NATIONAL ENERGY AUTHORITY
KINGDOM OF THAILAND

COMPREHENSIVE DEVELOPMENT SCHEME
NAM SAI YAI BASIN

SEPTEMBER 1968

OVERSEAS TECHNICAL COOPERATION AGENCY
GOVERNMENT OF JAPAN

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PREFACE

In response to the request of the Royal Government of Thailand,.the Government of Japan entrusted the Overseas Technical Cooperation Agency (OTCA) with the task of conducting a feasibility survey for the Nam Sai Yai hydroelectric power project in Thailand.

The OTCA, fully realizing the significance of the mission assigned to it, organized a survey team consisting of six experts of the Electric Power Development Company (EPDC) headed by Mr. Takeshi Tokuno and dispatched it to Thailand on October 16, 1967 for about 5 months.

The team made a survey for the feasibility study of the project as well as studied and discussed with the officials of the Royal Government of Thailand various problems concerning the project.

After the return of the team to Japan, the preliminary design work was carried out and the result is herewith submitted to the Royal Government of Thailand as the "Comprehensive Development Scheme Nam Sai Yai Basin".

It is my sincere hope that this report which is an outcome of the cooperation of the peoples of the Kingdom of Thailand and Japan, will prove to be useful in some way for.the future development of Thailand as well as for the promotion of friendship and economic cooperation between the two countries.

On behalf of the OTCA, we would like to take this opportunity to express our deepest appreciation to the Royal Government of Thailand; Embassy of Japan and other component authorities for their unlimited cooperation and assistance and warm hospitality extended to the team during their stay in Thailand.

September, 1968

S. Shibusawa

Shinichi Shibusawa
Director General
Overseas Technical Cooperation Agency

LETTER OF TRANSMITTAL

July 1968

Mr. Shinichi Shibusawa,
Director General,
Overseas Technical Cooperation Agency
Tokyo, Japan.

It is with great pleasure that we hereby submit the Report on Nam Sai Yai Basin Plan for Hydro Electric Power Development, based on field investigations carried out between October 1967 and March 1968 in response to your request.

This Report explains the development method by which the water resources of the entire Sai Yai River (Maenam Sai Yai) Basin can be most effectively utilized and covers studies not only of hydroelectric power development but also of agricultural development. Also, development of the neighboring Prachantakham River (Maenam Prachantakham) Basin which is related with the development of the Sai Yai River is touched upon.

The Nam Sai Yai Basin Plan may be outlined as consisting of the construction of 3 reservoirs and 4 power stations which will produce a maximum output 99 MW and available energy of 332,000 MWh per year and of a fourth reservoir which will irrigate 13,300 ha of cultivated land. Since the benefit-cost ratio will be 1.2 at the interest rate of 6% per annum, and the internal rate of return will be 7.9%, this may be said to be a highly economical development site.

For development of the Prachantakham River Basin, it is proposed to obtain electric power of a maximum output of 17.3 MW and available energy of 82,700 MWh per year through construction of 2 reservoirs and 3 power stations and also to irrigate 3,000 to 4,000 ha of paddy fields. The economics of this development, of which an internal rate of return is 4.8% will be inferior to that of Sai Yai.

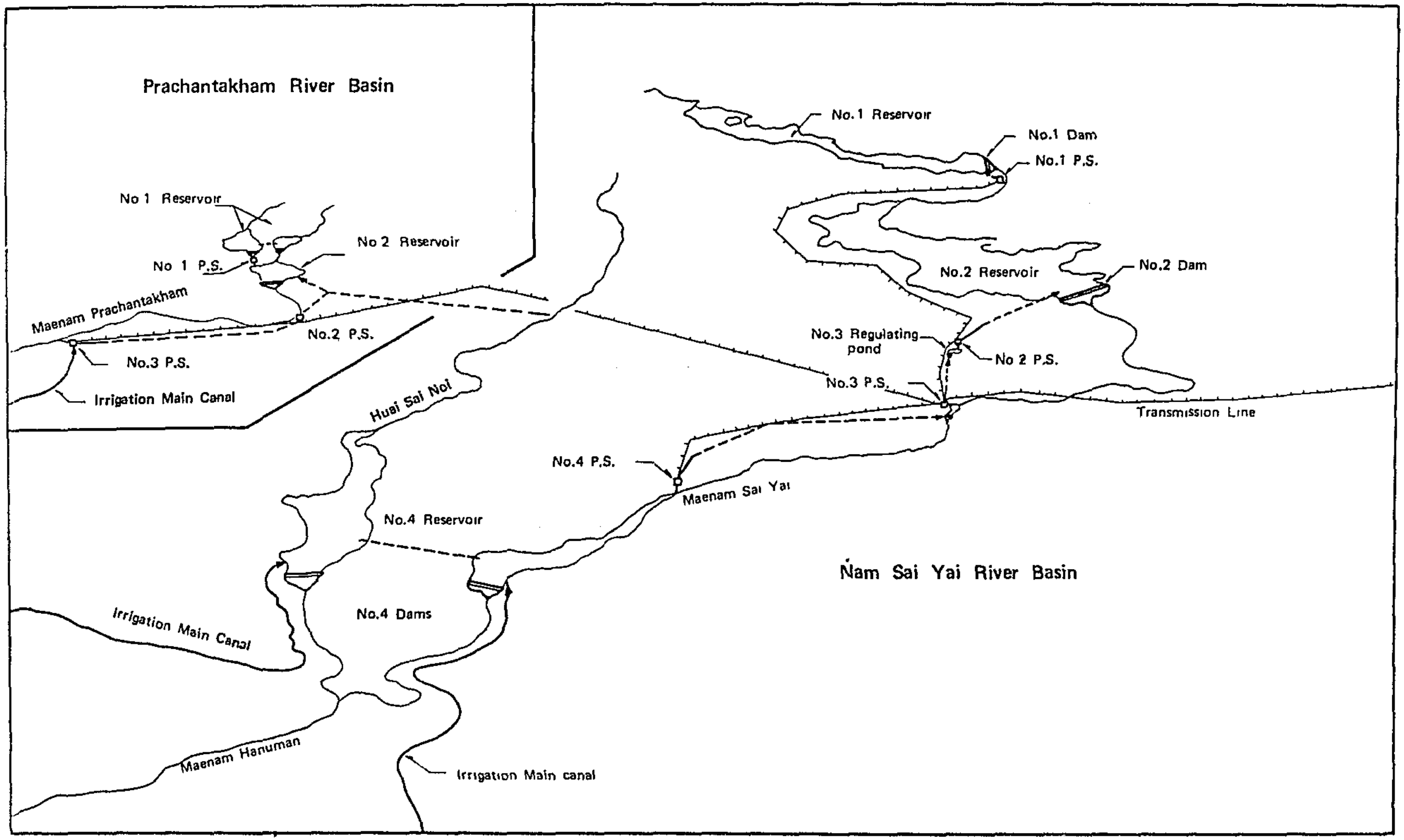
It is believed that this Report will be highly useful in long-range programs for development of water resources with emphasis on electric power development in Thailand.

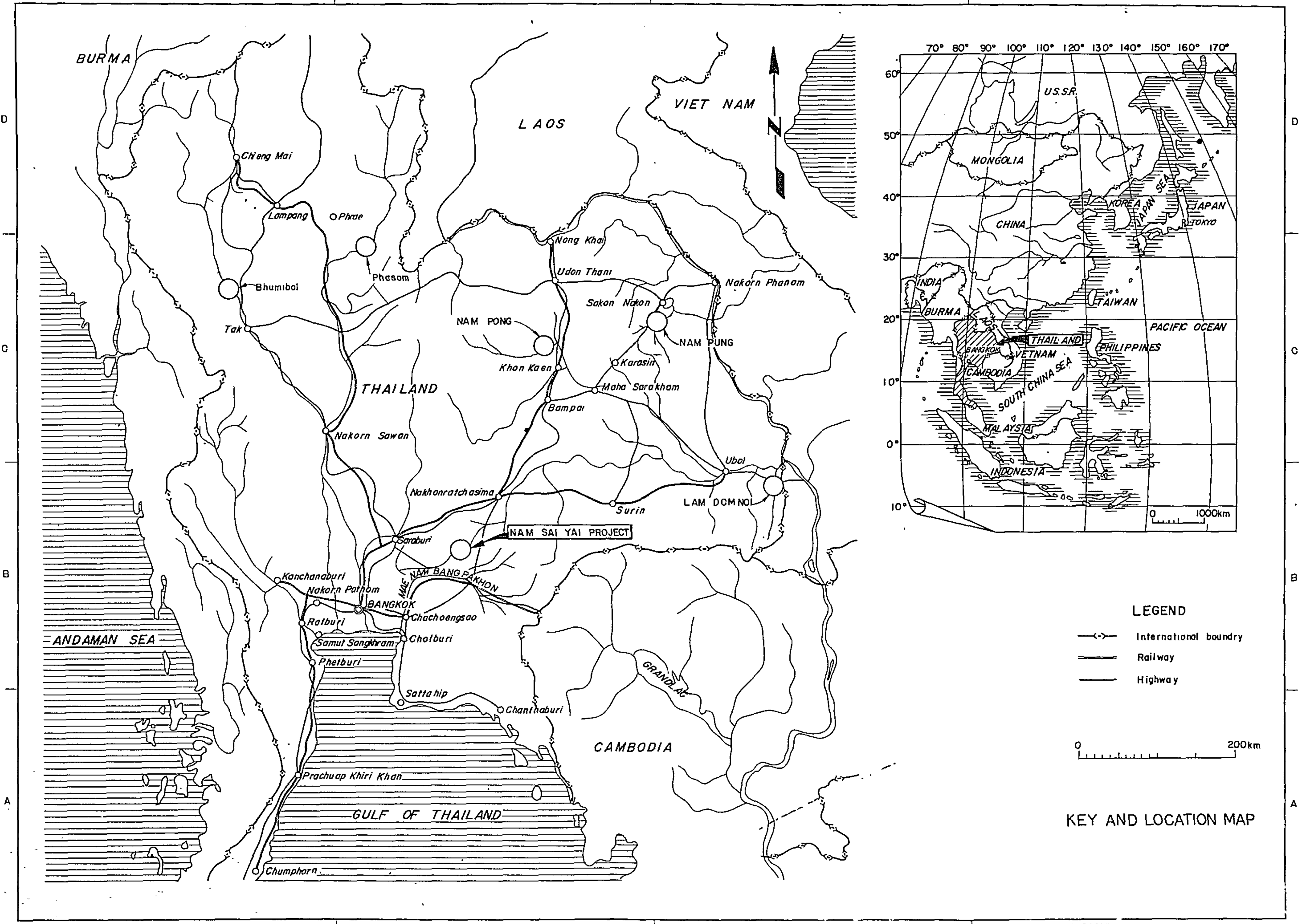
In closing, we wish to express our gratitude to Dr. Boonrod Binson, the National Energy Authority, the Mekong Committee, and the officers of the Japanese Embassy for their cooperation in making possible the field investigations and preparation of this Report. It is sincerely hoped that these development projects will be successfully carried out and will contribute to the economic progress of Thailand.

Very truly yours,

T. Tokuno.

Takeshi Tokuno, Chief
Japanese Survey Team for
Nam Sai Yai Hydroelectric Project


Prachantakham River Basin
No 1 Reservoir
No 2 Reservoir
No 1 P.S.
Maenam Prachantakham
No.2 P.S.
No.3 P.S.
Irrigation Main Canal
No.1 Reservoir
No.1 Dam
No.1 P.S.
No.2 Reservoir
No.2 Dam
No.3 Regulating pond
No 2 P.S.
No.3 P.S.
Transmission Line
Huai Sai Noi
No.4 P.S.
Maenam Sai Yai
No.4 Reservoir
Nam Sai Yai River Basin
No.4 Dams
Irrigation Main Canal
Maenam Hanuman
Irrigation Main canal



KEY AND LOCATION MAP

(A－3)

GENERAL DESCRIPTION OF PROJECT

I. NAM SAI YAI RIVER BASIN

(1) Reservoir and Dam	No.1	No.2	No.3	No.4
Reservoir				
Total Catchment Area (sq. km)	124	295	298	455 (Sai Yai River) 95 (Sai Noi River)
Normal High Water Surface Level (m)	727.5	591.0	510.0	44.0
Effective Storage Capacity (million cu. m)	90.0	110.0	1.6	24.0
Available Drawdown (m)	14.5	15.0	3.0	7.0
Dam				
Type	Fill Dam	Fill Dam	Fill Dam	Fill Dam
Height (m)	59	40	28	39 45
Length (m)	395	1,346	540	300 600
Volume (thousand cu.m)	840	1,700 (Included Dike)	400	500 700

(2) Power Station	No.1	No.2	No.3	No.4
Max. Available Discharge (c.m.s)	10.0	20.0	20.0	21.0
Firm Discharge (c.m.s)	3.1	7.3	7.3	7.4
Rated Head (m)	86.7	74.3	333.3	119.4
Installed Capacity (kW)	8,000	12,000	58,000	21,000
Available Energy (MWh/Year)	21,000	42,000	190,000	79,000

(3) Transmission Line 115 kV x 134 km

(4) Irrigation

Irrigable Area (ha)	13,300		
Gross Irrigation Water Requirement (c.m.s.)	1.8 – 13.4	Average	8.2
Main Canal Length (km)	76		

(5) Construction Cost

Total	$48,067,000	(฿ 992,600,000)
Dam	$14,556,000	(฿ 300,600,000)
Power Station (Included Transmission Line)	$29,889,000	(฿ 617,200,000)
Irrigation	$3,622,000	(฿ 74,800,000)

(6) Economic Evaluation B/C = 1.20

II. PRACHANTAKHAM RIVER BASIN

(1) Reservoir and Dam	No.1	No.2	No.3
Reservoir			
Total Catchment Area (sq. km)	62	149	172
Normal High Water Surface Level (m)	365	277	45
Effective Storage Capacity (million cu. m)	36.5	7.2	0.2
Available Drawdown (m)	25	17	5
Dam			
Type	Fill Dam	Fill Dam	Fill Dam
Height (m)	52.5	38.0	16.0
Length (m)	1,650	900	280
Volume (thousand cu. m)	1,260	710	95
(2) Power Station			
Max. Available Discharge (c.m.s.)	5.2	7.9	8.0
Firm Discharge (c.m.s.)	1.7	2.6	2.6
Rated Head (m)	74.1	208.0	22.4
Installed Capacity (kW)	3,000	13,800	470
Available Energy (MWh/Year)	9,900	65,600	7,200

(3) Transmission Line 115 kV x 16 km

(4) Irrigation

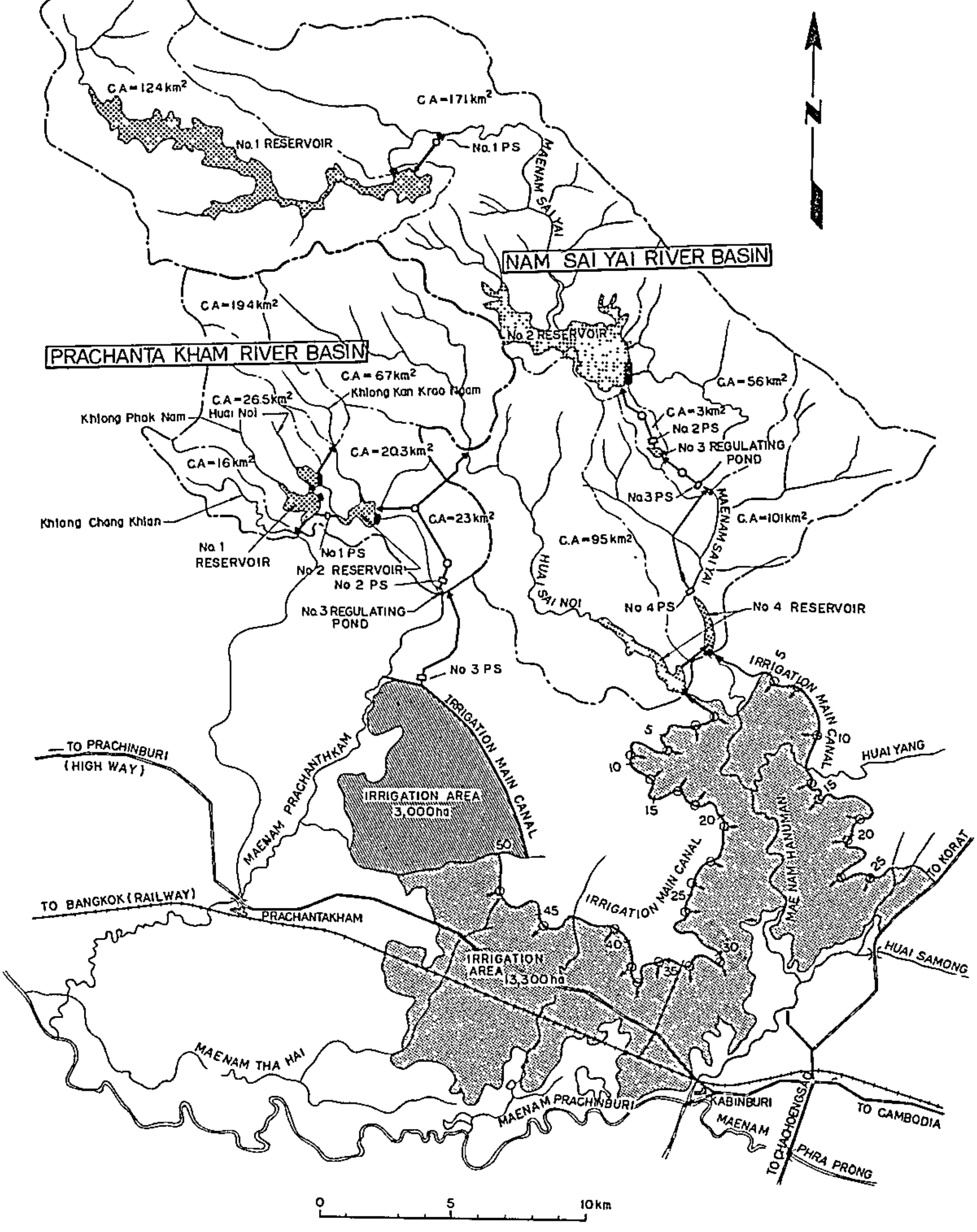
Irrigable Area (ha)	3,000 – 4,000* (* Operated for Irrigation Only)
Gross Irrigation Water Requirement (c.m.s.)	0.1 – 3.4, Average : 1.9
Main Canal Length (km)	20

(5) Construction Cost

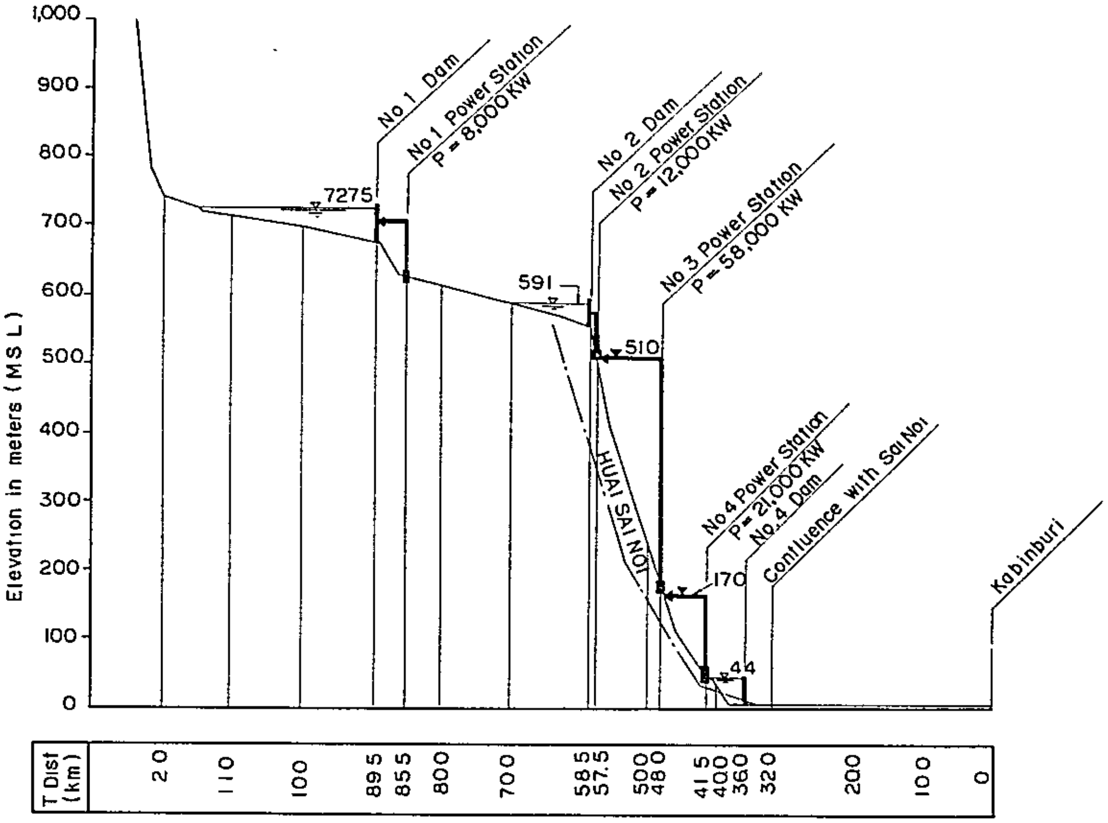
Total	$13,716,500	(฿ 283,200,000)

(6) Economic Evaluation Internal Rate of Return 4.8%

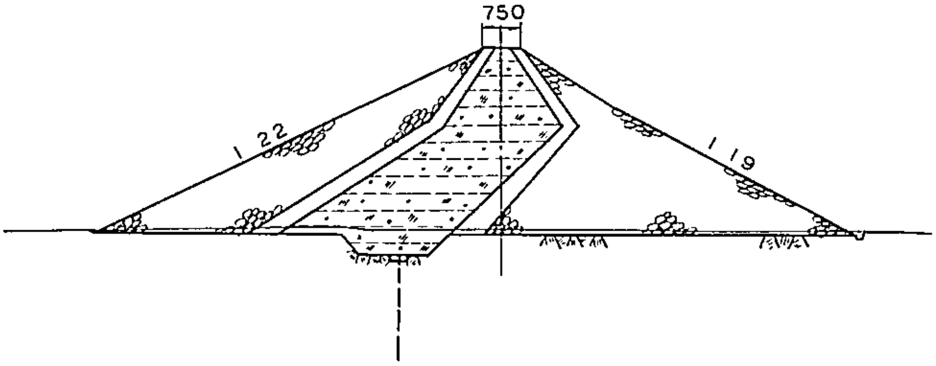
GENERAL PLAN



Nam Sai Yai River Profile



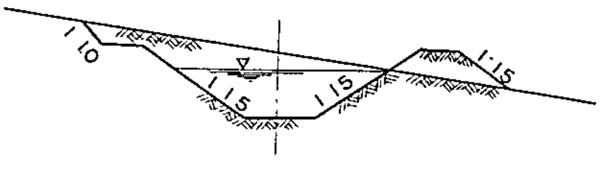
Rock-Fill Typical Section



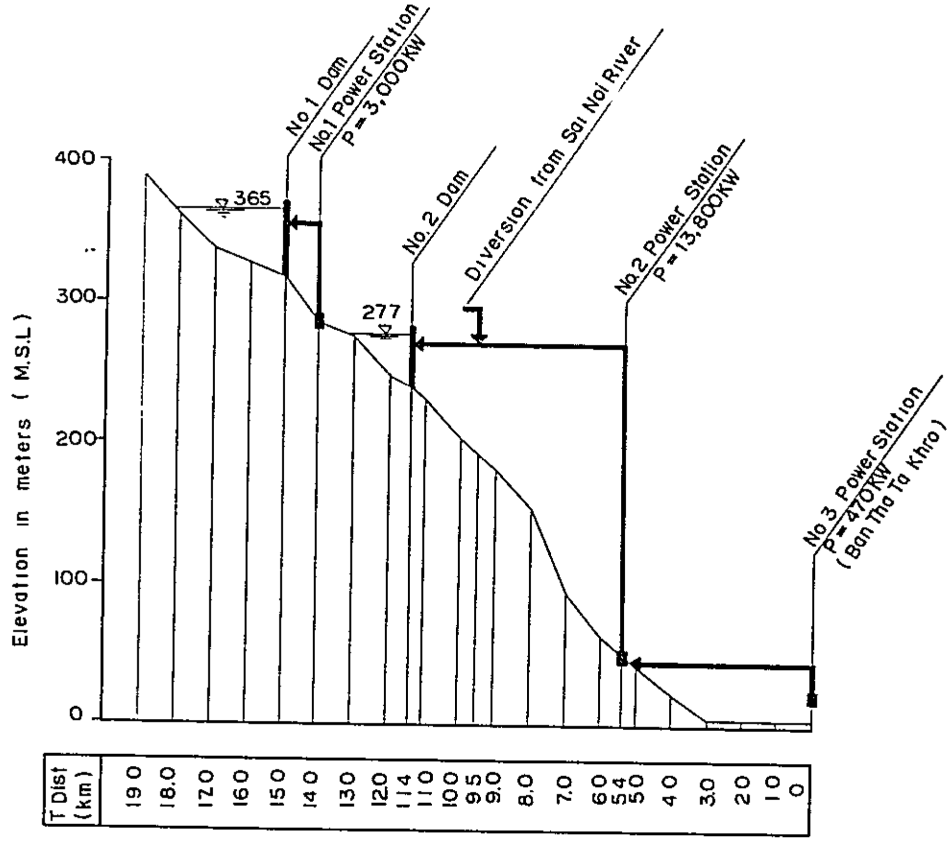
Typical Section of Tunnel

Typical Section of Irrigation Main Canal

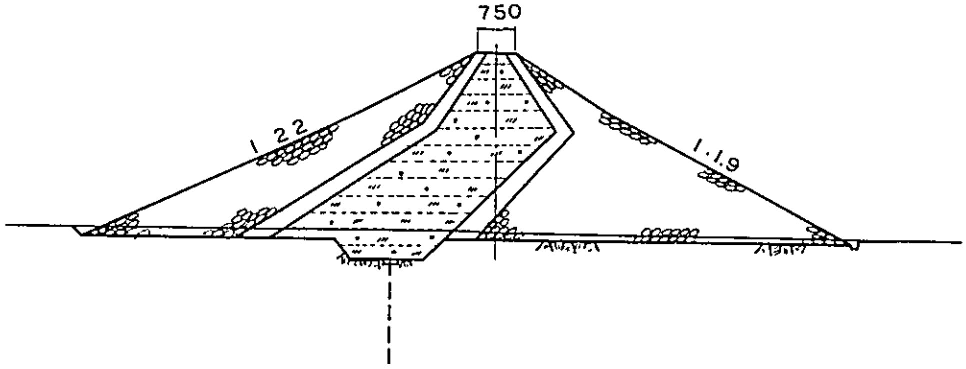
I = 1/3,000
n = 0.025



Prachantakham River Profile

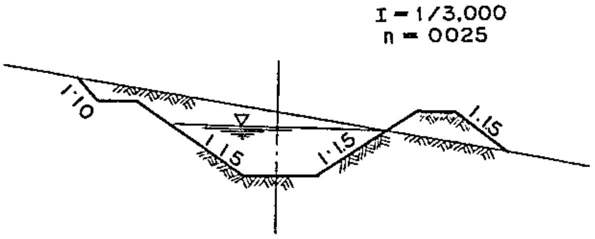


Rock–Fill Typical Section



Typical Section of Tunnel

Typical Section of Irrigation Main Canal



Unit and Conversion of Unit

mm	: Milimeter
cm	: Centimeter
m	: Meter
km	: Kilometer
sq.mm	: Square milimeter
sq.cm	: Square centimeter
sq. m	: Square meter
sq. km	: Square kilometer
ha	: Hectare
cu. m	: Cubic meter
gr	: Gram
kg	: Kilogram
ton	: Metric ton
m/sec	: Meter per second
c.m.s.	: Cubic meter per second
c.m.s.-day	: Cubic meter per second - day
kW	: Kilowatt
kWh	: Kilowatt hour
MW	: Megawatt
kV	: Kilovolt
kVA	: Kilovolt - ampere
MWh	: Megawatt - hour
r.p.m.	: Revolutions per minute
EL	: The height above mean sea level
° C	: Centigrade
p.p.m	: Parts per million by weight
%	: Percentage
$	: U.S. dollar
฿	: Baht
1 ha	: 10,000 sq.m, 6.25 rail
1 rai	: 1,600 sq.m, 0.16 ha
1 MW	: 1,000 kW
1 $	: 100 cent 1,000 mill 20.8 Baht, 360 Yen
1 ฿	: 100 Satang, 0.0481 dollar, 17.31 Yen

CONTENTS

APPENDIX

3. Records of Rainfall, evaporation, temperature, humidity and wind speed collected by the Royal Meteorological Department and NEA.

4. Result of Water Quality and Soil Tests, Prepared by NEA.

5. Feasibility Report, Quae Yai No.1 Hydroelectric Project, March 1968, prepared by EPDC.

6. Nam Phrom Hydro-electric Power Project Feasibility Report, August 1967, prepared by Government of Japan.

7. Statistical Year Book Thailand, 1964.

8. Census of Agriculture in Changwad Prachinburi, 1963.

9. Agricultural Statistics of Thailand, 1965;

10. The Seminar on Agricultural Experimentation on Irrigated Land in The Lower Mekong Basin (23 - 26, January 1966).

11. Japanese Government Ministry of Agriculture and Forestry Statistics and Investigations Department Data.

12. Report on The Chao Phya Project. (RID)

13. The Soils of Thailand : By Robert L. Pendleton, Sarot Montrakun, 1960.

14. Chemical investigation on River Water of South-Eastern Asiatic Countries (Report 1), The Quality of Waters of Thailand by J. Kobayashi, Okayama University, Japan.

CHAPTER 1

INTRODUCTION

1.1 ANTECEDENTS

Economic development undertaking based on the Second Five-Year Economic Development Plan (1966 - 1971) are being carried out in various parts of Thailand, and the development of the Sai Yai River (Maenam Sai Yai) Basin is one of the schemes adopted by the Government of Thailand (National Energy Authority, hereinafter called as NEA). The objectives of this Project are meeting the demand for electric power, which has been growing at a marked rate in recent years, and making possible irrigation of downstream cultivated lands.

Although surveys of the site had been initiated several years ago by NEA, the Government of Japan (Overseas Technical Cooperation Agency, hereinafter called as OTCA) at the request of the Government of Thailand dispatched a survey team of 6 engineers headed by Takeshi Tokuno to the site for a preliminary survey in 1965. The results were reported in June of that year in the "Report on Basic Studies for Development of Hydraulic Potentials of the Nam Sai Yai, Kingdom of Thailand".

Based on the said report, detailed investigations were carried out by NEA,which has planned the overall basin development scheme including the agricultural development, and in May 1967 the Government of Thailand requested the Government of Japan to conduct the re-examination of the said development scheme and a feasibility study of the site considered most economical. In response to this request, OTCA dispatched a survey team of 7 engineers headed by Takeshi Tokuno to carry out field surveys.

1.2 PURPOSES AND SCOPE OF INVESTIGATIONS

The present surveys, following the preliminary survey of 1965, had to include a re-examination of the development plan for the entire basin due to changes in electric power and progress in detailed investigations of the project area.

Therefore, the present surveys had the dual purpose of re-examining the above basin plan and conducting the feasibility study of the sites of the highest priority in the basin plan (Nam Sai Yai No.2 and No.3 Power Stations).

This Report gives the results of the re-examination of the basin plan, including the Sai Yai River (Maenam Sai Yai) and its tributary the Sai Noi River (Huai Sai Noi), and also touches upon the Prachantakham River (Maenam Prachantakham) which neighbors the catchement area and has a close relationship in the planning.

1.3 SURVEY AND STUDY

1.3.1 Field Survey

The field surveys were conducted during the 5 months from middle of October 1967 to the middle of March 1968. OTCA commissioned the field surveys to 7 engineers of the Electric Power Development Co., Ltd. (hereinafter called as EPDC) listed below.

Cheif	Takeshi Tokuno	Civil Engineer
Member	Narao Takemura	Irrigation & Drainage Engineer
Member	Shozo Yuzawa	Civil Engineer
Member	Hideo Sato	Civil Engineer
Member	Tsutomu Kidahashi	Electrical Engineer
Member	Azuma Tsunoda	Irrigation & Drainage Engineer
Member	Seizo Yamada	Civil Engineer

1.3.2 Preparation of Report

EPDC was commissioned to prepare the Report by OTCA. Based on various data collected in the field, EPDC prepared the Report under the direction of its Chief Engineer and upon studies carried out by its engineers from May to July 1968.

1.4 SOURCE OF DATA

All relevant data on which the present studies are based were furnished by NEA or made available through NEA from respective organizations in charge. The principal data obtained are as follows:

1. Aero-topographical map on two scales of 1:50,000 and 1:10,000, covering entire basin of the project area, prepared by the Royal Thai Survey Department. Surveyed-topographical map on a scale of 1:2,000, covering the area of No.2 and No.3 dam sites, No.2 and No.3 power stations and tunnel from the intake of No.2 power station to the tailrace of No.3 power station, prepared by NEA.

2. Run-off record of gaging stations located on the Sai Yai River as well as in adjacent basins, being maintained by NEA and Royal Irrigation Department (hereinafter called as RID).

CHAPTER 1

INTRODUCTION

CHAPTER 2

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 2

CONCLUSIONS AND RECOMMENDATIONS

2.1 CONCLUSIONS

The following conclusions have been reached as a result of investigations and studies on development of water resources of the Sai Yai River (Maenam Sai Yai) Basin.

1. In recent years, demand for electric power has remarkably been increased in Thailand. Although various programs to comply with this trend are formulated by the government agencies concerned, it is foreseen that there will be a shortage of electric power throughout the country between 1972 and 1974.

2. Demand for food in Thailand is being increased due to her population expansion and advancement of the national economy. The agricultural productivity in the Lower Sai Yai is low in comparison with that in the central plateau partly because irrigation facilities are still in less-developed condition.

3. This river system is exceedingly promising as a hydroelectric power development site. A maximum output of 99 MW and annual energy of approximately 332,000 MWh can be produced extremely economically by leading the water of No.1 Reservoir, which has an effective storage capacity of 90 million cu. m. and No.2 Reservoir, which has a capacity of 110 million cu.m and total head of approximately 690 m, to the downstream No.4 Reservoir. Thus development of this river basin will make possible satisfaction of the demand of Northeast Region of Thailand.

4. With construction of the upstream power plants, the duration of downstream discharge will be tremendously improved. As a result, only by construction of the relatively small No.4 Reservoir with an effective storage capacity of 24 million cu.m., it will become possible to irrigate 13,300 ha of cultivated land throughout the year. Also 200 ha of cultivated land could be free from flood inundation.

5. In view of these benefits, the economics of these projects can be express that the annual excess benefit will be $680,700 (฿14,100,000) at the interest rate of 6% per annum, and the benefit-cost ratio will be 1.2. While the internal rate of return will be 7.9%.

6. From an economic aspect (B/C) of the 4 power stations, Nam Sai Yai No.2 and No.3 Power Stations would have the highest priority.

7. The energy of the Sai Noi River (Huai Sai Noi) flow can be utilized only by diversion to the Prachantakham River (Maenam Prachantakham).

8. On the Prachantakham River Basin, it will be possible to obtain electric power of a maximum output of 17.3 MW and Available Energy of approximately 82,700 MWh/Yr through construction of 2 reservoirs and 3 power stations utilizing water resources and a total head of approximately 330m. At the same time it will become possible to irrigate 3,000 to 4,000 ha of downstream paddy fields throughout the year. However, the economics of this development of which an internal rate of return is 4.8% will be inferior to those of Sai Yai Basin.

2.2 RECOMMENDATIONS

Accordingly to the above conclusions, the following recommendations can be made.

1. Although a feasibility study regarding development of the highest-priority Nam Sai Yai No.2 and No.3 Power Stations including No.2 Reservoir, has been conducted parallel with the present study, various investigations and studies should be continued for commencement of construction.

2. Regarding the Nam Sai Yai No.1 Power Station including No.1 Reservoir and No.4 Power Station, it is desirable to go on to a feasibility study. Ground surveys and geological investigations of the No.1 Reservoir Dam Site and the sites of the major structures of the No.1 and No.4 Power Stations are considered best for the moment (See App. Table 2-1).

3. For future development, it is necessary that the run-off observations be make at the Nam Sai Yai No.1 Reservoir Site, the Sai Yai side and the Sai Noi side of the Nam Sai Yai No.4 Reservoir, and on the Prachantakham River.

4. In order to carry out the agricultural development as quickly as possible, various investigations should be started. (See App. Table 2-1) Especially the development scheme of the entire Prachinburi River (Maenam Prachinburi), including the relationship with development of neighboring basins and of downstream areas of poor drainage, should be made clear.

5. Since it is impossible to achieve agricultural development by merely completing irrigation and drainage facilities, cultivation techniques including farm management suited to the new agricultural environment will have to be studied. Introduction of new fruit crops is effective, but since the initial investment is large and a high technical level of cultivation is necessary regarding the feasibility of introducing this type of crop.

CHAPTER 3

PROBLEMS AND NECESSITY FOR DEVELOPMENT

FIGURES

TABLES

CHAPTER 3

PROBLEMS AND NECESSITY FOR DEVELOPMENT

3.1 ELECTRIC POWER SITUATION

3.1.1 General Situation

The Nam Sai Yai Project area, as shown in Fig. 3-1, is located in between the capital Bangkok and Nakornrachasima (Korat), an important city of the Northeast Region. Being within 150 km of both, it is in a geographically favorable location.

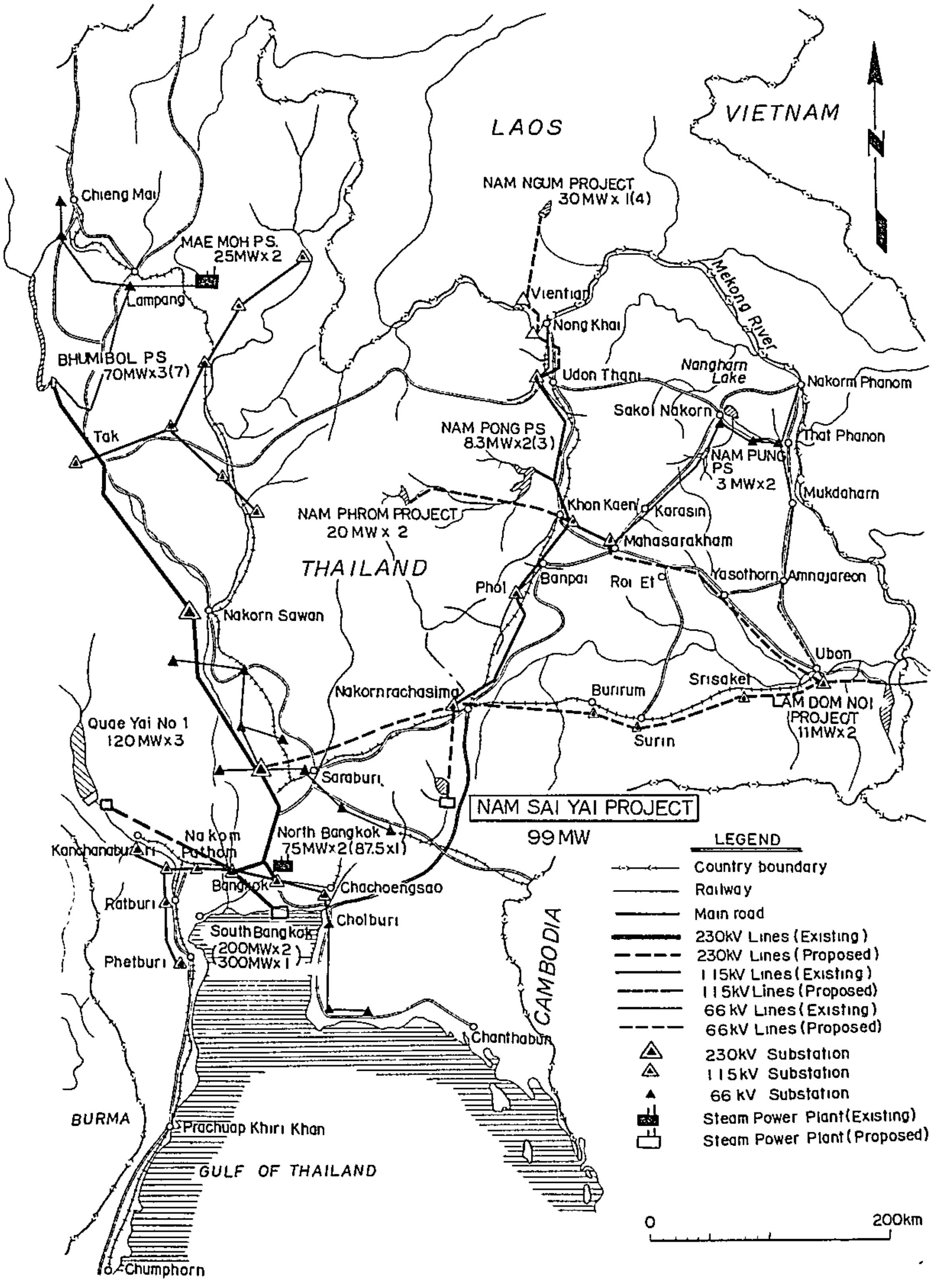
The power systems are presently being operated separately for the Norlitern Region, Central Region (supplied by YEA [*1]) and the Northeast Region (supplied by NEEA [*2]), but these are scheduled to be linked by interconnecting transmission lines by 1970. Therefore, the power produced at the Nam Sai Yai power stations will be supplied to all of the above areas.

The North and Central Regions and the Northeast Region differ considerably in social and economic conditions, the former requiring approximately 85% of the electric power of Thailand with the greatest advances in industrialization, while the latter is agricultural and least developed area in the country. The per capita income of the Northeast Region in 1963 was 1,299 Baht, only 30% of that of the Central Region. According to the 1966 statistics, power consumption per capita in the YEA System was 78 kWh/year against only 5 kWh/year in the NEEA System.

In recent years, the growth in power demand in Thailand has been quite prominent; especially in the last several years it has been astonishingly great. The growth rate in 1965 was 30.2% and in 1966, 29.9% which are exceedingly large figures. The reason for this great increase in power demand is thought to be the effective industrialization policy of Thailand reflecting the brisk economic activity of the country. During 1961 – 1963, the first half of the First Five-Year National Economic and Social Development Plan, the average growth rate in gross national product was 6% which exceeded the goal of 5%. In the Second Five-Year National Economic and Social Development Plan, the goal for growth rate is 8.5%. Although it cannot be denied that the war in Vietnam is producing a favorable effect on the economy of Thailand, since it is already on a solid footing, it is thought this growth rate will not be reduced even if the war should be terminated.

In the Northeast Region, NEEA is presently generating and transmitting power while PEA [*3] is distributing power and generating also by diesel on a small scale. NEA [*4] carries out development of hydroelectric power resources, but after completion of the project they are transferred to NEEA so that it does not become involved in operation and maintenance. The

FIG. 3-1 POWER SYSTEM OF NEEA AND YEA



Nam Pung Power Station (6 MW) of the Northeast Region completed in 1965 is an example of this type of arrangement. Added to the above, NEA is now planning to build Lam Dom Noi Power Station near Ubon in the southern part of the Northeast Region. Construction is scheduled to begin in 1968 and to be completed in 1970. Simultaneously, Ubon - Nakornrachasima and Ubon - Mahasarakham will be connected by 115 kV transmission lines to complete the transmission system of the Northeast Region. NEEA is presently supplying power to the Northeast Region with the Nam Pong and Nam Pung hydroelectric power stations and 115 kV transmission lines totalling 500 km as the nucleus. At the Nam Pong Power Station, a No.3 Unit has just been added, and as of May 1968 the station has reached its ultimate output of 25 MW.

To meet the increasing demand NEEA also constructed a 15 MW gas turbine power station at Nakornrachasima which went into operation in May 1968, after which another 15 MW gas turbine is planned to be built at Udon. Furthermore, Nam Phrom Power Station upstream of the Nam Pong Station is scheduled for start-up in 1972. The feasibility study was made by a Japanese Government survey team in 1967.

At the same time, the plan to connect the Angthong Substation of the YEA System and the Korat Substation of the NEEA System by a 115 kV, 2-circuit transmission line at the beginning of 1970 is being pushed ahead.

With the exception of small-scale diesel power plants, the supply capacity of the Northeast Region depends solely on reservoir-type hydroelectric power stations so that there is a shortage in the capacity to bear the base load part of demand. Upon connection of the YEA and NEEA Systems, the base load will be assumed by YEA's large-capacity thermal power stations through the tie line, and the most desirable form of operation which is the combination of hydro and thermal power will be realized. The reliability of the system will also be improved while it will become possible for cheap and abundant energy to be supplied. The interconnection will link all the power systems of Thailand will except for the Southern Region which is geographically isolated.

Construction of a 115 kV transmission line connecting Udon and Vientiane, the capital of Laos, is scheduled to be completed by the autumn of 1968. Electric power will be supplied from Thailand to Vientiane by this transmission line and it is also planned to supply power for construction of the Nam Ngum Project soon to be started.

The power transmitted by NEEA is supplied to PEA at the secondary side of substations and then distributed to consumers by PEA. PEA is planning to make connections between the NEEA System and isolated communities supplied by diesel power plants by extending its distribution lines. Since this expansion of the distribution network will provide power cheaper than that obtained from diesel plants, it is expected that new consumers will be added and energy consumption will be increased.

3.1.2 Load Forecast

(1) Supply Area

As previously stated, the YEA and NEEA Systems will be interconnected in 1970 and interchange of power will be accomplished by tie lines. Considering the present progress in survey work and anticipated construction periods, the start-up of the Nam Sai Yai power stations is expected to begin in 1973, so it will be possible to supply both the YEA and NEEA Systems with power produced at the Nam Sai Yai stations. Therefore, not only the NEEA supply area, but also the YEA area will be considered as the area to be supplied by the Nam Sai Yai Project.

(2) Load Forecasts Possible to Use

Concerning the NEEA supply area the "Nam Phrom Hydro-Electric Power Project Feasibility Report" submitted by the Japanese Government survey team in August 1967 gives a load forecast for 14 provinces of the Northeast Region, not including Loey, for a period of 15 years from 1967 to 1981. The demand of the Northeast Region is almost entirely for residential use. Growth rate was estimated at substations from past performance with local peculiarities, construction of distribution lines, industrial demand, demand of irrigation pump facilities, demand of military bases and Laotian demand all taken into consideration. According to the load forecast, the annual average growth rate for the 15-year period is 14.6% with peak demand increasing from 35.8 MW in 1968 to 120 MW in 1981.

On the load forecast of the YEA System, there is the "Feasibility Report, Quae Yai No.1 Hydroelectric Project" prepared by EPDC in March 1968. In this report, a long range forecast covering the period from 1971 to 1990 has been made for the 39 provinces in the YEA System service area.

In underdeveloped areas such as the Northeast Region, development of new power resources often brings about a sudden increase in demand, but in the YEA supply area which has a load center with a complete distribution network, the growth in power consumption will have a close connection with economic activities of the area. From this standpoint, the load forecast of the YEA area was based on the correlation between gross domestic product (GDP) and the amount of power consumption, as there is constant relation between power consumption per capita and GDP per capital which is recognized as applicable to countries throughout the world. Energy demand was based on growth in GDP assumed in the Second National Economic and Social Development Plan to which corrections were added according to year and locality and population growth rate.

These reports both present the most recent load forecasts for the supply areas, and as there have been no changes or modifications of a nature to fundamentally influence future demand estimates, the load forecast for the Nam Sai Yai Project Area can be obtained from the said reports. However, there have been minor changes made on the Nam Phrom Report fo which connection corrections will be necessary.

(a) The proposed output of the Nam Phrom Project has been changed from 56 MW to 40 MW and it is contemplated advancing start-up one year to 1972.

(b) The start-up of the Nam Ngum Project will probably be delayed one year to 1972.

(c) A gas turbine power plant (15 MW) is being planned to be provided at Udon in 1969.

(d) Construction of a cement plant is scheduled for 1972 at Choom Pae near Khon Kaen.

Regarding the load forecast of the YEA area, besides the abovementioned EPDC estimate, there is another forecast presented by AID which assumes a somewhat large demand than in the former. Although the reason for this discrepancy is not made clear, in the Quae Yai No.1 Feasibility Report, the safe side was taken and the AID load forecast was applied to the installations plan while the EPDC forecast was used in making an economic evaluation. The same method will be applied for purposes of this Report.

The 14 years until 1981 was taken as the period of load forecast for the Nam Sai Yai Project in order to match the period in the Nam Phrom Report. It is thought that a load forecast until 1981 will be adequate for the study of the scale, timing of development and effectivation of supply capacity.

(3) Load Forecast Results

The results after necessary corrections of the load forecasts in the beforementioned 2 reports are given in Fig. 3-2 and Table 3-1, 3-2.

According to Table 3-1, the kWh demand in 1973 will be 300 x 10^6 kWh for the NEEA System and 6,150 x 10^6 kWh for the YEA System, the demand of the former corresponding to approximately 5% of that of the latter. A peak demand of 83 MW in the NEEA System will be about 7% of that of 1,160 MW in the YEA System. Due to the small amount of industrial load, the load factor of the NEEA System is very low amounting 41.5% as compared with 61% of the YEA System. The exceedingly high growth rates for the NEEA System in 1968 and 1970 are due to the addition of the Nam Pung System and the Lam Dom Noi System which until then will not have been interconnected. The average growth rate of the NEEA System up to 1981 is 15% or an increase of 7.1 times in 14 years. In the YEA System, the kWh demand will be increased by 8 times in the 14 years with an annual average growth rate of 16%. In view of the fact that the past growth rates in the developing nations of the ECAFE Area average between 10 and 20% annually, the above growth rates may be judged to be

FIG. 3-2 LOAD FORECAST FOR THE YEA 1968 – 1981

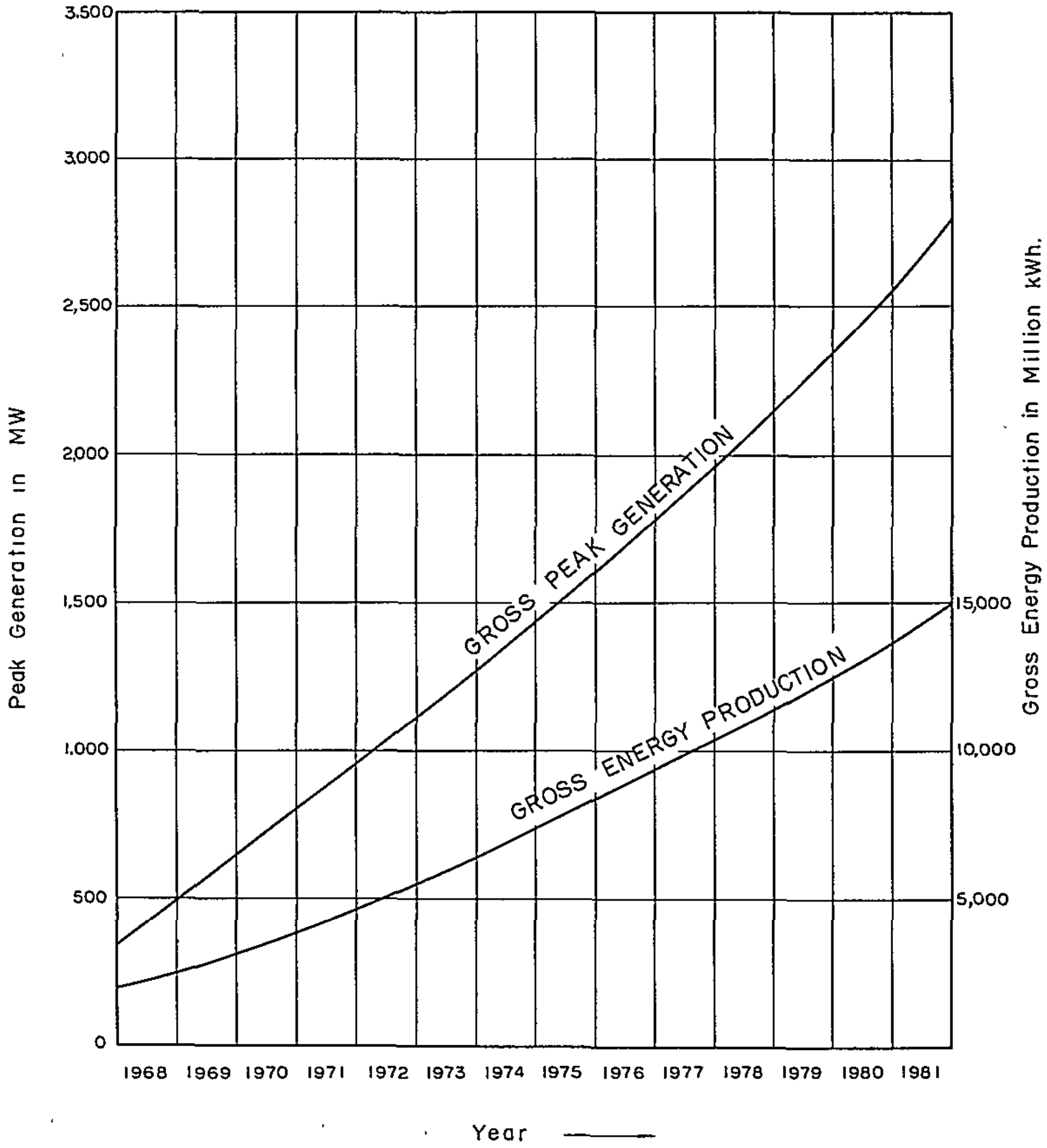


TABLE 3-1 LOAD FORECAST FOR THE YEAR 1968–1981 (AID LOAD FORECAST FOR YEA SYSTEM)

Fiscal Year	YEA System				NEEA System				Total			
	Energy Demand	Energy Growth Rate	Load Factor	Power Demand	Energy Demand	Energy Growth Rate	Load Factor	Power Demand	Energy Demand	Energy Growth Rate	Load Factor	Power Demand
	(million kWh)	(%)	(%)	(MW)	(million kWh)	(%)	(%)	(MW)	(million kWh)	(%)	(%)	(MW)
1968	2,330	28.7	59.5	447	123	76.0	38.0	37.1	2,453	30.5	57.8	484
1969	2,933	25.9	59.5	563	157	27.7	38.0	47.2	3,090	26.0	57.8	610
1970	3,631	23.8	60.0	691	220	40.0	38.6	65.0	3,851	24.7	58.2	756
1971	4,441	22.3	60.0	845	254	15.5	41.0	71.0	4,695	22.0	58.5	916
1972	5,275	18.8	60.5	995	280	10.2	41.3	77.5	5,555	18.5	59.0	1,073
1973	6,150	16.6	61.0	1.160	300	7.0	41.5	82.7	6,450	16.0	59.2	1,243
1974	7,047	14.6	61.0	1,319	322	7.2	42.0	87.5	7,369	14.3	60.0	1,407
1975	7,947	12.8	61.5	1,487	348	8.0	42.6	93.2	8,295	12.5	60.0	1,580
1976	8,897	12.0	61.5	1,651	371	6.7	42.6	99.5	9,268	11.7	60.5	1,751
1977	9,898	11.3	62.0	1,837	395	6.4	43.3	104	10,293	11.0	60.5	1,941
1978	10,929	10.4	62.0	2,012	420	6.3	43.2	111	11,349	10.5	61.1	2,123
1979	11,996	9.8	62.5	2,209	446	6.0	43.4	116	12,442	9.5	61.0	2,325
1980	13,154	9.7	62.5	2,403	474	6.5	44.3	122	13,628	9.5	61.7	2,525
1981	14,400	9.5	63.0	2,630	496	4.4	43.9	129	14,896	9.3	61.7	2,759

TABLE 3-2 LOAD FORECAST FOR THE YEAR 1968–1981 (EPDC LOAD FORECAST FOR YEA SYSTEM)

Fiscal Year	YEA System				NEEA System				Total			
	Energy Demand	Energy Growth Rate	Load Factor	Power Demand	Energy Demand	Energy Growth Rate	Load Factor	Power Demand	Energy Demand	Energy Growth Rate	Load Factor	Power Demand
	(million kWh)	(%)	(%)	(MW)	(million kWh)	(%)	(%)	(MW)	(million kWh)	(%)	(%)	(MW)
1968	2,253	24.4	59.5	432	123	76.0	38.0	37.1	2,376	26.0	57.7	469
1969	2,755	22.3	59.5	529	157	27.7	38.0	47.2	2,912	22.8	57.7	576
1970	3,313	20.3	60.0	630	220	40.0	38.6	65.0	3,533	21.5	58.0	695
1971	3,933	18.7	60.5	748	254	15.5	41.0	71.0	4,187	18.5	58.4	819
1972	4,582	16.5	60.5	865	280	10.2	41.3	77.5	4,862	16.3	58.9	943
1973	5,242	14.4	61.0	989	300	7.0	41.5	82.7	5,542	14.0	58.8	1,076
1974	5,970	13.9	61.0	1,117	322	7.2	42.0	87.5	6,302	13.8	59.7	1,205
1975	6,776	13.5	61.5	1,268	348	8.0	42.6	93.2	7,124	13.0	59.8	1,361
1976	7,657	13.0	61.5	1,421	371	6.7	42.6	99.5	8,028	12.7	60.3	1,521
1977	8,561	11.8	62.0	1,589	395	6.4	43.3	104.	8,956	11.6	60.5	1,693
1978	9,468	10.6	62.0	1,743	420	6.3	43.2	111	9,888	10.4	60.9	1,854
1979	10,453	10.4	62.0	1,925	146	6.0	43.4	116	10,899	10.1	61.0	2,041
1980	11,530	10.3	62.5	2,106	474	6.5	44.3	122	12,004	10.0	61.5	2,228
1981	12,602	9.3	62.5	2,302	496	4.4	43.9	129	13,098	9.0	61.5	2,431

reasonable.

