of this Project.

(4) PMP in Hard Pana Catchment Area (Including Nam Chon Site)

Depth-area-duration analysis was made to obtain the PMP to be considered for design of the Nam Chon Project.

Selecting the 6 storms since 1959 for which hydrologic data of Hard Pana and Kang Rieng Gaging Station were relatively well-kept, the average precipitation over the catchment areas of the two sites were studied by cumulative PMP considering the durations and respective MFs.

As a result, for the design objective PMP for the Nam Chon site belonging to the Hard Pana catchment area, PMP corresponding to the storm of September 29 ∿ October 10, 1963 mentioned in the preceding section was adopted, and it was found that for conversion from the Kang Rieng site a surcharge rate of 15% would be appropriate.

(5) Determination of PMF at Nam Chon Damsite

The PMP for the Nam Chon dmasite was determined as follows taking into account the results of depth-area-duration analysis and the antecedents of the Srinagarind Project.

° The storm of September 29 ∿ October 10, 1963 is selected as the objective storm. The duration of the storm is taken to be 5 days.

° A surcharge rate of 15% is considered in coverting the above storm to the Nam Chon site.

° Losses of 5 mm/day are considered for the entire period of the storm and the remaining 80% is considered as effective rainfall.

° The base flow is taken to be 300 m^3/sec.

The above may be tabulated in the form indicated below.

PMP for Nam Chon Project

Day ①	PMP (Kang Rieng) ②	PMP (Nam Chon) ③=②x 1.15	Loss ④=③- 5.0	Effective PMP ⑤=④x 0.8
1	56.0 mm	64.4 mm	59.4 mm	47.52 mm
2	191.8	220.6	215.6	172.48
3	25.9	29.8	24.8	19.84
4	42.8	49.2	44.2	35.36
5	33.5	38.5	33.5	26.80
Total	350.0 mm	402.5 mm		302.00 mm

The flood discharge was calculated combining the distribution of effective rainfall as shown above and the unit hydrograph for the Nam Chon site shown in Fig. 3-12.

As a result, PMF will be the following:

Peak flood discharge 5,900 m^3/sec

Total flood volume 1,800 x $10^6 m^3$

With this taken as the design flood discharge, the relations with the flood discharges of existing and planned dams in Thailand are clarified as shown in Fig. 3-13. Creager's curve has also been added to this figure. It may be seen from this figure also that the above design PMF will be reasonable as the design flood for the Nam Chon Project.

As for the flood discharge through spillway, see the section on the spillway Chapter 7, (2).

(6) Design Flood Discharge for Thi Khong Project

The design flood discharge for the Thi Khong damsite located approximately 8 km downstream of Nam Chon Power Station will be 2,800 m^3/sec considering the converted PMF of 300 m^3/sec of the remaining catchment area of 246 km^2 in addition to the spill discharge of 2,500 m^3/sec from Nam Chon Reservoir.

3.11 Flood Forecasting System

Two large reservoirs viz. Nam Chon Reservoir (effective storage capacity 4,100 x $10^6 m^3$) and Srinagarind Reservoir (effective storage capacity 7,470 x $10^6 m^3$) will be situated in the upstream of Vajiralongkorn Diversion Dam on the Quae Yai River after completion of the Upper Quae Yai Project.

Khao Laem Reservoir (effective storage capacity 4,800 x $10^6 m^3$) is now under construction on the Quae Noi River joins from the right bank in the near upstream of Vajiralongkorn Diversion Dam.

A various type of dams and power stations including pumped storage power station is also under planning on the Quae Yai River.

On the other hand, "Report on Technical Study for Mae Klong River Basin Flood Forecasting System, Thailand, March, 1978 - JICA -" has stated about the flood forecasting and warning system on the Mae Klong River basin.

But, as discharge through Srinagarind Power Station on the Quae Yai and natural runoff before starting the construction of the Khao Laem Project on the Quae Noi was taken into account, the above Report is to be reviewed considering the new-brought conditions.

(1) Retention Water Level of Srinagarind Reservoir

At present, water level of Srinagarind Reservoir is to be restricted to EL. 178.50 m in October which is expected to have the heaviest storm.

This was derived from the fact that the water level will rise at EL. 182.40 m under spilling maximum 2,420 m^3/sec discharge through the spillway during the design PMF (Peak flood discharge = 7,100 m^3/sec, Total flood volume = 3,900 x $10^6 m^3$) flowing into, and the level be confirmed below the abnormal high water level 182.50 m.

In the meantime, after completion of Nam Chon Reservoir, the design PMF for Nam Chon Dam (Peak flood discharge = 5,900 m^3/sec, Total flood volume = 1,800 x $10^6 m^3$) as explained in previous section and Fig. 7-4 in Chapter 7 will be spilled down into Srinagarind Reservoir after peak cut-off through spillway.

Studies were made concerning the possibility of mitigation of the above-mentioned limited water level of Srinagarind Reservoir taking the spill discharge and the flood inflow over the residual catchment area into consideration.

In this case, operation rule of gates is defined as follows:

- When the magnitude of flood inflow is less than the capacity of the spillway, the gates are partly opened such that the reservoir surface elevation is not changed.
- After the inflow is equal to the capacity of the spillway, the gates is fully opened untill the reservoir surface elevation comes back down at the normal high water level.

In conclusion, it could be found that only the time to peak of Srinagarind Reservoir water level is delayed, and that the mitigation of the limited water level of the Reservoir is difficult even after completion of the Upper Quae Yai Project.

Early employment of the flood forecasting system to Nam Chon and Srinagarind Reservoirs will be desirable in order to establish the comprehensive reservoirs operation control including the method of water level down according to the prediction of the flood attack in addition to the safety of dams.

(2) Flood Forecasting System

A flood forecasting system is mainly composed of

- Rainfall observation stations (Robot rain gage),
- Water level - runoff gaging stations (Telemetering system),
- Meteorological observation stations,
- A master control organization for integrated commands for data collection and analysis, gate operation, information transmission, etc.,

- A communication network making possible stable data transmission from individual stations to the master control organization at all times, and also transmission of commands without delay,

And for accurate and rapid predictions to be made is desirable for all of the above to be evenly provided.

In this study, a flood forecasting system is focused only to the Quae Yai River Basin over the whole Mae Klong River Basin.

An observation system should be introduced for the first stage as tabulated below.

	Srinagarind Basin (CA = 5,972 km^2)	Nam Chon Basin (CA = 4,908 km^2)	Remark
Rainfall Observation Station	Upstream of Huai Kha Kaeng (1 Stn.) Vicinity of back-water end of Srinagarind Reservoir (2 Stns.)	Upstream of Nam Mae Klong (1 Stn.) Upstream of Nam Mae Chan (1 Stn.)	Solar cell for robot rain gage can be in service during rainy season.
Water Level Observation Station	Vicinity of back-water end of Srinagarind Reservoir (2 Stns.)	Vicinity of back-water end of Nam Chon Reservoir (2 Stns.)	

The above arrangement is based on the condition that a rainfall, and a water level stations should be provided at least in each block over the 4 blocks covering the whole catchment area.

However, it is a matter of course that each power station has its function.

An effective reservoirs operation control including flood control to the downstream can be expected after grasping the correlation of inflow into between Nam Chon Reservoir and Srinagarind Reservoir and the meteorological conditions.

Fig. 3-1 Profile of the Quae Yai River

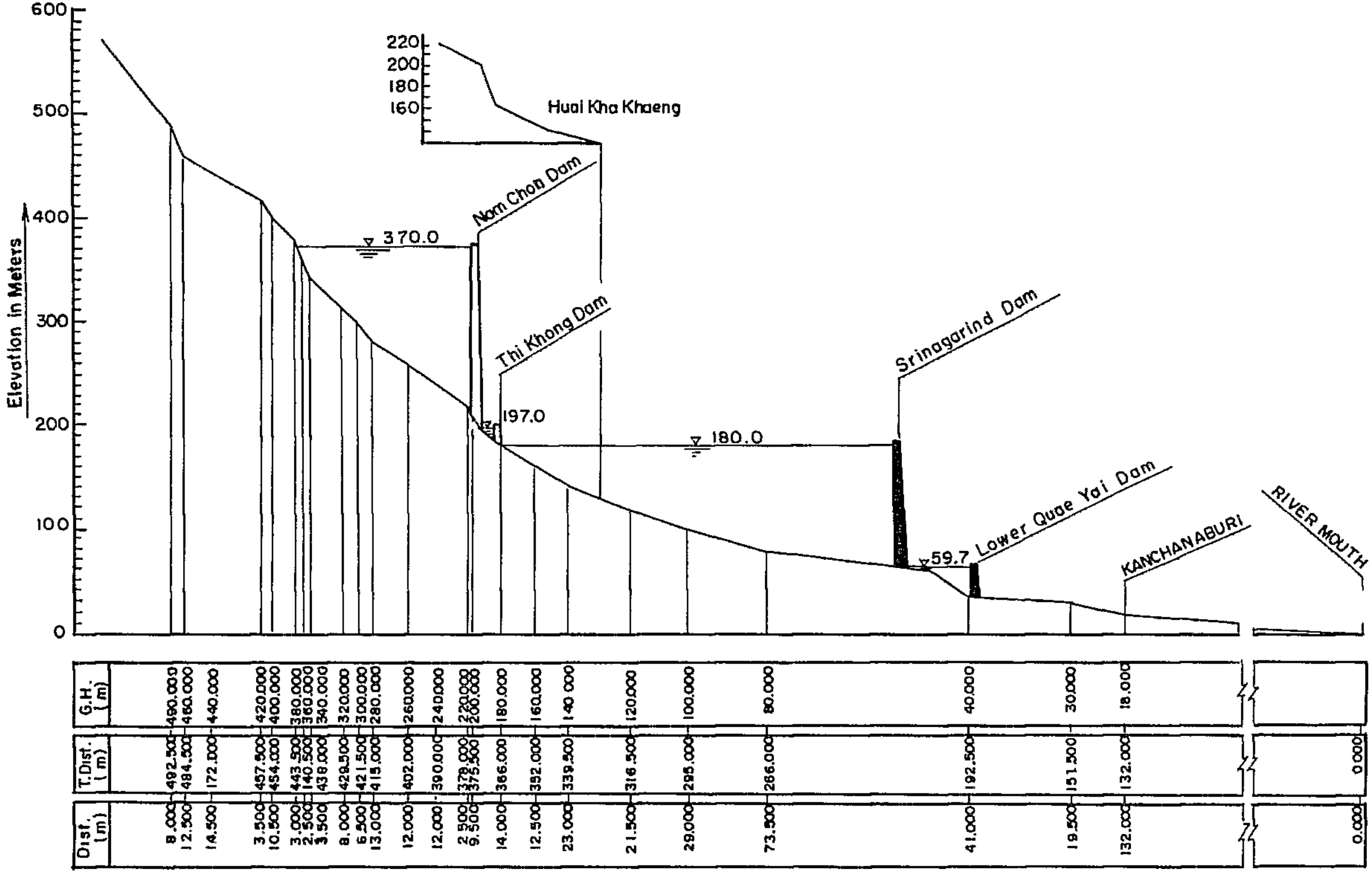


Fig3-2 Monthly Average Rainfall on the Quaeyai River Basin (1952~78)

