NATIONAL ENERGY AUTHORITY

KINGDOM OF THAILAND

FEASIBILITY REPORT

NAM SAI YAI

No. 2 AND No. 3 HYDROELECTRIC PROJECTS

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 "Feasibility Report of Nam Sai Yai No. 2 and No. 3 Hydroelectric Projects".

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

Shinichi Shibusawa
Director General
Overseas Technical Cooperation Agency

LETTER OF TRANSMITTAL

August 1968

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

Dear Sir:

Presented herewith is a Feasibility Report on the Nam Sai Yai Hydroelectric Project in the Kingdom of Thailand. The study, at your request, was undertaken by the Electric Power Development Company as a Survey Team organized by the Overseas Technical Cooperation Agency. The Agency dispatched the Survey Team, consisting of seven engineers for the purpose of conducting a feasibility study of the Nam Sai Yai Project. The Survey Team conducted investigations on topography, geology, materials, hydrology, etc. and surveys of the service area based on "Report on Basic Studies for Development of Hydraulic Potentials of the Nam Sai Yai", at the same time gathering other data necessary for preparation of the plan.

Upon its return to Japan, the Electric Power Development Company, based on the results of field investigations and on information gathered in Thailand, carried out analyses of hydrologic data, load forecasts, preliminary design, construction cost estimation, economic evaluation, etc. and prepared this report. The work was performed by the engineering staff of the Electric Power Development Company under the direction of its Chief Engineer.

The Nam Sai Yai Hydroelectric Power Development Project consists of constructing a dam on the midstream section of the Sai Yai River, and utilizing a rated head of 403 m, obtaining a total output of 70 MW by the Nam Sai Yai No.2 and No.3 Power Stations, a highly economical hydroelectric power development project using an extremely favorable head. The catchment area at the dam site is 295 sq.km, annual runoff approximately 250 million cu.m, with the runoff regulated by a reservoir having an effective storage capacity of 110 million cu. m for effective utilization of power generation. The annual energy production will amount to as much as 230 million kWh for the No.2 and No.3 Power Stations combined. This power will be transmitted to Korat Substation by a transmission line to be newly constructed to supply power not only to the Northeast Region of Thailand but also to the Central Region by means of an interconnecting transmission line.

Besides the above, this project is expected to improve the flow of water in the lower part of the Nam Sai Yai so that water for irrigation can be supplied to 7,000 hectares of farmland downstream including 200 hectares which can be protected from floods. A construction period of approximately 3 years with construction costs of 490 million Baht will be necessary for carrying out the Project. However, the cost-benefit ratio of this project is 1.17 and a surplus benefit of approximately 6.5 million Baht can be anticipated so that the project is believed to be justifiable both technically and economically.

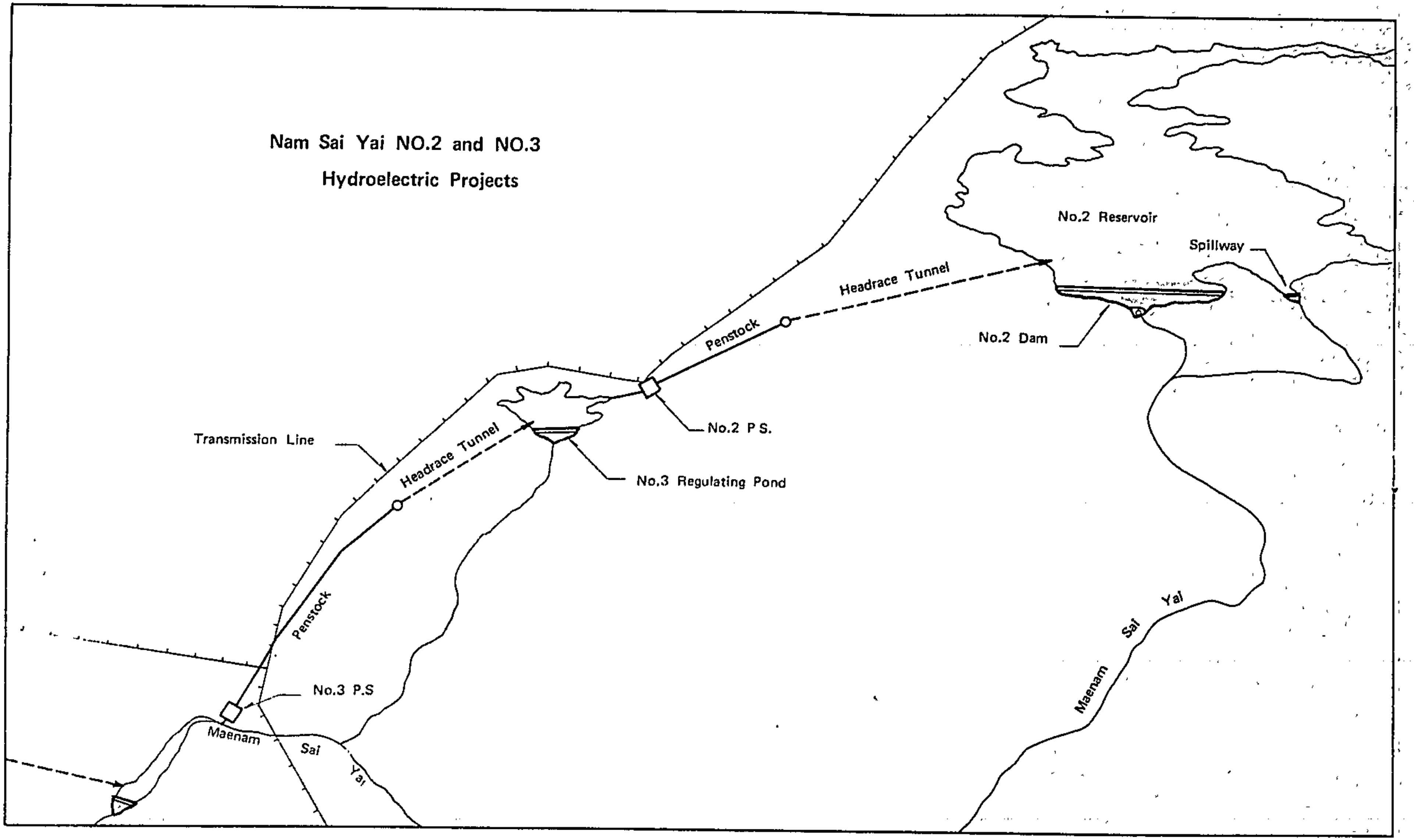
In Thailand, power demand has grown remarkably in recent years and when this situation is taken into consideration, it is believed the project will be realized by the end of 1973. Therefore, it will be necessary to start work on detailed design, construction of access roads, etc. as early as practicable.

In conclusion, we wish to express our sincerest appreciation to Dr. Boonrod Binson, the many officers of the National Energy Authority, the Mekong Committee, and the Japanese Embassy who were so helpful and cooperative to the Survey Team during its stay in Thailand.

Respectfully yours,

T. Tokuno.

Takeshi Tokuno, Chief of
Nam Sai Yai Survey Team


Nam Sai Yai NO.2 and NO.3
Hydroelectric Projects
No.2 Reservoir
Spillway
Headrace Tunnel
Penstock
No.2 Dam
No.2 P S.
Transmission Line
Headrace Tunnel
No.3 Regulating Pond
Penstock
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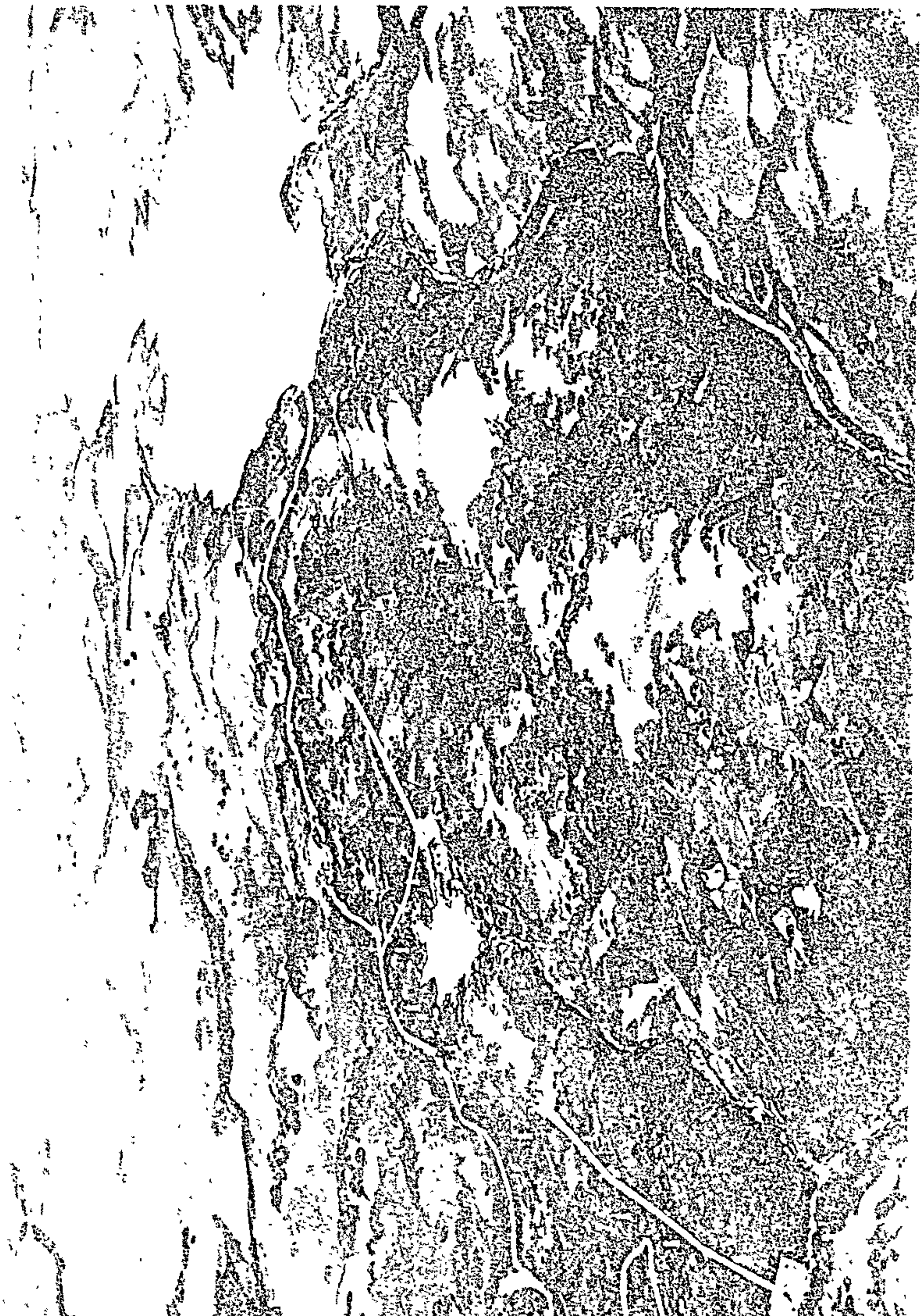
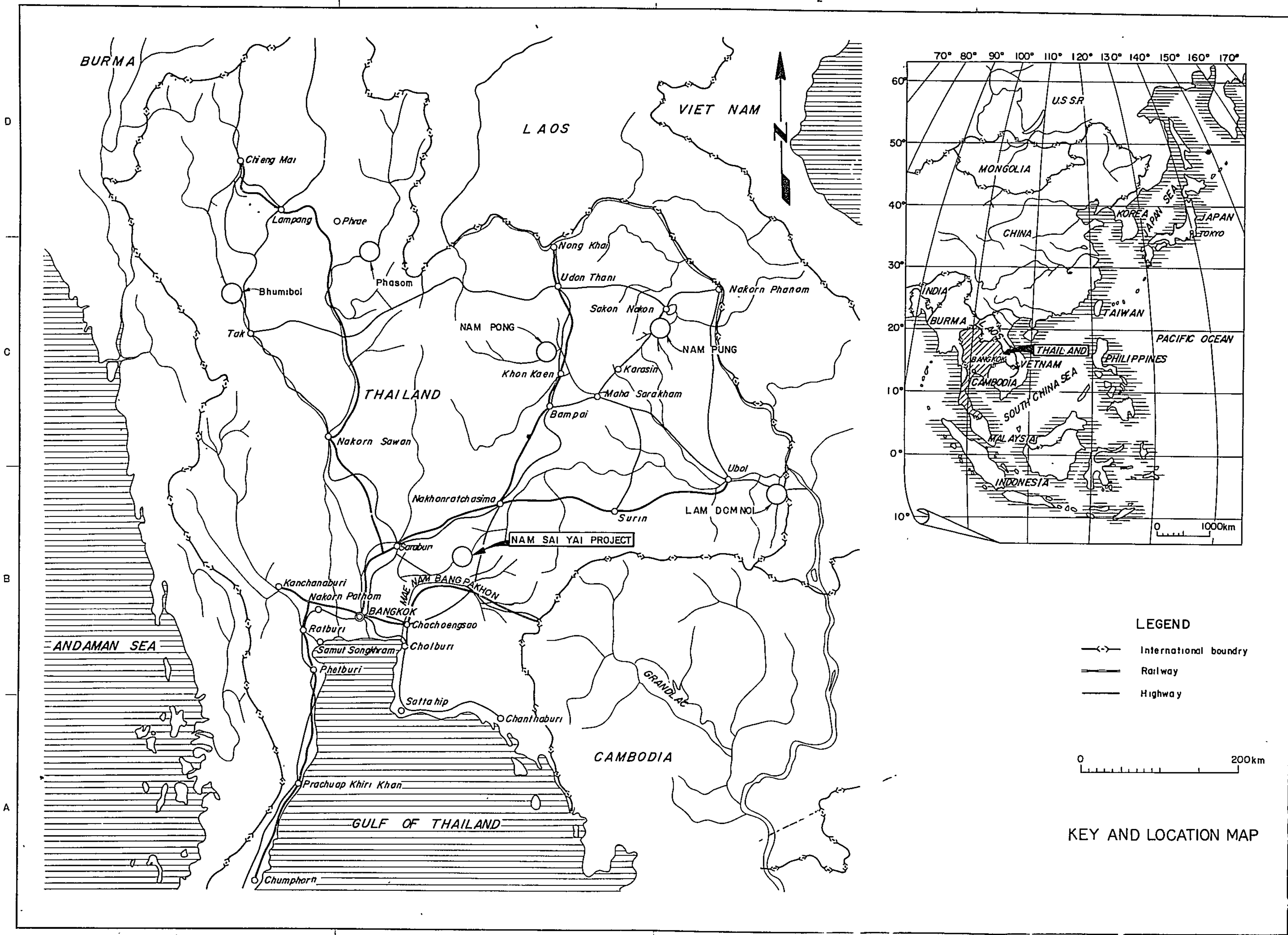




KEY AND LOCATION MAP

(A-3)

General Description of Project

1. Nam Sai Yai No.2 Power Station

1.1 Location	In the district of Amphur Kabinburi, Changwad Prachinburi
1.2 Catchment Area	295 sq.km
1.3 Annual Inflow	8.0 c.m.s. (252 million cu.m)
1.4 Flood	780 c.m.s. (maximum probable)
1.5 Reservoir	
Maximum Water Surface Level	592.75 m
Normal Water Surface Level	591.0 m
Water Surface Area	9.5 sq.km
Total Storage Capacity	140 million cu.m
Effective Storage Capacity	110 million cu.m
Available Drawdown	15 m
1.6 Dam	
Type	Rock and Earth-Fill
Elevation of Crest	595.00 m
Height	40.00 m
Length	1,346 m
Volume	1,400,000 cu.m (main dam) 300,000 cu.m (dike)
Slope of Upstream	1:1.9, 1:2.2 (rockfilled part) 1:3 (earthfilled part)
Slope of Downstream	1:1.6, 1:1.9 (rockfilled part) 1:2 (earthfilled part)
1.7 Spillway	
Type	Overflow
Capacity	400 c.m.s. at flood water level EL. 592.75 m
1.8 Intake	
Type	Tower Type
Control Gate	Roller Gate
1.9 Headrace Tunnel	
Type	Horse-Shoe Shape Pressure Tunnel
Length	1,668.0 m
Inside Diameter	3.10 m
1.10 Surge Tank	
Type	Differential
1.11 Penstock	
Type	On the Ground, Ring Girder Supported Type
Length	705.0 m
Inside Diameter	2.80 m
1.12 Power House	
Type	Indoor
1.13 Power Generation Facilities	
Unit Capacity	12,000 kW
Number of Unit	1
Turbine	
Type	Vertical Shaft Francis Type
Rated Head	70 m

Quantity of Discharge	20 c.m.s.
Rated Output	12,400 kW
Revolving Speed	333 rpm
Generator	
Type	Three-phase Synchronous Generator Vertical Shaft, Rotating Field, Closed Type
Capacity	13,000 kVA
Voltage	11 kV
Frequency	50 c/s
Power Factor	0.9 (lagging)
Transformer	
Type	Three-phase Outdoor Oil-immersed Self-cooled Type
Capacity	13,000 kVA
Voltage	11/115-110-120 kV

2. Nam Sai Yai No.3 Power Station

2.1 Location	On the Nam Sai Yai
2.2 Catchment Area	298 sq.km
2.3 Annual Inflow	8.1 c.m.s. (256 million cu.m)
2.4 Regulating Pond	
Normal Water Surface Level	510 m
Water Surface Area	0.6 sq.km
Total Storage Capacity	6.2 million cu.m.
Effective Storage Capacity	1.6 million cu.m.
2.5 Dam	
Type	Earth-filled
Elevation of Crest	513.00 m
Height	28.00 m
Length	540.00 m
Volume	400,000 cu.m.
Slope of Upstream	1:3
Slope of Downstream	1:2
2.6 Spillway	
Type	Overflow
Capacity	20 c.m.s.
2.7 Intake	
Type	Inclined Type
Control Gate	Roller Gate
2.8 Headrace Tunnel	
Type	Horse-shoe Shape Pressure Tunnel
Length	535 m
Inside Diameter	3.10 m
2.9 Surge Tank	
Type	Differential
2.10 Penstock	
Type	On the Ground, Ring Girder Supported Type
Length	1,390 m
Inside Diameter	2.60 m
2.11 Power house	
Type	Indoor

2.12 Power Generation Facilities	
Unit Capacity	29,000 kW
Number of Unit	2
Turbine	
Type	Vertical Shaft Francis Type
Rated Head	333.3 m
Quantity of Discharge	10 c.m.s.
Rated Output	29,700 kW
Revolving Speed	600 rpm
Generator	
Type	Three-phase Synchronous Generator Vertical Shaft, Rotating Field, Closed Type
Output Capacity	33,000 kVA
Voltage	11 kV
Frequency	50 c/s
Power Factor	0.9 (lagging)
Transformer	
Type	Three-phase Outdoor, Forced Oil, Forced Air-cooled Type
Capacity	33,000 kVA
Voltage	11/115-110-120 kV

3. Transmission Line

3.1 Location, Distance and Number of Circuits	Sai Yai No.2 – No.3,4 km 1 circuit Sai Yai No.3 – Korat Substation 105 km 2 circuits
3.2 Voltage	115 kV
3.3 Frequency	50 c/s
3.4 Conductor	240 sq. mm ACSR
3.5 Overhead Ground Wire	55 sq. mm GSC
3.6 Insulator	250 mm Suspension Insulator Ball and Socket Type
3.7 Support	Galvanized Steel Tower

4. Telecommunication Equipment

4.1 Power Line Carrier Telephone	One channel for load dispatching service and one channel for general service between Korat Substation and Sai Yai No.2 and No.3 power station
4.2 VHF Radio Telephone	Press-to-talk system, for line maintenance service Base Station: Korat Substation Relay Station: at an intermediate point between korat Substation and Nam Sai Yai No.2, No.3 Power Station Mobile Station
4.3 Fault Locator	For line maintenance service

5. Construction Cost

Nam Sai Yai No.2 Power Station	232 million Baht
Nam Sai Yai No.3 Power Station	189 "
Transmission Line and Telecommunication	69 "
Total	490 "

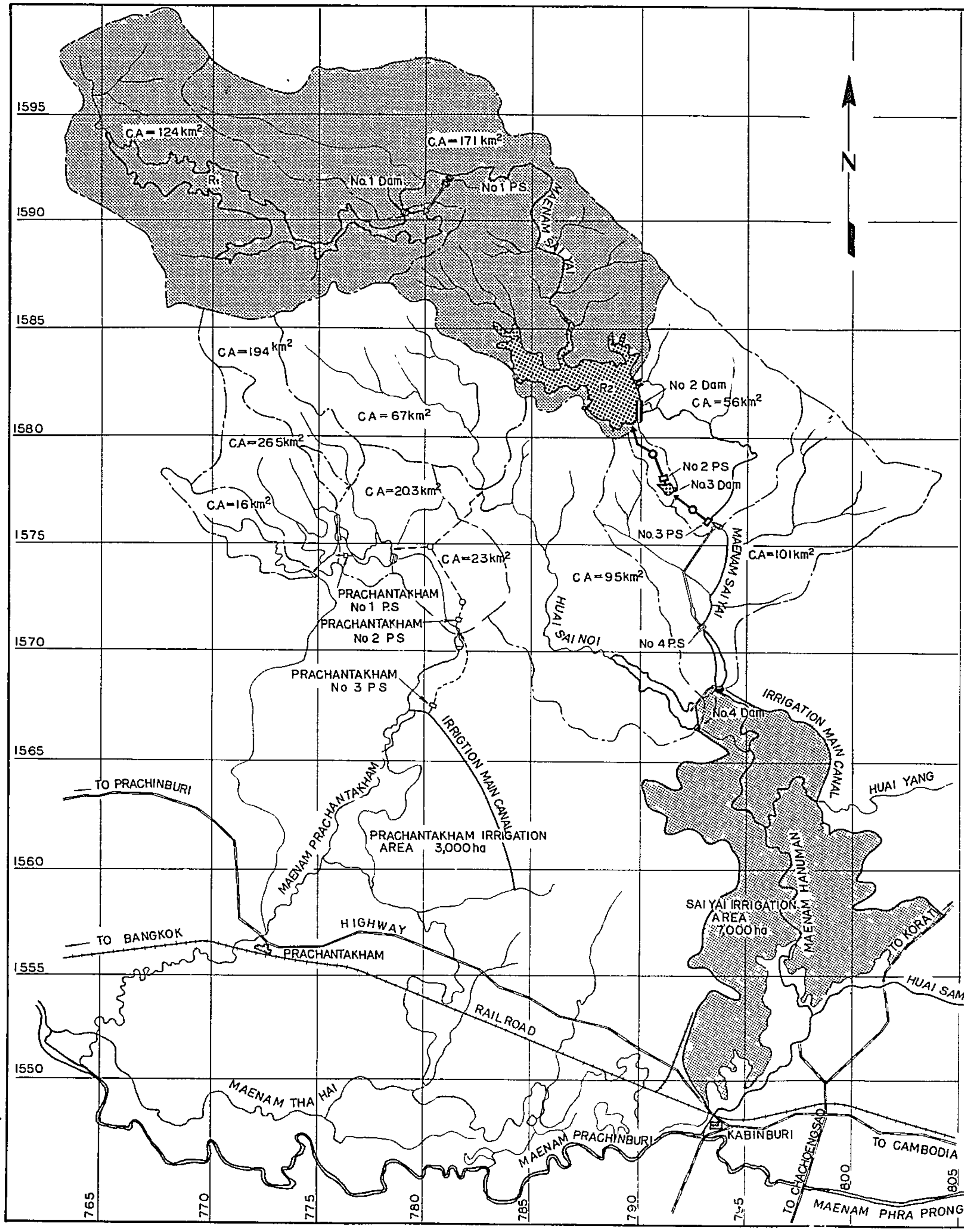
Foreign Currency	292 million Baht
Domestic Currency	198 "

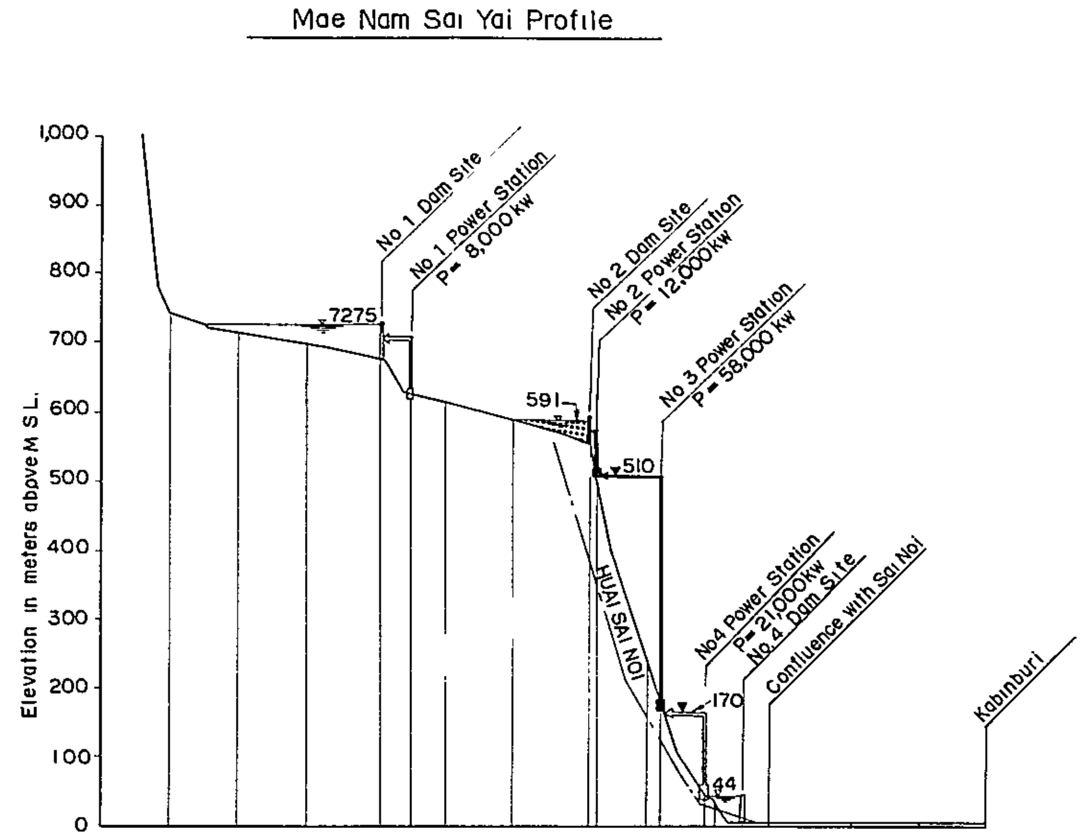
6. Available Energy per annum	
Nam Sai Yai No. 2 Power Station	40 million kWh
Nam Sai Yai No. 3 Power Station	190 "
Total	230 "

7. Benefit-Cost Ratio	
7.1 Power Generation Only	
Annual Cost	37.6 million Baht
Cost of Energy Delivered at Korat	0.167 Baht/per kWh
Annual Benefit from Power	44.1 million Baht
Surplus Benefit from Power	6.5 "
Benefit-Cost Ratio	1.17 "
7.2 Power Generation with Irrigation	
Annual Benefit from Irrigation	15.3 million Baht
Surplus Benefit	13.5 "
Benefit-Cost Ratio	1.29
7.3 Cost of Energy Delivered at Korat After Construction Cost of Dam is Allocated to Irrigation	0.154 Baht per kWh

8. Proposed Date of Operation	
Nam Sai Yai No.2 Power Station	October 1973
Nam Sai Yai No.3 Power Station	July 1974

9. Construction Period	
Nam Sai Yai No.2 Power Station	30 months
Nam Sai Yai No.3 Power Station	30 months





Station	Dist (km)	T Dist (km)	GH (m)
	10	120	740
	10	110	715
	10.5	100	700
No1Dam	4.0	89.5	670
No1P.S	5.5	85.5	630
	10.0	80	615
	11.5	70	590
No2 Dam	1.0	58.5	555
No2 P.S	7.5	57.5	510
	2.0	50	167
No3PS	8.0	48	170
No4PS	1.5	41.5	40
	6.0	40	35
No4Dam	4	36	12
	12	32	8
	10	20	5
	10	10	0
Kabinburi	0	0	-1.0

0 5 10km

GENERAL PLAN AND PROFILE

Unit and Conversion

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
rpm	:	Revolutions per minute
EL	:	The height above mean sea level
°C	:	Centigrade
p.p.m.	:	Parts per million
%	:	Percentage
$	:	U. S. dollar
฿	:	Baht
1 ha	:	10,000 sq.m, 6.25 rai
1 rai	:	1,600 sq.m, 0.16 ha
1 MW	:	1,000 KW
1 $	:	100 cents, 1,000 mills, 20.8 Baht, 360 Yen
1 ฿	:	100 Satang, 0.0481 dollar, 17.31 Yen

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CHAPTER 1

INTRODUCTION

CHAPTER 1. INTRODUCTION

1.1 AUTHORIZATION

The Government of Thailand has for some time been expediting an ambitious industrial development program to raise the national standard of living. In order to cope with the increase in demand for electric power which is the foundation of this program, the National Energy Authority (hereinafter called NEA) which is responsible for power supply has projected a hydroelectric power development plan at the upstream area of the Sai Yai River.

In May, 1967, Dr. Boonrod Binson, Secretary General of NEA, on behalf of the Government of Thailand requested the Japanese Government to carry out a feasibility study of the Upper Nam Sai Yai Hydroelectric Power Development Plan. The Japanese Government commissioned the Overseas Technical Cooperation Agency (hereinafter called OTCA) to execute the work, and the chief objective of the program being electric power development, OTCA in turn commissioned the Electric Power Development Company (hereinafter called EPDC) to make the actual study.

The scope of the feasibility study requested by the Government of Thailand covered the No.2 Dam and the No.2 and No.3 Power Stations of the hydroelectric development program, but at the same time it was requested that a preliminary study be made of the Nam Sai Yai Basin Development Plan based on the investigations performed after reconnessance study.

1.2 PRELIMINARY STUDY

Roughly half-way between Bangkok, the capital of Thailand and Korat, the central municipality of the Northeast Region which is the granary of Thailand, the Dangrek Mountain Range traverses the land in a southeasterly direction. The watershed area of this mountain range is a high-rainfall zone where annual precipitation is estimated to be approximately 2,000 mm. Therefore, the rivers and streams springing from this mountain range, with their great heads and favorable sites for reservoirs, have long been looked on as a promising power resource area. The Government of Thailand already possesses a development plan for the Lam Phra Phloeng River, a tributary of the Mune River which is a tributary of the Mekong River running down the northeastern slopes of the Dangrek Mountain Range. For this plan, the Comprehensive Report of Reconnaissance of the Major Tributaries of the Mekong River prepared by the Japanese Government proposed diversion of the upstream part of the Sai Yai River which is a tributary of the Bang Pakong River flowing down the southwestern slopes of the Dangrek Mountain Range.

Later, in February and March of 1965, the preliminary study by the Japanese Government based on the request from the Government of Thailand was carried out by a team of EPDC engineers headed by Takeshi Tokuno. The results of the study were submitted to the Government of Thailand in June 1965 under the title "Report on Basic Studies for Development of Hydraulic Potentials of the Nam Sai Yai, Kingdom of Thailand".

The above report proposes construction of two reservoirs each with an effective capacity of approximately 150 million cu.m on the upstream part of the Sai Yai River to bring the dry year runoff to about 90% of an average year. An intake at the right bank side of the downstream reservoir will be provided to divert the water to the upstream part of the Sai Noi River by a headrace tunnel in order to generate electric power. In short, this proposal was for construction of two reservoirs with normal high water levels at EL 730 m and EL 595 m on the upstream part of the Sai Yai River, and, taking advantage of the sharp drop in the topography down to EL 40 m, the following four power stations.

Power Station	Particulars			
	Max. Discharge	Rated Head	Installed Capacity	Available Energy per Annum
	c.m.s.	m	kW	million kWh
Sai Yai No.1	8.0	111.0	7,500	24
Sai Yai No.2	20.0	81.5	13,700	43
Sai Yai No.3	20.0	248.0	41,700	132
Sai Yai No.4	20.0	185.0	31,100	110
Total			94,000	309

In this study, in spite of the restriction caused by the extreme difficulty of carrying out field reconnaissance, it was possible to examine the scale of development and the economics with aerial photographs, topographical maps and basic information on hydrology, etc. It was recommended that the No.2 Dam and the No.2 and No.3 Power Stations be constructed as the first stage of the work.