As for per capita power consumption, assuming the population growth rates to be 3.2% and 3.48% for the NEEA System area and the YEA System area respectively, they will respectively be 23 kWh and 219 kWh in 1973 and 30 kWh and 404 kWh in 1981.

3.1.3 Supply and Demand Balance and Necessity for Development

(1) Case of Interconnection of YEA and NEEA Systems

In the systems related to the Nam Sai Yai Project, December is the month of critical condition, when the smallest difference between supply capacity and demand exists. Therefore the supply and demand balance was examined according to the daily load curve in December.

Concerning supply capacity, 2 existing hydroelectric plants, Nam Pung and Nam Pong, and 2 future plants, the Lam Dom Noi and Nam Phrom, as well as gas turbine plants of 30 MW were considered in the NEEA System. In the YEA System, Bhumibol, Phasom, Quae Yai No.1, Quae Yai No.2 and Quae Yai No.3 were considered as hydroelectric plants according to the YEA's expansion plan. For thermal plants, besides the existing North Bangkok (75 MW x 2), North Bangkok Extension, and South Bangkok (No.1 to No.3), a nuclear plant of 400 MW, another proposed thermal power plants (300 MW x 3) and gas turbine plants (15 MW x 4) were considered.

As is seen in the kW balance in Fig. 3-3, a requirement in supply capacity will occur in this system in 1972 and the requirement in power will not be overcome until South Bangkok No.3 (300 MW) is added to the system in 1975.

As described in 6.8, the Nam Sai Yai Project are exceedingly economical hydroelectric sites, and it will be advantageous to develop them at the earliest possible date to aid in eliminating the abovementioned power requirement.

Generally, the sequence of the stage development of the project shall be made in accordance to the priority of each stages. The priority of each stages for the Nam Sai Yai Project is as shown in 6.5. Taking the shortest construction periods conceivable at this time, Nam Sai Yai No.2 Power Station can be put into service in 1973 and Nam Sai Yai No.3 in 1974. Fig. 3-3 illustrates the state of operation of the Nam Sai Yai stations when they are put into operation according to this schedule. This shown that the Nam Sai Yai stations, as in the cases of the Bhumibol and Phasom Power Stations, will bear peak load to cover a portion of the shortage in supply capacity.

The entire output of the Nam Sai Yai No.2 and No.3 Power Stations will become effective 3 years after start-up. Development of No.4 and No.1 Power Stations shall be made after the construction of the said No.2 and No.3 Power Stations.

(2) Case of Independent NEEA System

In the preceding section, the timing of development was described in the case the YEA and NEEA service areas are considered as the unit demand areas. In such a case, the load forecast for the Northeast Region in fundamentally based on the Nam Phrom Feasibility Report. However, there is a possibility that the demand in the Northeast Region will grow at a higher rate and it is though necessary to consider such a case also. The following may be considered as causes of such large increase in demand.

(a) From 1968 to 1972, new power resources like gas turbines, Lam Dom Noi and Nam Phrom will be developed in the NEEA System with accompanying strengthening of the distribution network so that an extremely abrupt increase in demand is conceivable.

(b) The present electricity rate for residential use is exceedingly high in the PEA System, but with the power development of (a) above, there is a great possibility that this rate can be lowered to stimulate an increase in demand.

(c) Since the power consumption level in the NEEA System up to the present is extremely low, there is still very much room for increase.

Fig. 3-5 and Table 3-3 give the load forecast for the NEEA System based on the above position. This is a macroscopic view of the NEEA System alone in which case from 1973 when the Nam Sai Yai Project will have come into service and at which time an integrated system including the Lam Dom Noi System will have been established. The demand growth is estimated from past performance with the abovementioned factors taken into consideration resulting in an average kWh growth rate of 19.4% between 1968 and 1981 which is considerably higher than the 15% of the Nam Phrom Feasibility Report. The peak demand is estimated from the assumptions for overall losses and load factor. Based on this load forecast and using the same method as in the Nam Phrom Feasibility Report, the timing of start-up of the Nam Sai Yai Project was studied. In other words, it was regarded that new supply capacity would be added to the system at the time the power received from the YEA System through the tie line exceeds the reserve supply capacity of the system in this case only NEEA system was considered to be supply area. The result of this study is given in Fig. 3-6.

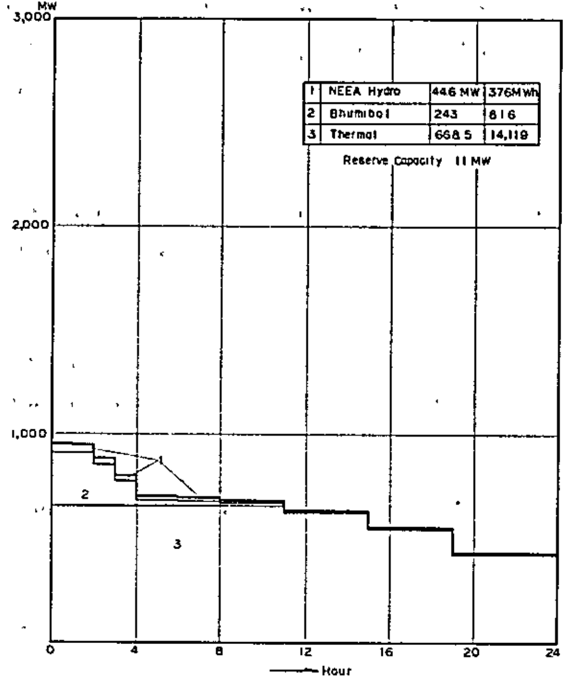
In the above case, the supply capacity, besides existing hydro power plants, was considered to consist of Lam Dom Noi, Nam Phrom, and tie line. Reserve Supply Capacity was considered to be comprised of gas turbines (Korat and Udon) and 1 unit of 8.3 MW at Nam Pong.

The reason is that gas turbine plants will be forced to operate at a high load factor due to shortage in supply capacity until the tie line with the YEA System is completed, but after completion, from the nature of gas turbine operation and economical aspects, it is judged better to operate them as auxiliary facilities. As for Nam Pong Power Station, it is considered that it will not be operated at the design capacity factor of 28% (3-unit operation) due to discharge for irrigation purposes and it was assumed this station would be operated using 2 units with one unit held in reserve.

FIG. 3-3 (1) KW BALANCE (A.I.D.)

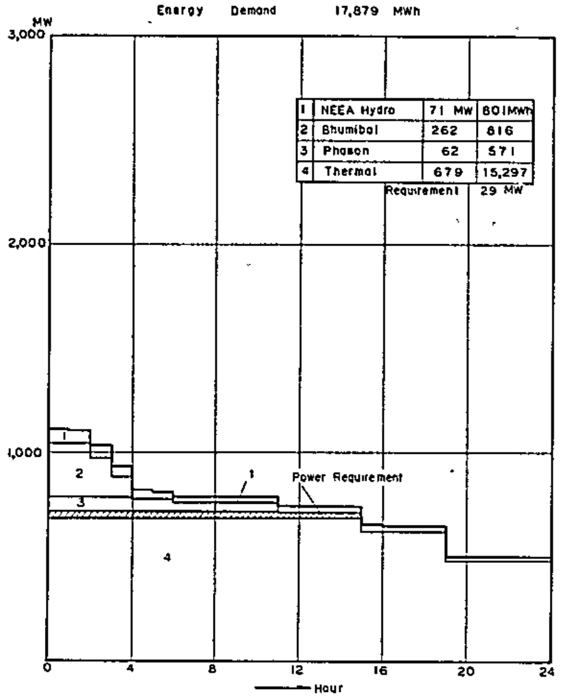
1971

Max Peak Demand 956 MW
Energy Demand 15,311 MWh



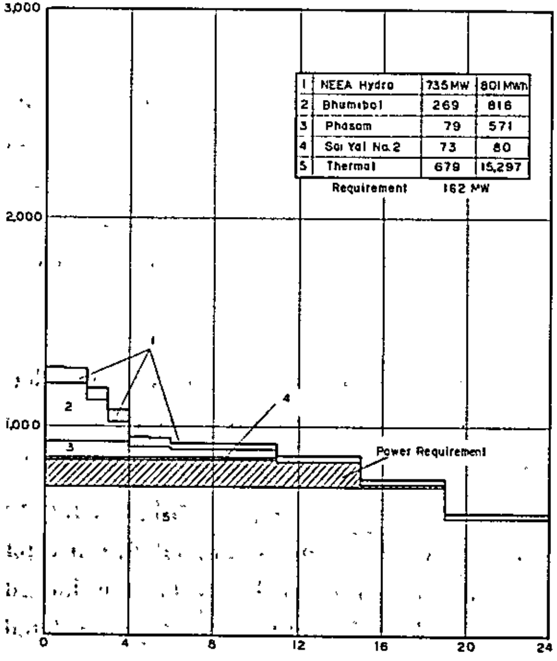
1972

Max Peak Demand 1,114.5 MW
Energy Demand 17,879 MWh



1973

Max Peak Demand 1,278.7 MW
Energy Demand 20,691 MWh



1974

Max Peak Demand 1,443 MW
Energy Demand 23,306 MWh

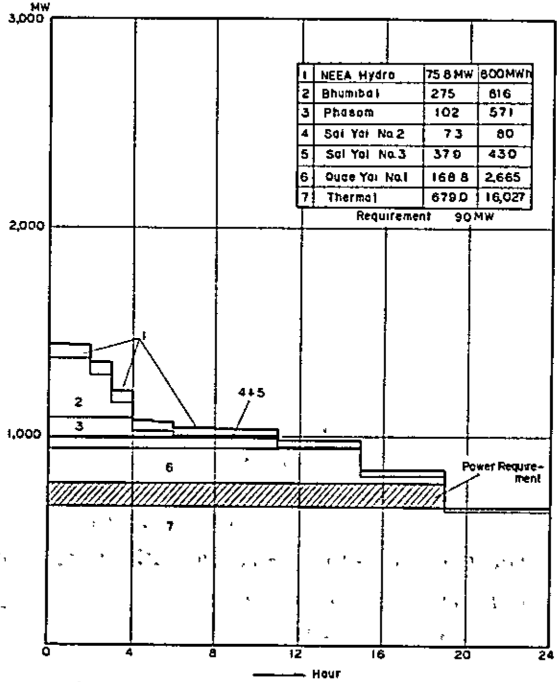
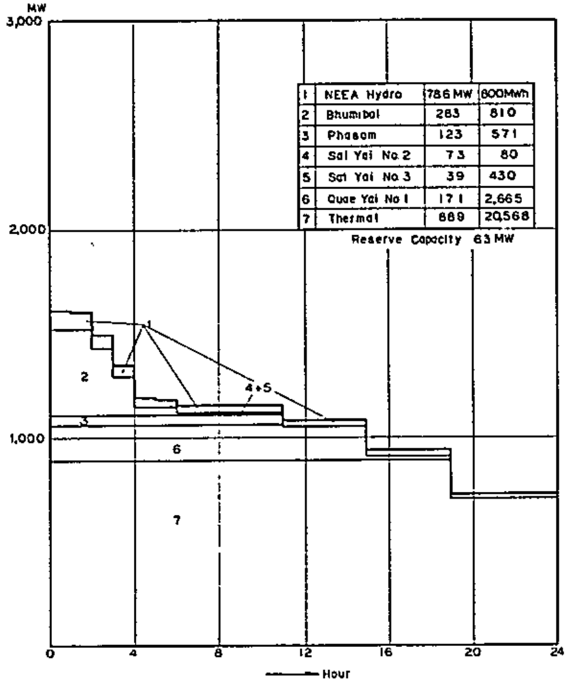


FIG. 3-3 (2) KW BALANCE (A.I.D.)

1975

Max. Peak Demand 1,601 MW
Energy Demand 25,930 Mwh

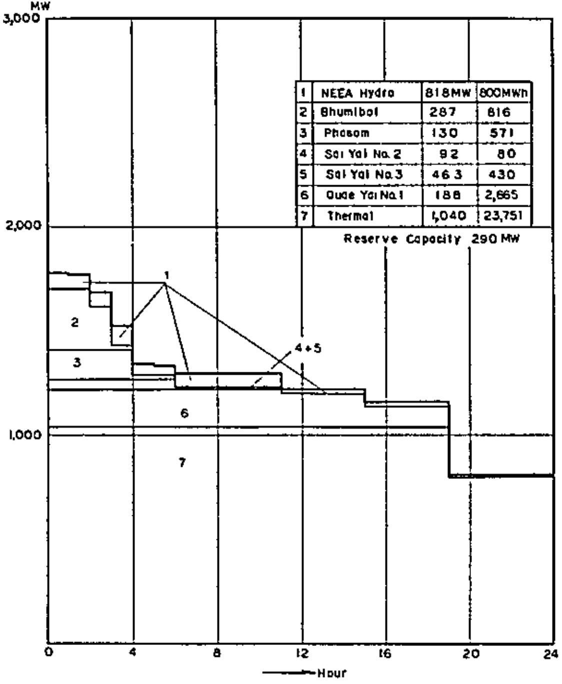


1	NEEA Hydro	786 MW	800Mwh
2	Bhumibol	283	810
3	Phasom	123	571
4	Sai Yai No 2	73	80
5	Sai Yai No 3	39	430
6	Quae Yai No I	171	2,665
7	Thermal	889	20,568

Reserve Capacity 63 MW

1976

Max Peak Demand 1,781 MW
Energy Demand 29,104 MWh

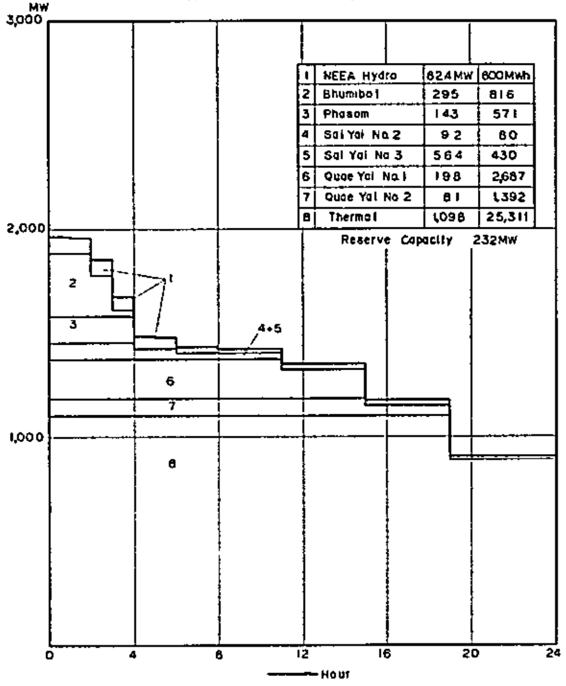


1	NEEA Hydro	818MW	800MWh
2	Bhumibol	287	816
3	Phasom	130	571
4	Sai Yai No. 2	92	80
5	Sai Yai No.3	463	430
6	Quae Yai No.1	188	2,665
7	Thermal	1,040	23,751

Reserve Capacity 290 MW

1977

Max Peak Demand 1963 MW
Energy Demand 32,086 MWh

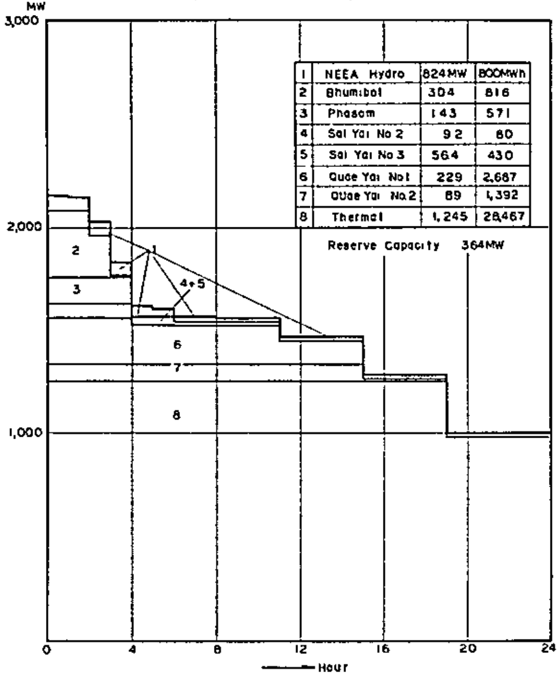


1	NEEA Hydro	824MW	800MWh
2	Bhumibol	295	816
3	Phasom	143	571
4	Sai Yai No 2	92	80
5	Sai Yai No 3	564	430
6	Quae Yai No.1	198	2,687
7	Quae Yai No 2	81	1,392
8	Thermal	1,098	25,311

Reserve Capacity 232MW

1978

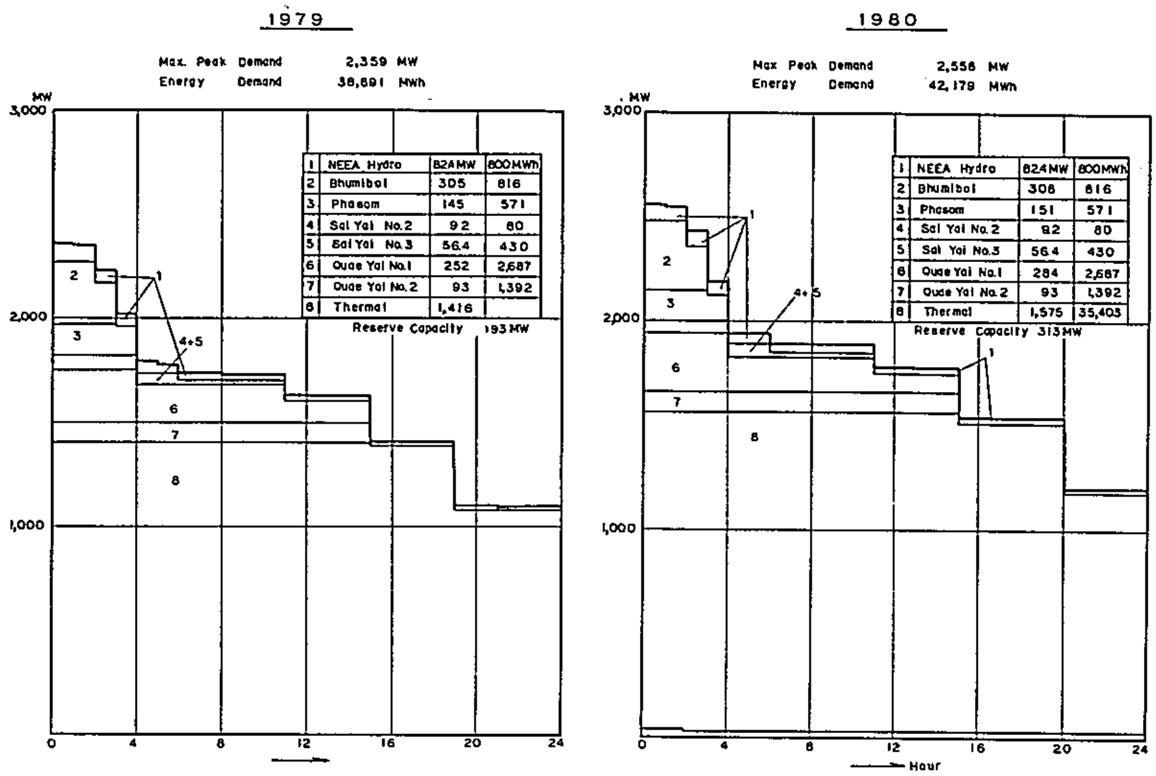
Max Peak Demand 2,157 MW
Energy Demand 25,243 MWh



1	NEEA Hydro	824MW	800MWh
2	Bhumibol	304	816
3	Phasom	143	571
4	Sai Yai No 2	92	80
5	Sai Yai No 3	564	430
6	Quae Yai No1	229	2,687
7	Quae Yai No.2	89	1,392
8	Thermal	1,245	28,467

Reserve Capacity 364MW

FIG. 3-3 (3) KW BALANCE (A.I.D.)



1979

Max. Peak Demand 2,359 MW
Energy Demand 38,691 MWh

1	NEEA Hydro	824MW	800MWh
2	Bhumibol	305	816
3	Phasom	145	571
4	Sai Yai No. 2	92	80
5	Sai Yai No. 3	56.4	430
6	Quae Yai No. 1	252	2,687
7	Quae Yai No. 2	93	1,392
8	Thermal	1,416	

Reserve Capacity 193 MW

1980

Max Peak Demand 2,556 MW
Energy Demand 42,179 MWh

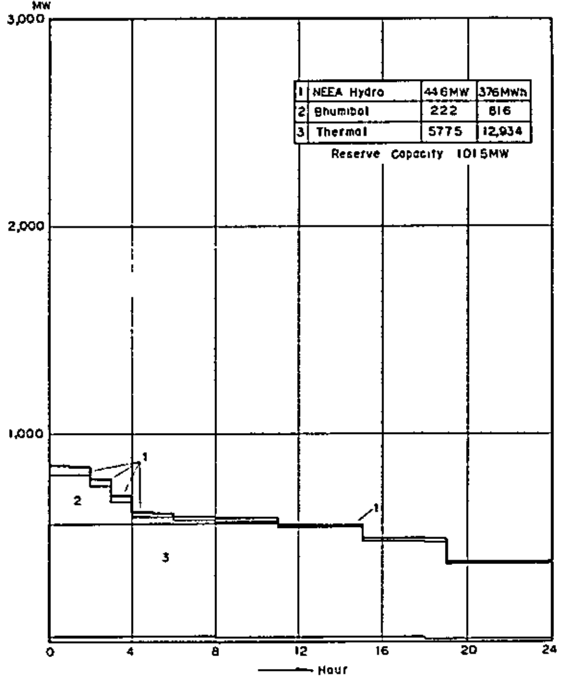
1	NEEA Hydro	824MW	800MWh
2	Bhumibol	308	616
3	Phasom	151	571
4	Sai Yai No. 2	82	80
5	Sai Yai No. 3	56.4	430
6	Quae Yai No. 1	284	2,687
7	Quae Yai No. 2	93	1,392
8	Thermal	1,575	35,403

Reserve Capacity 313 MW

FIG. 3-4 (I) KW BALANCE (E.P.D.C.)

1971

Max Peak Demand 844 MW
Energy Demand 13,478 MWh

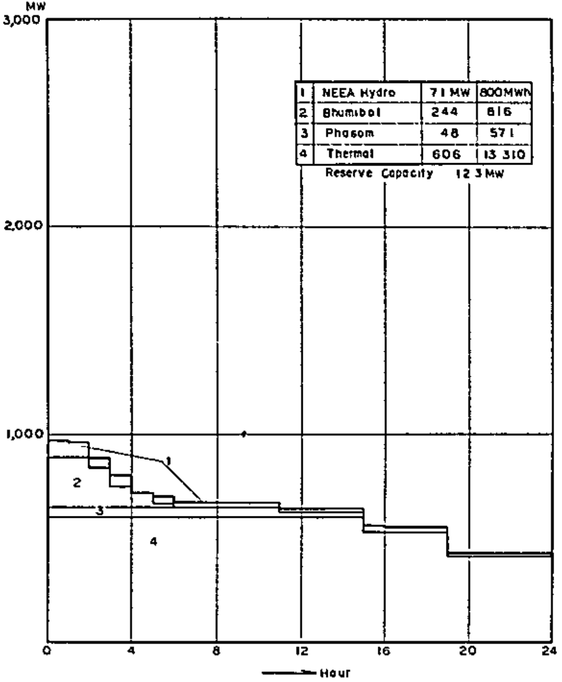


1	NEEA Hydro	44 6MW	376MWh
2	Bhumibol	222	816
3	Thermal	5775	12,934

Reserve Capacity 101 5MW

1972

Max Peak Demand 918 5 MW
Energy Demand 15,498 MWh

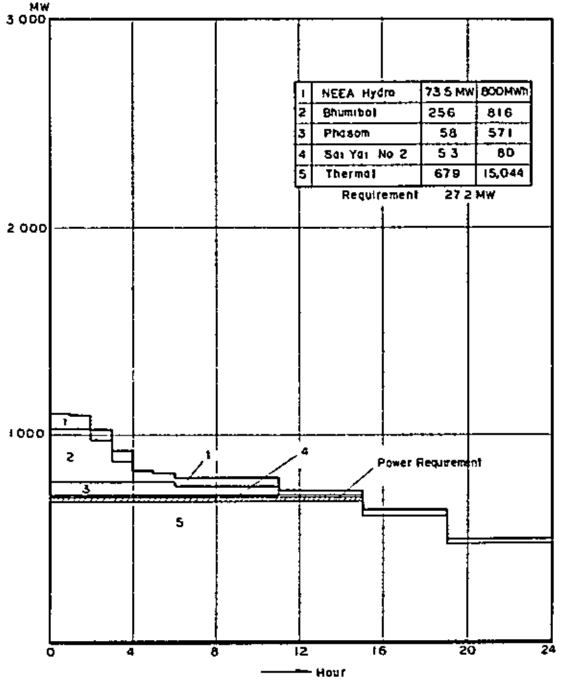


1	NEEA Hydro	7 1 MW	800MWh
2	Bhumibol	244	816
3	Phasom	48	57 1
4	Thermal	606	13 310

Reserve Capacity 12 3 MW

1973

Max Peak Demand 1,099 MW
Energy Demand 17,725 MWh

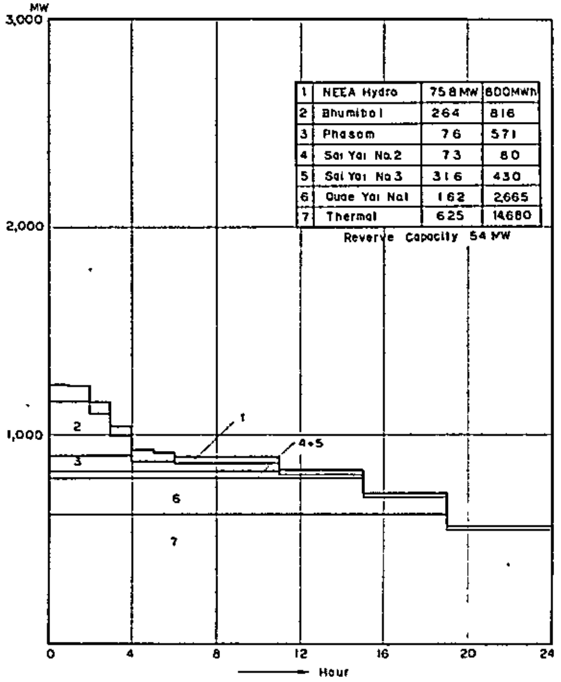


1	NEEA Hydro	73 5 MW	800MWh
2	Bhumibol	256	816
3	Phasom	58	571
4	Sai Yai No 2	5 3	80
5	Thermal	679	15,044

Requirement 27 2 MW

1974

Max Peak Demand 1,242 MW
Energy Demand 20,043 MWh



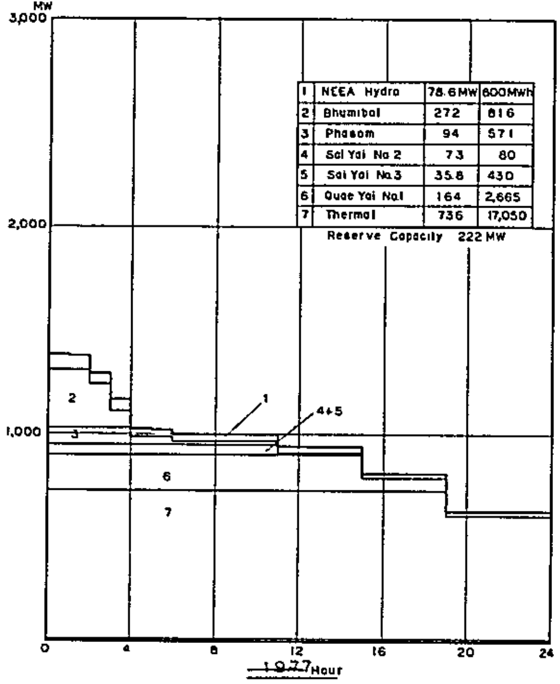
1	NEEA Hydro	75 8 MW	800MWh
2	Bhumibol	264	816
3	Phasom	7 6	571
4	Sai Yai No.2	7 3	8 0
5	Sai Yai No 3	31 6	430
6	Quae Yai Nai	162	2,665
7	Thermal	625	14680

Reverve Capacity 54 MW

FIG. 3-4 (2) KW BALANCE (E.P.D.C.)

1975

Max Peak Demand 1,387 MW
Energy Demand 22,414 Mwh

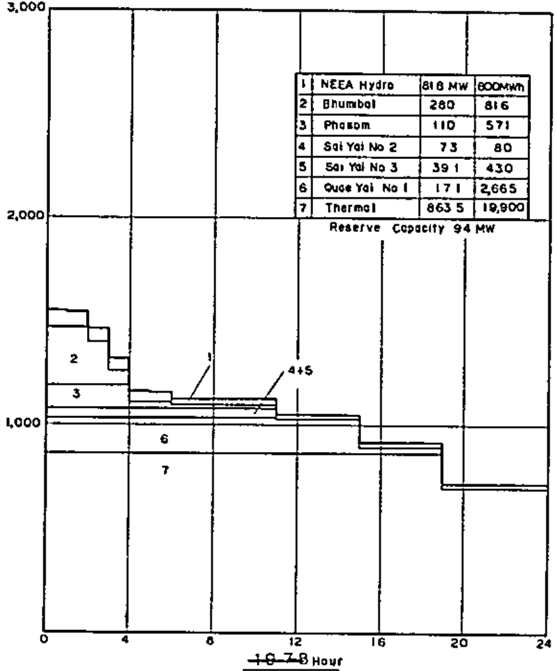


1	NEEA Hydro	78.6 MW	600 MWh
2	Bhumibol	272	816
3	Phasom	94	571
4	Sai Yai No 2	7.3	80
5	Sai Yai No.3	35.8	430
6	Quae Yai No.I	164	2,665
7	Thermal	736	17,050

Reserve Capacity 222 MW

1976

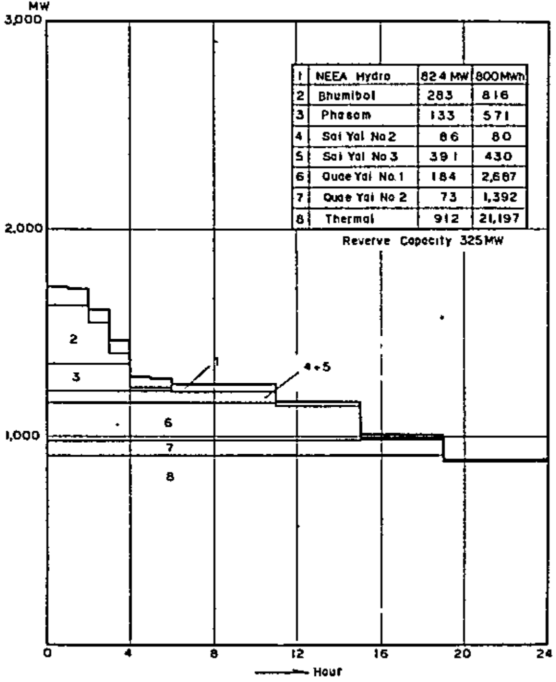
Max Peak Demand 1,553 MW
Energy Demand 25,268 MWh



1	NEEA Hydro	81.6 MW	600 MWh
2	Bhumbol	280	816
3	Phasom	110	571
4	Sai Yai No 2	7.3	80
5	Sai Yai No 3	39.1	430
6	Quae Yai No I	171	2,665
7	Thermal	863.5	19,900

Reserve Capacity 94 MW

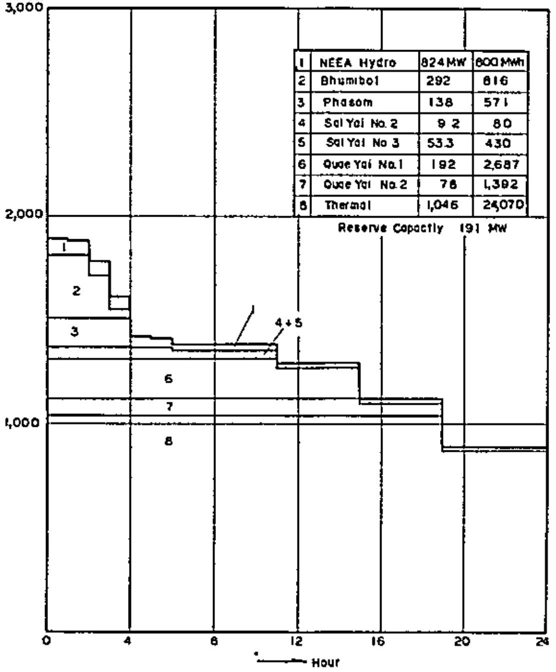
Max. Peak Demand 1,715 MW
Energy Demand 27,972 MWh



1	NEEA Hydro	82.4 MW	800 MWh
2	Bhumibol	283	816
3	Phasom	133	571
4	Sai Yai No 2	8.6	80
5	Sai Yai No 3	39.1	430
6	Quae Yai No.1	184	2,687
7	Quae Yai No 2	73	1,392
8	Thermal	912	21,197

Reverve Capacity 325 MW

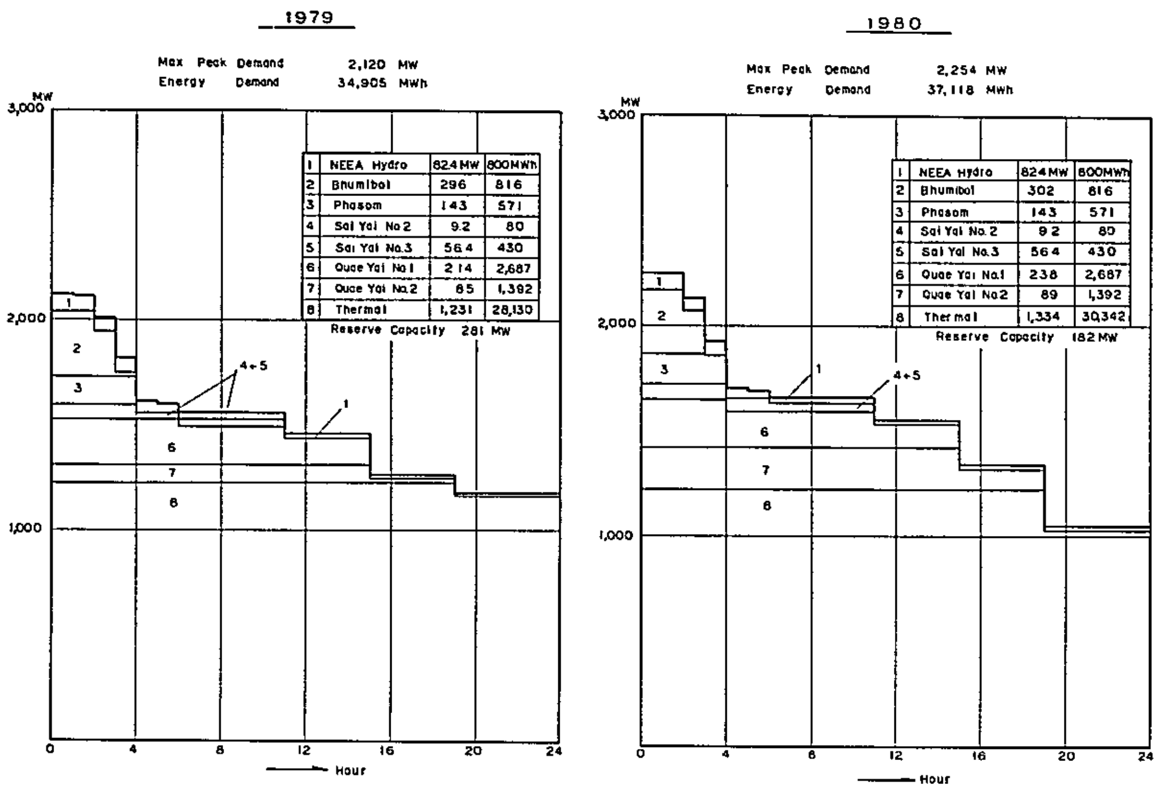
Max Peak Demand 1,890 MW
Energy Demand 30,846 MWh



1	NEEA Hydro	82.4 MW	800 MWh
2	Bhumibol	292	816
3	Phasom	138	571
4	Sai Yai No. 2	9.2	80
5	Sai Yai No 3	53.3	430
6	Quae Yai No.1	192	2,687
7	Quae Yai No.2	78	1,392
8	Thermal	1,046	24,070

Reserve Capactly 191 MW

FIG. 3-4 (3) KW BALANCE (E.P.D.C.)



1979

Max Peak Demand 2,120 MW
Energy Demand 34,905 MWh

1	NEEA Hydro	824 MW	800MWh
2	Bhumibol	296	816
3	Phasom	143	571
4	Sai Yai No 2	9.2	80
5	Sai Yai No.3	56.4	430
6	Quae Yai No I	214	2,687
7	Quae Yai No.2	85	1,392
8	Thermal	1,231	28,130

Reserve Capacity 281 MW

1980

Max Peak Demand 2,254 MW
Energy Demand 37,118 MWh

1	NEEA Hydro	824MW	800MWh
2	Bhumibol	302	816
3	Phasom	143	571
4	Sai Yai No. 2	9 2	80
5	Sai Yai No.3	56 4	430
6	Quae Yai No.1	238	2,687
7	Quae Yai No2	89	1,392
8	Thermal	1,334	30,342

Reserve Capacity 182 MW

FIG. 3-5 LOAD FORECAST FOR THE NORTHEAST REGION (1968–1981)

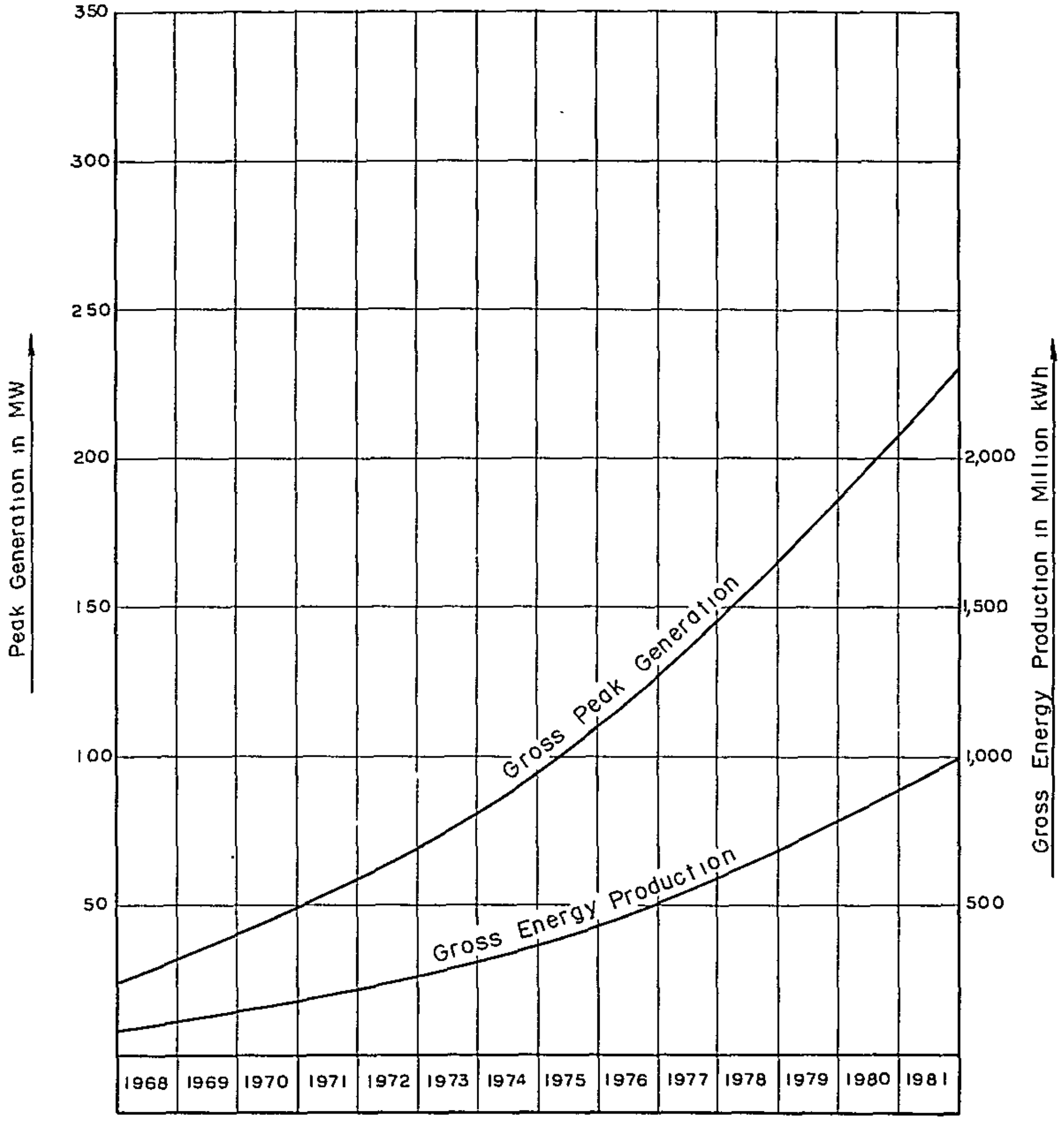
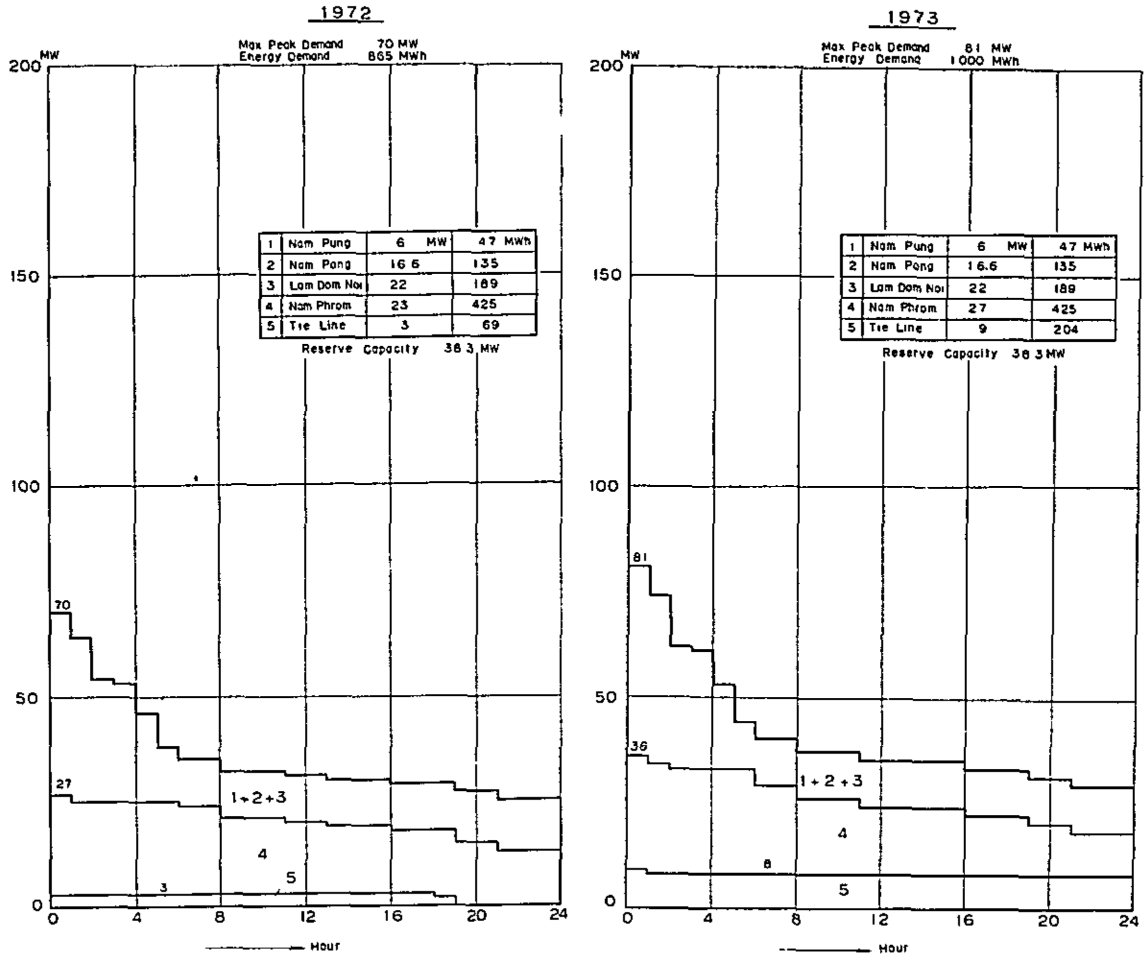


TABLE 3-3 LOAD FORECAST FOR NORTHEAST REGION (1968 - 1981)

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Energy Demand at Customer (million kWh)	77.5	99	126	158	193	232	279	329	388	450	523	594	680	760
Increasing rate (%)	30	27.5	27.5	25	22.5	20	20	18	18	16	16	14	14	12
Loss Factor (%)	30	30	29	28	27	26	25	25	24	24	24	23	23	23
Energy Demand at Power plant (million kWh)	111	142	178	220	265	314	372	440	510	592	688	771	884	986
Load Factor (%)	36	37	37	38	38	39	39	40	40	41	41	42	42	43
Peak Demand (MW)	31.0	38.4	48.1	58.0	69.8	80.5	95.4	110	128	145	168	183	210	229
Estimated Population (thousand)	11,125	11,481	11,850	12,230	12,620	13,020	13,440	13,870	14,310	14,770	15,245	15,733	16,240	16,760
Energy Generation per Capita (MWh)	10	12.5	15	18	21	24	28	32	36	40	45	49	55	59
Energy Consumption per Capita (kWh)	7	8.6	10.5	13	15	18	21	24	27	31	34	38	42	45

FIG. 3-6 (1) ESTIMATED LOAD BALANCE



1972

Max Peak Demand 70 MW
Energy Demand 865 MWh

1	Nam Pung	6 MW	47 MWh
2	Nam Pong	16 6	135
3	Lam Dom Noi	22	189
4	Nam Phrom	23	425
5	Tie Line	3	69

Reserve Capacity 38 3 MW

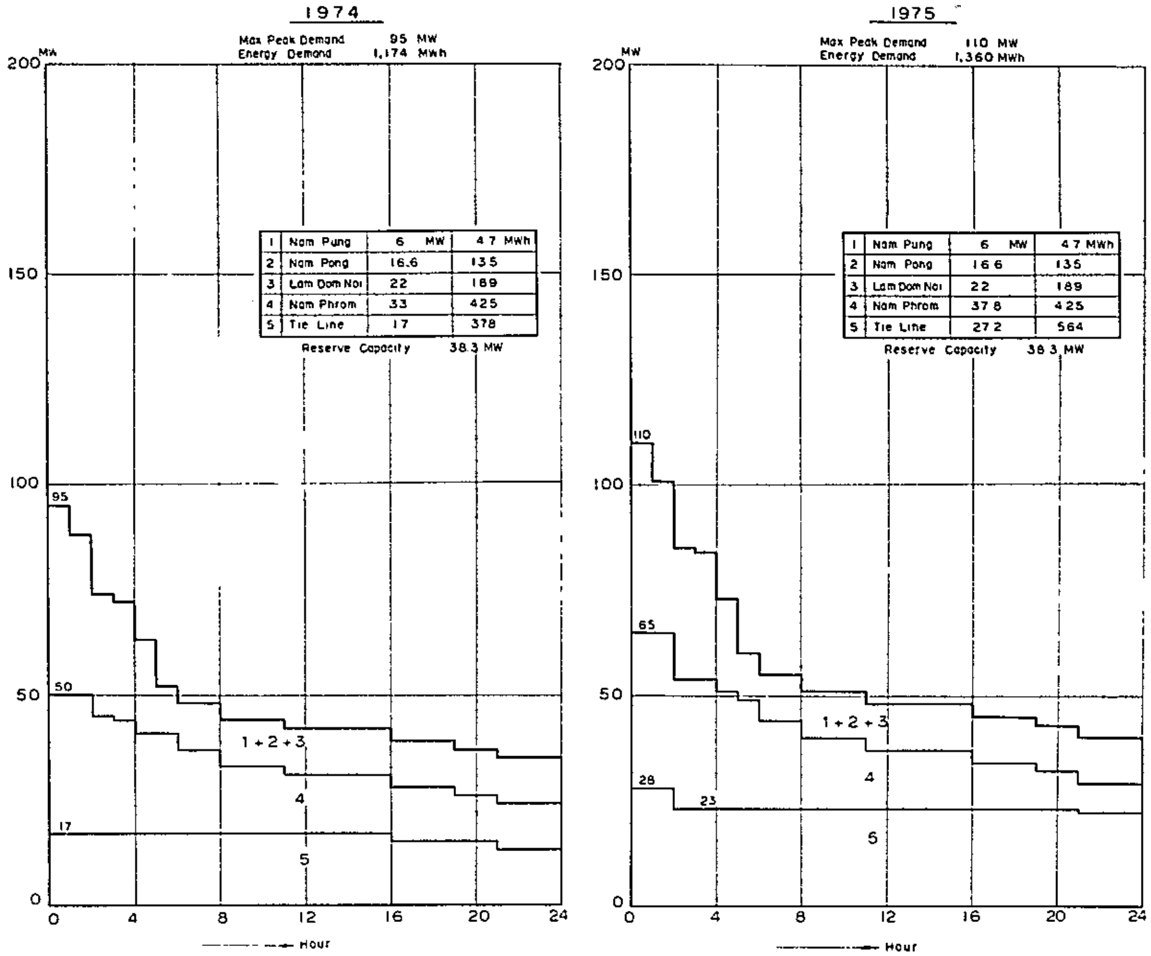
1973

Max Peak Demand 81 MW
Energy Demand 1 000 MWh

1	Nam Pung	6 MW	47 MWh
2	Nam Pong	16.6	135
3	Lam Dom Noi	22	189
4	Nam Phrom	27	425
5	Tie Line	9	204

Reserve Capacity 38 3 MW

FIG. 3-6 (2)   ESTIMATED LOAD BALANCE



1974

Max Peak Demand 95 MW
Energy Demand 1,174 MWh

1	Nam Pung	6 MW	4 7 MWh
2	Nam Pong	16.6	135
3	Lam Dom Noi	22	189
4	Nam Phrom	33	425
5	Tie Line	17	378

Reserve Capacity 38.3 MW

1975

Max Peak Demand 110 MW
Energy Demand 1,360 MWh

1	Nam Pung	6 MW	4 7 MWh
2	Nam Pong	16 6	135
3	Lam Dom Noi	22	189
4	Nam Phrom	37 8	425
5	Tie Line	27 2	564

Reserve Capacity 38 3 MW

FIG. 3-6 (3) - ESTIMATED LOAD BALANCE

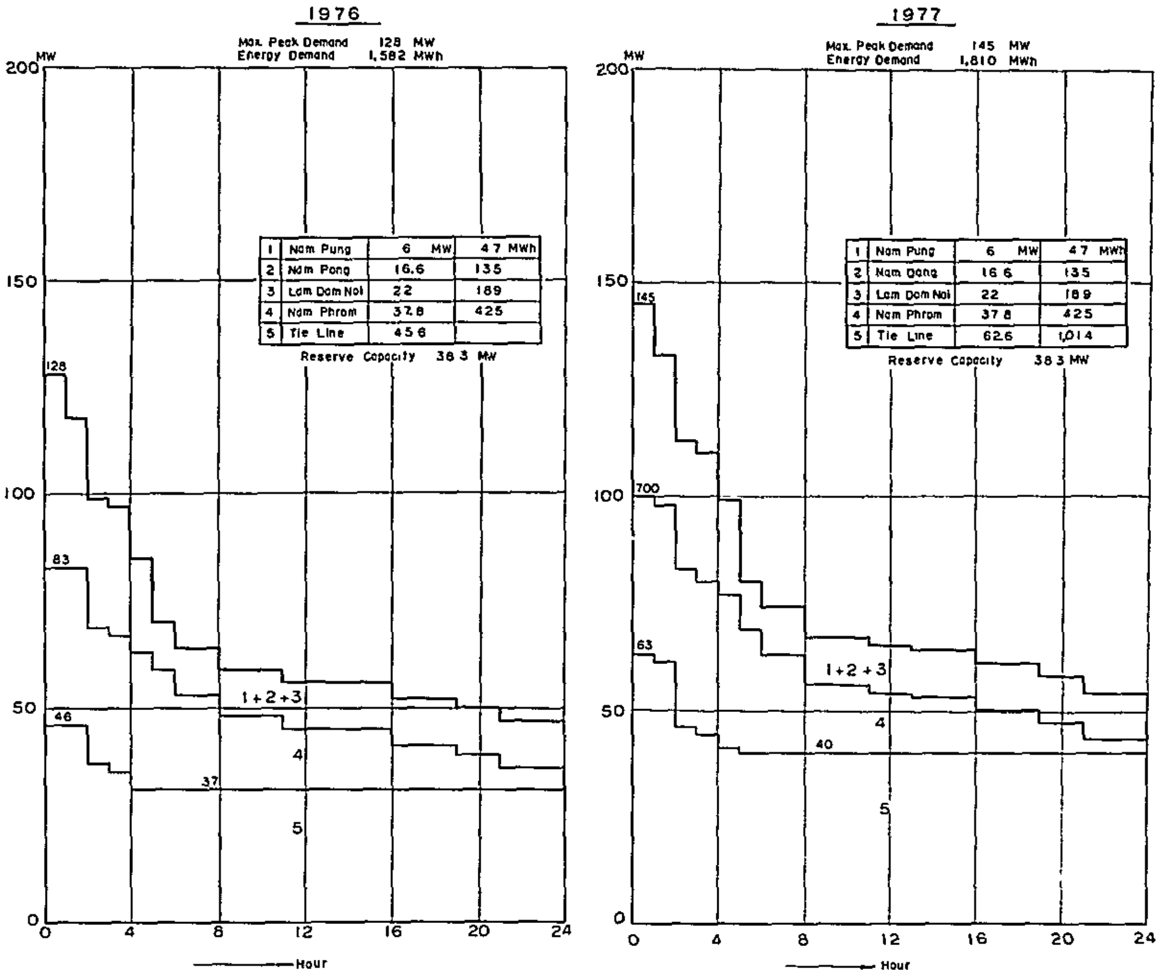
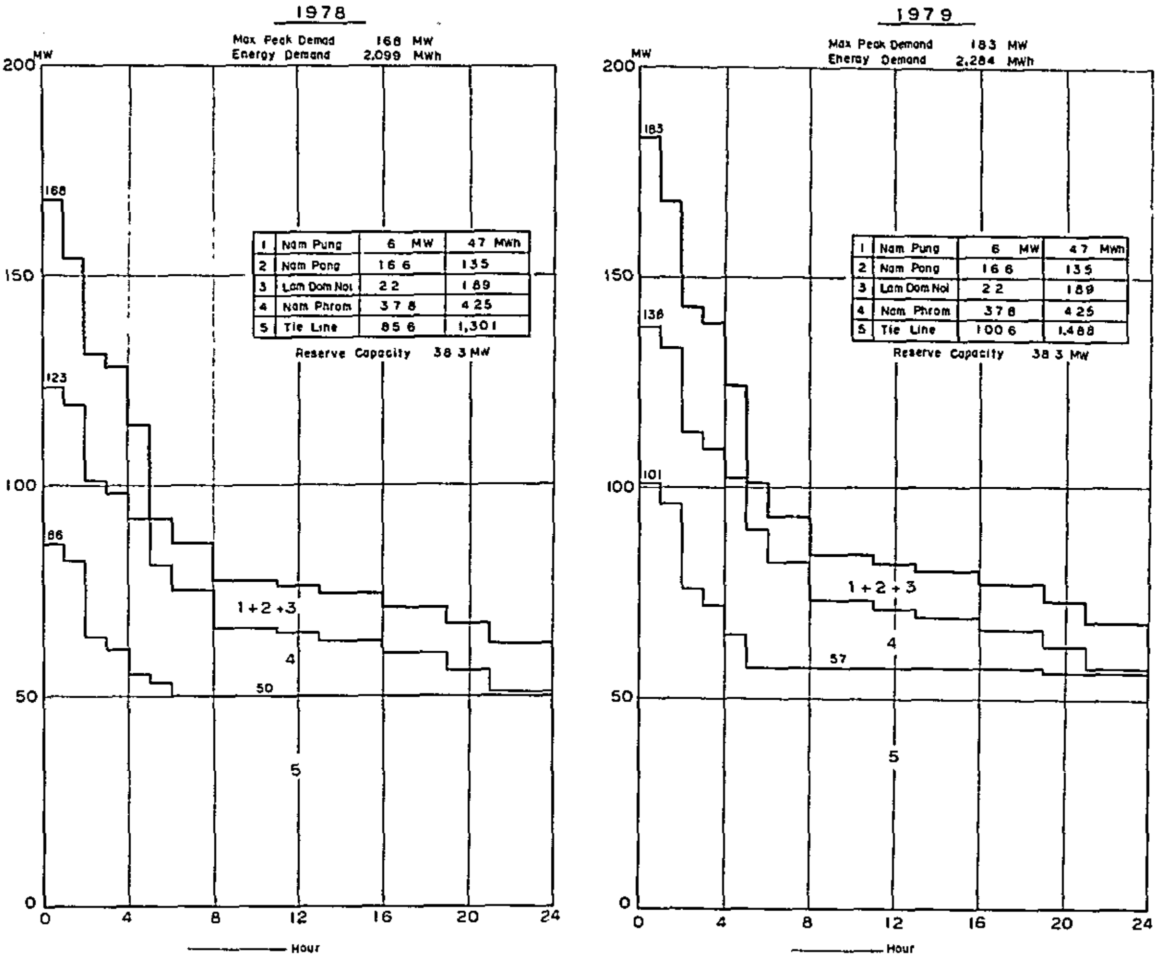


FIG. 3-6 (4) ESTIMATED LOAD BALANCE



1978

Max Peak Demad 168 MW
Energy Demand 2,099 MWh

1	Nam Pung	6 MW	47 MWh
2	Nam Pong	16 6	135
3	Lam Dom Noi	2 2	1 89
4	Nam Phrom	3 7 8	4 25
5	Tie Line	85 6	1,301

Reserve Capacity 38 3 MW

1979

Max Peak Demand 183 MW
Energy Demand 2,284 MWh

1	Nam Pung	6 MW	47 MWh
2	Nam Pong	16 6	135
3	Lam Dom Noi	2 2	189
4	Nam Phrom	37 8	4 25
5	Tie Line	100 6	1,488

Reserve Capacity 38 3 MW

There is a possibility to forecast surplus capacity at Nam Ngum Power Station after supplying to its own services area and this surplus capacity could be considered as a reserve capacity. But the reliability of this surplus is very low because of the capacity is not decided distinctly at the present stage it would be dangerous to base an installation plan on.this and it has been omitted from the present considerations.