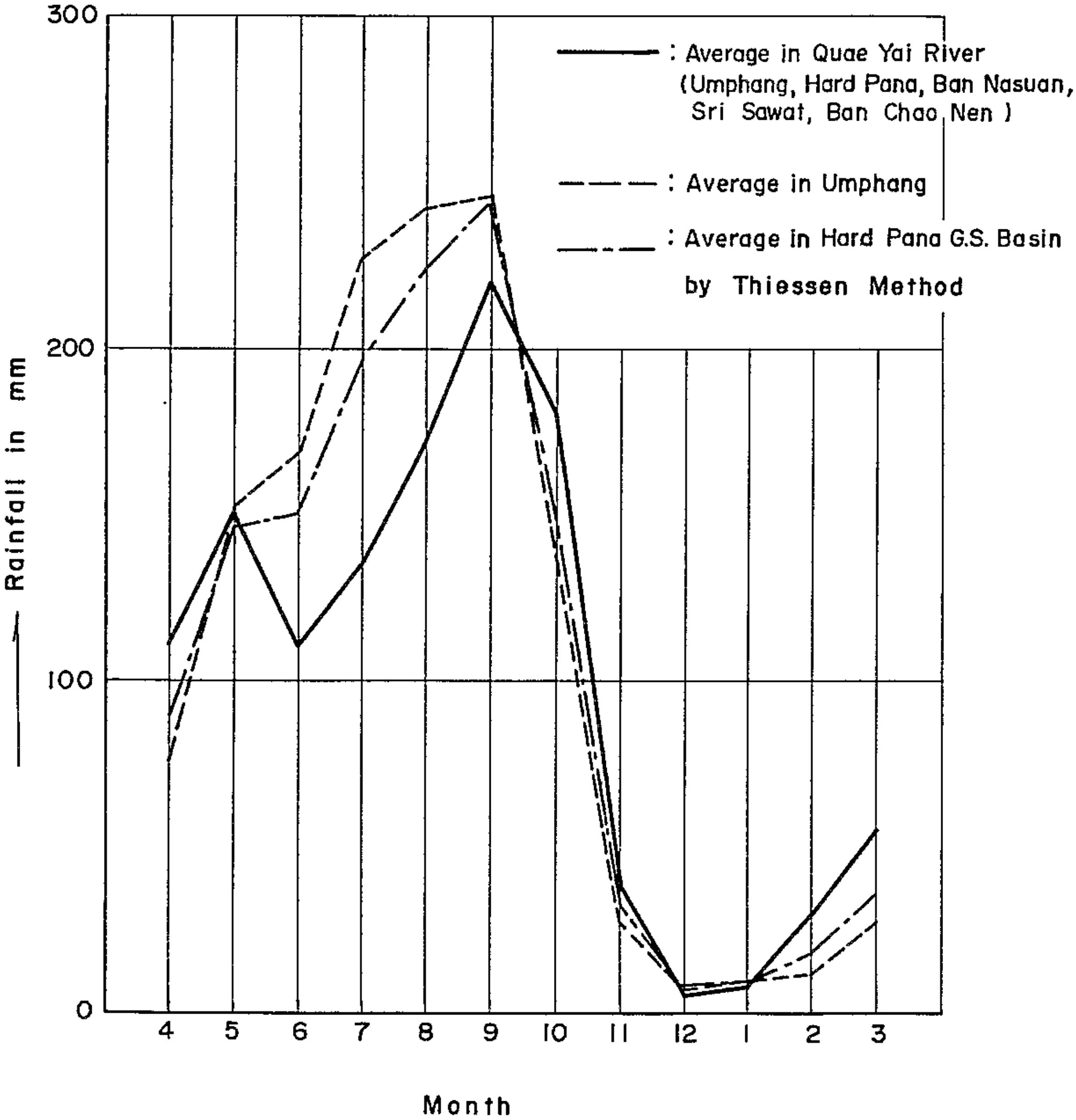
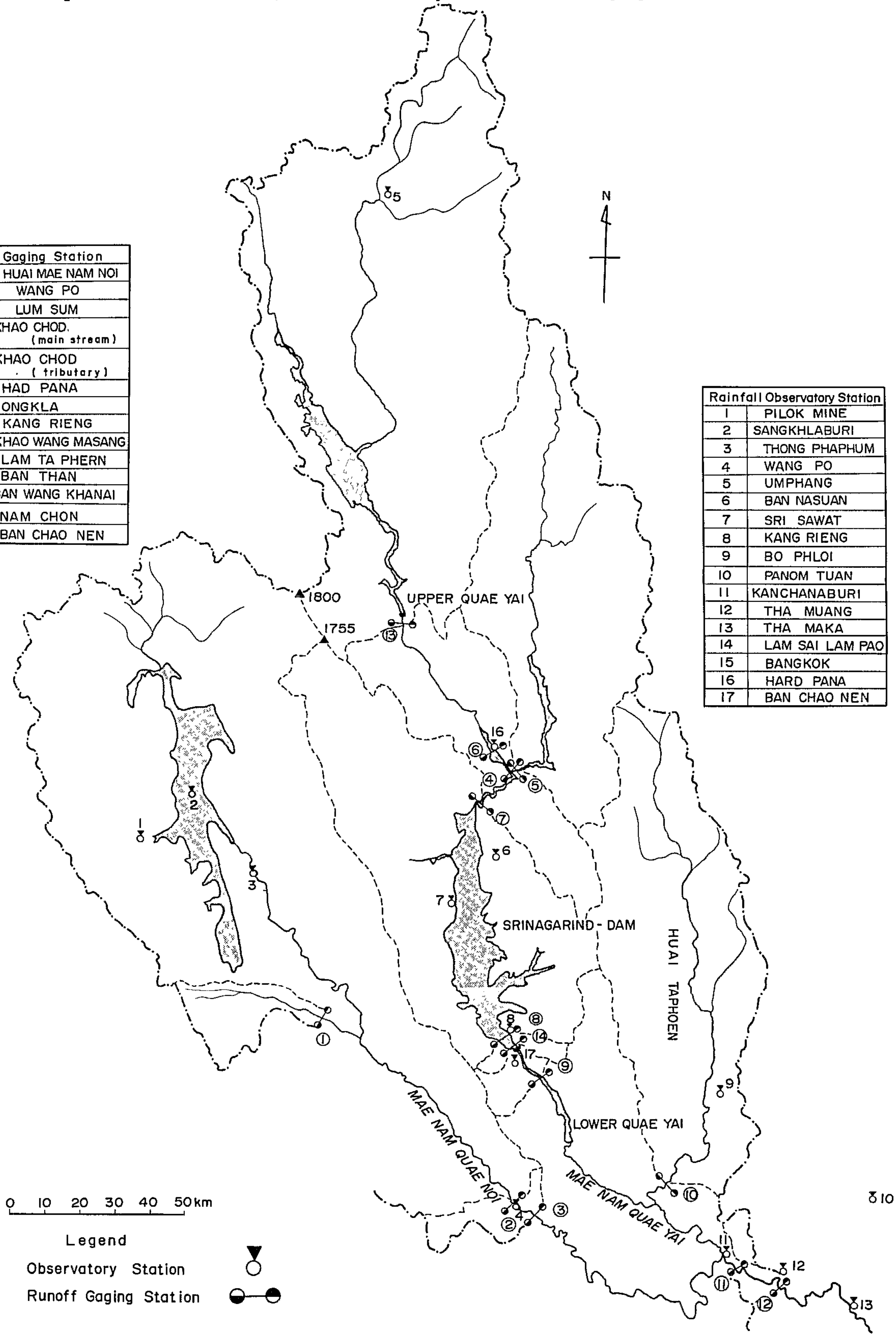


Fig. 3-3 Location Map of Observatory Stations and Gaging Stations



Runoff Gaging Station	
①	HUAI MAE NAM NOI
②	WANG PO
③	LUM SUM
④	KHAO CHOD. (main stream)
⑤	KHAO CHOD . (tributary)
⑥	HAD PANA
⑦	ONGKLA
⑧	KANG RIENG
⑨	KHAO WANG MASANG
⑩	LAM TA PHERN
⑪	BAN THAN
⑫	BAN WANG KHANAI
⑬	NAM CHON
⑭	BAN CHAO NEN

Rainfall Observatory Station	
1	PILOK MINE
2	SANGKHLABURI
3	THONG PHAPHUM
4	WANG PO
5	UMPHANG
6	BAN NASUAN
7	SRI SAWAT
8	KANG RIENG
9	BO PHLOI
10	PANOM TUAN
11	KANCHANABURI
12	THA MUANG
13	THA MAKA
14	LAM SAI LAM PAO
15	BANGKOK
16	HARD PANA
17	BAN CHAO NEN

Fig. 3-4 Runoff and Rainfall

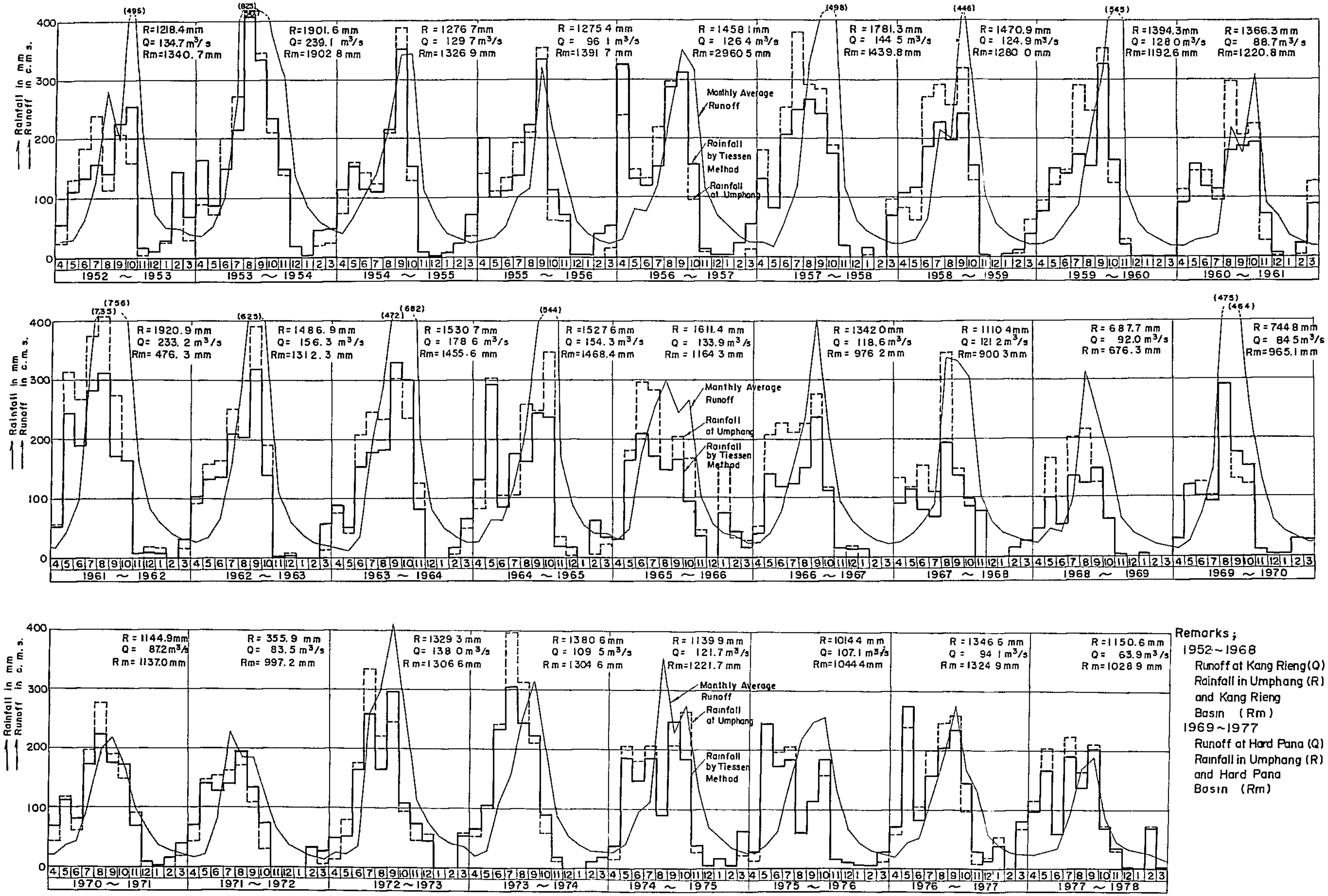
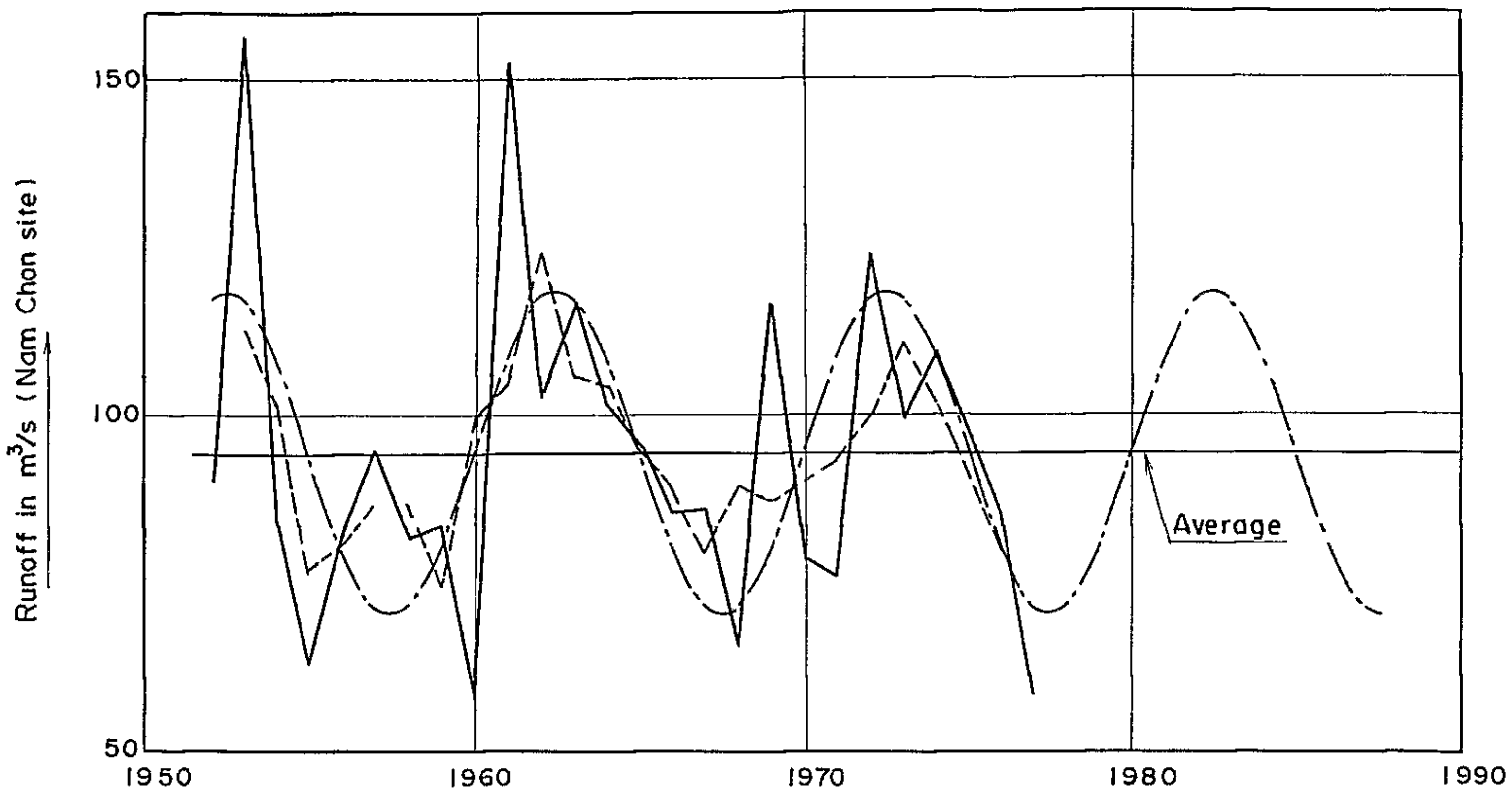