1.3 OBJECTIVE AND SCOPE OF REPORT

1.3.1 OBJECTIVE

In order to cope with the immediate shortage in electric power supply, NEA has planned to realize the electric power development of the upstream area of Sai Yai River at an early date and is preparing to apply to the Government of Thailand for budgeting of definite study and preparatory works and for approval to proceed. The report concerns the studies on the technical and economic feasibility of the No.2 Dam and the No.2 and No.3 Power Stations which are part of the Upper Nam Sai Yai Electric Power Development Plan recommended as the first stage work in the preliminary survey performed in 1965. It has been prepared for NEA to apply to the Government of Thailand for authorization of the Project and to obtain construction funds for the work.

1.3.2 SCOPE

Although the Nam Sai Yai No.2 and No.3 Projects are exclusively for power generation, there will be benefits in agriculture and flood control. The scope of the surveys and studies summarized in this report is concerned with projection of the Nam Sai Yai No.2 and No.3 Projects which is most suited to meeting the power demand of the Project area in the most economical manner. As this will be the part of the Nam Sai Yai Basin Development Plan, this report will also touch briefly upon the plans for development of the entire basin.

1.4 SURVEYS AND STUDY

1.4.1 FIELD SURVEYS

The firld surveys were conducted during the 5 months from the middle of October 1967 to the middle of March 1968. These field surveys were carried out in regard to both the Nam Sai Yai No.2 and No.3 Development Plan and the Basin Development Plan.

In order to carry out these surveys, EPDC dispatched a survey team of 7 engineers listed below.

Chief	Takeshi Tokuno	Civil Engineer
Member	Narao Takemura	Irrigation and Drainage Enineer
"	Shozo Yuzawa	Civil Engineer
"	Hideo Sato	Civil Engineer
"	Tsutomu Kidahashi	Electrical Engineer
"	Azuma Tsunoda	Irrigation and Drainage Engineer
"	Seizo Yamada	Civil Engineer

1.4.2 STUDIES IN JAPAN

After return of the Survey Team to Japan, from February 18 to August 31, 1968, based on the information gathered in Thailand, studies of the project plan were carried out at the head office of EPDC by EPDC engineers under the direction of their Chief Engineer. Such work as analysis of hydrologic data, load forecast, detailed study of the project plan, preliminary design, estimation of construction costs and economic evaluation were carried out in order to prepare this report.

1.5 SOURCE OF DATA

The necessary basic information concerning meteorology, hydrology and power demand and supply was furnished by NEA. Surveys of sites for construction of main structures such as dams, intake tunnels, penstock lines and powerhouses, geological survey of the dam site, and core boring for materials investigations were performed by NEA and the information obtained was furnished to the Survey Team. The Survey Team further requested NEA to carry out some amount of supplementary land surveys and to dig test pits for material investigation. The various tests of the soil materials for the dam were conducted in Bangkok at Chulalongkon University at the request of the Survey Team.

The principal data obtained is as follows:

a. Aero-topographical map on 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.

b. Runoff record of gaging stations located on the Sai Yai River as well as in adjacent basins, being maintained by NEA and Royal Irrigation Department (herein after referred to as "RID").

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

d. Results of Water Quality and Soil Tests, prepared by NEA.

e. Feasibility Report, Quae Yai No.1 Hydroelectric Project, March 1968, prepared by Electric Power Development Co., Ltd.

f. Nam Phrom Hydroelectric Power Project Feasibility Report, August 1967, prepared by Japanese Government.

g. Statistical Year Book, Thailand, 1964

h. Census of Agriculture in Changwad Prachinburi, 1963.

CHAPTER 2

CONCLUSIONS AND RECOMENDATIONS

CHAPTER 2. CONCLUSIONS AND RECOMMENDATIONS

2.1 CONCLUSIONS

The following conclusions are arrived at as a result of surveys and studies on the Nam Sai Yai No.2 and No.3 Projects:

(1) The growth in demand for electric power in Thailand has been spectacular in recent years, percentages of increase of 34%, 34.6% and 30.3% in energy consumption having been recorded in the years 1965, 1966 and 1967 respectively. These high rates of increase are considered attributed to rapid industrialization, improvement in national living standards, surfacing of latent demand due to development of new power sources, expansion and consolidation of transmission and distribution lines and it is believed this marked growth trend will continue in the future.

Since the NEEA system and the YEA system will be interconnected by a tie line at the beginning of 1970, it is expected that the two systems will thereafter be operated on an integrated basis. Under such circumstances, it is estimated that the power and energy demand of such systems will grow to 756 MW and 3,851 million kWh respectively in 1970 and 1,580 MW and 8,295 million kWh in 1975 in a combined system.

(2) To cope with such a demand, both the NEEA System and the YEA System are going ahead with their programs to increase facilities, but in spite of this, requirement of supply capacity will occur in 1972 to 1974.

Therefore, in order to meet this requirement, it will be necessary for development of a new power source by the end of 1972.

(3) As the new power supply capacity mentioned above, the Nam Sai Yai No.2 and No.3 Projects were investigated and as a result it was concluded that in cost, potential and locality, these projects were exceedingly favorable compared to other hydroelectric power projects within the system. There are no difficult problems in design or construction involved in these projects.

(4) The Nam Sai Yai Hydroelectric Power Development Project consists of the construction of a dam on the midstream portion of the Sai Yai River, Nam Sai Yai No.2 and No.3 Power Stations, with a total output of 70 MW, utilizing a total head of 421 meters and a transmission line to Korat Substation.

(5) The No.2 Reservoir which is a principal part of the project is located at the Wang Heo site on the Sai Yai River, about 30km upstream of the confluence with the Sai Noi River. The normal high water surface level and the effective storage capacity are 591 meters and 110 million cu.m. respectively. The dam will be a fill-type with a total embankment of 1.4 million cu.m..

The main feature of the two power stations are as follows:

Power Station	Rated Head (m)	Maximum Discharge (cms)	Installed Capacity (kW)	Dependable Capacity (kW)	Available Energy per Annum (million kWh)
No.2	70	20	12,000	9,200	40
No.3	333	20	58,000	56,400	190
Total	403	–	70,000	65,600	230

Vertical-shaft Francis turbines should be adopted for the generators of both No.2 and No.3 Stations. One unit will be installed for the former and two units for the latter.

(6) The transmission line will be 115 kV with 1 circuit between No.2 and No.3 Power Stations and 2 circuits between No.3 Power Station and Korat Substation.

(7) The period of construction required for each of the two stations is expected to be 30 months. The construction schedule of the No.2 Power Station will be governed by the diversion tunnel and embankment of the middle portion of the dam which are to be constructed during the first and second dry periods respectively. The construction schedule of the No.3 Power Station should be staggered 9 months to avoid congestion of work.

(8) The construction costs required for the Nam Sai Yai No.2 and No.3 Projects will total 490 million Baht of which 421 million Baht will be for the power generation facilities and 69 million Baht for the transmission lines.

Of the total cost of 490 million Baht, the equivalent of 292 million Baht will be required to be paid in foreign currency and 198 million Baht in domestic currency.

The interest rate was taken to be 6% per annum for both foreign and domestic currency which would result in interest during construction of 40 million Baht.

(9) Taking into account the system load balance and transmission losses, the annual salable energy at Korat Substation would be 225 million kWh. In comparison, the annual cost of the Nam Sai Yai No.2 and No.3 Power Stations uniformly distributed over serviceable years is 37.6 million Baht. Therefore, the energy cost per kWh at Korat Substation would be 0.167 Baht.

(10) In order to make an economic evaluation of the Nam Sai Yai No.2 and No.3 Projects, the solely heavy oil-burning thermal power station built in the vicinity of Bangkok with an installed capacity of 400 MW (200 MW, 2 units) was assumed. Using this as a measure, the annual benefit of the Nam Sai Yai Project would be 44.1 million Baht. Against this figure, the annual cost will be 37.6 million Baht as mentioned above so that the surplas benefit will be 6.5 million Baht and the benefit-cost ratio 1.17. Besides internal rate of return was calculated to be 7.8%.

Further, when this Project is carried out, the run off during dry season at the confluence of the Sai Yai and the Sai Noi River will be increased from the present 1.0 c.m.s. to 6.7 c.m.s. Should this water be utilized for irrigation, 7,000 ha of farmland can be irrigated and when the benefit of 11.7 million Baht and the annual cost of the irrigation facilities of 7.8 million Baht respectively are added to the abovementioned power generation case and benefit respective the overall purplus benefit from this Project will be 12.9 million Baht and the benefit-cost ratio 1.23.

(11) Unit sales price of every at Korat Substation can be set at a rate of 0.22 Baht per kWh which is considerably below the rates of existing system. Still the project will produce sufficient revenues which enable the repayment of foreign currency in 20 years and of domestic currency in 50 years.

2.2 RECOMMENDATIONS

(1) Based on the concludions stated in the preceding section, the Nam Sai Yai No.2 and No.3 Project is judged to be technically and economically quite feasible but it will be necessary for construction of this Project to be started in early 1971 with various preliminary works including access roads, field offices, living quarters, etc. completed by the end of 1970. As for a definite study, it should be completed by the first quarter of 1970 after which tenders should be invited and contracts let to civil engineering contractors.

(2) Since the abovementioned schedule would be fairly hurried, it will be necessary for field surveys required for a definite study to be done in succession to this survey. These surveys would comprise material investigations for the dam and other structures, and borings and preparation of topographical maps necessary for design of the structures. Fortunately, a fair amount of borings and topographical maps for the Nam Sai Yai Project have already been prepared, but it is necessary for investigations of the topography and geology of the power station sites and of various materials for the dam to be carried out in succession to the investigations made up to the present, while for tunnel construction, data sufficient for selection of a schedule for the above must be prepared.

CHAPTER 3

MARKET SURVEY AND LOAD FORECAST

FIGURES

TABLES

CHAPTER 3 MARKET SURVEY AND LOAD FORECAST

3.1 MARKET SURVEY

3.1.1 Back Ground

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, geographically, in a favorable location.

The power systems are presently being operated separately for the Northern Region, Central Region (supplied by YEA) and the Northeast Region (supplied by NEEA), 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 as 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%. (See Appendix Table D-3, 4)

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.

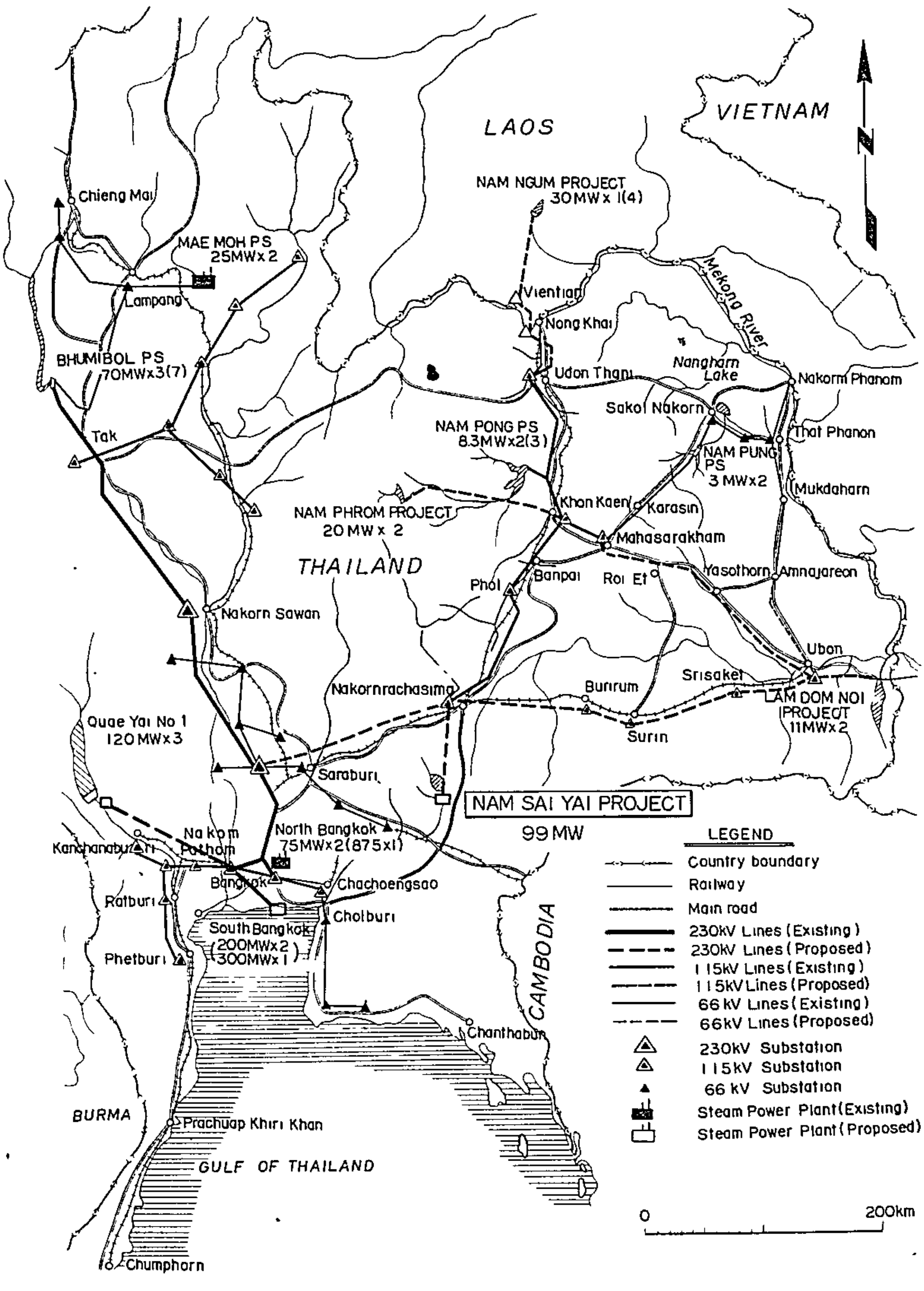
3.1.2 Pattern of Electric Power Supply in Thailand

(1) Organization

All power supply activities of Thailand are undertaken by the state and the agencies mentioned in the following.

1. Development of Power Source and Generation and Transmission of Electric Power.

FIG. 3-1 POWER SYSTEM OF NEEA AND YEA



NEA (National Energy Authority) belongs to the Ministry of National Development and it is engaged mainly in regulating the agencies concerning power source development. NEA additionally undertakes power source development itself, however it does not undertake the operation and maintenance of power plants.

YEA (Yanhee Electricity Authority) 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 and PEA. The energy production in 1967 was 1,810 million kWh.

NEEA (Northeast Electricity Authority) undertakes power supply to the Northeast Region of Thailand.

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

2. Power Distribution

MEA (Metropolitan Electricity Authority) 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.

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

(2) Power Supply in the Northeast Region of Thailand

In the Northeast Region, NEEA is presently generating and transmitting power while PEA is distributing power and generating power also by diesels on a small scale. NEA 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 Nam Pong 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 Ubol in the southern part of the Northeast Region. Construction is scheduled to begin in 1968 and to be completed in 1970. Simultaneously, Udon - Nakornrachasima and Udon - Mahasarakhan 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 to start operation 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 requirement 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 except for the Southern Region which is geographically isolated.

Construction of a 115-kV transmission line connecting Udon and Vientiane, 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 start.

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.

3.2 LOAD FORECAST

3.2.1 Supply Area

As previously stated, the YEA and NEEA Systems will be interconnected in 1970 and interchange of power will be accomplished through the tie lines. Considering the present progress in survey work and anticipated construction periods, the start of operation 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.

3.2.2 Load Forecasts

(1) Available Load Forecast

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. Demand in 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. (See Appendix Table D-5 – D-7). 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 the Electric Power Development Company 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. (Appendix Table D-3). 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 relationship between power consumption per capita and GDP per capita which is recognized as applicable to countries throughout the world. (Appendix Fig. D-1). 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, locality and population growth rate. (Appendix Table D-9)

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

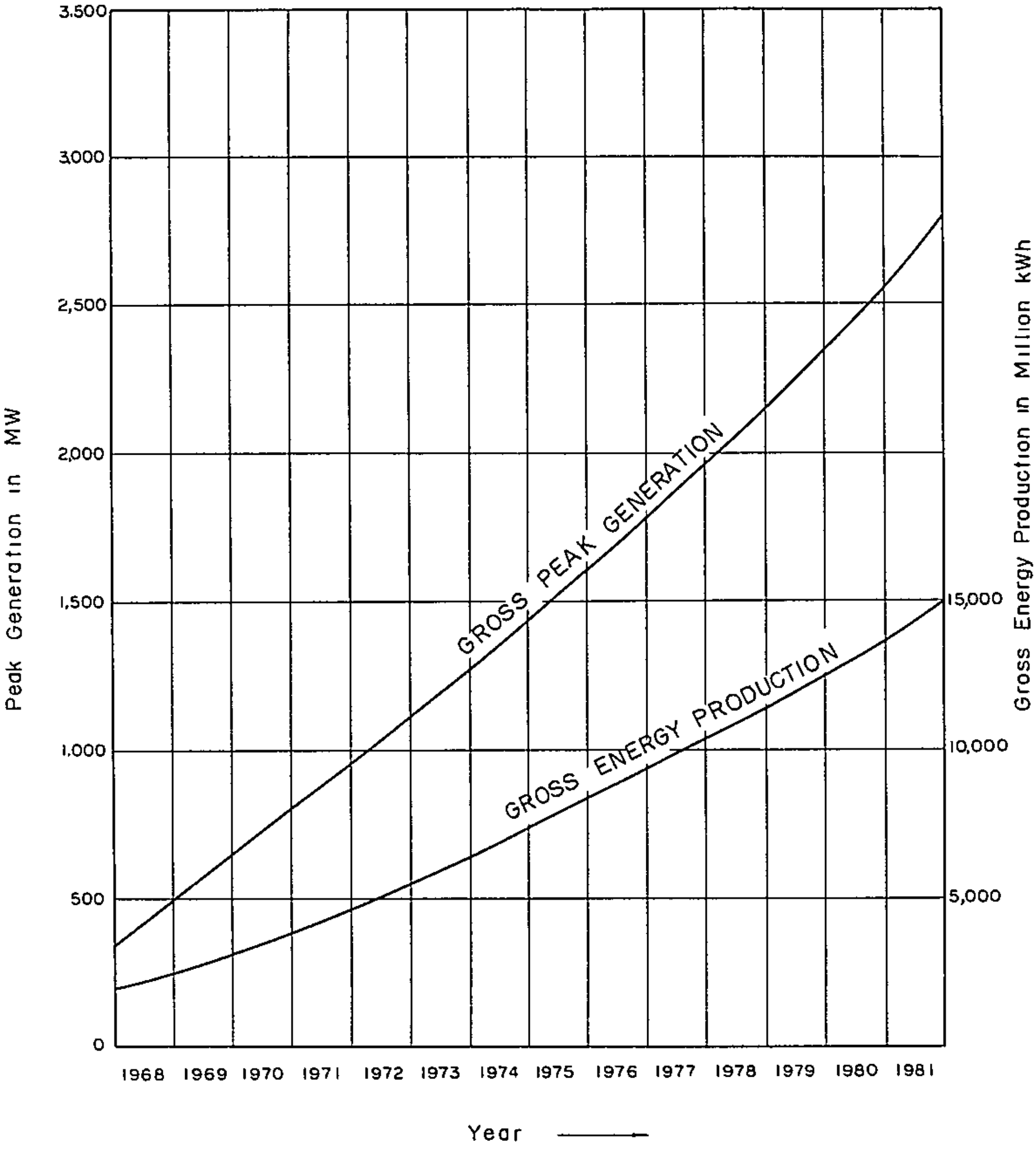


TABLE 3-1 LOAD FORECAST FOR THE YEAR 1968–1981 (AID LOAD FORECAST FOR YEA SYSTEM)

Fiscal Year	YEA System Energy Demand (million kWh)	YEA System Energy Growth Rate (%)	YEA System Load Factor (%)	YEA System Power Demand (MW)	NEEA System Energy Demand (million kWh)	NEEA System Energy Growth Rate (%)	NEEA System Load Factor (%)	NEEA System Power Demand (MW)	Total Energy Demand (million kWh)	Total Energy Growth Rate (%)	Total Load Factor (%)	Total Power Demand (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	43.1	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 Energy Demand (million kWh)	YEA System Energy Growth Rate (%)	YEA System Load Factor (%)	YEA System Power Demand (MW)	NEEA System Energy Demand (million kWh)	NEEA System Energy Growth Rate (%)	NEEA System Load Factor (%)	NEEA System Power Demand (MW)	Total Energy Demand (million kWh)	Total Energy Growth Rate (%)	Total Load Factor (%)	Total Power Demand (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	446	6.0	43.4	116	10,899	10.1	61.0	2,011
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

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 covering demand and supply capacity made on the Nam Phrom Report for which connection corrections will be necessary. (Appendix Table D-8)

1. The proposed output of the Nam Phrom Project has been changed from 56 MW to 40 MW and it is contemplated advance operation one year to 1972.

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

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

4. 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 larger 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.

(2) Load Forecast Results

The results after necessary corrections of the load forecasts in the aforementioned two reports are given in Fig. 3.2 and Tables 3-1 and 3-2.

According to Table 3.1, the kWh demand in 1973 will be 300 million kWh for the NEEA System and 6.150 million kWh for the YEA System, the demand of the former corresponding to approximately 5% of that of the latter.

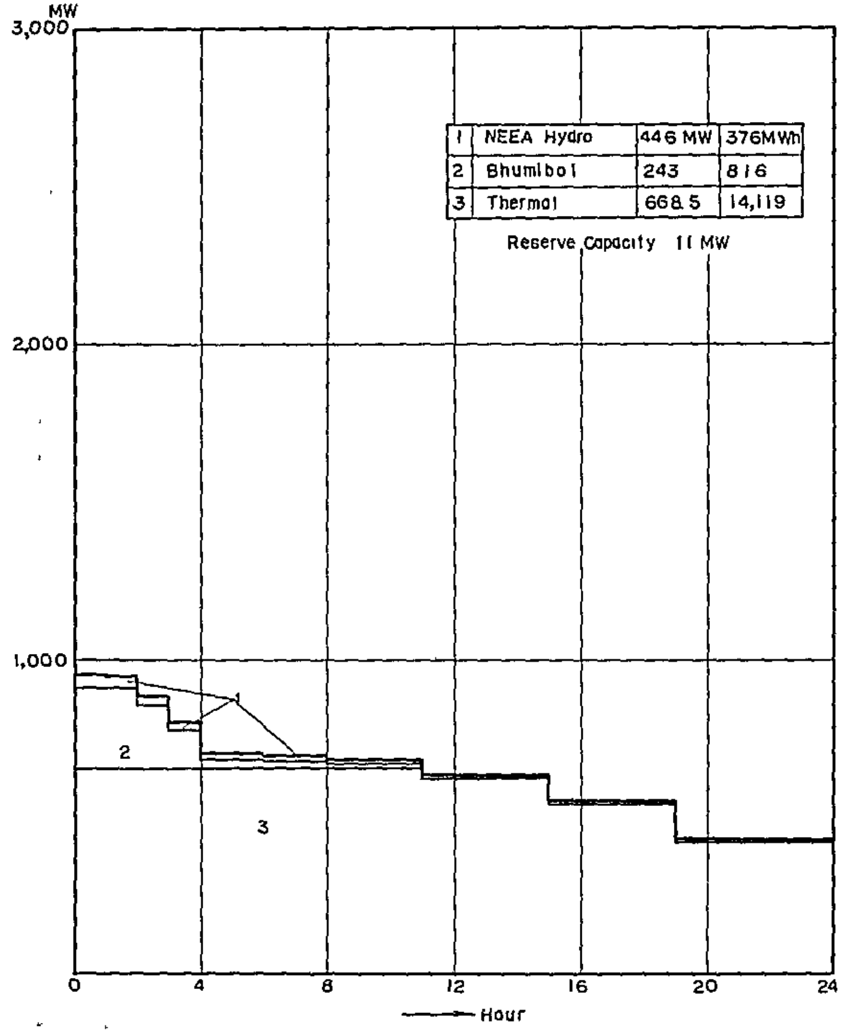
A peak demand of 83 MW in the NEEA System will be about 7% of that of 1,160 MW in the YEA System. Due to the small amount of industrial load, the load factor of the NEEA System is very low amounting 41.5% as compared with 61% of the YEA System. (Appendix Fig. D-1, 4)

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

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

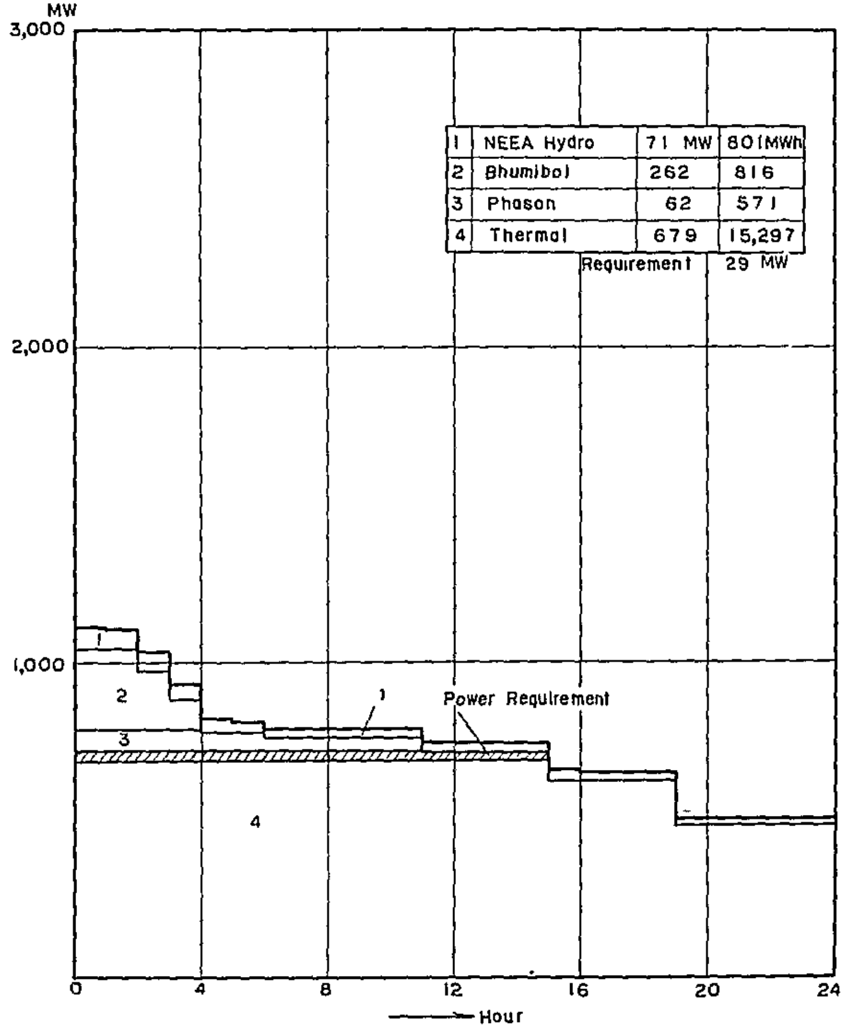
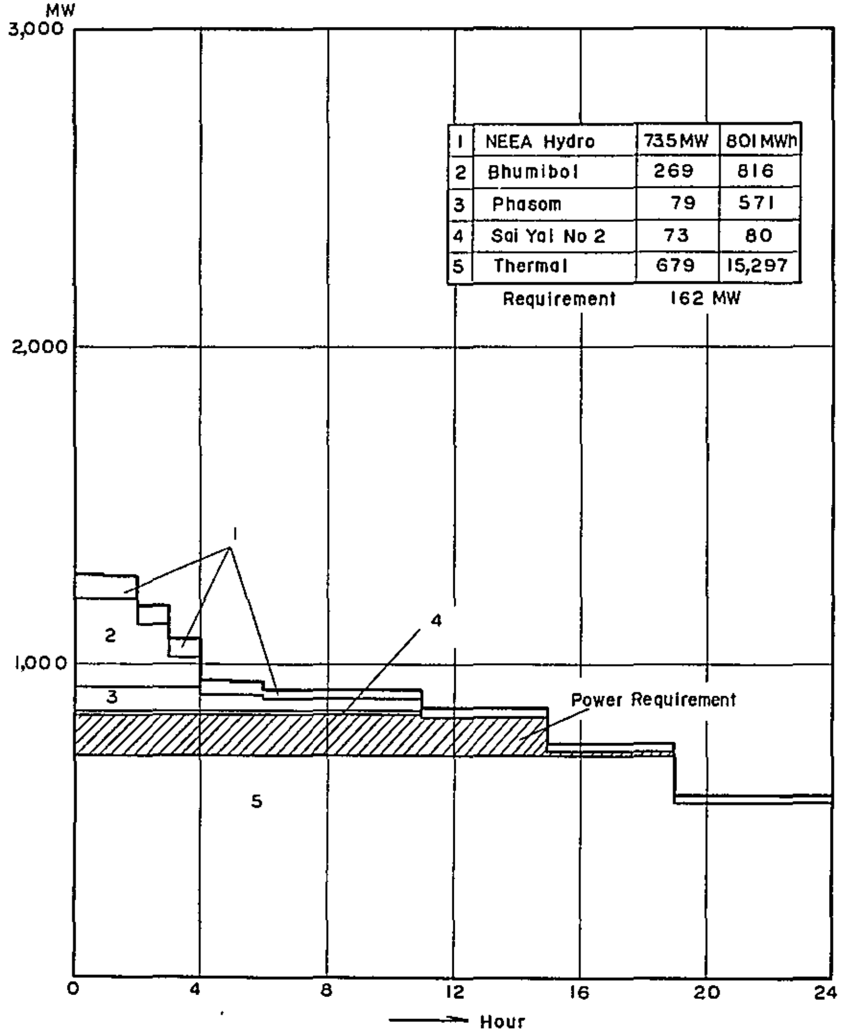


FIG. 3-3 (2) KW BALANCE (A.I.D.)