Study of the kW balance Fig. 3-6 reveals that in 1976 and 1977 power received over the YEA tie line will be 46 MW and 63 MW respectively. Since the total reserve supply capacity of the system of 38.3 MW will be greatly exceeded after that, it will become necessary to complete the Nam Sai Yai No.1 to No.4 Power Stations between 1976 and 1980.

If the NEEA System is considered independently and there is a fairly rapid growth in power demand, recommended that start-up of the Nam Sai Yai Project be around 1976. Therefore, as started in 3.1.3 (1), if development is begun around 1973, such a situation can be adequately met and the power supply in the NEEA System can be carried out in a stable manner.

NOTE:

*1 YEA (Yanhee Electricity Authority)

YEA is supplying power to the Central and Northern Regions of Thailand. As the Bangkok District which comprises 80% of the national demand is in its supply area, YEA is the central system in the electric power industry of Thailand. The facilities of this Authority include Bhumibol Hydroelectric Power Station (280 MW, final output 420 MW), North Bangkok Thermal Power Station (150 MW, being expanded), transmission lines and substations of 230 kV, and the installed capacity amounted to 430 MW in 1967.

Power stations presently under construction are Phasom Hydro (125 MW x 2), South Bangkok Thermal (200 MW x 2) and North Bangkok Thermal (87.5 MW).

YEA sells power to MEA*5 and PEA. The energy production in 1967 was 1,810 x 10^6 kWh.

*2 NEEA (North East Electricity Authority)

NEEA supplies electric power to the Northeast Region of Thailand.

*3 PEA (Provincial Electricity Authority)

PEA distributes power to all of Thailand except the capital area. It buys power wholesale from YEA, NEEA and LA*6 in their respective areas, but at communities not connected with these systems, PEA itself owns diesel plants for power generation and distribution.

*4 NEA (National Energy Authority)

NEA is subordinate to the Ministry of National Development. Besides its chief responsibilities of establishing electric power development plans and supervising the operations of electric power corporations, it also carries out development of power resources.

*5 MEA (Metropolitan Electricity Authority)

MEA is a power distribution authority which supplies power to Greater Bangkok, i,e. the City of Bangkok, Thonburi and environs, and obtains its power from YEA at a primary substation. Approximately 80% of the total demand of Thailand is concentrated in this area.

*6 LA (Lignite Authority)

LA is responsible for generation of power using lighnite at Mae Moh. (12.5 MW) and Krabi (40 MW) power plants.

3.2 AGRICULTURAL SITUATION

Bestowed with favorable temperatures and utilizing the large quantity of rainfall provided by the southwest monsoon from June to September, the rice cropping which has been developed around the Central Plain has sustained the economy of Thailand for the past century. The agricultural population occupies 75% of the entire nation, and until very recently rice comprised more than one-third of all exports.

However, due to recent economic development and the rapid growth in population, the domestic demand for rice has increased and not only have exports been reduced, but the ability to meet of the future requirements of the country is thought to be in danger. Moreover, the rapid population growth and food shortage in Asia bring to bear the urgency of a policy for increasing the production of food in Thailand.

Changwad Prachinburi in the project area is an agricultural province of the southeastern part of the Central Plain. Productivity is low: the average yield per unit area for the past 7 years was 1.2 ton/ha which is much lower than the national average of 1.43 ton/ha and the Central Plain average of 1.65 ton/ha. (See App. Table 3-1) Such problems as the form of land ownership and methods of product distribution may be among the reasons for poor productivity, but it is thought the direct and indirect harm inflicted by inadequate irrigation and drainage facilities is of the greatest consequence.

Although approximately 1,400 mm of water are necessary for the growth of paddy rice, rainfall during the growing period is 640 mm to 1,310 mm; moreover, distribution of rainfall during this period is not uniform so that on the whole there is not enough water. (See App. Fig. 3-1) When rainfall is intensified, the paddy rice is often submerged by flood and washed away.

In this manner, direct damage to cultivated land is inflicted by irregular rainfall where irrigation and drainage facilities are imperfect. There is also indirect damage which should not escape attention, such as the inability to cultivate at the proper time, and the prorogation in introduction of high-yield species requiring much fertilizer from the fear of drought although the soil is infertile. (See 6.4.1)

The result is that the farmer is mired in a low-level and unstable agriculture with loss of incentive so that modernization of agriculture is hindered. In view of this present situation, the first step for promotion of agriculture is to expedite improvements for ground works for agricultural production in which irrigation and drainage facilities are a major part.

CHAPTER 4

PRESENT STATE OF DEVELOPMENT AREA

FIGURES

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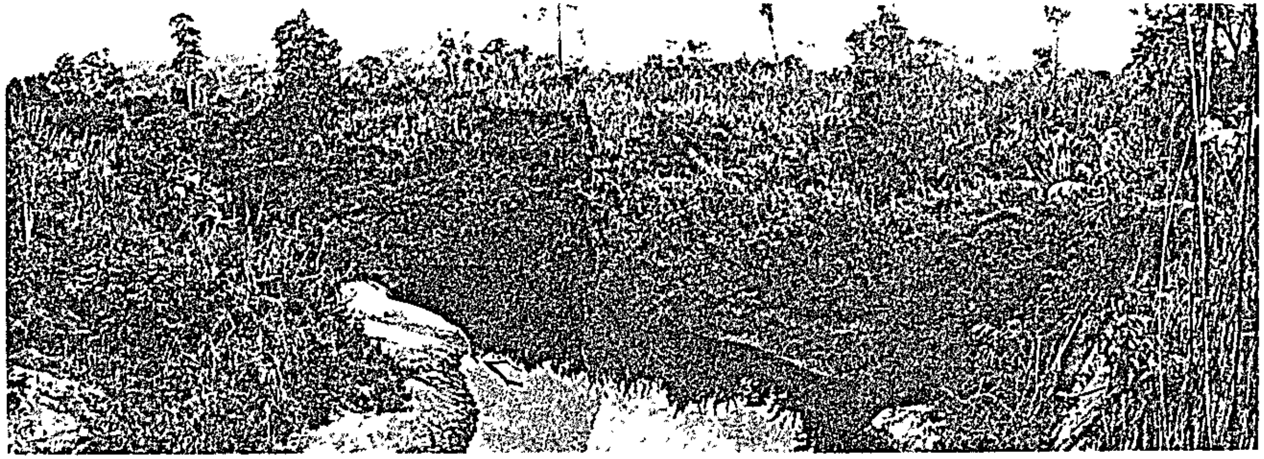
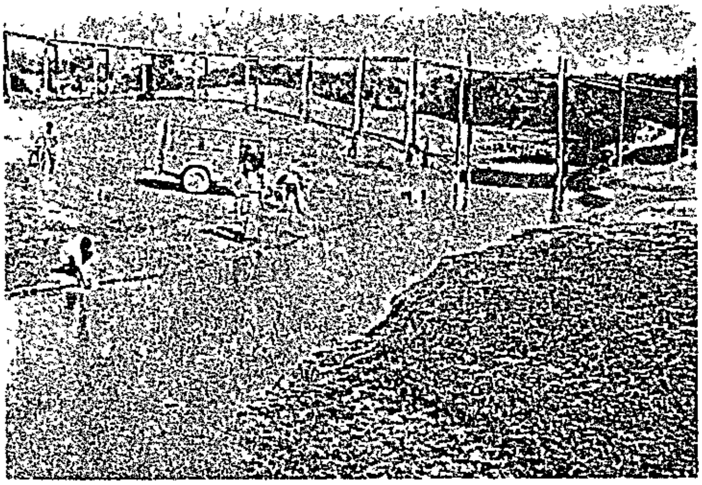
Sai Yai River
(Approximately 1 Km upstream of the Confluence of the Sai Yai and Sai Noi Rivers.)



Sai Noi River
(Approximately 1 Km upstream of the Confluence of the Sai Yai and Sai Noi Rivers.)

Prachantakham No. 2
Dam Site



Prachantakham River
(Near the Ban Ko Kancho.)

CHAPTER 4

PRESENT STATE OF DEVELOPMENT AREA

4.1 OUTLINE

The Sai Yai River (Maenam Sai Yai), Sai Noi River (Huai Sai Noi) and Prachantakham River (Maenam Prachantakham) catch the waters of the adjoining area of the southwestern part of the Korat Plateau and the northern mountainous area of Changwad Prachinburi to join the Prachinburi River (maenam Prachinburi) which further downstream becomes the Bang Pa Kong River (Maenam Bang Pa Kong). The total catchment area of these rivers at their debouchment to the plain is 722 sq.km (See General Plan) and is covered by jungle.

The basal rock of the Korat Plateau is a formation of the Korat series belonging to the Mesozoic Era and consists mainly of sandstone with some distribution of conglomerate and red shale.

The elevation of the catchment area is 1,000 m at the highest point and 35 to 40 m at the transition to the plain area where the bottom of the rivers are at an elevation of 5 to 8 m.

The rivers are generally steep in the mountainous areas, but at places on the way downstream, there are stretches at which the currents are slowed. (See General Plan) Rainfall is heavy in the upper river basin (approximately 2,000 mm annually) as compared with other parts of the central and northeastern Thailand, and the average annual discharge is 30 c.m.s. per 1,000 sq.km. (See App. Fig. 4-15)

The rivers after emerging from the mountains change to gentle gradients and meander downstream. The gradients until confluence with the Prachinburi River are approximately 1/4,000 to 1/3,000 for the Hanuman River (Maenam Hanuman; downstream of the confluence of Sai Yai and Sai Noi), and approximately 1/5,000 to 1/4,000 for the Prachantakham River.

The land of downstream area is generally flat, except for the right bank of the Hanuman River where there are some undulations. Near the confluences with the Prachinburi River it is completely flat being inundated in the rainy season. Although there are some sparse forests, the greater part of the land is used for paddy rice, with fields mainly distributed along the right bank of the Hanuman River.

4.2 HYDROLOGY

4.2.1 Climate and Precipitation

The project area has a tropical monsoon climate. From November to February, the area has extremely little rainfall and moderate temperatures due to the northeast monsoon which brings cold, dry air from the China mainland. March and April is the hot season, attributable to the retreat of the northeast monsoon. From May to September, the southwest monsoon prevails and brings a stream of warm humid air from the Indian Ocean, and rainfall is abundant. October is the period of transition from the southwest to the northeast monsoon season.

Fig. 4-1 shows the monthly mean, maximum and minimum temperature at Prachinburi from 1951 to 1966. .The annual mean temperature, monthly maximum temperature and monthly minimum temperature at the project site averaged per 16 years are 28.5 ° C, 36.1° C and 18.6° C respectively. The highest temperature recorded at the project site is 40.6° C, and the lowest is 10.8 °C. Fig. 4-2 shows the distribution of monthly rainfall at observatories in the Sai Yai River Basin, on the basis of a fifteen-year average.

The isohyetal map of annual rainfall in the project area prepared on the basis of data from 1953 to 1967 is shown in Fig. 4-3. According to this map, the annual rainfall of the Sai Yai River Basin is approximately 2,200 mm in the uppermost reaches and approximately 2,100 mm in the entire basin including Sai Noi River.

It will be noted from these figures that the temperature and precipitation in the project area are characteristic of tropical monsoons.

FIG. 4-1 MONTHLY TEMPERATURE OF PRACHINBURI
(1952–1965)

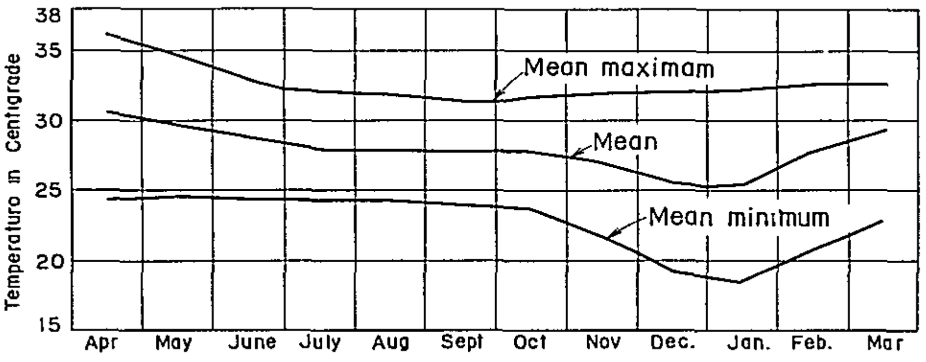


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FIG. 4-2 MONTHLY RAINFALL IN SAI YAI BASIN
(1953–1967)

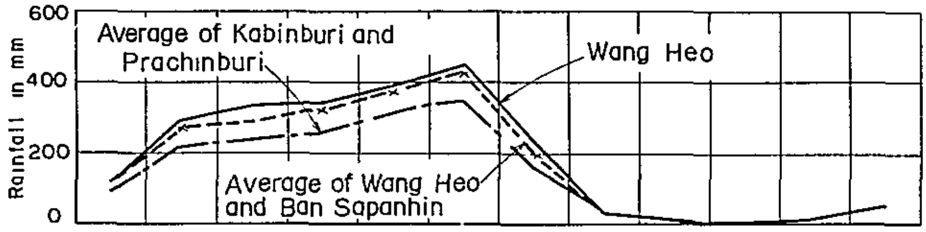
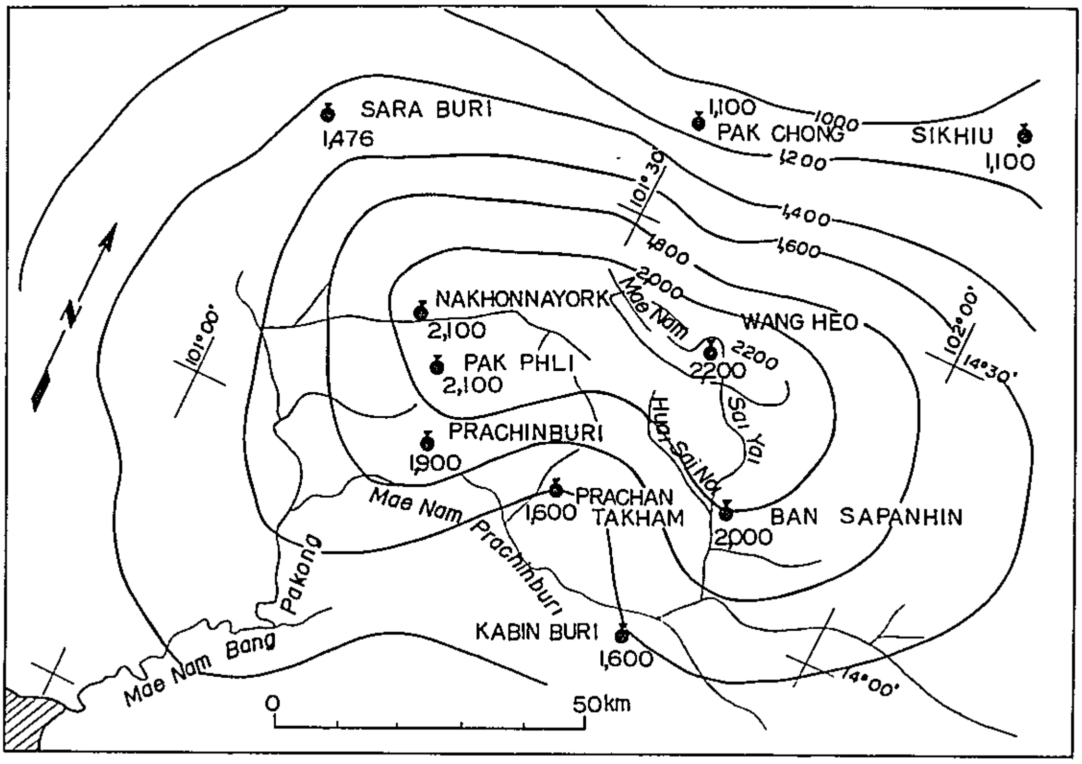


FIG. 4-3   ISHOHYETAL MAP OF ANNUAL RAINFALL IN MM (1953 – 1967)



4.2.2 River Run-off and Flood Discharge

Run-off and rainfall data in the project area are available for the past four years at Wang Heo (or Kao Keep Samut) and Ban Sapanhin. Furthermore, rainfall data at four stations in the vicinity are available from 1953 to 1967. Based on these data, elaborated studies have been carried out to assess river run-off and flood discharge of the Nam Sai Yai Project.

The details are given in Appendix Hydrological Study and Data. The annual run-off throughout the four years is 956 mm above Wang Heo and 1,027 mm above Ban Sapanhin, and the annual rainfall is 2,435 mm above Wang Heo and 2,115 mm above Ban Sapanhin.

According to the above figures, the run-off coefficient is approximately 40% above Wang Heo and approximately 49% above Ban Sapanhin. These values are quite reasonable considering that the water loss in the Sai Yai River Basin above Wang Heo is much greater than in the basin of the Sai Yai River between Wang Heo and Ban Sapanhin and Sai Noi River, due to the river bed gradient being is gentler than that of the latter.

Besides, since evapotranspiration in the project area, based on evaporation data or the Blaney-Criddle Formula, is estimated to be approximately 1,300 mm, the run-off of Wang Heo and Ban Sapanhin is quite reliable.

Furthermore, according to studies on the long-term hydrological cycles in the country based on precipitation records from the past fifteen years, the period from 1953 to 1967, for which the estimated run-off at the project sites are available, is considered to be the average hydrological condition, and it also includes a critical dry period of several years.

Monthly run-off at the project sites from 1953 to 1967, which provide the basis for reservoir operation study and energy production estimation, are calculated as follows.

(1) Run-off at dam sites in the basin above Wang Heo

$$Qd = \frac{Ad}{Aw} \cdot Qw$$

where:
Qd = Monthly run-off of proposed dam site
Qw = Monthly run-off of Wang Heo as shown in App. Table 4-3.
Ad = Catchment area of proposed dam site
Aw = Catchment area of Wang Heo, 295 sq. km

(2) Run-off at dam sites in the basin between Wang Heo and Ban Sapanhin

$$Qd = \frac{Ad}{Ab - Aw} \cdot (Qb - Qw)$$

where:
Qd = Monthly run-off of proposed dam site
Qb = Monthly run-off of Ban Sapanhin as shown in App. Table 4-4
Qw = Monthly run-off of Wang Heo as shown in App. Table 4-3
Ad = Catchment area of proposed dam site
Ab = Catchment area of Ban Sapanhin, 636 sq.km
Aw = Catchment area of Wang Heo, 295 sq. km

(3) Run-off at dam site in the Prachantakham River Basin

$$Qd = \frac{Ad}{Ab} \cdot Qb$$

where:
Qd = Monthly run-off of proposed dam site
Qb = Monthly run-off of Ban Sapanhin
Ad = Catchment area of proposed dam site
Ab = Catchment area of Ban Sapanhin, 636 sq. km

The maximum flood flow ever recorded at Wang Heo on the Sai Yai River was 180 c.m.s. on August 18, 1966, and on the same day the flood discharge at Ban Sapanhin was 270 c.m.s. as shown in App. Fig. 4-13.

This flood corresponds to a 20 year frequency flood as follows:

TABLE 4 - 1 FLOOD FREQUENCY OF WANG HEO

Return Period in Year	Peak Flood in c.m.s.	Total Flood Volume in million cu.m.
20	180	21
50	260	26
100	300	30
200	390	38
1,000	580	54
10,000	770	70

The flood hydrograph after completion of the reservoir in the basin will be described in 6.2.4.

CHAPTER 5

SCHEME OF DEVELOPMENT

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CHAPTER 5

SCHEME OF DEVELOPMENT

In hydroelectric power development in a tropical savannah climate region where there is a clear distinction between rainy and dry seasons, the provision of reservoirs is essential.

As the dam sites for hydroelectric power development of the Sai Yai River system, the narrows 3 km upstream of the confluence with the Sai River (to be called R_1) and the narrows 20 km further downstream (to be called R_2) were selected. In order to utilize the head of approximately 690 m for power generation, 3 proposals were first considered for the route of the waterways. (See Fig. 5-1)

1. Conduct water along the Sai Yai River. (Plan A)
2. Conduct water to the Sai Noi River from R_2 and then along the Sai Noi. (Plan B)
3. Conduct water from R_2 to the Sai Noi River and then to the Prachantakham River. (Plan B')

Of these 3 proposals, the amount of water which can be utilized, the length of the waterway and the total head are all roughly the same, and it was thought there would not be very much difference in the construction costs for power and irrigation facilities and in the benefits derived.

However, in the case of the Plan B', the altered discharge conditions of the downstream Hanuman River would greatly affect boat navigation and intake of domestic water, while there would be increased construction costs for the downstream part of the Prachantakham River it has a gentle gradient and small capacity of river channel. Therefore, this proposal was eliminated.

After detailed examinations were made of the Plans A and B, it was found that the Plan B involved difficulties in construction and that the Plan A was superior in respect to construction costs. (See Table 5-1, App. Table 5-1) As a result, it was decided the Sai Yai River should be developed along its valley.

Effective utilization of the water resources of the remaining Sai Noi River was studied at this point. In this area, a site topographically suited for construction of a reservoir could not be found and diversion to the adjoining Prachantakham River was considered. It was proposed to conduct the water of the upstream 67 sq.km of the Sai Noi River to the Prachantakham River, and utilize it by combining with the water of the reservoirs which are located at the confluence of the Phnok Nam and Noi Rivers and 3 km downstream of the confluence on the upstream of Prachantakham River. Therefore, besides the Sai Yai River, development of the Prachantakham River was considered in this Report.

FIG. 5-1 ALTERNATIVE SCHEMES

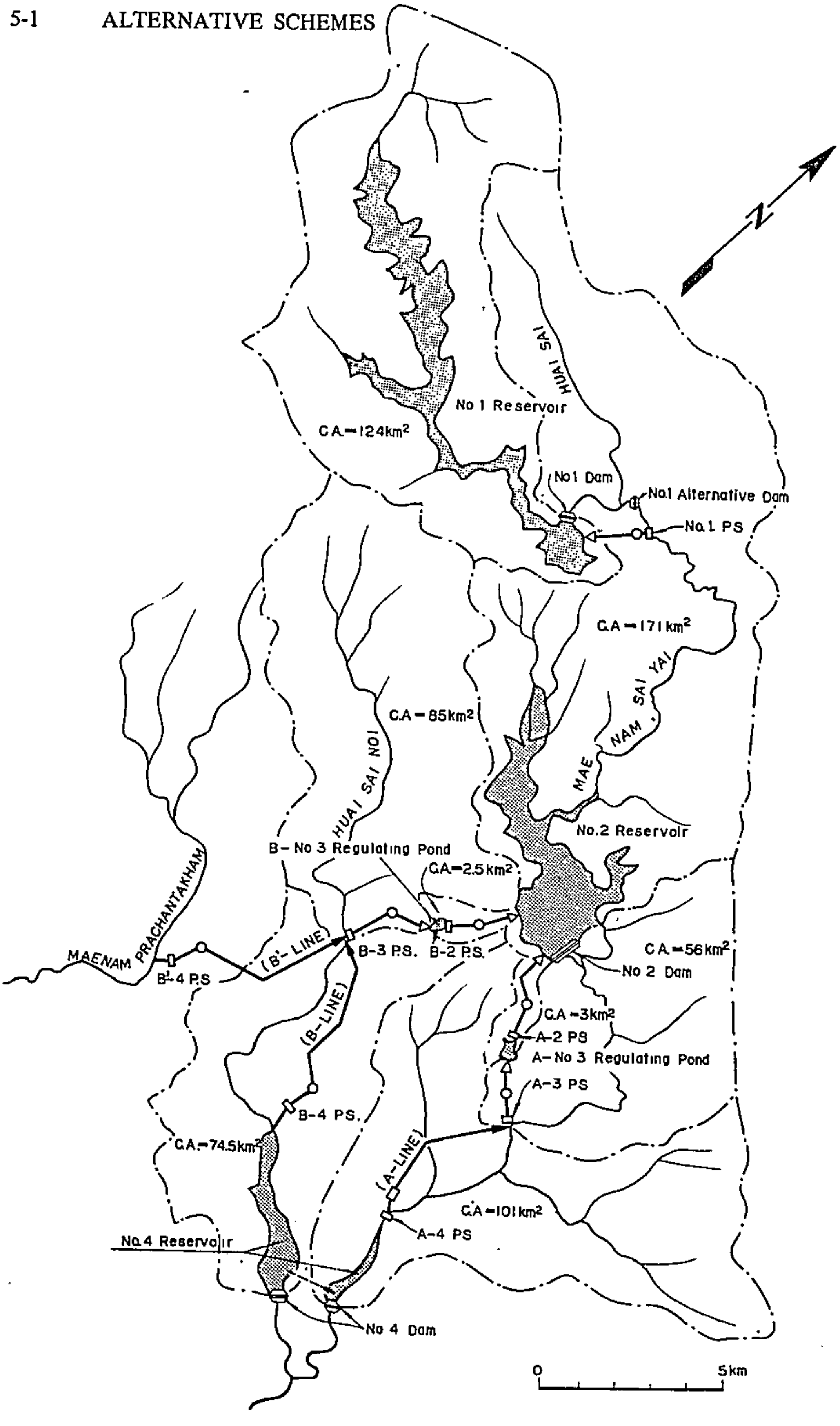

TABLE 5-1 FEASTURES OF THE PROPOSED POWER-STATIONS BY CASE OF A, B AND B' LINES

Item	Unit	A-Line	B-Line	B'-Line
No.1 P.S.				
Available Discharge (Max.)	c.m.s.	10.0	10.0	10.0
Available Discharge (Firm)	c.m.s.	3.1	3.1	3.1
Rated Head	m	86.7	86.7	86.7
Installed Capacity	MW	8.0	8.0	8.0
Available Energy	MWh/Yr.	21,000	21,000	21,000
No.2 P.S.				
Available Discharge (Max.)	c.m.s.	20.0	20.0	20.0
Available Discharge (Firm)	c.m.s.	7.3	7.3	7.3
Rated Head	m	74.3	89.3	89.3
Installed Capacity	MW	12.0	15.0	15.0
Available Energy	MWh/Yr.	42,000	50,000	50,000
No.3 P.S.				
Available Discharge (Max.)	c.m.s.	20.0	20.0	20.0
Available Discharge (Firm)	c.m.s.	7.3	7.3	7.3
Rated Head	m	333.3	296.7	296.7
Installed Capacity	MW	58.0	50.0	50.0
Available Energy	MWh/Yr.	190,000	170,000	170,000
No.4 P.S.				
Available Discharge (Max.)	c.m.s	21.0	21.5	21.5
Available Discharge (Firm)	c.m.s	7.4	7.4	7.4
Rated Head	m	119.4	136.4	130.3
Installed Capacity	MW	21.0	25.0	24.0
Available Energy	MWh/Yr.	79,000	96,000	92,000
Total Installed Capacity	MW	99.0	98.0	97.0
Total Available Energy	MWh/Yr.	332,000	337,000	333,000

CHAPTER 6

DEVELOPMENT OF SAI YAI RIVER BASIN

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DEVELOPMENT OF SAI YAI RIVER BASIN

6.1 OUTLINE

At site R_1 upstream of the Sai Yai River (catchment area 124 sq. km) the No.1 Reservoir at HWL 727.5 m with an effective storage capacity of 90 million cu.m. and at Site R_2 (catchment area 295 sq.km) the No. 2 Reservoir at HWL 591 m with an effective storage capacity of 110 million cu.m will be constructed. Utilizing the total head of 97.5 m between the No.1 and No.2 Reservoirs, the No.1 Power Station with an installed capacity of 8,000 kW will be constructed, while the head of 547 m from the No.2 Reservoir to the debauchment from the mountain area will be utilized to build the No.2 Power Station with an installed capacity of 12,000 kW, the No.3 Power Station with an installed capacity of 58,000 kW and the No.4 Power Station with an installed capacity of 21,000 kW in order from the upstream.

At the intake site for the No.3 Power Station, the design will call for the No.3 Regulating Pond with an effective storage capacity of 1.6 million cu.m. No.4 Power Station will also use the water of the catchment area (59 sq. km) remaining below the No.2 Reservoir.

The No.4 Reservoir which will have a high water level of 44m, will be built on both the Sai Yai and Sai Noi Rivers at 3 km upstream of their confluence to irrigate 13,300 ha of cultivated land on both banks of the Hanuman River.

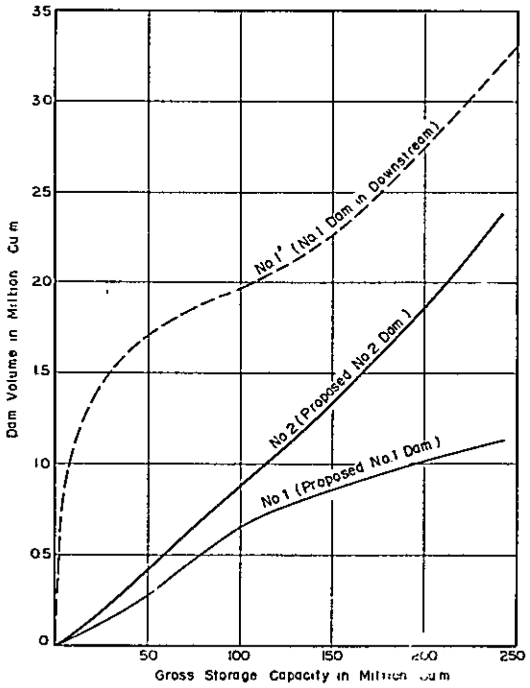
6.2 RESERVOIRS

6.2.1 Nam Sai Yai No.1 and No.2 Reservoirs

(1) Comparison of Dam Sites for No.1 Reservoir

In selecting the dam site for the No.1 Reservoir, a point immediately downstream of the confluence of the Sai Yai River and the Sai River (Huai Sai) [Downstream Plan] and a point 3 km upstream [Upstream Plan] were considered. Against a catchment area of 124 sq. km for the Upstream Plan, the Downstream Plan would have an area of 176 sq.km or an approximately 40% increase, but the reservoir efficiency (storage capacity/volume of dam) of the Downstream Plan would be extremely poor. (See Fig. 6-1) Moreover, if a reservoir is built downstream (No.2 Reservoir), there would be no special necessity for a large catchment area, and therefore, the Upstream Plan was selected.

FIG. 6-1 RELATION BETWEEN DAM VOLUME AND GROSS STORAGE CAPACITY



(2) Scale of No.1 and No.2 Reservoirs

The run-off at the No.1 and No.2 Reservoir sites was obtained by multiplying the monthly specific run-off estimated in 4.2 by the respective catchment areas. (See Fig. 6-2, 6-3)

The result, the inflow at the No.2 Reservoir (including the catchment area of the No.1 Reservoir) is 348 million cu.m annually in wet years (1965 - 1966), and 193 million cu.m annually in dry years (1963 - 1964) differing greatly, (15-year average inflow 252 million cu.m) while for average years the maximum monthly average run-off is 20 c.m.s. for September and the minimum 0.5 c.m.s. for March and April showing a broad fluctuation.

Therefore, in order to use this water effectively for power generation, a large-scale reservoir is necessary. However, considering the relationship between construction cost of such a dam and other structures and the benefit derived, it is not always economical to use the water resources 100%.

Also, the reservoir efficiency for No.1 Reservoir is superior to that of the No.2 Reservoir. (See Fig. 6-1) For the above reasons the scales of the No.1 and No.2 Reservoirs were scaled so that the excess benefit oftained from the No.1 to No.4 Power Stations would be the maximum. In other words, the effective capacities of the No.1 and No.2 Reservoirs were combined in various ways with the 15-year average inflow of 106 million cu.m and 146 million cu.m respectively, and the excess benefit of power generation for each combination was calculated. The results as shown in Fig. 6-4 disclosed the fact that HWL of 727.5m for the No.1 Reservoir (effective capacity 90 million cu.m) and the HWL of 591 m (effective capacity 110 million cu.m) of the No.2 Reservoir was the most advantageous capacity.

FIG. 6-2 MONTHLY MEAN RIVER RUN-OFF AND POWER DISCHARGE AT NO.1 DAM

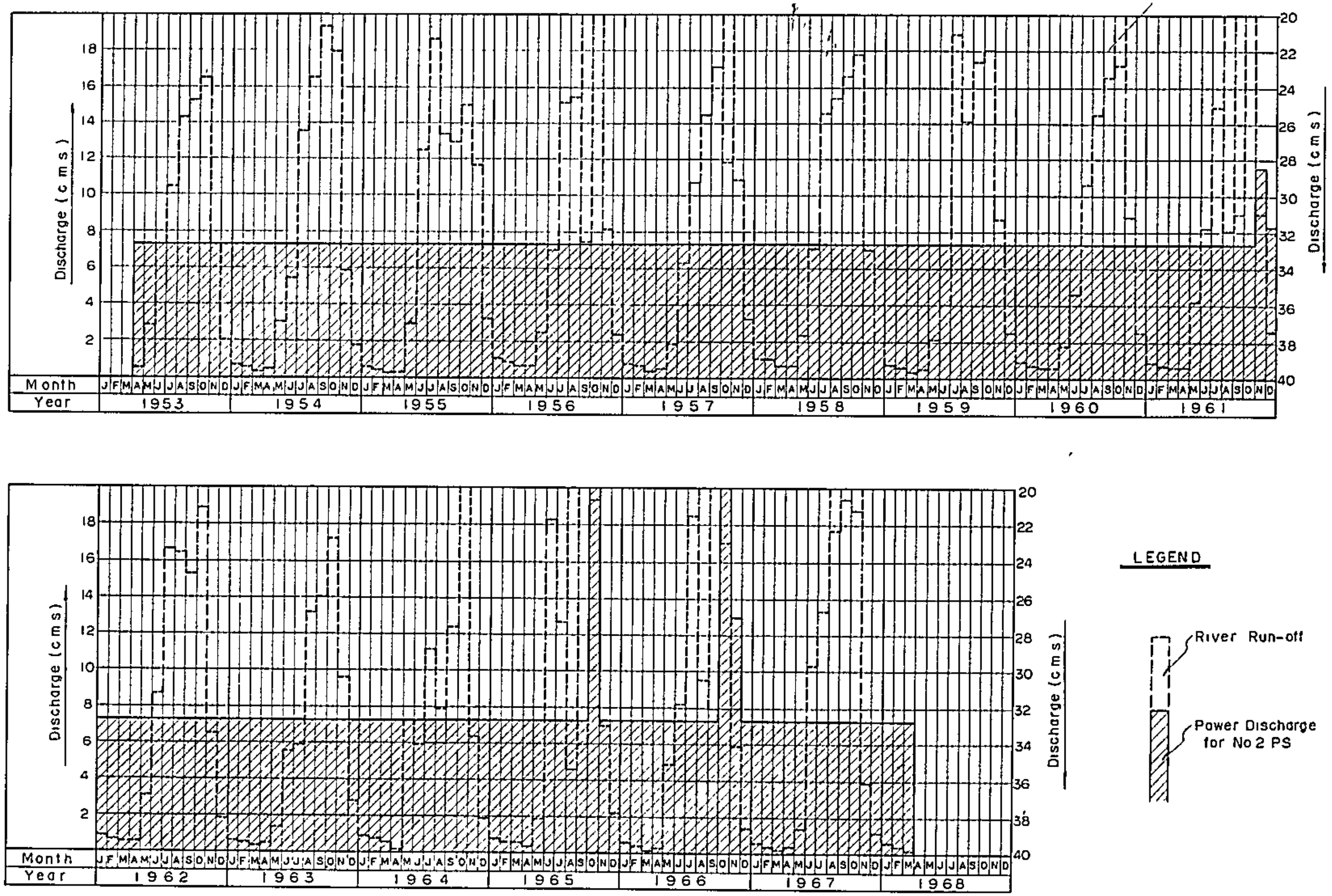


FIG. 6-3 MONTHLY MEAN RIVER RUN-OFF AND POWER DISCHARGE AT NO.2 DAM

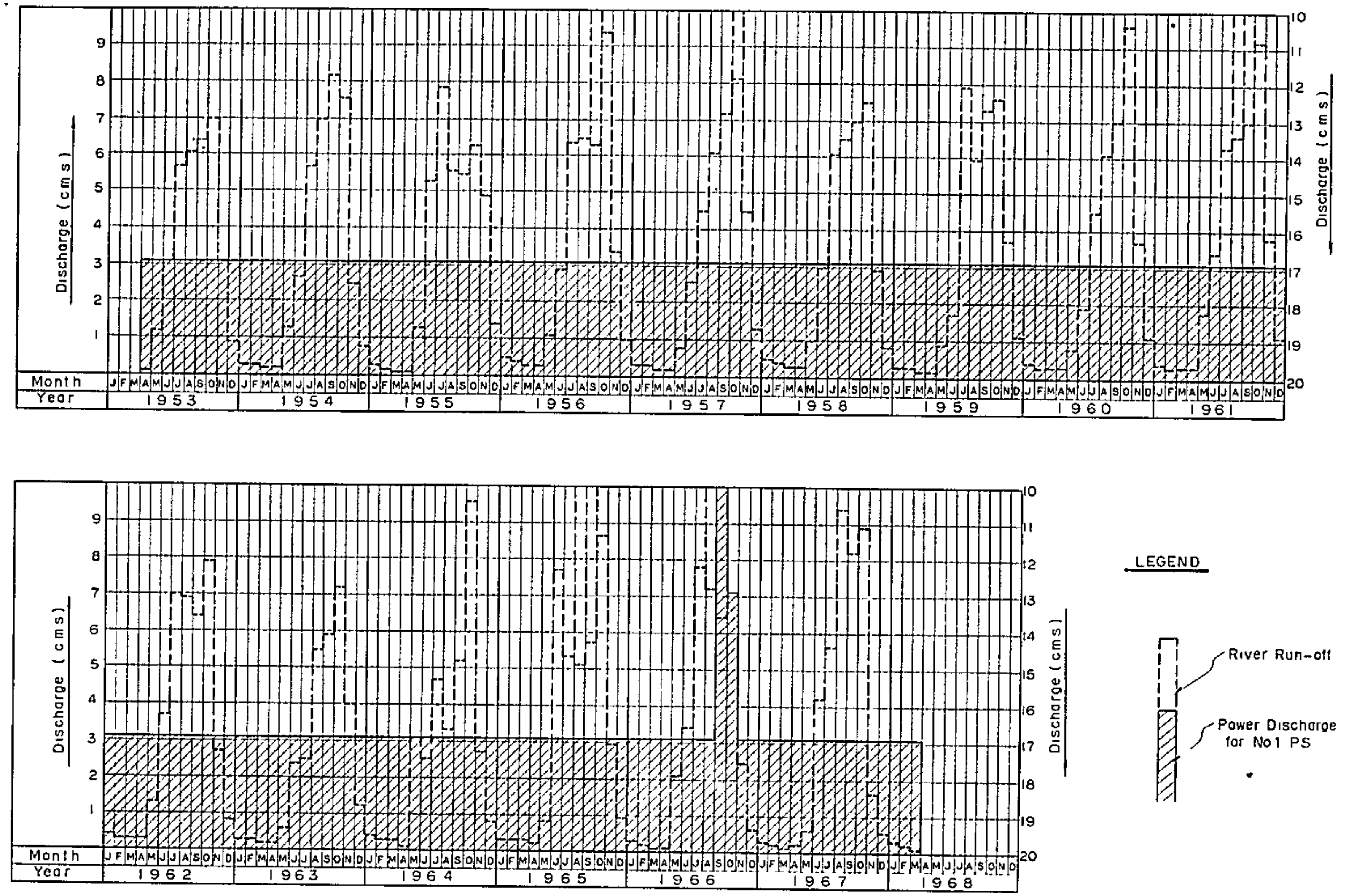


FIG. 6-4 EXCESS BENEFIT OF ALTERNATIVE SCHEME (WITH UP AND DOWN STREAM DEVELOPMENT)

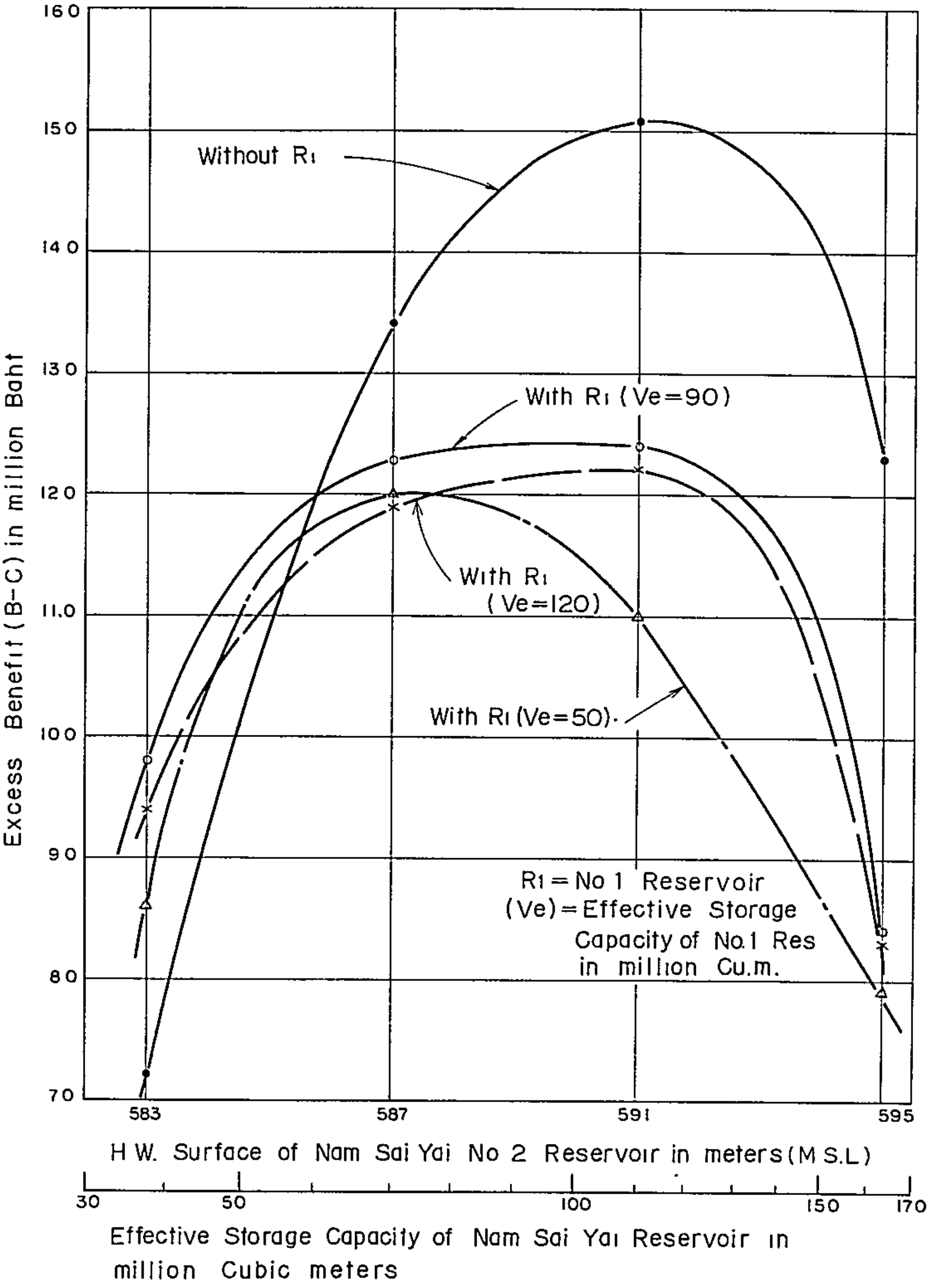
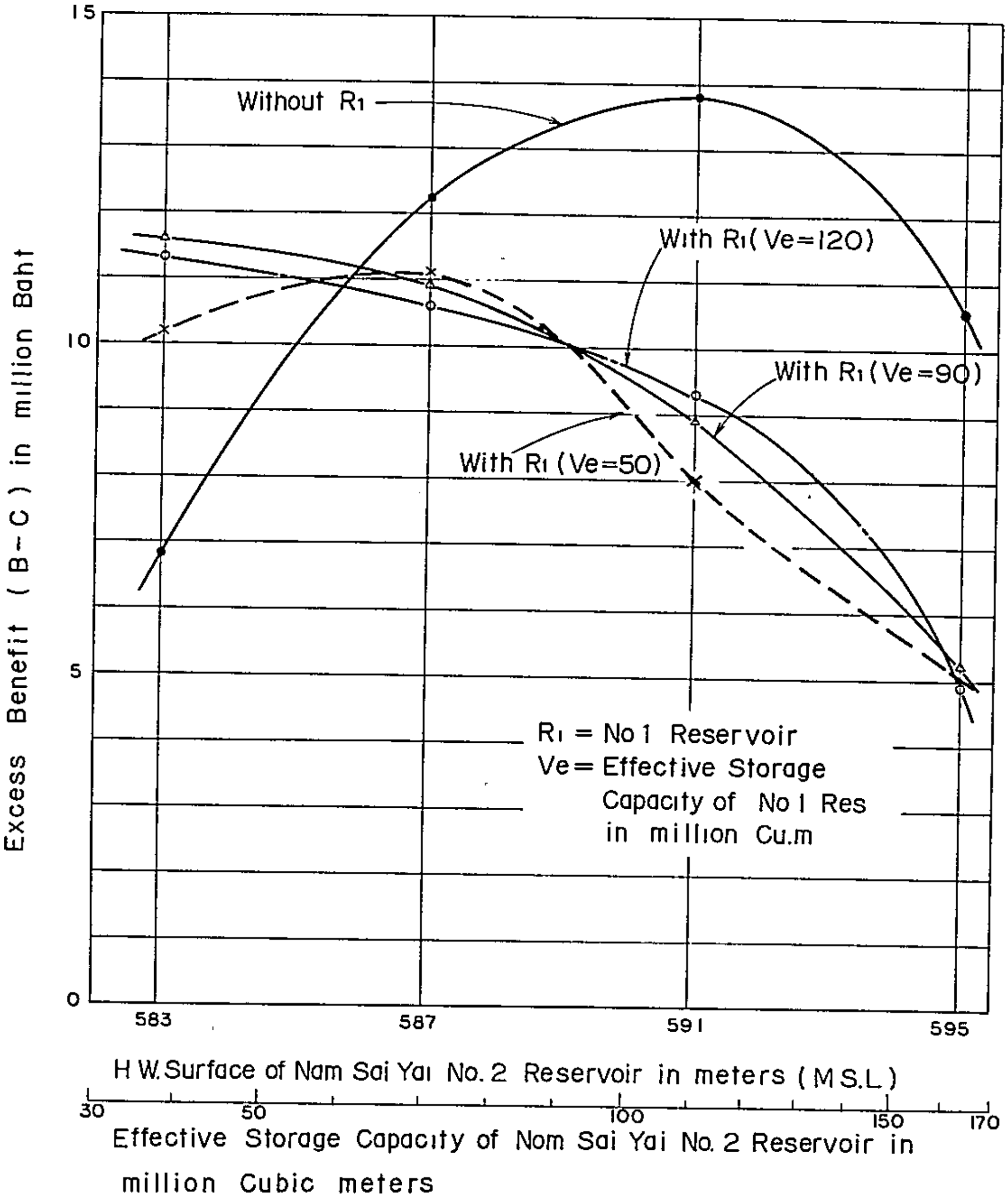


FIG. 6-5 EXCESS BENEFIT OF ALTERNATIVE SCHEME (ISOLATED DEVELOPMENT)



In the above study, the items considered as premises were as follows.

(a) The tail water level of the No.1 Power Station would be 630 m.

(b) A regulating pond would be provided downstream of the No.2 Power Station with its tail water level at 510 m.

(c) The average intake water level of the No.3 Power Station would be 509m and the tail water level 170 m.

(d) The intake water level of the No.4 Power Station would be at 170 m with the inflow being the sum of the generation discharge of the No.3 Power Station and the run-off of the catchment area downstream of the No.2 Reservoir.

(e) The evaporation from the water surface of the reservoir would be 1,500 mm.

(f) The load factors of the power stations would be 33%.

(g) The dam would be fill-type. Crest elevation of dam was calculated by adding 4 m to the normal high water level. Storage capacity and the volume of dam were obtained from Fig. 6-1 and App. Fig. 6-1, 2 & 3, and the construction cost was calculated under the same criterial as in 6.7.

(h) The cost and benefit would be according to the same criteria as in 6.8.

The scale of the No.1 and No.2 Reservoirs were determined according to the above. From the viewpoint of power demand, it would be uneconomical to construct the two simultaneously and it naturally would be necessary to consider the order of priority.

In the Sai Yai River system, the profile between the No.2 Reservoir and No.3 Power Station has the steepest grade, and it is thought the No.2 and No.3 power stations should be given priority in development as described in detail in 6.5.

Moreover, the following considerations were made. Two cases, one in which the No.2 and No.3 Power Stations would be operated using only the No.2 Reservoir and the other in which the above two power stations would be operated utilizing the No.1 and No.2 Reservoirs, were compared to decide the reservoir scales that would result in the greatest excess benefit. The results are as shown in Fig.6-5, and it was made clear that the scales previously determined, (No.1 Reservoir HWL 727.5 m, No.2 Reservoir HWL 591 m) would be satisfactory.

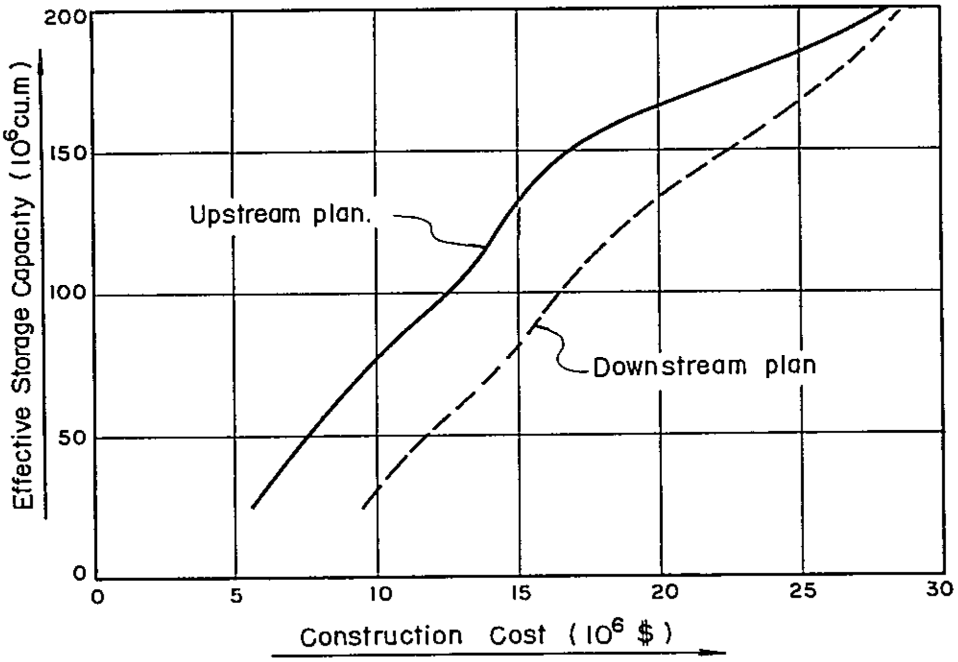
6.2.2 Nam Sai Yai No.4 Reservoir

(1) Comparison of Dam Sites

Two dam sites for the No.4 Reservoir were considered topographically favorable: immediately downstream of the confluence of the Sai Yai River and Sai Noi River (Downstream Plan), and approximately 3 km upstream of the confluence in which case both rivers would be dammed and the reservoirs connected with a tunnel (Upstream Plan).