Fig. 3-5 Cycle of Runoff and Rainfall (3 Points Moving Average Method)



Note :
Annual
3 Points Moving Ave.
Prominent Harmonic Wave

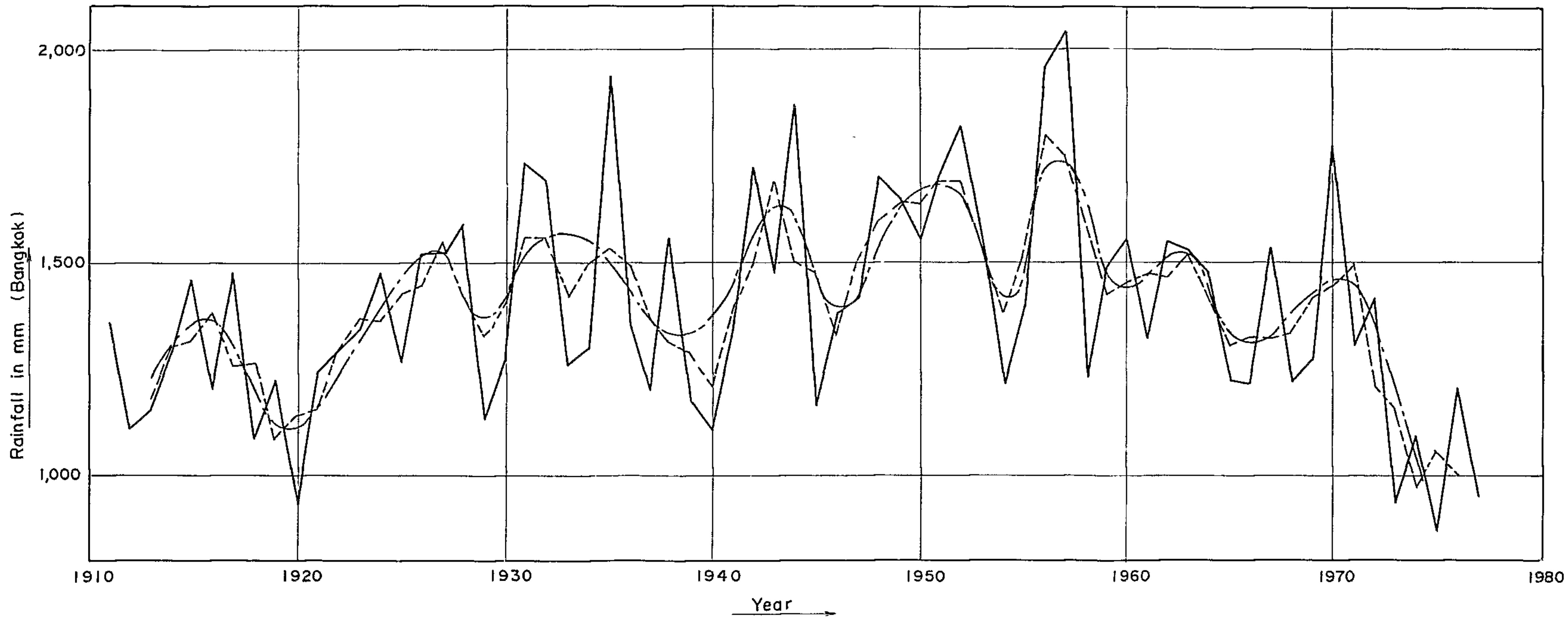
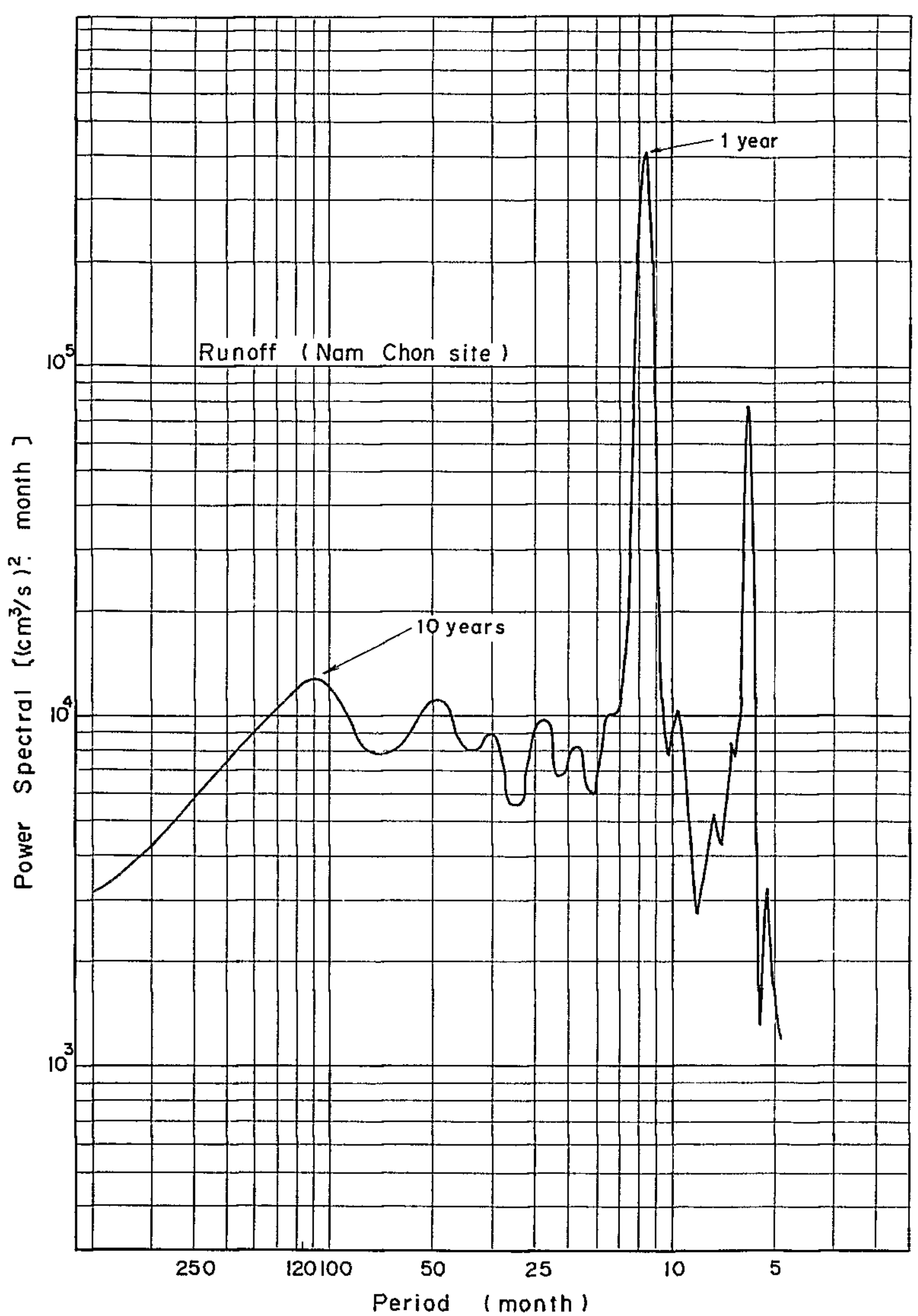


Fig. 3-6 Cycle of Runoff and Rainfall (Spectral Analysis)



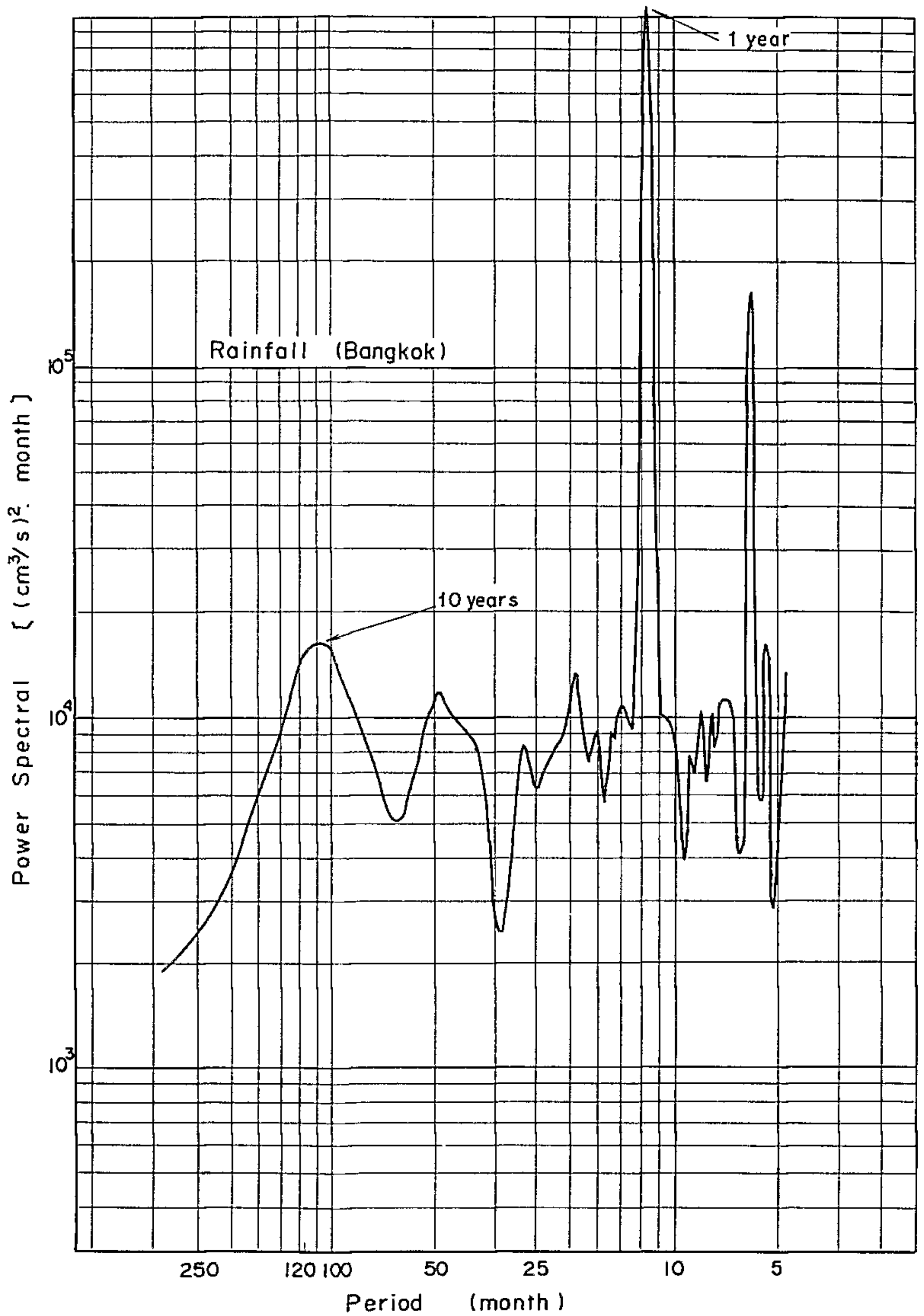


Fig 3—7 Ratio of Annual Rainfall and Specific Runoff of Each Site to Hard Pana G.S.