1973

Max Peak Demand 1,278 7 MW
Energy Demand 20,691 MWh

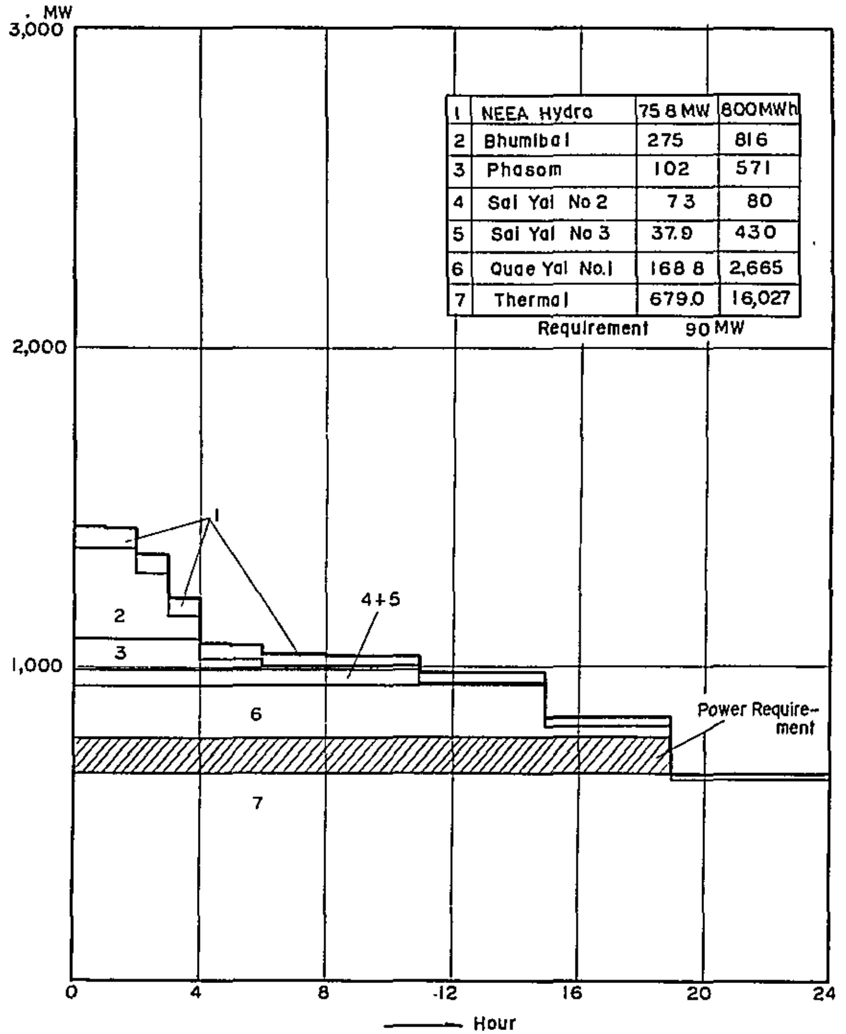


1	NEEA Hydro	735MW	801MWh
2	Bhumibol	269	816
3	Phasom	79	571
4	Sai Yai No 2	73	80
5	Thermal	679	15,297

Requirement 162 MW

1974

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



1	NEEA Hydro	75 8 MW	800MWh
2	Bhumibal	275	816
3	Phasom	102	571
4	Sai Yai No 2	7 3	80
5	Sai Yai No 3	37.9	430
6	Quae Yai No.1	168 8	2,665
7	Thermal	679.0	16,027

Requirement 90 MW

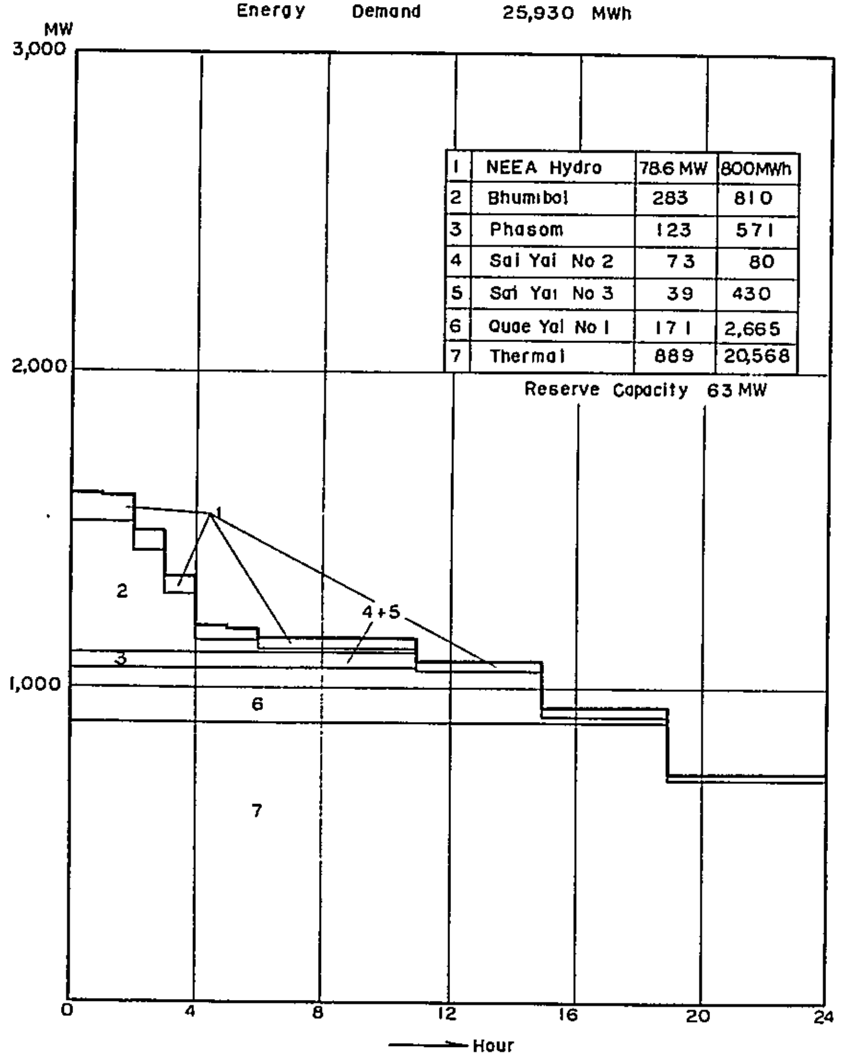
FIG. 3-3 (3) KW BALANCE (A.I.D.)

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	818 MW	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 I	188	2,665
7	Thermal	1,040	23,751

Reserve Capacity 290 MW

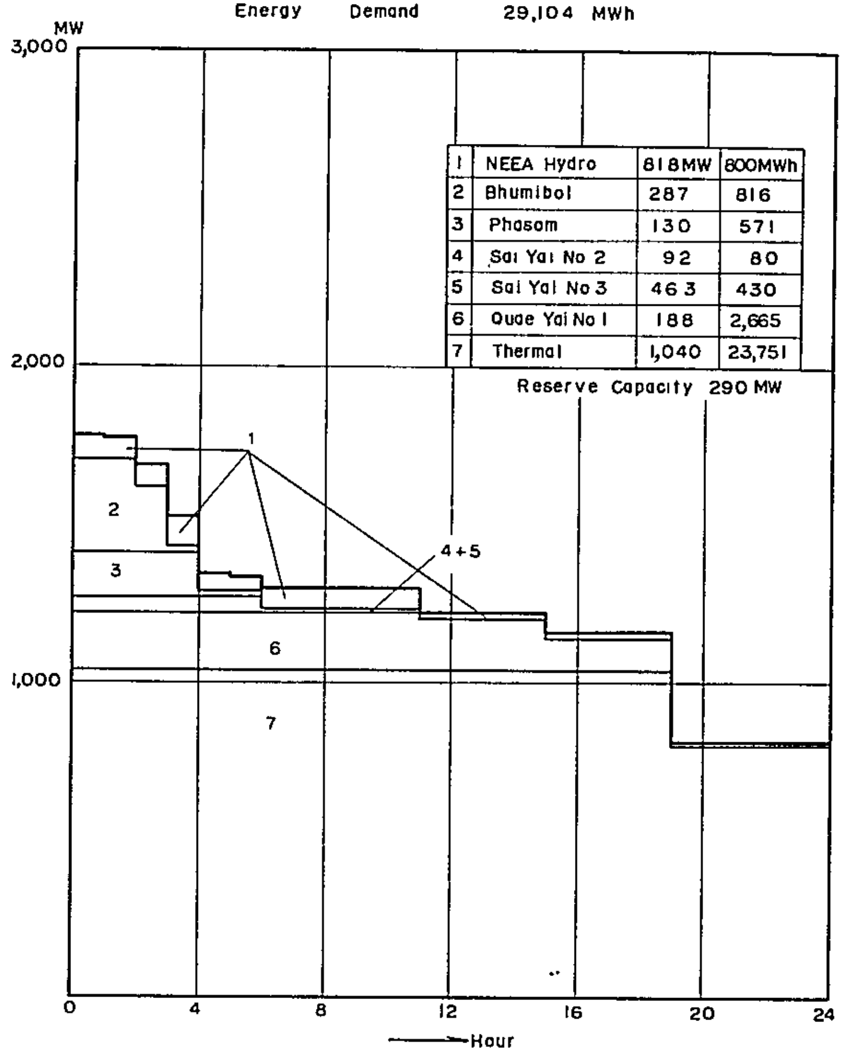
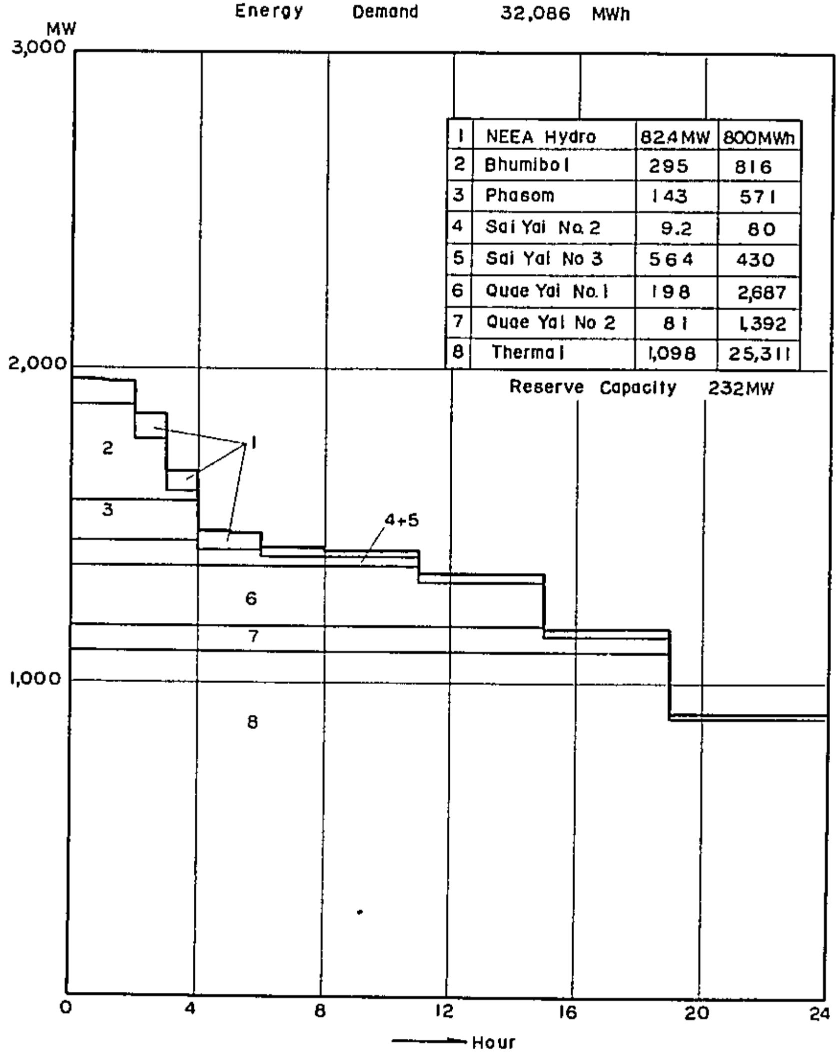


FIG. 3-3 (4) KW BALANCE (A.I.D.)

1977

Max. Peak Demand 1,963 MW
Energy Demand 32,086 MWh

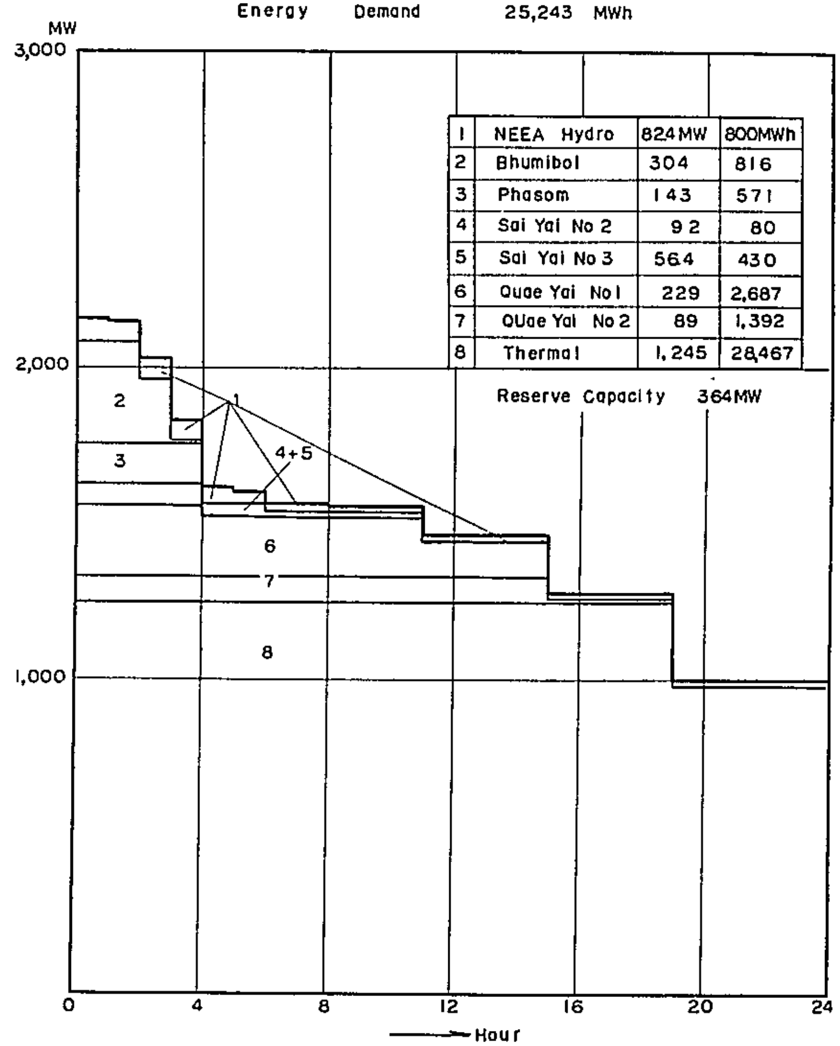


1	NEEA Hydro	824 MW	800MWh
2	Bhumibol	295	816
3	Phasom	143	571
4	Sai Yai No. 2	9.2	80
5	Sai Yai No 3	564	430
6	Quae Yai No. 1	198	2,687
7	Quae Yai No 2	81	1,392
8	Thermal	1,098	25,311

Reserve Capacity 232MW

1978

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



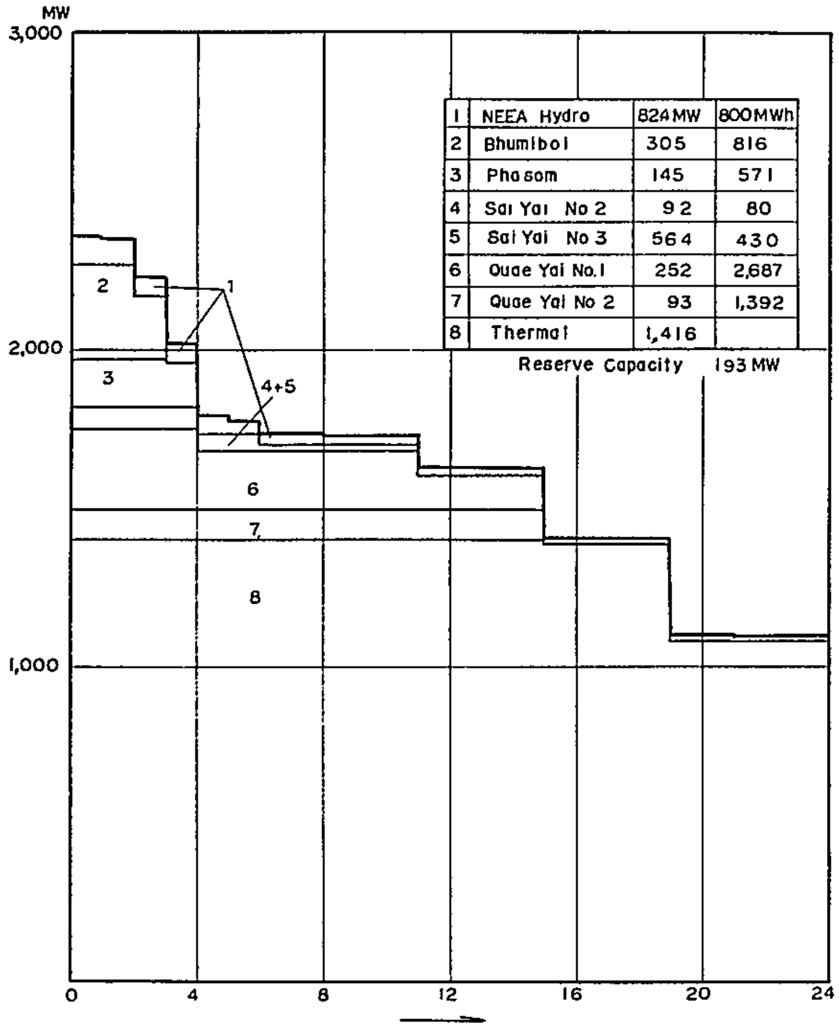
1	NEEA Hydro	824 MW	800MWh
2	Bhumibol	304	816
3	Phasom	143	571
4	Sai Yai No 2	92	80
5	Sai Yai No 3	564	430
6	Quae Yai No 1	229	2,687
7	QUae Yai No 2	89	1,392
8	Thermal	1,245	28,467

Reserve Capacity 364MW

FIG. 3-3 (5) KW BALANCE (A.I.D.)

1979

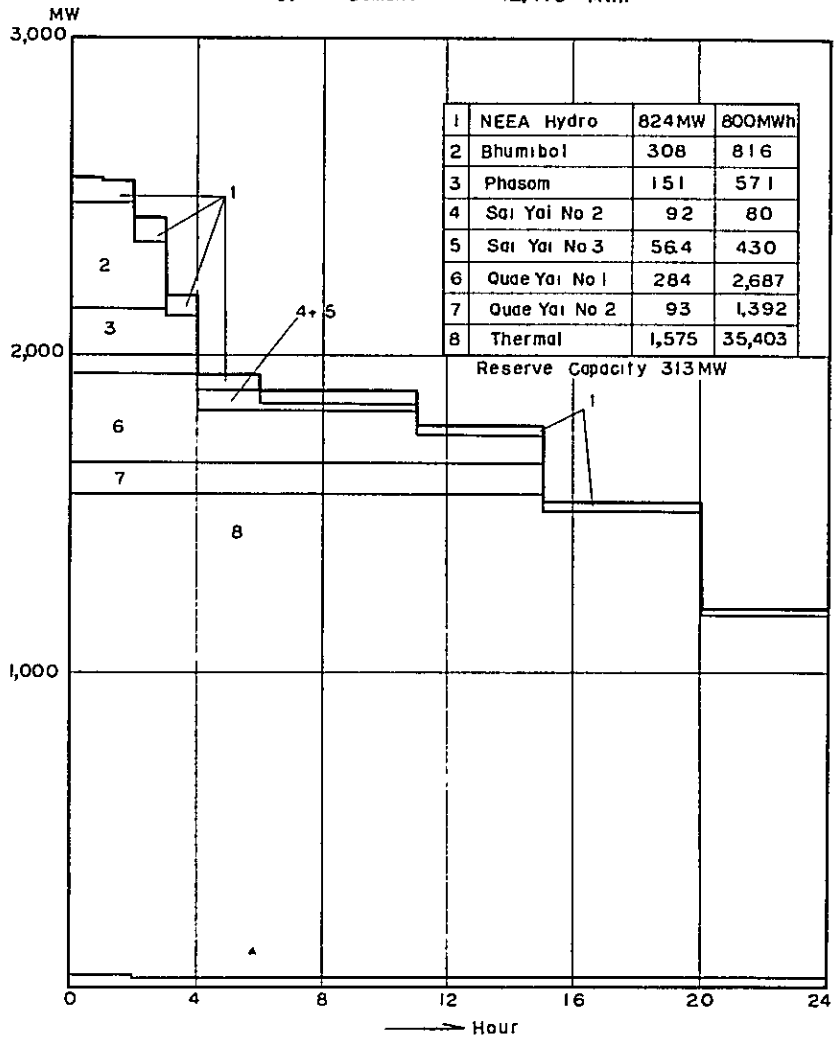
Max Peak Demand 2,359 MW
Energy Demand 38,891 MWh



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	564	430
6	Quae Yai No.1	252	2,687
7	Quae Yai No 2	93	1,392
8	Thermal	1,416	

1980

Max Peak Demand 2,558 MW
Energy Demand 42,179 MWh



1	NEEA Hydro	824MW	800MWh
2	Bhumibol	308	816
3	Phasom	151	571
4	Sai Yai No 2	92	80
5	Sai Yai No 3	564	430
6	Quae Yai No I	284	2,687
7	Quae Yai No 2	93	1,392
8	Thermal	1,575	35,403

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 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 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.

3.3 SUPPLY AND DEMAND BALANCE AND NECESSITY FOR DEVELOPMENT

3.3.1 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, two existing hydroelectric plants, Nam Pung and Nam Pong, and two 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 and Quae Yai No. 2 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, 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 and Table D-12, 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 Chapter 10, 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.

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 shows that the Nam Sai Yai stations, as in the cases of the Bhumibol and Phasom Power Stations, will bear peak loads to cover a portion of the requirement in supply capacity.

FIG. 3-4 LOAD FORECAST FOR THE NORTHEAST REGION
(1968–1981)

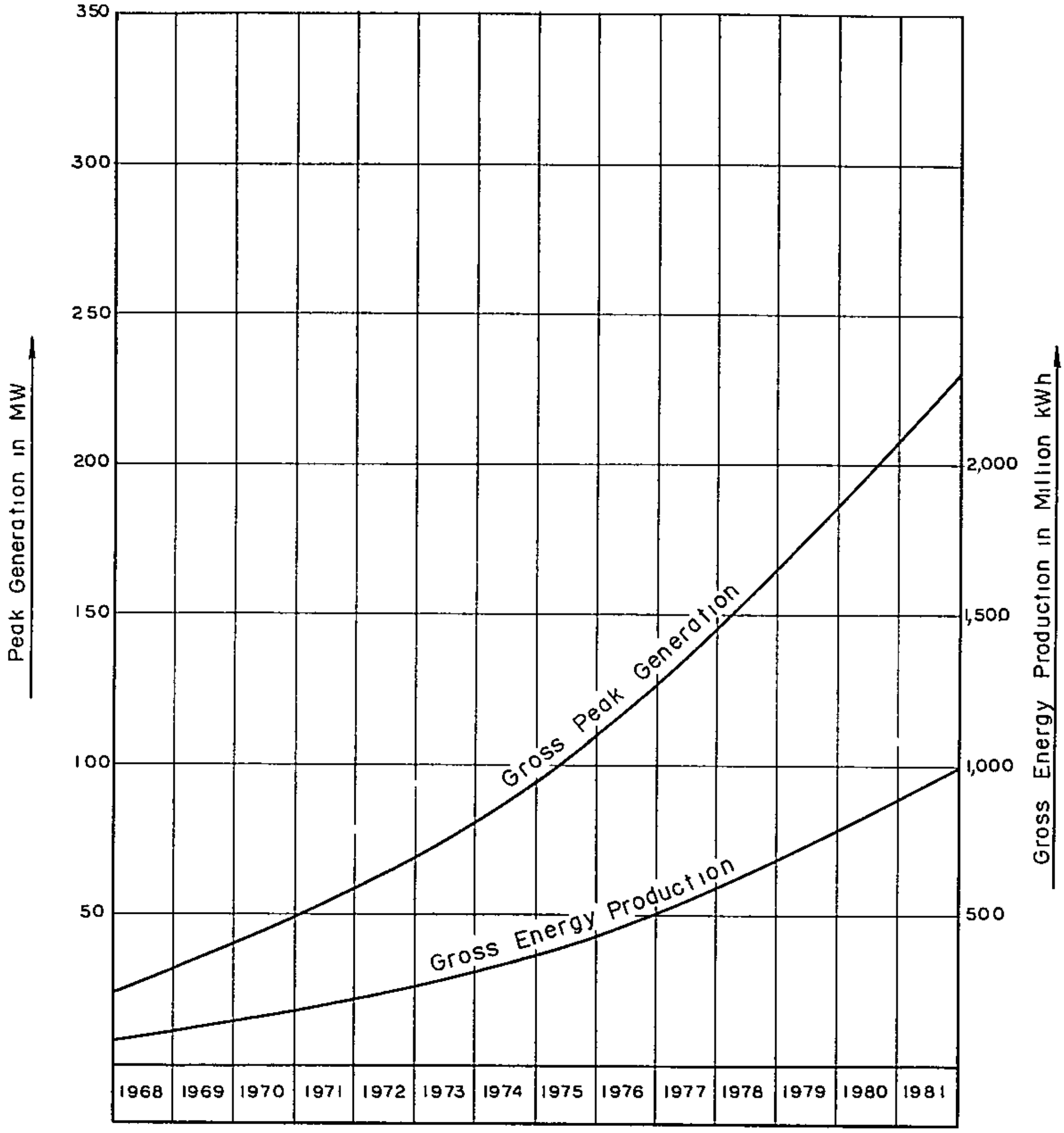


TABLE 3-3 LOAD FORECAST FOR NORTHEAST REGION (1968 - 1981)

	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

The entire output of the Nam Sai Yai No. 2 and No. 3 Power Stations will become effective 3 years after starting operation.

Studies of kWh balance throughout a year based on the energy demands estimated by AID and EPDC were made, the results of which are shown in Table D-10 and Table D-11 in the Appendix D. According to the result of the study, it is evident that the generating capacity expansion program is sufficient to maintain kWh balance of the system.

3.3.2 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 thought necessary to consider such a case also.

The following may be considered as the cause of such large increases in demand.

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

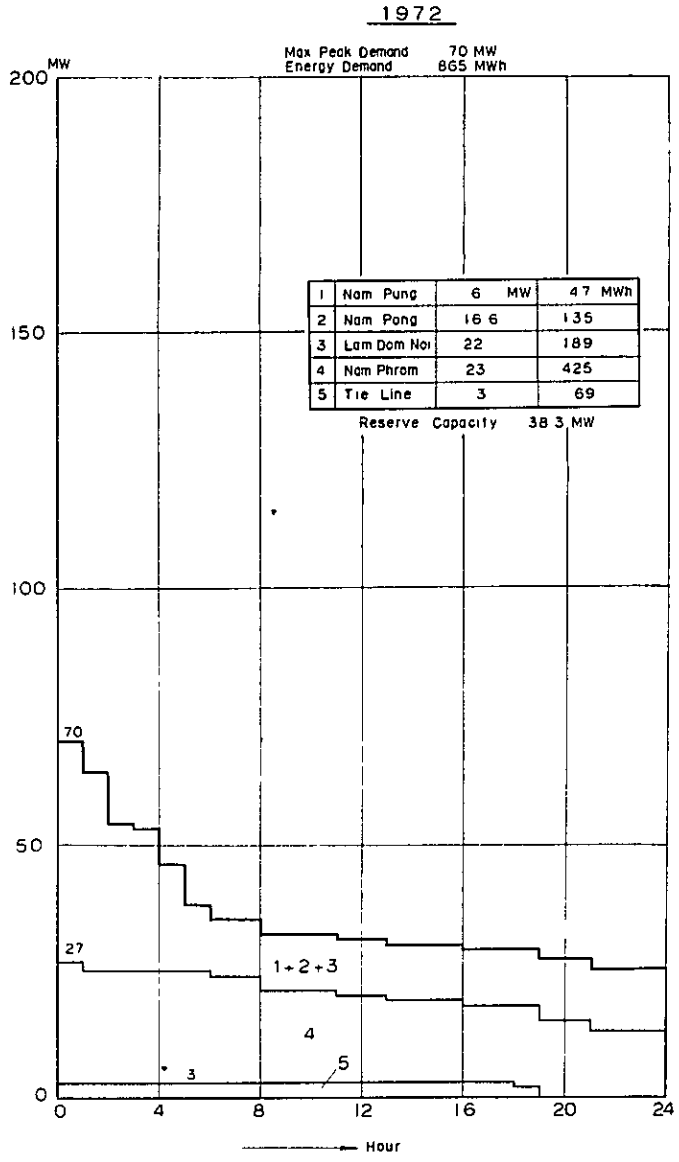
2) The present electricity rate is exceedingly high in the PEA System, but with the power development of 1) above, there is a great possibility that this rate can be lowered to stimulate an increase in demand.

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

Fig. 3-4 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 when from 1973 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 the 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 of overall losses and load factor. (Appendix Table D-1)

Based on this load forecast and using the same method as in the Nam Phrom Feasibility Report, the timing for starting operation of the Nam Sai Yai Project was studied. In other words, it was regarded that the new supply capacity would be added to the system at the time 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. 3-5.