The dams in both cases were considered to be fill types and with the intake levels at 37 m. Construction costs were compared for securing the same effective storage capacity. Obviously, the effect on the tail water level of the No.4 Power Station was included in the considerations. The result, as indicated in Fig. 6-6, shows that the Upstream Plan is of greater advantage.

FIG. 6-6 RELATION BETWEEN CONSTRUCTION COST AND STORAGE CAPACITY (NO.4 RESERVOIR)

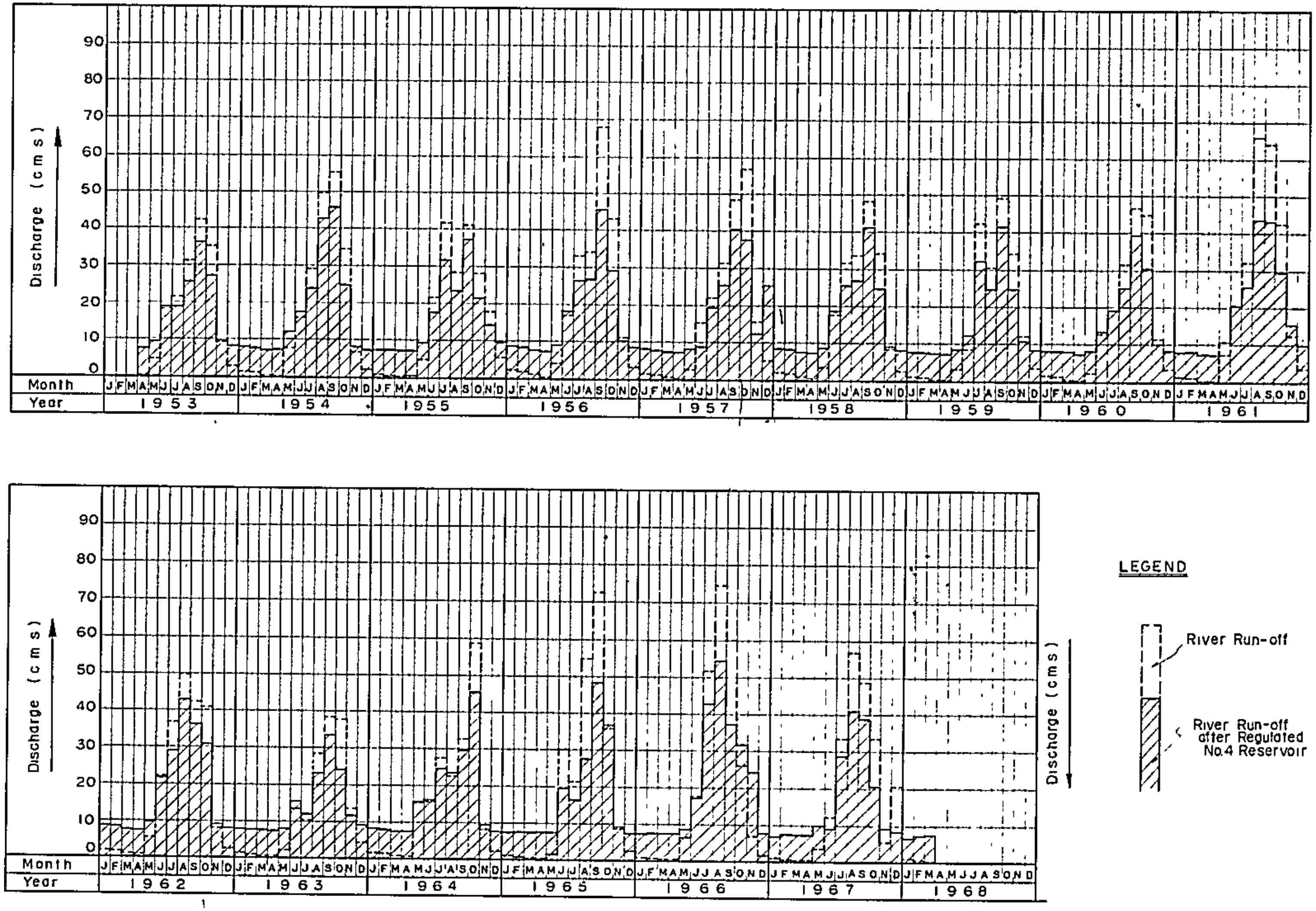


(2) Scale of No.4 Reservoir

After the No.1 and No.2 Reservoirs are constructed upstream and the No.1 to No.4 Power Stations are in operation, the quantity of river flow at the site of the No.4 Reservoir will be greatly improved as shown in Fig. 6-7, the dry season (from January to April) run-off of an average year being immediately increased from 1.0 c.m.s. to 7.7 c.m.s. However, in spite of this improvement, there will still be a difference of approximately 18 c.m.s. between rainy season (from June to November) run-off and dry season run-off.

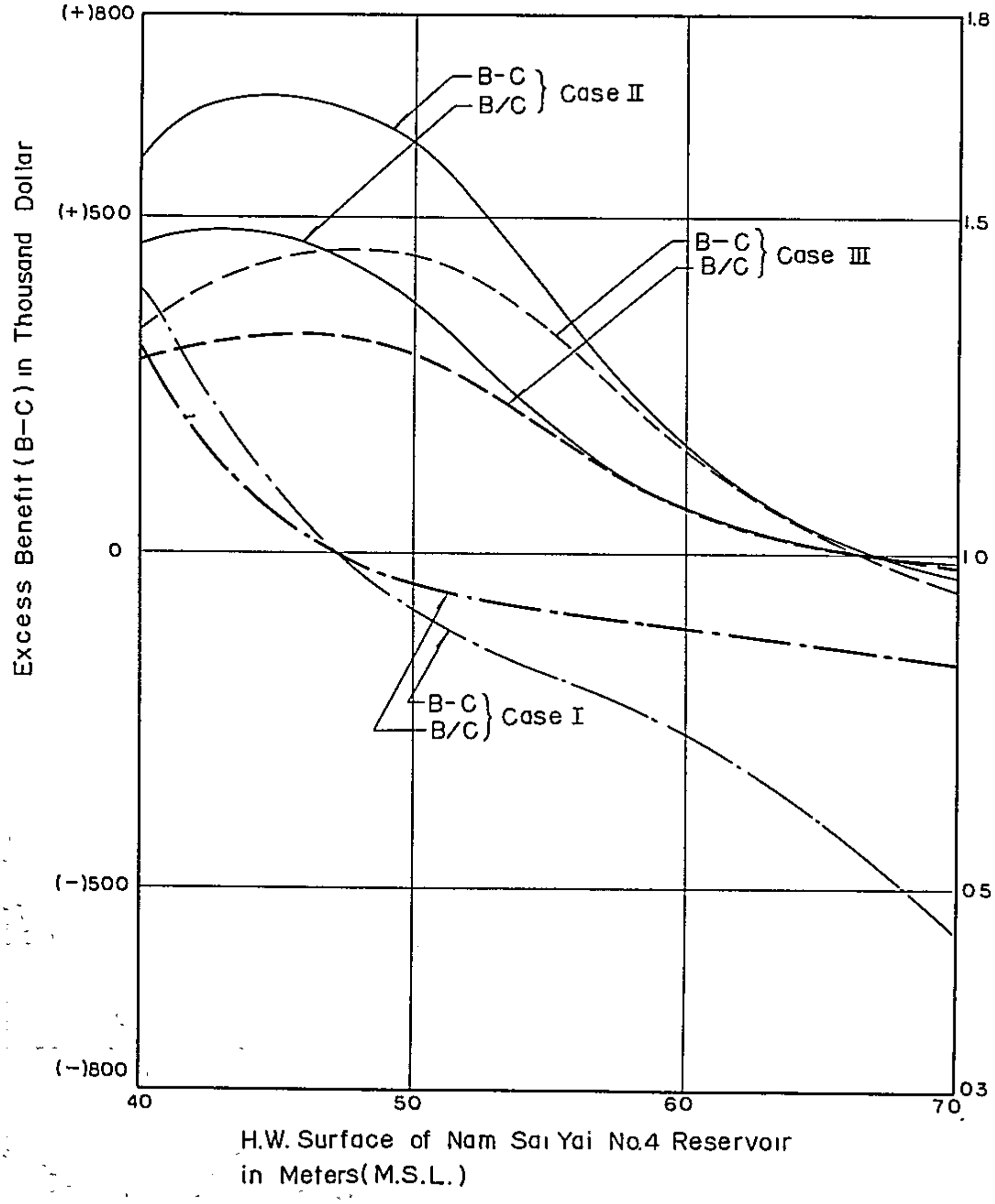
In order to utilize this water effectively for irrigation of cultivated land, it would be necessary to build a reservoir with a considerable regulating capacity. However, in view of the topography of the dam site (See Fig. 6-6 and App. Fig. 6-4), it cannot be said it would be economical to effectively use all water. Besides, since the No.4 Power Station is upstream, raising the water level of the reservoir will lower the generating output. Therefore, the scale of the reservoir was determined so as to get the maximum excess benefit obtainable from both irrigation and the No.4 Power Station.

FIG. 6-7 MONTHLY MEAN RIVER RUN-OFF AND POWER DISCHARGE AT NO.4 DAM



For irrigation, various combinations of irrigated areas and cropping patterns were studied, and for each case the necessary reservoir scale was assumed, and the corresponding installations dictated by the tail water levels for the No.4 Power Station were considered. The excess benefits obtained from the various combinations are shown in Fig. 6-8. It is found that a reservoir with a high water level of 44 m (effective storage capacity 24 million cu.m) would be the most economical, making possible an irrigated area of 13,300 ha (paddy rice: 1st-crop 10,000 ha, 2nd-crop 5,000 ha, upland crops 3,300 ha) and a dependable capacity of 19,500 kW(installed capacity 21,000 kW)at the No.4 Power Station.

FIG. 6-8 EXCESS BENEFIT (B–C) AND COST BENEFIT RATIO (B/C) CURVES (NO.4 RESERVOIR)



The premises for the above study were as follows.

(a) The inflow of the reservoir was assumed to be the run-off during a dry year (1964 - 1965) with the No.1 to No.4 Power Stations in operation.

(b) The 67 sq. km of the upstream part of the Sai Noi River basin would be diverted to the Prachantakham River.

(c) The cropping patterns were assumed to be the following 3 cases.

case	I	II	III	
Paddy rice, 1st-crop	75%	75%	75%	
2nd-crop	–	37.5%	75%	
Fruits	15%	15%	15%	limited to 3,300 ha
Upland Crops	10%	10%	10%	

The water requirement per unit area was calculated according to the criteria of 6.4.3.

(d) Intake level would be EL 37 m.

(e) The evaporation from the surface of reservoir would be 1,500 mm.

(f) The intake level of the No.4 Power Station would be at EL 170 m, and the load factor would be 33%.

(g) The dam would be a fill type. Crest elevation of dam was calculated by adding 4 m to the normal high water level. Storage capacity and the volume of dam were obtained from App. Fig. 6-4, 6-8, and the construction cost calculated by the same criteria as in 6.7.

(h) Costs and benefits were calculated according to 6.8. It was assumed the full benefit of No.4 Power Station would be obtained simultaneously with start-up.

Also, the limitations to the scale of using water resources for irrigation were considered. In other words, using the beforementioned criteria, the scale of the reservoir when the excess benefit becomes zero was studied. The result was a reservoir with a normal high water level of 65 m, and an effective storage capacity of 152 million cu.m.; an irrigation area of 24,600 ha (paddy rice: 1st-crop 21,400 ha, 2nd-crop 10,700 ha; upland crops 3,300 ha), and a maximum output at No.4 Power Station of 15,900 kW.

6.2.3 Effect of Upstream Projects on Nam Sai Yai No.4 Reservoir

The following 3 cases were studied regarding this matter.

(1) Scale of the No.4 Reservoir without any upstream projects.

(2) Effect on the No.4 Reservoir of construction upstream of the No.2 Reservoir, the No.2 and No.3 Power Stations.

(3) Effect on the No.4 Reservoir of construction upstream of the No.1 and No.2 Reservoirs and the No.1 to No.4 Power Stations.

The above studies were based on examination of optimum scale and on identical criteria. The results are as shown in Tables 6-1, 6-2 and indicate that when the irrigated area is 13,300 ha, the completion of No.2 Reservoir will be saved $8,310,000 (฿ 171,600,000)in construction costs of the No.4 Reservoir, and the completion of No.1 Reservoir will save an additional $480,000 (฿ 9,912,000).

If No.4 Reservoir is large enough to have a high water level of 44 m as beforementioned, at the time of completion of No.2 Reservoir (no diversion from the Sai Noi River), the irrigable area would be 12,300 ha (paddy rice: 1st-crop 9,200 ha, 2nd-crop 4,600 ha, upland crops 3,100 ha), moreover when No.1 Reservoir is completed, the irrigable area would become 13,400 ha (paddy rice: 1st-crop 10,100 ha, 2nd-crop 5,050 ha, upland crops 3,300 ha).

A study was also carried out on the scale of irrigation in the case of No.2 Reservoir being constructed and an intake weir was provided on the downstream of Sai Yai River for irrigation. This is described in a separate feasibility report.

6.2.4 Flood Control

The No.1, No.2 and No.4 Reservoirs described in 6.2.1 and 6.2.2 all have the same purpose of water utilization. However, because of the retarding actions of these reservoirs, they would also naturally alleviate floods. The No.1 and No.2 Reservoirs constructed with past floods in mind (180 c.m.s. August 1966, See App. Fig. 4-10), will reduce floods by 80 c.m.s. as shown in App. Fig. 4-13.

According to estimates from flooded mark, the discharge of the largest known flood near Ban Wong Mon on the Hanuman River was approximately 500 c.m.s. If it was reduced 80 c.m.s. above reservoirs, it is estimated the flood discharge in the vicinity of Ban Wong Mon would be 420 c.m.s. with the water level lowered approximately 0.8m. As a result, it is thought at least 200 ha of cultivated land on both banks of the Hanuman River would be free from flooding (See 6.4.1).

TABLE 6-1 INFLUENCES ON NO.4 RESERVOIR BY UPSTREAM PROJECTS.(Based on Irrigable Area 13,300 ha.)

Case	H.W.L.	Effective storage capacity	No.4 P.S Installed capacity	Construction Cost (Annual Cost : C)				Benefit : B			B - C	B/C
				No.4 Reservoir	No.4 P.S.	Irrigation	Total	Power	Irrigation	Total		
	m	10^6 cu.m	kW	10^3 $	10^3 $	10^3 $	10^3 $	10^3 $	10^3 $	10^3 $	10^3 $	
Without Power Project	60.5	117.5	-	13,679 (1,278)	- (-)	3,622 (338)	17,301 (1,616)	-	1,395	1,395	(-) 221	0.86
With No.2 Reservoir and No.2, No.3 power stations	45.7	32.1	-	5,369 (502)	- (-)	3,622 (338)	8,991 (840)	-	1,395	1,395	555	1.66
With No.1 and No.2 Reservoirs and No.1 No.4 power stations	43.8	23.6	19,500	4,889 (457)	8,286 (609)	3,622 (338)	16,797 (1,404)	692	1,395	2,087	683	1.49

Note : 1. Including 67 sq km of Catchment Area on Sai Noi River
2. Benefits are calculated from No 4 Power Station and Irrigation only.

TABLE 6-2 INFLUENCES ON NO.4 RESERVOIR BY UPSTREAM PROJECT (Based on Normal H.W.L. 44 Meter)

Case	No.4 P.S Installed capacity	Irrigable Area	Construction Cost (Annual cost : C)				Benefit : B			B - C	B/C
			No.4 Reservoir	No.4 P.S.	Irrigation	Total	Power	Irrigation	Total		
	kW	ha	10^3 $	10^3 $	10^3 $	10^3 $	10^3 $	10^3 $	10^3 $	10^3 $	
Without power project	-	5,100 Paddy Rice 1st-crop 3,825 2nd-crop 1,912 Upland crops 1,275	4,949 (462)	- (-)	1,390 (130)	6,339 (592)	-	536	536	(-) 56	0.91
With No.2 Reservoir, and No.2, No.3 power stations		12,000 Paddy Rice 1st-crop 9,225 2nd-crop 4,612 Upland crops 3,075	4,949 (462)	- (-)	3,352 (313)	8,301 (775)	-	1,294	1,294	519	1.67
With No.1 and No.2 Reservoirs and No.1 to No.4 power stations	19,500	13,400 Paddy Rice 1st-crop 10,100 2nd-crop 5,050 Upland crops 3,300	4,949 (462)	8,286 (609)	3,647 (341)	16,882 (1,412)	691	1,402	2,093	681	1.48

Note
1. Including 67 sq.km of Catchment Area on Sai Noi River
2. Benefits are calculated from No 4 Power Station and Irrigation only.

6.3 POWER

6.3.1 Power Generations

The scales of the power stations corresponding to the optimum scales of the reservoirs studied in 6.2.1 will be as follows.

Power Station	Available Discharge (c.m.s.) Firm	Max.	Rated Head (m)	Installed Capacity (kW)
No.1	3.1	10.0	86.7	8,000
No.2	7.3	20.0	74.3	12,000
No.3	7.3	20.0	333.3	58,000
No.4	7.4	21.0	119.4	21,000
Total			613.7	99,000

Based on the above scales, the electric energy produced for the 15 years from 1953 was calculated, and the result in annual averages is given below.

Power Station	Available Energy (MWh/Yr.)
No.1	21,000
No.2	42,000
No.3	190,000
No.4	79,000
Total	332,000

The dependable capacity would be as follows:

Power Station	Dependable Capacity (MW)
No.1	6.0
No.2	11.8
No.3	56.0
No.4	19.5
Total	93.3

6.3.2 Transmission Lines

The power produced by the above would be supplied to the Central and Northeast Region. For this purpose two circuits of 115 kV transmission line totaling 105 km length would be constructed between No.3 Power Station and existing Korat Substation. And another one circuit of 115 kV transmission line would be constructed to connect the 18km between No.1 Power Station and No.2 Power Station, the 4 km between No.2 Power Station and No.3 Power Station and the 7 km between No.4 Power Station and No.3 Power Station respectively.

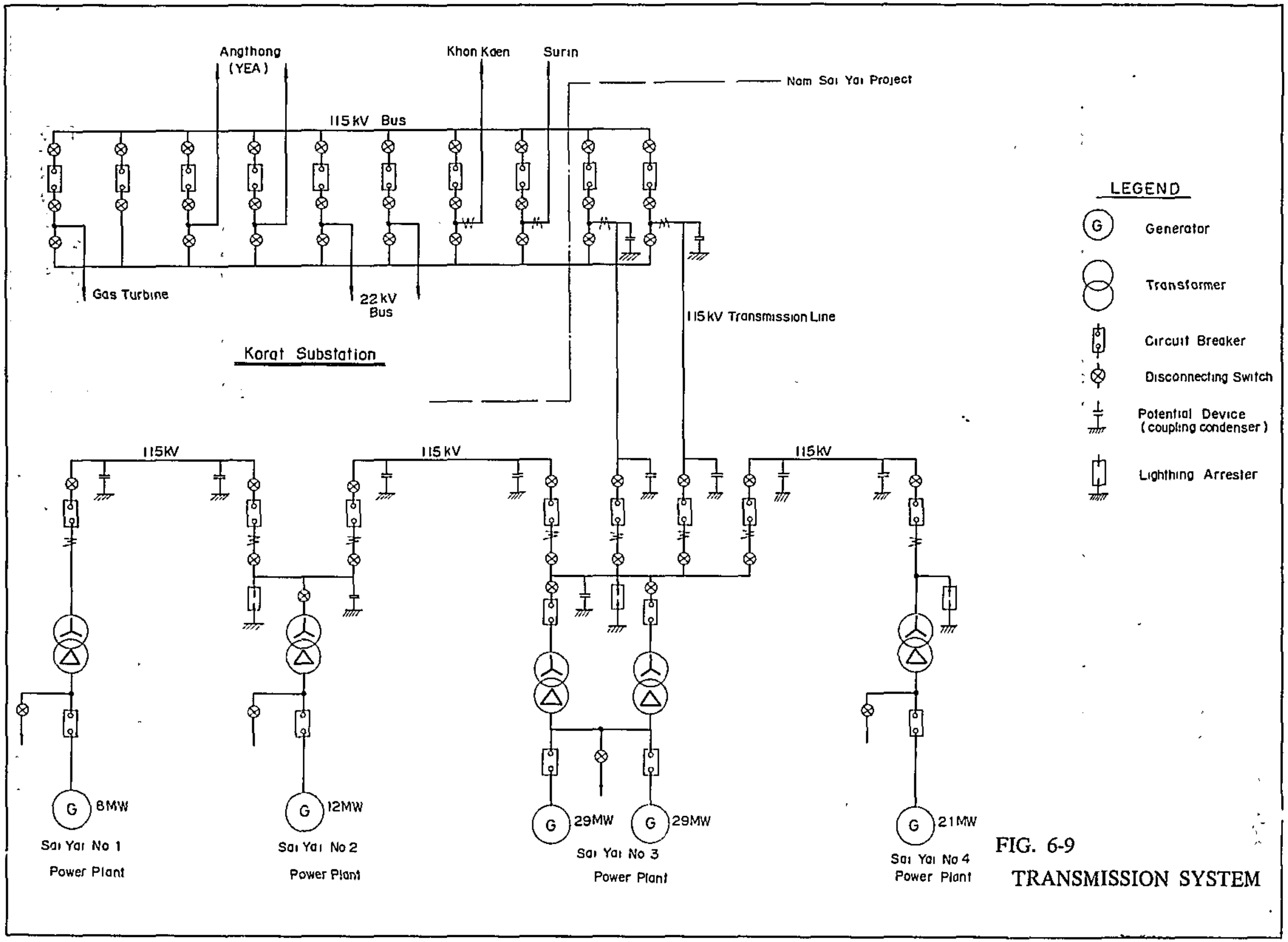
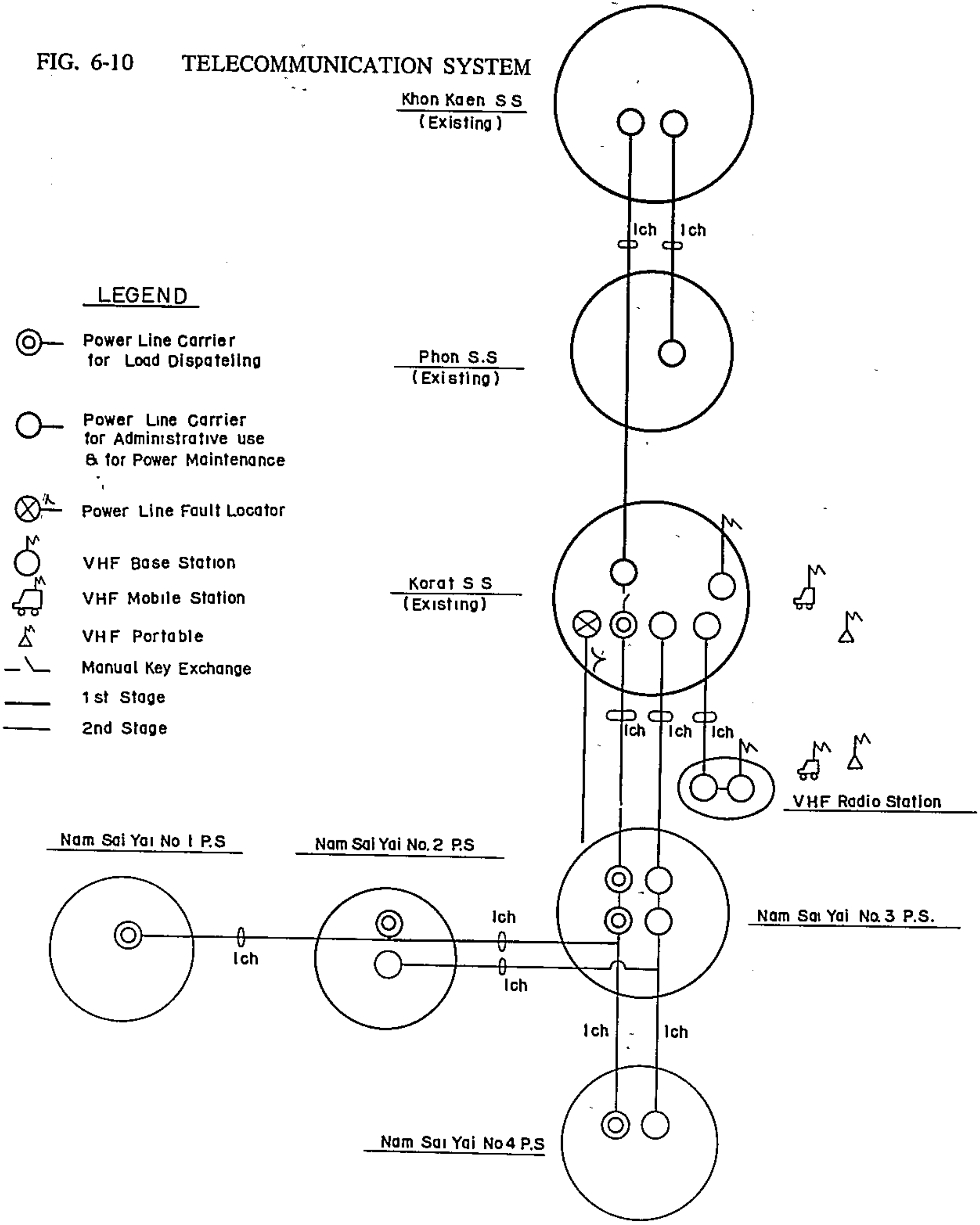


FIG. 6-9
TRANSMISSION SYSTEM

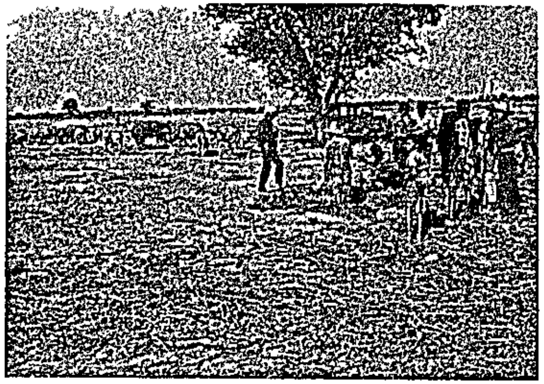
6.3.3 Telecommunication System

Power line carrier telephone system will be provided between Korat Substation and Sai Yai Power Station for load dispatching and general business purpose. For transmission line maintenance, VHF radio and fault locator will be provided. (See Fig. 6-10)

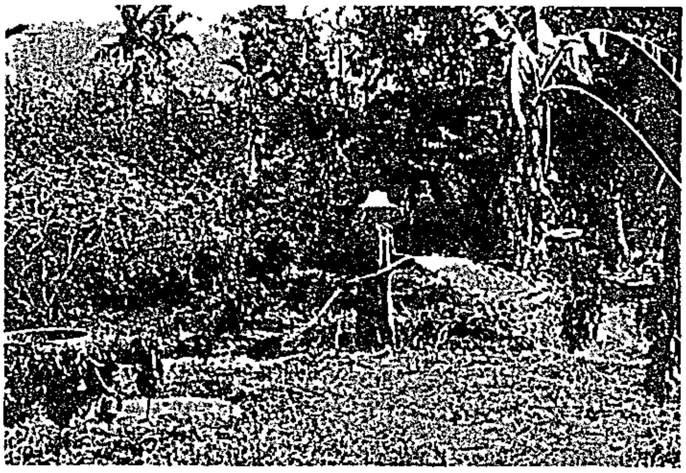
FIG. 6-10 TELECOMMUNICATION SYSTEM



Proposed irrigation area on the left bank of the Hanuman River



Inundated area in rainy season on the lower reaches of the Hanuman River



Water sprinkling
(Banana and Coffee)

Orchard (orange)

6.4 AGRICULTURAL DEVELOPMENT

6.4.1 Outline of State of Agriculture

(1) Social Situation

Changwad Prachinburi has an area of 11,795 sq. km and population of 334,895, which is 28 persons per 1 sq. km, and it is comprised of 9 Amphurs including Amphur Kabinburi and Prachantakham.[*1] The project area is located in these two Amphurs. The cultivated area of these two Amphurs amounts to 426,446 rai (68,200 ha) with 13,103 farming households,[*2] indicating that the cultivated area per household is 33 rai (5.2 ha). The area of land holding is as shown in App. Table 6-1.

The main cities of Changwad are Prachinburi and Kabinburi, which are relatively well located in respect to transportation and traffic. The Eastern Line of the State Railways of Thailand and 2 highway routes connect them to Bangkok in approximately 3 hours so that they take part in the commerce activities of Bangkok.

(2) Meteorology

The average annual temperature of this region is 28.5 °C, the average monthly maximum temperature 31 °C (April) and the average monthly minimum temperature 27 °C (December and January). As the optimum temperature for growth of rice is around 30 °C, the temperature of this region satisfies this condition without any question and it would be possible to grow rice throughout the year. (See App. Table 4-1)

Rainfall averages 1,508.1 mm annually (1953 - 1968) with the maximum being 2,422.8 mm from April 1961 through March 1962. The minimum was 994.6 mm from April 1965 through March 1966 with most of the rainfall concentrated in June through October. (See App. Table 4-2)

Rice is cultivated during this latter period, although it has already been stated in 3.2 that this is insufficient to supply the needs for growth of rice. For perennial plants such as fruit, irrigation is a must.

(3) Water Quality

App. Table 6-2 shows the water quality of the Sai Yai River and Sai Noi River investigated by the Science Department commissioned by NEA. The water quality of the Prachinburi River investigated by Jun Kobayashi[*3] of Okayama University is as shown in App. Table 6-3. According to the said tables, it is considered that the water of the Sai Yai River System is entirely satisfactory for irrigation purposes.

[*1] Statistical Yearbook Thailand, 1964

[*2] Census of Agriculture, 1963

[*3] Chemical investigation on River Waters of South-Eastern Asiatic Countries, (Report 1); The Quality of Waters of Thailand by J. Kobayashi, Okayama University, Japan.

(4) Utilization of Land

The utilization of the 426,446 rai (68,200 ha) of cultivated land of Amphur Kabinburi and Prachantakham is as shown in App. Table 6-4 indicating that 332,242 rai (53,200 ha) corresponding to approximately 78% is land in crops, 28,544 rai (4,600 ha) or 7% is fallow and other arable land or land in tree crops.

App. Fig. 6-9, from aerial photographs, shows the land lower than EL 40 m surrounded by the Hanuman River, Prachinburi River and the Prachantakham River and the land lower than EL 30 m from the right bank of the Hanuman River to Samong River (Huai Samong) and distinguishes between paddy fields and other land. In a total area of 31,000 ha, it was estimated that paddy fields amounted to 19,000 ha.

Judging from the manner of utilization of land in the abovementioned Amphur and from field survey, it is estimated that the remaining 12,000 ha are distributed as follows: 2,000 ha in fields, 1,500 ha tree crops, and 8,500 ha grasslands.

(5) Soil

In the present field investigations, 38 test holes (approximately 1 m deep) were provided within the project area. The results are shown in App. Fig. 6-10 and App. Table 6-5. The results of soil investigations made in 1960 by the Japanese Government Survey Mission[*1] are also included in the above figure and table.

The mother rock is Mesozoic sandstone, being characteristically silty loam or silty clay loam in the inundated areas along the rivers and almost entirely sandy loam in other areas. (See App. Fig. 6-10) Along the national highway from Kabinburi to Prachantakham, mostly on the north side, laterite stratum is distributed near the surface. Here, there are places where the topsoil is about 10 cm thick. Although this land is utilized for paddy field because water is readily available, productivity is not high.

Chemically, the entire area is acidic and totally lacking in fertilizing components. This is due to the high temperature and humidity in which organisms are rapidly decomposed and washed away and to the old custom of cultivation without fertilizers. However, if irrigation facilities are completed, species of paddy rice of the heavy fertilization, high-yield type can be introduced so that a great increase in productivity can be looked forward to, while on sandy soil at higher elevations, cultivation of fruit such as mango will become possible.[*2] Since this land is relatively close to consumer areas, future growth in this type of agriculture can be expected.

[*1] Report on Basic Studies for Development of Hydraulic Potentials of the Nam Sai Yai, Kingdom of Thailand.

[*2] Robert L. Pendleton, Sarot Montrakus, The Soils of Thailand.

(6) Drainage Situation

As already mentioned, rainfall is concentrated from June through October, and in August and September the rivers rise and flood low lands.

Based on the past maximum flooded mark of Hanuman River investigated in the field by NEA, the inundated area is estimated to be 1,200 sq. km as shown in App. Fig. 6-10. The inundation of these areas does not last over long periods as is the case along the Prachinburi River, and it is though considerable alleviation can be achieved by completion of the group of upstream dams.

Regarding the Prachantakham River and the Prachinburi River, judging by the inundated conditions along the Hanuman River, the flooding occurs to an elevation of 8 m and it is estimated the period of inundation is much longer than along the Hanuman River. Levees have been build along the Prachinburi River, while on the right bank between Kabinburi and Prachantakham water gates have been provided in 4 places, but these are considered to be inadequate. Floating rice is being cultivated in these constantly inundated areas. As it would require an enormous expenditure to complete drainage works, it is thought too early to take up this problem for solution.

On the other hand, the underground water level of these inundated areas is lowered (approximately 3 m) in the dry season, and if irrigation water could be obtained, since the soil conditions are excellent, it can be said this is an area which can be well utilized.

(7) State of Farm Management

Farm management at Amphur Kabinburi and Prachantakham is centered around rice cropping.

The scale of farms per household is 33 rai (5.2 ha)^{*1} of which paddy fields comprise 26 rai (4.2 ha)^{*2} which is higher than the national average of 19 rai (3.0 ha)^{*3} per household of which paddy fields comprise 11 rai (1.8 ha). As shown in App. Table 6-1, approximately 50%^{*1} of the farmers cultivate 10 to 35 rai (1.6 to 5.6 ha). The acreage of major crops and production of this region are given in App. Table 6-6^{*1} of which paddy rice and fruit will be described in particular below.

Paddy Rice

Paddy rice cultivation is presently based on the transplanting method, except for parts which are constantly inundated during the rainy season where floating rice is grown.

*1 Census of Agriculture, 1963
*2 Amphur Survey, 1967
*3 Statistical Yearbook 1964

The growing period of ordinary cultivation is as shown in Fig. 6-11 and transplanting is carried out when the rains flood the paddies. Since the beginning of the rainy season differs each year, it is seldom that 30th day seedlings after seeding which are considered to be the best are trasplanted. Harvesting is done from November to January after the end of the rainy season. Farming depends only on human and animal power, fertilizer and agricultural chemicals not being much used. (See App. Table 6-7,8,9) As for productivity, as stated in 3.2, the average yield for the last 7 years in Changwad Prachinburi has been 1.2 tons per hectare. (See App. Table 3-1)

Individual records were unobtainable, for drought, flood, disease and insect damage. In 1962, for a planted area of 1,046,730 rai (167,480 ha) in Changwad Prachinburi, the harvested area was 935,744 rai[*1] (slightly less than 90%), while in 1966 at Amphur Kabinburi, despite the fact that it was a wet year, 11,560 rai (1,850 ha) (5% of the paddy field area of 217,865 rai) (34,860 ha)[*2] was harmed by drought. Disease and insect damage occurred on 5,787 rai (930 ha) (3% of the entire area) in Amphur Kabinburi in 1966.

Fruit

There are no fruit orchards of consequence in the project area. It was possible to learn of the production situation of durian and orange from farmers growing these fruits. The trees produce from the fifth year after planting and reach the highest productivity around the 30th year. Around the 40th year production begins to drop. The production of mature trees is roughly as given in App.Table 6-10. Old trees are successively replanted with yound trees so that over a long term or over a wide area approximately 80 to 90% of the trees can be said to be productive. The average yield for bearing period will be 60 to 70% of the highest productivity.

6.4.2 Agricultural Production Without and With Project

(1) Agricultural Production without Project

Paddy Rice

If the project is not realized, the present level of rice cropping techniques would continue and little increase in productivity could be expected. Therefore, the yield of paddy rice per unit area was considered to remain the average 1.2 ton/ha of the past 7 years in Changwad Prachinburi while the sales price was calculated to be the average ฿1.2/kg ($58.50/ton, farmer's price) of rice produced in this area in 1966. Gross income was calculated at $70.20 per hectare.

[*1] Census of Agriculture, 1963

[*2] Amphur Kabinburi Survey

Production costs and net income were estimated as shown in App. Table 6-11 upon questioning of farmers in the project area. Production cost per hectare of harvested area proved to be $32.86 and $34.50 per hectare for the whole area planted. Compared with the abovementioned gross income of $70.20 per hectare, the net earnings was calculated as being $35.70 and the net earning ratio approximately 51%.

Upland Crops

The fruit trees are perennial plants and now being irrigated in some manner. Therefore, even if the project is not realized, it is thought the present gross income, production costs and net earning will not be altered. Considering the farmer operating 25 rai (4.0 ha) of durian and oranges as described in 6.4.1 (7), the above is estimated to be $1,000, $633, and $367 respectively. (See App. Table 6-12).

Unless irrigated, field crops in general would be limited to cultivation only in the rainy season. The productivity would be unstable, as at present, with profitability being at best about the same as rice (See Table 6-3). Here, the gross income, production cost and net earning were considered to be $70.20, $34.50 and $35.70 respectively.

TABLE 6-3 GROSS INCOME FROM EXISTIG UPLAND CROPS

Crop	Average Yield (ton/ha)	Unit Price per ton ($)	Income per ha ($)
Jute *	1.25	72.6	91
Ground Nuts *	0.88	96.8	85
Mung Bean *	0.94	60.5	57
Sesame	0.50	121.0	61
Peper	0.94	169.4	159
Egg Plant	2.50	48.4	121
Chinease Cabbage	4.88	72.6	354
Tomato	2.69	72.6	195
Onion	2.19	96.8	212

Note : * Truck Crops for Sale

(2) Agricultural Production with Project

Paddy Rice

Needless to say, direct damage from drought and flood will be markedly reduced upon realization of the project, and since there will be free maneuverability of water, good quality, high-yield strains of rice can be introduced and adequate fertilizer freely used. Also there will be no need to be bound by present customs concerning the cultivation period, and it will be possible to delay the head sprounting period until November after the end of the rainy season when ample sunshine can be had to produce high yields. Furthermore, with increase in the demand for rice and incentive of the farmer, two-crop and even three-crop cultivation will be possible.

For this project, the changes in cultivation periods and production quantities were estimated as shown in Fig. 6-11 and 6-12 referring to test results obtained at the Sam Chook Experimental Farm (See App. Table 6-15) and the performance of farmers in the project area. The average yield per hectare upon completion of construction was estimated to be 1.4 tons as the harvest of Changwad Prachinburi in a bumper-crop year, 1.7 tons 5 years later as the harvest of high-yield farmers in the project area, 2.0 tons 10 years later (equalling the results at the experimental farm), with a 1% increase annually thereafter. (Approximately 3 tons per hectare in the 50th year)

FIG. 6-11 PRESENT AND PROPOSED GROWING PERIOD

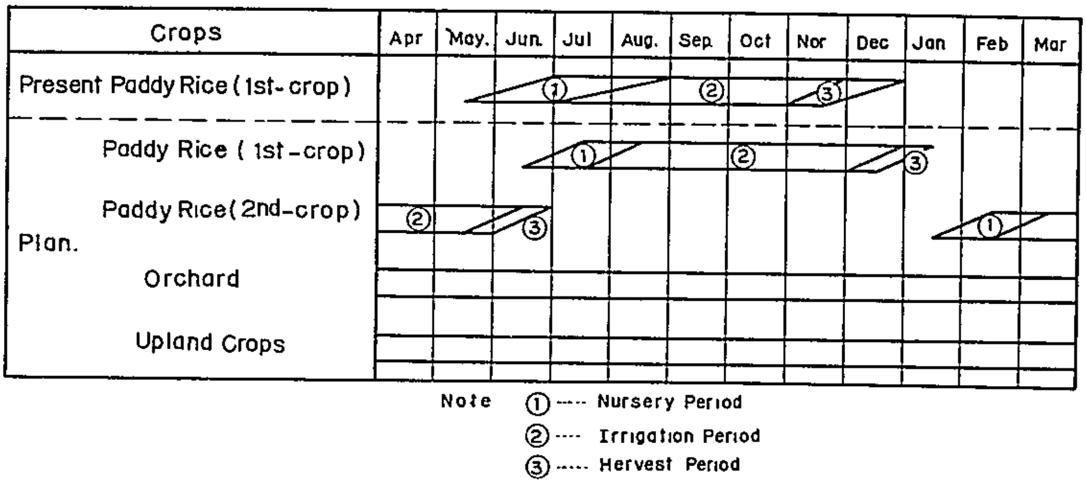
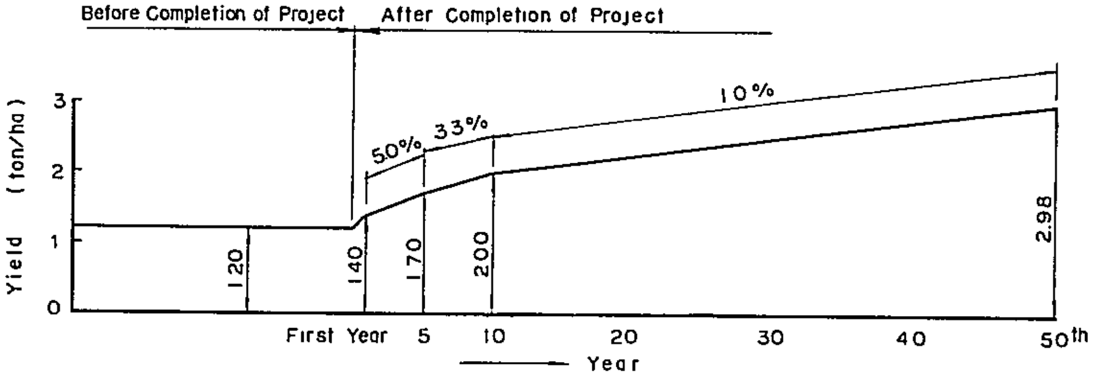


FIG. 6-12 CHANGE IN PADDY RICE YIELD



As for 2nd-crop cultivation, this will depend also on the demand, the incentive of the farmer, and availability of labor so that it is inconceivable the entire project area will be placed under this system immediately after completion of construction. Therefore, for the purposes of this Report, it was assumed 2nd-crop cultivation would be introduced gradually from the first year, reaching 50% of the paddy field area in 5 years with no increase thereafter. The yield per hectare was considered to be the same as for 1st-crop cultivation at that time. The price per ton was taken to be the 1966 farmer's price and was calculated at $58.50/ton (฿1.2/kg).

The production costs necessary for securing the above production quantities were estimated based on the costs of present rice cultivation. As shown in App. Table 6-13, the production cost when 2 tons of paddy rice are produced per hectare is $46,55 meaning a net earning of $70.45 and net earning ratio of approximately 60%.

Therefore; the net earning when the project is realized was calculated to be 60% of gross income. The yearly net earning of the 50 years from realization of the project calculated from the above is given in App. Table 6-16.

Upland Crops

Existing fruit orchards already are provided with irrigation facilities. When the construction according to the project is completed, the water charge will be $57*[1] per hectare as described in 6.8.1 or a reduction of $20 from the $77 per hectare (See 6.4.2 (2), App. Table 6-12) in the case the project is not carried out. Regarding newly planted fruit-trees, it is thought the gross income and the production cost will be the same as if the project is not realized with the exception of water charge. In other words, as indicated in App. Table 6-14, it is estimated that the gross income per hectare will be $1,000, the production cost $554, the net earning $446 and the net earning ratio 45%.

As for field crops in general, the effect of the increase in production through irrigation is great. Also, it will become possible to cultivate various crops in the dry season. Especially, in view of maintaining soil fertility, the introduction of legumes in crop rotation is desirable. (This also being true for paddy field.) Since there are many varieties of crops and the cultivated area is small, the gross income and production costs were assumed to be in accordance with those of paddy rice.

(3) Prevention of Production Decreases through Flood Control

Although damage from flooding differs according to the type of crop, the stage at which the flooding occurs and the duration of the flooding, the rate of reduction in yield of paddy rice can be estimated as 50% according to project area interview and experience in Japan.*[2] If overhead flooding with probability of 1/2 is prevented 2 days during the period in which heads

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*1 $752,500/13,300 ha = $57

*2 Japanese Government Ministry of Agriculture and Forestry Statistics and Investigations Department Data are formed, decreases of approximately 100 tons and $5,850 annually would be avoided for 200 ha of caltivated land.

Moreover, damage to facilities will be prevented, but since records of past damages were not available it was not possible to express this merit in monetary terms.

6.4.3 Irrigation

(1) Irrigable Area

The optimum scale of irrigation studied in 6.2.2 is 10,000 ha of paddy fields (50% two-crop cultivation) and 3,300 ha of upland fields. These areas were distributed on topography, soil and present state of land utilization as shown in Table 6-4 and General Plan.

TABLE 6-4 AVAILABLE AREA BY LAND CATEGORY

Land Category	Present	Planned (Irrigable Area)
Paddy fields	10,000 ha	10,000 ha
Orchard	700	2,000
Upland fields	1,300	1,300
Grassland	1,300	––
Total	13,300	13,300

(2) Unit Irrigation Water Requirement

The unit water requirement for paddy fields with the cultivation period stated in 6.4.2 (2) was calculated pn the following conditions:

(a) Cultivation would be by the transplanting method with the area of nursery beds to be 1/15 of paddy rice area, the seedling period to be 30 days and the water requirment in depth to be 20 mm.

(b) Water requirement for preparation of paddy fields is to be 200 mm.

(c) Evapotranspiration during cultivation in the main paddy would be calculated by the Blaney-Criddle Method with the seasonal consumptive-use coefficient k = 1.0 for the first crop and k = 1.2 for the second crop.

Paddy Rice	Irrigation Period	Days	Evapotranspiration	Ratio
1st-Crop	Jun. 25 – Dec. 11	151	890[*1]	1.01
			880[*2]	1.00
2nd-Crop	Feb. 20 – Jun. 8	90	690[*1]	1.23
			560[*2]	1.00

Note : *1 Result of Sam Chook Experimental Farm
*2 Blaney-Criddle Method (k= 1.0)

(d) Percolation losses would be 3 mm/day, judging from the soil texture.

(e) The past minimum rainfall recorded in 1965-1966 would be adopted as the effective rainfall on field surfaces, and as the effectiveness ratio would vary according to rainfall intensity, the values of App. Tables 6-18, 19 would be followed.

(f) Conveyance and operation losses would be considered as 25% since waterway structures would be mostly unlined.

The results of the above are as indicated in App. Tables 6-18 and 6-19.

The unit irrigation water requirements for orchard and upland fields were calculated according to the following.

(a) Evapotranspiration would be obtained by the coefficient of crop of k = 0.65 in the Blaney-Criddle Method.

(b) As in the case of paddy fields, the rainfall of 1965 - 1966 would be adopted for the effective rainfall with the effectiveness ratio 50% in view of the water holding capacity of soil and rainfall intensity.

(c) Irrigation efficiency would be 70% on the basis of farrow or basin irrigation.

(d) Conveyance and operation losses would be 25% as in the case of paddy fields.

The results of the above are as given in App. Table 6-20.

(3) Irrigation Water Requirement at the Reservoir Site

The irrigation water requirement at the reservoir site was calculated from the irrigated area described in 6.4.3 (1) and the unit irrigation water requirements obtained in 6.4.3 (2). The results are given in Table 6-5.

TABEL 6-5 WATER REQUIREMENT FOR PROPOSED IRRIGABLE AREA (13,300 ha)

Item	Unit	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.
Paddy Rice (1st-crop) 10,000 ha	c.m.s	-	-	0.590	6.960	11.310	1.770	9.880	11.310
Paddy Rice (2nd-crop) 5,000 ha	c.m.s	7.480	7,100	0.600	-	-	-	-	-
Upland Crops 3,300 ha	c.m.s	2.564	2,960	0.888	1.772	1.175	0	1.416	2.069
Diversion Water Requirement	c.m.s	10,044	10.060	2.078	8.732	12.485	1.770	11.296	13.359

Item	Unit	Dec.	Jan.	Feb.	Mar.	Total	Average
Paddy Rice (1st-crop) 10,000 ha	c.m.s	6.320	-	-	-	48.140	6.975
Paddy Rice (2nd-crop) 5,000 ha	c.m.s	-	0.320	3.700	8.805	28.005	4.690
Upland Crops 3,300 ha	c.m.s	2.459	2.495	1.617	2.551	21.966	1.837
Diversion Water Requirement	c.m.s	8.779	2.815	5.317	11.356	98.111	8.214

Next, the state of water utilization for the period from April 1962 to June 1966 during which drought prevailed was studied for the Nam Sai Yai No.4 Reservoir (effective storage capacity 24 million cu.m.) decided on in 6.2.2. The result indicated in Fig.6-13 shows that the lowest water level of the reservoir would be EL 37.0 m as in May 1965.

(4) Water Conduction and Distribution

The irrigation water requirement at the reservoir site for the irrigated area of 13,300 ha is as shown in Table 6-5. This water will be taken from both the right and left banks of the No.4 Reservoir. In other words, for the 3,500 ha of cultivated land on the left bank of the Hanuman River, the water would be taken in from the left side of the dam. The scale of the waterway would be required to be a maximum 4.5 c.m.s. and the length 26 km. For the cultivated land of 9,800 ha on the right bank, water will be taken from the right side of the dam. It will be necessary for the waterway to have a maximum capacity of 11.6 c.m.s. and a length of 50 km.

In view of the topography (according to a 1/10,000 scale topographical map) and the distribution of cultivated land, a diversion plan as shown in Fig. 6-14 was decided upon.

6.5 SEQUENCE OF STAGE DEVELOPMENT

On the Sai Yai River Basin, as stated previously, the development of No.1 to No.4 Power Stations is feasible. However, from the aspect of power demand, it will not be necessary for all of these power stations to be started up simultaneously.

Regarding the sequence of development, it would be desirable for the sites to be taken up in the order of highest economy, and therefore, the following considerations were made.

FIG. 6-13 RESERVOIR OPERATION (NO.4 RESERVOIR)

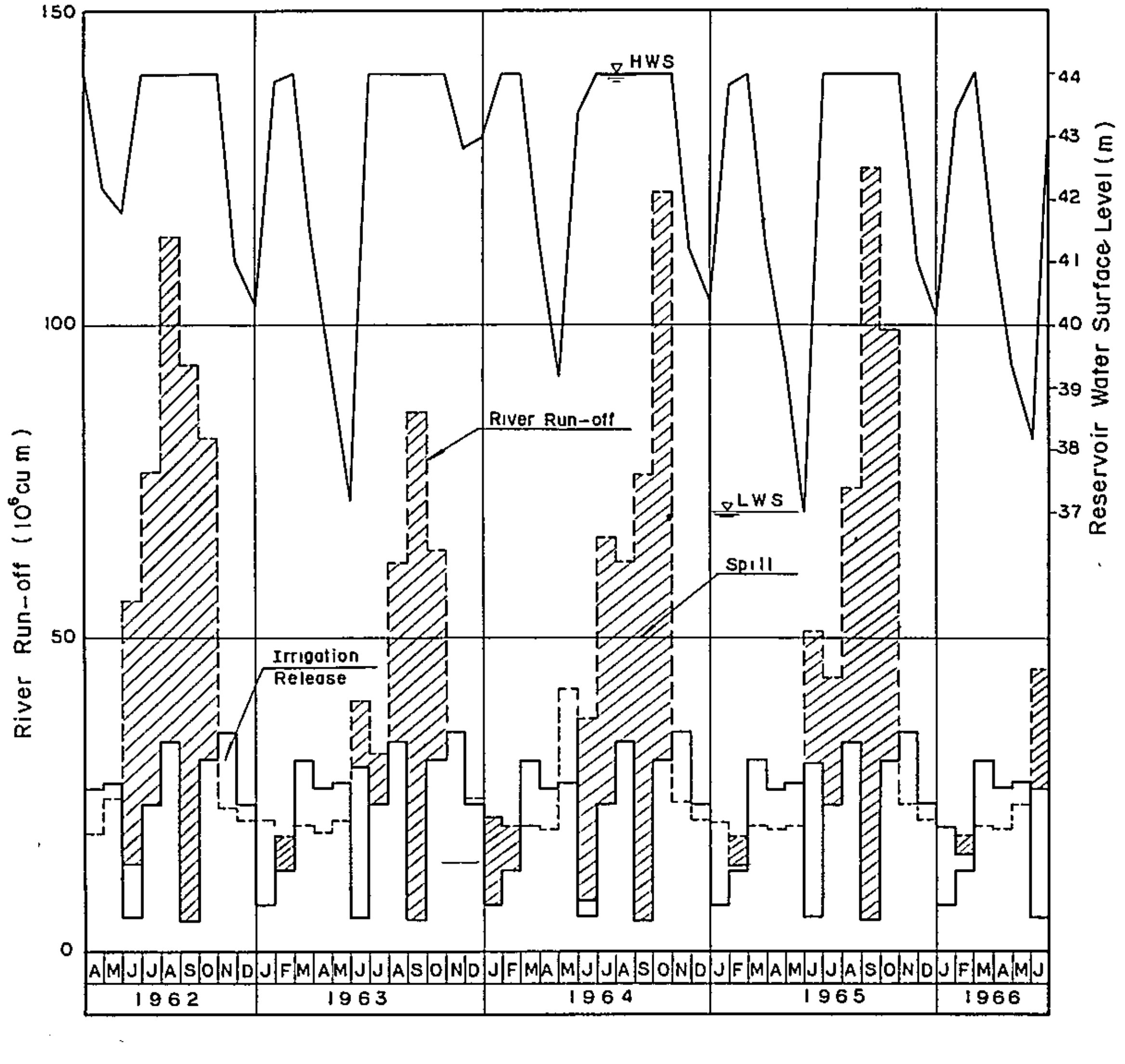
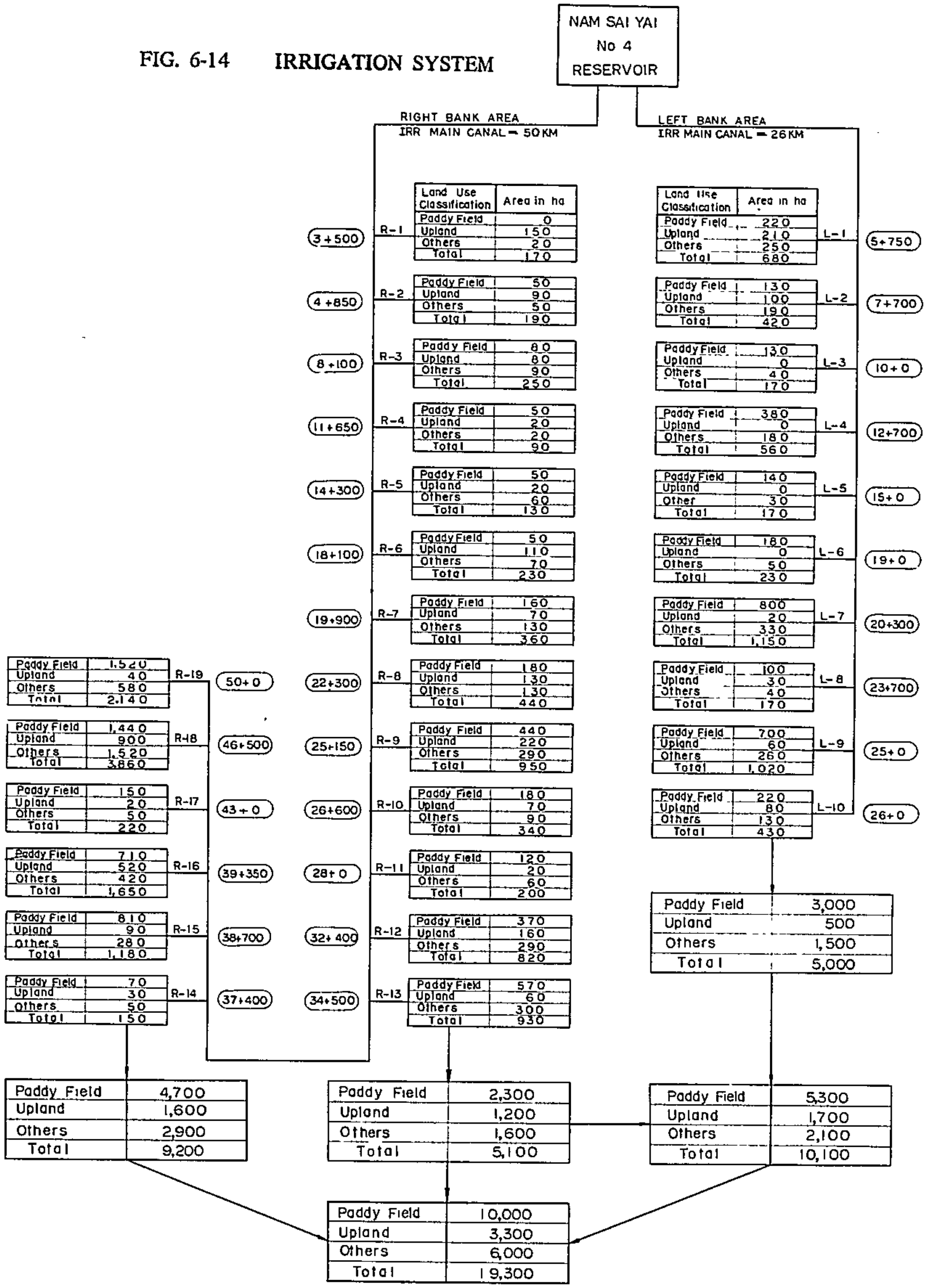


FIG. 6-14 IRRIGATION SYSTEM



R-1 3+500

Land Use Classification	Area in ha
Paddy Field	0
Upland	150
Others	20
Total	170

R-2 4+850

Paddy Field	50
Upland	90
Others	50
Total	190

R-3 8+100

Paddy Field	80
Upland	80
Others	90
Total	250

R-4 11+650

Paddy Field	50
Upland	20
Others	20
Total	90

R-5 14+300

Paddy Field	50
Upland	20
Others	60
Total	130

R-6 18+100

Paddy Field	50
Upland	110
Others	70
Total	230

R-7 19+900

Paddy Field	160
Upland	70
Others	130
Total	360

R-8 22+300

Paddy Field	180
Upland	130
Others	130
Total	440

R-9 25+150

Paddy Field	440
Upland	220
Others	290
Total	950

R-10 26+600

Paddy Field	180
Upland	70
Others	90
Total	340

R-11 28+0

Paddy Field	120
Upland	20
Others	60
Total	200

R-12 32+400

Paddy Field	370
Upland	160
Others	290
Total	820

R-13 34+500

Paddy Field	570
Upland	60
Others	300
Total	930

R-14 37+400

Paddy Field	70
Upland	30
Others	50
Total	150

R-15 38+700

Paddy Field	810
Upland	90
Others	280
Total	1,180

R-16 39+350

Paddy Field	710
Upland	520
Others	420
Total	1,650

R-17 43+0

Paddy Field	150
Upland	20
Others	50
Total	220

R-18 46+500

Paddy Field	1,440
Upland	900
Others	1,520
Total	3,860

R-19 50+0

Paddy Field	1,520
Upland	40
Others	580
Total	2,140

L-1 5+750

Land Use Classification	Area in ha
Paddy Field	220
Upland	210
Others	250
Total	680

L-2 7+700

Paddy Field	130
Upland	100
Others	190
Total	420

L-3 10+0

Paddy Field	130
Upland	0
Others	40
Total	170

L-4 12+700

Paddy Field	380
Upland	0
Others	180
Total	560

L-5 15+0

Paddy Field	140
Upland	0
Other	30
Total	170

L-6 19+0

Paddy Field	180
Upland	0
Others	50
Total	230

L-7 20+300

Paddy Field	800
Upland	20
Others	330
Total	1,150

L-8 23+700

Paddy Field	100
Upland	30
Others	40
Total	170

L-9 25+0

Paddy Field	700
Upland	60
Others	260
Total	1,020

L-10 26+0

Paddy Field	220
Upland	80
Others	130
Total	430

Paddy Field	3,000
Upland	500
Others	1,500
Total	5,000

Paddy Field	4,700
Upland	1,600
Others	2,900
Total	9,200

Paddy Field	2,300
Upland	1,200
Others	1,600
Total	5,100

Paddy Field	5,300
Upland	1,700
Others	2,100
Total	10,100

Paddy Field	10,000
Upland	3,300
Others	6,000
Total	19,300

The No.1 and No.2 Reservoirs would be exclusively for power generation and the construction cost of the reservoirs would be allocated in proportion to the excess benefit of each power station. The benefit of each power station was calculated with the stipulation that benefit would be that at the time when full benefit is obtained at each power station. The results are as shown in App. Table 6-21 disclosing that the No.2 and No.3 Power Stations would be the most economical.