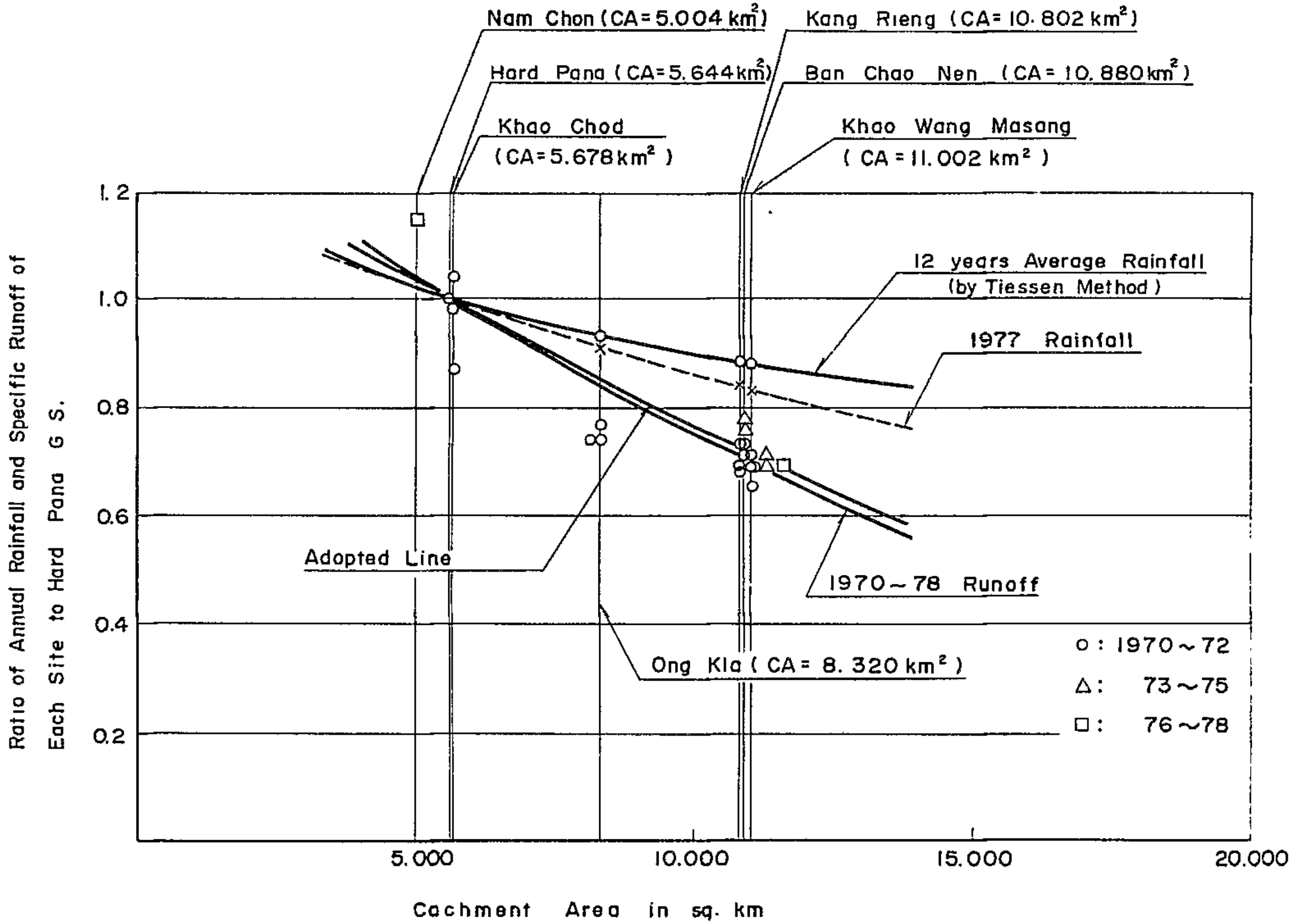


Fig 3-8 Ratio of Specific Runoff and Rainfall of Each Site to Hard Pana G.S. (Feb.~Apr.)

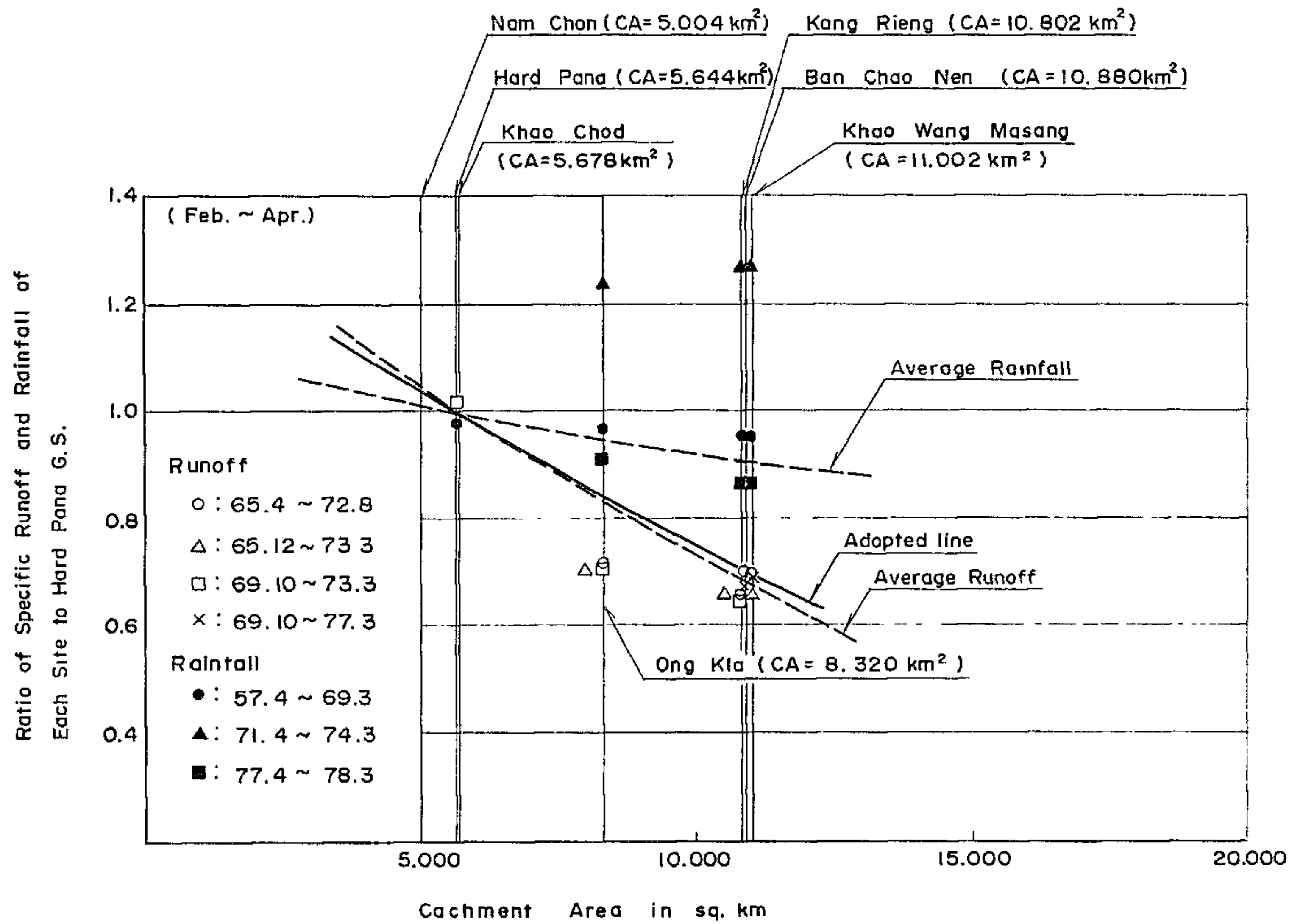


Fig 3-9 Ratio of Specific Runoff and Rainfall of Each Site to Hard Pana G.S. (May~Jul.)

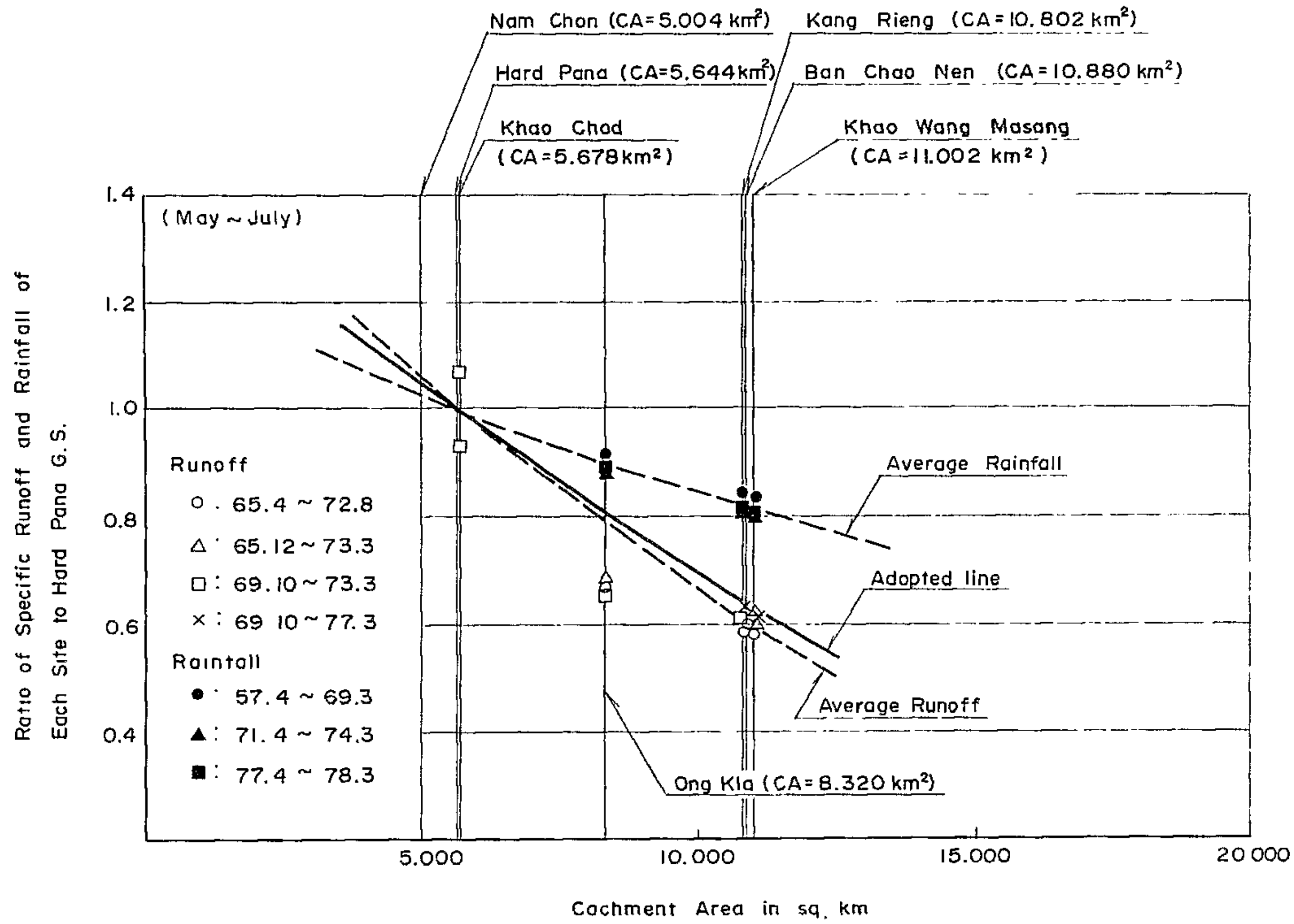


Fig 3-10 Ratio of Specific Runoff and Rainfall of Each Site to Hard Pana G.S. (Aug.~Oct.)