FIG. 3-5 (1)   KW BALANCE (NEEA)



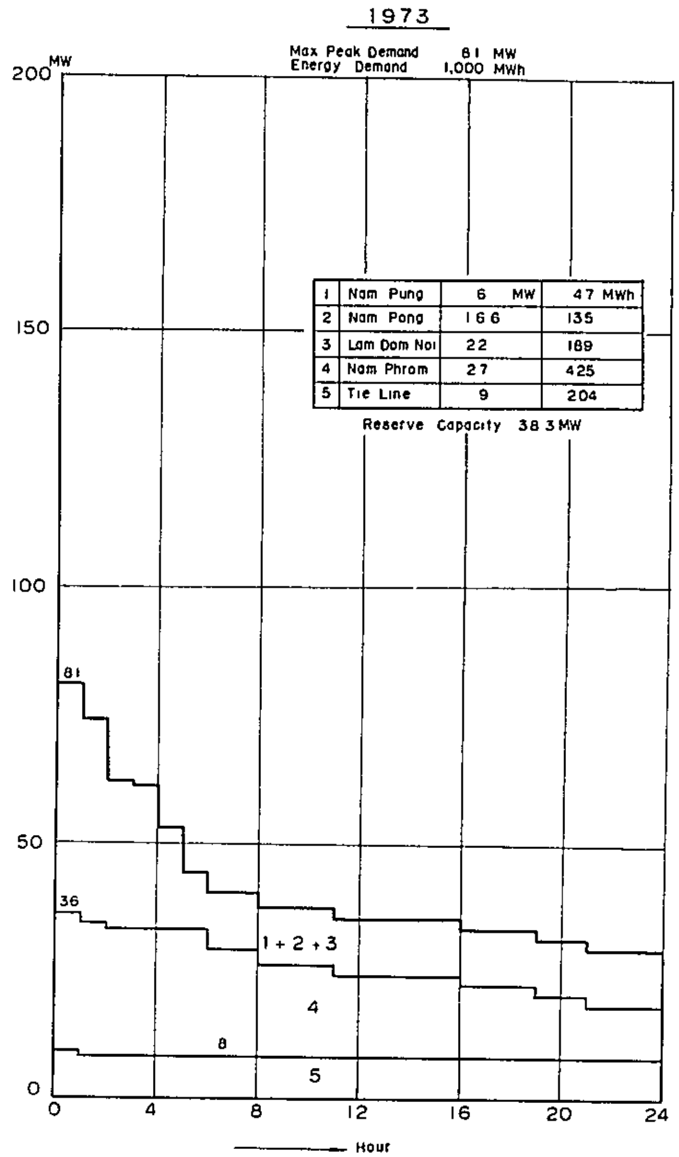


FIG. 3-5 (2) KW BALANCE (NEEA)

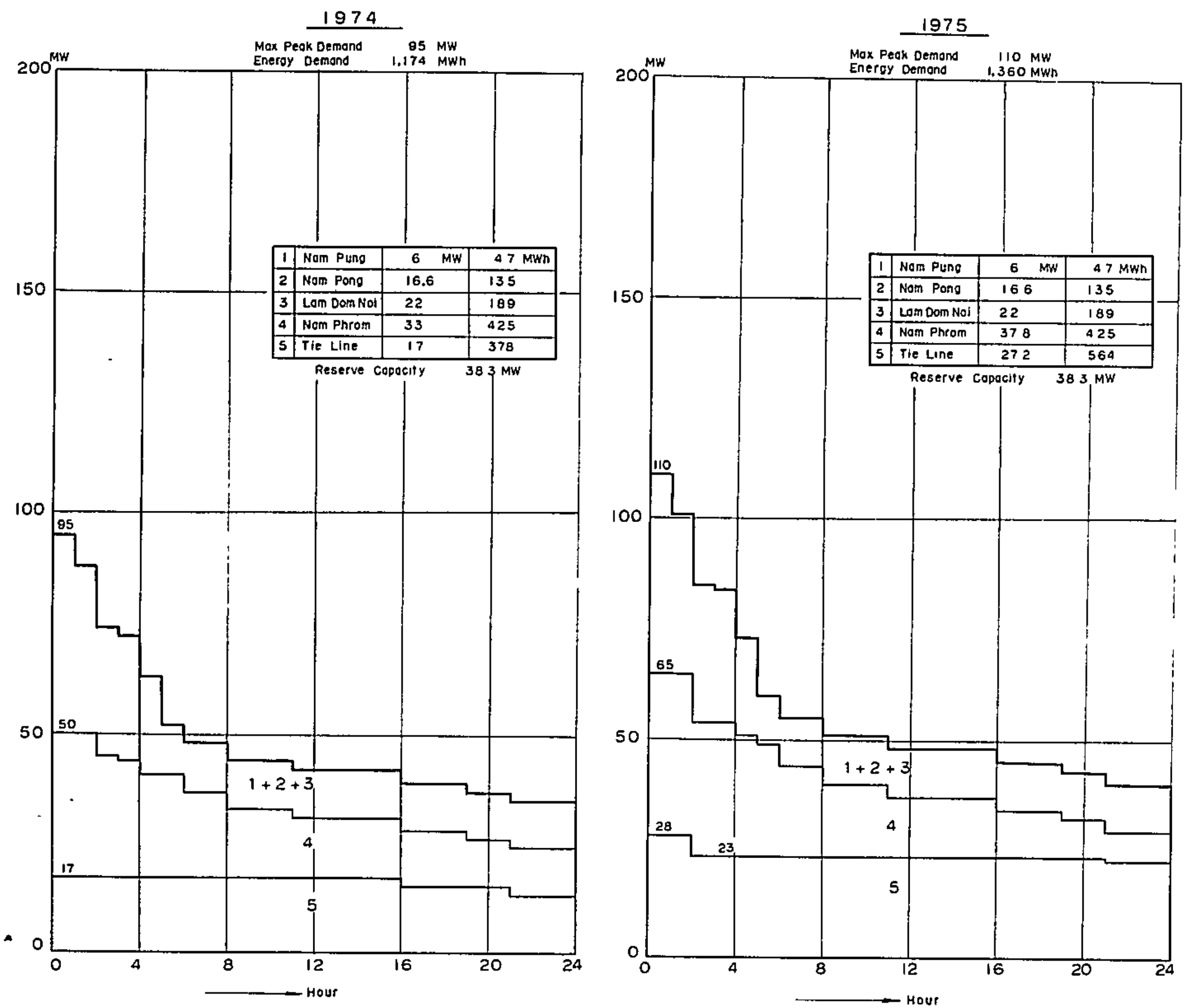
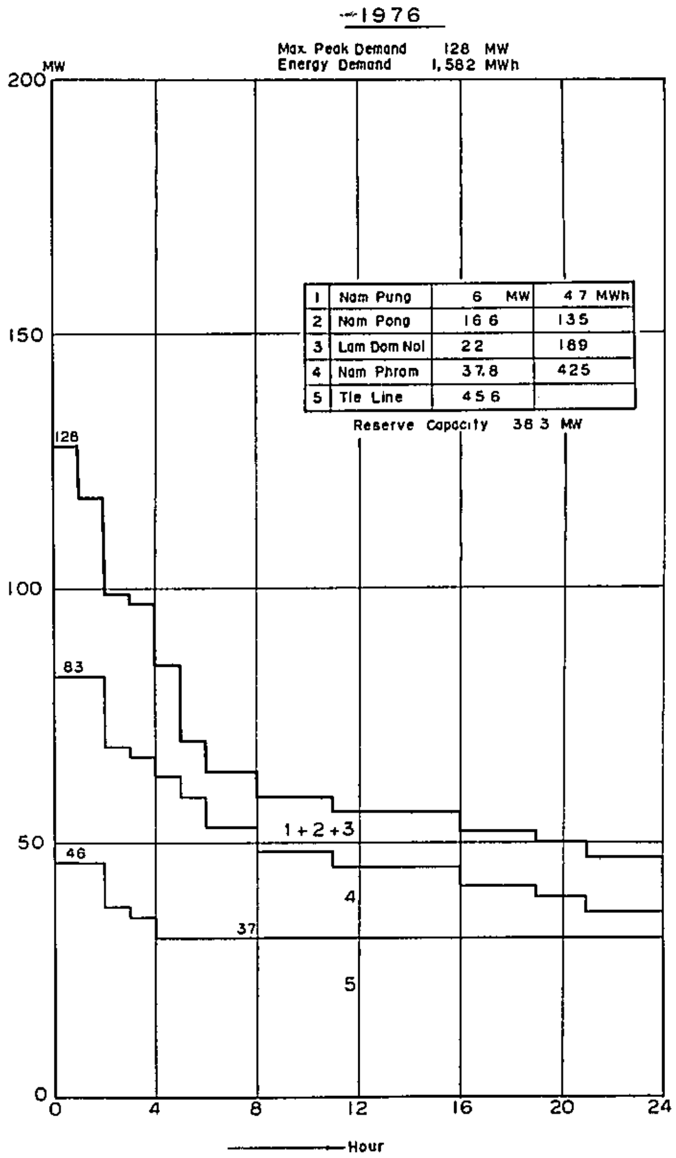
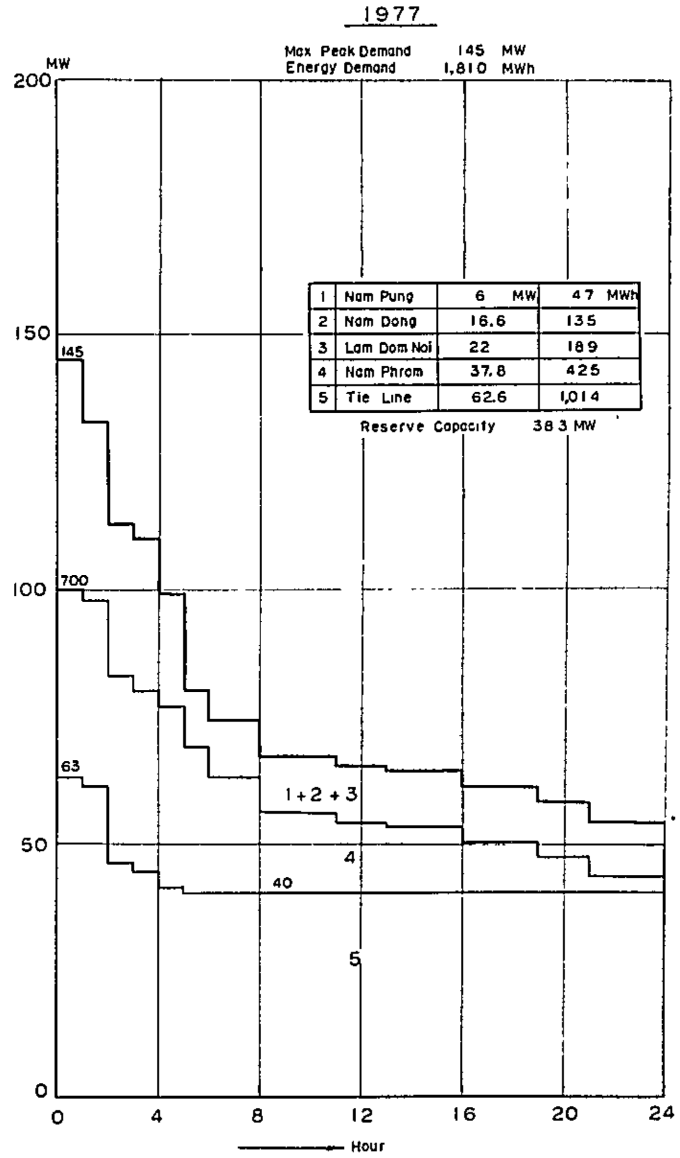


FIG. 3-5 (3)   KW BALANCE (NEEA)



1	Nam Pung	6 MW	4 7 MWh
2	Nam Pong	16 6	135
3	Lam Dom Noi	2 2	189
4	Nam Phrom	37.8	425
5	Tie Line	45 6	

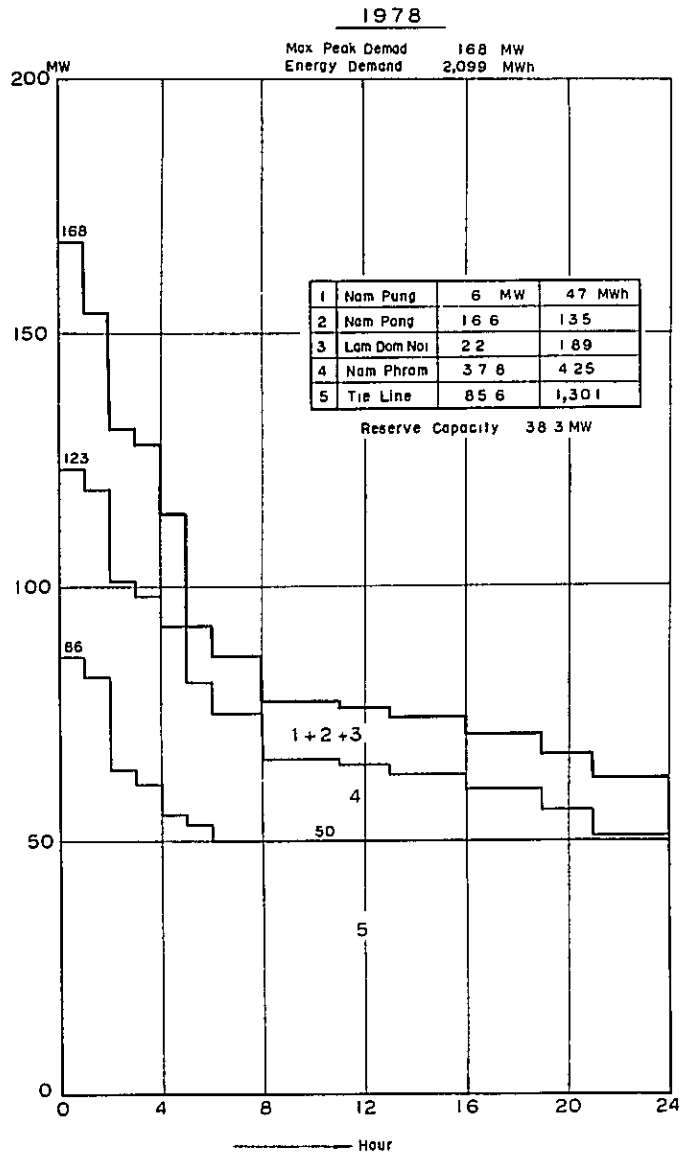
Reserve Capacity 38 3 MW



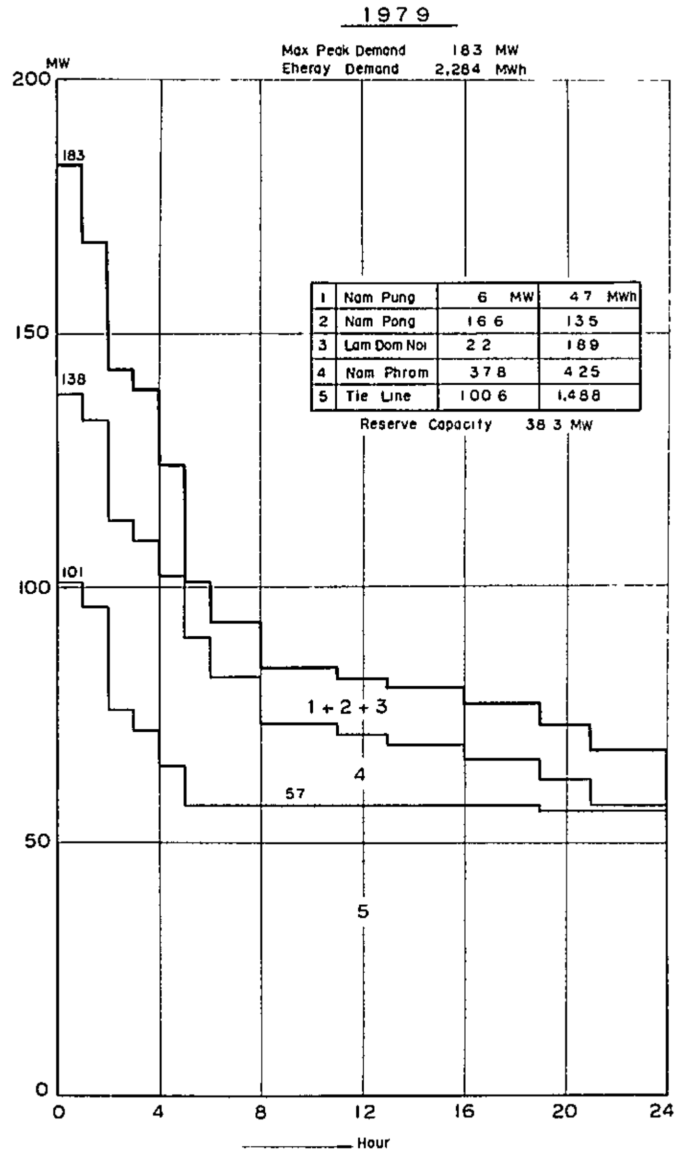
1	Nam Pung	6 MW	4 7 MWh
2	Nam Dong	16.6	135
3	Lam Dom Noi	22	189
4	Nam Phrom	37.8	425
5	Tie Line	62.6	1,014

Reserve Capacity 38 3 MW

FIG. -3-5 (4)   KW BALANCE (NEEA)



1	Nam Pung	6 MW	47 MWh
2	Nam Pong	16 6	135
3	Lam Dom Noi	2 2	1 89
4	Nam Phrom	37 8	4 25
5	Tie Line	85 6	1,301



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

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 comprise 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 requirement 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 reserve facilities. As for the 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 operate using two units with one unit held in reserve.

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

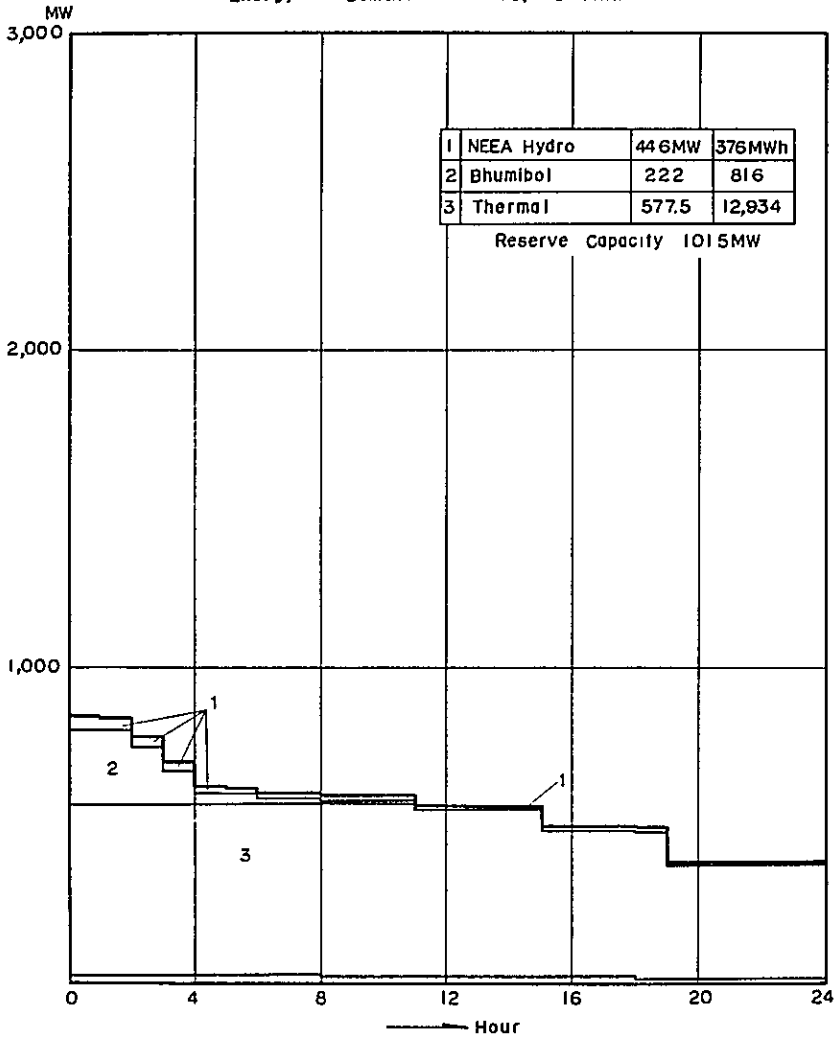
Study of the kW balance reveals that in 1976 and 1977 power received over the YEA tie line will be 46 MW and 63 MW respectively. Since the total reserve supply capacity of the system of 38.3 MW will be greatly exceeded after that, it will become necessary to complete the Nam Sai Yai No. 2 and No. 3 Power Stations in 1976 and 1977 respectively.

If the NEEA System is considered independently and there is a fairly rapid growth in power demand, it is recommend that the Nam Sai Yai Project will start around 1976. Therefore, as stated 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.

FIG. 3-6 (1) KW BALANCE (E.P.D.C.)

1971

Max Peak Demand 844 MW
Energy Demand 13,478 MWh



1972

Max Peak Demand 918.5 MW
Energy Demand 15,498 MWh

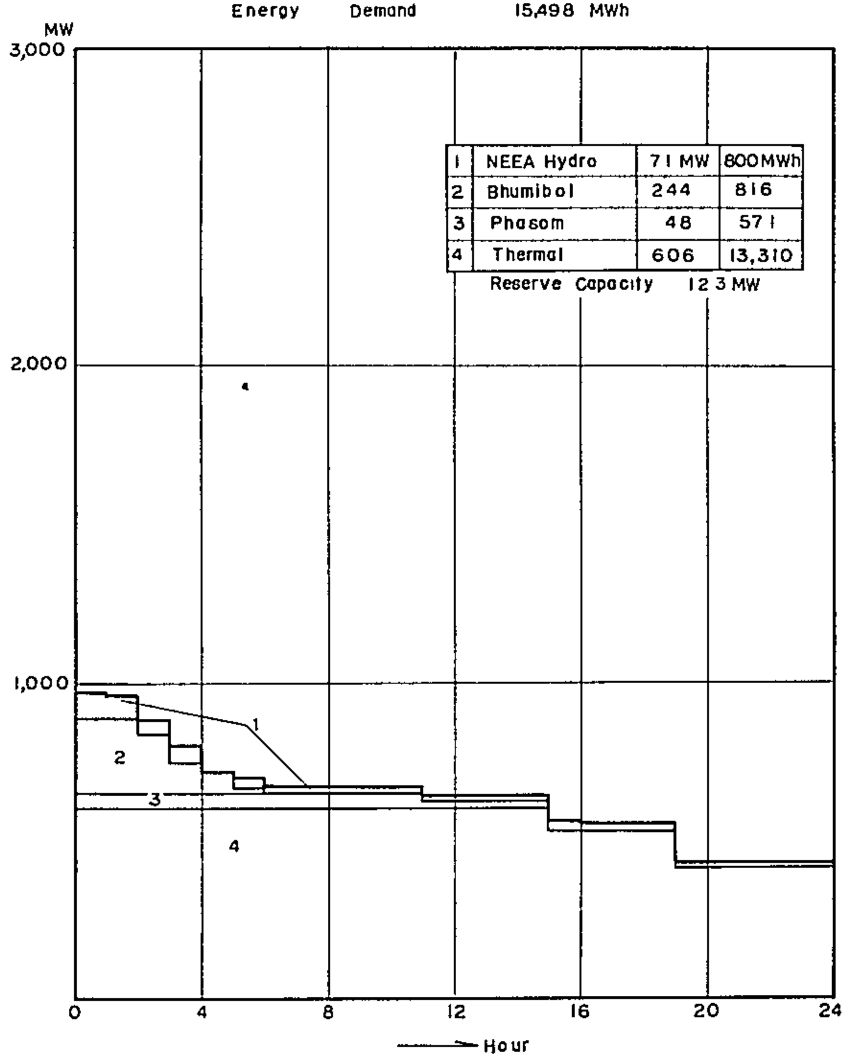
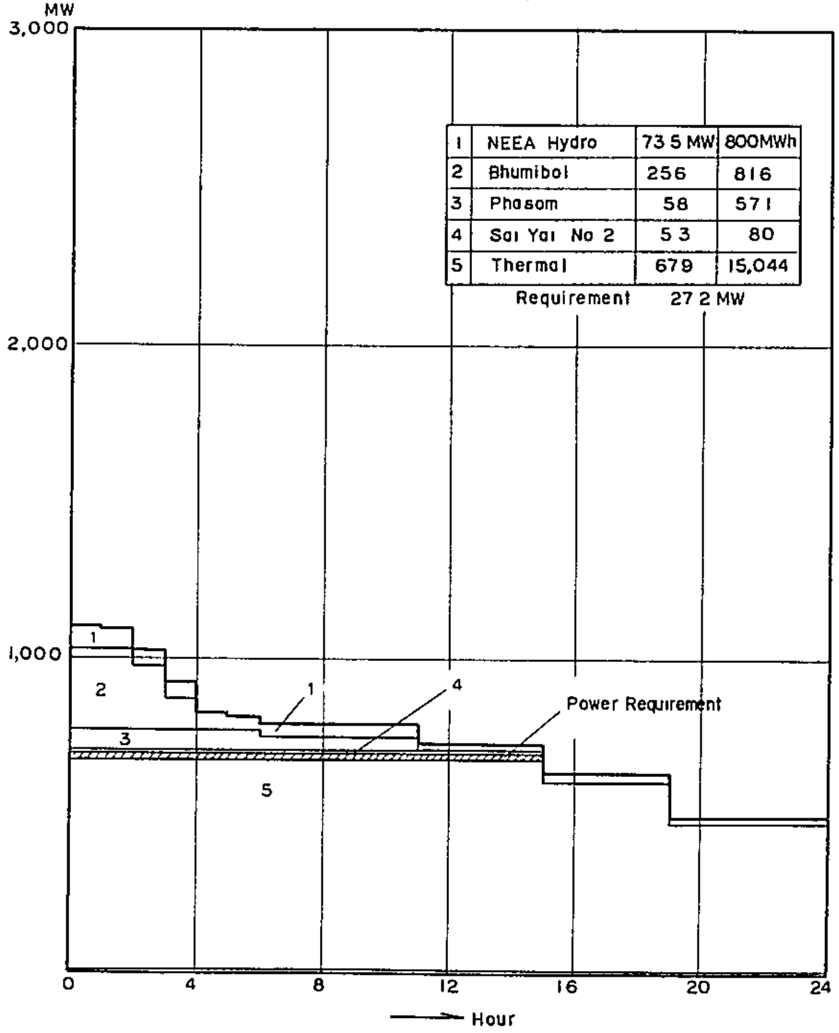


FIG. 3-6 (2) KW BALANCE (E.P.D.C.)

1973

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

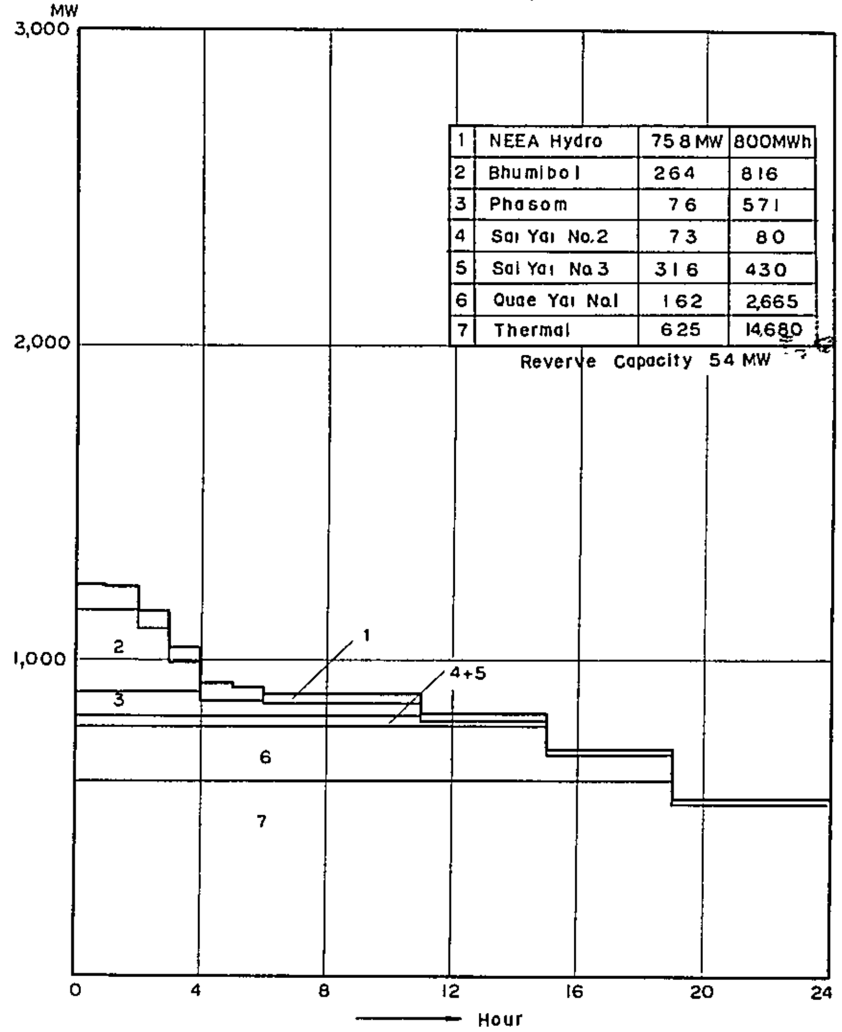


1	NEEA Hydro	73 5 MW	800MWh
2	Bhumibol	256	816
3	Phasom	58	571
4	Sai Yai No 2	5 3	80
5	Thermal	679	15,044

Requirement 27 2 MW

1974

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



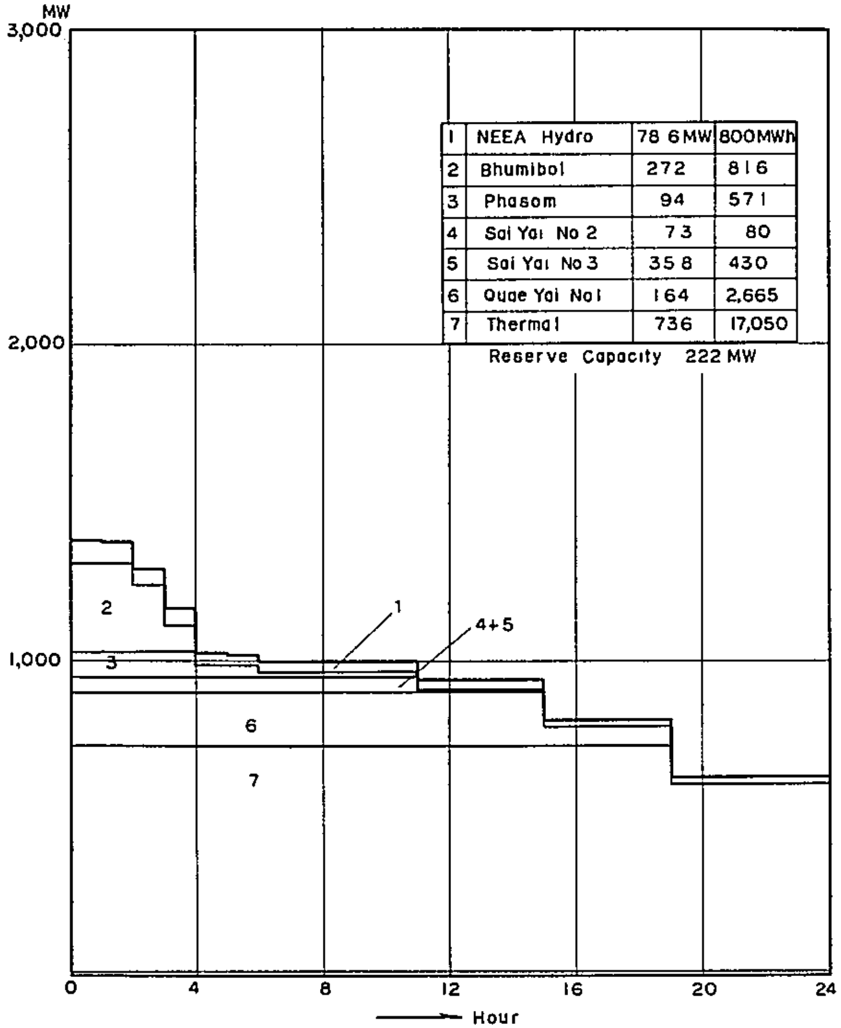
1	NEEA Hydro	75 8 MW	800MWh
2	Bhumibol	264	816
3	Phasom	7 6	571
4	Sai Yai No.2	7 3	8 0
5	Sai Yai No 3	31 6	430
6	Quae Yai No.I	16 2	2,665
7	Thermal	62 5	14,680

Reverve Capacity 54 MW

FIG. 3-6 (3) KW BALANCE (E.P.D.C.)

1975

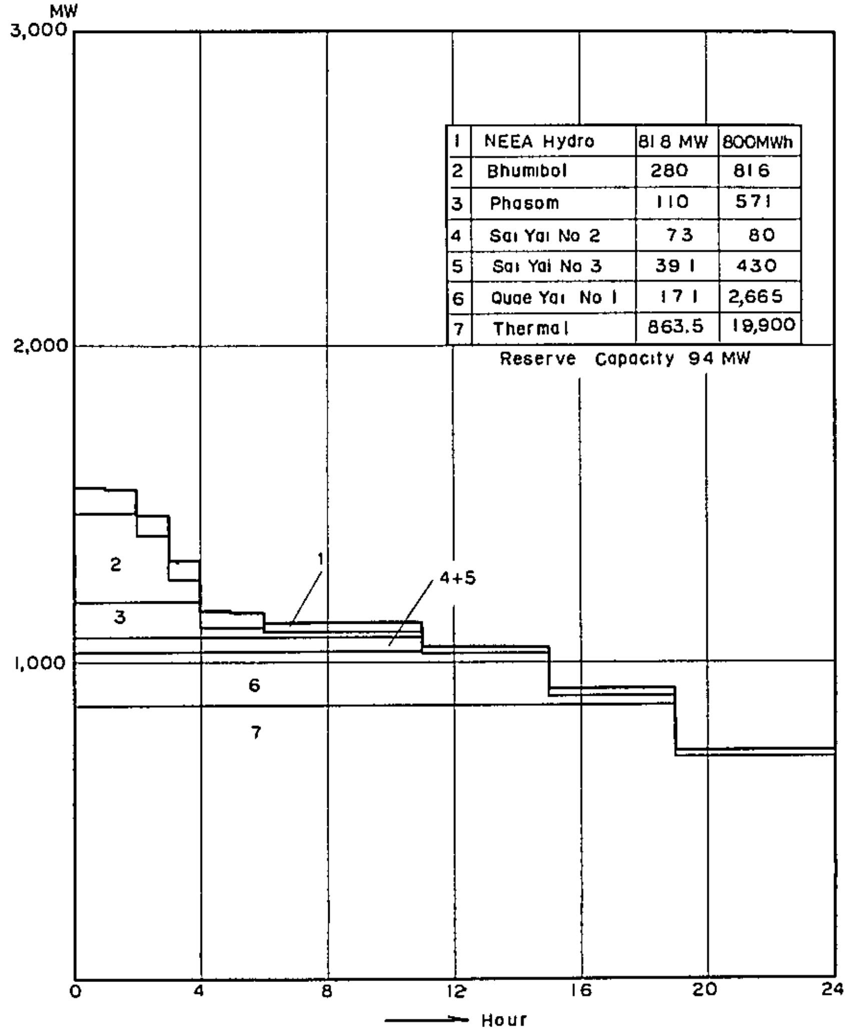
Max Peak Demand 1,387 MW
Energy Demand 22,414 MWh



1	NEEA Hydro	78 6 MW	800MWh
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

1976

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

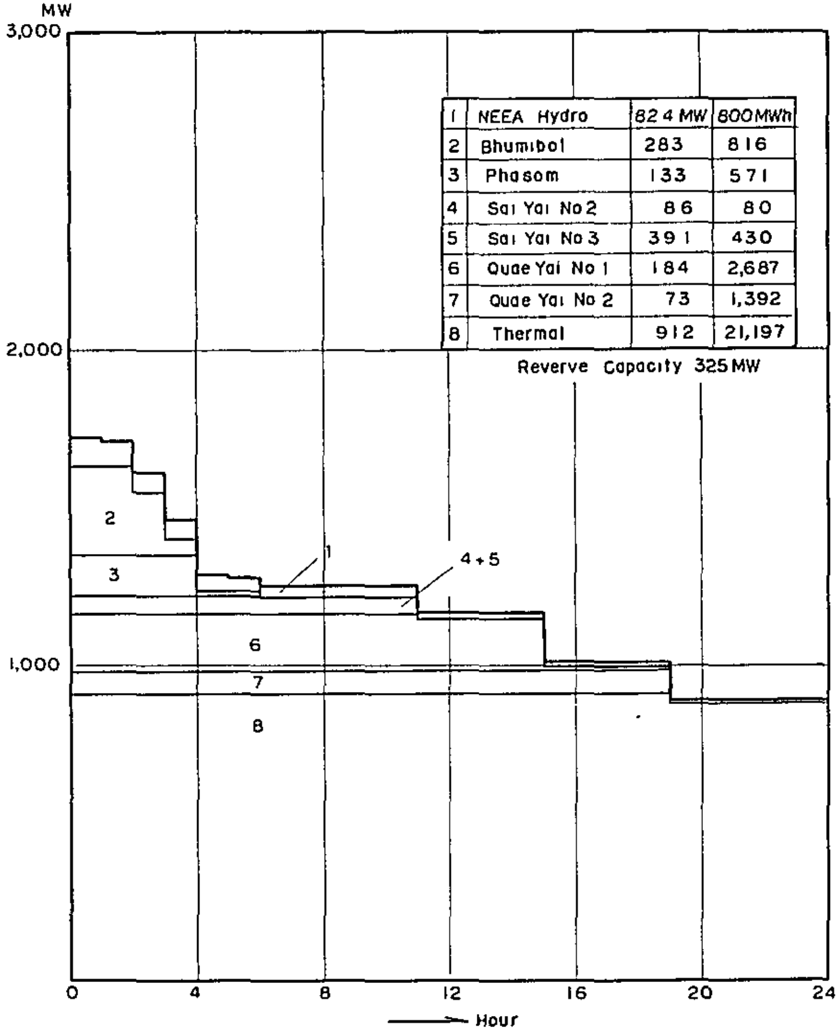


1	NEEA Hydro	81 8 MW	800MWh
2	Bhumibol	280	816
3	Phasom	110	571
4	Sai Yai No 2	7 3	80
5	Sai Yai No 3	39 I	430
6	Quae Yai No I	17 I	2,665
7	Thermal	863.5	19,900

FIG. 3-6 (4)   KW BALANCE (E.P.D.C.)