Also, similar studies were made on the assumption that the No.1 Reservoir is not constructed. The results given in App. Table 6-22 again show that the No.2 and No.3 Power Stations would be most economical.

As a result of the above, it was decided the sequence of development should be as given below in consideration the periods necessitated for the execution of the construction.

Sequence	Power Station	Start-up
1	No.2	1974
2	No.3	1975
3	No.4	1978
4	No.1	1982

Regarding agricultural development, it would be desirable for it to be undertaken as soon as possible in view of the increasing demand for food. In the economic evaluation made in 6.8, it was assumed that 7 years would be required for surveying, designing and construction, and that irrigation would begin in 1976.

6.6 OUTLINE OF MAJOR STRUCTURES

The outlines of the major structures necessary for development of the Sai Yai River Basin are as given in Table 6-6.

TABLE 6-6 DESCRIPTION OF STRUCTURES

Dam

Dam	No.1	No.2	No.3	No.4
Type	Fill Dam	Fill Dam	Fill Dam	Fill Dam
Height (m)	59	40	28	39(Sai Yai River) 45(Sai Noi River)
Length (m)	395	1,346	540	300 600
Volume (thousand cu.m)	840	1,700 (Included Dike)	400	500 700
Headrace Tunnel				
Type	Horse-Shore	Horse-Shore	Horse-Shore	Horse-Shore
Length (m)	1,800	1,668	535	1,400
Inside Diameter (m)	2.30	3.10	3.10	2.40
Power Station				
Type of Power House	In-door	In-door	In-door	In-door
Rated Head (m)	86.7	70.0	333.3	119.4
Max. Available Discharge (c.m.s.)	10.0	20.0	20.0	21.0
Firm Discharge (c.m.s.)	3.1	7.3	7.3	7.4

Transmission Line

Distance (km)	134
Voltage (kV)	115

Irrigation	Total	Left Bank Area	Right Bank Area
Irrigable Area (ha)	13,300	3,500	9,800
Main Canal Length (km)	76	26	50
Max. Capacity (c.m.s.)		4.5	11.6

6.7 COST ESTIMATE

It is estimated that the construction cost required for development of the Sai Yai River Basin will be totalled to $48,067,000. (See Table 6-7)

Table 6 - 7 Construction Costs

Type of Construction	Construction Costs	
	$	10³ ฿
Dam		
No.1	3,912,900	80,800
No.2	4,745,900	98,000
No.3	978,200	20,200
No.4	4,919,000	101,600
Subtotal	14,556,000	300,600
Power Station		
No.1	2,803,900	57,900
No.2	6,702,300	138,400
No.3	8,058,300	166,400
No.4	8,450,500	174,500
Subtotal	26,015,000	537,200
Transmission lines and substations	3,874,000	80,000
Irrigation		
Main canals	1,600,000	33,000
Laterals and other works	2,022,000	41,800
Subtotal	3,622,000	74,800
Total	48,067,000	992,600

6.8 ECONOMIC JUSTIFICATION

6.8.1 Annual Costs

Calculations of annual costs were made for the 50 years after 1974 when the No.2 Power Station go into operation. The amortization of investment costs was calculated at the interest rate of 6% per annum.

Operation maintenance and replacement costs amounting to 1% of construction costs were added to the above for dams and power stations. As a result, annual cost is estimated to be $2,307,300 (฿ 47,700,000). As for the transmission line, operation, maintenance and replacement costs amounting to 3.3% of construction costs were included, and as a result the annual cost is estimated at $373,800. (฿ 7,700,000)

As for irrigation structures, operation, maintenance and replacement costs amounting to

3% of construction costs were included and as a result, the annual cost is estimated at $752,500 (฿15,500,000)

The result of the above, the amount of annual cost is estimated to be $3,433,600 (฿ 70,900,000)

6.8.2 Annual Benefits

Calculations of benefits were also made for 50 years as in the case of annual costs.
For unit benefit price of power production, a standard thermal power station in Bangkok was taken as a standard (oil burning thermal power station with a 200 MW unit output) and the costs per kW and kWh considered as the benefit of the Project. The estimates were $14.5 (฿300) per kW and 5.4 mill (11.2 Satang) per kWh.

Considering that the output and energy production of No.1 to No.4 Power Stations would be absorbed one after another in accordance with demand growth, the annual output and energy production for 50 years from starting up multiplied by the above unit benefit price and equalized for 50 years from 1974 at the interest rate of 6% would result in an annual benefit of $2,798,400 (฿57,800,000).

Regarding agriculture, for the projected area of 13,300 ha, the difference between the net earning with the project (paddy rice: 1st-crop 10,000 ha, 2nd-crop 5,000 ha; fruit-trees 2,000 ha; upland crops 1,300 ha) and the net earning without project (paddy rice: 1st-crop 10,000 ha; fruit-trees 700 ha; upland crops 1,300 ha; grass 1,300 ha) for 50 years was taken and equalized for 50 years from 1974 at 6% interest rate to arrive at a benefit of $1,315,900 (฿ 27,200,000).

It should be noted that the amount of production decreases prevented by flood control was estimated to be an annual average of $5,850 (See 6.4.2 (3)) which is included in the above benefit.

The total benefit from power generation and agriculture is calculated to be $4,114,300 (฿ 85,000,000) annually.

6.8.3 Excess Benefit and Benefit Cost Ratio

From the results of estimates of benefits and costs, the total excess benefit was calculated at $680,700 (฿14,100,000) annually.

If the No.1 and No.2 Reservoirs are considered as facilities exclusively for power generation, the breakdown of excess benefit would be $117,300 (฿ 2,400,000) for power generation and $563,400 (฿ 11,600,000) for agriculture while the ratios of benefits and costs would be 1.20 overall, 1.04 for power generation and 1.75 for agriculture respectively.

The case of No.1 and No.2 Reservoirs are considered as dual-purpose facilities, the costs for these facilities would be allocated by the alternative-justifiable cost method, the breakdown of excess benefit would be $366,000 (฿ 7,600,000) for Power, and $314,700 (฿ 6,500,000) for agriculture while the ratios of benefits and costs would be 1.15 for power and 1.31 for agriculture. While the internal rate of return for this project was estimated to be 7.9%.

Introduction newly of fruit crops will be required large initial investiment and a high level of cultivation techniques, therefore if ordinary upland crops were cultivated instead of fruit crops the benefit would be $894,100 (฿ 18,500,000) for agriculture, while the total excess benefit would be $252,900 (฿ 5,200,000) and the ratio of benefit and cost would be 1.07. In this case the internal rate of return would be 6.7%.

CHAPTER 7

DEVELOPMENT OF PRACHANTAKHAM RIVER BASIN

FIGURES

TABLES

CHAPTER 7

DEVELOPMENT OF PRACHANTAKHAM RIVER BASIN

7.1 OUTLINE

The development of this river basin is proposed to make effective the hydraulic energy of the Sai Noi River and to supply irrigation water to the downstream cultivated area of the Prachantakham River. The outline is as described below.

The No.1 Reservoir, HWL 365 m and effective storage capacity 36.5 million cu.m. would be constructed at the confluence of the Phok Nam River (Khlong Phok Nam), the upstream section of the Prachantakham River, and the Noi River (Huai Noi; catchment area 26.5 sq.km). The No.2 Reservoir, HWL 277 m and effective storage capacity 7.2 million cu.m, would be established at a point 3 km downstream (catchment area 20.3 sq.km) from the former.

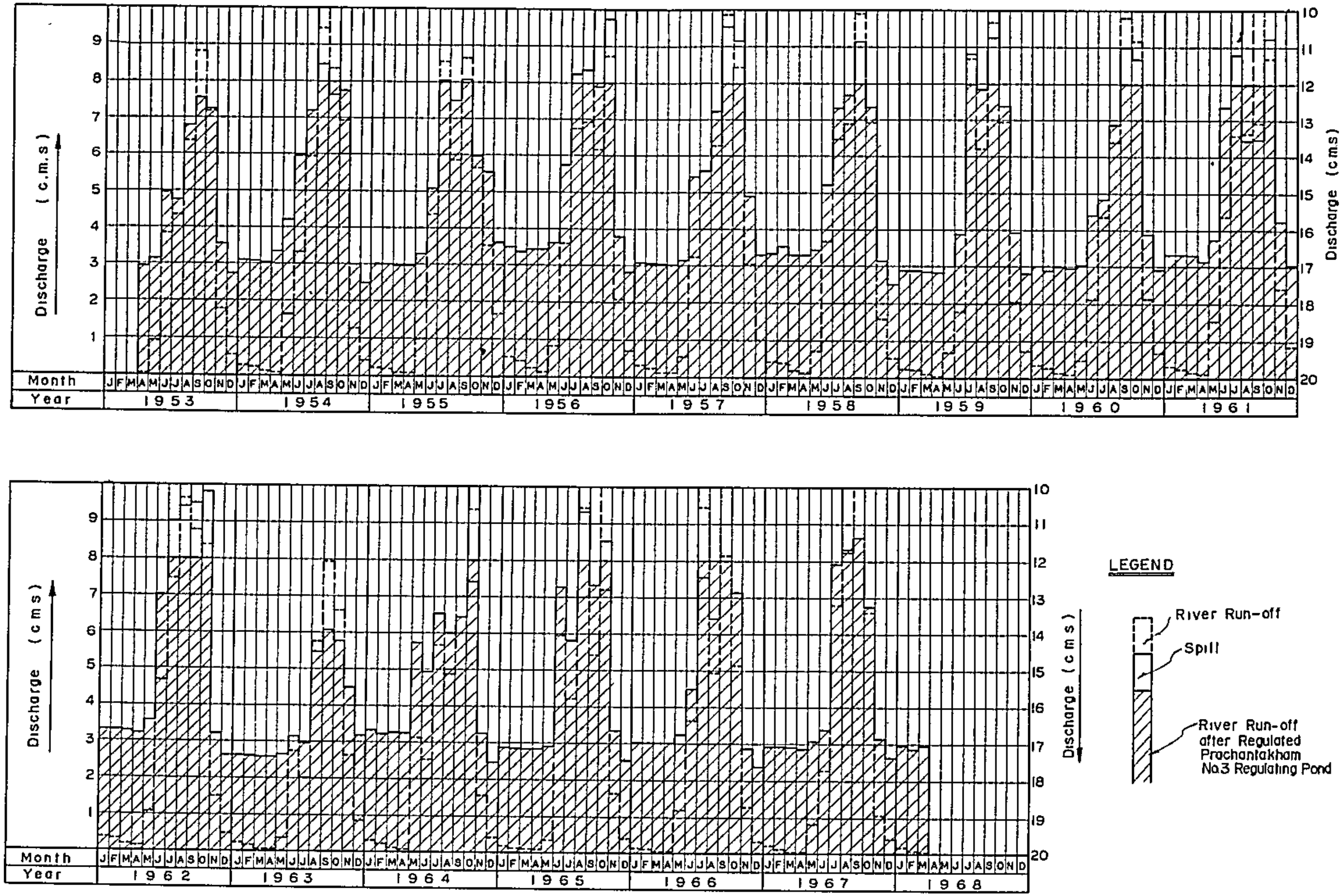
The No.1 Reservoir would be supplied with an approximate annual average of 1.5 million cu.m. of water from the adjacent Chang Khlan River (Khlong Chang Khlan; catchment area 16 sq.km) on the west by a tunnel with 0.5 km of length and a capacity of 7.8 c.m.s., and an annual average 18.8 million cu.m. from the Kan Krao Ngam River (Khlong Kan Krao Ngam; catchment area 19.4 sq.km) adjacent on the north by a tunnel 1.6 km long with a capacity of 7.8 c.m.s. To utilizing the head of approximately 80 m down to the No.2 Reservoir, a No.1 Power Station with a maximum output of 3,000 kW would be built downstream of the No.1 Reservoir.

The No.2 Power Station would be built downstream of the No.2 Reservoir. The water used at this power station would be a combination of the water from the Sai Noi River (catchment area 67 sq.km) and the No.2 Reservoir. From the Sai Noi River, an approximate annual average of 58 million cu.m. of water would be conducted by a tunnel 3.1 km long with a capacity of 7.8 c.m.s. This water, would be stored in the No.2 Reservoir during off peak period of the No.2 Power Station. For the No.2 Power Station, the head of 226 m to the downstream regulating pond could be utilized, and the maximum output would be 13,800 kW.

This pond with storage capacity of 152,000 cu.m to make possible daily regulation would be constructed at 4 km upstream of Ban Tha Ta Takhro, and also use water of the catchment area (23 sq.km) remaining below the No.2 Reservoir. (See Fig. 7-1) From this, the water would be conducted to Ban Tha Ta Takho site by s waterway 4 km long with a capacity of 8.0 c.m.s. Thereon, utilizing the head of approximately 20 m No.3 Power Station with maximum output of 470 kW would be built.

The discharge would be conducted to the left bank area of the Prachantakham River by a waterway 20 km long with maximum capacity of 4 c.m.s. to supply 3,000 ha of paddy fields. (See General Plan)

FIG. 7-1 MONTHLY MEAN RIVER RUN-OFF AND POWER DISCHARGE AT PRACHANTAKHAM NO.3 REGULATING POND



7.2 RESERVOIR

The run-off at each reservoir and each intake site were obtained by multiplying the specific run-off estimated in 4.2 by the respective catchment areas.

In the event the capacities of the tunnels for conducting water from the Chang Khlan River and the Kan Krao Ngam River to the No.1 Reservoir are both 7.8 c.m.s. (minimum cross section for construction), the run-off of these rivers can be drawn 100%. Adding the run-off of its own catchment area (26.5 sq.km), the inflow at No.1 Reservoir would be as shown in Fig. 7-2.

Regarding intake from the Sai Noi River, when the capacity of the waterway is 7.8 cu.m. (minimum cross section for construction), approximately 90% of the run-off would be drawn. Using this water combined with the inflow to No.2 Reservoir, including the inflow to No.1 Reservoir, the total would be as shown in Fig. 7-3.

If there are 3 consecutive years of drought (1962 - 1965) and if it were attempted to use this water 100%, a combined capacity of approximately 85.6 million cu.m. would be necessary for the No.1 and No.2 Reservoirs.

However, judging by the topography of the reservoir sites (See App. Fig. 7-1) there would be economical problems in providing reservoirs with such capacities. And the reservoir efficiency of No.2 Reservoir would also be poor compared to the No.1 Reservoir. (See Fig.7-4)

Therefore, the scales of the No.1 and No.2 Reservoirs were determined to as HWL 365 m, effective storage capacity 36.5 million cu.m. for the No.1 Reservoir, HWL 277 m, effective storage capacity 7.2 million cu.m. for the No.2 Reservoir.

The above would result in the No.1 Reservoir having a capacity greater than the capacity necessary (19.8 million cu.m.) for averaging the dry-year inflow (1962 - 1963), but it is considered that the No.1 Power Station would be used for dry-season power supply.

The proposed No.3 regulating pond to be developed downstream of the No.2 Power Station will conduct the water after the power discharge from No.2 Power Station, as well as the water from inflow of the 23 sq.km of its own catchment area. (See Fig. 7-1) The said regulating pond was determined at HWL 45 m and at storage capacity 152,000 cu.m. in order to enable the daily regulation of the power discharge from No.2 Power Station.

FIG. 7-2 MONTHLY MEAN RIVER RUN-OFF AND POWER DISCHARGE AT PRACHANTAKHAM NO. 1 DAM

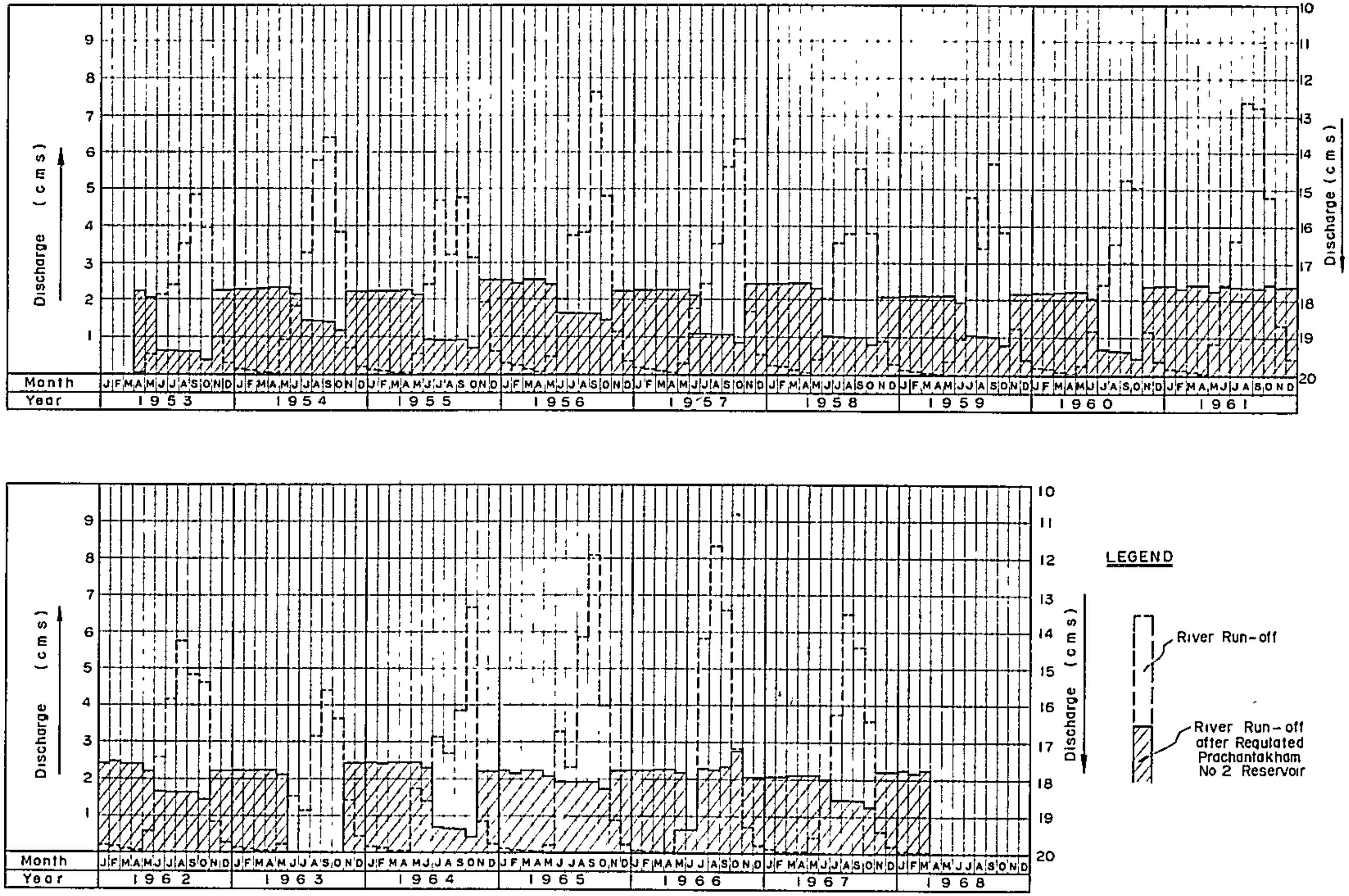


FIG. 7-3 MONTHLY MEAN RIVER RUN-OFF AND POWER DISCHARGE AT PRACHANTAKHAM NO.2 DAM

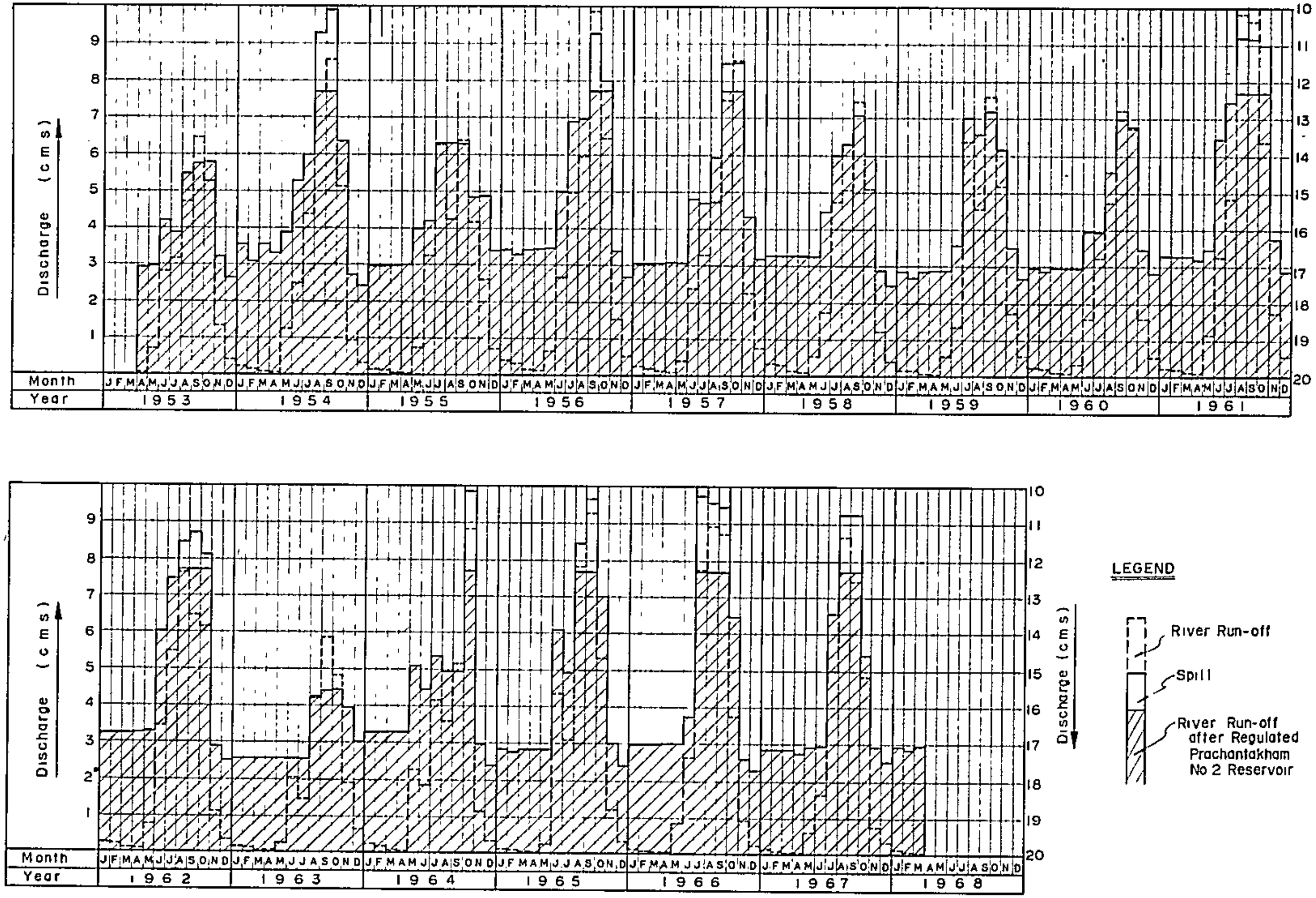
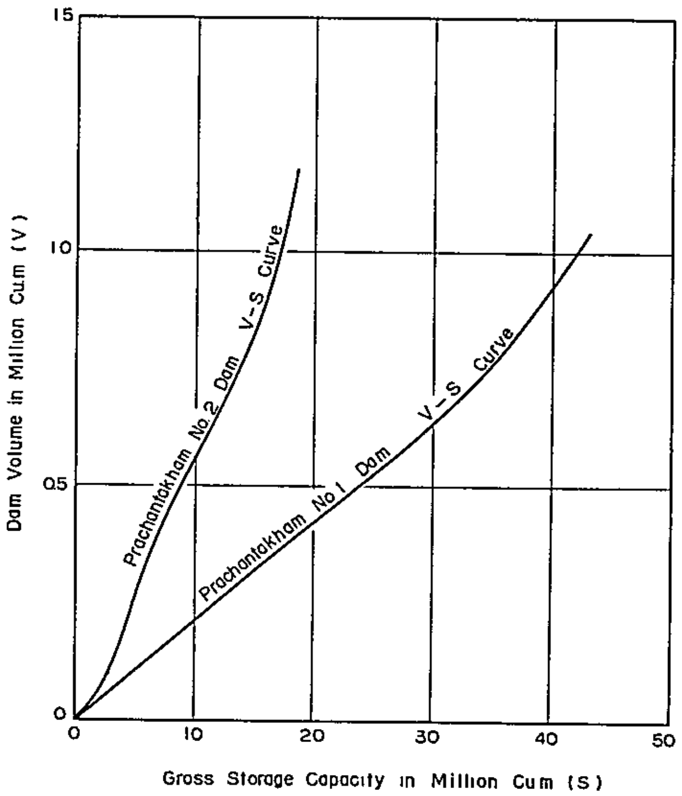


FIG. 7-4 RELATION BETWEEN DAM VOLUME AND GROSS STORAGE CAPACITY (PRACHANTAKHAM)



7.3 POWER

Based on the scale of the reservoirs determined in the preceding paragraph, the scale of the No.1, No.2 and No.3 Power Stations would be as follows.

Power Station	Available Discharge (c.m.s.)		Rated Head (m)	Max. Output (kW)
	Firm	Max.		
No.1	1.7	5.2	74.1	3,000
No.2	2.6	7.9	208.0	13,800
No.3	2.6	8.0	22.4	470

The energy produced from these scales of generation would be an annual average of 9,900 MWh for No.1 Power Station, 65,600 MWh for No.2 Power Station and 7,200 MWh for No.3 Power Station, giving a total of 82,700 MWh.

The power produced at these power stations would be interconnected with the Sai Yai Power Station System. The transmission line required for this purpose would be a 115 kV, 1-circuit, 16 km long line.

7.4 IRRIGATION

There are practically no upland fields in the downstream area of the Prachantakham River. Therefore, only paddy fields were considered as objects of irrigation.

Based on the optimum scale of water resource facilities studied in 7.2, the irrigable area would be 3,000 ha. The irrigable area selected the districts lower than EL 18 m along the left bank of the Prachantakham River where water is presently most scarce. (See General Plan) The irrigation water requirement at the No.3 power station was calculated assuming that 50% of the paddy fields would be used for two-crop cultivation in the future as in the case of the Sai Yai Project from 1962 to 1965 during which drought prevailed. The results are given in Table 7-1.

Should the above irrigation be carried out, the paddy fields would be relieved of perennial drought, and heavy-fertilizer, high-yield types of rice could be introduced. Two-crops a year cultivation would be possible, so that it is estimated approximately 7,000 tons of rice could be produced annually. In order to realize the said production, an intake canal, capacity (1.0 c.m.s. – 4.0 c.m.s.) of 20 km length from the intake site of No.3 Power Station to the irrigation area and an irrigation system reaching to the ends of the cultivated land would be required to be constructed.

Now, if the reservoirs as described in 7.2 would be operated for irrigation only the irrigable area of paddy fields would become 4,000 ha for 1st-crop and 2,000 ha for 2nd-crop.

TABLE 7-1 IRRIGATION WATER REQUIREMENTS AND AVAILABLE WATER AT No.3 POWER STATION

Item	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Average	Remark
Water Requirements														
One-Crop 3,000 ha			0.177	2.088	3.393	0.531	2.964	3.393	1.896				2.094	
Two-Crop 1,500 ha	2.244	2.130	0.180							0.096	1.110	2.642	1.407	
Total (1)	2.244	2.130	0.357	2.088	3.393	0.531	2.964	3.393	1.896	0.096	1.110	2.642	1.913	
No.3 P.S. (1962-1963) (2) Discharge	3.252	3.545	6.969	8.000	8.000	8.000	8.000	3.193	2.588	2.622	2.608	2.589	4.954	(1)/(2) x 100 = 39%
Spill out	1.008	1.415	6.612	5.912	4.607	7.469	5.036	0	0.692	2.526	1.498	0		
No.3 P.S. (1963-1964) (3) Discharge	2.589	2.650	3.141	2.972	5.450	6.034	5.763	4.488	3.191	3.330	3.205	3.290	3.853	(1)/(3) x 100 = 50%
Spill out	0.345	0.520	2.784	0.884	2.057	5.503	2.799	1.095	1.295	3.234	2.095	0.648		
No.3 P.S. (1964-1965) (4) Discharge	3.278	5.732	4.960	6.531	6.000	6.425	8.000	3.281	2.484	2.875	2.867	2.859	4.623	(1)/(4) x 100 = 41%
Spill out	1.034	3.602	4.603	4.443	2.607	5.894	5.036	0	0.588	2.779	1.759	0.217		

7.5 OUTLINE OF MAJOR STRUCTURES AND THEIR CONSTRUCTION COSTS

The outlines of the structures to be built under this project and the construction costs required are as given in Table 7-2.

TABLE 7-2 APPROXIMATE CONSTRUCTION COSTS

Type of Construction	Outline		Construction Cost	
			$	10^3 ฿
No.1 Dam	Fill-type Height Dam Volume	 52.5 m 1,262x10^3 Cu.m	3,486,800	72,000
No.2 Dam	Fill-type Height Dam Volue	 38.0 m 710x10^3 Cu.m	2,125,900	43,900
Waterway (from Sai Yai River)	Length Capacity	3.1 km 7.8 c.m.s	532,700	11,000
No.1 Power Station	Output	3,000 kW	1,307,500	27,000
No.2 Power Station	Output	13,800 kW	4,239,000	87,500
No.3 Power Station	Output	470 kW	930,900	19,300
Transmission Line and Substation Works	Distance	16 kW	193,700	4,000
Irrigation Works	Main Canal Irrigable Area	20 km 3,000 ha	900,000	18,500
Total			13,716,500	283,200

7.6 ECONOMIC JUSTIFICATION

The economic evaluation of this project was expressed in terms of the internal rate of return. The annual interest rate when the annual costs for 50 years equal the annual benefits was estimated at 4.8%. (See Table 7-3)

TABLE 7 - 3 ANNUAL COST AND BENEFIT

Item	$	10^3 ฿
Annual Cost	888,100	18,300
Dam and Waterway	387,800	8,000
Power	425,500	8,800
Irrigation	74,800	1,500
Annual Benefit	888,100	18,300
Power	676,300	13,900
Irrigation	211,800	4,400

Now, if the reservoirs would be operated mainly for irrigation purpose, the internal rate of return would be equal approximately to the one in the above case.

APPENDIX

I. HYDROLOGICAL STUDY

APPENDIX

1. RUN-OFF GAGING STATIONS AND METEOROLOGICAL STATIONS

In the project area, three streamflow gaging stations, two on the Sai Yai River and one on the Hanuman River downstream of the confluence of the Sai Yai and the Sai Noi, have been established. Water level reading is made by staff gage one to five times per day.

Wang Heo Gaging Station on the Sai Yai River, which has a catchment area of 295 sq.km, is in just as good a location as the proposed No.2 dam site. Discharge observation is made every other day by current meter, which has been in operation since January 1st, 1965.

Kao Keep Samut Gaging Station on the Sai Yai River, which has a catchment area of 420 sq.km, was located approximately 16 km below the Wang Heo Gaging Station from March 1964 until December 1964, but in January 1965, the station was moved to the Wang Heo Gaging Station.

Since difference in catchment area between Wang Heo and Kao Keep Samut is comparatively small, they will be considered to be interrelated gaging stations. Therefore, the catchment area of Kao Keep Samut is converted into that of Wang Heo and will be considered to come under Wang Heo.

Ban Sapanhin Gaging Station on the Hanuman River, which has a catchment area of 636 sq.km, is located at the Hanuman River downstream of the confluence with the Sai Yai and Sai Noi Rivers. Discharge observation is made every other day as at the Wang Heo by current meter which has been in operation since July, 1963.

For the development of the Prachantakham River, one gaging station on the Prachantakham River called Ban Takhro will be established in the near future.

Rainfall observations in the project area have daily records for a long period, and most of them are availab' lt

Two new rainfall observatories, called R-2 and Ban Ta Sum, will be established in the near future at the locations shown in App. Fig. 4-1.

The locations, catchment areas and existing data of gaging stations and rainfall observatories within the basin as well as related area are shown in App. Fig. 4-1.

2. CATCHMENT AREA OF PROPOSED SITES

The catchment areas of the proposed dam sites were estimated on the basis of a topographical map on a scale of 1:50,000 prepared by the Royal Thai Survey Department.

The catchment areas of the two proposed dam sites are as follows:

Proposed Dam Sites	Unit	Catchment Area Total Area	Incremental Area
Nam Sai Yai No.2[*1]	sq.km	295	295
Nam Sai Yai No.2[*2]	sq.km	298	3 [*3]

[*1] On Sai Yai River

[*2] On Pla Kang River which is a tributary of the Sai Yai River

[*3] Only Pla Kang River

3. VERIFICATION OF DATA

Verification of data was made by comparing simultaneous run-off data of the Wang Heo and the Ban Sapanhin.

The hydrographs of daily run-off of the two gaging stations from January 1964 through December 1967 are shown in App. Fig. 4-2. It was revealed that the two hydrographs are similar except for one or two days and also that their quantitative and time-lag relations are quite reasonable. App. Fig. 4-3 shows the rating curves which provide the basis for estimation by discharge of the Wang Heo in 1965, 1966 and 1967, and the Kao Keep Samut in 1964.

App. Fig. 4-4 shows the rating curves which provide the basis for estimation of discharge of the Ban Sapanhin from 1964 through 1967. It can be seen that the Wang Heo, the Kao Keep Samut and the Ban Sapanhin Gaging Station rating curves have been made on the basis of an adequate number of direct measurements using a current meter and have been revised annualy to cope with river bed change due to flood flow. Moreover, since the plotting points in these figures generally are close together, these rating curves are considered to be very reliable. A correlation of monthly average specific run-off between Ban Sapanhin and Wang Heo from January 1964 through December 1967 is shown in App. Fig. 4-5 (3). This correlation proves that there is a good correlation between the average monthly run-off of the two gaging stations, and verifies that this run-off is reliable.

Annual rainfall of Wang Heo, which was correlated on the basis of the annual rainfall in Bangkok from 1911 through 1952 and on the monthly rainfall of Kabinburi and Prachinburi from 1953 through 1967, is shown in App. Fig. 4-5 (1). The average annual rainfall of Wang Heo from 1953 through 1967, from which estimation run-off at Wang Heo is possible, was 2,240 mm practically the same as from 1911 through 1967 which was 2,150 mm. Therefore, energy production estimated on the basis of run-off records from 1963 through 1967 can be considered to be the same as the energy production expected during the life of the project. It should be noted that the period from 1953 through 1967 which was used as the basis for studies on reservoir capacity includes a critical dry period of several years.

As the result of the abovementioned studies, it can be concluded that the run-off data of

Wang Heo and Ban Sapanhin Gaging Stations is very reliable, and the period from 1953 through 1967 is long enough to formulate a hydroelectric development scheme.

4. RIVER RUN-OFF

4.1 Method of Estimating Run-off

The equations for prediction of seasonal run-off from rainfall data have been developed on the basis of a paper entitled "prediction of seasonal run-off from rainfall" by Boonchob Kanchanalak, Hydrology Section, Survey Division, Royal Irrigation Department, September 1964.

According to this paper, the development of correlation has been derived as below.

The effective portion of basin rainfall which reflects run-off each month may be represented by the regression equation as follows.

$$Pe = aP_1 + bP_2 + cP_3 + dP_4 + \dots\dots\dots\dots\dots + rP_n \qquad \text{(Formula 1)}$$

where Pe is effective basin rainfall; P_1, P_2, P_3 .... P_n are previous basin rainfall occuring at different periods; and a, b, c .... r are weights of effectiveness.

For practical convernience, each period of previous rainfall adopted in this study is 15 days or the first half and the last half of a month.

In determining the weight of effectiveness, a trial and error method checking with the correlation line may be employed with success.

The seasonal monthly run-off are obtained multipling Pe by the run-off coefficient which is determined by the trial and error method with the correlation line as well as the weights of effectiveness.

The rainfall run-off correlations developed on the basis of rainfall and run-off data of Wang Heo and Ban Sapanhin from 1964 through 1967, employing the method as mentioned above, are as below:

(WANG HEO)

May: Q_{May} = 0.10 (0.5 Pa16 - 30+ 1.0 Pm1 - 15+ 0.5 Pm16 - 31)
June: $Q_{\text{June - 1}}$ = 0.20 (0.5 Pm16 - 31 + 0.95 Pj1 - 15 + 0.3 Pj16 - 30)
(Pe≦400mm)
: $Q_{\text{June - 2}}$ = 0.25 (0.5 Pm16 - 31 + 0.95 Pj1 - 15 + 0.4 Pj16 - 30)
(Pe> 400 mm)
July: Q_{July} = 0.40 (0.05 Pj 1 - 15 + 0.6 Pj16 - 30 + 0.9 Pl1 - 15 + 0.4 Pl 16 - 31)
Aug.: $Q_{\text{Aug.- 1}}$ = 0.40 (0.1 Pl 1 - 15 + 0.6 Pl 16 - 31 + 0.9 Pg1 - 15 + 0.4 pg16 - 31)
(Pe≧400 mm)
$Q_{\text{Aug.- 2}}$ = 0.60 (0.1 Pl 1 - 15 + 0.6 Pl16 - 31 + 0.9 Pg1 - 15 + 0.4 Pg16 - 31)
(Pe> 400 mm)
Sept.: $Q_{\text{Sept. - 1}}$ = 0.45 (0.1 Pg1 - 15 + 0.6 Pg16 - 31+ 0.75 Ps1 - 15 + 0.20 Ps16 - 30)
(Pe ≤ 400 mm)
$Q_{\text{Sept. - 2}}$ = 0.50 (0.25 Ps1 - 15+ 0.6 Pg16 - 31 + 0.75 Ps1 - 15 + 0.20 Ps16 - 30)
(Pe> 400 mm)
Oct.: $Q_{\text{Oct.}}$ = 0.50 (0.25 Ps1 - 15 + 0.8 Ps16 - 30 + 0.8 Po1 - 15 + 0.3 Po16 - 31)
Nov.: $Q_{\text{Nov.}}$ = 0.45 (0.20 Po1 - 15+ 0.7 Po16 - 31 + 1.0 Pn1 - 30)

(Formula 2)

where: $Q_{\text{May - Nov.}}$ = Monthly run-off of Wang Heo in May - Nov. (mm)
Figures outside of parenthesis, such as 0.10, 0.20 .... 0.45 = Run-off coefficient

Pa16 - 30 = Rainfall of Wang Heo from 16 to 30 in April (mm)
Pm1 - 15 = Rainfall of Wang Heo from 1 to 15 in May (mm)
Pm16 - 31 = Rainfall of Wang Heo from 16 to 31 in May (mm)
Pj1 - 15 = Rainfall of Wang Heo from 1 to 15 in June (mm)
Pj16 - 30 = Rainfall of Wang Heo from 16 to 30 in June (mm)
Pl 1 - 15 = Rainfall of Wang Heo from 1 to 15 in July (mm)
Pl 16 - 31 = Rainfall of Wang Heo from 16 to 31 in July (mm)
Pg1 - 15 = Rainfall of Wang Heo from 1 to 15 in Aug. (mm)
Pg16 - 31 = Rainfall of Wang Heo from 16 to 31 in Aug. (mm)
Ps1 - 15 = Rainfall of Wang Heo from 1 to 15 in Sept. (mm)
Ps16 - 30 = Rainfall of Wang Heo from 16 to 30 in Sept. (mm)
Po1 - 15 = Rainfall of Wang Heo from 1 to 15 in Oct. (mm)
Po16 - 31 = Rainfall of Wang Heo from 16 to 31 in Oct. (mm
Pn1 - 30 = Rainfall of Wang Heo from 1 to 30 in Nov. (m

Values in parenthesis (Pe) = Effective basin rainfall represented by Wang Heo (mm)
Figures in front of Pe, such as 0.5, 1.0, 0.05 .... 0.3 = Weight of effectiveness

(BAN SAPANHIN)

May: Q_{May} = 0.10 (0.5 Pa16 - 30+ 1.0 Pm1 - 15 +0.5 Pm16 - 31)
June: Q_{June} = 0.30 (0.5 Pm16 - 31+ 0.95 Pj1 - 15+ 0.4 Pj16 - 30)
July: Q_{July} = 0.50 (0.05 Pj 1 - 15+ 0.6 Pj16 - 30 + 0.9 Pl 1 - 15+ 0.4 Pl 16 - 31)
Aug.: $Q_{Aug.}$ - 1 = 0.50 (0.1 Pl 1 - 15 +0.6 Pl 16 - 31+ 0.9 Pg1 - 15 + 0.4 Pg16 - 31)
(Pe $\leqq$ 350 mm)
$Q_{Aug.}$ - 2 = 0.70 (0.1 Pl 1 - 15 +0.6 Pl 16 - 31 + 0.9 Pg1 - 15 + 0.4 Pg16 - 31)
(Pe$>$ 350 mm)
Sept.: $Q_{Sept.}$ = 0.75 (0.1 Pg1 - 15 + 0.6 Pg16 - 31 + 0.75 Ps1 - 15+ 0.20 Ps16 - 30)
Oct.: $Q_{Oct.}$ = 0.55 (0.25 Ps1 - 15+ 0.8 Ps16 - 30 +0.8 Po1 - 15+ 0.3 Po16 - 31)
Nov.: $Q_{Nov.}$ = 0.40 (0.2 Po1 - 15+ 0.7 Po16 - 31 + 1.0 Pn1 - 30)

(Formula 3)

where: $Q_{May-Nov.}$= Monthly run-off of Ban Sapanhin in May - Nov. (mm)
Figures outside of parenthesis, such as 0.10, 0.30 ...... 0.40= Run-off coefficient

Pa16 – 30 = Average rainfall of Wang Heo and Ban Sapanhin from 16 to 30 in April (mm)
Pm1 – 15 = Average rainfall of Wang Heo and Ban Sapanhin from 1 to 15 in May (mm)
Pm16 – 31 = Average rainfall of Wang Heo and Ban Sapanhin from 16 to 31 in May (mm)
Ps 1 – 15 = Average rainfall of Wang Heo and Ban Sapanhin from 1 to 15 in June (mm)
Ps16 – 30 = Average rainfall of Wang Heo and Ban Sapanhin from 16 to 30 in June (mm)
Pl 1 – 15 = Average rainfall of Wang Heo and Ban Sapanhin from 1 to 15 in July (mm)
Pl 16 – 31 = Average rainfall of Wang Heo and Ban Sapanhin from 16 to 31 in July (mm)
Pg1 – 15 = Average rainfall of Wang Heo and Ban Sapanhin from 1 to 15 in Aug. (mm)
Pg16 – 31 = Average rainfall of Wang Heo and Ban Sapanhin from 16 to 31 in Aug. (mm)
Ps 1 – 15 = Average rainfall of Wang Heo and Ban Sapanhin from 1 to 15 in Sept. (mm)
Ps16 – 30 = Average rainfall of Wang Heo and Ban Sapanhin from 16 to 30 in Sept. (mm)
Po 1 – 15 = Average rainfall of Wang Heo and Ban Sapanhin from 1 to 15 in Oct. (mm)
Po16 – 31 = Average rainfall of Wang Heo and Ban Sapanhin from 16 to 31 in Oct. (mm)
Pn 1 – 30 = Average rainfall of Wang Heo and Ban Sapanhin from 1 to 30 in Nov. (mm)

Values in parenthesis (Pe) = Effective basin rainfall represented by average of Wang Heo and Ban Sapanhin. (mm)

Figures in fron of Pe, such as 0.5, 1.0, 0.95 .... 0.3 = Weight of effectiveness

Formula 2, 3 was verified by the reliabilities with the correlation lines as shown in App. Fig. 4-6, which resulted in a good correlation between actual and correlated monthly run-off.

For the purpose of obtaining the effective basin rainfall above Wang Heo and Ban Sapanhin before 1964, two correlations of effective monthly rainfall: Wang Heo and Ban Sapanhin Vs. the average of Kabinburi and Prachinburi were developed as shown in App. Figs. 4-7 (1), (2) and Formula 4, 5.

$$Y - 1 = 0.89\,X + 98\ (X + 30\ \text{mm}) \quad \ldots\ldots\ldots \quad \text{(Formula 4)}$$

$$Y - 2 = 0.96\,X + 57\ (X + 50\ \text{mm}) \quad \ldots\ldots\ldots \quad \text{(Formula 5)}$$

where: $Y - 1$ = Effective monthly rainfall of Wang Heo (mm)

$Y - 2$ = Average effective monthly rainfall of Wang Heo and Ban Sapanhin (mm)

X = Average effective monthly rainfall of Kabinburi and Prachinburi (mm)

Run-off in dry season was estimated by employing the regression courves as shown in App. Fig. 4-7 and Formula 6,7.

(Wang Heo)

$$\left.\begin{array}{lll} \text{Dec.:} & Q_{\text{Dec.}} & = 0.30\,Q_{\text{Nov.}} \\ \text{Jan.:} & Q_{\text{Jan.}} & = 0.10\,Q_{\text{Nov.}} \\ \text{Feb.:} & Q_{\text{Feb.}} & = 0.08\,Q_{\text{Nov.}} \\ \text{Mar.:} & Q_{\text{Mar.}} & = 0.06\,Q_{\text{Nov.}} \\ \text{Apr.:} & Q_{\text{Apr.}} & = 0.06\,Q_{\text{Nov.}} \end{array}\right]\text{(Formula 6)}$$

(Ban Sapanhin)

$$\left.\begin{array}{ll} Q_{\text{Dec.}} & = 0.34\,Q_{\text{Nov.}} \\ Q_{\text{Jan.}} & = 0.16\,Q_{\text{Nov.}} \\ Q_{\text{Feb.}} & = 0.12\,Q_{\text{Nov.}} \\ Q_{\text{Mar.}} & = 0.07\,Q_{\text{Nov.}} \\ Q_{\text{Apr.}} & = 0.05\,Q_{\text{Nov.}} \end{array}\right]\text{— (Formula 7)}$$

where: $Q_{\text{Dec.}}$ = Monthly Run-off in December

The comparison of actual monthly run-off and correlated monthly run-off, which were obtained according to the abovementioned methods, revealed that the correlated run-off have a considerable reliability as shown in App. Fig. 4-9.

The monthly average run-off of Wang Heo and Ban Sapanhin Gaging Stations calculated employing the above methods are tabulated in App. Table 4-3, 4.

4.2 Run-off at Proposed Dam Site

The run-off from 1953 through 1967 at the proposed dam sites will be calculated as follows:

(1) Run-off at dam sites in the basin above Wang Heo or at Wang Heo.

$$Qd = \frac{Ad}{Aw} \cdot Qw \quad \ldots\ldots\ldots\ldots \text{(Formula 8)}$$

where: Qd = Monthly run-off of proposed dam site
Qw = Monthly run-off of Wang Heo as shown in App. Table 4-3
Ad = Catchment area of proposed dam site
Aw = Catchment area of Wang Heo as shown in App. Table 4-3, 295 sq.km.

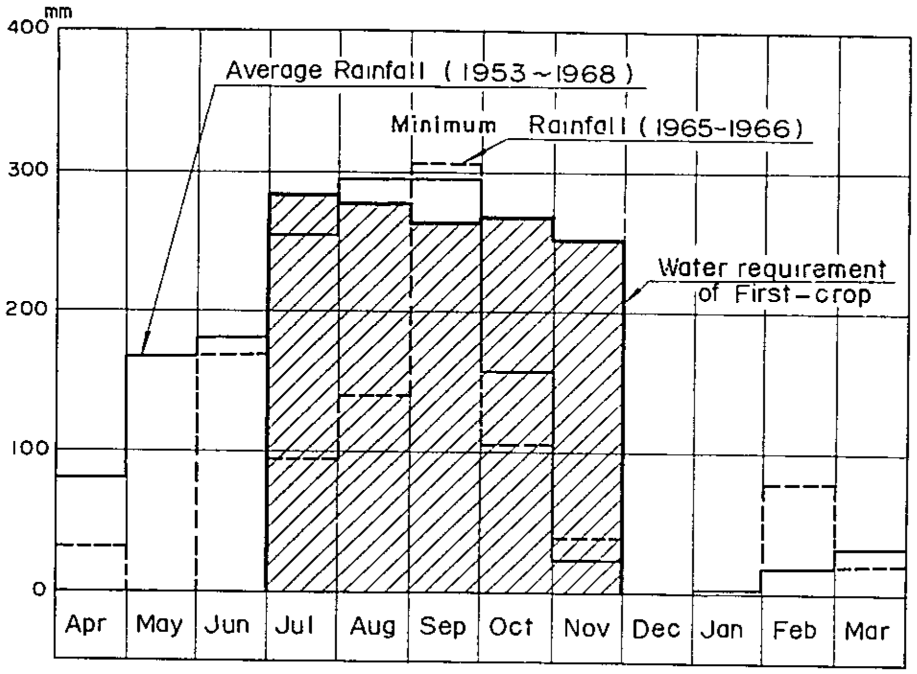
(2) Run-off at dam sites in the basin between Wang Heo and Ban Sapanhin

$$Qd = \frac{Ad}{Ab - Aw} \cdot Qb - Qw \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(Formula 9)}$$

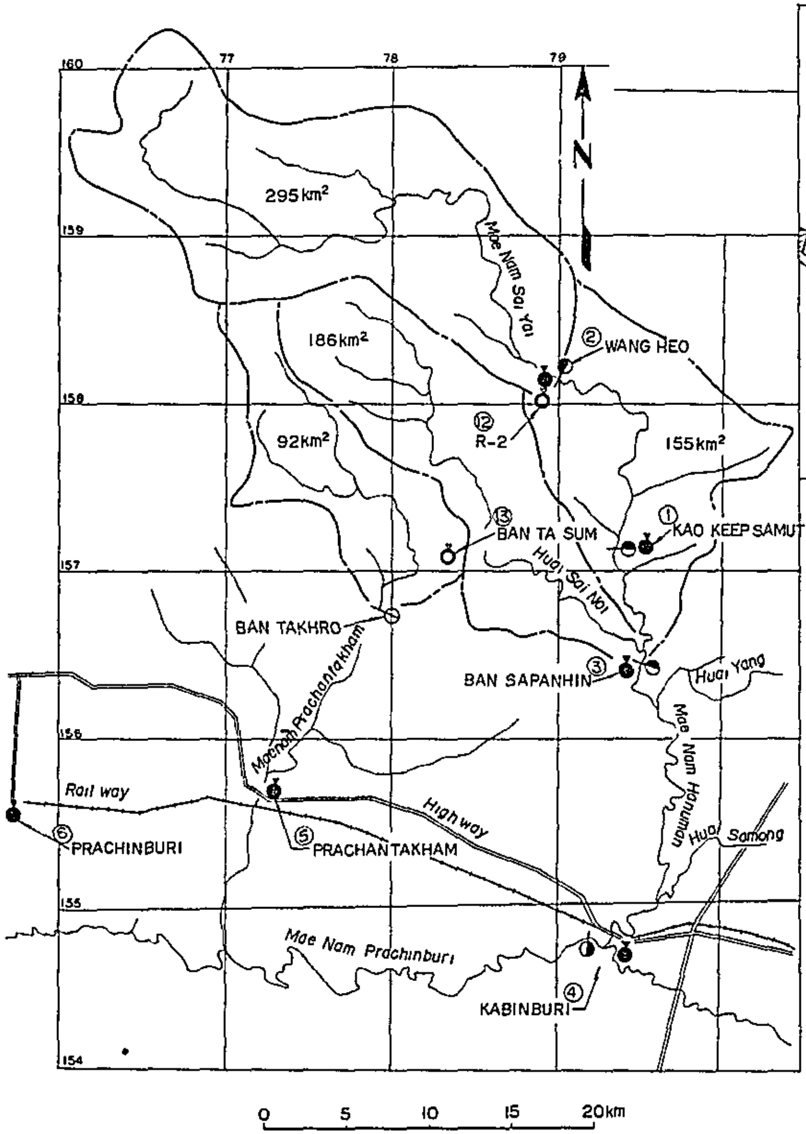
where: Qd = Monthly run-off of proposed dam site
Qb = Monthly run-off of Ban Sapanhin as shown in App. Table 4-4
Qw = Monthly run-off of Wang Heo as shown in App. Table 4-3
Ad = Catchment area of proposed dam site
Ab = Catchment area of Ban Sapanhin as shown in App. Table 4-4,636 sq.km
Aw = Catchment area of Wang Heo as shown in App. Table 4-3, 295 sq.km.