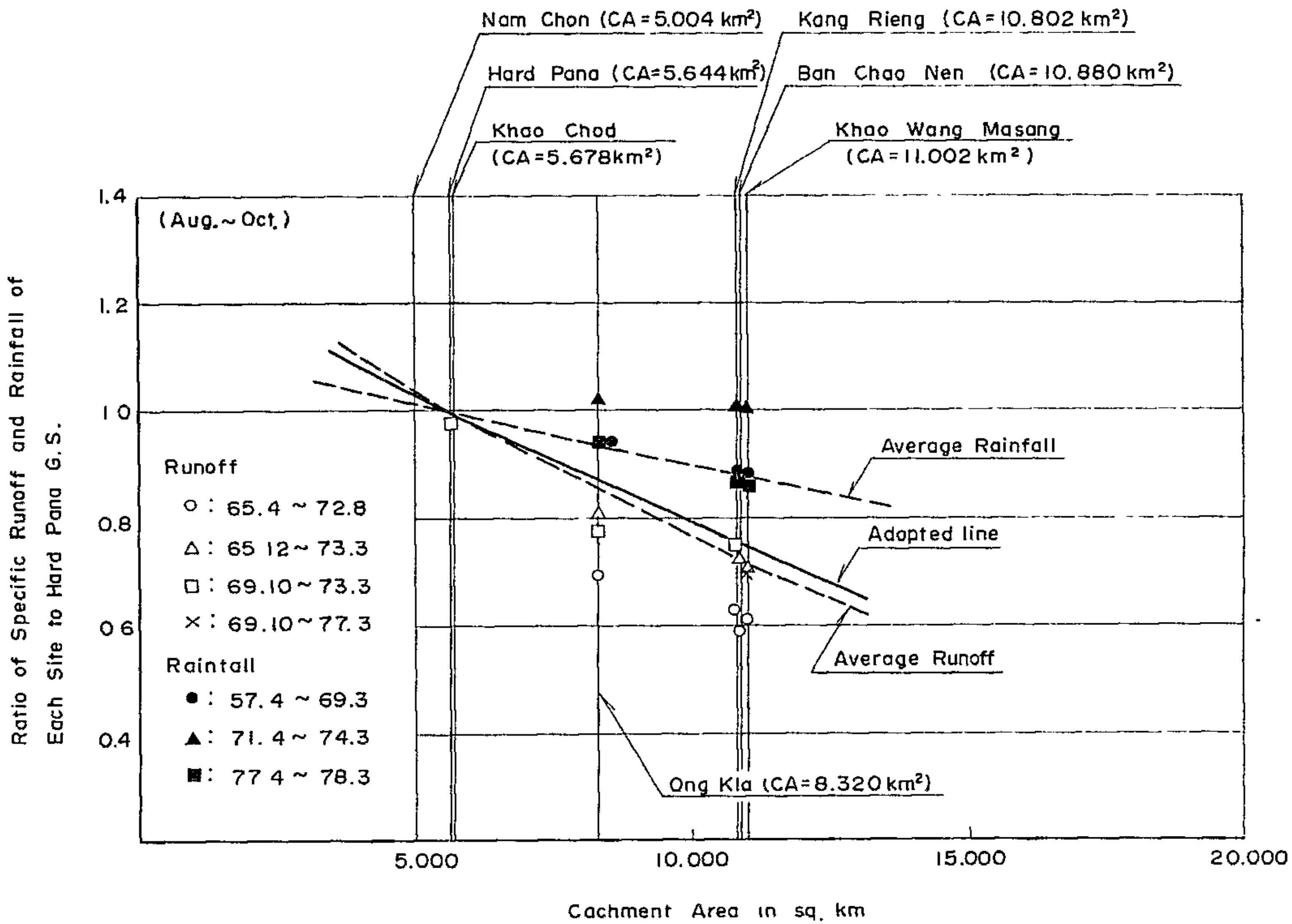


Fig 3-11 Ratio of Specific Runoff and Rainfall of Each Site to Hard Pana G.S. (Nov.~Jan.)