1977

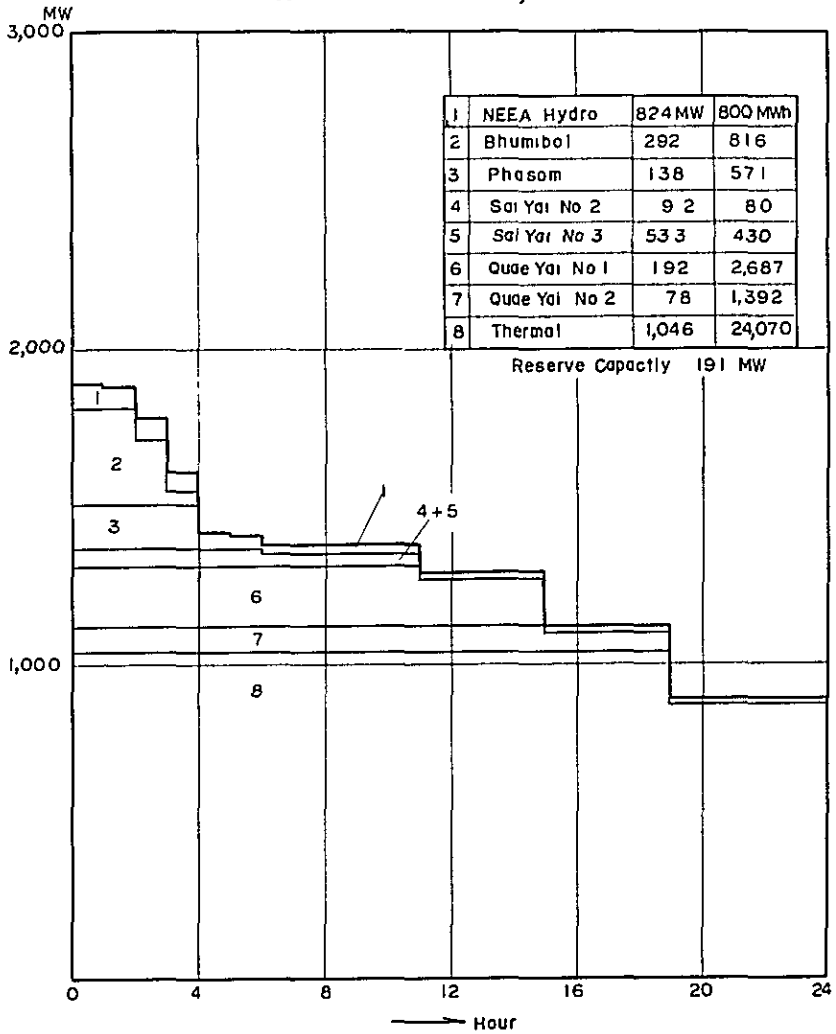
Max Peak Demand 1,715 MW
Energy Demand 27,972 MWh



1	NEEA Hydro	82 4 MW	800 MWh
2	Bhumibol	283	816
3	Phasom	133	571
4	Sai Yai No 2	86	80
5	Sai Yai No 3	391	430
6	Quae Yai No 1	184	2,687
7	Quae Yai No 2	73	1,392
8	Thermal	912	21,197

1978

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



1	NEEA Hydro	824 MW	800 MWh
2	Bhumibol	292	816
3	Phasom	138	571
4	Sai Yai No 2	92	80
5	Sai Yai No 3	533	430
6	Quae Yai No 1	192	2,687
7	Quae Yai No 2	78	1,392
8	Thermal	1,046	24,070

FIG. 3-6 (5) 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	92	80
5	Sai Yai No 3	564	430
6	Quae Yai No 1	214	2,687
7	Quae Yai No 2	85	1,392
8	Thermal	1,231	28,130

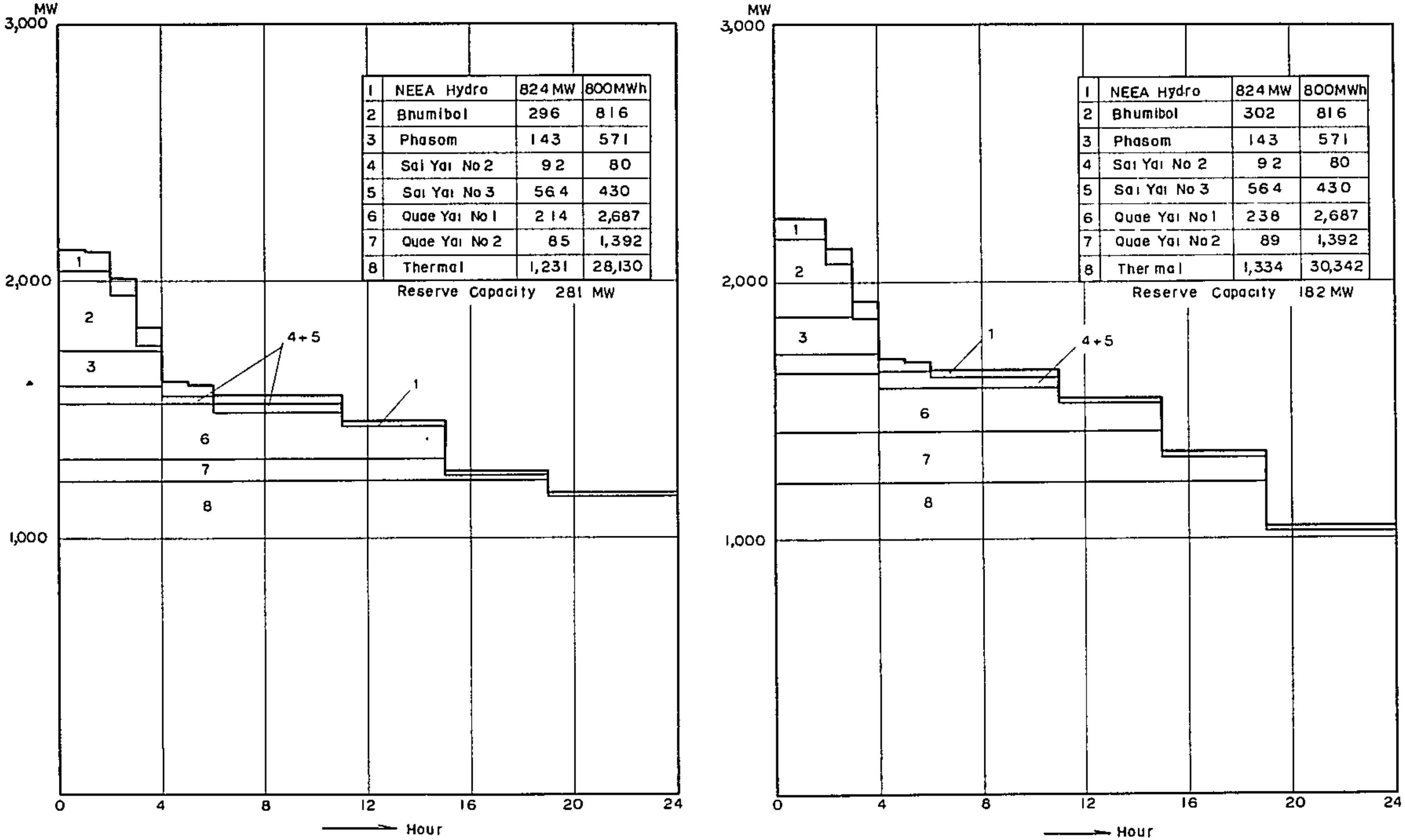
Reserve Capacity 281 MW

1980

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

1	NEEA Hydro	824 MW	800MWh
2	Bhumibol	302	816
3	Phasom	143	571
4	Sai Yai No 2	92	80
5	Sai Yai No 3	564	430
6	Quae Yai No 1	238	2,687
7	Quae Yai No 2	89	1,392
8	Thermal	1,334	30,342

Reserve Capacity 182 MW



CHAPTER 4

SCHEME OF DEVELOPMENT

FIGURES

TABLES

CHAPTER 4. SCHEME OF DEVELOPMENT

4.1 PHYSICAL FEATURES AND HYDROLOGICAL CONDITION

4.1.1 Sai Yai River Basin and Location of Project Site

The Sai Yai River springs from the Dangrek Mountain Range and snakes southward gathering the waters of this mountain area which is one of the high rainfall zones of Thailand. Roughly halfway between Bangkok, the capital of Thailand, and Korat, the central city of the Northeast Region, this mountain range has a number of peaks reaching an elevation of approximately 1,000m. The northeastern slope is part of the basin of the Mune River system. The Mune River being a tributary of the Mekong River which flows down the Korat Plateau, while the southwestern slope is part of the basin of the Sai Yai River, a tributary of the Bang Pakong River.

The Sai Yai River flows down from where the No. 2 Dam is contemplated to the junction of the Sai Noi River with a gradient of approximately 1/40 and the difference in head about 500m, offering the most favorable head for hydroelectric power development in the basin.

After this, the Nam Sai Yai flows south to the vicinity of Kabinburi and then changes its course to the west, and upon confluence with the Bang Pakong River, enters the Gulf of Thailand at a point approximately 60 km east of Bangkok.

As stated above, the mountain district of the project area is favored with water resources. On the other hand, the plain area belongs to the eastern end of the Bangkok Plain and is a low and level area with an elevation of not more than 40m, but with uneven distribution of rainfall, loss of fertility of the soil and imperfect water utilization facilities, the productivity of agriculture is extremely low and unstable at present. Therefore, if the water stored in the mountain region of the Sai Yai River were to be utilized for downstream agriculture, it will become possible to cultivate abundant agricultural crops throughout the year.

The highway leading from Bangkok to the Cambodian border passing Nakhon Nayok and Prachinburi, is used to reach Kabinburi, the entrance to the project site; a distance of approximately 150km from Bangkok. From here, the route heads north along the Sai Yai River. From Kabinburi, passing Khok Kachong, a distance of approximately 35km can be negotiated by automobile, but after that only passage on foot is possible.

Fortunately, up to the No. 2 Dam site, a path is being cut under the direction of NEA and the base camp can be reached on foot in slightly less than a day. The area along the way is covered with jungle and the visibility is poor. However, NEA has already begun work on an access road so that in the near future access to the project area will involve no difficulties.

4.1.2 Geology

(1) Topography

The Project Area is located at the southwestern margin of the Korat Plateau. The Korat Plateau is spread out over the northeastern part of Thailand and comprises approximately 1/3 of the entire area of the country. This plateau is adjacent to Laos on the north and east across the Mekong River while it is bordered by the Petchabun Mountains and the flat-topped peaks of Dong Phaya Yen to the west and the Sam Kam Phaeng Mountains and the Don Red Scarp to the south.

The Project Area, or the Nam Sai Yai and Nam Sai Noi Basins, is a gently undulating tableland between 300 and 900m in elevation. The surface of this tableland presents a flat topography while on the southwestern and northeastern sides there are steep cliffs of 100 to several hundred meters in height, and the area comprises a horst extending in a northwest to southeast direction.

The channels of the Nam Sai Yai and its tributary, the Nam Sai Noi, are governed by the geologic structure and have a close relationship to strike and dip and weak lines of strata.

The river gradient of the Nam Sai Yai is steep in the upstream and downstream portions with rapids and waterfalls here and there, but in the midstream portion corresponding to the reservoir area, the gradient is extremely gentle.

(2) Geology

The Korat Plateau is at the outer zone edge of the Cambodian Mass which comprises the nucleus of the Indosina Peninsula. The basal rock is the Korat Group belonging to the Mesozoic Era mainly consisting of sandstone, siltstone and shale with conglomerate found in parts. These strata are layered in exceedingly gentle dip and folded with very gentle undulating due to the Later Cimerian Activity of the Burmese-Malayan Orogene it shows very gently undulating folding.

(3) Rock Type

Sandstone is either fine-grained or coarse-grained, but conglomeratic portions can sometimes be seen. Fresh rock is gray to dark gray, but weathered sections have been changed to yellowish brown or reddish brown, while at flat areas it is frequently seen to have been subject to lateritization. Due to differences in grain size and cementation the resistivity to weathering differs and although surface rock may be dense and hard, deeper sections partly may show increased absorption or be in the form of weak beds. The general hardness of the sandstone is about the degree of whetstone and fresh rock is almost impermeable.

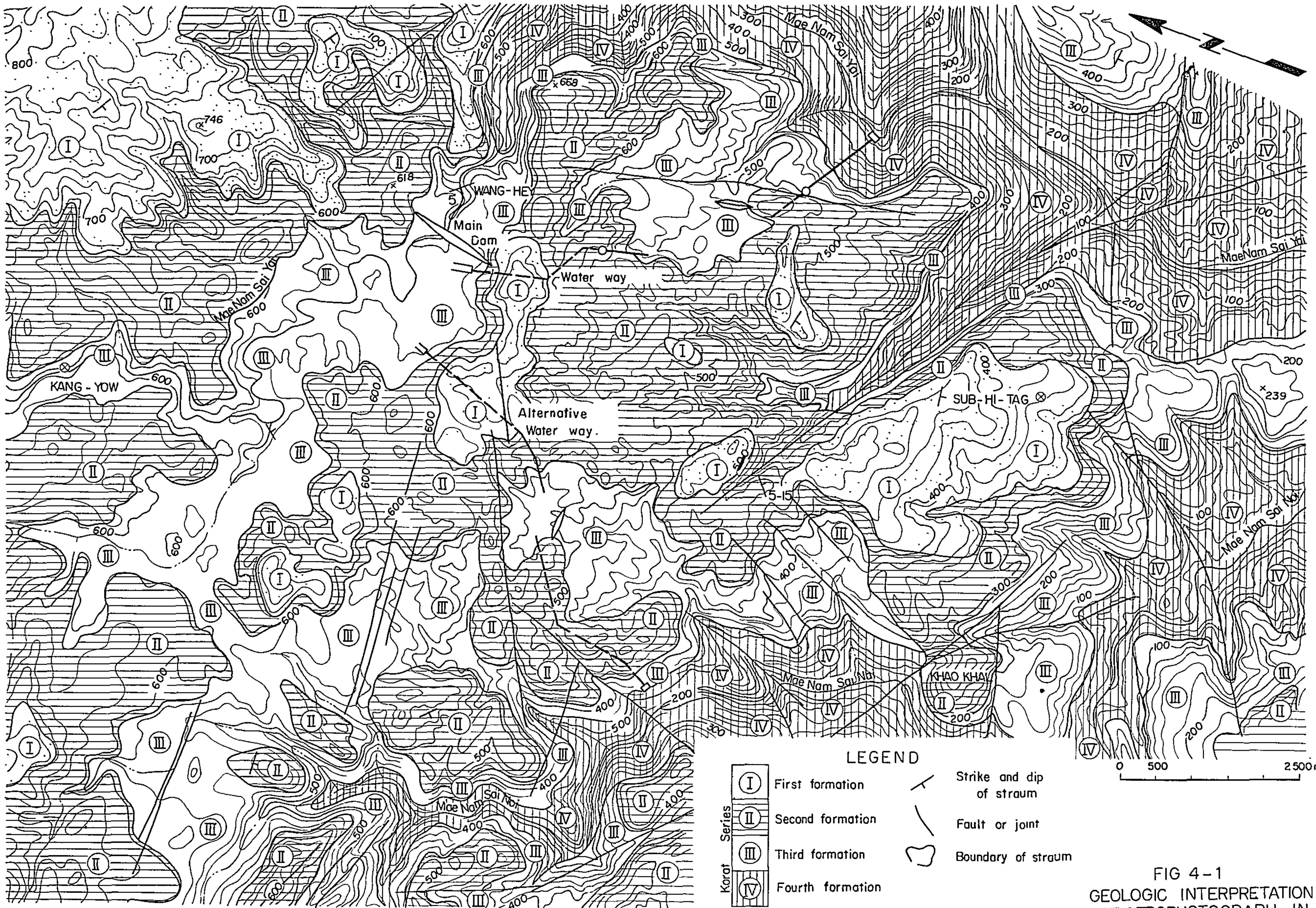


FIG 4-1
GEOLOGIC INTERPRETATION OF AEROPHOTOGRAPH IN PROJECT AREA

Remarks ; These formations are mostly constituted of sandstone and localy inserted with thin beds of shale and conglomerate
This division shows the difference of rock facies, but not follows the kinds of rock.

The surface of the sandstone shows development of vertical joints and cracks. It is not infrequent that weathering action has extended deeply along these joints and cracks, further progressing in a horizontal direction along bedding planes and weak layers so that the hard sandstone at the surface is at times drifting mass or a bed rock consisting of alternations in sandwich form of hard and soft rock is seen.

In the weathering process, the sandstone tends to be disintegrated to sand directly from the rock mass, and therefore, river deposits are scarce in gravel.

Conglomerate is often found in boulder form in the southern part of the Project Area, but outcrops cannot be seen. The pebbles are chiefly siliceous rock of finger tip size and as the matrix is loose in general, the rock disintegrates readily due to weathering.

Siltstone and shale have been changed to soil at the surface by weathering and in comparison with the distribution, there are extremely few outcrops. Fresh rock is in most cases dark gray, but at times it is chocolate color or dark green. The resistivity to weathering is poorer than in the case of sandstone and there is some siltstone with air-slaking properties.

(4) Stratigraphy and Geologic Structure

Fig. 4-1 has been prepared based on aerophotography taking into account results of surface reconnaissance and core borings and indicates distribution of rock facies and geologic structure.

The first formation roughly covers the flat top and would be of comparatively thin sandstone and fine sandy material covering this sandstone. The second formation and third formation appear to be alternations of siltstone and sandstone with siltstone predominating in the former formation and sandstone in the latter. The fourth formation appears to be massive sandstone.

Marcroscopically, the strata appear to dip extremely gently in a southwestern to southern direction and present gently undulating folds. Nowhere is there any extreme folding. Although, no large faults are seen, there are joints and cracks. Of the weak lines, the one from the vicinity of Mt. Khao Khal to the upstream part of the Nam Sai Noi appears clearly to be a fault.

(5) Alluvium

The mountain land of the Project Area is covered by shallow weathered residual soil with few rock outcrops. This weathered residual soil, is chiefly silty fine-grained sand, but in places is clayey. In places of flat terrain, lateritization, although weak, has occurred and grains or nodules of laterite are seen in the soil.

There are numerous river and flood plain deposits within the river. basin. Almost all of these deposits are composed of fine-grained sand with gravel being deposited only very locally. Also, most of the gravels are small in size.

(6) Geology of Structure

Main Dam (See Appendix Fig. B-1)

1. Rock is exposed at the river bed portion of the dam site, but on the mountainside portions on both banks there are no rock outcrops. According to information from core borings and auger borings, the thickness of overburden is 4.5m to 9.3m generally being 6m.

2. The dam site is composed of strata which is chiefly sandstone. However, near core boring Hole-7 on the left bank and Hole-2 on the right bank, siltstone is developed. While at both wing sections, near Hole-8 to Hole-9 on the left bank and Hole-1 on the right bank, a strata chiefly of sandstone is distributed underneath thin siltstone. According to these geologic conditions, the siltstone appears to exist in the form of lenses.

3. Of these rocks, sandstone is generally speaking in sound condition, but siltstone is easily weathered and the surface portion is a weak layer from 2 to 5m thick. Also, on the left bank at core borings Hole-1 and Hole-2, there are fine-grained sand and siltstone with air-slaking properties underneath the weathered strata. These airslaking rocks require special consideration in construction.

4. The strata generally shows strike of NW-SE and dip of $5^\circ - 10^\circ$ SW. Besides prominent joints of N 10° W strike and near vertical dip, cracks are developed and the rock has been transformed into blocks in some places by weathering occurring along these cracks and joints. The weathering action has at times progressed in a horizontal direction so that sound blocks of bed rock are found on top of weak strata. Also, in the bed rock in the river bed, there are numerous potholes of diameters of several tens of centimeters to more than a meter. However, it does not appear there are large-scale faults.

5. According to water leakage tests carried out utilizing core boring holes, prominently permeable strata cannot be found except in weathered rock near the ground surface. However, for weak horizontal strata and rock with airslaking properties, special considerations must be given in grouting.

6. Of dam construction materials, it is thought soil materials can be found near the damsite. However, regarding concrete aggregates, as river bed gravel deposits are scarce and the distribution of sound sandstone is limited, further thorough surveys should be made.

(7) Powerhouse and Headrace (See Appendix Fig. B-1 – B-6)

1. As a result of comparison studies of proposed A-line Alternative, B-line made by reconnaissance and core borings, proposed scheme was adopted as the electric power and agricultural development projects would be of about the same scale, the geologic conditions are somewhat better, the tunnel length is considerably shorter and savings in construction costs can be realized.

2. The core borings made amounted to 13 holes with a total length of 227 m for A-line and 22 holes with a total length of 415 m for B-Line.

3. The geology of A-Line is comprised of the Korat Group of siltstone, sandstone and alternations of these rocks. The headrace will generally pass through fresh rock. It does not appear air-slaking strata as seen in B-Line will be found.

4. Neither large-scale faults nor spring water can be seen in the vicinity of the waterway route of proposed scheme.

5. At the dam site for the regulating pond of proposed scheme, there is fresh, sound rock mainly consisting of siltstone on the left bank and sandstone from the river bed to the right bank. However, the overburden is fairly thick being approximately 9 m on the left bank, approximately 3 m at the river bed and approximately 4 m on the right bank. Near the abutment section at the right bank there is weathered rock of approximately 4-m thickness underneath the surface deposits.

6. Near the No.3 Power Station of proposed scheme, the thickness of surface deposits is approximately 5 m underneath which there is fresh, massive, sound, fine-grained to medium-grained sandstone. The slope of the penstock behind the powerhouse is approximately 20° and under present conditions this slope is stable. However, locally, there are spots which are fairly steep with some places being in the form of short rock cliffs. The thickness of overburden and weak, weathered strata is fairly great being as much as 10 m in places.

7. Although it should be possible to utilize excavation muck obtained when driving tunnels as concrete aggregate for waterway lining, there will be a considerable amount of siltstone and shale along the tunnel route and it will be necessary for further field investigations and laboratory test to be made regarding aggregates.

4.1.3 Climate and Rainfall

The project area has a tropical monsoon climate. From November to February, there is extremely little rainfall and moderate temperatures due to the northeast monsoon which brings cold, dry air from the China mainland prevail. 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. 4-2 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 at a 16 year average 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. 4-3 shows the distribution of monthly rainfall at observatories in the Sai Yai River Basin, on the basis of a 15 year average.

The isohyetal map of annual rainfall in the project area prepared on the basis of data from 1953 through 1967 is shown in Fig. 4-4. According to this map, the annual rainfall of the Sai Yai River Basin is about 2200 mm in the uppermost reaches and about 2100 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 monsoon.

4.1.4 River Runoff and Flood Discharge

River runoff and rainfall data in the project area are available for 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 this data, elaborated studies have been carried out to assess the river runoff and flood discharge of the Nam Sai Yai Project.

Details are given in Appendix A, Hydrological Study and Data. The annual runoff throughout the four years is 956 mm above Wang Heo, 1,027 mm above Ban Sapanhin, While the annual rainfall for the four years is 2,435 mm above Wang Heo and 2,115 mm above Ban Sapanhin.

According to the above figures, the runoff coefficient is about 40% above Wang Heo and about 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 the Sai Noi River, due to the river bed gradient which is gentle in comparison with that of the latter.

Besides, evapo-transpiration in the project area based on evaporation data and the Blaney-Criddle Formula is estimated to be about 1,300 mm, it also verifies that the runoff at 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 over the past fifty years, the period from 1953 to 1967, for which the estimated runoffs 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.

FIG. 4-2 MONTHLY TEMPERATURE OF PRACHINBURI (1952–1965)

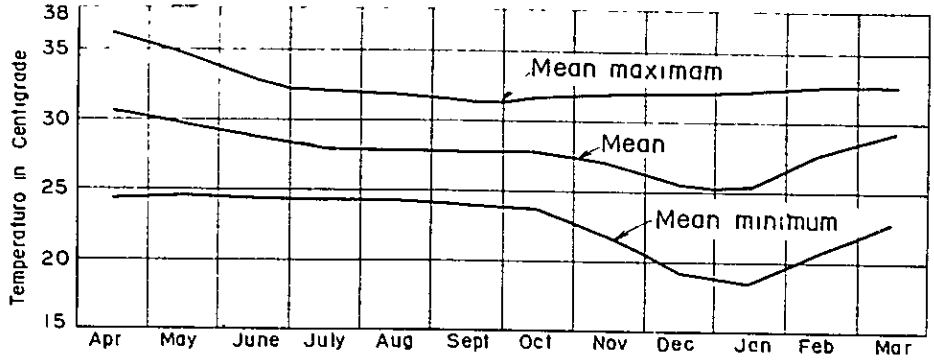


FIG. 4-3 MONTHLY RAINFALL IN SAI YAI BASIN (1953–1967)

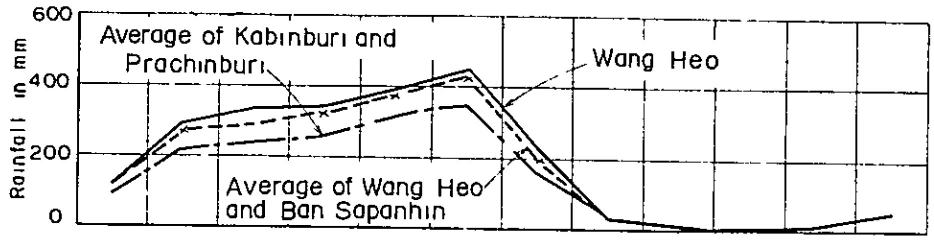
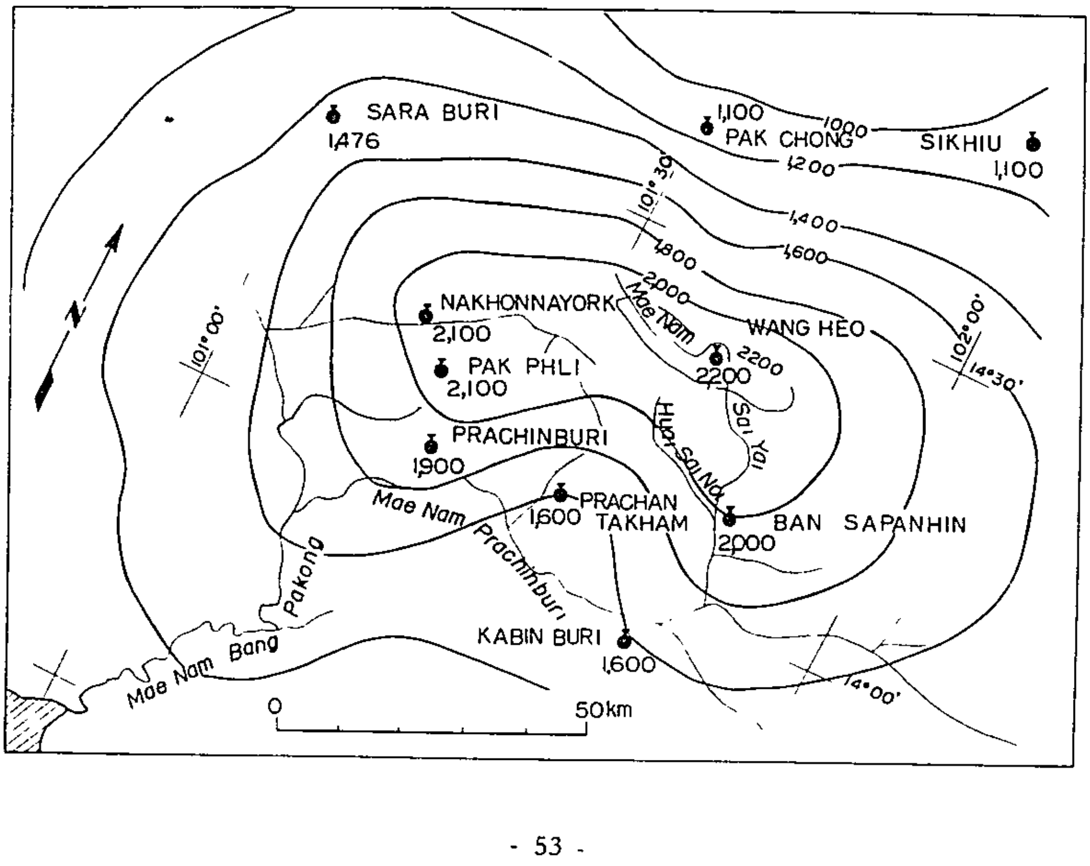


FIG 4-4 ISHOHYETAL MAP OF ANNUAL RAINFALL IN MM (1953 – 1967)



The average monthly runoff at the No.2 proposed dam site from 1953 through 1967, which provides the basis for reservoir operation study and energy production estimation, are as shown in Table 4-1. The values from Apr. 1964 through Mar. 1968 in this table were calculated on the basis of the runoff actually observed at Wang Heo Gaging Station and other values were estimated on the basis of Kabinburi and Prachinburi rainfall.

The probable maximum flood discharge at the No.2 Proposed dam site which is the basis for design of the spillway was estimated to be 780 c.m.s., according to the physical method. The maximum recorded flood in the past four years was 180 c.m.s. on August 18, 1966.

The flood discharge for various return periods estimated by Gumbel's and the Hazen-Foster Type 3 method is as follows.

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

According to the hydrograph prepared on the basis of past recorded floods, the duration of the probable maximum flood was estimated at about three days and the volume of flow at about 71 million cu.m.

The discharge and the hydrograph of the maximum probable flood which are to provide the basis for designing the spillway should be determined at the time of the definite studies. However, due to the large surface area of the Nam Sai Yai No.2 Reservoir, the only possible change in the discharge as well as the flood hydrograph as a result of definite studies would raise or lower the water surface level of the reservoir only by a few centimeters, and would not have any effect on the construction cost of the spillway.

Therefore, the aforementioned discharge and hydrograph can be used as the basis of the cost estimation for the feasibility studies.