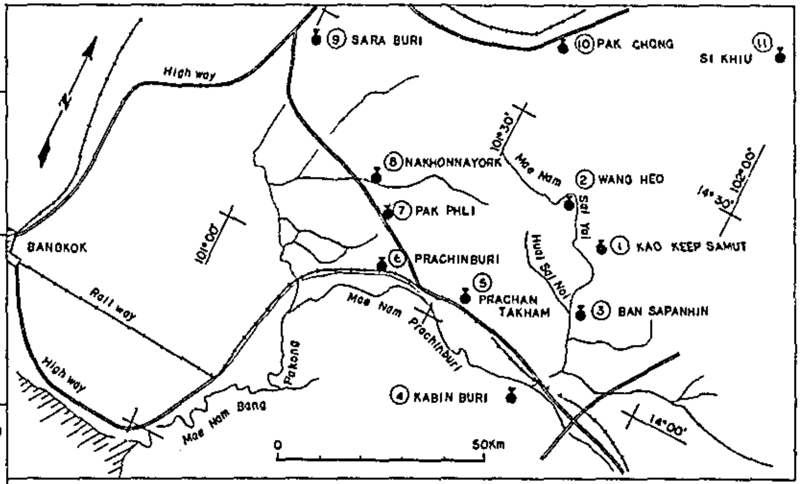
II FIGURES

APPENDIX FIG. 3-1 RAINFALL AND WATER REQUIREMENT



APPENDIX FIG. 4-1 LOCATION MAP OF RAINFALL AND RUN- OFF GAGING STATION





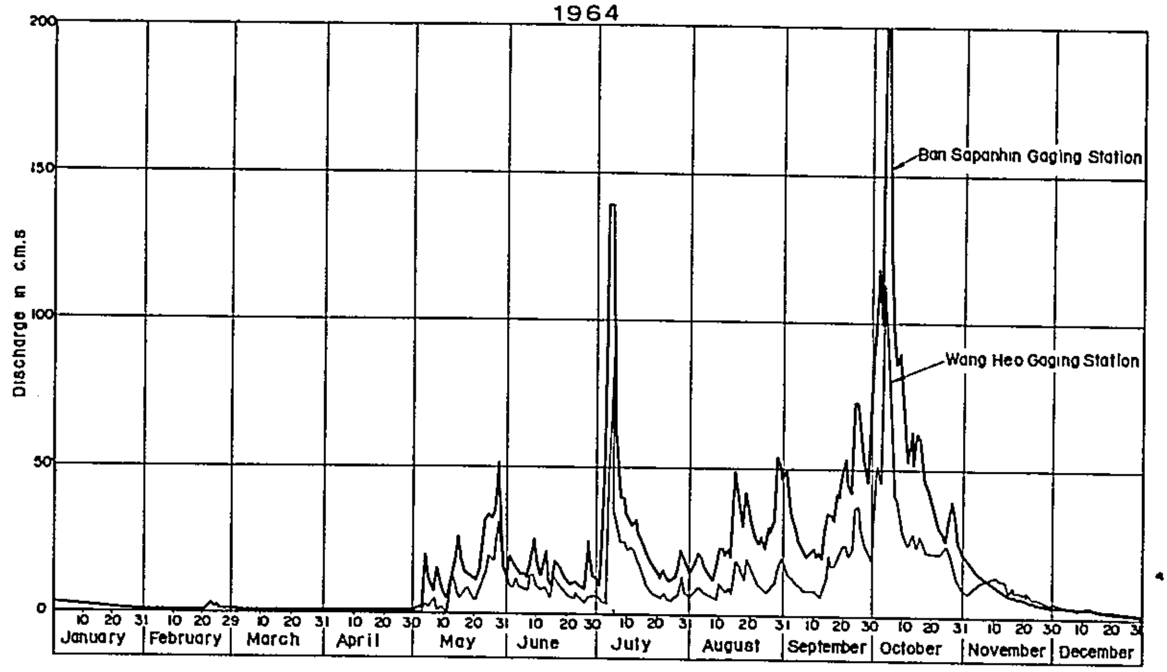
RUNOFF GAGING STATIONS AND EXISTING DATA (Daily Record)

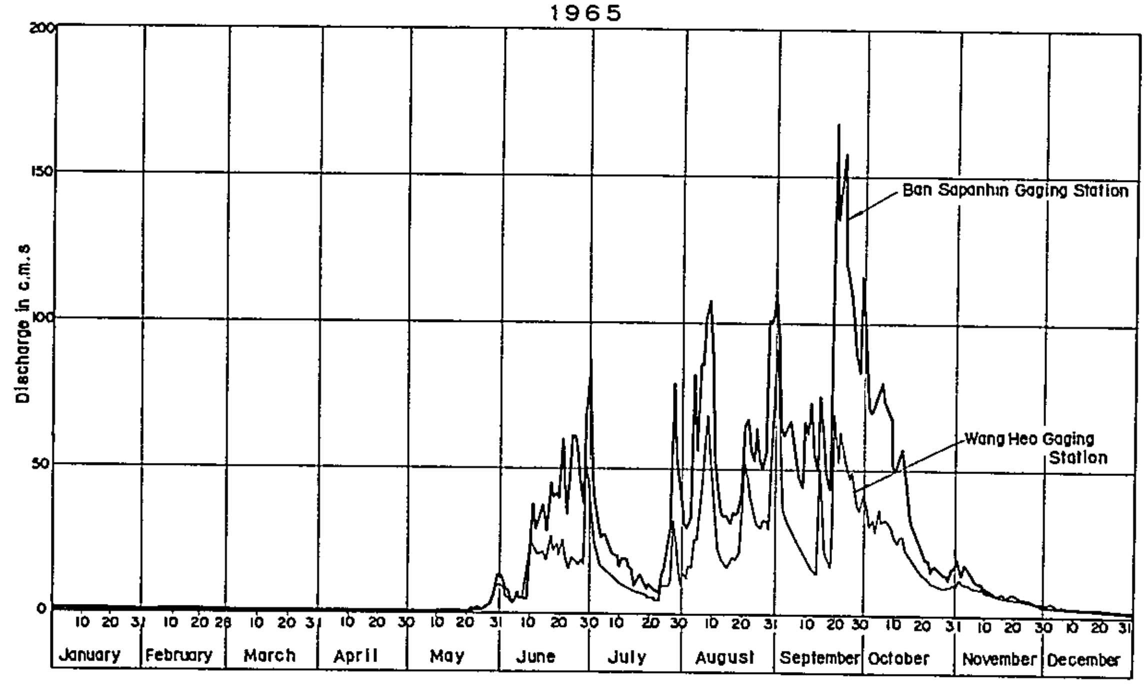
STATION	RIVER	C A	'52	'53	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'66	'66	'67	'68
KAO KEEP SAMUT	SAI YAI	420km²													Mar				
WANG HEO	〃	295														Moved	—	—	
BAN SAPANHIN	HANUMAN	636													July	—	—	—	
KABINBURI	PRACHIN BURI	7,502	—	—	—	—	—	—	—	—	—	—		—	—	—	—	—	
BAN TAKHRO	PRACHANTAKHAM	92	Proposed Gaging Station to be established																

RAINFALL OBSERVATORYS AND EXISTING DATA (Daily Record)

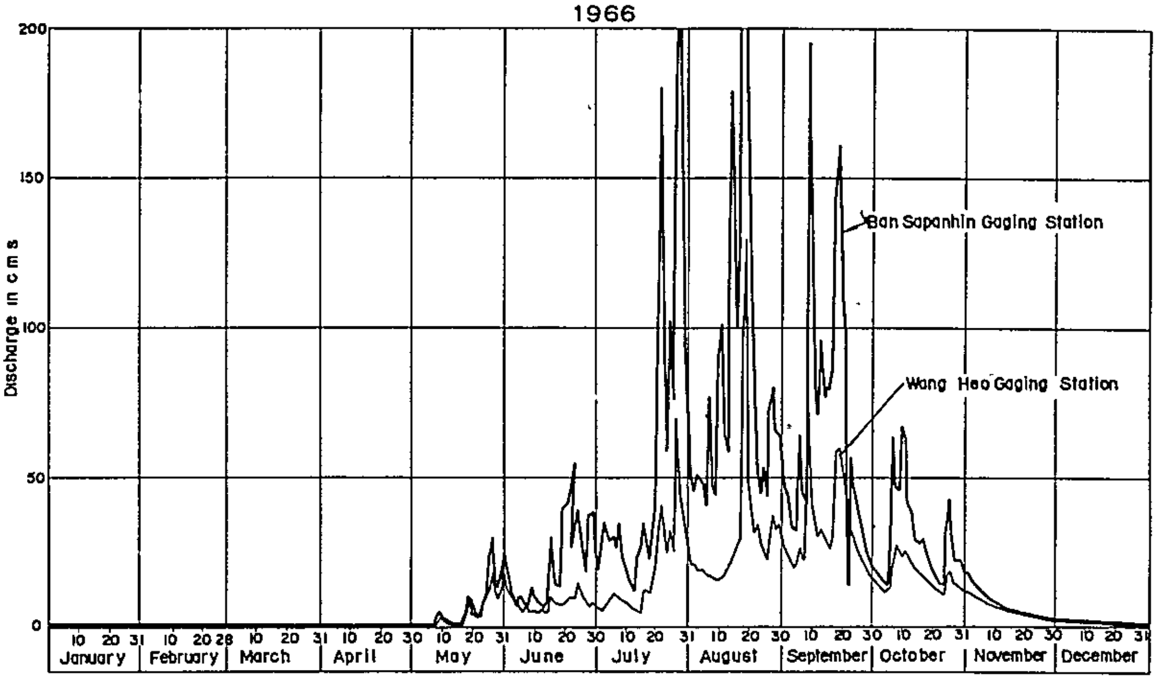
NO.	STATION	'45	'46	'47	'48	'49	'50	'51	'52	'53	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
1	KAO KEEP SAMUT																				Mar				
2	WANG HEO																					Moved	—	—	
3	BAN SAPANHIN																				July	—	—	—	
4	KABINBURI								—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
5	PRACHANTAKHAM									—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
6	PRACHINBURI									—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
7	PAK PHLI													—	—	—	—	—	—	—	—	—	—	—	
8	NAKHON NAYORK								—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
9	SARA BURI												—	—	—	—	—	—	—	—	—	—	—	—	
10	PAK CHONG												—	—	—	—	—	—	—	—	—	—	—	—	
11	SI KHIU												—	—	—	—	—	—	—	—	—	—	—	—	
12	R-2	Proposed Observatory to be established																							
13	BAN TA SUM	〃																							

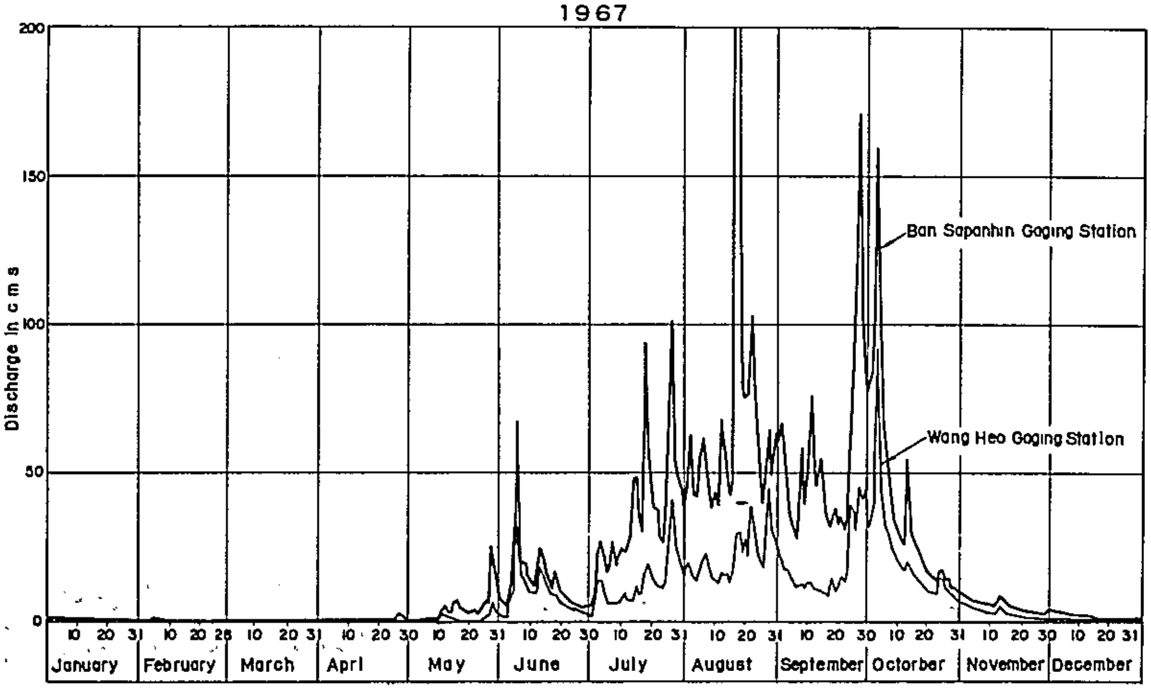
APPENDIX FIG. 4-2 (1) HYDROGRAPH OF WANG HEO AND BANG SAPANHIN



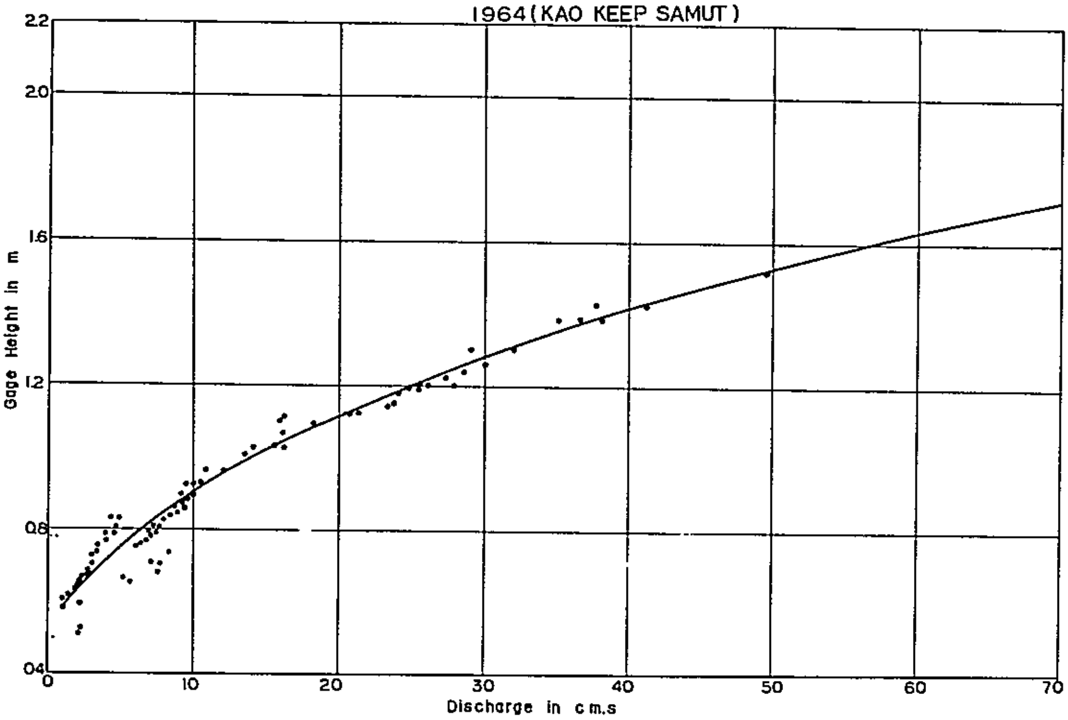


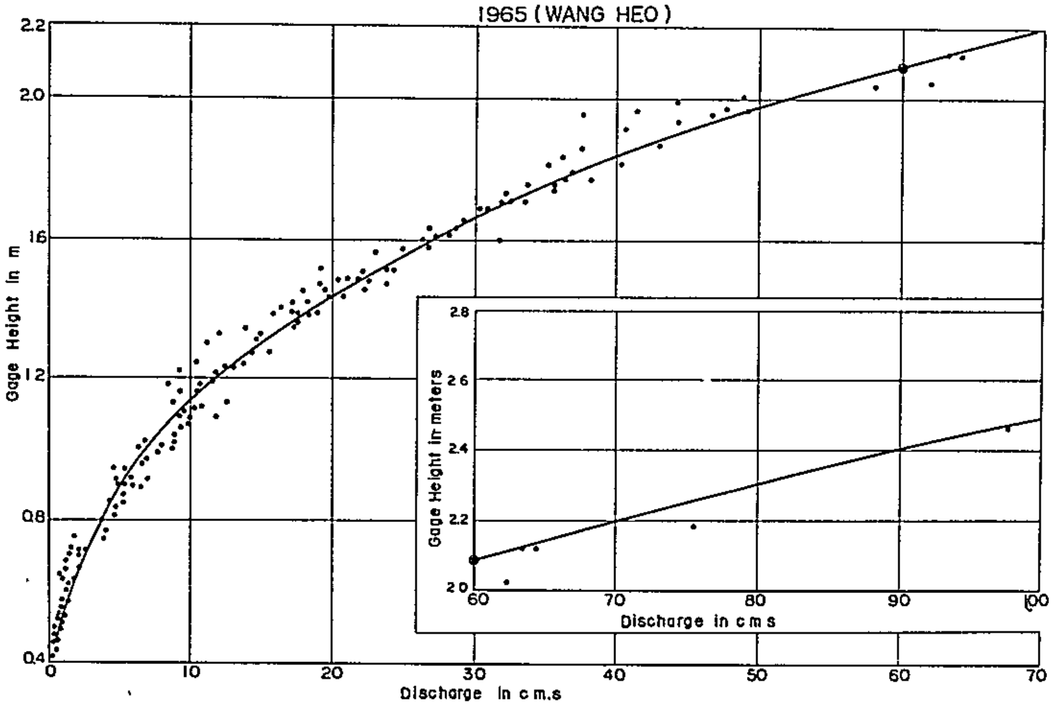
APPENDIX FIG. 4-2 (2) HYDROGRAPH OF WANG HEO AND BANG SAPANHIN



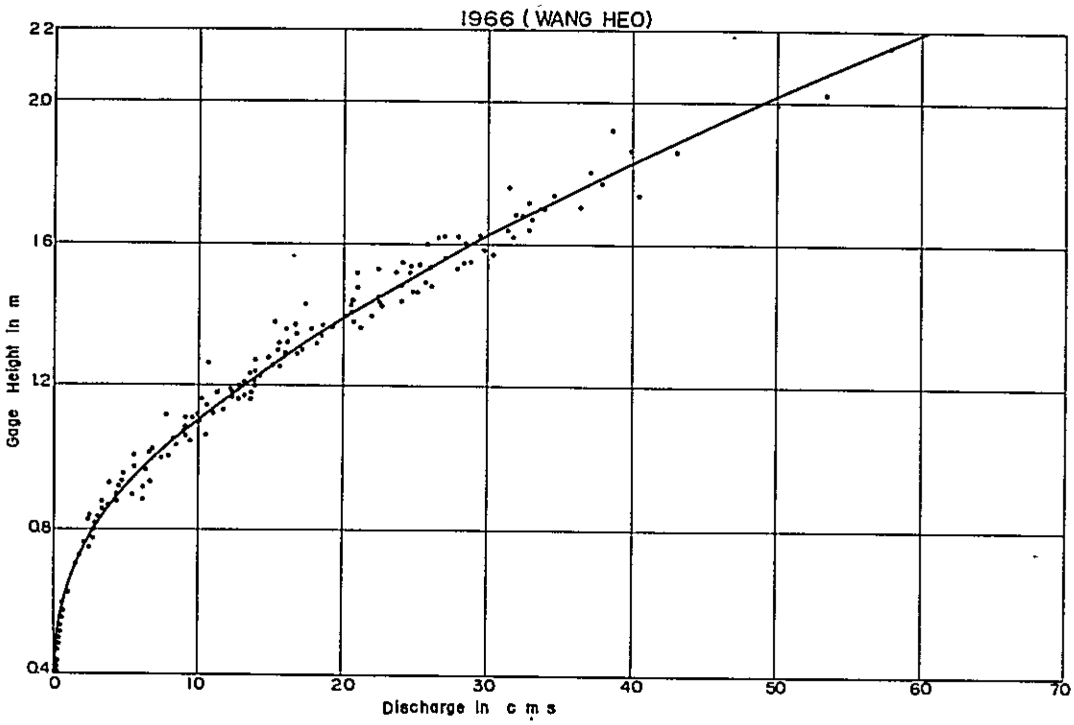


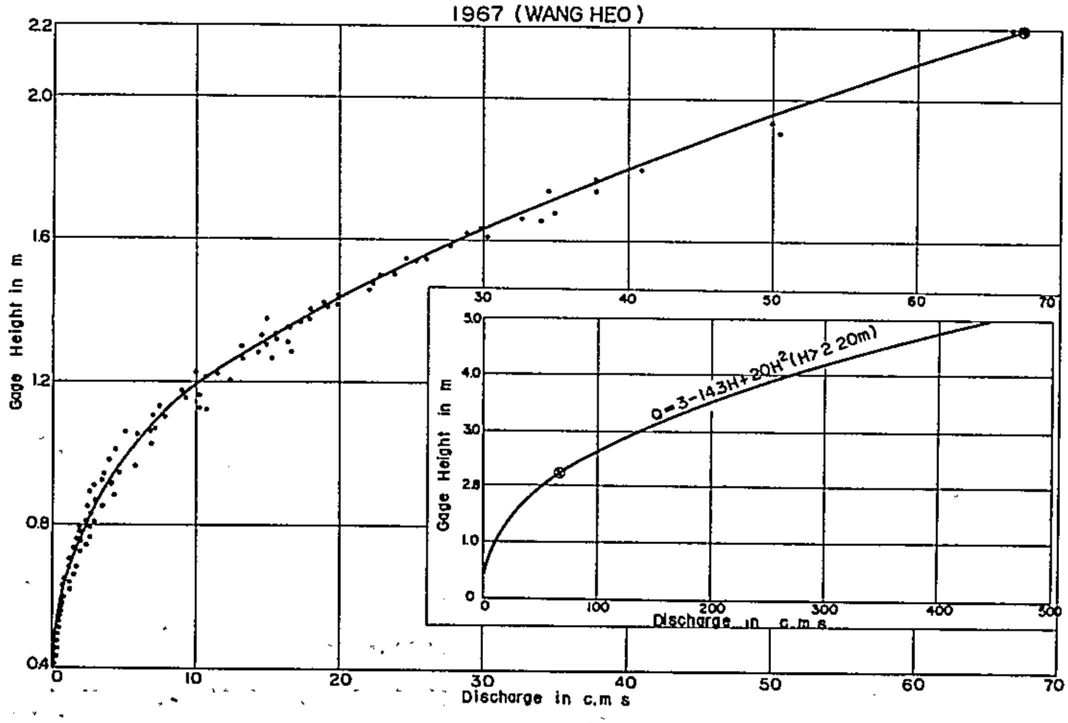
APPENDIX FIG. 4-3 (1) RATING CURVES OF KAO KEEP SAMUT AND WANG HEO ON SAI YAI RIVER



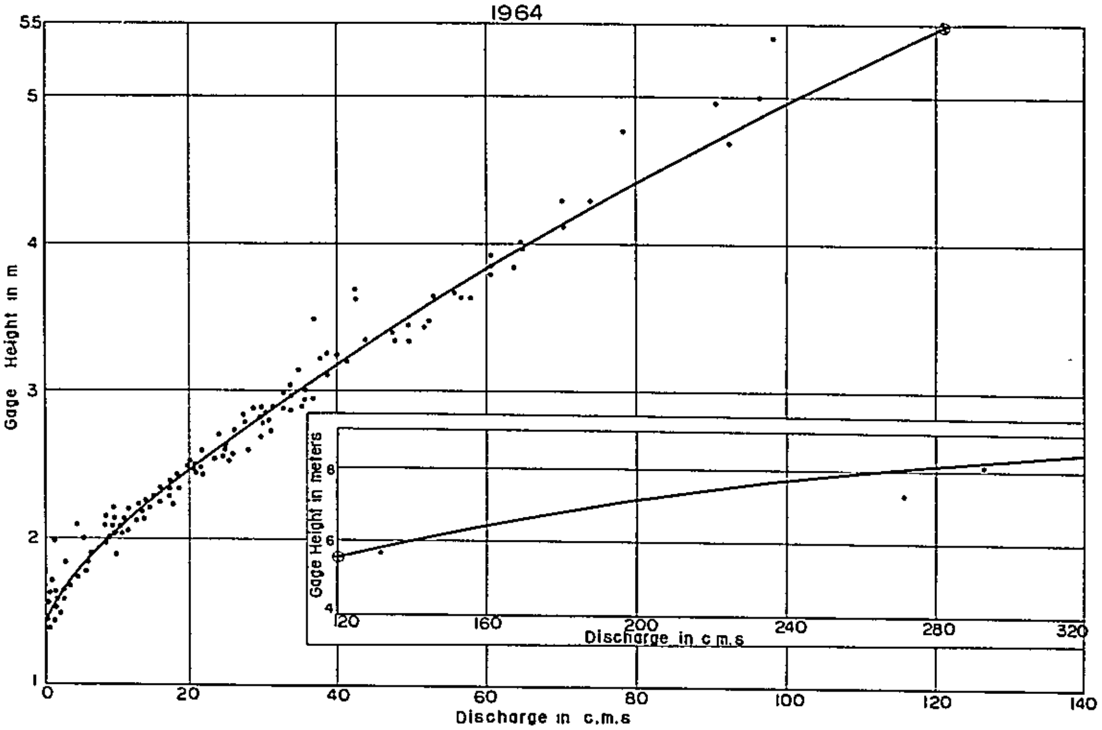


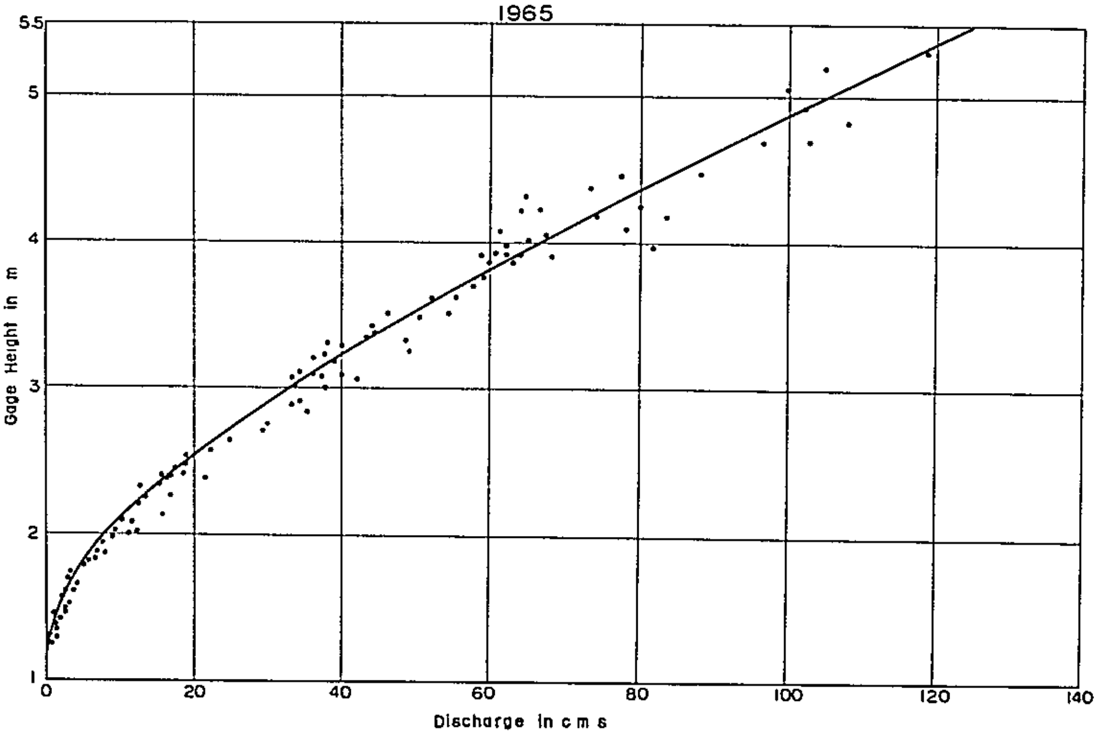
APPENDIX FIG. 4-3 (2) RATING CURVES OF KAO KEEP SAMUT AND WANG HEO ON SAI YAI RIVER



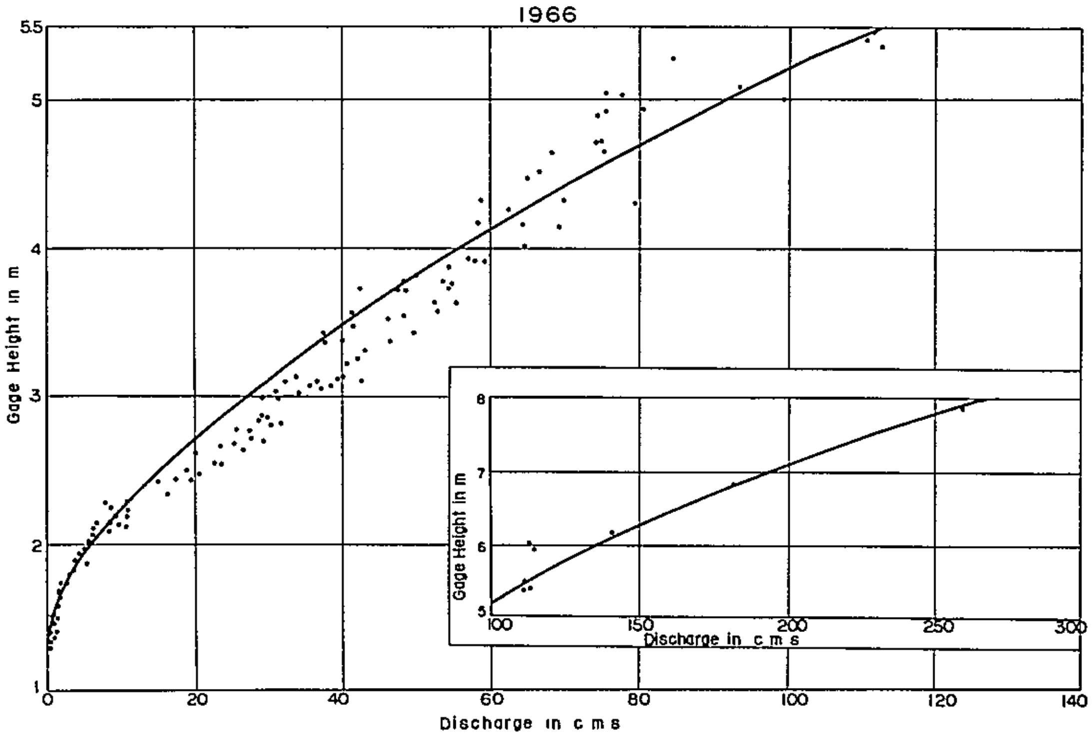


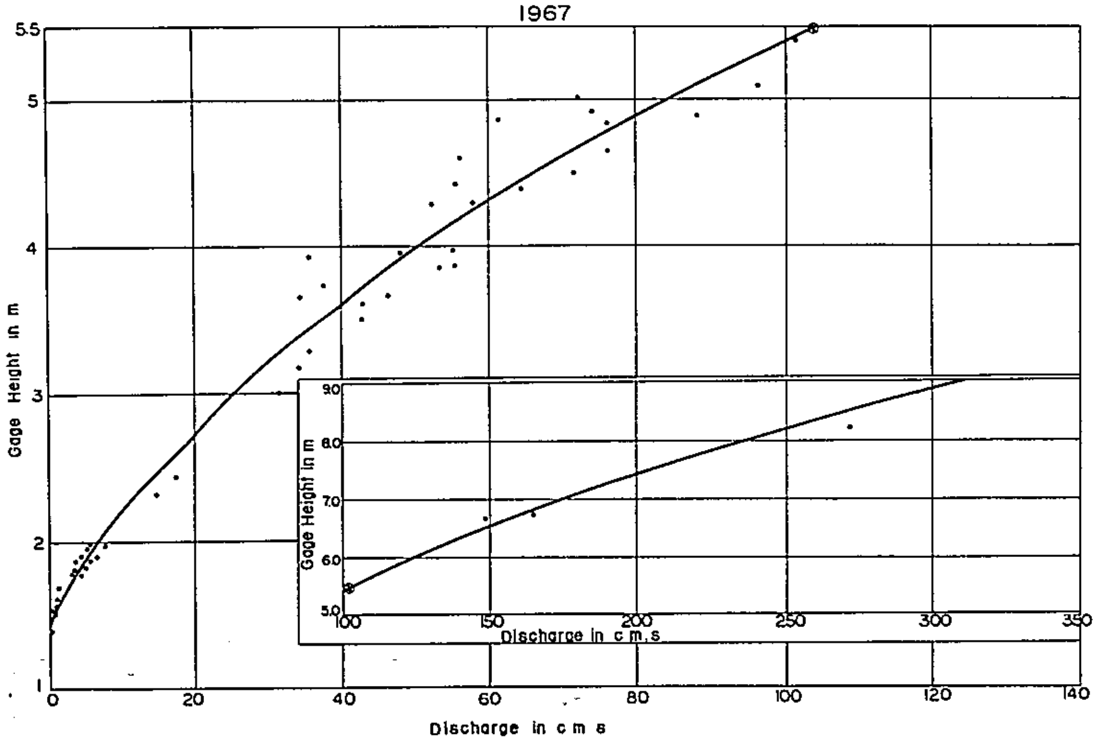
APPENDIX FIG. 4-4 (1) RATING CURVES OF BAN SAPANHIN ON HANUMAN RIVER





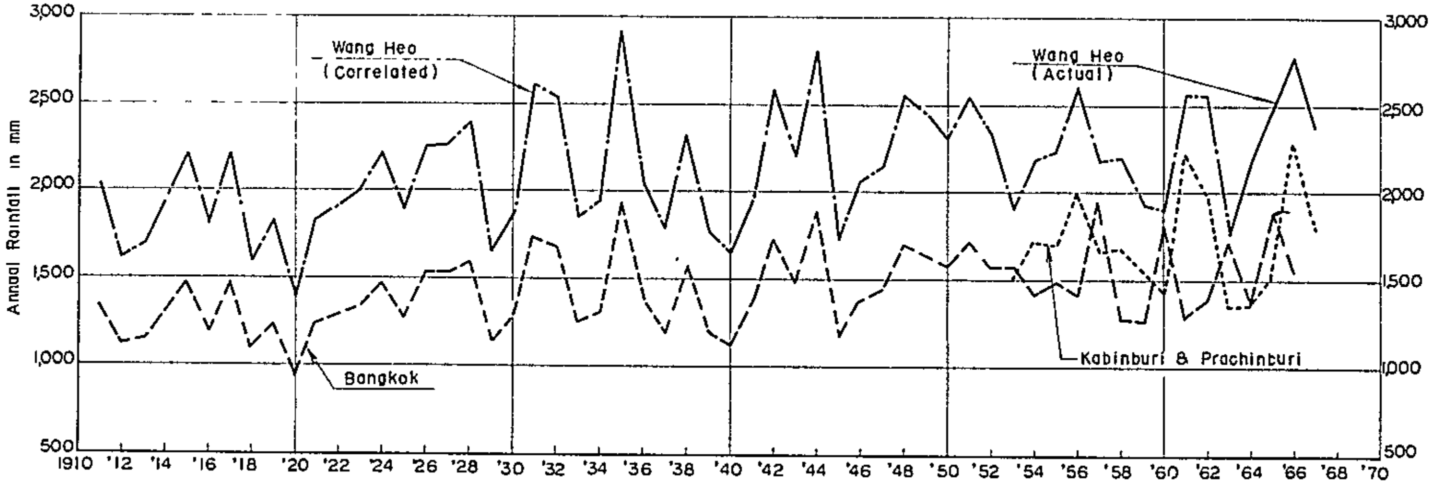
APPENDIX FIG. 4-4 (2) RATING CURVES OF BAN SAPANHIN ON HANUMAN RIVER

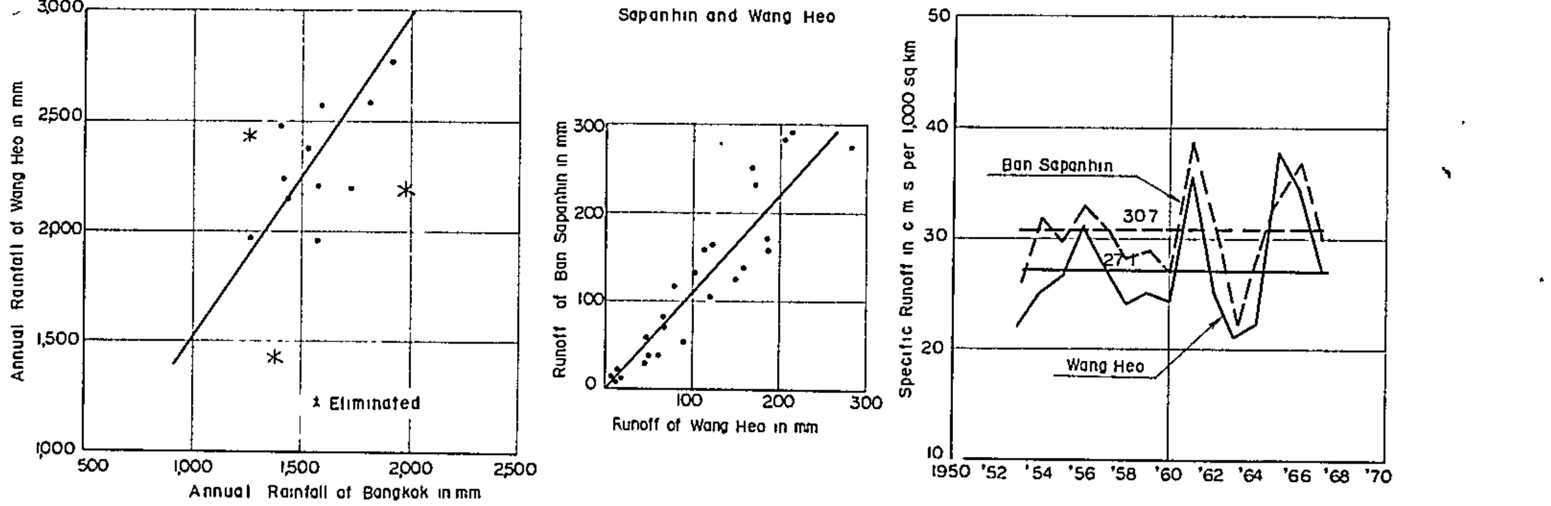




APPENDIX FIG. 4-5 RAINFALL AND AVERAGE SPECIFIC RUN-OFF

(1) Annual Rainfall Fluctuation



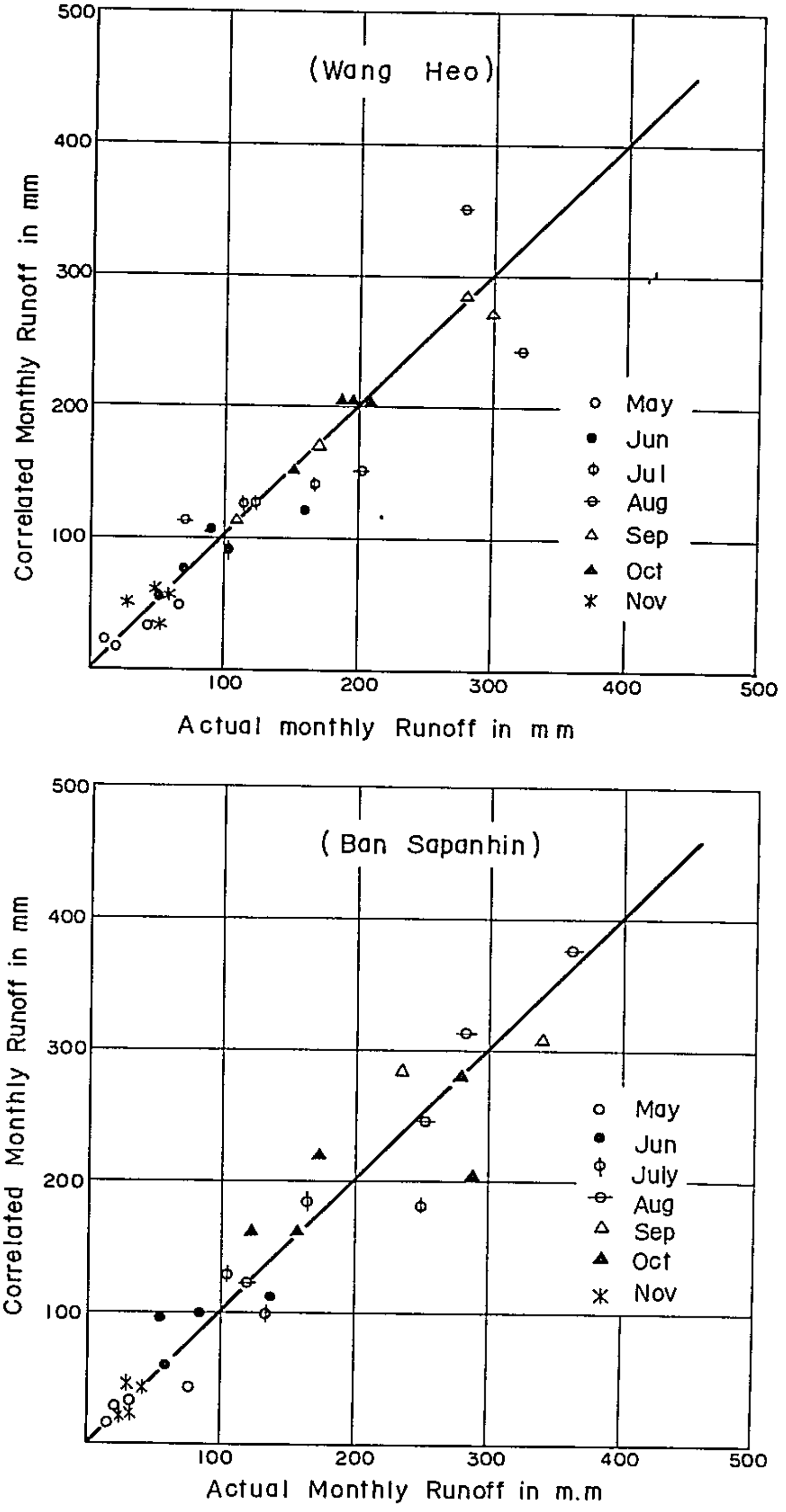


(2) Correlation of Annual Rainfall between Wang Heo and Bangkok

(3) Correlation of monthly Runoff between Ban Sapanhin and Wang Heo

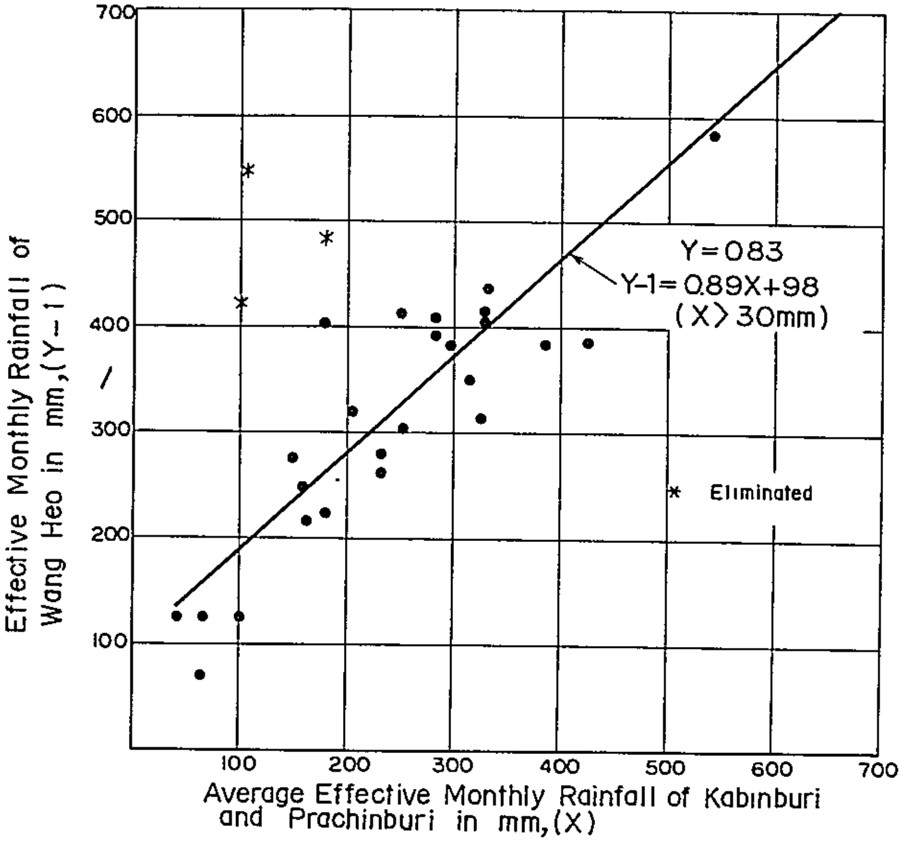
(4) Annual Average Specific Runoff Fluctuation

APPENDIX FIG. 4-6 CORRELATION BETWEEN ACTUAL AND CORRELATED MONTHLY RUN-OFF

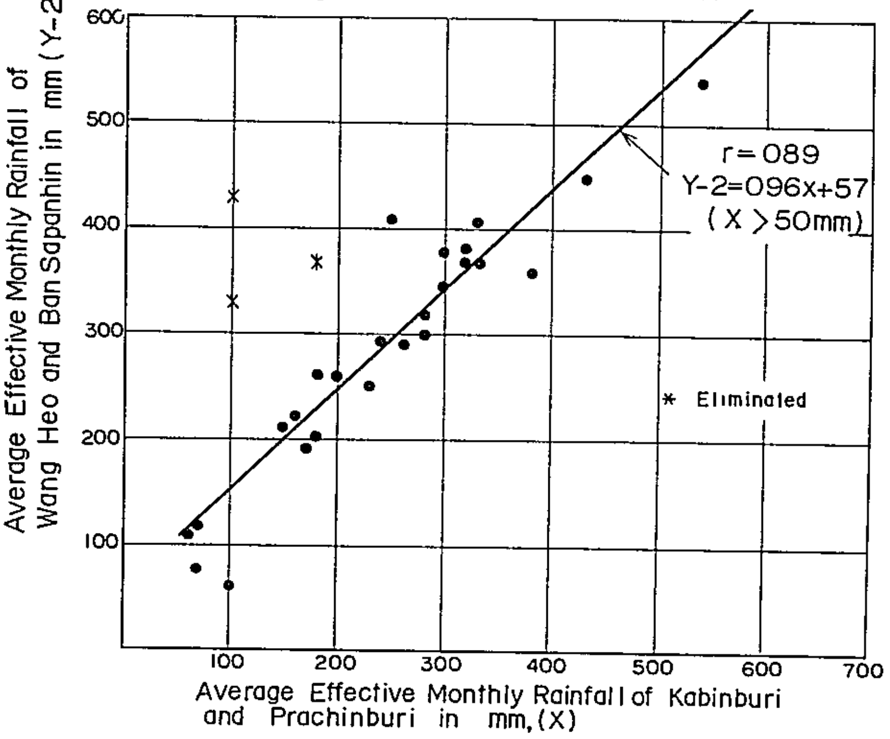


APPENDIX FIG. 4-7 CORRELATION OF EFFECTIVE MONTHLY RAINFALL

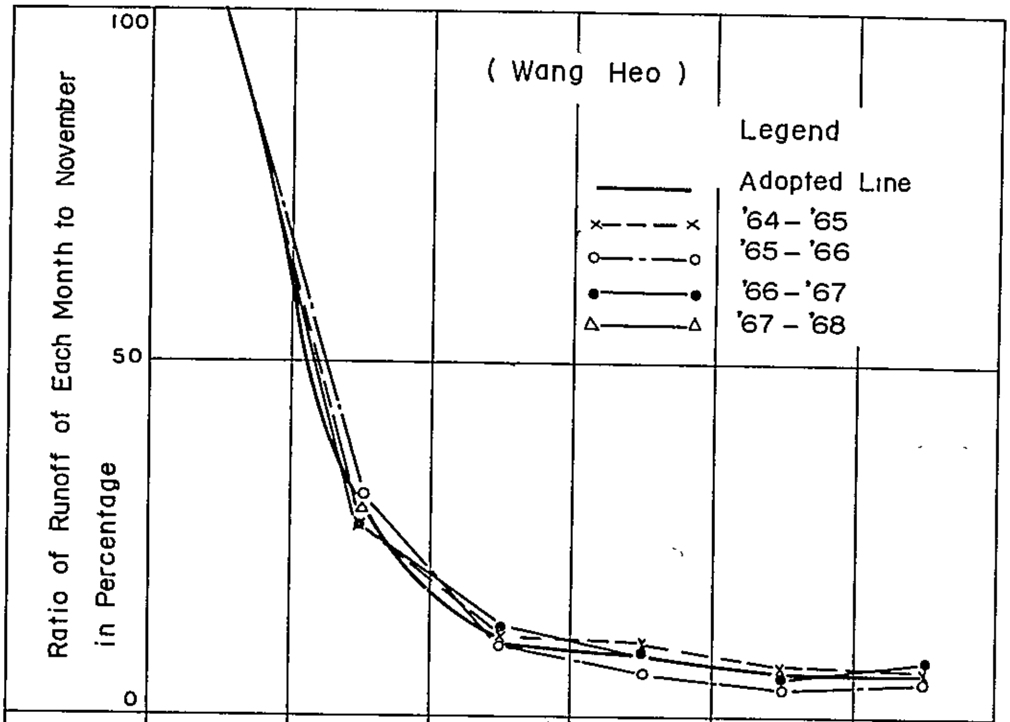
(1) Wang Heo Vs. Average of Kabinburi and Prachinburi



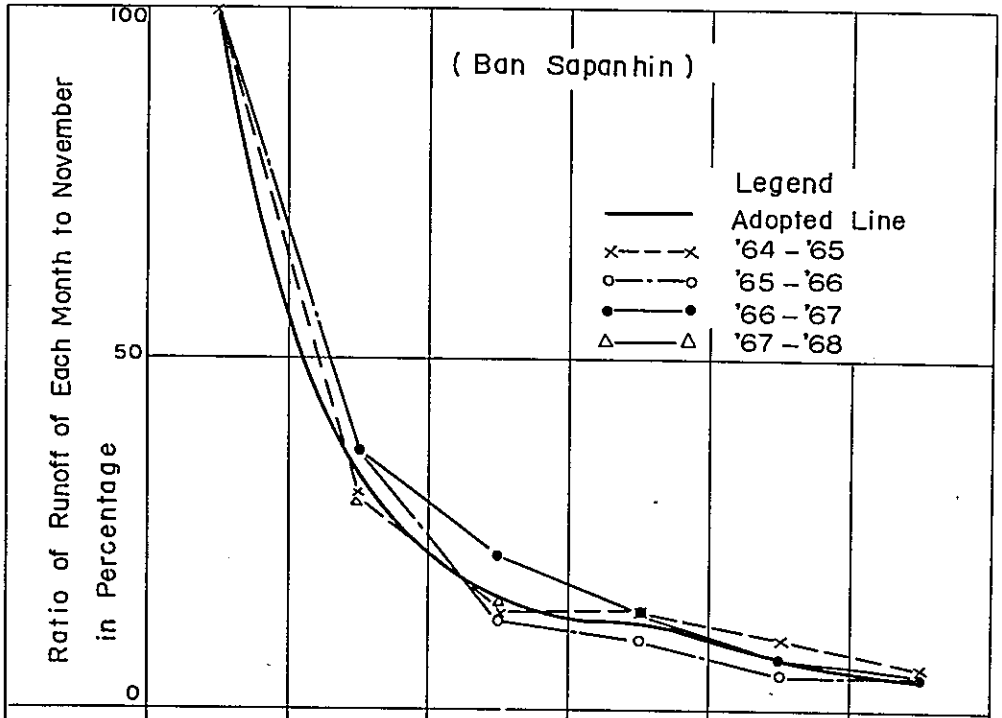
(2) Averoge of Wang Heo and Ban Sapanhin Vs. Average of Kabinburi and Prachinburi



APPENDIX FIG. 4-8 REGRESSION CURVES OF HYDROGRAPH



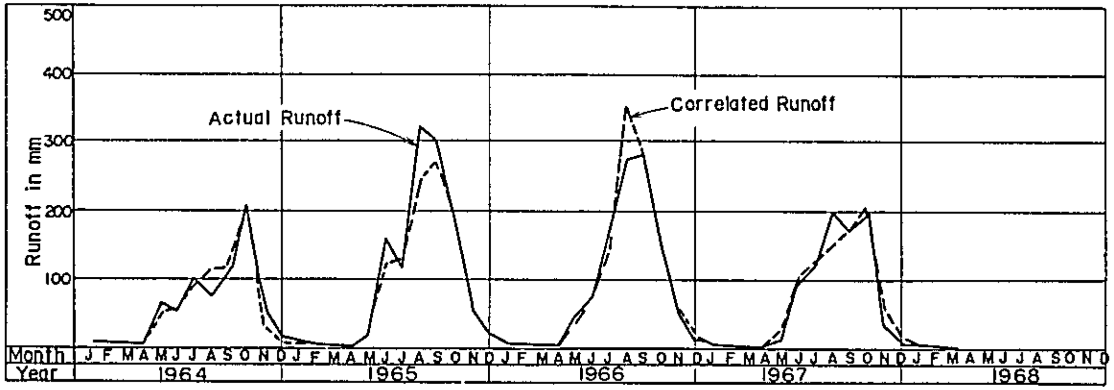
Month	Nov	Dec.	Jan.	Feb.	Mar.	Apr.
Average (%)	100	30	10	8	6	6



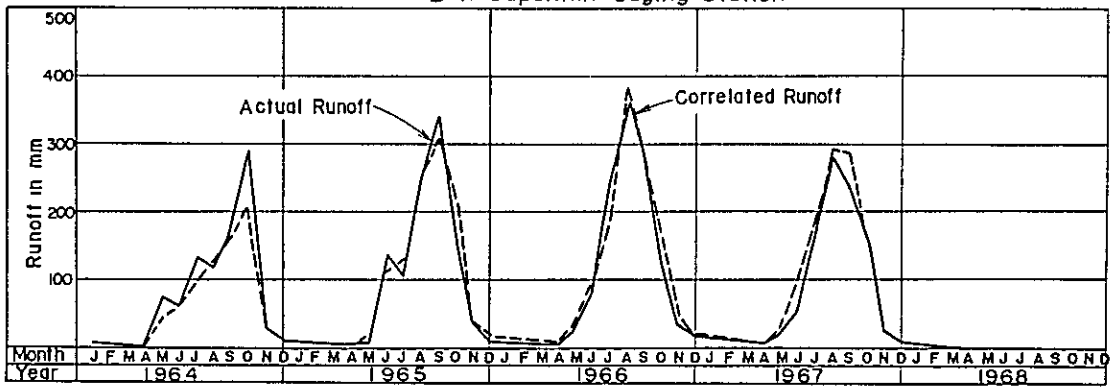
Month	Nov.	Dec.	Jan.	Feb.	Mar	Apr
Average (%)	100.	34	16	12	7	5