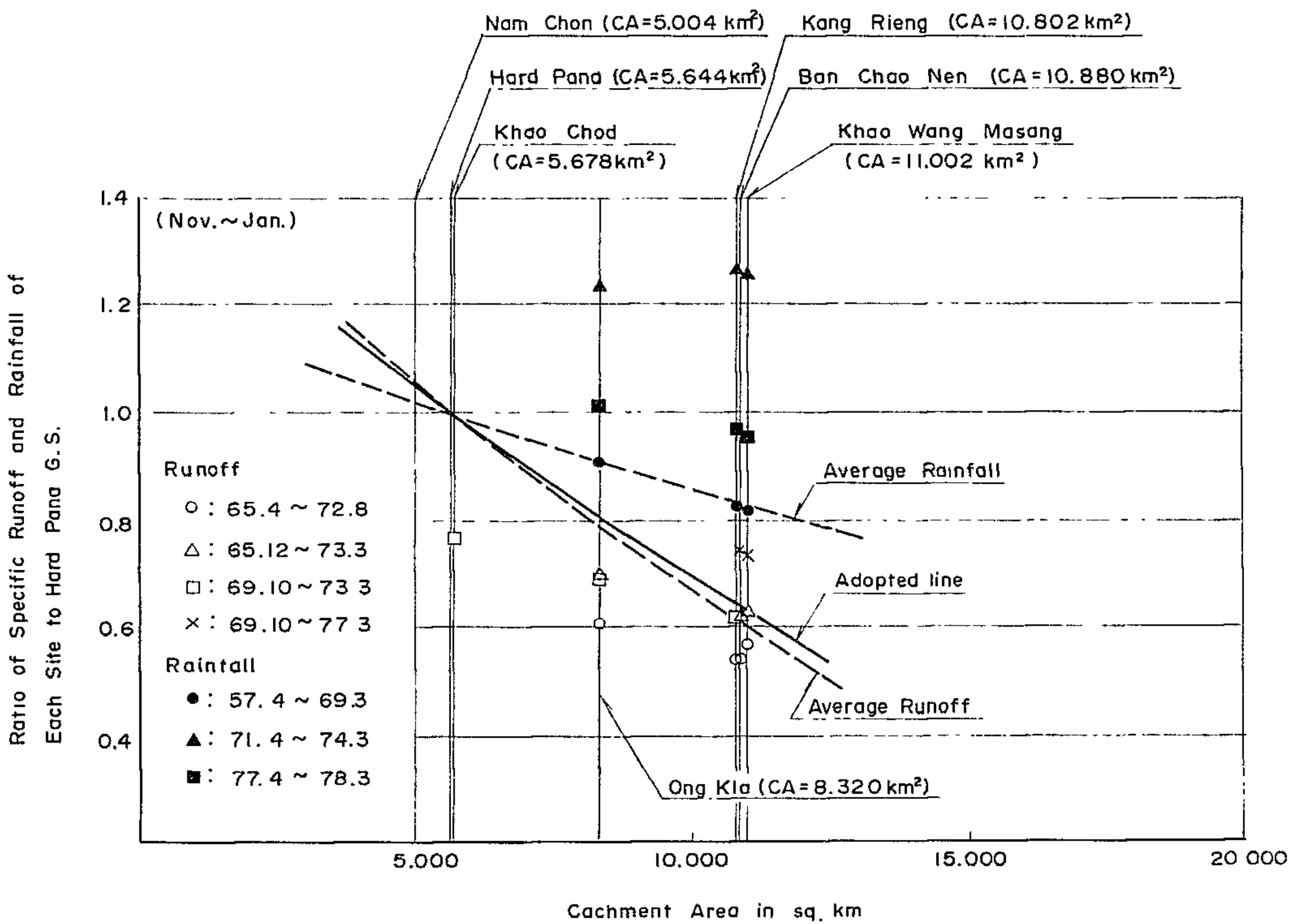


Fig.3-12 Unit Hydrograph at Nam Chon

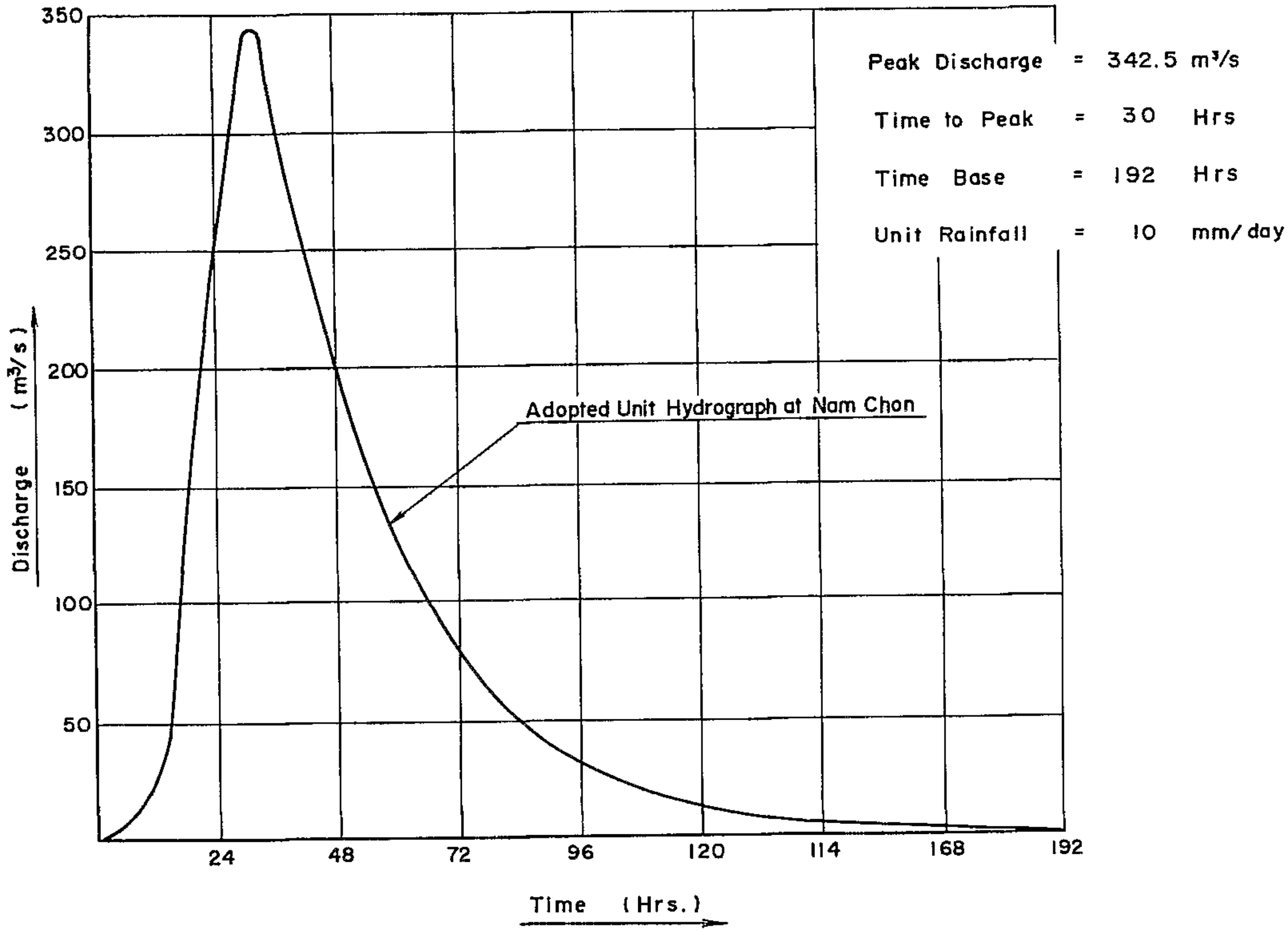
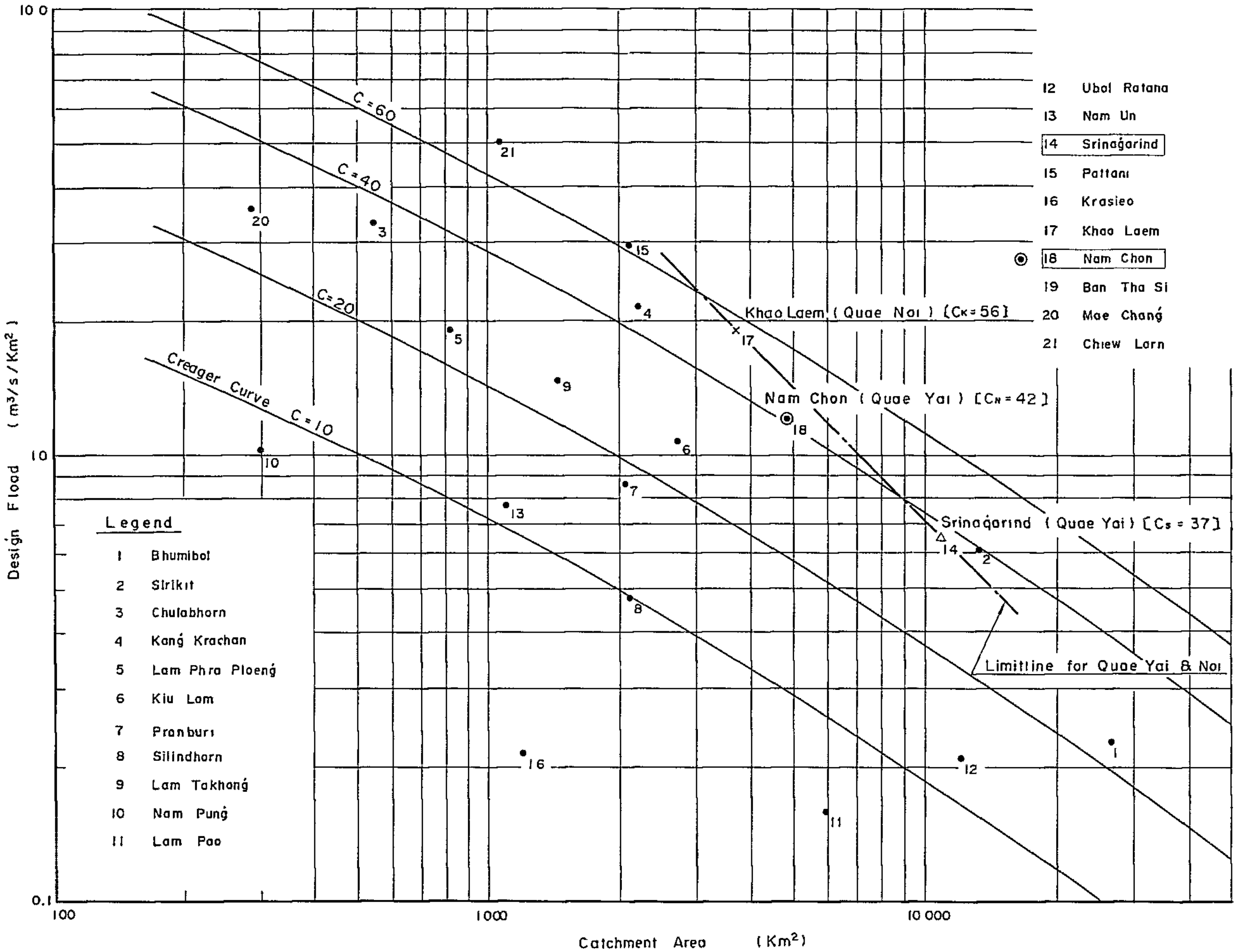
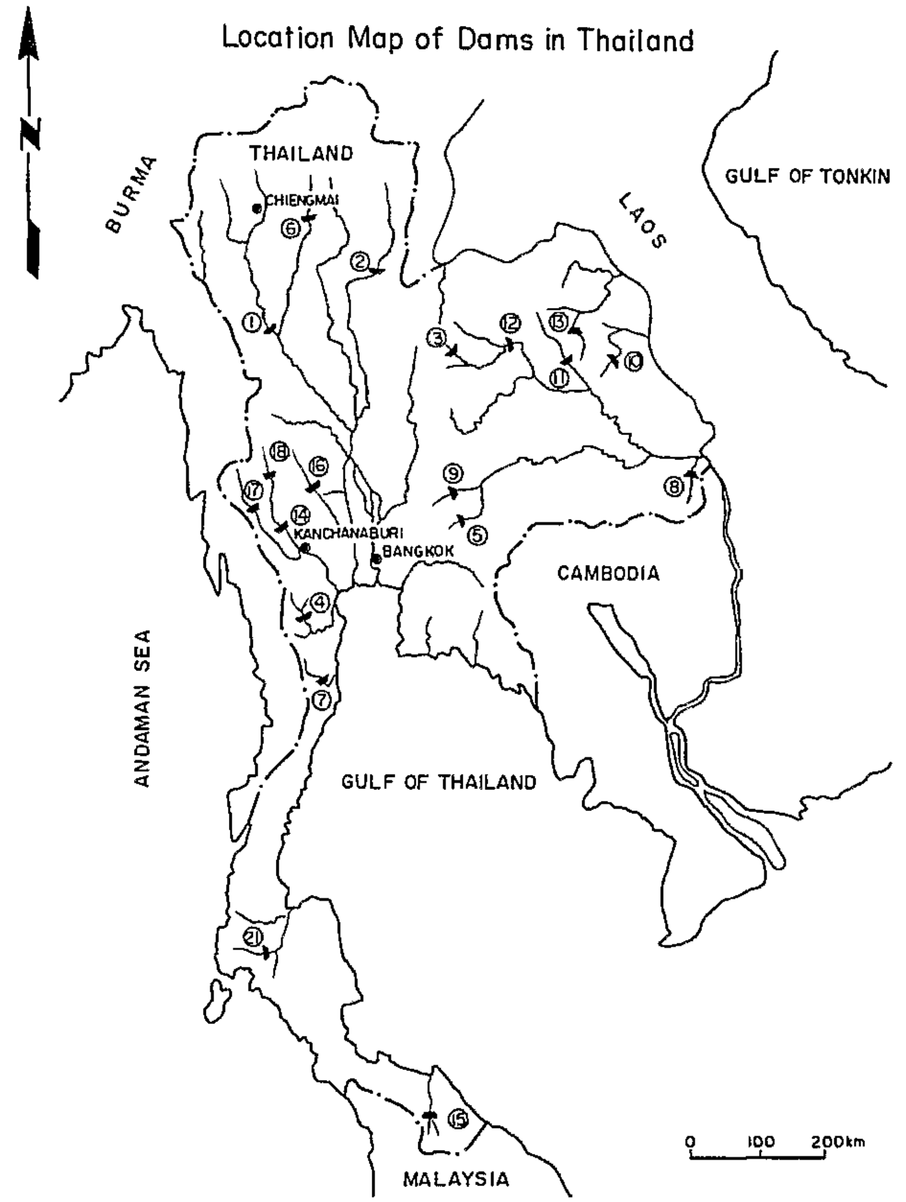


Fig. 3-13 Comparison of Design Floods in Thailand



Location Map of Dams in Thailand



Notes;

1. Creager's Eq.
   (Unit in cfs-sq. Miles) $q = 46\,C\,A^{(0.894\,A^{-0.048}-1)}$
   (Unit in m³/s-sq km) $q = 0.503\cdot C\cdot(0.3861\,A)^{[0.894\times(0.3861\,A)^{-0.048}-1]}$
2. Values in [ ] are Creager's coefficients C derived from Design PMF

Table 3-1 Annual Rainfall at Each Observatory Station

Station	Period	Average Annual Rainfall (mm)
Umphang	1952 - 1978	1,403.7
Kang Rieng	1952 - 1968	1,021.7
Sangkhla buri	1952 - 1978	2,312
Kanchana buri	1911 - 1978	1,000
Bangkok	1911 - 1978	1,390

Table 3-2 Estimation of Evapotranspiration

Month	t (°C)	p (%)	k.p	$\frac{(45.7t + 813)}{100}$	$U = k.p \frac{(45.7t + 813)}{100}$ (mm)
Jan.	22.1	7 94	4.76	18.23	86.8
Feb.	24.7	7.36	4.42	19.42	85.8
Mar.	27 2	8.43	5.06	20.56	104.0
Apr.	28.9	8.44	5.06	21.34	108.0
May	28.4	8.98	5 39	21.11	113.8
Jun.	27.7	8.80	5.28	20.79	109.8
Jul.	27.1	9.05	5.43	20.51	111.4
Aug.	27.0	8.83	5.30	20.47	108.5
Sep.	27.1	8.28	4.97	20.51	101.9
Oct.	26.5	8.26	4.96	20.24	100.4
Nov.	24.1	7.75	4.65	19.14	89.0
Dec.	22.0	7.88	4.73	18.18	86.0
Annual	—	—	—	—	1,205.4

Remarks;

t: Mean temperature at Hard Pana from 1970 to 1978.

p: Monthly percent of daytime hours of the year, can be obtained from a table prepared by Blaney-Criddle, according to the location of the proposed reservoir site (about Lat. 15°N, Long. 99°E).

k: Empirical coefficient to be estimated 0.60 by kinds of crop or vegetation.

Table 3-3 Measurement of Pan Evaporation at Hard Pana Station

(mm)

YEAR	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1970								66.2	102.2	94.7	86.7	90.9	
1971	114.0	122.7	147.4	176.2	146.1	91.2	79.0	130.1	112.3	111.2	106.8	110.9	1,447.9
1972	129.0	170.8	181.1	157.2	206.3	105.7	85.7	97.7	104.6	118.4	78.8	97.1	1,532.4
1973	128.0	154.0	174.7	205.3	168.2	126.8	108.0	106.3	97.4	103.0	81.3	111.0	1,564.0
1974	130.0	145.5	162.5	169.2	137.9	97.1	133.7	89.2	97.6	103.9	85.6	108.0	1,460.2
1975	91.4	141.0	159.5	175.1	133.9	92.3	109.1	93.4	106.4	98.4	102.7	102.9	1,406.1
1976	106.5	130.7	188.3	187.2	112.4	150.5	99.3	89.3	103.9	100.6	109.0	125.0	1,502.7
1977	137.0	156.5	194.2	173.6	173.4	113.7	114.5	91.6	120.0	134.5	116.0	146.7	1,671.7
1978	146.7	132.4	213.4	209.3	161.8	134.4	110.2	85.2	85.0	102.0	103.2	116.0	1,599.6

Table 3-4 Estimation of Evaporation

Month	(1) Precipitation (mm)	(2) Available Precipitation for Crop Consumption (1) x 0.8	(3) Evapotranspiration obtained by Blaney-Criddle (mm)	(4) Evapotranspiration (mm)	(5) Evaporation from Reservoir water surface (mm)	(6) Net Evaporation Loss (4) — (5) (mm)
Jan.	8.5	6.8	86.8	6.8	91.0	(-) 84.2
Feb.	16.8	13.4	85.8	13.4	106.4	(-) 93.0
Mar.	38.3	30.6	104.0	30.6	129.7	(-) 99.1
Apr.	62.3	49 8	108.0	49.8	138.2	(-) 88.4
May	170.0	136.0	113.8	113.8	116.3	(-) 2.5
June	140.3	112.2	109.8	109.8	91.1	(+) 18.7
July	202.9	162.3	111.4	111 4	81.2	(+) 30.2
Aug.	157.7	126.2	108.5	108.5	72.7	(+) 35.8
Sept.	207.7	166.2	101.9	101.9	74.6	(+) 27.3
Oct.	123.0	98.4	100.4	98.4	79.7	(+) 18.7
Nov.	30.2	24.2	89.0	24.2	73.4	(-) 49.2
Dec.	17.9	14.3	86.0	14.3	80.2	(-) 65 9
Annual	1,175.6	940.4	1,205.4	782.9	1,134.5	(-) 351.6

Table 3-5 Runoff Gaging Station and Existing Data

River	Station	Cachment Area km2	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
Mae Nam Quae Noi	Huai Mae Nam Noi	321			—	—	—	—	—	—	—	—	—	—	—	—	—
Mae Nam Quae Noi	Wang Po	6,500	62 —	—	—	—	—	—	—	—	—	—	—				
Mae Nam Quae Noi	Lum Sum	7,008		—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mae Nam Quae Yai	Khao Chod (Main Stream)	5,678		—	—	—	—	—	—	—	—						
Mae Nam Quae Yai	Khao Chod (Tributary)	2,350		—	—	—	—	—									
Mae Nam Quae Yai	Hard Pana	5,644						—	—	—	—	—	—	—	—	—	—
Mae Nam Quae Yai	Ongkla	8,320			—	—	—	—	—	—	—						
Mae Nam Quae Yai	Kang Rieng	10,802	52 —	—	—	—	—	—	—	—	—						
Mae Nam Quae Yai	Khao Wang Masang	11,002			—	—	—	—	—	—	—	—	—	—	—	—	—
Huai Ta Phern	Lam Ta Phern	2,340		—	—		—	—	—	—	—	—	—	—	—		
Mae Nam Mae Klong	Ban Tham	25,466 (till' Mar. 63) 27,200	57 —	—													
Mae Nam Mae Klong	Ban Wang Khanai	27,300		—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mae Nam Quae Yai	Nam Chon	5,004															—
Mae Nam Quae Yai	Ban Chao Nen	10,880				—	—	—	—	—	—	—	—	—	—		