The net balanced evaporation loss from the reservoir surface reduced by evapo-transpiration was assumed to be 500 mm per annum on the basis of the evaporation record of Wang Heo, evapo-transpiration estimated by the Blaney-Criddle Formula, and of the runoff and rainfall records at Wang Heo.

Sedimentation at the project site was assumed to be 300 cu.m per year per sq.km resulting in a total sediment encroachment of about 9 million cu.m in one hundred years, according to the empirical formula obtained from measurement of existing reservoirs in Japan.

4.2 COMPREHENSIVE DEVELOPMENT PLAN FOR NAM SAI YAI BASIN

The Nam Sai Yai Basin Development Plan features regulation of runoff by large-scale reservoirs and development of large amounts of electric power utilizing great heads, the regulated runoff would be further regulated for agriculture by an irrigation dam to be provided at the lowest point, from which the water would be conveyed to downstream waste land as well as cultivated land, thereby vastly increasing the agricultural production of this region. The Sai Yai River approximately 30 km upstream of its confluence with the Sai Noi River drops approximately 20 m in a waterfall. Below this waterfall, the river flows down a narrow gorge at a steep gradient and no suitable site for a dam can be found. Above the waterfall, the terrain suddenly opens up, and the river gradient is gentle. Taking advantage of the change in the topography, the point approximately 350 m upstream of the waterfall will be the site for the Sai Yai No. 2 Dam. A fill-type dam, 40 m high and 1,400 m long, will provide a reservoir with an effective capacity of 110 million cu.m. Downstream of the No.2 Dam, the favorable head will be utilized for diverting the river to build the NO.2 Power Station (maximum discharge 20 c.m.s, rated head 70.0 m, installed capacity 12,000 kW) and the No.3 Power Station (maximum discharge 20 c.m.s, rated head 333.3 m, installed capacity 58,000 kW). After power generation, the water will be returned to the Sai Yai River and upon providing an intake dam on the main stream, the water will be conducted by a tunnel to the No.4 Reservoir which will be constructed for irrigation purposes. The head to the No.4 Reservoir will be utilized to build the No.4 Power Station (maximum discharge 21.0 c.m.s, rated head 119.4 m, installed capacity 21,000 kW)

Above the No.2 Dam Site, immediately upstream of the No.2 Reservoir, the river gradient again becomes steep, but after about 10 km the valley again opens up and the gradient becomes gentle. Therefore, a dam site will be selected here and a fill-type dam, 40 m high and 400 m long will be constructed to provide a reservoir with an effective capacity of 90 million cu.m. The No.1 Power Station with maximum discharge of 10 c.m.s, rated head of 86.7 m and installed capacity of 8,000 kW will be built below the dam. It should be noted that if the head between the No.1 and No.2 Power Stations is fully used, the waterway construction cost will be exceedingly high, therefore, it was decided to build the powerhouse at a point about 4 km downstream from the dam.

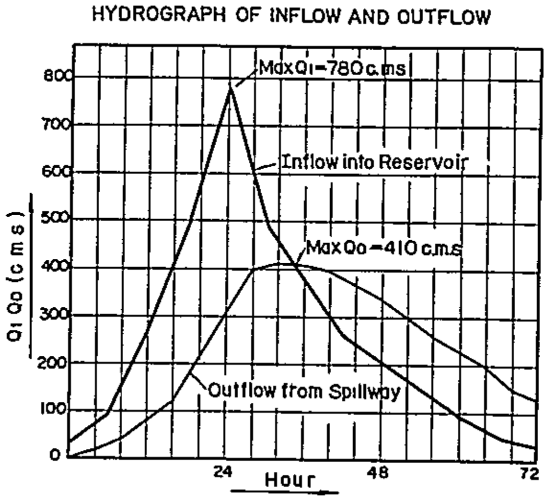
In establishing a final plan (A-Line), a proposal to divert the water from the No.2 Reservoir to the Sai Noi River, build a series of power plants (B-Line) instead of the main river and another proposal to build the No.2 and No.3 Power Stations as one were also examined. The economic comparisons of the former are as indicated in Table 4-2. While the considerations of the latter are described in detail in Chapter 7, Description of Structures and Equipments.

As a result of studies, the mainstream plan with two power stations was adopted.

As previously stated, by construction of the two reservoirs, the total effective capacity will be 200 million cu.m and utilizing the head of 687.5 m between EL 727.5 m and EL 40.0 m, it is proposed to secure an installed capacity totalling 99,000 kW and available energy per annum of 332 million kWh. The power generated at the power stations of the Nam Sai Yai is to be concentrated at the Nam Sai Yai No.3

FIG. 4-5

FLOOD CONTROL OPERATION OF NAM SAI YAI NO.2 RESERVOIR



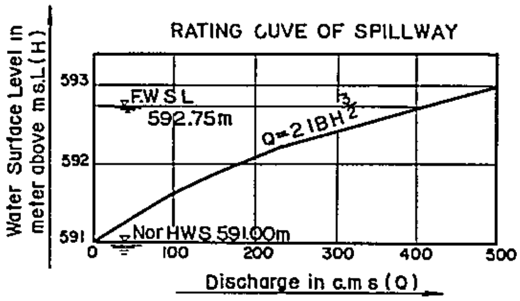
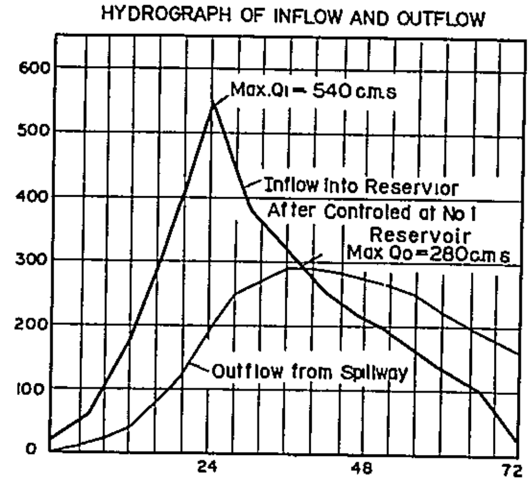


FIG. 4-6

FLOOD CONTROL OPERATION OF NAM SAI YAI NO. 2 RESERVOIR (WITH NO.1 RESERVOIR)



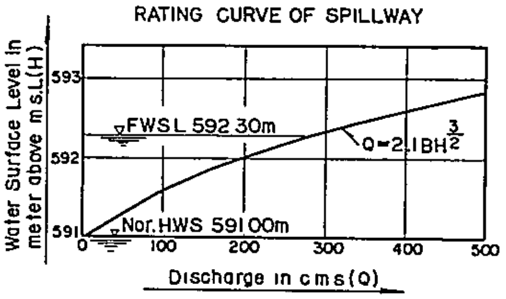
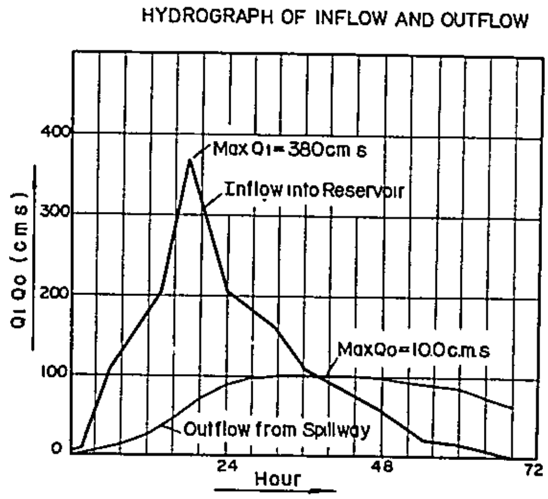
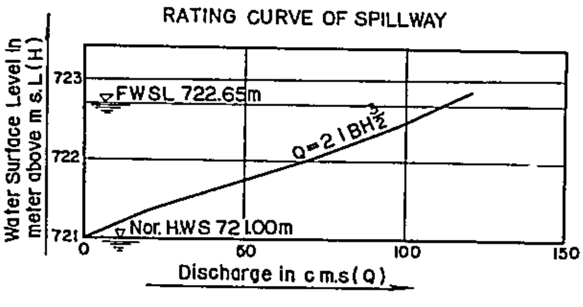


FIG. 4-7

FLOOD CONTROL OPERATION OF NAM SAI YAI NO.1 RESERVOIR





Power Station by a 115-kV transmission line and transmitted from there by a 2-circuit, 115-kV line to the Korat Substation.

Furthermore, the water regulated at these reservoirs can be utilized to irrigate 13,300 ha of farmland throughout the year by building a relatively small-scale reservoir for agricultural purposes (effective storage capacity 24 million cu.m).

On adopting the mainstream plan, the water of the upstream part of the Sai Noi River could be diverted to the Prachantakham River Basin and the water of the reservoir on the upstream part of this river managed for use in power generation and irrigation – the so-called Prachantakham Plan. Of these plans, the No.2 Dam and the No.2 and No.3 Power Stations which are economically the most superior are included in this Feasibility Report as the Nam Sai Yai No.2 and No.3 Projects.

4.3 SCHEME OF DEVELOPMENT FOR NAM SAI YAI NO.2 AND NO.3, PROJECTS

4.3.1 Power Generation

The Nam Sai Yai First Stage Project is comprised of the No.2 and No.3 Power Stations with the No.2 Reservoir as the backbone of the plan. The runoff of the Sai Yai River varies greatly not only seasonly, but also by year. Therefore, in order to utilize the water resources effectively, not only would it be necessary to store the rainy season water for discharge in the dry season, but also to store the waters of the wet years for discharge in dry years.

For the reservoir in this Project, as described in Chapter 5, it will be suitable to provide high water level of 591.0 m and effective storage capacity of 110 million cu.m a scale slightly smaller than the one proposed in the Reconnaissance Study. As for the location of the dam axis, the line mentioned in the Reconnaissance Study will be appropriate. The dam will be approximately 40 m high with a crest length of 1,346 m and a volume of 1,400,000 cu.m. Upon consideration of the topography, geology and construction materials for the dam, it was decided that a fill-type dam with two kinds of cross sections, one for the river bed and the other for both banks would be the most economical. On the left bank of the reservoir, at three locations of low elevation, dikes will be provided. The spillway will be located at a depression at about 600 m on the left bank of the dam. For a maximum probable flood discharge of 780 c.m.s, after completion of the upstream No.1 Dam, a peak cut will be made by the No.1 and No.2 Dams so that at a surcharge of 1.3 m the spillway will have the capacity to discharge 280 c.m.s, while before completion of the No.1 Dam, the peak cut will be made only by the No.2 Dam so that at a surcharge of 1.75 m the spillway will discharge 410 c.m.s as shown in Fig. 4.5 – 4.7.

For river handling, a diversion tunnel with an inner diameter of 3.0 m and total length of 250 m will be provided on the right bank with only the dry-season runoff taken into account. Excavation and embankment of the middle portion of the dam will be completed in one dry season. The diversion tunnel will be provided with outlet valve at the plug for flushing sand or for emergency cases.

The intake to be built in the reservoir will be a tower type with no bridge, connection being made by a servicing boat.

Regarding the waterway system, a proposal to conduct water along the main stream and another to divert the water to the Sai Noi River were studies, and it was concluded that the former would be more economical. Particularly, if only the No.2 and No.3 Power Stations are contemplated, the mainstream proposal is far superior. Next, a proposal to eliminate the No.2 Power Station and instead, conduct water by a pressure tunnel to the site of the No.3 Power Station on the main stream where only one power plant would be built, and another proposal to conduct water directly from the intake by a embedded inclined penstock to an underground powerhouse and then discharge it by a long tailrace tunnel with its outlet at the No.3 Power Station site were considered. As a result it was decided to provide a No.3 Regulating Pond and two power stations.

The No.2 Power Station will be located at a point 410 m up the tailrace from the No.3 Regulating Pond. The powerhouse will be a semi-underground type with maximum discharge of 20.0 c.m.s and maximum installed capacity of 12,000 kW. Using one vertical shaft Francis type turbine, the annual energy production will be 40 million kWh. The power produced here would be raised to a voltage of 115 kV by a step-up transformer and transmitted to Korat Substation via the No.3 Power Station by a 115-kV transmission line. There would be by a one-man control system.

An inner diameter of 3.10 m was adopted for the tunnels after calculations on the smallest sum of the annual cost and the annual lost benefit due to lost head for the No.1 and No.2 Powers Stations combined. Surge tanks were selected to be the differential type in consideration of the stability of water surface.

For the No.3 Power Station, the head from the high water level of the No.3 Regulating Pond at 510.0 m to a point on the Sai Yai River at 170 m was utilized. This will be a power plant with a high head, maximum available water of 20.0 c.m.s, rated head of 333.3 m, maximum output of 58,000 kW and annual energy production of 190 million kWh making it the most economical power station of this river system. In other words, the No.3 Power Station will be the main power station in the entire Sai Yai River System and the power generated at the various power stations of the system will first be gathered here after which transmission will be made to Korat Substation. The powerhouse will be a surface type with 2 units each of a vertical shaft Francis turbine with a 29-MW output capacity and a 33-MVA generator. There will be by a one-man control system with all machinery and equipment controlled from the control room. The outdoor switchyard from which a 115-kV, 3-circuit (ultimately 4 circuits) line will be led out will be long and narrow due to the topography.

The penstock line of the No.3 Power Station will be approximately 1,400 m long and comprises the most important part of this power development program. The headrace tunnel and the surge tank are similar to those of the No.2 Power Station.

4.3.2 Transmission and Communication Systems

The power generated at the Nam Sai Yai No.2 and No.3 Power Stations, as shown in Fig. 3.1, will be transmitted to the Korat Substation of the NEEA System by constructing a new 115-kV transmission line where it will be connected to the NEEA and YEA Systems. The voltage of this transmission line was selected to be 115 kV in view of interconnection with existing power systems. Along the 4 kilometers between the No.2 and No.3 Power Stations there will be a 115-kV, 1-circuit line, while along the 105 kilometers between the No.3 Power Station and Korat Substation there will be a 115-kV, 2-circuit line of a neutral point direct grounding, 3-phase, 3-conductor type. The conductors will be 240 sq. mm ACSR, and the supporting structures will be galvanized steel towers.

The transmission line will be routed as near to roads as possible for convenience of construction and maintenance.

At the Korat Substation, the 115-kV bus line will be extended and switches, circuit breakers, outdoor steel structures necessary for the outgoing 115-kV, 2-circuit transmission line will be increased.

Two circuits power line carrier telephone apparatus will be provided between Korat Substation, and the Sai Yai No.3 and No.2 Power Stations for load-dispatching and general business purposes. For line maintenance, a communications circuit comprised of VHF radio apparatus will be provided.

Further, a transmission line fault locator apparatus will be provided for quick elimination of trouble. The communications systems are indicated in Fig. 4.8.

FIG. 4-8 TELECOMMUNICATION SYSTEM DIAGRAM

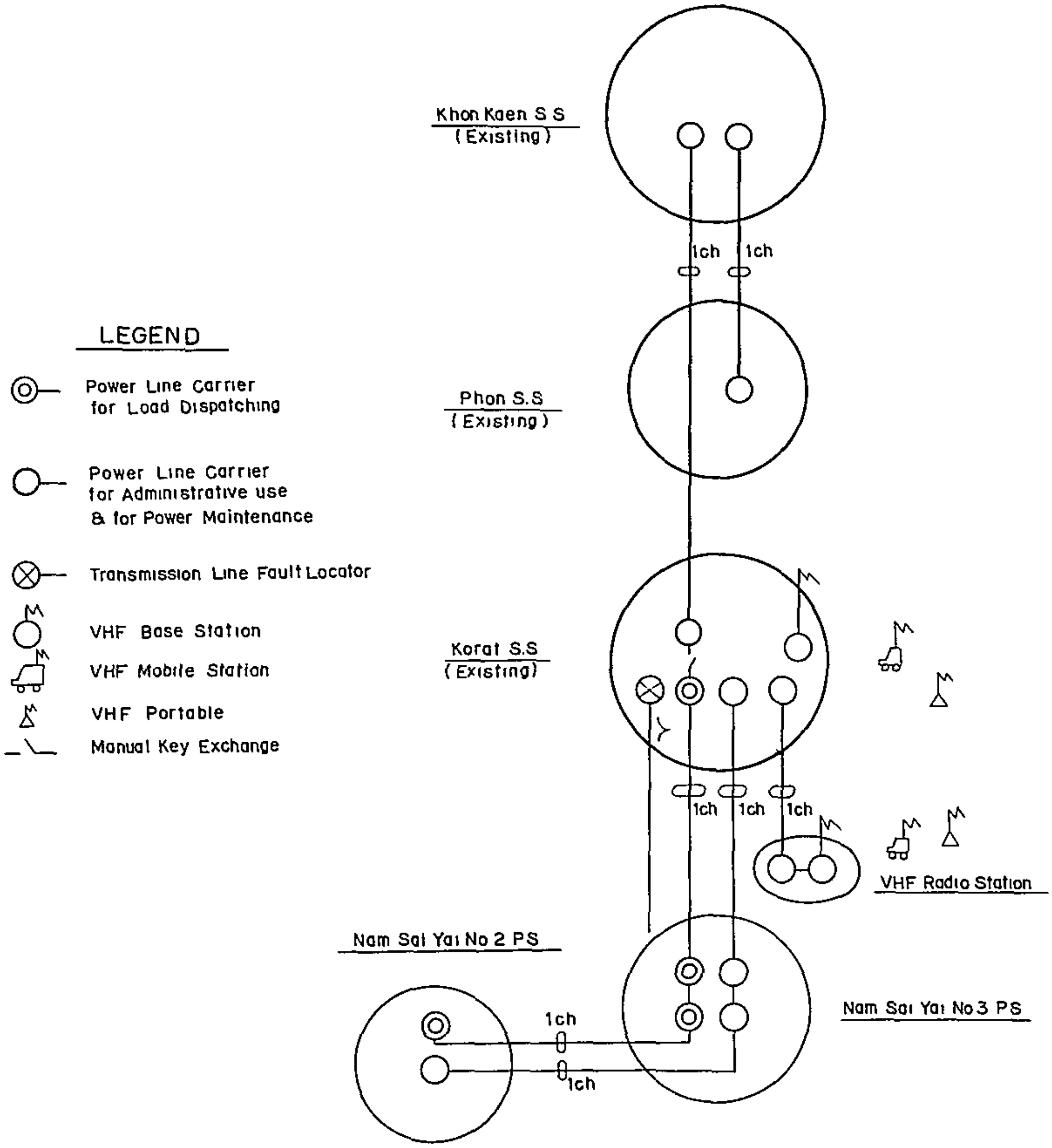


TABLE 4-1 Average Monthly Runoff at No. 2 Dam Site
(Catchment Area: 295 sq.km)

Unit: c.m.s

Year	Apr.	May	June	July	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) * Runoff observed actually
(2) Other values were estimated on the basis of Kabinburi and Prachinburi Rainfall.

TABLE 4-2 Economic Comparison between Mainstream Plan (A-Line) and Diversion Plan (B-Line)

Item	A-Line	B-Line
Construction Cost		
No. 2 Dam	98,000	98,000
No. 2 Power Station	138,400	132,000
No 3 Power Station (Including No. 3 Regulating Pond)	186,600	220,000
No. 4 Power Station	174,500	205,000
Total	597,500	655,000
Annual Cost	43,900	48,100
Annual Benefit		
No 2 Power Station	8,800	9,800
No. 3 Power Station	37,800	33,600
No. 4 Power Station	11,700	14,000
Total	58,300	56,900
Surplus Benefit	14,400	8,800
Benefit Cost Ratio	1.32	1.18

CHAPTER 5

RESERVOIR

FIGURES

TABLES

CHAPTER 5. RESERVOIR

5.1 OPTIMUM SCALE OF RESERVOIR

5.1.1 Basic Consideration

For the reservoir of the Nam Sai Yai No.2 and No.3 Projects, two cases were studied, case A with one dam at Wang Heo and case B with two dams, one at Wang Heo and the other at a site (hereinafter called R-1), 31 km upstream from Wang Heo.

Although Wang Heo is a favourable site in regard to geological and material conditions, there is the disadvantage of having to dike two or three sites around the reservoir in case the reservoir surface level is over 590 m. On the other hand, R-1 is a favorable site as it is ravine and the reservoir has a considerably large capacity; however the catchment area is small. If only the catchment area is taken into consideration for selection of the dam site, in general, Wang Heo is more economical. However, since R-1 is a topographically favorable site, the optimum scale in many combination of development of two reservoirs was studied.

Normal high water surface level of the two cases were compared. The measurements of the dam at Wang Heo were 595 m, 591 m, 587 m and 583 m for case A. Three measurements at R-1: 630 m, 627.5 m and 625 m combined with those at Wang Heo gave twelve cases for the case B. Also made was a comparison between the Nam Sai Yai No.2 and No.3 Projects developed as an isolated project and development of the upstream and the downstream projects in succession taking into account the total effect of the entire river basin development.

The conditions upon which the analyses of the scale of development were made are as follows.

(1) The dependable peak capacity and annual energy production used throughout the comparison of the respective plans of development were calculated on the runoff data of Wang Heo actually observed and that assumed on the basis of the rainfall at Prachinburi and Kabinburi covering a period of 15 years.

(2) The runoff expected to be available at the upstream project was presumed on the basis of the above runoff multipled by ratio of the catchment areas. The runoff for the downstream project was assumed on the basis of the runoff of Ban Sapanhin actually observed and the rainfall at Prachinburi and Kabinburi covering a period of 15 years.

(3) Effective storage capacity of the reservoir and available discharge for power in each plan of development were determined by the use of a residual mass curve which gives maximum energy production. In the calculation of the available discharge, an annual net balanced evaporation loss of 500 mm from

the reservoir surface was considered. However, when the reservoir water surface is near the minimum water surface, it is as same as the dry season, and since rainfall cannot be expected, a margin capacity of 1 m was taken as the emergency reserve.

(4) Calculation of the reservoir storage capacity was based on aero-topographic maps on a scale of 1:10,000 which were modified by actual survey maps.

(5) Installed capacity of each project was determined assuming a plant factor of 33 percent. Dependable peak capacity is the maximum output at minimum water surface level of the reservoir.

(6) The construction cost of each plan of development was estimated on preliminary designs made from actual survey maps of 1 : 2,000 for the No.2 and No.3 project and with the aid of aero-topographic maps on scales of 1 : 10,000 and 1 : 50,000 for the other projects.

(7) The criteria employed in the calculation of annual benefit and cost are described in Chapter 10, Economic Justification. Namely, the benefits of dependable peak capacity and energy are 300 Baht kW and 0.112 Baht/kWh respectively which correspond to the fixed cost and variable cost of the thermal alternative including import duty on fuel. The annual equalized cost factors of dam and generating facilities; and transmission lines, substation and telcommunication are 7.35 percent and 9.65 percent respectively.

5.1.2 Isolated Development of Nam Sai Yai No.2 and No.3 Projects

The general features of each alternative plan if the Nam Sai Yai No.2 and No.3 Projects developed as an isolated project are as shown in Appendix E-Table. E-1. Fig. 5-1 shows the relation between reservoir normal high water surface level (effective storage capacity) and surplus benefit, according to whcih the surplus benefit becomes maximum at a reservoir normal high water surface level of 591 m at the Wang Heo site. (See Appendix E Table E-2).

5.1.3 Development of Nam Sai Yai No.2 and No.3 Projects

Combined with Upstream and Downstream Projects

The influence of the upstream and downstream projects on the scale of development of the Nam Sai Yai No.2 and No.3 Projects was studied. The general features of the upstream and downstream projects are as shown in Appendix E-Table E-1

The study was made on the following assumptions:

(1) The downstream project (No.4 Power Station) and the upstream project (No.1 Power Station and Dam) will be developed in succession 4-years and 8-years respectively after the No.2 and No.3 Projects. The annual cost benefit of each project are, therefore, calculated on the current value converted at the time of completion of the Nam Sai Yai

No.2 and No.3 Projects, applying an annual discount rate of 6 percent.

(2) No compensation was made for reduced power generation at Nam Sai Yai No.2 and No.3 Projects due to reservoir filling during construction period of No.1 Reservoir.

Fig. 5-2 shows the relation between reservoir normal water surface level and surplus benefit. According to Fig. 5-2, the surplus benefit will be maximum when the reservoir normal high water surface level of the Nam Sai Yai No.2 Project is at an elevation of 591 m in case the entire Sai Yai River basin is developed. (See Appendix E, Table E-2, -3)

5.1.4 Optimum Scale of Reservoir

As described in the preceding paragraph, it is found that the surplus benefit will be maximum if the normal high water surface level is fixed at an elevation of 591 m at Wang Heo in case either the Nam Sai Yai No.2 and No.3 Projects are developed as an isolated project or in combination with upstream and downstream projects.

From the above mentioned examination, it is concluded that the plan to select the dam site for the No.2 Project at Wang Heo and to create a reservoir with a normal high water surface level of elevation 591 m would be the most economical.

The gross storage capacity, effective storage capacity and available drawdown for this scale of development are 140 million cu.m, 110 million cu.m and 15 m respectively. The regulated firm discharge in case the Nam Sai Yai No.2 and No.3 are developed as an isolated project or together with the upstream project are 6.4 c.m.s. and 7.3 c.m.s., respectively. The area-capacity curve and residual mass curve of the reservoir are shown in Fig. 5-3 and Fig. 5-4, -5.

5.2 RESERVOIR OPERATION

Inflow to the Nam Sai Yai No.2 Reservoir is estimated to be 348 million cu.m in a wet year, 252 million cu.m in an average year and 193 million cu.m in a dry year. The ratio of inflow between dry and wet years is 1 to 1.4, and there is considerable annual fluctuation. So far as in flow of any one year is concerned, approximately 90 per cent of the annual inflow is concentrated in the 6 months of June through November. Therefore, operation rule of the Nam Sai Yai No.2 Reservoir must be established so as to control such fluctuation of inflow to obtain a constant discharge and to minimize spillage. Fig. 5-6 is a reservoir operation curve obtained through trial-and-error method. If this reservoir operation is adopted for a period of 15 years for which runoff data is available, the available discharge for power, overflow and reservoir water surface level of Nam Sai Yai No.2 Reservoir will be as shown in Fig. 5-7. According to this figure the Nam Sai Yai No.2 Reservoir guarantees a firm discharge of 6.4 c.m.s. throughout the 15 year period, after deducting evaporation loss. Since this operation rule is of a tentative nature, a more elaborate rule must be prepared before actual operation of the reservoir.

FIG. 5-1 SURPLUS BENEFIT OF ALTERNATIVE SCHEME (ISOLATED DEVELOPMENT)

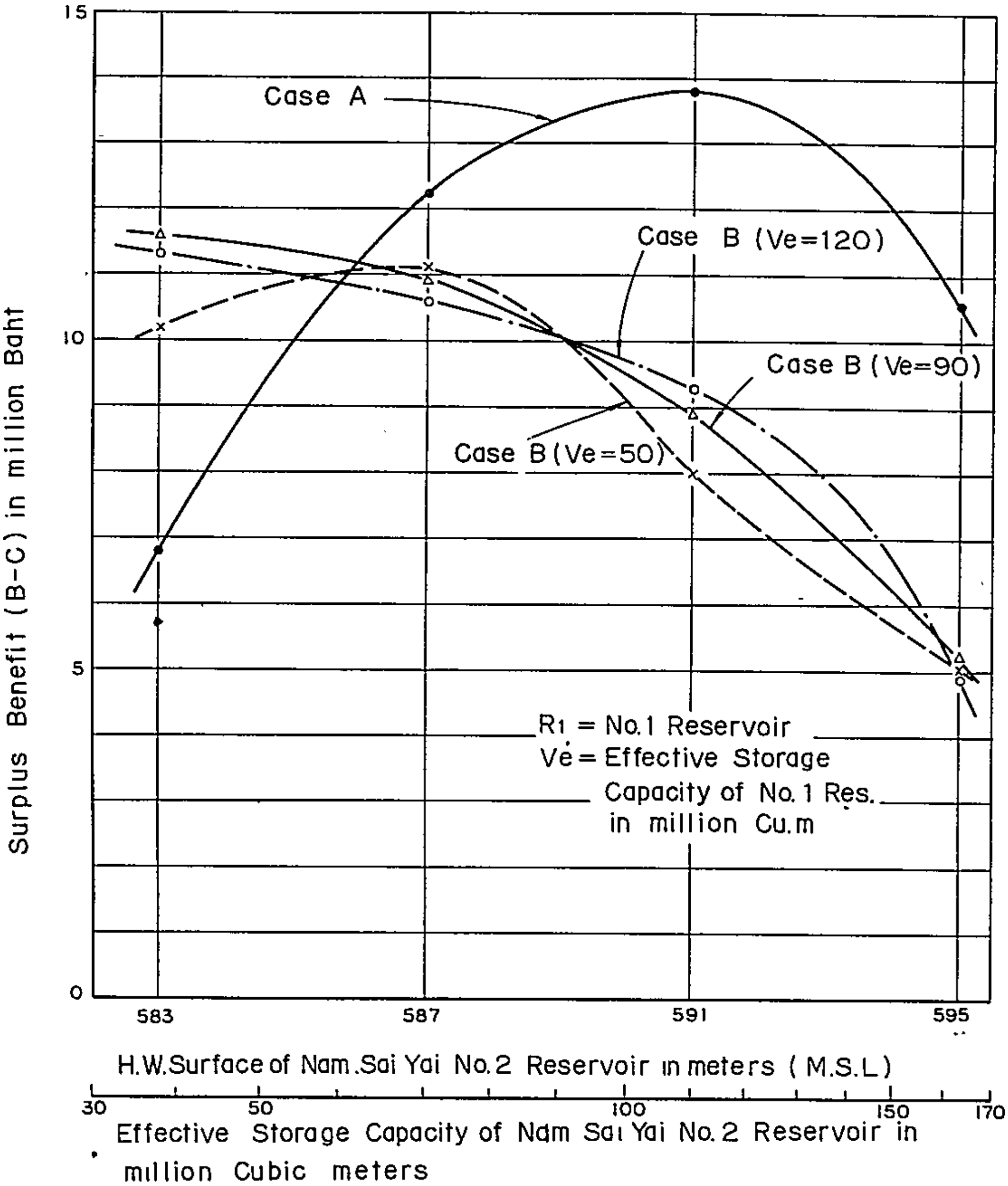


FIG. 5-2 SURPLUS BENEFIT OF ALTERNATIVE SCHEME (WITH UP AND DOWN STREAM DEVELOPMENT)