APPENDIX FIG. 4-9 COMPARISON OF ACTUAL MONTHLY RUN-OFF AND CORRELATED MONTHLY RUN-OFF

Wang Heo Gaging Station

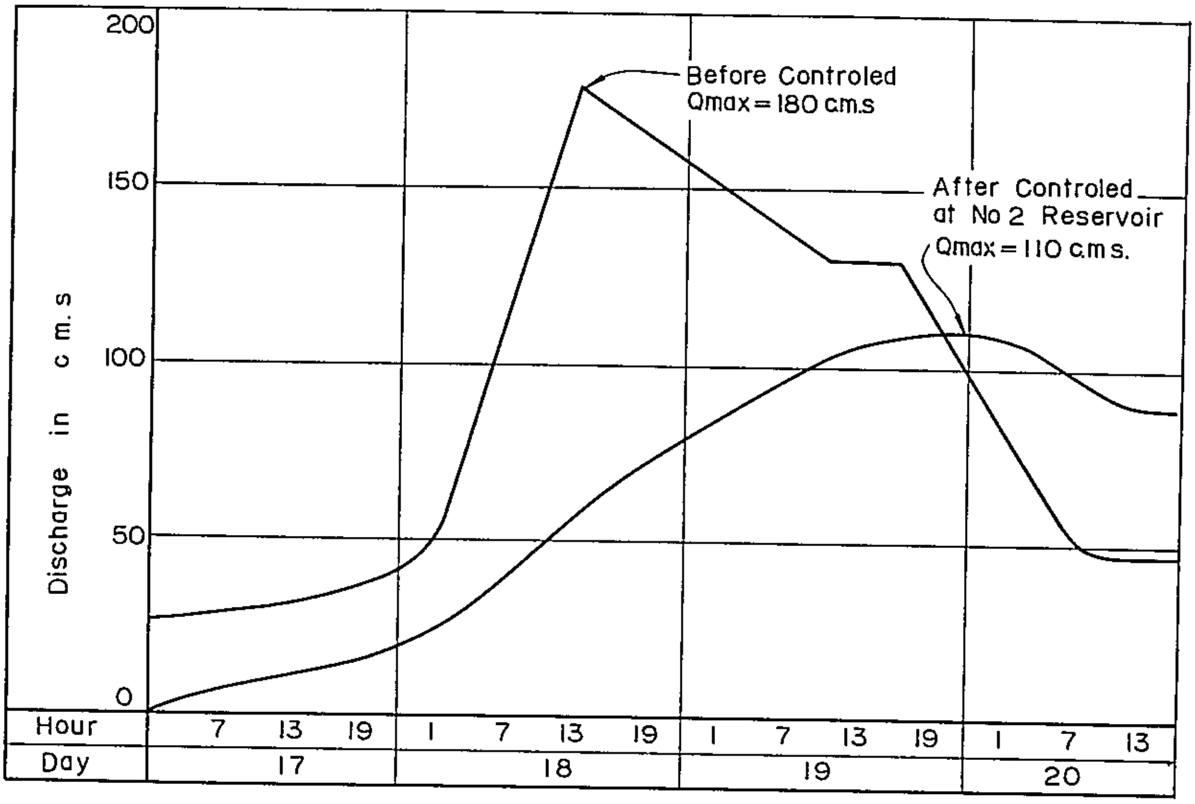


Ban Sapanhin Gaging Station



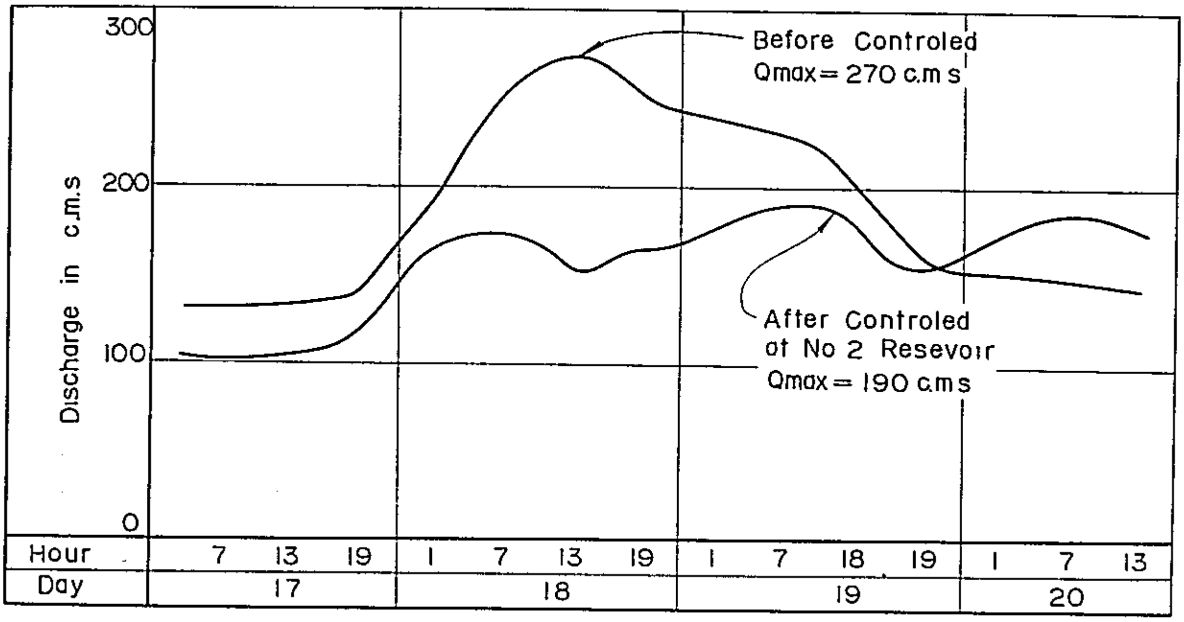
APPENDIX FIG. 4-10 FLOOD HYDROGRAPH OF WANG HEO (NO.2 DAM)

(Aug. 17, 1966 ~ Aug. 20, 1966)



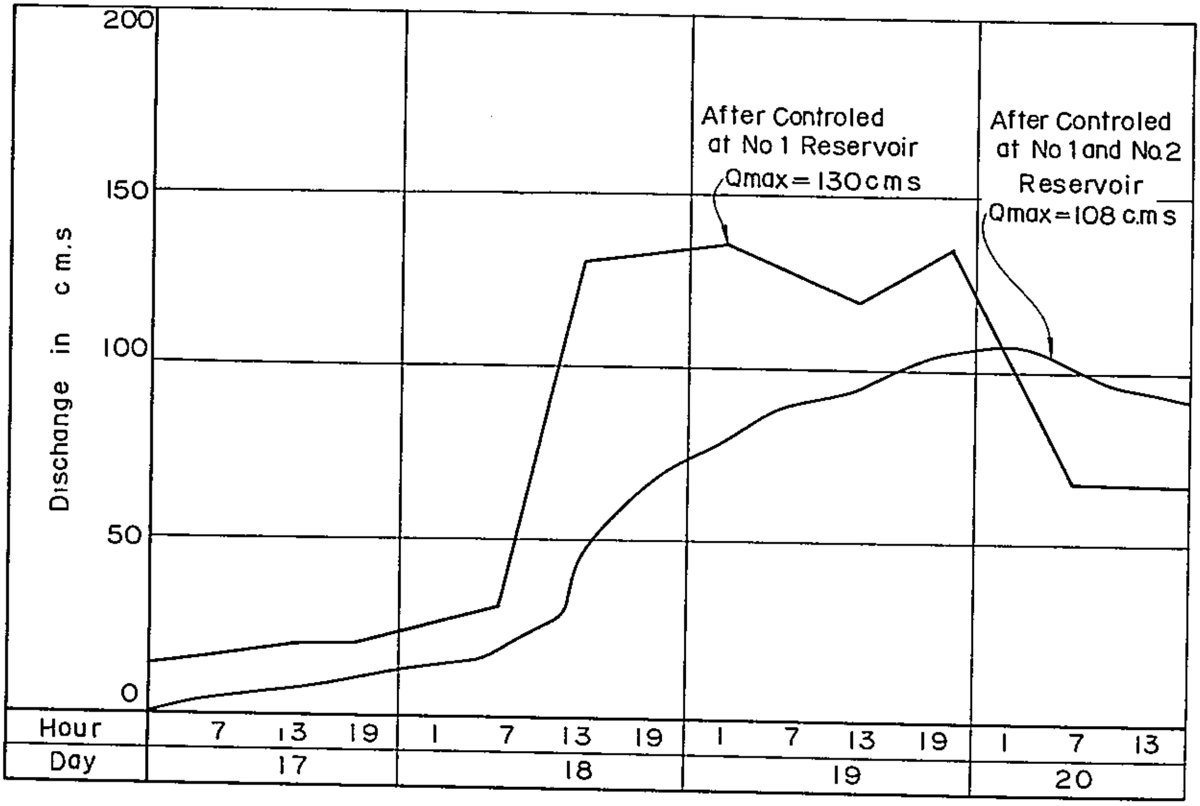
APPENDIX FIG. 4-11 FLOOD HYDROGRAPH OF BAN SAPANHIN

(Aug. 17, 1966 ~ Aug. 20, 1966)



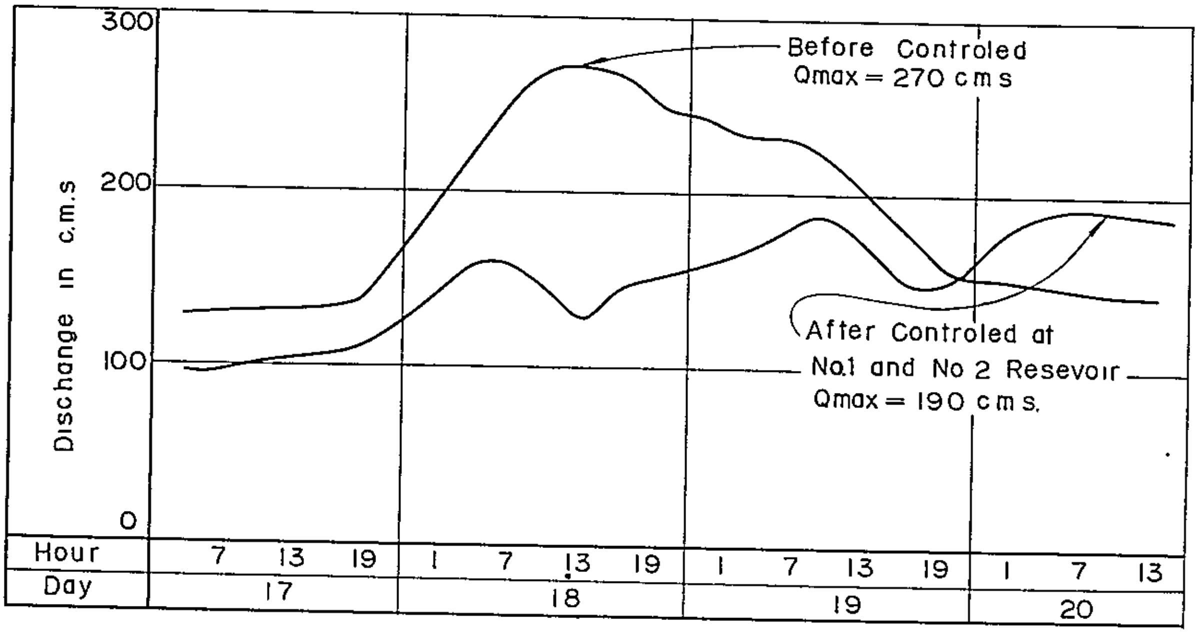
APPENDIX FIG. 4-12 FLOOD HYDROGRAPH OF WANG HEO (NO.2 DAM)

(Aug. 17, 1966 ~ Aug. 20, 1966)

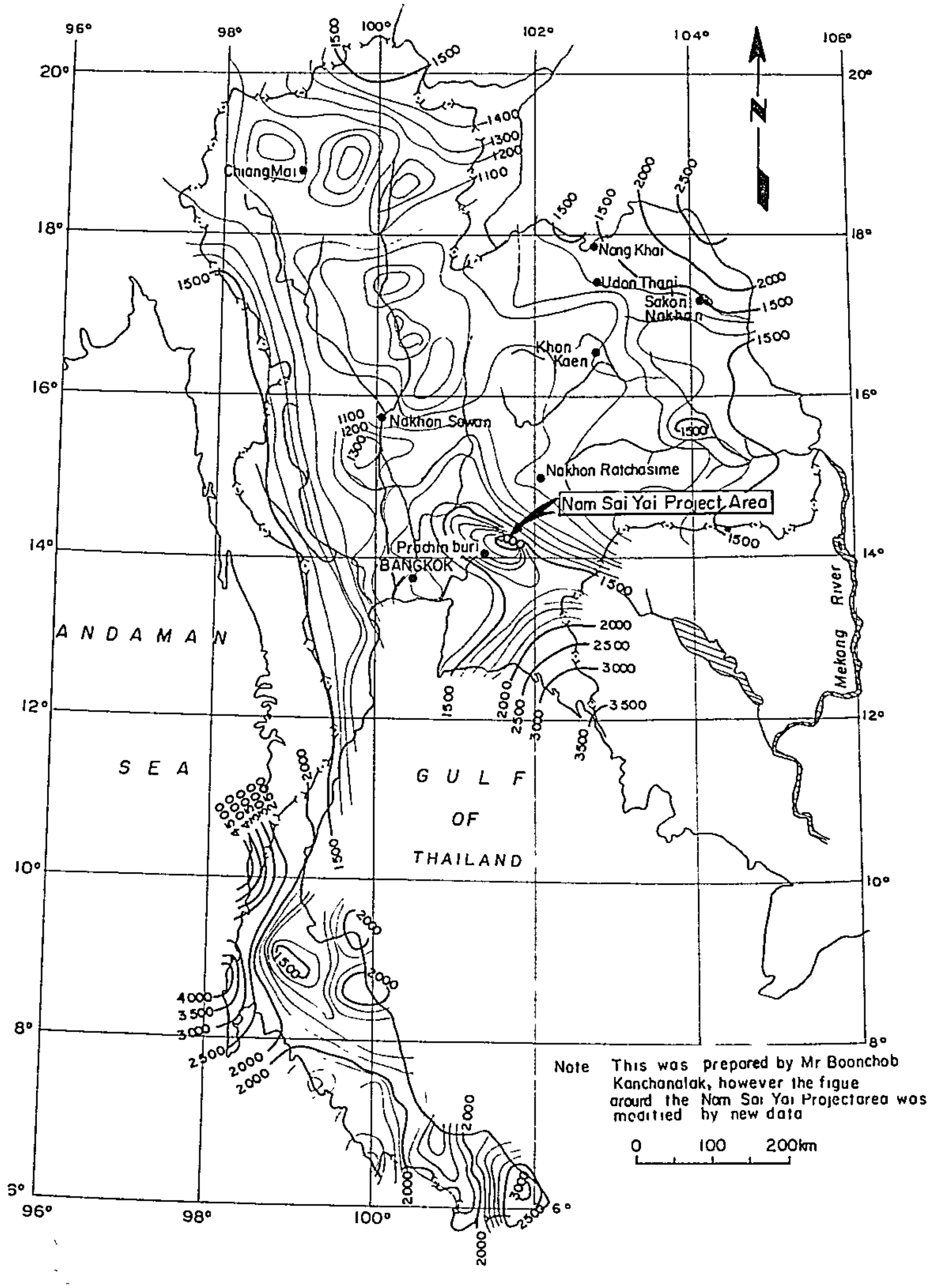


APPENDIX FIG. 4-13 FLOOD HYDROGRAPH OF BAN SAPANHIN

(Aug. 17, 1966 ~ Aug. 20, 1966)



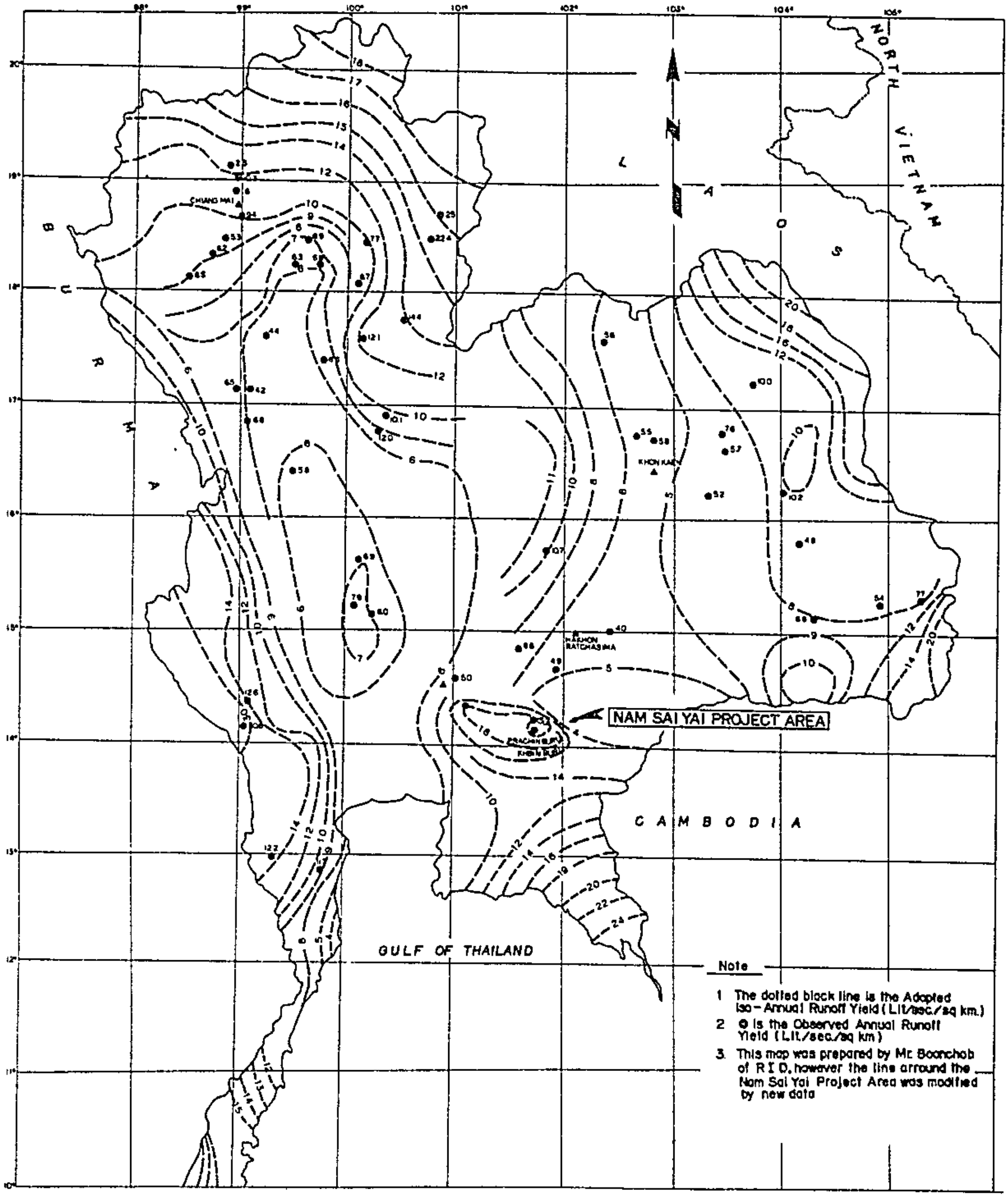
APPENDIX FIG. 4-14 ISOHYETAL MAP OF MEAN ANNUAL RAINFALL (1906 – 1960)



Note This was prepared by Mr Boonchob Kanchanalak, however the figue aroud the Nam Sai Yai Projectarea was modified by new data

0 100 200km

APPENDIX FIG. 4-15 MAP OF SPECIFIC RUN-OFF



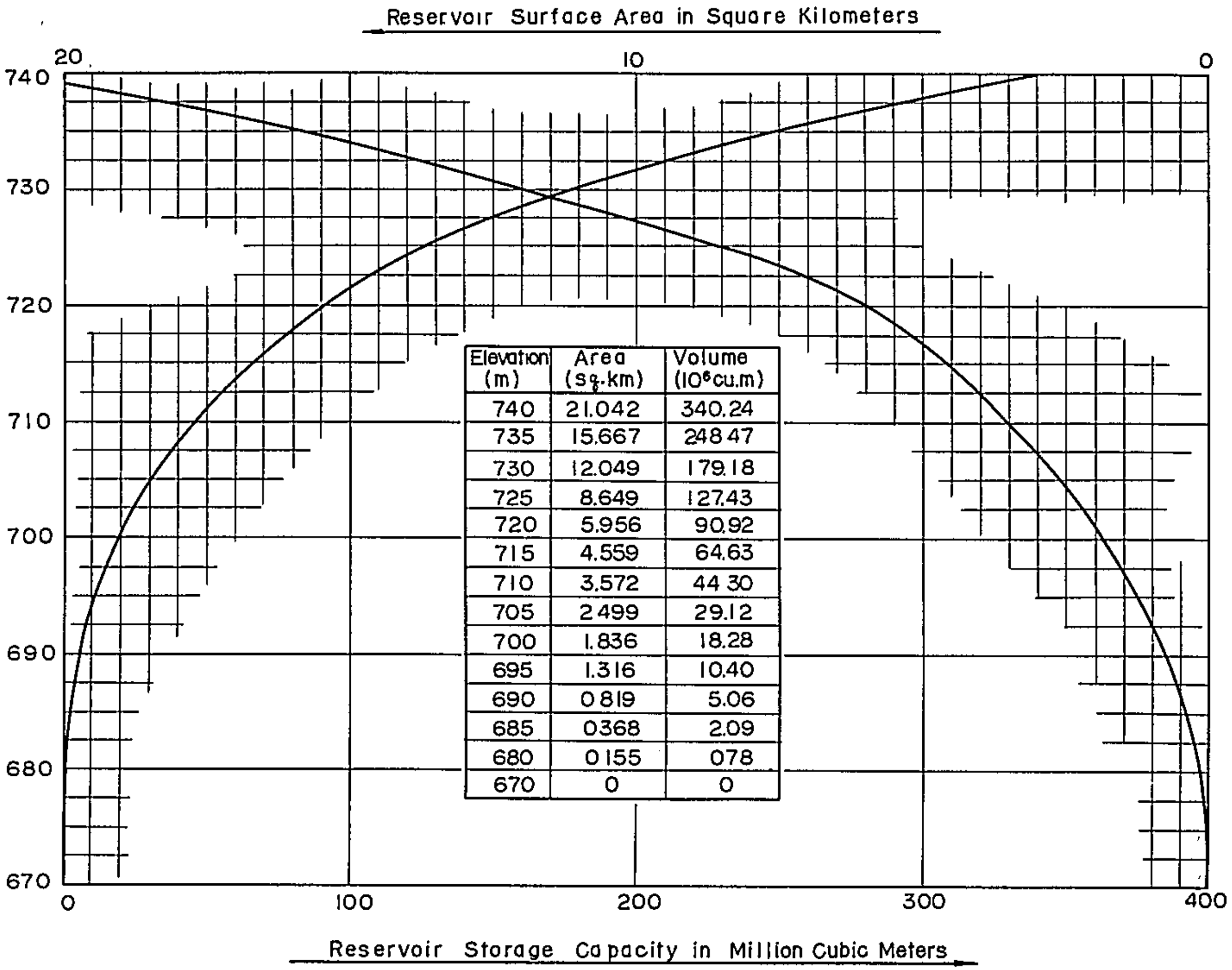
Note

1 The dotted black line is the Adopted Iso-Annual Runoff Yield (Lit/sec./sq km.)

2 ⊙ Is the Observed Annual Runoff Yield (Lit./sec./sq km)

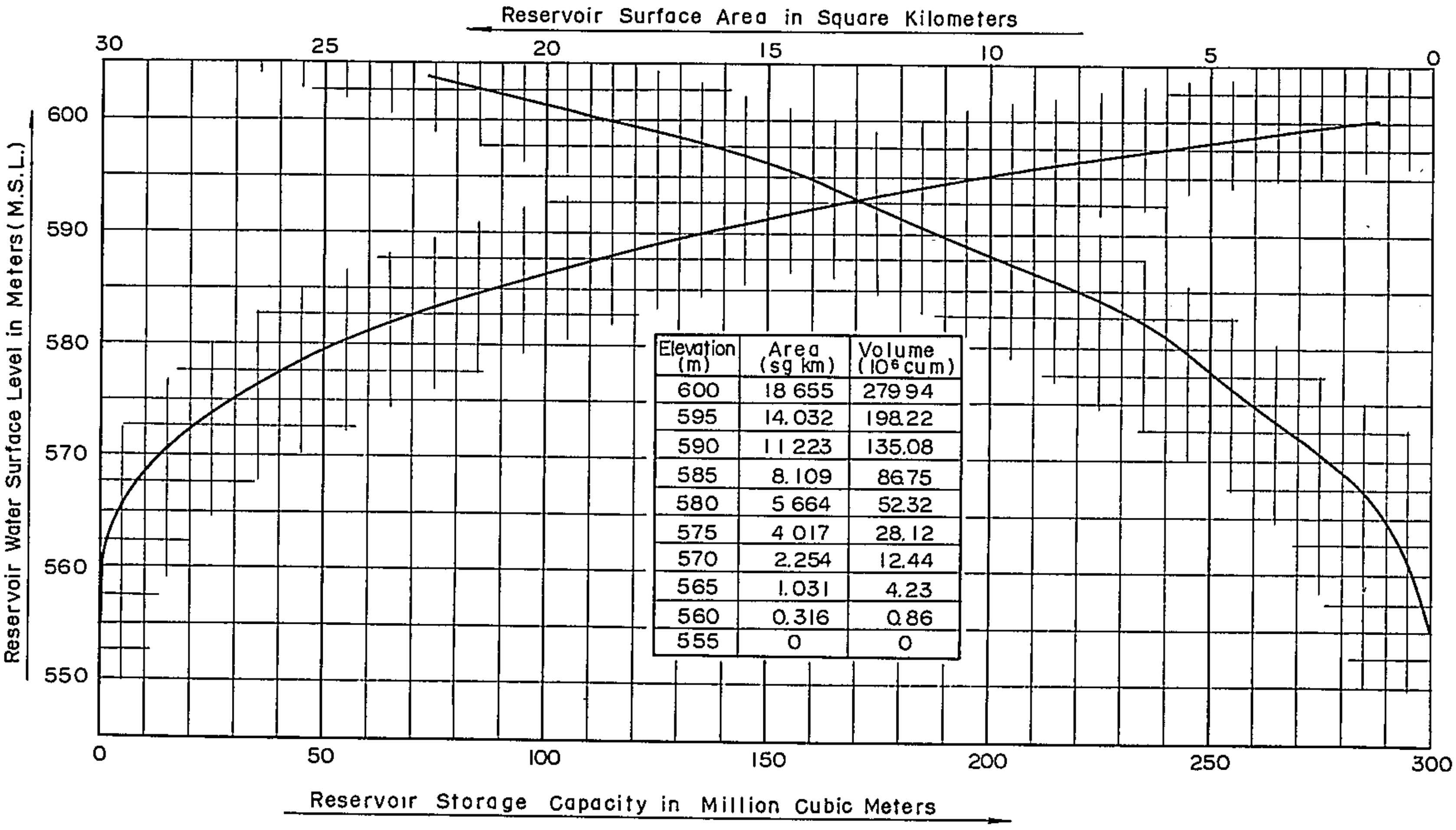
3. This map was prepared by Mr. Boonchob of R I D, however the line arround the Nam Sai Yai Project Area was modified by new data

APPENDIX FIG. 6-1 AREA CAPACITY CURVES FOR NO.1 RESERVOIR



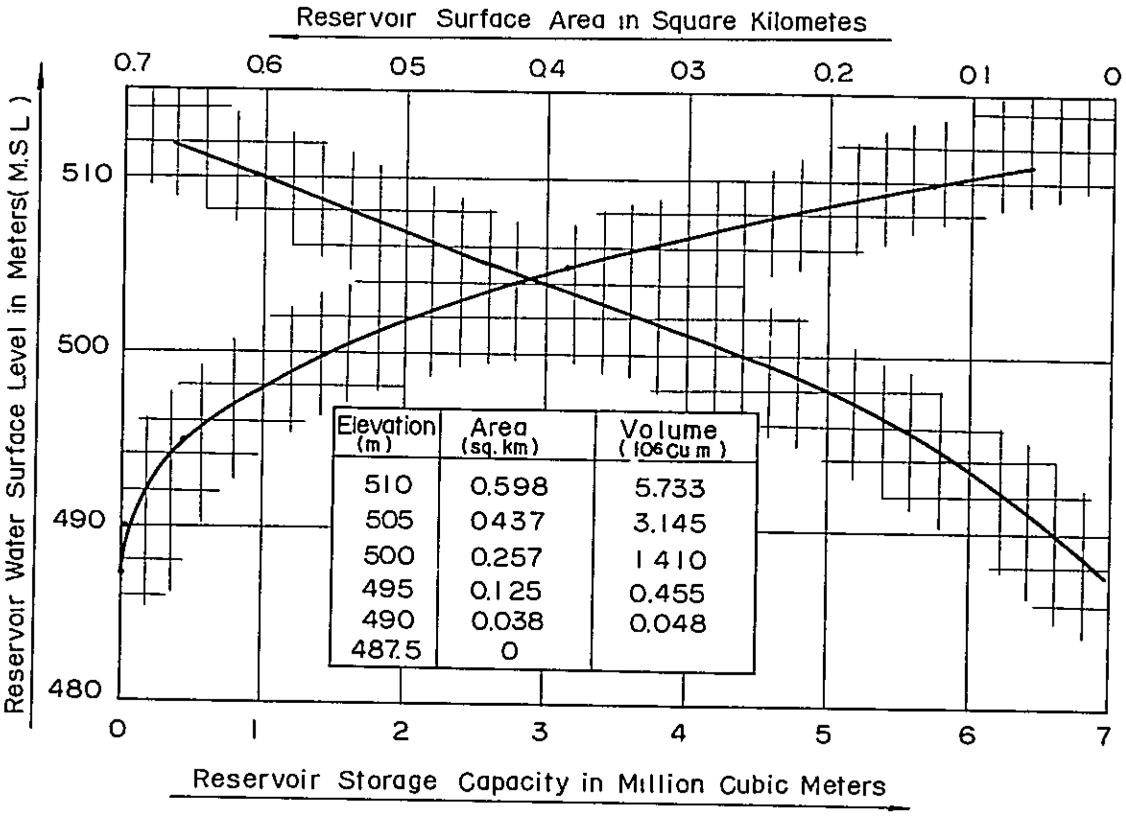
Elevation (m)	Area (sq.km)	Volume (10^6cu.m)
740	21.042	340.24
735	15.667	248 47
730	12.049	179.18
725	8.649	127.43
720	5.956	90.92
715	4.559	64.63
710	3.572	44 30
705	2.499	29.12
700	1.836	18.28
695	1.316	10.40
690	0 819	5.06
685	0368	2.09
680	0 155	078
670	0	0

APPENDIX FIG. 6-2 AREA CAPACITY CURVES FOR NO.2 RESERVOIR



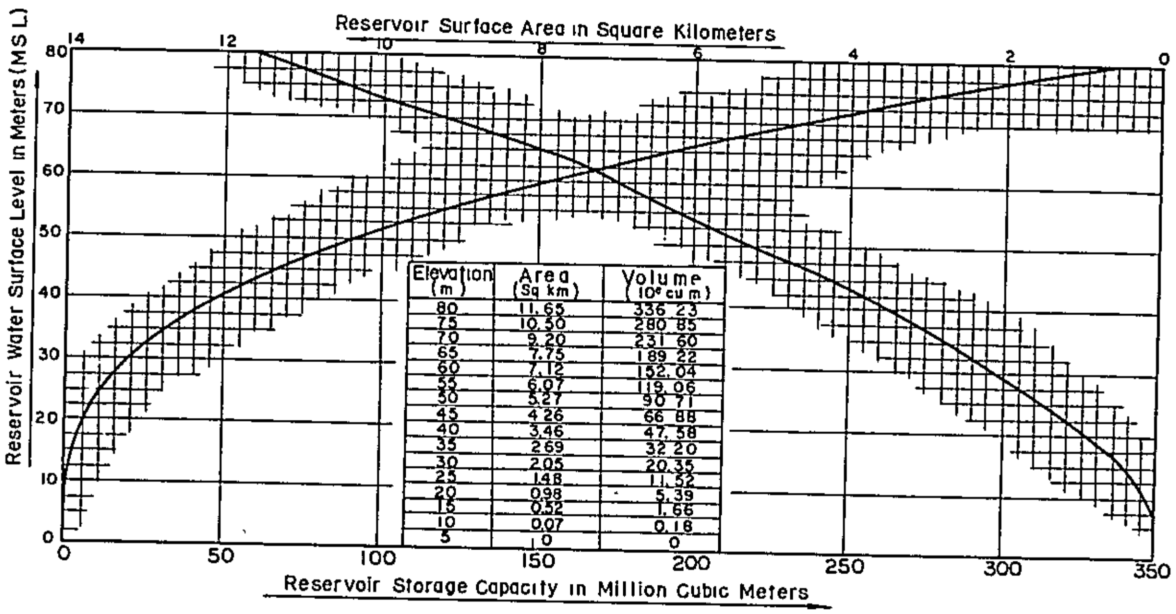
Elevation (m)	Area (sg km)	Volume (10^6 cum)
600	18 655	279 94
595	14.032	198.22
590	11 223	135.08
585	8.109	86.75
580	5 664	52.32
575	4 017	28.12
570	2.254	12.44
565	1.031	4.23
560	0.316	0.86
555	0	0

APPENDIX FIG. 6-3 AREA CAPACITY CURVES FOR A-NO.3 REGULATING POND



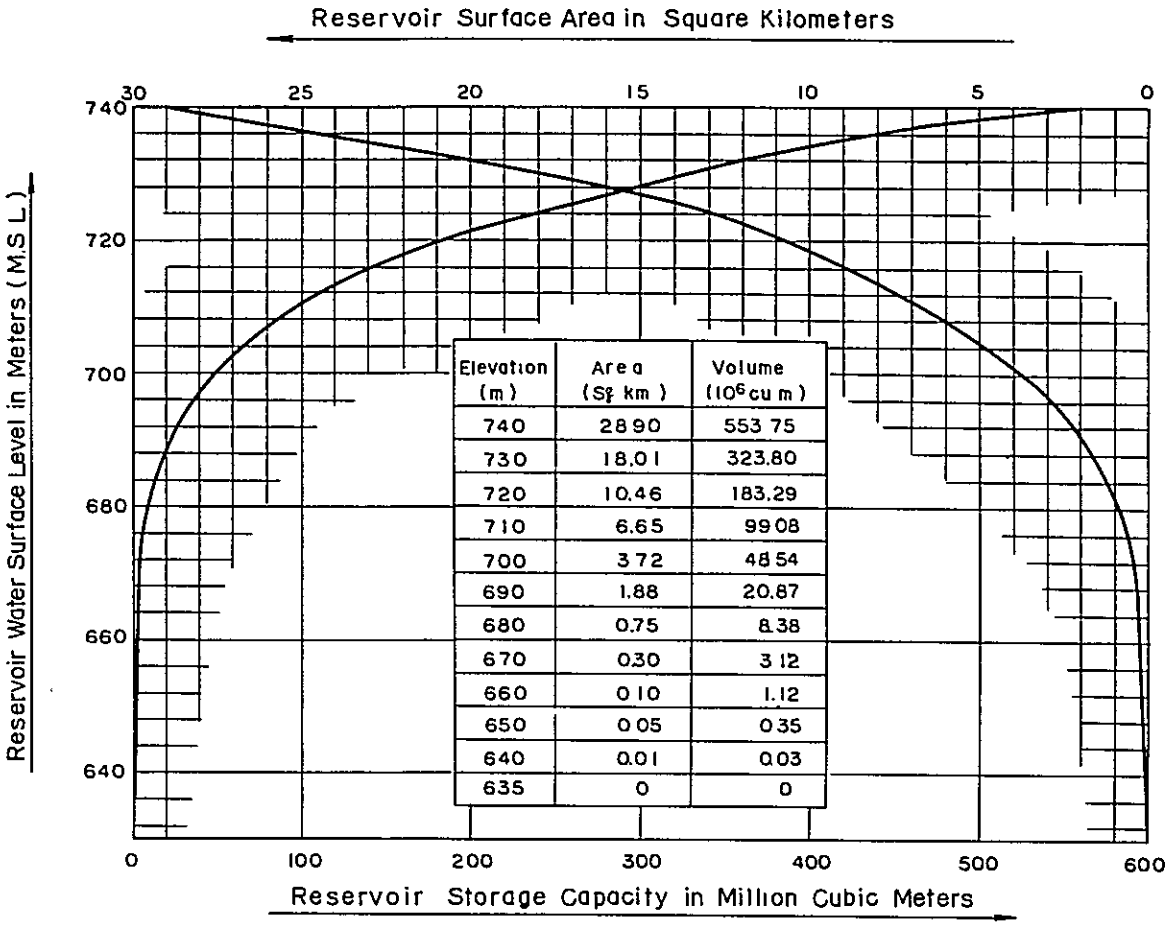
Elevation (m)	Area (sq. km)	Volume (10^6 cu m)
510	0.598	5.733
505	0437	3.145
500	0.257	1 410
495	0.1 25	0.455
490	0.038	0.048
487.5	0	

APPENDIX FIG. 6-4 AREA CAPACITY CURVES FOR NO.4 RESERVOIR



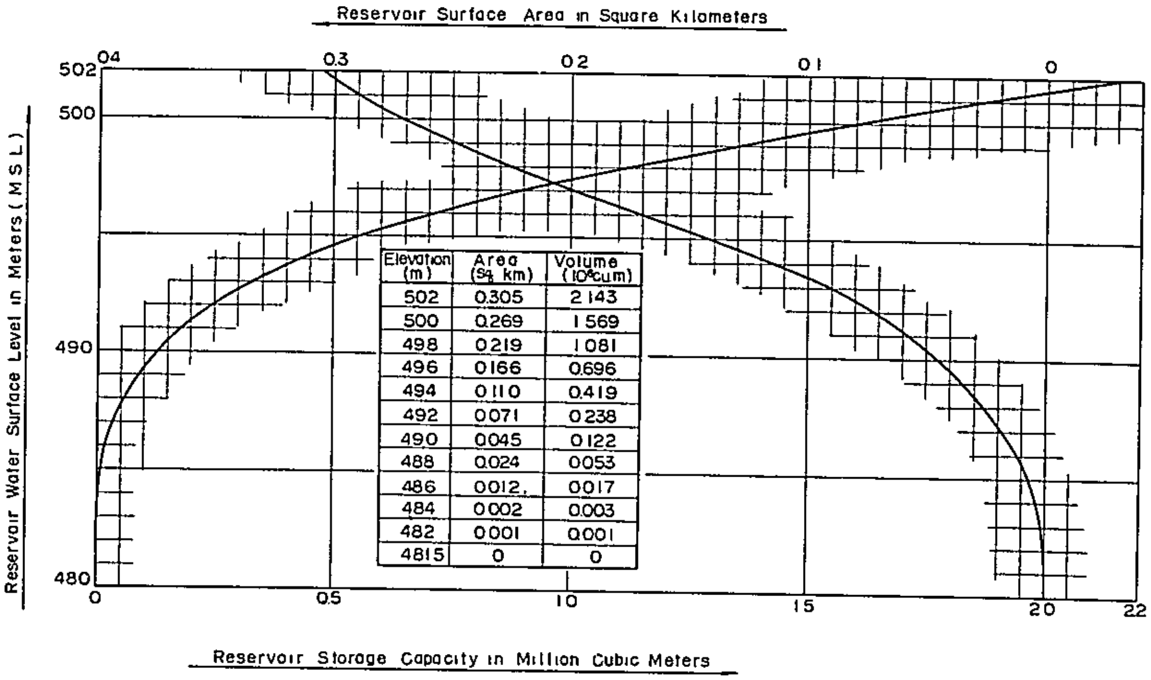
Elevation (m)	Area (Sq km)	Volume (10^6 cu m)
80	11.65	336 23
75	10.50	280 85
70	9.20	231 60
65	7.75	189 22
60	7.12	152.04
55	6.07	119.06
50	5.27	90 71
45	4 26	66 88
40	3.46	47.58
35	2 69	32 20
30	2.05	20.35
25	1.48	11.52
20	0.98	5.39
15	0.52	1.66
10	0.07	0.18
5	0	0

APPENDIX FIG. 6-5 AREA CAPACITY CURVES FOR NO.1 RESERVOIR (ALTERNATIVE)



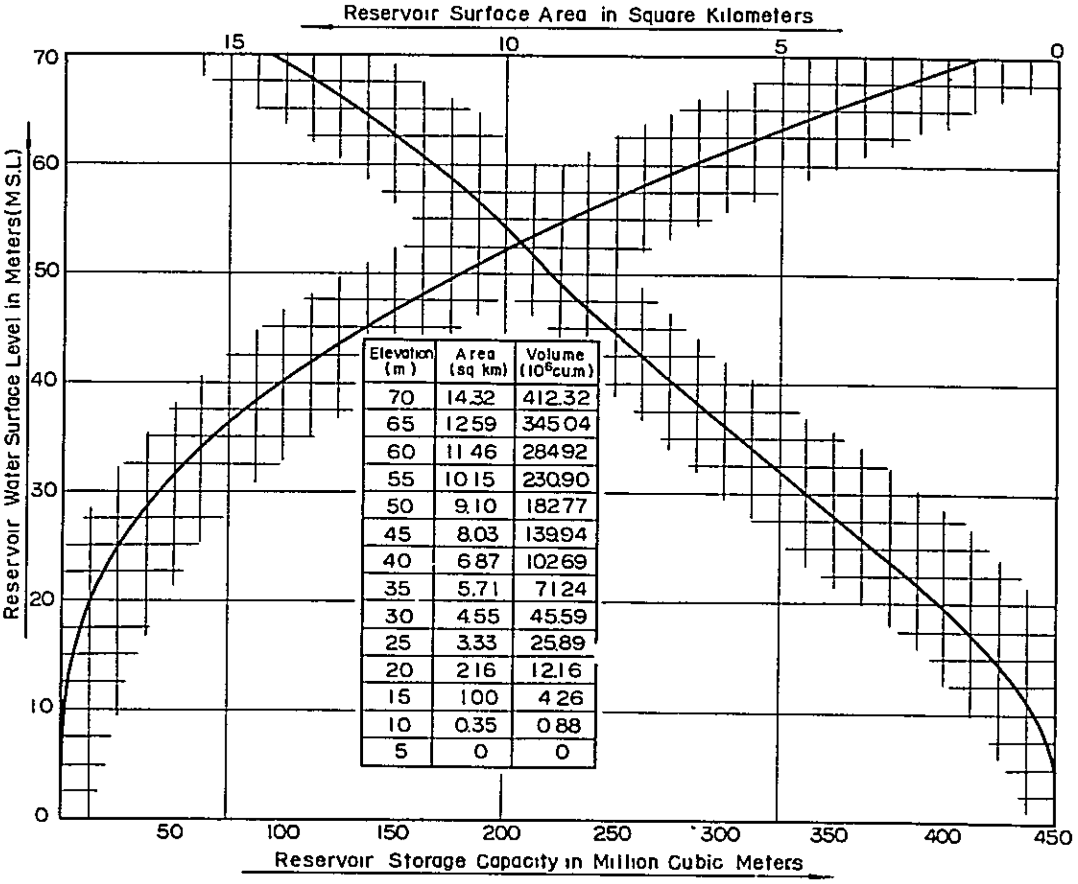
Elevation (m)	Area (Sq km)	Volume (10^6cu m)
740	2890	553 75
730	18.01	323.80
720	10.46	183.29
710	6.65	9908
700	3 72	48 54
690	1.88	20.87
680	0.75	8.38
670	030	3 12
660	0 10	1.12
650	0 05	035
640	0.01	0.03
635	0	0

APPENDIX FIG. 6-6 AREA CAPACITY CURVES FOR B-NO.3 REGULATING POND



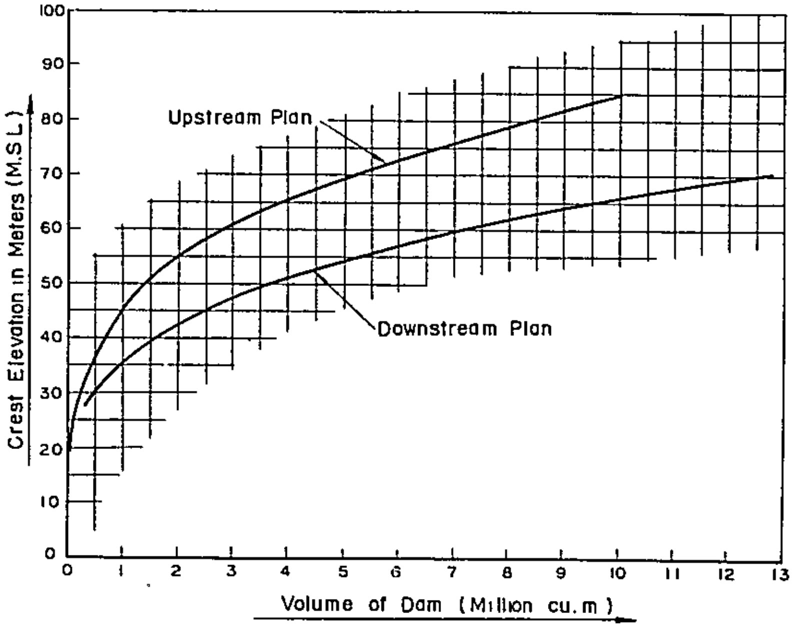
Elevation (m)	Area (Sq km)	Volume (10^6cum)
502	0.305	2 143
500	0.269	1 569
498	0219	1 081
496	0166	0.696
494	0110	0.419
492	0071	0 238
490	0045	0 122
488	0.024	0053
486	0012.	0017
484	0002	0.003
482	0001	0.001
4815	0	0

APPENDIX FIG. 6-7 AREA CAPACITY CURVES FOR NO.4 RESERVOIR



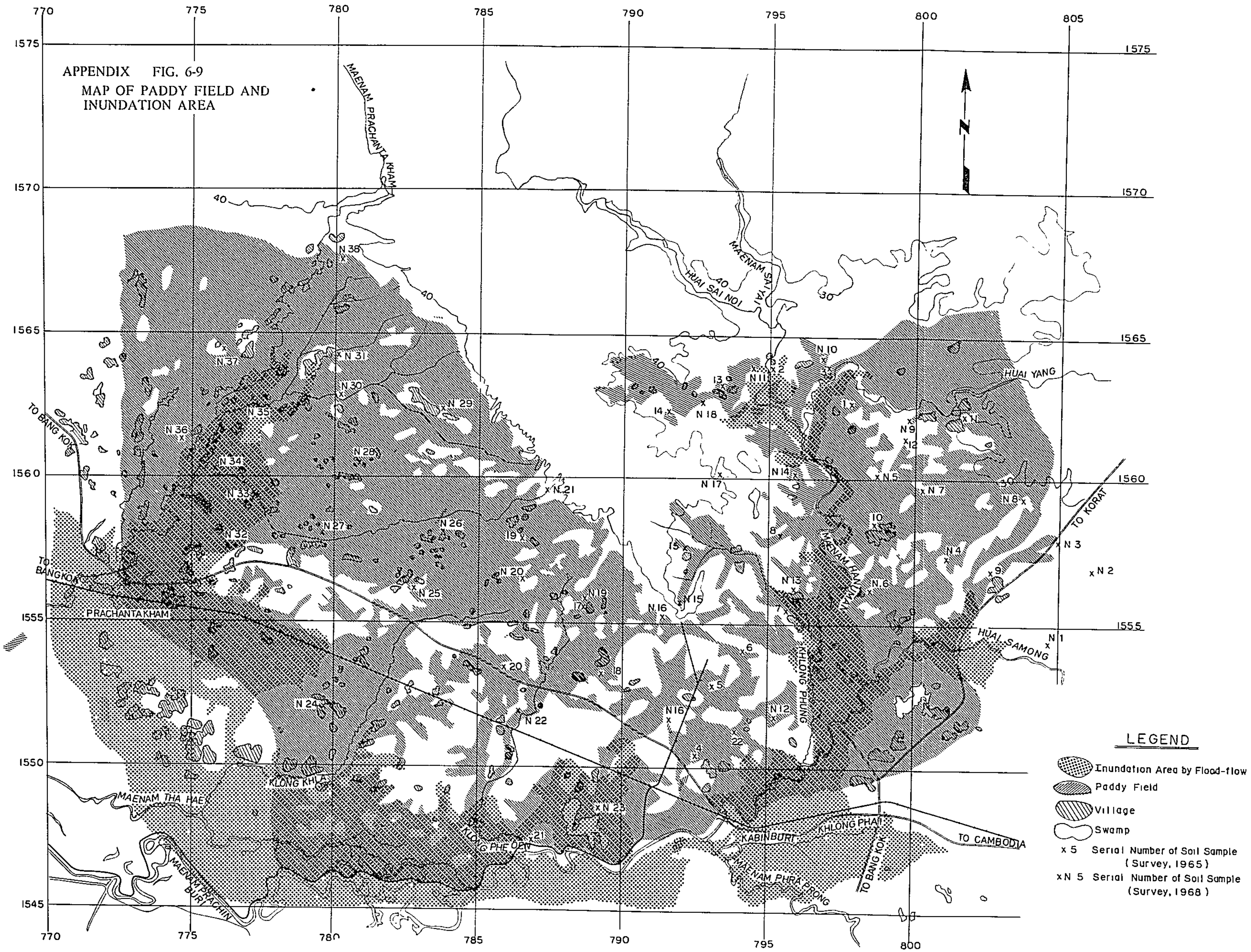
Elevation (m)	Area (sq km)	Volume (10^6cu.m)
70	14.32	412.32
65	12.59	345.04
60	11.46	284.92
55	10.15	230.90
50	9.10	182.77
45	8.03	139.94
40	6.87	102.69
35	5.71	71.24
30	4.55	45.59
25	3.33	25.89
20	2.16	12.16
15	1.00	4.26
10	0.35	0.88
5	0	0

APPENDIX FIG. 6-8 RELATION BETWEEN VOLUME OF DAM AND CREST ELEVATION (NO.4 DAM)



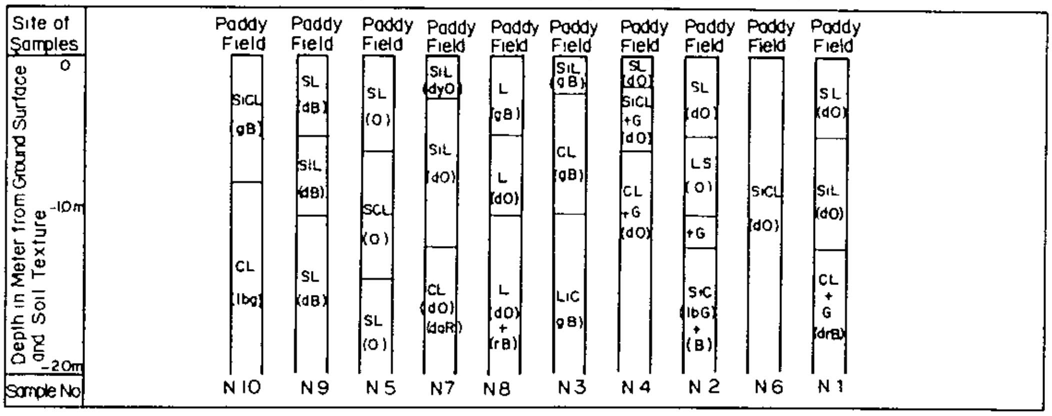
APPENDIX FIG. 6-9

MAP OF PADDY FIELD AND INUNDATION AREA

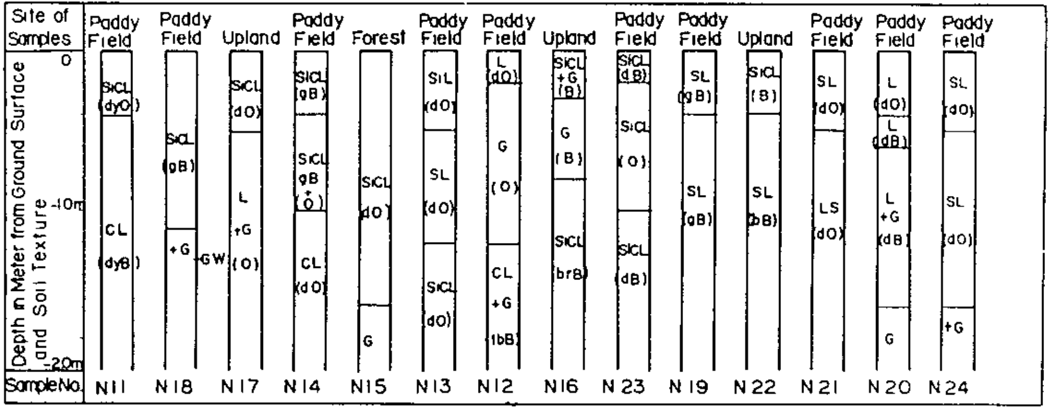


APPENDIX FIG. 6-10 SOIL PROFILE

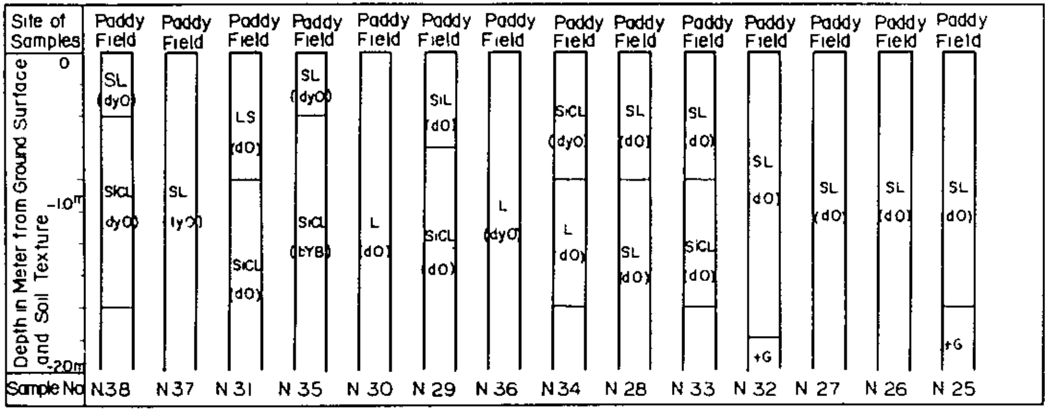
Maenam Hanuman (Left Bank Area)

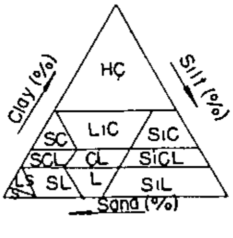


Maenam Hanuman (Right Bank Area)



Prachanta Kham (Left Bank Area)



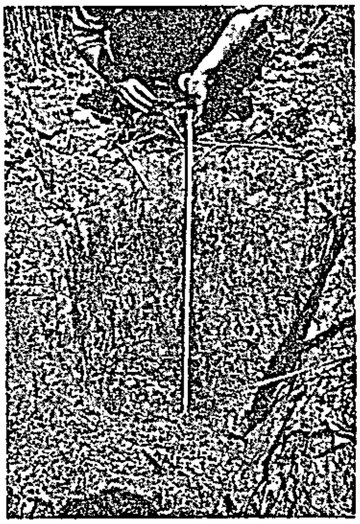


TEXTURE

S	Sand
LS	Light Sand
SL	Sandy Loam
L	Loam
SiL	Silty Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
LiC	Light Clay
SiC	Silty Clay
HC	Heavy Clay
G	Gravel