Table 3-6 Rainfall Observatory Station and Existing Data

Station	Year																							
	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
Pilok Mine																								
Sangkhlaburi	52																							
Thong Phaphum	52																							
Wong Po	54																							
Unphang	52																							
Ban Nasuan																								
Sri Sawat	54																							
Kang Rieng	52																							
Bo Phloi	54																							
Panom Tuan	52																							
Kanchanaburi																								
Tha Muang	52																							
Tha Maka	52																							
Lan Sailampao																								
Bang Kok (Don Muang)	52																							
Hard Pana																								
A Muang (Kanchanaburi)	52																							
Ban Chao Nen																								
Sai Yok (Huai Mae Nam Noi)																								

Table 3-7 Annual Cumulative Correlation of Specific Runoff

Station	Station	Period	
Hard Pana	Khao Wang Masang	1970 - 1976	0.70
Hard Pana	Kang Rieng	1970 - 1972	0.71
Hard Pana	Ban Chao Nen	1970 - 1976	0.74
Hard Pana	Khao Chod	1970 - 1972	1.00
Hard Pana	Nam Chon	1978	1.15
Hard Pana	Ban Wang Khanai	1970 - 1976	0.77

Table 3-8 Annual Cumulative Correlation of Rainfall

Station	Station	Period		
		1957-1968	1971-1973	1977
Kang Rieng	Hard Pana	1.13	1.10	1.19
Kang Rieng	Ongkla	1.05	1.04	1.08
Kang Rieng	Kao Wang Masang	0.99	0.99	0.99

Table 3-9 Seasonal Correlation of Specific Runoff

Station	Station	Period	Feb. - Apr.	May - Jul.	Aug. - Oct.	Nov. - Jan.
Hard Pana	Khac Chod	Oct.'69 - Aug.'72	1.0215	0.9304	0.9719	0.7691
Hard Pana	Kang Rieng	Oct.'69 - Mar.'73	0.6489	0.6094	0.7440	0.6148
Hard Pana	Ongkla	Oct.'69 - Mar.'73	0.7079	0.6596	0.7703	0.6921
Hard Pana	Ban Chao Nen	Oct.'69 - Mar.'77	0.6727	0.6379	0.7532	0.7432
Hard Pana	Khao Wang Masang	Oct.'69 - Mar.'77	0.6893	0.6057	0.6989	0.7341
Khac Chod	Kang Rieng	Apr.'65 - Aug.'72	0.6570	0.6272	0.6412	0.6953
Khac Chod	Ongkla	Jul.'66 - Aug.'72	0.7167	0.7168	0.7087	0.7868
Khac Chod	Ban Chao Nen	Apr.'67 - Aug.'72	0.7033	0.6439	0.6019	0.6983
Khac Chod	Khao Wang Masang	Jul.'66 - Aug.'72	0.6931	0.6230	0.6264	0.7392
Khac Chod	Khao Chod (T)	Dec.'65 - Dec.'69	0.1016	0.0856	0.0934	0.1928
Kang Rieng	Ongkla	Jul.'66 - Mar.'73	1.1006	1.1232	1.0792	1.1266
Kang Rieng	Ban Chao Nen	Apr.'67 - Mar.'73	1.0226	1.0124	0.9674	0.9945
Kang Rieng	Khao Chod (T)	Dec.'65 - Dec.'69	0.1525	0.1473	0.1539	0.2952
Kang Rieng	Khao Wang Masang	Jul.'66 - Mar.'73	1.0063	0.9797	0.9480	1.0171

Table 3-10 Seasonal Correlation of Rainfall

Station	Station	Period	Feb.-Apr.	May-Jul.	Aug.-Oct.	Nov.-Jan.
Hard Pana	Ongkla	Apr.'57 - Mar.'69	0.9674	0.9168	0.9416	0.9081
Hard Pana	Kang Rieng	Apr.'57 - Mar.'69	0.9516	0.8439	0.8863	0.8266
Hard Pana	Khao Wang Masang	Apr.'57 - Mar.'69	0.9521	0.8390	0.8813	0.8193
Hard Pana	Ongkla	Apr.'71 - Mar.'74	1.2306	0.8781	1.0220	1.2347
Hard Pana	Kang Rieng	Apr.'71 - Mar.'74	1.2698	0.8045	1.0093	1.2607
Hard Pana	Khao Wang Masang	Apr.'71 - Mar.'74	1.2673	0.7996	1.0047	1.2544
Hard Pana	Ongkla	Apr.'77 - Mar.'78	0.9075	0.8827	0.9401	1.0946
Hard Pana	Kang Rieng	Apr.'77 - Mar.'78	0.8625	0.8142	0.8658	0.9678
Hard Pana	Khao Wang Masang	Apr.'77 - Mar.'78	0.8634	0.8091	0.8600	0.9513

Table 3-11 Monthly Runoff at Hard Pana G.S. (Annual Cumulative Correlation Method)

(10^6 m^3)

Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual
1952	51.19	55.82	115.97	254.82	546.61	370.86	964.84	380.27	144.71	98.03	86.10	78.00	3,147.22
1953	66.64	104.46	195.77	536.89	1,721.54	913.01	731.42	577.91	264.55	166.70	107.70	93.96	5,480.55
1954	73.04	134.80	203.32	280.11	439.63	645.69	671.10	214.59	132.85	75.85	54.82	47.09	2,972.89
1955	55.16	64.20	101.66	202.30	225.66	602.41	410.44	257.90	117.10	76.07	51.31	41.81	2,206.02
1956	56.35	157.11	144.01	239.72	462.02	656.37	612.68	221.38	136.41	100.65	60.24	47.70	2,894.64
1957	42.53	31.71	120.11	231.49	638.05	769.93	968.72	224.03	118.47	81.13	52.01	42.80	3,320.98
1958	43.86	56.41	123.69	416.28	387.11	839.60	529.12	193.91	108.56	73.15	47.97	40.66	2,860.32
1959	40.10	59.51	105.99	165.55	418.23	604.27	1,060.16	208.97	113.40	73.92	51.87	36.77	2,938.74
1960	33.31	52.12	58.35	73.52	424.07	327.55	601.09	167.73	136.17	70.23	47.08	39.10	2,030.32
1961	32.19	92.59	184.29	684.73	1,429.76	1,423.16	778.10	308.73	162.82	111.48	72.21	62.25	5,342.31
1962	53.65	69.05	127.63	319.02	643.89	1,176.56	694.46	208.97	119.43	77.03	47.44	42.02	3,579.15
1963	29.55	24.69	63.58	385.15	579.69	888.54	1,326.67	395.33	170.21	105.82	68.43	52.90	4,090.56
1964	52.90	126.82	120.11	243.15	429.91	741.70	1,058.21	323.79	175.06	107.38	74.15	80.91	3,534.09
1965	48.19	85.74	378.74	593.69	660.25	502.41	497.86	208.45	126.98	99.85	76.47	62.03	3,340.66
1966	46.37	88.12	172.63	370.07	521.83	845.10	455.27	177.01	120.34	87.05	56.27	47.65	2,987.71
1967	47.41	72.42	120.32	211.38	742.80	695.64	612.34	199.69	123.53	80.14	59.53	54.85	3,020.05
1968	45.85	90.80	82.45	219.39	710.85	474.08	303.52	130.64	86.54	70.01	43.76	36.75	2,294.64
1969	32.45	53.25	169.02	367.40	1,134.17	1,154.27	511.17	286.00	141.10	105.42	64.93	58.31	4,077.49
1970	50.80	96.42	113.79	289.27	527.64	567.65	458.01	252.46	167.94	99.10	65.08	60.53	2,748.69
1971	42.25	57.59	222.65	610.68	495.50	479.52	321.41	165.89	99.37	69.64	44.60	33.48	2,642.58
1972	63.76	63.21	97.72	696.38	811.56	1,067.90	733.88	298.08	199.27	133.38	92.17	94.28	4,351.59
1973	47.69	75.26	285.12	425.87	680.31	819.07	551.75	216.43	139.54	96.96	62.66	66.69	3,467.35
1974	66.61	109.55	241.06	294.62	953.51	588.38	736.56	360.29	180.26	134.99	83.22	75.53	3,824.58
1975	61.43	96.96	162.52	383.01	583.89	640.22	680.31	347.33	173.56	113.83	77.17	64.28	3,384.51
1976	49.77	114.10	130.38	310.69	492.83	715.39	439.26	331.78	148.38	103.65	64.35	63.21	2,963.79
1977	60.13	74.73	83.98	231.68	452.65	489.89	233.82	116.38	91.07	74.19	60.40	45.53	2,014.53
Total	1,293.18	2,107.44	3,924.86	9,036.86	17,113.96	18,999.17	16,942.17	6,773.94	3,697.62	2,485.65	1,672.02	1,469.09	85,515.96
Mean	49.74	81.06	150.96	347.57	658.23	730.74	651.62	260.54	142.22	95.60	64.31	56.50	3,289.08

Table 3-12 Monthly Runoff at Hard Pana G.S. (Seasonal Correlation Method)

($10^6 m^3$)

Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual
1952	51.94	62.25	129.31	284.15	519.07	352 18	916.25	421.30	160.36	108.61	87.33	79.12	3,171.87
1953	67.60	116.48	218.32	598.68	1,634.84	867.02	694.59	640.30	293.10	184.70	109.25	95.30	5,520.18
1954	74.08	150.31	226.72	312.36	417.48	613.19	637.30	237.76	147.20	84.05	55.62	47.76	3,003.83
1955	55.96	71.59	113.35	225.60	214.27	572.05	389.79	285.74	129.74	84.26	52.07	42.43	2,236.85
1956	57.15	175.19	160.57	267.30	438.78	623.32	581.83	245.28	151.14	111.50	61.11	48.37	2,921.54
1957	43.16	35.35	133.93	258.12	605.91	731.18	919.95	248.18	131.24	89.86	52.76	43.42	3,293.06
1958	44.50	62.92	137.92	464.19	367.61	797.30	502.47	214.82	120.26	81.02	48.65	41.25	2,882.91
1959	40.67	66.37	118.20	184.60	397.15	573.84	1,006.76	231.52	125.64	81.91	52.62	37.28	2,916.56
1960	33.80	58.12	65.09	81.99	402.70	311.07	570.82	185.82	150.87	77.81	47.76	39.67	2,025.52
1061	32.66	103.25	205.52	763.53	1,357.76	1,351.49	738.92	342.04	180.39	123.50	73.25	63.16	5,333.47
1962	54.43	77.00	142.33	355.75	611.45	1,117.31	659.48	231.52	132.34	85.33	48.12	42.61	3,557.67
1963	29.99	27.56	79.55	429.48	550.49	843.80	1,259.84	438.00	188.59	117.23	69.41	53.68	4,087.62
1964	53.65	141.42	133.93	271.13	408.24	704.35	1,004.91	358.73	193.97	118.97	75.21	82.09	3,546.60
1965	48.19	85.74	378.74	593.69	660.25	502.41	497.86	208.45	126.98	99.85	76.47	62.03	3,340.66
1966	46.37	88.12	172.63	370.07	521.83	845.10	455.27	177.01	120.34	87.05	56.27	47.65	2,987.71
1967	47.41	72.42	120.32	211.38	742.80	695.64	612.34	199.69	123.53	80.14	59.53	54.85	3,020.05
1968	45.85	90.80	82.45	219.39	710.85	474.08	303.52	130.64	86.54	70.01	43.76	36.75	2,294.64
1969	32.45	53.25	169.02	367.40	1,134.17	1,154.27	511.17	286.00	141.10	105.42	64.93	58.31	4,077.49
1970	50.80	96.42	113.79	289.27	527.64	567.65	458.01	252.46	167.94	99.10	65.08	60.53	2,748.69
1971	42.25	57.59	222.65	610.68	495.50	479.52	321.41	165.89	99.37	69.64	44.60	33.48	2,642.58
1972	63.76	63.21	97.72	696.38	811.56	1,067.90	733.88	298.08	199.27	133.38	92.17	94.28	4,351.59
1973	47.69	75.26	285.12	425.87	680.31	819.07	551.75	216.43	139.54	96.96	62.66	66.69	3,467.35
1974	66.61	109.55	241.06	294.62	953.51	588.38	736.56	360.29	180.26	134.99	83.22	75.53	3,824.58
1975	61.43	96.96	162.52	383.01	583.89	640.22	680.31	347.33	173.56	113.83	77.17	64.28	3,384.51
1976	49.77	114.10	130.38	310.69	492.83	715.39	439.26	331.78	148.38	103.65	64.35	63.21	2,963.79
1977	60.13	74.73	83.98	231.68	452.65	489.89	233.82	116.38	91.07	74.19	60.48	45.53	2,014.53
Total	1,302.30	2,225.96	4,125.12	9,501.01	16,693.54	18,497.62	16,418.07	7,171.44	3,902.72	2,616.96	1,683.85	1,479.26	85,617.85
Mean	50.09	85.61	158.66	365.42	642.06	711.45	631.46	275.82	150.10	100.65	64.76	56.89	3,292.99