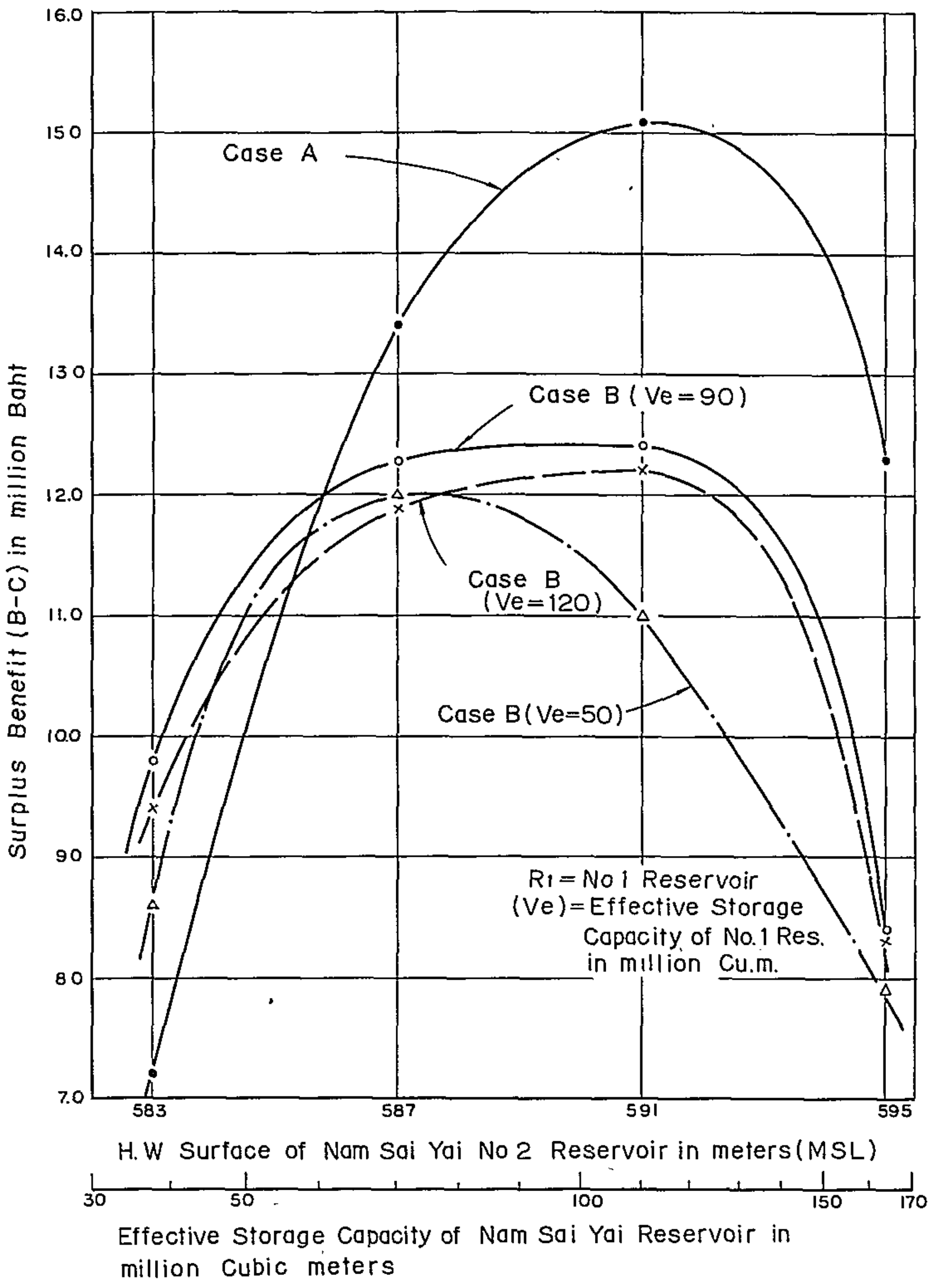
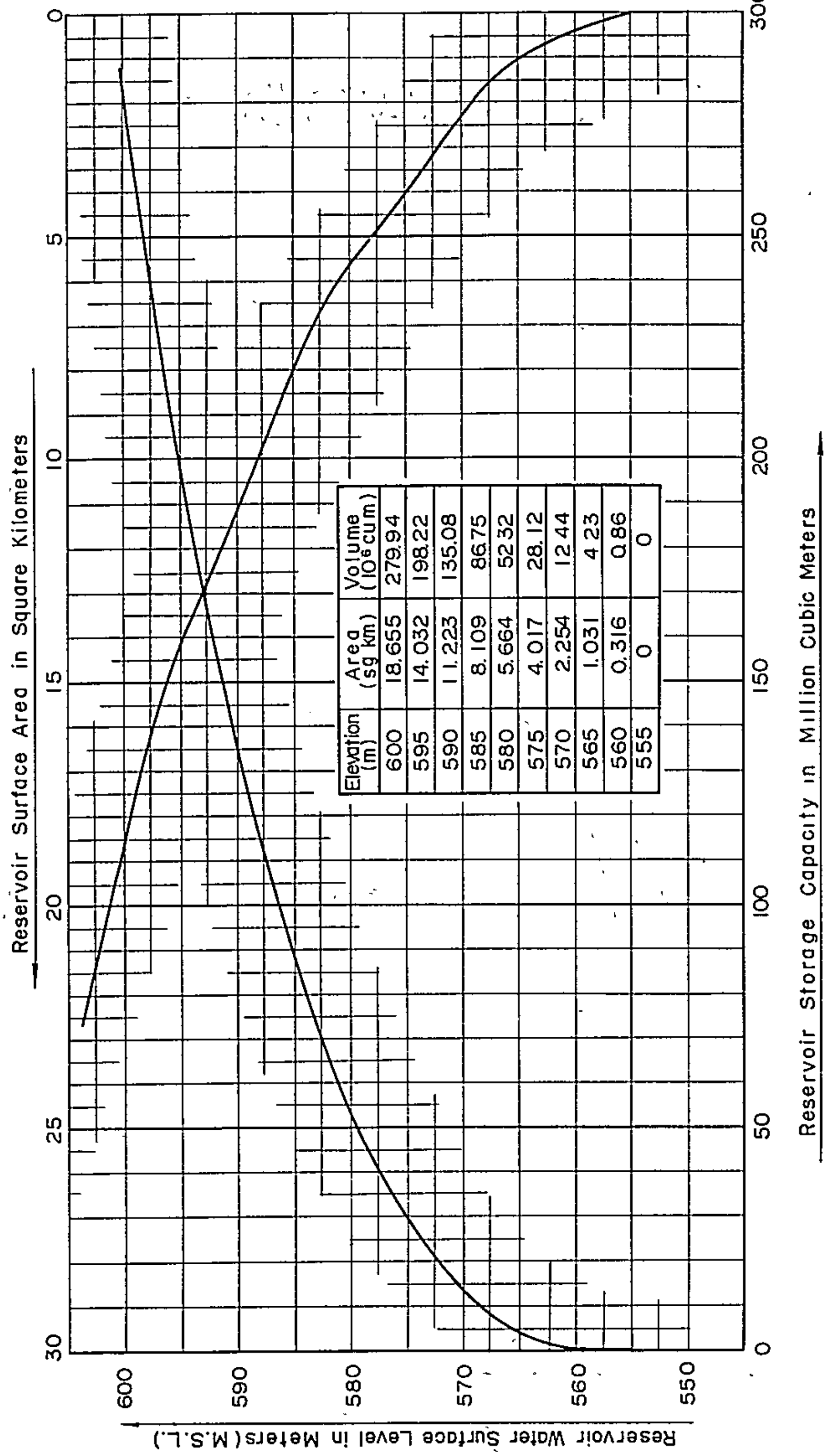


FIG. 5-3 AREA CAPACITY CURVE



Elevation (m)	Area (sq km)	Volume (10^6 cu m)
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

AND RESERVOIR PLAN FOR NO. 2 RESERVOIR

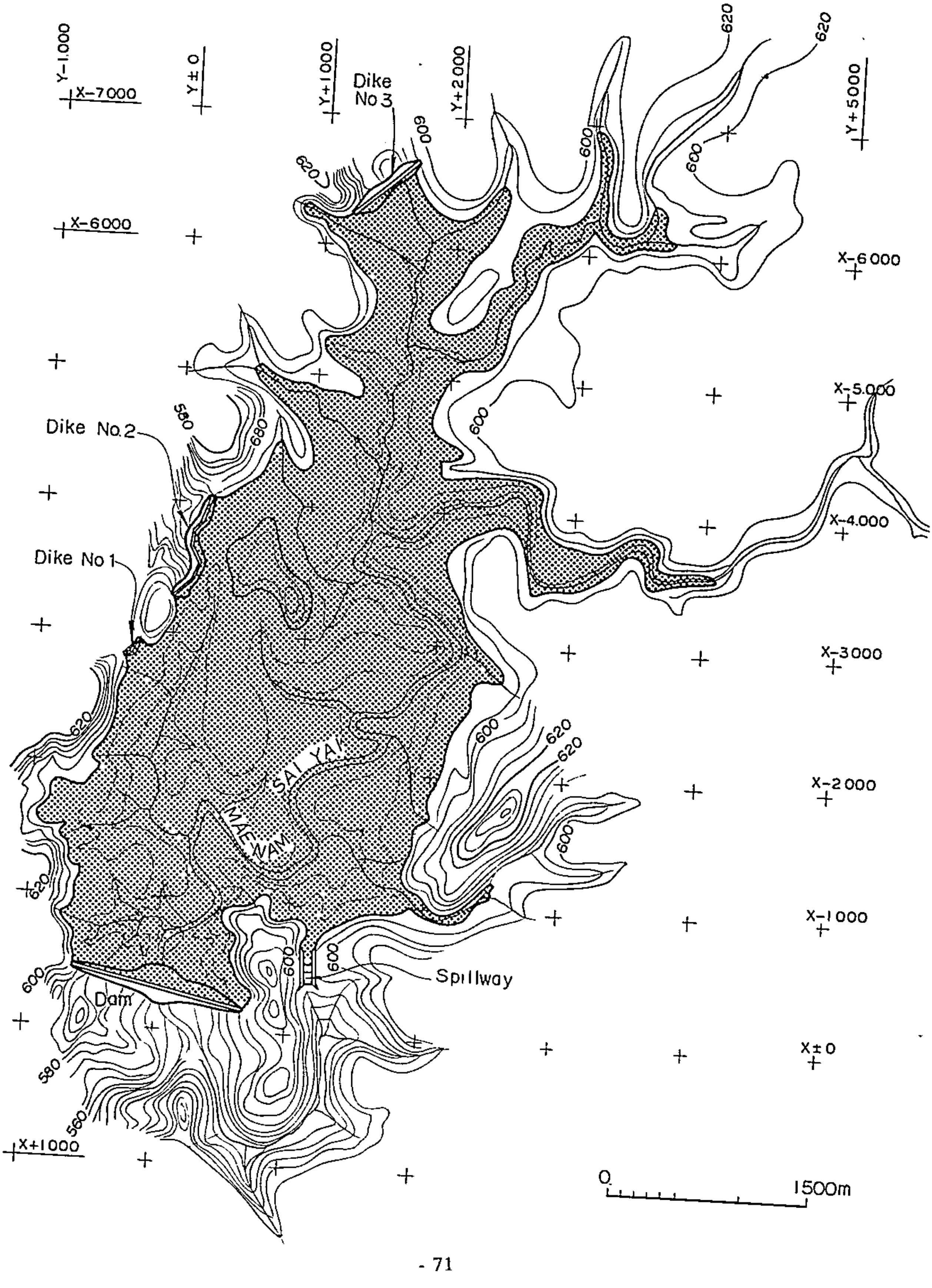


FIG. 5-4 RESIDUAL MASS CURVE OF NO. 2 RESERVOIR
(ISOLATED DEVELOPMENT)

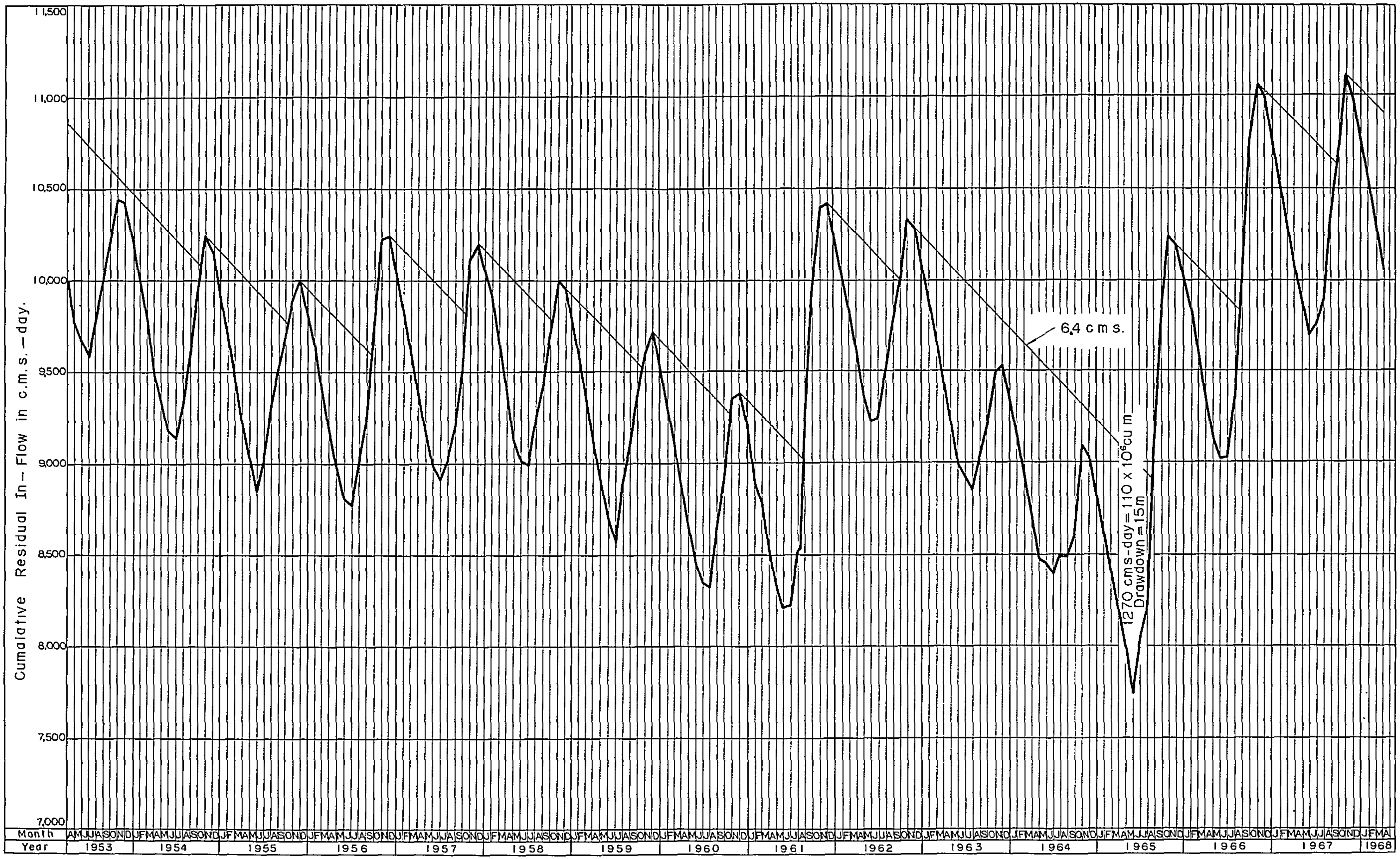


FIG. 5-5 RESIDUAL MASS CURVE OF NO. 2 RESERVOIR
(WITH UP AND DOWN DEVELOPMENT)

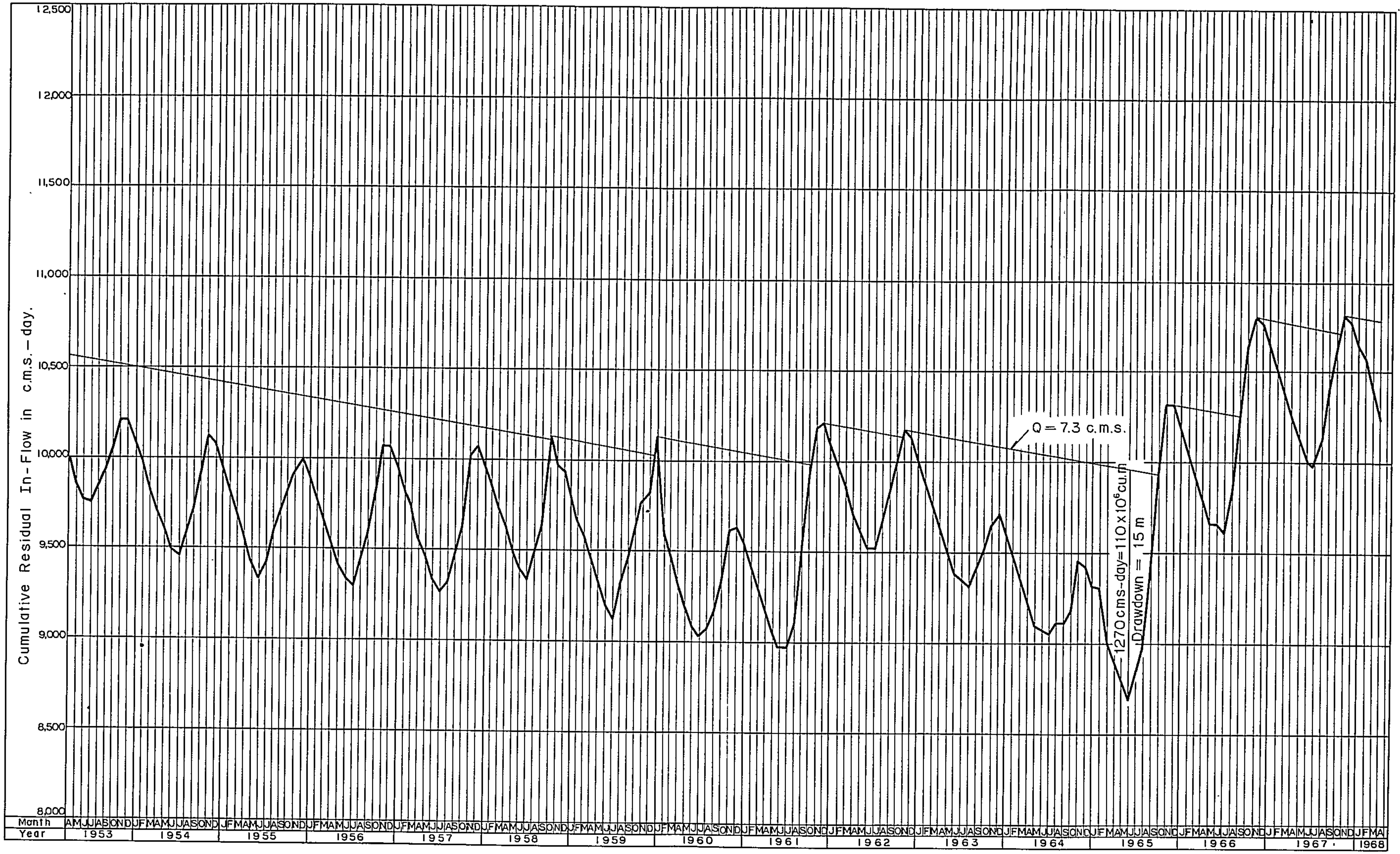
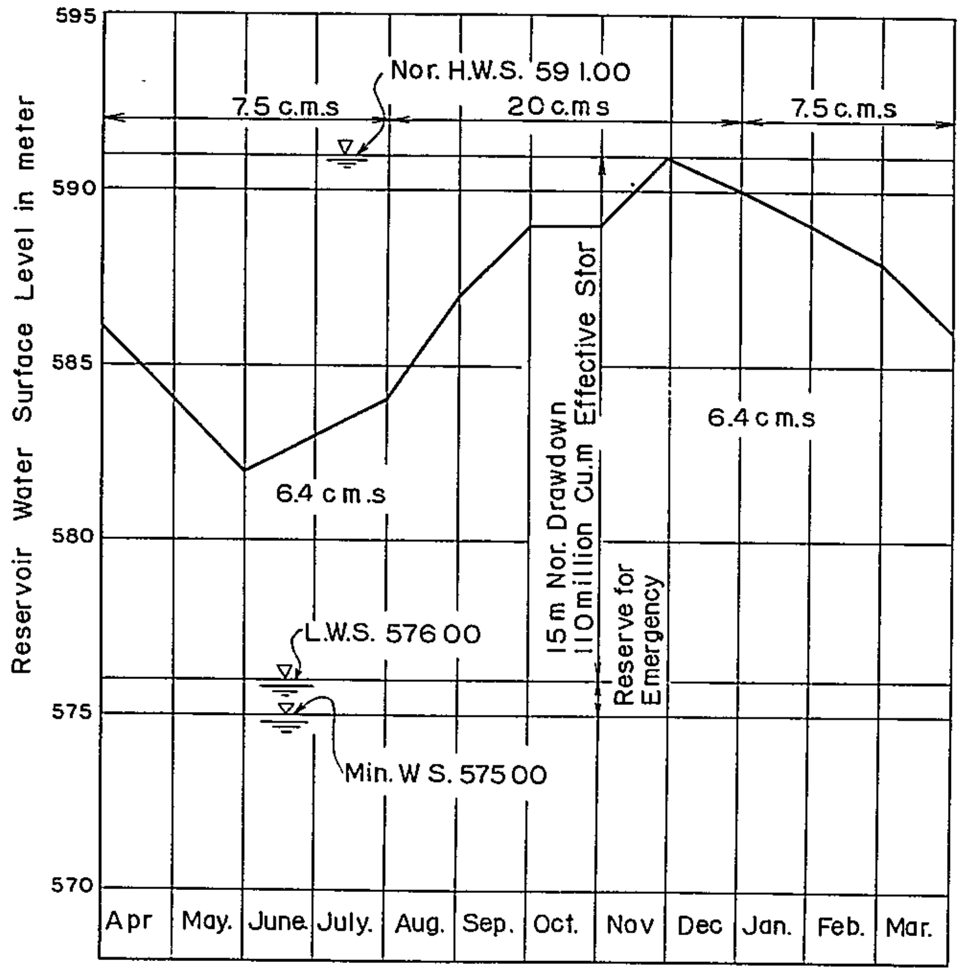


FIG. 5-6 TENTATIVE OPERATION RULE

Month	Hu m	Vu mill.Cu.m	Month
Apr.	584	530	Apr.
May	582	380	May.
Jun.	583	450	Jun.
Jul.	584	530	Jul.
Aug.	587	800	Aug.
Sep.	589	1.020	Sep
Oct.	589	1.020	Oct.
Nov.	591	1.270	Nov.
Dec.	590	1.150	Dec.
Jan.	589	1.020	Jan.
Feb.	588	900	Feb.
Mar.	586	700	Mar.



(1) Symbols (Unit: c.m.s.-Days per month)

Vn-1	:	Storage at the end of previous month
Vn	:	Storage at the end of current month
Hn	:	Reservoir water surface at the end of current month
Vu	:	Standard upper limit of storage at the end of current month
Vmax	:	Maximum storage
Vmin	:	Minimum storage
fn	:	Overflow in current month
Qu	:	Standard upper limit of runoff
QM	:	Standard runoff
qn	:	Inflow in current month
Qn	:	Discharge for power in current month
Qmax	:	Maximum discharge for power
Qs	:	Standard discharge for power
Ev	:	Evaporation loss

(2) Constants (Unit: c.m.s. per month)

$$Qu = \begin{cases} 20.2 \text{ (Sept. – Dec.)} \\ 7.7 \text{ (Jan. – Aug.)} \end{cases} \qquad Qmax = \begin{cases} 20 \text{ (Aug. – Dec.)} \\ 7.5 \text{ (Jan. – July)} \end{cases} \qquad Ev. = 0.2$$

$$QM = 6.6 \qquad Qs = 6.4 \qquad Ev. = 0.2$$

Basic Formulae (Storage Capacity)

$$Vmax \geqq Vn\text{-}1 + qn - Qn - Ev \Longrightarrow Vn = Vn\text{-}1 + qn = Qn - Ev$$

$$Vn\text{-}1 + qn - Ev > Vmax \Longrightarrow \begin{cases} Vn = Vn\text{-}1 + qn - Qn - Ev - fn \\ fn = Vn\text{-}1 + qn - Qn - Ev - Vmax \end{cases}$$

$$Hn = 576 + 0.181 \times Vn - 0.000005 \times (Vn)^2$$

(3) Operation Rule (Discharge for Power)

1. $Vn\text{-}1 + qn > Vu$

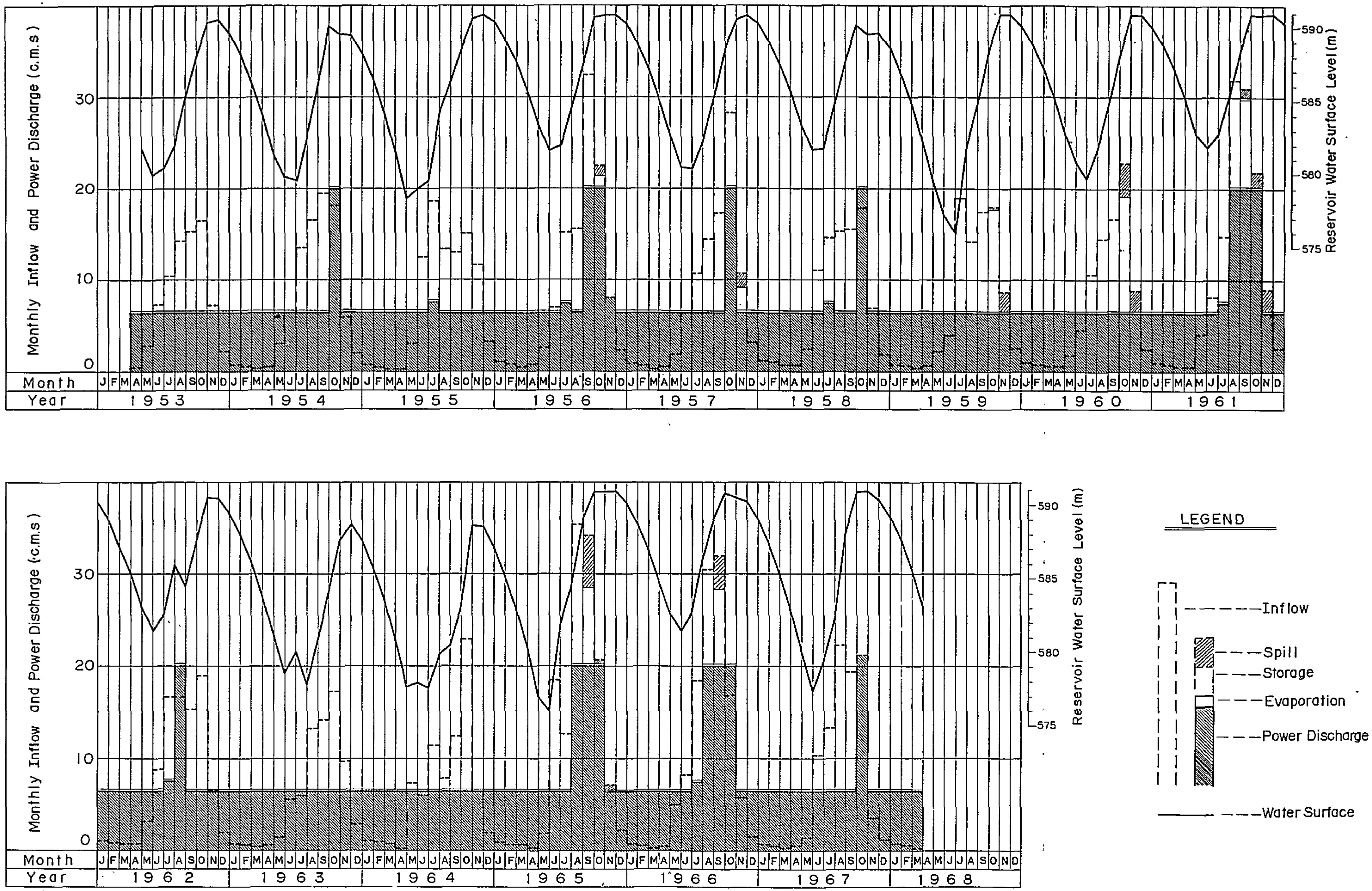
   (1) $Vn\text{-}1 + qn - Vu \geqq Qu \Longrightarrow Qn = Qmax$

   (2) $Qu > Vn\text{-}1 + qn - Vu > QM \Longrightarrow Qn = Vn\text{-}1 + qn - Vu - Ev$

   (3) $QM \geqq Vn\text{-}1 + qn - Vu \Longrightarrow Qn = Qs$

2. $Vu \geqq Vn\text{-}1 + qn \Longrightarrow Qn = Qs$

FIG. 5-7 INFLOW POWER DISCHARGE AND RESERVOIR WATER SURFACE



5.3 EFFECT ON THE DOWNSTREAM AREA

5.3.1 General

According to the operation of the Nam Sai Yai No.2 and No.3 Power Stations after completion of the No.2 Reservoir, the streamflow duration on the downstream area will be much improved.
Fig. 5-8 illustrates the hydrograph of the average monthly flow at the No.4 Dam site on the Sai Yai River after completion of the No.2 Reservoir in comparison with that before construction. According to this, the streamflow in a dry season (January–April) will be increased from 1.0 c.m.s. to 6.7 c.m.s.. Moreover, the flood flow at Ban Sapanhin Gaging Station on the Hanuman River just downstream of the confluence of the Sai Yai and Sai Noi will be reduced from 270 c.m.s. to 190 c.m.s. by completion of the No. 2, Reservoir.
These changes will act effectively on irrigation and flood prevention in the downstream area.

5.3.2 Irrigation

The land on both banks of the Hanuman River is being used mainly for paddy fields which have inadequate irrigation facilities, and the paddy rice is cultivated during the rainy season.

However, if there is enough water to be used for irrigation throughout the year, it is not only possible to expect increase in rice production but also the introduction of two-crop and even three-crop a year cultivation in correspondance with the increasing demand for rice and incentive of farmers.

Furthermore, on sandy soil at higher elevations, planting of profitable fruits will be introduced, since this land is relatively close to consumer areas. The effects of the Nam Sai Yai Hydro Power Project on the downstream area have been studied with the following 2 cases:

(1) The increased agricultural production by irrigation, for which water was diverted from the equalizing pond at the downstream of the Sai Yai River;

(2) The costs of the alternative irrigation project of which the irrigated area is the same as in case (1) if it is assumed that the hydroelectric power project is not implemented.
The studies were made of the irrigation projects in case (1) on the basis of cropping patterns as shown below.

(Unit : ha)

	Plan	Paddy Fields		Orchard	Upland	Grassland
		1st crop	2nd crop			
A	Present	6,300	–	–	–	–
	Planned	6,300	3,700	–	–	–
B	Present	5,300	–	300	700	700
	Planned	5,300	2,650	1,000	700	–
C	Present	5,300	–	300	700	700
	Planned	5,300	2,650	300	1,400	–
D	Present	5,300	–	300	700	700
	Planned	5,300	–	1,000	700	–

Note: The available water and the irrigation water requirement at the diversion site of Nam Sai Yai River were shown in Table 5-1.

TABLE 5-1 THE AVAILABLE WATER AND THE IRRIGATION WATER REQUIREMENT AT THE DIVERSION SITE ON SAI YAI RIVER

Month	Available *1 water c.m.s.	Irrigation water requirement *2		
		Plan-A c.m.s.	Plan-B, C c.m.s.	Plant-D c.m.s
1964				
Apr.	6.49	5.54	5.29	1.33
May	9.39	5.25	5.30	1.54
Jun.	12.39	0.81	0.95	0.63
Jul.	15.89	4.38	4.62	4.62
Aug.	26.49	7.13	6.58	6.58
Sept.	28.39	1.12	0.91	0.91
Oct.	28.19	6.22	5.95	5.95
Nov.	7.09	7.13	7.07	7.07
Dec.	6.69	3.98	4.62	4.62
1965				
Jan.	6.69	0.24	1.50	1.33
Feb.	6.69	2.74	2.80	0.84
Mar.	6.49	6.52	6.00	1.33

Note: *1 See Fig. 5-8.
*2 Irrigation water requirement was calculated according to the same criteria as shown in the Nam Sai Yai Basin Plan 6.4.3.

The annual benefit of each plan, with an interest rate of 6% for 50 years of serviceable life was estimated as follows.

(Unit: million Baht)

Plan	Paddy Rice		Fruits	Upland Crops	Total
	1st crop	2nd crop			
A	4.48	4.94	–	–	9.42
B	3.77	3.54	6.99	0.97	15.27
C	3.77	3.54	0.49	2.45	10.25
D	3.77	–	6.99	0.97	11.73

Note 1: Agricultural production and benefit were calculated according to the same criteria as shown in the Nam Sai Yai Basin Plan 6.8.2.

Note 2: The effect of flood control described in the following paragraph is included in the benefit of each plan.

The obtain these benefits, it is necessary to construct irrigation facilities such as diversion dam, main canal, laterial canals, etc. (See general plan and Fig. 5-9).

The construction costs were estimated to be 82,870,000 to 84,240,000 Baht as shown in Table 5-2. The annual costs throughout 50 years of serviceable life are estimated to be 7,740,000 to 7,870,000 Baht by applying a depreciation cost of 6.34% at an interest rate of 6% per annum, as well as a replacement, operation and maintenance cost amounting to 3% of the construction cost.

TABLE 5-2 CONSTRUCTION AND ANNUAL COST (Without Hydro-Power Project)

(Unit: million Baht)

Plan	A	B,C,D
Construction Cost		
(1) Irrigation Facilities	70.24	71.41
(2) Engineering Fees (3.5%)	2.46	2.50
(3) Administration Cost (4%)	2.91	2.95
(4) Interest during construction (n x 0.4 x 0.06) n = 4	7.26	7.38
Total	82.87	84.24
Annual Cost (Construction Cost x 0.0934)	7.74	7.87

From the results of estimates of costs and benefits, the surplus benefit was calculated as follows.