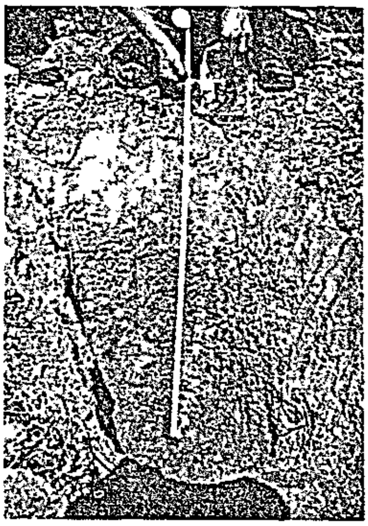
COLOR

B	Brown
bB	Bright Brown
BrB	Bright Reddish Brown
ByB	Bright Yellowish Brown
dB	Dull Brown
drB	Dark Reddish Brown
dyB	Dull Yellowish Brown
gB	Grayish Brown
rB	Reddish Brown
lbG	Light Brownish Gray
O	Orange
dO	Dull Orange
dyO	Dull Yellowish Orange
lyO	Light Yellowish Orange
daR	Dark Red

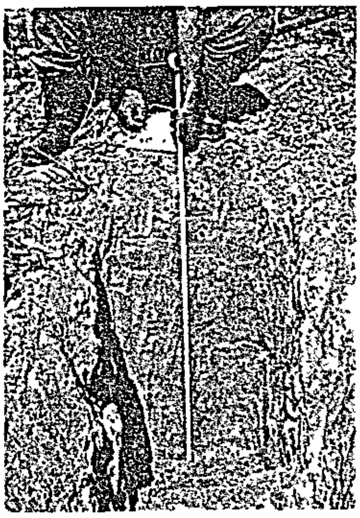


Sample N.5

Sample N 12

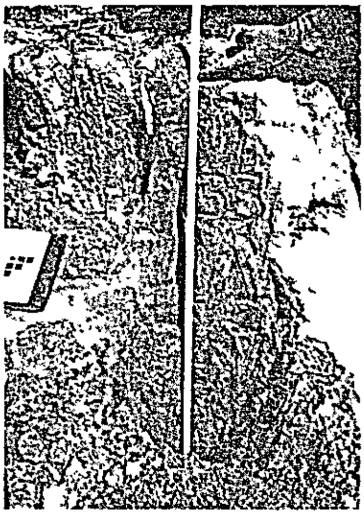


Sample N.17



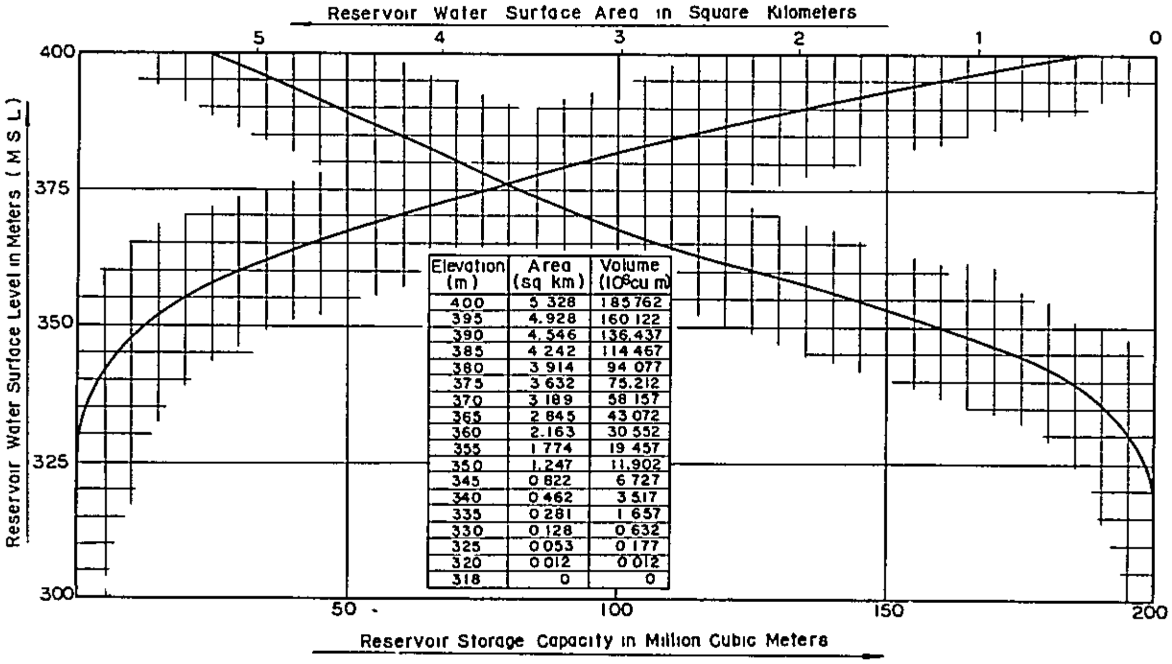
Sample N.19

Sample N.23



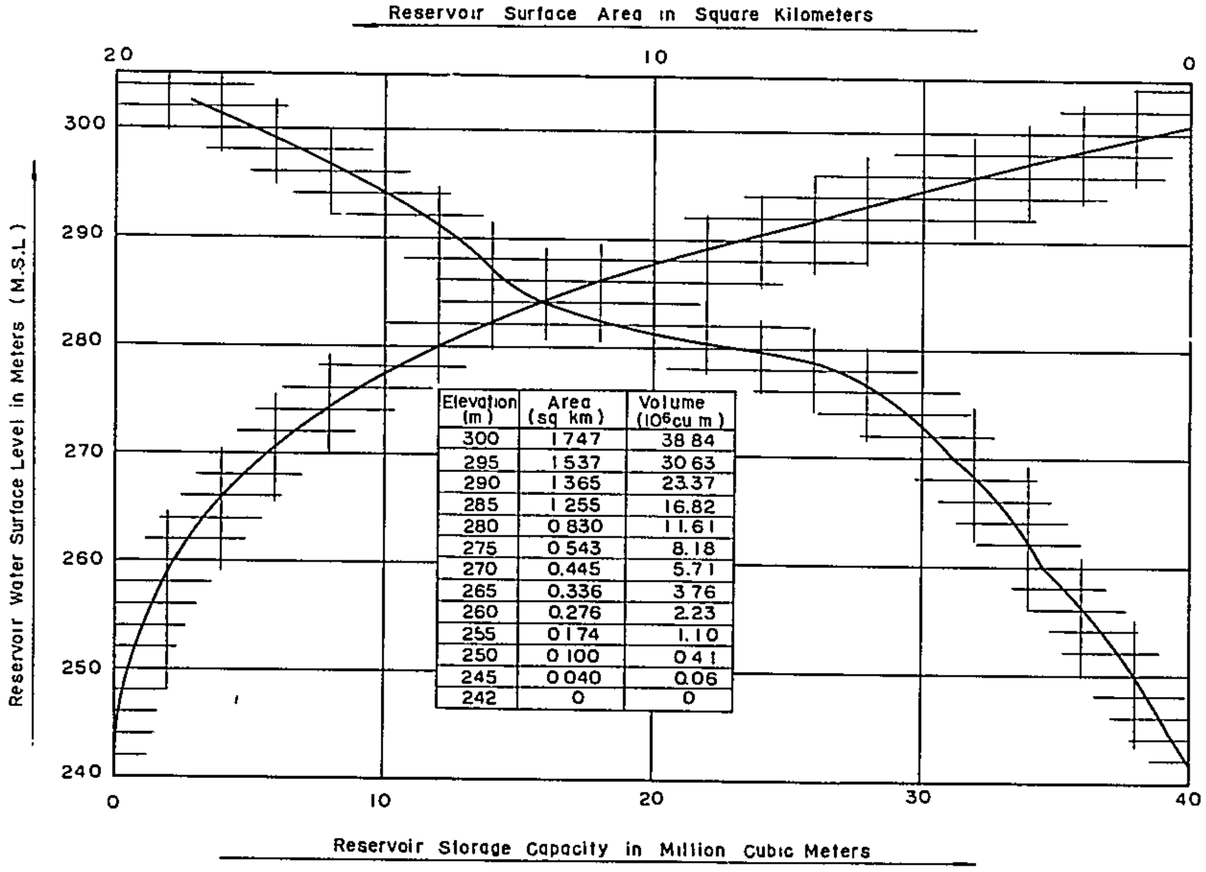
Sample N.35

APPENDIX FIG. 7-1 AREA CAPACITY CURVES FOR PRACHANTAKHAM NO.1 RESERVOIR



Elevation (m)	Area (sq km)	Volume (10^6cu m)
400	5 328	185762
395	4.928	160 122
390	4.546	136.437
385	4 242	114 467
380	3 914	94 077
375	3 632	75.212
370	3 189	58 157
365	2 845	43 072
360	2.163	30 552
355	1 774	19 457
350	1.247	11.902
345	0 822	6 727
340	0 462	3 517
335	0 281	1 657
330	0 128	0 632
325	0 053	0 177
320	0 012	0 012
318	0	0

APPENDIX FIG. 7-2 AREA CAPACITY CURVES FOR PRACHANTAKHAM NO.2 RESERVOIR



Elevation (m)	Area (sq km)	Volume (10^6cu m)
300	1747	38 84
295	1537	30 63
290	1 365	23.37
285	1 255	16.82
280	0 830	11.61
275	0 543	8.18
270	0.445	5.71
265	0.336	3 76
260	0.276	2.23
255	0 174	1.10
250	0 100	0 41
245	0 040	0.06
242	0	0

III TABLES

APPENDIX TABLE 2-1 RECOMMENDED FUTURE INVESTIGATIONS

1. Surveying
   - a. Topographical maps (based on actual measuring)

Scale :	1 to 2,000
Contour interval :	2 m
Area :	Nam Sai Yai No.1 Dam Site Nam Sai Yai No.4 Dam Site Nam Sai Yai No.1 Power Station Nam Sai Yai No.4 Power Station

   - b. Topographical maps (based on U.S. Army's aerial photos)

Scale :	1 to 10,000
Contour interval :	2.5 m
Area :	Entire irrigable area

   - c. River profiles

     Between Nam Sai Yai No.1 and No.2 Reservoirs

2. Geological Survey

   By means of boring

Nam Sai Yai No.1 Dam Site :	30 m x 9
Nam Sai Yai No.4 Dam Site :	30 m x 15
Nam Sai Yai No.1 Power Station :	20 m x 1
Nam Sai Yai No.4 Power Station :	20 m x 1

3. Embankment Materials Survey and Laboratory Tests
   - Nam Sai Yai No.1 Dam and Power Station
   - Nam Sai Yai No.4 Dam and Power Station
4. Agricultural Investigations
   - Land Utilization Survey
   - Soil Survey and Tests
   - Drainage Condition
5. Gaging of Stream Flow
   - Nam Sai Yai No.1 Dam Site
   - Nam Sai Yai No.4 Dam Site (Sai Yai Side and Sai Noi Side)
   - Prachatakham River

APPENDIX TABLE 3-1 AVERAGE YIELD PER HECTARE OF PADDY RICE PRODUCTION

Unit : Ton

Year	Whole Kingdom	Central Plain	Changwad Prachinburi
1958	1.36*1	*1	*1, 2
1959	1.29		
1960	1.39	1.50	1.09
1961	1.45	1.62	1.36
1962	1.49	1.65	1.19
1963	1.60	1.82	1.16
1964	1.62		1.10
1965	1.61		1.28
1966			1.25
Average	1.43	1.65	1.20

Source : *1 Statistical Year Book (1964)
*2 Area and Rice Production (Prachinburi)
*3 Agricultural Statistics of Thailand 1965

APPENDIX TABLE 4-1 MONTHLY MEAN TEMPERETURE AT PRACHINBURI

(Unit : °C)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
1951	27.0	28.6	30.4	31.0	29.3	28.0	27.7	28.0	27.7	27.6	28.0	25.8	28.3
1952	26.9	28.5	27.7	29.1	28.9	27.6	27.3	26.8	27.2	26.8	27.9	25.5	27.5
1953	27.2	26.8	28.4	29.4	27.4	26.9	27.2	26.8	27.2	27.8	27.6	27.2	27.5
1954	28.3	27.6	29.1	29.8	27.6	27.2	27.8	28.3	27.6	28.5	27.3	26.4	28.0
1955	26.1	28.8	30.4	30.0	29.5	28.3	28.9	28.7	28.2	28.3	26.4	25.8	28.3
1956	25.9	29.5	30.8	29.4	29.0	29.1	28.3	28.1	28.0	28.0	26.1	26.1	28.2
1957	27.3	28.5	29.9	30.6	31.6	29.2	28.6	28.5	27.8	27.8	28.2	27.6	28.8
1958	28.2	28.2	31.3	31.9	31.3	29.2	28.4	28.6	28.0	28.2	27.4	26.4	28.9
1959	27.1	29.9	29.2	31.1	29.9	30.8	28.1	28.5	28.4	28.4	28.5	28.6	29.0
1960	28.0	29.3	31.4	32.1	30.2	29.4	29.2	28.9	28.5	28.5	28.4	26.7	29.2
1961	26.5	29.2	30.0	31.1	29.2	29.0	28.4	28.4	28.3	28.4	28.5	27.6	28.7
1962	26.1	28.1	30.6	31.0	29.9	29.1	28.5	28.6	28.1	28.8	28.4	26.3	28.6
1963	24.8	28.8	30.2	30.9	31.6	29.5	28.6	28.5	28.4	28.1	28.4	26.9	28.7
1964	29.2	29.2	30.9	31.5	29.5	29.6	29.2	28.3	28.1	28.5	26.7	26.3	28.9
1965	26.4	29.1	30.0	30.7	29.1	28.6	28.9	28.8	28.3	28.7	28.5	28.4	28.8
1966	29.0	29.7	31.6	31.2	28.9	29.7	28.9	28.6	28.4	28.7	28.2	27.8	29.2
Ave-rage	27.1	28.7	30.1	30.7	29.6	28.8	28.4	28.3	28.0	28.2	27.8	26.8	28.5

APPENDIX TABLE 4-2 MONTHLY RAIN FALL AT KABINBURI

(Unit : m.m.)

Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
'53-'54	61.5	243.3	229.0	242.3	218.2	257.9	109.3	19.1	0	0	0	51.7	1,432.3
'54-'55	182.8	170.0	142.9	229.6	267.9	441.3	58.7	0	0	0	10.4	38.1	1,541.7
'55-'56	150.5	136.1	239.2	125.1	264.3	217.3	129.5	74.9	0	8.6	0	0	1,345.5
'56-'57	107.9	144.0	257.7	231.6	182.2	494.5	123.8	32.2	0	0	21.6	96.0	1,691.5
'57-'58	19.1	135.9	117.6	148.0	198.5	258.1	260.3	0	0	28.1	18.2	2.4	1,186.2
'58-'59	71.0	112.7	139.6	236.3	279.6	302.7	82.3	0	0	0	31.8	24.3	1,280.3
'59-'60	125.6	70.5	47.1	324.8	214.4	198.1	135.3	77.3	0	0	0	31.8	1,224.9
'60-'61	24.9	97.5	192.9	143.4	288.6	321.7	180.9	0	0	0	0	61.2	1,311.1
'61-'62	113.3	447.9	269.6	424.8	610.4	306.1	184.1	0	0	0	0	66.6	2,422.8
'62-'63	73.8	128.1	267.6	329.9	89.4	389.7	171.1	0	0	0*	10.6*	76.5*	1,536.7
'63-'64	83.3*	80.3*	184.7	445.0*	320.8	216.8	197.5	45.0	0	0*	50.0*	24.0*	1,647.4
'64-'65	62.3*	80.6	115.8	44.2	336.1	231.5	212.5	0	0	0	40.9	0	1,123.9
'65-'66	30.7	0	170.1	96.8	139.8	305.0	105.9	39.9	0.9	3.0	79.8	22.7	994.6
'66-'67	54.2	417.7	248.8	344.8	528.0	284.9	188.8	25.0	11.7	6.4	10.8	0	2,121.1
'67-'68	72.8	254.5	84.4	442.3	464.1	199.5	213.0	21.6	0	0	0	0	1,752.2
Total	1,233.7	2,519.1	2,707.0	3,808.9	4,402.3	4,425.1	2,353.0	335.0	12.6	46.1	274.1	495.3	22,612.2
Average.	82.2	167.9	180.5	253.9	293.5	295.0	156.9	22.3	0.8	3.1	18.3	33.0	1,507.5

NOTE: * Estimated on the basis of Kabinburi and Prachinburi Rainfall

TABLE 4-3 MONTHLY AVERAGE RUN-OFF AT WANG HEO

(CATCHMENT AREA 295 sq.km)

(unit: c.m.s.)

Year	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual Average
'53-'54	0.5	2.9	7.3	10.5	14.4	15.3	16.6	7.3	2.1	0.7	0.6	0.4	6.6
'54-'55	0.5	3.1	6.5	13.6	16.6	19.4	18.0	5.9	1.8	0.6	0.5	0.3	7.3
'55-'56	0.3	3.0	12.5	18.7	13.4	13.0	15.1	11.7	3.3	1.1	0.9	0.7	7.8
'56-'57	0.7	2.6	7.0	15.2	15.5	32.5	22.4	8.2	2.4	0.8	0.7	0.4	9.1
'57-'58	0.5	1.9	6.3	10.7	14.5	17.2	28.2	10.8	3.2	1.1	1.0	0.7	8.0
'58-'59	0.7	2.4	7.1	14.6	15.4	16.6	17.8	7.0	2.0	0.7	0.6	0.4	7.1
'59-'60	0.5	2.2	4.0	18.9	14.1	17.4	18.0	8.7	2.5	0.9	0.7	0.6	7.4
'60-'61	0.6	1.8	4.6	10.6	14.5	16.6	22.8	8.9	2.5	0.9	0.7	0.6	7.1
'61-'62	0.6	4.2	8.2	14.9	31.9	31.0	21.8	9.0	2.6	0.9	0.7	0.6	10.5
'62-'63	0.6	3.1	8.7	16.6	16.5	15.3	18.9	6.5	1.9	0.7	0.6	0.4	7.5
'63-'64	0.5	1.4	5.6	5.9	13.2	14.0	17.2	9.6	2.8	0.9	0.8	0.6	6.1
'64-'65	0.2*	7.3*	5.9*	11.2*	7.8*	12.4*	22.8*	6.4*	1.8*	0.8*	0.6*	0.6*	6.5
'65-'66	0.4*	1.9*	18.3*	12.7*	35.4*	34.0*	20.7*	7.0*	2.2*	0.6*	0.4*	0.2*	11.2
'66-'67	0.3*	4.9*	8.2*	18.5*	30.5*	32.1*	16.9*	5.8*	1.4*	0.6*	0.4*	0.2*	10.1
'67-'68	0.4*	1.4*	10.3*	13.3*	22.3*	19.4*	21.2*	3.8*	1.1*	0.6*	0.4*	0.2*	7.9
Average	0.5	2.9	8.1	13.7	19.5	20.0	19.9	7.8	2.2	0.8	0.6	0.5	8.0

NOTE:

(1) * Run-off observed actually

(2) Other values were estimated on the basis of Kabinburi and Prachinburi Rainfall.

APPENDIX TABLE 4-4 MONTHLY AVERAGE RUN-OFF AT BAN SAPANHIN
(CATCHMENT AREA 636 sq. km)

(Unit : c.m.s.)

Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual Average
'53-'54	0.6	5.5	21.9	24.6	36.3	50.2	40.8	10.3	3.3	1.7	1.3	0.7	16.4
'54-'55	0.6	9.5	19.2	33.9	59.5	66.2	39.6	7.4	2.4	1.2	1.1	0.5	20.1
'55-'56	0.5	5.7	25.1	48.6	33.2	49.4	32.2	20.2	6.6	3.1	2.5	1.4	19.0
'56-'57	1.0	5.0	20.7	38.4	39.3	78.7	49.5	12.1	4.0	1.9	1.6	0.9	21.1
'57-'58	0.7	3.3	18.5	25.4	36.3	57.8	65.6	17.5	5.7	2.6	2.4	1.2	19.8
'58-'59	1.0	4.3	21.2	36.7	39.1	57.6	39.3	9.3	3.1	1.4	1.3	0.7	18.0
'59-'60	0.6	4.0	10.3	49.3	35.3	58.8	39.6	13.3	4.3	2.1	1.8	0.9	18.4
'60-'61	0.7	2.8	12.3	24.9	36.5	55.8	51.9	12.3	4.0	1.9	1.6	0.9	17.2
'61-'62	0.7	8.8	25.1	37.4	75.8	74.5	49.3	13.8	4.5	2.1	1.8	0.9	24.6
'62-'63	0.7	5.9	26.6	42.4	59.0	50.0	47.4	8.6	2.8	1.4	1.1	0.5	20.6
'63-'64	0.5	2.1	15.7	11.4	32.5	45.3	37.4	15.0	5.0	2.1	1.5	0.8	14.1
'64-'65	0.5*	17.8*	14.7*	32.4*	27.9*	39.8*	68.4*	8.9*	2.4*	1.1*	1.1*	0.7*	18.0
'65-'66	0.5*	2.2*	33.8*	24.2*	60.6*	82.9*	41.1*	9.3*	2.7*	1.6*	0.8*	0,4*	21.6
'66-'67	0.5*	6.8*	20.7*	60.0*	85.7*	67.9*	29.3*	7.4*	2.2*	1.3*	0.8*	0.4*	23.6
'67-'68	0.6*	4.7*	13.1*	38.7*	67.0*	57.7*	37.5*	6.2*	2.4*	1.2*	0.5*	0.4*	19.2
Average	0.6	5.9	19.9	35.2	48.2	59.5	44.6	11.4	3.7	1.7	1.4	0.8	19.5

NOTE: (1) * Run-off observed actually

(2) Another values were estimated on the basis of Kabinburi and Prachinburi Rainfall

APPENDIX TABLE 5-1 ECONOMIC COMPARISON AMONG A, B AND B'-LINES

	Unit	A-Line	B-Line	B'-Line
Construction Cost				
No.1 Reservoir	$	3,912,900	3,912,900	3,912,900
	10^3฿	80,800	80,800	80,800
No.2 Reservoir	$	4,745,900	4,745,900	4,745,900
	10^3฿	98,000	98,000	98,000
No.1 Power Station	$	2,803,900	2,803,900	2,803,900
	10^3฿	57,900	57,900	57,900
No.2 Power Station	$	6,702,300	6,392,400	6,392,400
	10^3฿	138,400	132,000	132,000
No.3 Power Station (Included No.3 Regulating Pond).	$	9,036,500	10,653,900	10,653,900
	10^3฿	186,600	220,000	220,000
No.4 Power Station	$	8,450,500	9,927,500	9,927,500
	10^3฿	174,500	205,000	205,000
Total	$	35,652,000	38,436,500	38,436,500
	10^3฿	736,200	793,700	793,700
Annual Cost	$	2,310,000	2,494,000	2,494,000
	10^3฿	47,700	51,500	51,500
Annual Benefit				
No.1 Power Station	$	130,800	130,800	130,800
	10^3฿	2,700	2,700	2,700
No.2 Power Station	$	426,100	450,400	450,400
	10^3฿	8,800	9,300	9,300
No.3 Power Station	$	1,830,500	1,627,100	1,627,100
	10^3฿	37,800	33,600	33,600
No.4 Power Station	$	566,600	678,000	648,900
	10^3 ฿	11,700	14,000	13,400
Total	$	2,954,000	2,886,300	2,857,200
	10^3฿	61,000	59,600	59,000
Excess Benefit	$	644,000	392,200	363,200
	10^3฿	13,300	8,100	7,500
Benefit Cost Ratio		1.28	1.16	1.15

APPENDIX TABLE 6-1 AREA OF LAND HOLDING BY SIZE BY AMPHUR KABINBURI AND PRACHANTAKHAM

Amphur	Kabinburi		Pranchantakham	
Size (Rai)	Area	%	Area	%
	Rai		Rai	
Under - 1.9	69	-	35	-
2 - 3.9	942	0.3	294	0.2
4 - 5.9	1,619	0.5	788	0.6
6 - 7.9	1,786	0.6	751	0.6
8 - 9.9	2,148	0.7	1,062	0.8
10 - 14.9	10,054	3.4	4,686	3.7
15 - 19.9	14,096	4.7	6,577	5.1
20 - 24.9	19,464	6.5	9,139	7.1
25 - 29.9	21,234	7.1	9,506	7.4
30 - 34.9	26,336	8.8	10,707	8.3
35 - 39.9	19,924	0.7	10,883	8.5
40 - 44.9	20,059	6.7	10,443	8.1
45 - 49.9	16,392	5.5	8,599	6.7
50 - 54.9	31,346	10.4	10,380	8.1
55 - 59.9	12,210	4.1	5,808	4.5
60 - 99.9	64,053	21.5	28,901	22.5
100 -139.9	20,021	6.7	7,129	5.6
140 - Over	16,413	5.5	2,592	2.0
Total	298,166	100.0	128,280	100.0

APPENDIX TABLE 6-2 TEST RESULTS OF WATER QUALITY

Unit: p.p.m

River	Time of Sampling	Ca	Mg.	Na	K	HCo_3	SO_4	Cl	SiO_2	Fe	PO_4	NO_3-N	NH_4-N	Albumi-noid-N	$KMnO_4$	T.D.S	T.S.S	Turbidity	PH	Hardness
Sai Yai	1968-Mar.	1.6	0.5	1.4	0.5	9.0	nil	5.0	6.0	0.44		0.032	0.158	0.092					8.0	
Sai Noi	1968-Mar.	1.6	0.7	2.2	0.7	13.0	nil	8.0	3.0	0.99		0.030	0.071	0.042					8.0	

APPENDIX TABLE 6-3 TEST RESULTS OF WATER QUALITY

Unit: p.p.m

River	Time of Sampling	Ca	Mg.	Na	K	HCO_3	SO_4	Cl	SiO_2	Fe	PO_4	NO_3-N	NH_4-N	Albumi-noid-N	$KMnO_4$	T.D.S	T.S.S	Turbidity	PH	Hardness
	1956-Jul.	2.3	0.5	1.8	1.0	13.3	2.0	0.7	8.2	0.15	0.0	0.48	0.03	0.18	8.8	33	-	81.9	6.0	7.9
	Aug.	2.9	0.6	1.6	0.8	14.7	0.0	0.3	8.3	0.03	0.0	0.01	0.13	0.14	9.7	31	40.6	43.0	6.0	9.8
	Oct.	6.5	1.7	2.2	0.8	33.0	1.4	1.2	9.4	0.03	0.0	0.02	0.05	0.01	6.1	45	32.6	27.4	6.5	23.2
	Nov.	8.1	2.5	4.9	0.8	41.3	3.6	3.6	11.6	0.04	0.0	0.02	0.03	0.00	3.7	60	26.8	22.5	6.6	30.3
Prachin-	Dec.	8.1	2.8	5.9	1.0	41.9	3.0	5.2	11.0	0.03	0.0	0.04	0.02	0.01	7.8	68	42.6	19.5	6.5	31.8
buri	1957-Jan.	9.9	4.2	9.8	1.4	50.7	5.3	11.1	13.6	0.05	0.0	0.12	0.18	0.26	16.6	85	53.3	43.5	6.5	42.2
	Feb.	12.6	4.4	13.1	2.0	61.3	8.0	15.9	14.3	0.08	0.0	0.21	0.09	0.25	2.8	110	76.2	24.2	6.7	49.5
	Mar.	13.4	4.8	14.9	2.3	68.2	10.0	19.4	15.1	0.05	0.0	0.24	0.10	0.23	3.3	114	132.8	40.8	6.5	53.4
	Apr.	12.4	6.9	15.3	3.5	59.1	11.8	19.4	16.4	0.06	0.0	0.27	0.08	0.10	2.8	120	23.9	114.2	6.5	59.2
	May.	11.0	3.6	16.5	1.8	55.5	9.1	20.5	17.7	0.03	0.0	0.26	0.06	0.11	3.9	120	163.0	118.8	6.6	42.4
	Jun.	5.5	1.4	6.9	3.8	25.8	8.2	8.4	11.6	0.10	0.0	0.30	0.17	0.04	3.3	73	156.6	225.2	6.2	19,7
Average		8.4	3.0	8.4	1.7	42.3	5.7	9.6	12.5	0.06	0.0	0.18	0.09	0.10	6.3	78.1	74.8	69.2	6.4	33.6

Source : Chemical investigation on River Waters of South - Eastern Asiatic Countries (report 1)
The Quality of waters of Thailand by J.Kobayashi, Okayama University, Japan.

APPENDIX TABLE 6-4 TOTAL AREA OF HOLDINGS BY LAND USE BY AMPHUR

Area in Rai (ha)

Amphur	Total Area of holding	Arable Land						Land in tree Crops		Pasture Land		Wood Land		Other Land	
		Land in crops				Fallow and others									
		Total Area	%	Irrigated Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
Kabinburi	298,097 (47,696)	217.865 (34,858)	73,1	66,496 (10,639)	22.3	12,975 (2,076)	4.4	9,348 (1,496)	3.1	2,182 (349)	0.7	50,129 (8,021)	16.8	5,598 (896)	1.9
Prachanta -Kham	128,245 (20,519)	114,377 (18,300)	89.2	48,435 (7,750)	37.8	3,692 (591)	2.9	2,529 (405)	2.0	124 (20)	0.1	2,044 (327)	1.6	5,479 (877)	4.3
Total	426,342*1 (68,215)	332,242 (53,158)	77.4	114,931 (18,389)	26.9	16,667 (2,666)	3.9	11,877 (1,901)	2.8	2,306 (369)	0.5	52,173 (8,348)	12.2	11,077 (1,773)	2.5
	426,446*2 (68,231)														
Changwad Total	1,322,499*1 (211,600)	1,051,039 (168,166)	79.5	472,135 (75,542)	35.7	62,869 (10,059)	4.8	34,775 (5,564)	2.6	8,784 (1,406)	0.7	131,025 (20,964)	9.9	34,007 (5,441)	2.6
	1,322,980*2 (211,677)														

*1 Excludes holdings under 2 Rai (Total 481 Rai)

*2 Includes Holdings under 2 Rai (Total 481 Rai)

Source : Census of Agriculture 1963

MAENAM HANUMAN (LEFT BANK AREA)

Serial Number of Samples	Site of Samples	Top Soil		Chemical, Characteristic										
		Texture	Colour	PH	NH_4-N mg	NO_3-N mg	P_2O_5 mg	K_2O mg	Phosphate Absorption	CaO %	Al_2O_3 mg	MgO mg	Mn_2O_3 p p m	Nacl %
2	Forest	Loam	Dark Red	4-4 5			0 1			Less than 0 07	10			
3	Paddy Field	Loam	Dark Reddish Brown	5 5-6 0			1 0			More than 0 20	5			
N 10	Paddy Field	Silty Clay Loam	Grayish Brown	5 0	Less than 1	Less than 0 125	0 1	0		Less than 0 07	5	15	10	0 01
1	Paddy Field	Sandy Loam		5 0			0 1			Less than 0 07	10			
N 9	Paddy Field	Sandy Loam	Dull Brown	5 0	Less than 1	Less than 0 125	1 0	0	700	Less than 0 07	5	Less than 5	10	0 01
11	Paddy Field	Sandy Loam		4 5			1 0			More than 0 20	5			
12	Paddy Field	Sandy Loam		4 5			0 1			Less than 0 07	10			
N 5	Paddy Field	Sandy Loam	Orange	5 0	2 5	Less than 0 125	0 1	0	Less than 500	Less than 0 07	5	Less than 5	10	0 01
N 7	Paddy Field	Silty Loam	Dull Yellowish *Orange*	5 0	Less than 1	Less than 0 125	0 1	0		Less than *0 07*	5	25	More than 30	0 05
N 8	Paddy Field	Loam	Grayish Brown	5 0	Less than 1	Less than 0 125	0 1	15	Less than 500	Less than 0 07	5	35	10	0 01
N 3	Paddy Field	Silty Loam	Grayish Brown	5 5	2 5	0 5	0 1	0	700	Less than 0.07	5	25	10	0 01
10.	Paddy Field	Loam Sand	Dull Yellowish Orange											
N 4	Forest	Sandy Loam	Dull Orange	5 5	Less than 1	Less than 0 125	0 1	0	Less than 500	Less than 0 07	5	*15*	*10*	*0 01*
9	Paddy Field	Sandy Loam	Dull Yellowish Orange	4 5-5 0			0 1			Less than 0 07	15			
N 2	Paddy Field	Sandy Loam	Dull Orange	5 0	2 5	Less than 0 125	0 1	0	Less than 500	Less than 0 07	5	Less than 5	5	0 01
N 6	Paddy Field	Silty Clay Loam	Dull Orange	5 0	Less than 1	Less than 0 125	0 1	0		0 15	5	35	5	0 01
N 1	Paddy Field	Sandy Loam	Dull Orange	5 5	2 5	Less than 0 125	0 1	3	More than 2000	Less than 0 07	5	Less than 5	10	0 05

PRACHANTA KHAM (LEFT BANK AREA)

Serial Number of Samples	Site of Samples	Top Soil		Chemical Characteristic										
		Texture	Colour	PH	NH_4-N mg	NO_3-N mg	P_2O_5 mg	K_2O mg	Phosphate Absorption	CaO %	Al_2O_3 mg	MgO mg	Mn_2O_3 p p m	Nacl %
N 38	Paddy Field	Sandy Loam	Dull Yellowish Orange											
N.37	Paddy Field	Sandy Loam	Light Yellowish Orange											
N 31	Paddy Field	Loamy Sand	Dull Orange											
N 35	Paddy Field	Sandy Loam	Dull Yellowish Orange											
N.30	Paddy Field	Loam	Dull Orange											
N.29	Paddy Field	Silty Loam	Dull Orange											
N 36	Paddy Field	Loam	Dull Yellowish Orange											
N 34	Paddy Field	Silty Clay Loam	Dull Yellowish Orange											
N 28	Paddy Field	Sandy Loam	Dull Orange											
N 33	Paddy Field	Sandy Loam	Dull Orange											
N 32	Paddy Field	Sandy Loam	Dull Orange											
N.27	Paddy Field	Sandy Loam	Dull Orange											
N 26	Paddy Field	Sandy Loam	Dull Orange											
N 25	Paddy Field	Sandy Loam	Dull Orange											

MAENAM HANUMAL (RIGHT BANK AREA)

Serial Number of Samples	Site of Samples	Top Soil		Chemical Characteristic										
		Texture	Colour	PH	NH_4-N mg	NO_3-N mg	P_2-O_5 mg	K_2O mg	Phosphate Absorption	CaO %	Al_2O_3 mg	MgO mg	Mn_2O_3 p.p m	Nacl %
N 11	Paddy *Field*	Silty Clay *Loam*	Dull *Yellowish* Orange	5 0	*2 5*	Lessthan 0 125	*0 1*		*850*	Lessthan 0.07	5	Lessthan 5	Morethan 30	*0 05*
14	Grass Land	Sandy Loam	Dull Yellowish Brown	5 0			0 1			Lessthan 0 07	10			
N 18	Paddy Field	Silty Clay Loam	Grayish Brown	5 5	Lessthan 1	Lessthan 0 125	0 1			Lessthan 0 07	5	15	10	0 01
13	Paddy Field	Loam	Yellowish Orange	5 5			0 1			0 15	15			
N. 17	*Upland*	Silty Clay Loam	Dull Orange	5 0	*Lessthan* 1	*Lessthan* 0 125	0 1		*Lessthan* 500	*Lessthan* 0.07	5	25	10	
N 14	Paddy Field	Silty Clay Loam	Grayish Brown	5 0	Lessthan 1	Lessthan 0 125	0 1			Lessthan 0 07	5	Lessthan 5	Morethan 30	0 01
14	Grass Land	Sandy Loam	Dull Yellowish Brown	5 0			0 1			Lessthan 0 07	10			
8	Paddy Field	Sandy Loam	Dull Orange	4 5			0 1			Lessthan 0.07	10			
15	Forest	*Sandy* Loam	Dull Yellowish Brown	4 5			0 1			Lessthan 0 07 -	10			
N 15	Forest	Silty Clay Loam	Dull Orange	5 0	2 5	0 5	0 1	0	Less han 500	Lessthan 0 07	5	35	Morethan 30	0 05
N 13	Paddy Field	Silty Loam	Dull Orange	5 5	Lessthan 1	Lessthan 0 125	0 1		Lessthan 500		5	Lessthan 5	Morethan 30	Morethan 0 15
16	Upland	Loam	Dull Orange	5 0			0 1			Lessthan 0 07	10			
7	Paddy Field	Loam	Dull Brown	4 5			0 1			Lessthan 0 07	15			
6	Forest	Sandy Loam	Dull Brown	4 5			0 1			0 15	5			
N 12	Paddy Field	Loam	Dull Orange	5 0	Lessthan 1	Lessthan 0 125	0. 1			Lessthan 0 07	5	Lessthan 5	Morethan 30	0.01
4	Paddy Field	Sandy Loam		5 5			0 1			Lessthan 0 07	5			
22	Paddy Field	Sandy Loam		5 0			0 1			Lessthan 0 07	5			
4	Paddy Field	Sandy Loam	Light Reddish Gray	5 5			0 1			0 10	5			
N 16	Upland	Silty Clay Loam	Brown	6 5	Lessthan 1	Lessthan 0 125	0 1	0	Lessthan 500	Morethan 0 20	5	25	Morethan 30	0 01
16	Upland	Loam	Grayish Orange	5 0			0 1			Lessthan 0 07	10			
N 23	Paddy Field	*Silty Clay* Loam	Dull Brown	5 5	Lessthan 1	0 5	0 1			0 10	5	35	Morethan 30	0 005
18	Paddy Field	Loam	Yellowish Orange	5 0			0 1			0 15	5			
21	Paddy Field	Loam	Dark Grayish Orange	5 0			1 0			0 15	10			
N 19	Paddy Field	Sandy Loam	Grayish Brown	5 0	2 5	Lessthan 0 125	0 1			Lessthan 0 07	5	15	10	0 01
17	Paddy Field	Loamy Sand	Dull Yellowish Orange											
N 22	Upland	Silty Clay Loam	Brown	7.0	Lessthan 1	Lessthan 0 125	0 1		Lessthan 500	0 10	5	25	10	0 01
N 21	Paddy Field	Sandy Loam	Dull Orange	5 5	2 5	Lessthan 0 125	0 1			Lessthan 0 07	5	15	10	0 01
19	Paddy Field	Loamy Sand	Dull Yellowish *Orange*	4 5			0 1			Lessthan 0 07	5			
N 20	Paddy Field	Loam	Dull Orange	5 0	Lessthan 1	Lessthan 0 125	0 1			Lessthan 0 07	5	Lessthan 5	5	0 01
20	Paddy Field	Sandy Loam	Dull Orange	5 0			0 1			Lessthan 0 07	5			
N. 24	Paddy Field	Sandy Loam	Dull Orange	5 5	Lessthan 1	Lessthan 0. 125	0 1			Lessthan 0 07	5	Lessthan 5	10	0 01

APPENDIX TABLE 6-5 PHYSICAL AND CHEMICAL CHARACTERISTIC OF SOIL SAMPLES

APPENDIX TABLE 6-6 HOLDING, AREAS AND PRODUCTION OF MAIN CROPS IN CHANGWAD PRACHINBURI

Crops	Total Holdings	Holdings reporting	Planted Area in Rai (ha)	Harvested Area in Rai (ha)	Number of trees	Number of beaing trees	Average yield per Rai (ha)		Ave. per holding Reporting	Ave. No. of Trees per holding reporting
							Planted Area	Harvested Area		
Rice	38,693	34,887	1,046,730 (167,477)	935,744 (147,719)			173.8 (1.09)	194.4 (1.22)		
Maize	38,693	197	2,797 (448)	2,228 (356)			186 (1.16)	234 (1.46)		
Fresh Chilli	40,237	339	376 (60)						1.1 (0.18)	
Water Melon	40,237	425	757 (121)						1.8 (0.29)	
Stem Vegetable	40,237	573	812 (130)						1.4 (0.22)	
Tuber & Root crop	40,237	1,744	5,332 (853)						3.1 (0.50)	
Fruits Bearing Vegetable	40,237	1,838	3,525 (564)						1.9 (0.30)	
Coconut	40,237	22,602			150,428	34,352				7
Durian	40,237	1,169			25,559	2,719				22
Mango	40,237	21,817			170,562	106,625				8
Sugarpaln	40,237	4,041			32,145	9,414				8
Rambutan	40,237	1,797			25,187	10,110				14
Orange	40,237	7,973			34,859	15,983				4
Lime	40,237	8,506			24,167					3
Tamarind	40,237	14,333			39,248					3
Jack fruit	40,237	14,643			65,168					4
Betel-nut	40,237	6,222			48,227					8
Kapok	40,237	14,776			130,840					9
Dried Chilli	40,237	726		527 (84)				22 (0.14)		
Sesame	40,237	495		1,139 (182)				49 (0.31)		
Groundnut*1	40,237	1,503		5,304 (849)				137 (0.86)		
Pine apple*2	40,237	2,083		1,149 (184)				249 (1.56)		
Banana	40,237	3,565		3,959 (633)				420 (2.63)		

*1 Yield per Rai in number instead of Kg.

*2 Yield per Rai in Bunch instead of Kg.

Source : Census of Agriculture 1963 (Changwad Prachinburi)

APPENDIX TABLE 6-7 USE OF POWER ON HOLDING BY TENURE OF HOLDING

	No of holding	Percent of total
Human power only	5,103	13.2
Animal power	31,044	80.2
Mechanical power	381	1.0
Animal & mechanical power	2,165	5.6
Total Holding	38,693	100.0

Source: Census of Agriculture 1963

APPENDIX TABLE 6-8 USE OF SELECTED AGRICULTURAL EQUIPMENT ON HOLDING BY TENURE OF HOLDING.

	Holdings Reporting	Percent of Total
Electric or gasoline Motors	338	0.9
Tractors	1,957	5.1
Sprayers	502	1.3
Threshers	33	0.1
Wind milts and water wheels	6	–
Total Holding	38,693	7.4

Source: Census of Agriculture 1963

APPENDIX TABLE 6-9 USE OF FERTILIZERS AND SOIL DRESSINGS ON HOLDINGS BY TENURE OF HOLDING.

	Holdings Reporting	Percent of Total
Chemical fertilizers	620	1.6
Other fertilizers	11,694	30.2
Chemical and others	1,360	3.5
Soil dreesings	107	0.3
Total Holdings	38,693	35.6

Source : Census of Agriculture 1963.

APPENDIX TABLE 6-10 GROSS INCOME BY MAIN FRUITS

Name	Number of Tree (Hectare)	Average Yield per Tree	Unit Price ($)	Income Per ha ($)
Durian	45	50	1.00	2,250
Orange	300	50*	1.00	1,500
Coconut	144			
Banana				305

* Average Yield per kg.

APPENDIX TABLE 6-11 PRODUCTION COST OF PADDY RICE PER HECTARE (Before Completion of Project)

Item	Production Cost ($)		Remarks
Seed or Seedling	3.8		Paddy Rice : 1st-crop only
Firtilizer and Manure	-		Yield : 1.2 ton/ha
Extermination of Noxious Insects and Diseases	-		
Agricultural Implement	3.5		
Building (Depreciation and Maintenance)	2.4		
Draft Animals	7.3		
Labor	14.6		
Duties and Taxes	0.3		
Subtotal	31.9		
Capital Interest	0.96		
Total	32.86 34.50	*1 *2	
Gross Income	72.2		1.2^t x $58.5^\$$ = $70.2^\$$
·Net Earning	37.34 35.70	*1 *2	
Net Earning Ratio	53.0% 51.0%	*1 *2	

NOTE : *1 The figures without parenthis corresponds to harvesting area.

*2 The figures in the parenthis corresponds to planted area.

APPENDIX TABLE 6-12 PRODUCTION COST OF FRUITS PER HECTARE (Before Completion of Project)

Item	Production Cost ($)	Remarks
Seed or Seedling	120	
Firtilizer and Manure	110	
Extermination of Noxious Insects and Diseases	70	
Agricultural Implement	15	
Building (Depreciation and Maintenance)	5	
Draft Animals	-	
Labor	145	
Duties and Taxes	3	
Water Charge	132	Fuel ; 22, pipe line and others; 55, Amortization for pumping up facilities; 55.
Miscellaneous Materials	15	
Subtotal	615	
Capital Interest	18	
Total	633	
Gross Income	1,000	
Net Earning	367	
Net Earning Ratio	37%	

APPENDIX TABLE 6-13 PRODUCTION COST OF PADDY RICE PER HECTARE (After Completion of Project)

Item	Production Cost ($)	Remarks
Seed or Seedling	3.8	Paddy Rice: 1st-crop only
Firtilizer and Manure	5.9	Yield: 2.0 ton/ha
Extermination of Noxious Insects and Diseases	0.6	
Agricultural Implement	4.2	
Building (Depreciation and Maintenance)	3.4	
Draft Animals	8.8	
Labour	18.0	
Duties and Taxes	0.5	
Subtotal	45.2	
Capital Interest	1.35	
Total	46.55	
Gross Income	117.0	$2.0^{t} \times 58.5^{\$} = 117^{\$}$
Net Earning	70.45	
Net Earning Ratio	60%	

APPENDIX TABLE 6-14 PRODUCTION COST OF FRUITS PER HECTARE (After Completion of Project)

Item	Production Cost ($)	Remarks
Seed or Seedling	120	
Firtilizer and Manure	110	
Extermination of Noxious Insects and Diseases	70	
Agricultural Implement	15	
Building (Depreciation and Maintenance)	5	
Draft Animals	–	
Labour	145	
Duties and Taxes	3	
Water Charge	55	
Miscellaneous Materials	15	
Subtotal	538	
Capital Interest	16	
Total	554	
Gross Income	1,000	
Net Earning	446	
Net Earning Ratio	45%	

APPENDIX TABLE 6-15 CULTIVATION PERIOD OF PADDY RICE IN SAM CHOOK EXPERIMENTAL FARM (Central Plain)

Item	Paddy Rice 1st - Crop	Paddy Rice 2nd-Crop
Variety	Bang-Phra	Leong Kamin
Transplanting	25 Jun. 1964	20 Feb. 1965
Transplanting - Tillering	25 Jun. - 10 July	20 Feb. - 7 Mar.
Tillering - Pregnancy	10 July - 24 Oct.	8 Mar. - 21 Apr.
Pregnancy - Heading	25 Oct. - 7 Nov.	22 Apr. - 2 May
Heading	7 Nov.	2 May
Heading - Dough Ripening	8 Nov. - 23 Nov.	5 May - 22 May
Drainage	23 Nov.	22 May
Harvesting	11 Dec.	8 June
Irrigation Period	151 days	90 days
Cultivation Period	168 days	107 days

Source : The Seminar on Agricultural Experimentation and Demonstration on Irrigated Land in the Lower Mekong Basin (23-26, Jan. 1966)

APPENDIX TABLE 6-16 GRASS INCOME AND NET EARNING OF PADDY RICE PER HECTER

Year	Production ton	Gross income $	Net Earning $	Year	Production ton	Gross income $	Net Earning $
1	1.40	81.9	49.1	27	2.37	138.6	83.2
2	1.47	86.0	51.6	28	2.39	139.8	83.9
3	1.54	90.1	54.1	29	2.42	141.6	85.0
4	1.62	94.8	56.9	30	2.44	142.7	85.6
5	1.70	99.5	59.7	31	2.46	143.9	86.3
6	1.76	103.0	61.2	32	2.49	145.7	87.4
7	1.81	105.9	63.5	33	2.51	146.8	88.1
8	1.87	109.4	65.6	34	2.54	148.6	89.2
9	1.94	113.5	68.1	35	2.56	149.8	89.9
10	2.00	117.0	70.2	36	2.59	151.5	90.9
11	2.02	118.2	70.9	37	2.62	153.3	92.0
12	2.04	119.3	71.6	38	2.64	154.4	92.6
13	2.06	120.5	72.3	39	2.67	156.2	93.7
14	2.08	121.7	73.0	40	2.70	158.0	94.8
15	2.10	122.9	73.7	41	2.72	159.1	95.5
16	2.12	124.0	74.4	42	2.75	160.9	96.5
17	2.14	125.2	75.1	43	2.78	162.6	97.6
18	2.17	126.9	76.1	44	2.81	164.4	98.6
19	2.19	128.1	76.9	45	2.83	165.6	99.4
20	2.21	129.3	77.6	46	2.86	167.3	100.4
21	2.23	130.5	78.3	47	2.89	169.1	101.5
22	2.25	131.6	79.0	48	2.92	170.8	102.5
23	2.28	133.4	80.0	49	2.95	172.6	103.6
24	2.30	134.5	80.7	50	2.98	174.3	104.6
25	2.32	135.7	81.4	Average	2.32	135.6	81.33
26	2.35	137.5	82.5				

NOTE : 1) Price of paddy adopted is $58.5/ton.
2) Net Earning Rate is assumed of 60% of the gross income.

APPENDIX TABLE 6-17 COMSUMPTIVE USE BY BLANEY-CRIDDLE METHOD

	Jan.	Feb	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct	Nov.	Dec.	Total	Average
Monthly Mean T(°C) *1	27.1	28.7	30.1	30.7	29.6	28 8	28 4	28 3	28.0	28.2	27 8	26 8	342.5	28 5
Temperature T(°F)	80.8	83.7	86.2	87.3	85.3	83 8	83.1	82.9	82 4	82 8	82.0	80.2	1,005.5	83.4
Daytime Hours *2	7.97	7.38	8 45	8.41	8.96	8 79	9 03	8 77	8 28	8.28	7.77	7.91	100.00	
Comsumptive Use Factor f= t x p	6 44	6.18	7.28	7.34	7.64	7.37	7.50	7.27	6.82	6.86	6.37	6.34		
Comsumptive Use of Paddy Rice 1st-crop K = 1.0	163.6	157.0	184.9	186.4	194.1	187.2	190 5	184 7	173.2	174.2	161.8	161.0		
Comsumptive Use of Paddy Rice 2nd-crop K = 1.20	196.3	188 4	221.9	223 7	232 9	224.6	228 6	221.6	207.8	209 0	194.2	193.2		
Comsumptive Use of Upland Crops K = 0.65	106.3	102.1	120.2	121.2	126 2	121.7	123.8	120 1	112.6	113.2	105.2	104.7	1,377.3	3 8mm/day

NOTE: *1 Monthly Mean Temperature of Prachinburi (1951–1966)

*2 Percent Day-time Hour; Latitude 14° North, K = Seasonal Consumptive-use Coefficient.

APPENDIX TABLE 6-18 WATER REQUIREMENT FOR PADDY RICE (1ST-CROP)

(per 1,000 ha)

Month		Apr.	May	Jun.	Jul	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total	Average
Water Requirement	10^3cu.m			128.0	1,6995	3,417.0	2,632 0	2,672.0	2,518 0	1,270 0				14,336 5	
Rainfall (1965–1966)	mm	30.7	0	170 1	96 8	139.8	305.0	105 9	39 9	0.9	3 0	79.8	22.7	994 6	
Available Rainfall Rate	%			75	75	75	75	65	80	90					
Available Rainfall	10^3cu.m			12.7	301.5	1,146.9	2,288.0	688.0	319 0	0				4,756.1	
Net Water Requirement	10^3cu.m			115.3	1,398 0	2,270.1	344.0	1,984.0	2,199.0	1,270 0				9,580 4	
	c m s.			0.044	0 522	0.848	0.133	0 741	0 848	0 474				3,610	0.524
Diversion Water Requirement	c m s.			0 059	0.696	1,131	0.177	0.988	1.131	0.632				4,814	0.698

APPENDIX TABLE 6-19 WATER REQUIREMENT FOR PADDY RICE (2ND-CROP)

(Per 1,000 ha)

Month	Unit	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total	Average
Water requirement	10^3cu.m	3,137.0	2,852.0	393.5							128.0	1,666,3	3,761.6	11,938.4	
Rainfall (1965-1966)	m.m	30.7	0	170.1	96.8	139.8	305.0	105.9	39.9	0.9	3.0	79.8	22.7	994.6	
Available Rainfall Rate	%	75	75	75							90	90	90		
Available Rainfall	10^3cu.m	230.0	0	159.5							0	324.8	223.6	937.9	
Net Water Requrement	10^3 cu.m	2,907.0	2,852.0	234.0							128.0	1,341.5	3,538.0	11,000.5	
Net Water Requirement	c.m.s	1.122	1.065	0.090							0.048	0.555	1.321	4.201	0.704
Diversion Water Requirement	c.m.s	1.496	1.420	0.120							0.064	0.740	1.761	5.601	0.938

APPENDIX TABLE 6-20 WATER REQUIREMENT FOR UPLAND CROPS

(per 1,000 ha)

Month	Unit	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total	Average
Water Requirement	m.m	121.2	126.2	121.7	123.8	120.1	112.6	113.2	105.2	104.7	106.3	102.1	120.2	1,377.3	3.8mm/day
Rainfall	m.m	30.7	0	170.1	96.8	139.8	305.0	105.9	39.9	0.9	3.0	79.8	22.7	994.6	
Available Rainfall	m.m	15.4	0	85.1	48.4	69.9	152.5	53.0	20.0	0	0	39.9	11.4	495.6	1.3mm/day
Net water Requirement	m.m	105.8	126.2	36.6	75.4	50.2	0	60.2	85.2	104.7	106.3	62.2	108.8	921.6	2.5mm/day
Net water Requirement	10^3cu.m	1,058.0	1,262.0	366.0	754.0	502.0	0	602.0	852.0	1,047.0	1,063.0	622.0	1,088.0	9,216.0	
Net water Requirement	c.m.s	0.408	0.471	0.141	0.282	0.187	0	0.225	0.329	0.391	0.397	0.257	0.406	3.494	0.292
Diversion water requirement	c.m.s	0.777	0.897	0.269	0.537	0.356	0	0.429	0.627	0.745	0.756	0.490	0.773	6.656	0.557

APPENDIX TABLE 6-21 COST ALLOCATION OF NO.1 AND NO.2 RESERVOIRS

Item	Unit	No.1 P.S.	No.2 P.S. No.3 P.S.	No.4 P.S.	Total
(1) Annual cost to be allocated (No.1,2 Reservoirs)	$				634,500
	10^3 ฿				13,100
(2) Annual benefit (B)	$	203,400	2,237,300	716,700	3,157,400
	10^3 ฿	4,200	46,200	14,800	65,200
(3) Cost with purpose excluded	$	203,400	1,157,400	619,900	1,980,700
	10^3 ฿	4,200	23,900	12,800	40,900
(4) Remaining benefit	$	0	1,079,900	96,800	1,176,700
	10^3 ฿	0	22,300	2,000	24,300
(5) Percent distribution	%	0	92	8	100
(6) Remaining joint cost	$	0	583,700	50,800	634,500
	10^3 ฿	0	12,100	1,000	13,100
(7) Total annual cost (C)	$	203,400	1,741,100	670,700	2,615,200
	10^3 ฿	4,200	36,000	13,800	54,000
(8) Excess benefit (B-C)	$	0	496,200	46,000	542,200
	10^3 ฿	0	10,200	1,000	11,200
(9) Benefit cost ratio (B/C)		1.00	1.28	1.07	1.21

NOTE: Annual cost to be allocated No.1 Reservoir 285,700 $ (5,900x10^3 ฿)

No.2 Reservoir 348,800 $ (7,200x10^3 ฿

Total 634,500 $ (13,100x10^3 ฿)

APPENDIX TABLE 6-22 COST ALLOCATION OF NO.2 RESERVOIR (Without No.1 Reservoir)

Item	Unit	No.2 P.S No.3 P.S	No.4 P.S.	Total
(1) Annual cost to be allocated (No.2 Reservoir)	$			348,800
	10^3 ฿			7,200
(2) Annual benefit (B)	$	2,237,300	716,700	2,954,000
	10^3 ฿	46,200	14,800	61,000
(3) Cost with purpose excluded	$	1,157,400	619,900	1,777,300
	10^3 ฿	23,900	12,800	36,700
(4) Remaining benefit	$	1,079,900	96,800	1,176,700
	10^3 ฿	22,300	2,000	24,300
(5) Percent distribution	%	92	8	100
(6) Remaining joint cost	$	320,900	27,900	348,800
	103 ฿	6,600	600	7,200
(7) Total annual cost (C)	$	1,478,300	647,800	2,126,100
	10^3 ฿	30,500	13,400	43,900
(8) Excess benefit (B-C)	$	759,000	68,900	827,900
	10^3 ฿	15,700	1,400	17,100
(9) Benefit cost ratio (B/C)		1.51	1.11	1.39