Table 3-13 Difference of the Average Inflow at the Hard Pana Site

($10^6 m^3$)

Period	Feb. - Apr.	May - Jul.	Aug. - Oct.	Nov. - Jan.	Annual
Annual Cumulative Correlation Method	170	580	2,041	498	3,289
Seasonal Correlation Method	172	610	1,985	526	3,293

Table 3-14 Monthly Runoff at No. 9-A Dam Site

(10^6 m^3)

Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual
1952	44.56	53.89	111.95	245.98	436.87	296.40	771.16	364.72	138.82	94.01	74.90	67.87	2,701.13
1953	57.98	100.84	189.01	518.27	1,375.95	729.73	584.59	554.30	253.72	159.90	93.70	81.74	4,699.73
1954	63.53	130.12	196.27	270.41	351.38	516.09	536.38	205.83	127.44	72.77	47.71	40.95	2,558.88
1955	48.00	61.98	98.13	195.31	180.34	481.46	328.05	247.35	112.31	72.93	44.65	36.40	1,906.91
1956	49.01	151.65	139.01	231.41	369.30	524.62	489.69	212.34	130.84	96.53	52.40	41.49	2,488.29
1957	37.01	30.61	115.94	223.46	509.97	615.39	774.27	214.85	113.62	77.78	45.26	37.23	2,795.39
1958	38.18	54.45	119.39	401.84	309.38	671.04	422.89	185.98	104.11	70.15	41.73	35.38	2,454.52
1959	34.89	57.45	102.33	159.79	334.26	482.97	847.31	200.41	108.77	70.90	45.13	31.98	2,476.19
1960	28.98	50.33	56.35	70.98	338.92	261.79	480.42	160.86	130.60	67.36	40.96	34.02	1,721.57
1961	28.02	89.38	177.91	660.98	1,142.74	1,137.47	621.90	296.11	156.15	106.92	62.83	54.16	4,534.57
1962	46.68	66.67	123.20	307.96	514.63	940.38	555.04	200.41	114.56	73.87	41.27	36.56	3,021.23
1963	25.71	23.86	68.87	371.79	463.31	710.18	1,060.32	379.16	163.25	101.48	59.53	46.04	3,473.50
1964	46.01	122.43	115.94	234.71	343.59	592.82	845.76	310.55	167.91	102.98	64.50	70.42	3,017.62
1965	41.32	74.22	327.86	513.96	555.69	422.83	419.01	180.46	109.92	86.43	65.58	53.19	2,850.47
1966	39.76	76.28	149.43	320.36	439.20	711.27	383.17	153.24	104.19	75.34	48.26	40.87	2,541.37
1967	40.67	62.70	104.17	182.99	625.17	585.48	515.38	172.86	106.95	69.37	51.06	47.06	2,563.86
1968	39.32	78.61	71.38	189.93	598.27	399.01	255.44	113.09	74.91	60.61	37.55	31.52	1,949.64
1969	27.84	46.10	146.32	318.06	954.55	971.48	430.23	247.59	122.14	91.25	55.59	50.01	3,461.26
1970	43.57	83.46	98.50	250.40	444.08	477.76	385.48	218.56	145.38	85.79	55.81	51.91	2,340.70
1971	36.24	49.85	192.74	528.66	417.03	403.57	270.52	143.60	86.03	60.29	38.26	28.71	2,255.50
1972	54.69	54.72	84.60	602.85	683.05	898.78	617.67	258.03	172.52	115.47	79.06	80.86	3,702.30
1973	40.90	65.17	246.84	368.65	572.59	689.37	464.38	187.35	120.80	83.94	53.73	57.21	2,950.93
1974	57.13	94.84	208.68	255.06	802.50	495.20	619.92	311.90	156.04	116.86	71.37	64.79	3,254.29
1975	52.70	83.94	140.69	331.56	491.43	538.82	572.59	300.67	150.26	98.54	66.20	55.12	2,882.52
1976	42.69	98.78	112.86	268.96	414.78	602.10	369.70	287.22	128.46	89.73	55.18	54.21	2,524.67
1977	51.58	64.68	72.71	200.56	380.98	412.31	196.78	100.75	78.83	64.23	51.87	39.05	1,714.33
Total	1,116.97	1,927.01	3,571.08	8,224.89	14,049.96	15,568.32	13,818.05	6,208.19	3,378.53	2,265.43	1,444.19	1,268.75	72,841.37
Mean	42.96	74.12	137.35	316.34	540.38	598.78	531.46	238.78	129.94	87.13	55.55	48.80	2,801.59

Table 3-15 Monthly Runoff at Nam Chon Dam Site

(10^6 m^3)

Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual
1952	46.97	56.84	118.07	259.46	464.92	315.45	820.66	388.33	147.82	100.12	78.99	71.57	2,869.20
1953	61.15	106.36	199.35	546.63	1,464.31	776.59	622.14	590.22	270.17	170.27	98.80	86.19	4,992.18
1954	67.00	137.24	207.02	285.20	373.93	549.22	570.82	219.15	135.69	77.49	50.30	43.20	2,716.26
1955	50.62	65.38	103.50	206.00	191.91	512.39	349.13	263.40	119.59	77.67	47.08	38.38	2,025.05
1956	51.68	159.95	146.63	244.06	393.00	558.29	521.14	226.10	139.33	102.77	55.25	43.74	2,641.94
1957	39.04	32.27	122.29	235.67	542.70	654.89	823.98	228.77	120.98	82.84	47.71	39.27	2,970.41
1958	40.25	57.45	125.92	423.86	329.26	714.12	450.05	198.03	110.86	74.67	44.01	37.31	2,605.79
1959	36.78	60.61	107.93	168.55	355.72	513.99	901.74	213.40	115.81	75.50	47.58	33.72	2,631.33
1960	30.56	53.06	59.43	74.86	360.70	278.61	511.28	171.28	139.06	71.73	43.18	35.86	1,829.61
1961	29.55	94.28	187.66	697.16	1,216.13	1,210.52	661.83	315.29	166.28	113.83	66.24	57.13	4,815.90
1962	49.22	70.31	129.96	324.81	547.68	1,000.75	590.69	213.40	121.97	78.66	43.52	38.54	3,209.51
1963	27.11	25.18	72.63	392.14	493.07	755.78	1,128.41	403.73	173.83	108.07	62.77	48.53	3,691.25
1964	48.52	129.13	122.29	247.56	365.66	630.87	900.08	330.66	178.78	109.68	68.03	74.25	3,205.51
1965	43.57	78.29	345.82	542.08	591.39	450.00	445.93	192.14	117.05	92.03	69.16	56.11	3,023.57
1966	41.94	80.46	157.62	337.91	467.41	756.94	407.79	163.17	110.94	80.24	50.90	43.10	2,698.42
1967	42.87	66.13	109.85	193.01	665.31	623.06	548.46	186.06	113.86	73.87	53.85	49.60	2,723.93
1968	41.47	82.90	75.27	200.32	636.68	424.62	271.86	120.42	79.76	64.55	39.58	33.24	2,070.67
1969	29.34	48.61	154.33	335.47	1,015.86	1,033.87	457.85	263.63	130.06	97.17	58.71	52.74	3,677.64
1970	45.96	88.04	103.89	264.12	472.60	508.42	410.22	232.71	154.81	91.36	58.86	54.75	2,485.74
1971	38.21	52.58	203.29	557.59	443.81	429.49	287.87	152.90	91.60	64.20	40.34	30.27	2,392.15
1972	57.67	57.72	89.22	635.85	726.89	956.50	657.33	274.75	183.68	122.94	83.37	85.25	3,931.17
1973	43.13	68.73	260.34	388.85	609.34	733.64	494.19	199.51	128.62	89.38	56.66	60.32	3,132.71
1974	60.24	100.01	220.11	269.02	854.03	527.01	659.72	332.11	166.17	124.44	75.26	68.30	3,456.42
1975	55.55	88.52	148.39	349.72	522.98	573.43	609.34	320.16	159.98	104.94	69.78	58.15	3,060.94
1976	45.00	104.19	119.05	283.70	441.43	640.77	393.43	305.83	136.79	95.54	58.21	57.16	2,681.10
1977	54.38	68.22	76.67	211.54	405.43	438.77	209.42	107.28	83.94	68.38	54.70	41.17	1,819.90
Total	1,177.78	2,032.46	3,766.53	8,675.14	14,952.15	16,567.99	14,705.36	6,610.43	3,597.43	2,412.34	1,522.84	1,337.85	77,358.80
Mean	45.30	78.17	144.87	333.66	575.08	637.23	565.59	254.25	138.36	92.78	58.57	51.46	2,975.32

Table 3-16 Monthly Runoff at Thi Khong Dam Site

($10^6 m^3$)

Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual
1952	48.86	59.11	122.81	269.85	483.48	328.04	853.45	400.13	152.29	103.15	82.13	74.41	2,977.71
1953	63.58	110.62	207.33	568.57	1,522.78	807.59	646.97	608.11	278.37	175.41	102.77	89.65	5,181.75
1954	69.67	142.76	215.32	296.66	388.85	571.15	593.61	225.82	139.81	79.82	52.30	44.92	2,820.69
1955	52.64	68.00	107.65	214.25	199.59	532.84	363.06	271.38	123.21	80.03	48.98	39.91	2,101.54
1956	53.76	166.38	152.49	253.86	408.70	580.58	541.95	232.94	143.54	105.90	57.48	45.51	2,743.09
1957	40.59	33.59	127.19	245.13	564.37	681.05	856.87	235.69	124.65	85.33	49.62	40.85	3,084.93
1958	41.86	59.76	130.97	440.84	342.41	742.63	468.02	204.02	114.21	76.95	45.77	38.78	2,706.22
1959	38.26	63.02	112.26	175.30	369.91	534.50	937.73	219.88	119.32	77.78	49.49	35.06	2,732.51
1960	31.80	55.20	61.82	77.86	375.08	289.73	531.69	176.46	143.29	73.90	44.92	37.31	1,899.06
1961	30.72	98.06	195.18	725.12	1,264.69	1,258.86	688.27	324.83	171.31	117.29	68.90	59.41	5,002.64
1962	51.19	73.12	135.17	337.85	569.53	1,040.71	614.26	219.88	125.70	81.05	45.26	40.07	3,333.79
1963	28.20	26.17	75.56	407.89	512.75	785.95	1,173.46	415.96	179.10	111.34	65.27	50.49	3,832.14
1964	50.47	134.29	127.19	257.50	380.25	656.06	936.02	340.69	184.22	113.00	70.74	77.22	3,327.65
1965	45.33	81.42	359.69	563.83	614.99	467.96	463.74	197.98	120.61	94.84	71.92	58.34	3,140.65
1966	43.62	83.70	163.94	351.46	486.05	787.16	424.07	168.12	114.29	82.68	52.93	44.81	2,802.83
1967	44.58	68.78	114.28	200.75	691.88	647.95	570.37	189.66	117.31	76.12	56.00	51.59	2,829.27
1968	43.13	86.24	78.30	208.35	662.13	441.57	282.71	124.08	82.20	66.50	41.17	34.55	2,150.93
1969	30.53	50.57	160.52	348.92	1,056.41	1,075.14	476.14	271.62	134.00	100.12	61.08	54.85	3,819.90
1970	47.80	91.57	108.06	274.72	491.46	528.74	426.62	239.76	159.50	94.12	61.21	56.94	2,580.50
1971	39.74	54.69	211.46	579.95	461.54	446.65	299.36	157.54	94.36	66.13	41.94	31.50	2,484.86
1972	59.98	60.02	92.79	661.35	755.92	994.71	683.58	283.10	189.26	126.69	86.70	88.68	4,082.78
1973	44.87	71.49	270.79	404.44	633.68	762.93	513.93	205.55	132.53	92.08	58.93	62.73	3,253.95
1974	62.65	104.03	228.93	279.81	888.13	548.05	585.07	342.17	171.20	128.22	78.29	71.03	3,588.58
1975	57.78	92.08	154.35	363.75	543.88	596.34	633.68	329.86	164.83	108.10	72.59	60.45	3,177.69
1976	46.81	108.37	123.82	295.08	459.05	666.35	409.15	315.08	140.91	98.43	60.53	59.46	2,783.04
1977	56.56	70.98	79.76	220.03	421.61	456.30	217.81	110.52	86.49	70.47	56.88	42.83	1,890.24
Total	1,224.98	2,114.02	3,917.63	9,023.12	15,549.12	17,229.54	15,292.59	6,810.83	3,706.51	2,485.45	1,583.80	1,391.35	80,328.94
Mean	47.11	81.31	150.68	347.04	598.04	662.67	588.18	261.95	142.56	95.59	60.92	53.51	3,089.57