(Unit: million Baht)

Plan	Annual Benefit	Annual Cost	Surplus Benefit
A	9.4	7.7	1.7
B	15.3	7.9	7.4
C	10.3	7.9	2.4
D	11.7	7.9	3.8

If the hydro-power project is not realized, it is considered necessary to create a reservoir for irrigation at the confluence of the Sai Yai and Sai Noi Rivers.

The effective storage capacity of the reservoir corresponding to the irrigated area and cropping pattern, and construction costs including those irrigation facilities are given hereunder.

Plan	Irrigated Area *1 (ha)			Effective Storage of Reservoir (million cu.m)	Construction Cost for Irrigation (million Baht)
	Paddy Fields		Upland		
	1st crop	2nd crop			
A'	6,300	3,700	—	42	171.2
B'	5,300	2,650	1,700	46	177.6
C'	5,300	2,650	1,700	46	177.6
D'	5,300	—	1,7001	10	130.2

Note: *1 Detail of cropping pattern is the same as in case 1.

The annual cost of the above plans were estimated according to the same criteria as in case 1. The following is obtained as a result of comparison with the benefits estimated in Case 1.

Plan	Annual Cost (million Baht)	Annual Benefit *1 (million Baht)	Benefit-Cost Ratio
A'	16.0	9.9	0.59
B'	16.6	15.3	0.92
C'	14.8 *2	10.3	0.70
D'	10.9 *2	11.7	1.07

Note: *1 Annual benefit is the same as in case (l)
*2 Annual cost includes replacement, operation and maintenance cost accounting for 2% of the construction cost.

As mentioned above, the economics of the irrigation project without hydro power project is considered to be poor.

The comparison of the construction costs of case 1 and case 2 (See Table 5-3) has revealed that 46 million to 93.4 million Baht may be saved in irrigation costs when and if a hydro power-project is realized.

TABLE 5-3. COMPARISON OF THE CONSTRUCTION COSTS BETWEEN CASE 1 AND CASE 2

(Unit: million Baht)

Plan	(1) Case 1 With Hydro-power Project	(2) Case 2 Without Hydro-power Project	(2) – (1)
A	82.9	171.2	88.3
B	84.2	177.6	93.4
C	84.2	177.6	93.4
D	84.2	130.2	46.0

It was concluded from the above studies that the development of irrigation only is economically poor, if the hydro-power project is carried out, a construction cost for irrigation facilities may be saved and a surplus benefit of 1.7 million to 7.4 million Baht could be expected from the irrigation project in the downstream area.

5.3.3 Flood Control

Since the Nam Sai Yai No.2 Reservoir has a surcharge capacity of 31 million cu.m., the flood flow will be naturally controlled.

Flood control was studied on the basis of the maximum flood flow ever recorded at No.2 dam site as shown in Fig. 5-9 and 5-10. According to this figure, the flood flow at Ban Sapanhin Gaging Station would be reduced from 270 c.m.s. to 190 c.m.s., resulting in a peak-cut of the flood flow of 80 c.m.s.

It is expected from this that the water level around Ban Won Mon on the Hanuman River will be reduced about 0.8 meters, and about 200 ha of the paddy fields will be protected from inundation.

Although the damage caused by inundation differs according to the kind of crop, inundating season and inundating period, destruction of the rice crop is estimated to be about 50% based on field investigation studies and data in Japan.

In accordance with this figure, it was estimated that about 100 tons (or about 121,000 Baht) per year of damage to the rice crop will be prevented by flood control at the No.2 Reservoir.

FIG. 5-8 RIVER RUNOFF AND IRRIGATION RELEASE AT NO. 4 DAM SITE

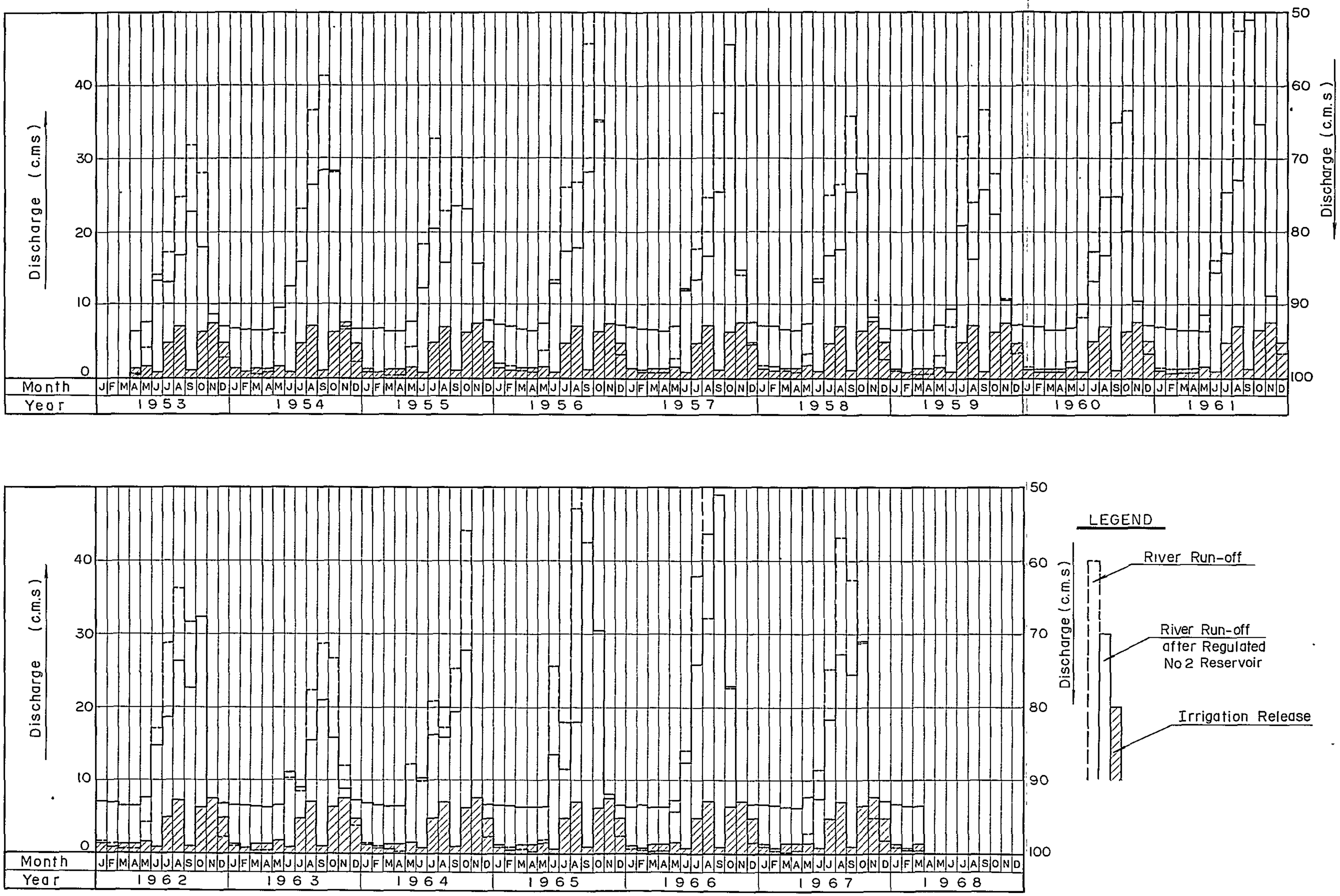


FIG. 5-9 IRRIGATION SYSTEM

NAM SAI YAI No 4 RESERVOIR

RIGHT BANK AREA
IRR. MAIN CANAL – 37.5 KM

Land Use Classification / Area in ha

Block	Station	Paddy Field	Upland	Others	Total
R-1	6+500	0	150	20	170
R-2	7+850	50	90	50	190
R-3	11+100	80	80	90	250
R-4	14+650	50	20	20	90
R-5	17+300	50	20	60	130
R-6	21+100	50	110	70	230
R-7	22+900	160	70	130	360
R-8	25+300	180	130	130	440
R-9	28+150	440	220	290	950
R-10	29+600		70	90	340
R-11	31+0	120	20	60	200
R-12	35+400	370	160	290	820
R-13	37+500	570	60	300	930

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

LEFT BANK AREA
IRR. MAIN CANAL – 26 KM

Land Use Classification / Area in ha

Block	Station	Paddy Field	Upland	Others	Total
L-1	5+750	220	210	250	680
L-2	7+700	130	100	190	420
L-3	10+0	130	0	40	170
L-4	12+700	380	0	180	560
L-5	15+0	140	0	30	170
L-6	19+0	180	0	50	230
L-7	20+300	800	20	330	1,150
L-8	23+700	100	30	40	170
L-9	25+0	700	60	260	1,020
L-10	26+0	220	80	130	430

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

Total

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

FIG. 5-10 FLOOD HYDROGRAPH OF WANG HEO (NO. 2 DAM SITE)

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

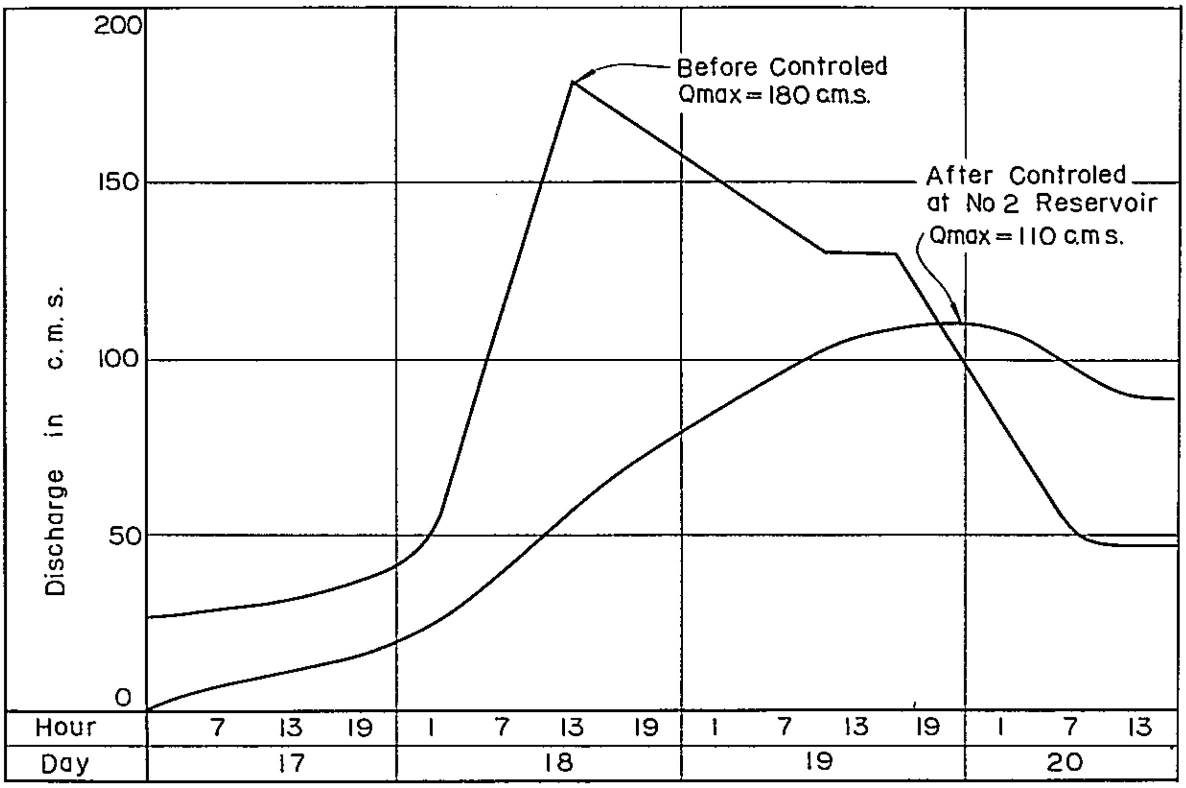
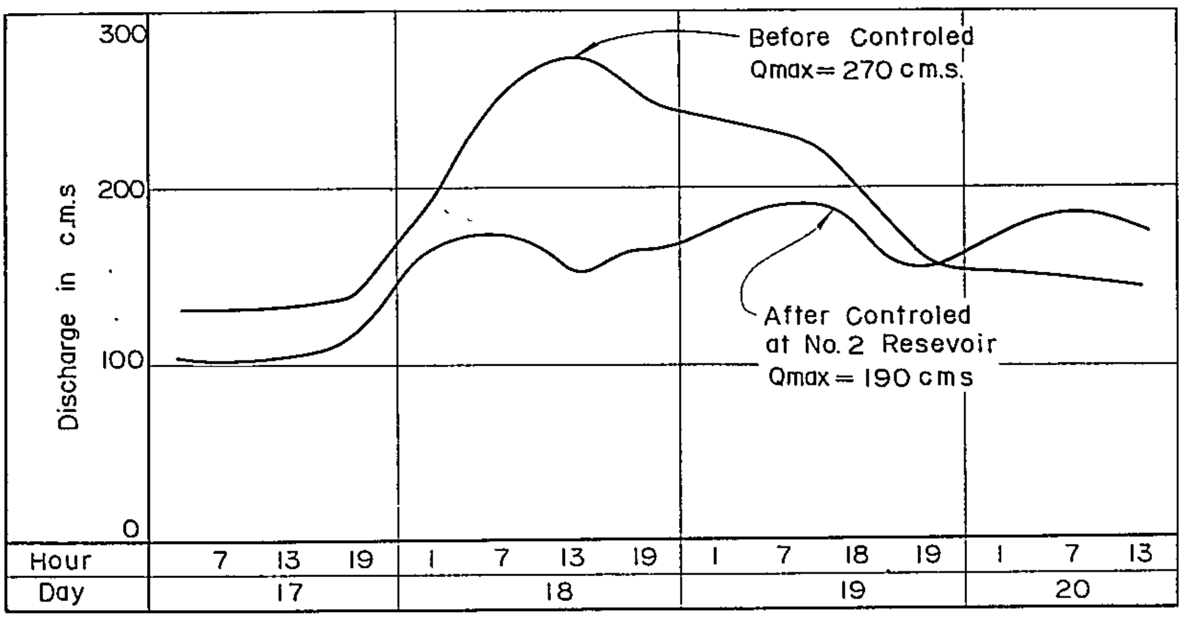


FIG. 5-11 FLOOD HYDROGRAPH OF BAN SAPANHIN

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



CHAPTER 6

POWER PRODUCTION

FIGURES

TABLE

CHAPTER 6. POWER PRODUCTION

6.1 FIRM AND CONTINUOUS POWER

As described in the preceding chapter, the regulated firm discharge of the Nam Sai Yai No.2 and No.3 Projects is 6.4 c.m.s.. Therefore, according to the proposed No.2 Reservoir low water surface level of 575 m and tail water surface level of 510 m for the No.2 Project, and the proposed No.3 regulating pond low water surface level of 507 m and the tail water surface level of 170 m for the No.3 Project, which corresponds to the regulated firm discharge, the firm power and continuous power for No.2 and No.3 Power Stations are calculated to be approximately 3,200 kW, and 18,000 kW respectively.

6.2 REQUIRED PLANT FACTOR

As described in 3.1.3, the severest conditions for power supply and demand are in the month of December.

A study was made of the operation patterns required of the Nam Sai Yai No.2 and No.3 Power Stations from 1972 to 1981 based on the daily load curve for a December weekday.

The result of this study is shown in Fig. 3-4. Nam Sai Yai No.2 Power Station will bear the peak load of the system and be operated for 3 years from start of operation in 1973 at a fairly high load factor of 45.7%, and from 1976 and thereafter, operation will be at the limit of the dependable peak supply capacity and the load factor will be lowered to 36.3%.

At Nam Sai Yai No.3 Power Station, the load factor will also be 47.2% in 1974 when operation is started, but 3 years later in 1977, the entire output will have become effective and the load factor will drop to 31.8%, subsequent operation being at this load factor.

As described above, Nam Sai Yai No.2 and No.3 are power stations which will bear the peak loads of the system: therefore the plant factor of this power station group was placed at 33%.

6.3 NUMBER OF UNITS

One turbine-generator will be installed at Nam Sai Yai No.2 Power Station and two at the No.3 Power Station.

Economically, since it is desirable to minimize the number of units, a 58-MW unit for the No.3 Power Station would be feasible. However as it is the main power station of the Nam Sai Yai System, 29-MW units were adopted for better reliability.

The No.2 Power Station will have a small output of only 12 MW, therefore, one unit will be provided. As the No.2 and No.3 Power Stations are hydraulically connected, and if there is trouble or periodical inspection at No.2, No.3 Power Station would probably stop. In order to avoid this, a discharge valve with a capacity of 20 c.m.s. will be provided at the No.2 Power Station so that in case of long periods of stoppage at No.2, discharge downstream can be continued to enable the No.3 Power Station to operate.

6.4 INSTALLED CAPACITY AND DEPENDABLE CAPACITY

Installed capacity, dependable capacity and calculations thereof are shown in Table 6-1. The intake level was taken as the average water level of the reservoir for installed capacity and the minimum water level of the reservoir for dependable peak output.

The tail water level was taken as the estimated water level at the power station outlet when maximum discharge is used.

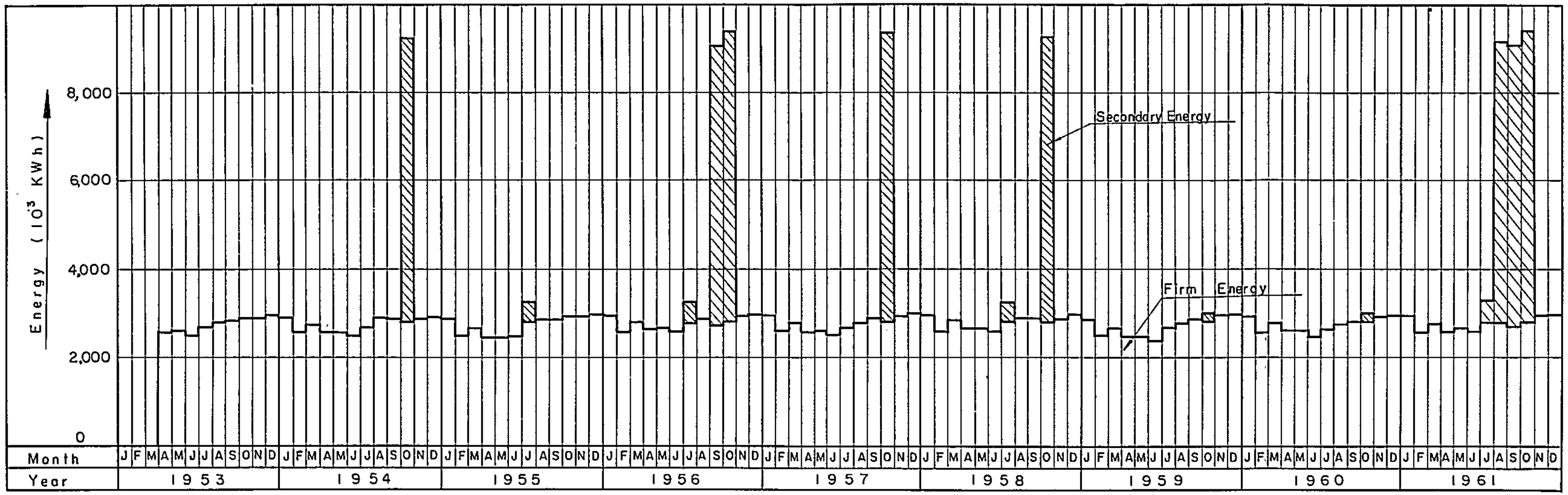
6.5 ENERGY PRODUCTION

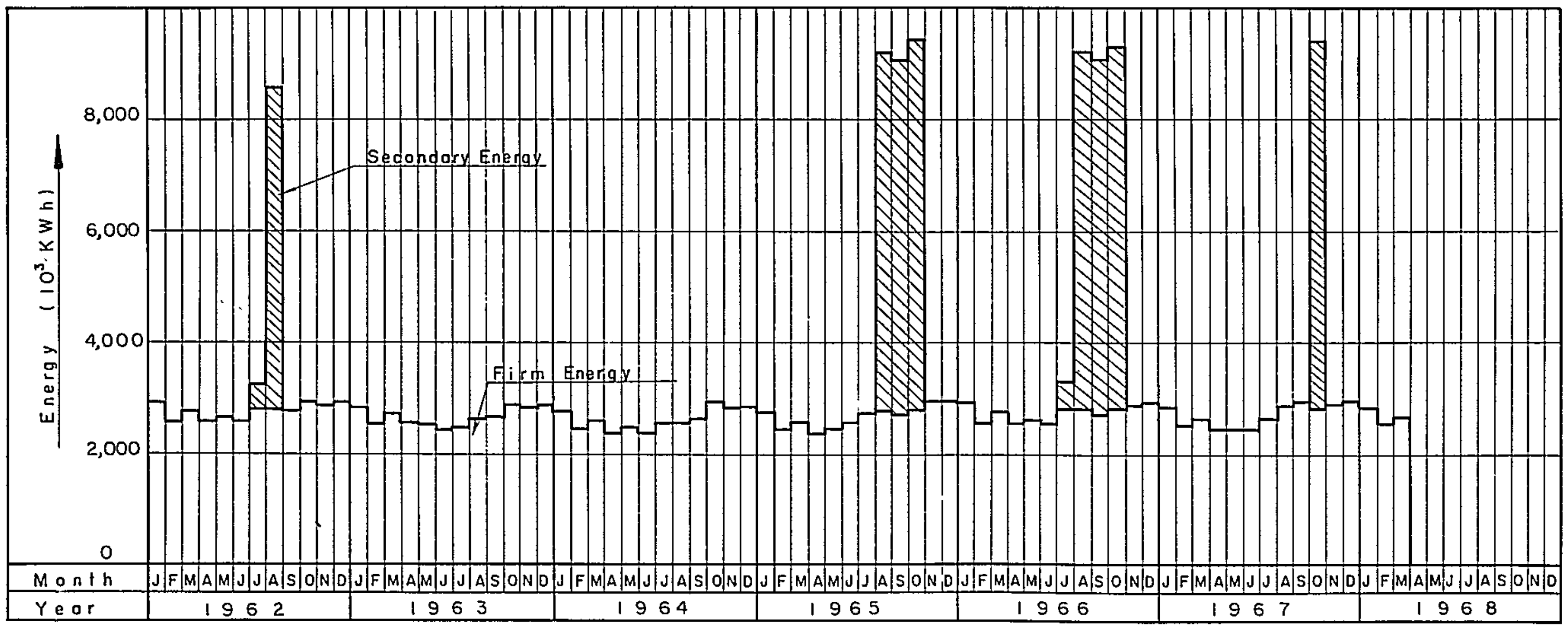
Monthly energy production covering a 15-year period was calculated from the available discharge for power and reservoir water surface level obtained from the operation rule described in 5.3, the result of which is shown in Fig. 6-1, 2. The average annual firm energy, secondary energy and total energy for the 15-year period are 33 million kWh, 7 million kWh and 40 million kWh at the No.2 Power Plant respectively; and 159 million kWh, 31 million kWh and 190 million kWh at the No.3 Power Plant respectively as described in the table. Secondary energy is energy with power discharge exceeding the firm discharge. (See Appendix. G. TABLE G-1, 2)

TABLE 6-1 CALCULATION OF OUTPUT

Item	Sai Yai No.2 Power Station		Sai Yai No.3 Power Station	
	Installed Capacity	Dependable Capacity	Installed Capacity	Dependable Capacity
Discharge (c.m.s.)	20	18.4	20	20
Nor. Intake Water Surface Level (m)	585.5	575.0	509.0	507.0
Tail Water Surface Level (m)	510.0	510.0	170.0	170.0
Rated Head (m)	70.0	59.3	333.3	331.3
Output (MW)	12	9.2	58	56.4

FIG. 6-1 MONTHLY ENERGY OF NAM SAI YAI NO. 2 POWER STATION

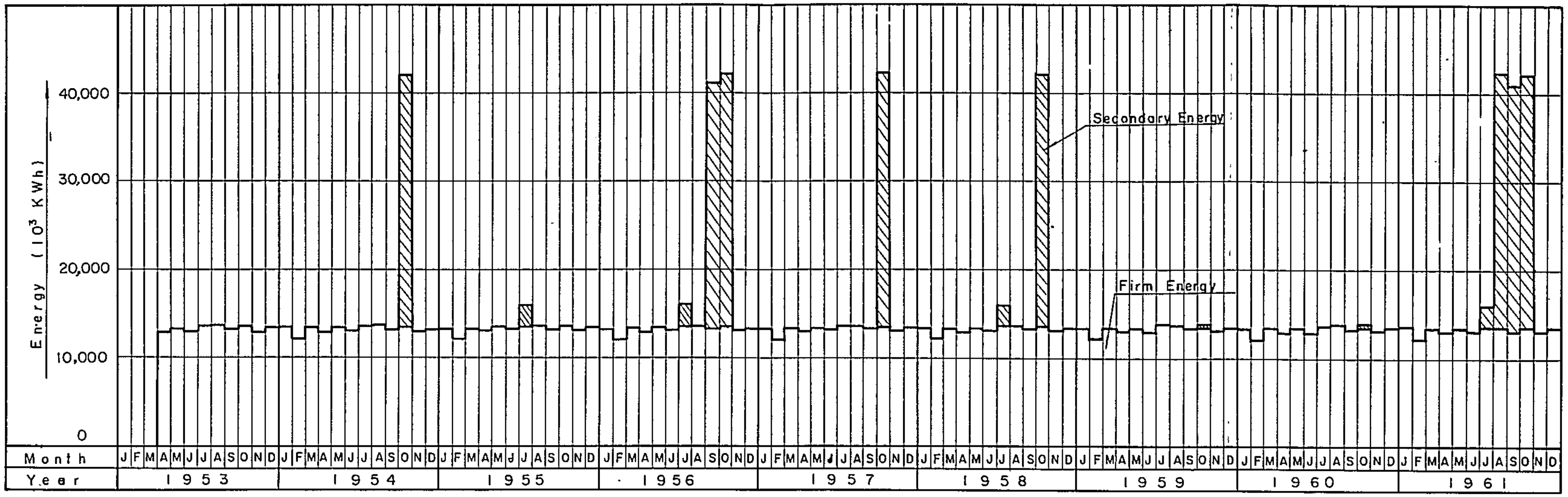


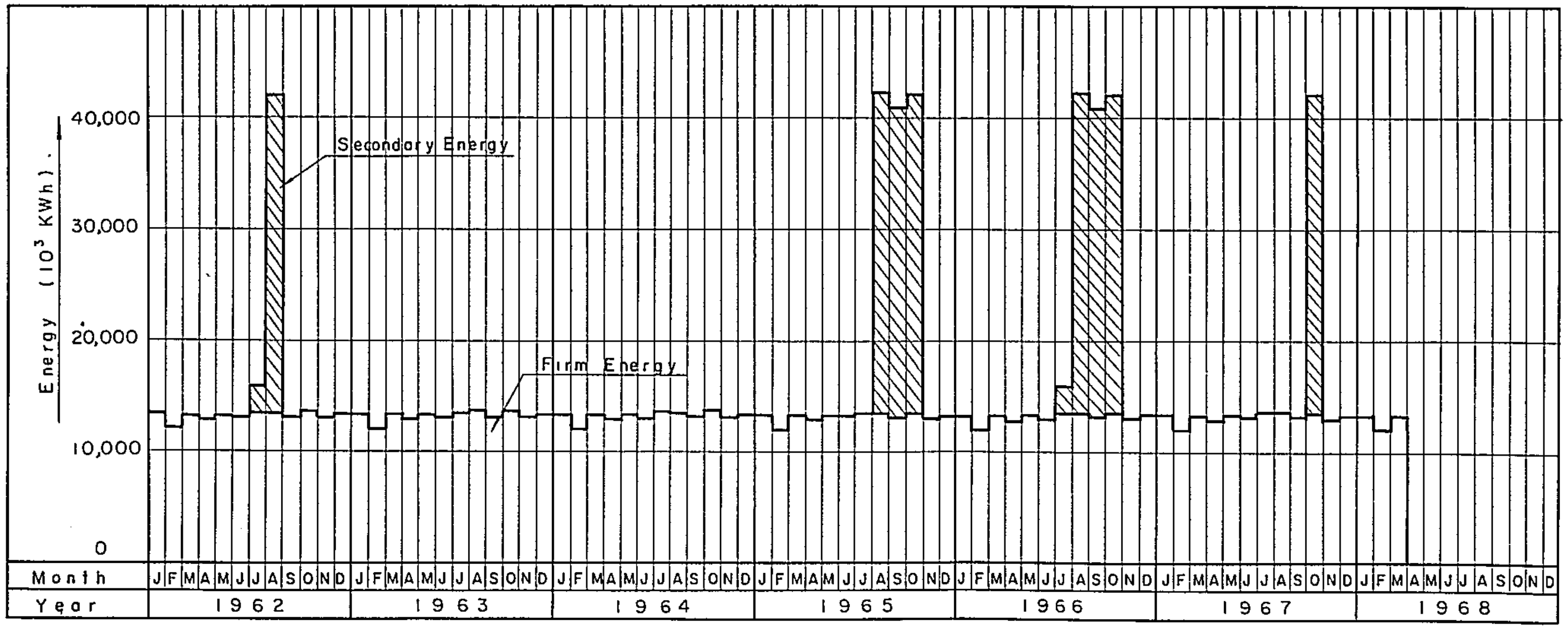


(10^3 KWh)

Annual			
Water Year.	Firm Energy	Secondary Energy	Total Energy
'53 ~ '54	32,853.0	0	32,853.0
'54 ~ '55	32,428.0	6,432.0	38,860.0
'55 ~ '56	32,999.0	424.0	33,423.0
'56 ~ '57	33,166.0	13,430.0	46,596.0
'57 ~ '58	32,937.0	6,598.0	39,535.0
'58 ~ '59	32,948.0	6,887.0	39,835.0
'59 ~ '60	32,484.0	216.0	32,700.0
'60 ~ '61	32,855.0	216.0	33,071.0
'61 ~ '62	33,083.0	19,834.0	52,917.0
'62 ~ '63	33,137.0	6,289.0	39,426.0
'63 ~ '64	31,591.0	0	31,591.0
'64 ~ '65	31,410.0	0	31,410.0
'65 ~ '66	32,305.0	19,606.0	51,911.0
'66 ~ '67	33,721.0	18,864.0	52,585.0
'67 ~ '68	32,603.0	6,608.0	39,211.0
Total	490,520.0	105,404.0	595,924.0
Average	32,701.3	7,027.0	39,728.3

FIG. 6-2 MONTHLY ENERGY OF NAM SAI YAI NO. 3 POWER STATION





(10³ KWh)

Annual			
Water Year	Firm Energy	Secondary Energy	Total Energy
'53~'54	158,580 0	0	158,580.0
'54~'55	158,5410	28,537.0	187,078.0
'55~'56	158,665.0	2,514.0	161,179 0
'56~'57	158,243.0	58,979.0	217,222.0
'57~'58	158,519.0	28,749.0	187,268.0
'58~'59	158,376.0	30,962.0	189,3380
'59~'60	158,578.0	208.0	158,786.0
'60~'61	158,406.0	308.0	158,714 0
'61~'62	158,170.0	87,756.0	245,926.0
'62~'63	158,456.0	30,975.0	189,431.0
'63~'64	158,453 0	0	158,453.0
'64~'65	158,568.0	0	158,568.0
'65~'66	158,353 0	85,435.0	243,788.0
'66~'67	158,070.0	87,722.0	245,792.0
'67~'68	158,631 0	28,6030	187,234.0
Total	2,376,6090	470,749 0	2,847,357 0
Average	158,440 6	31,383.2	189,823.8

CHAPTER 7

OUTLINE OF STRUCTURES AND EQUIPMENTS

DRAWINGS

FIGURES

CHAPTER 7. OUTLINE OF STRUCTURES AND EQUIPMENTS

7.1 GENERAL

As a result of previous reconnaissance, the Report on Basic Studies for Development of Hydraulic Potentials of the Nam Sai Yai submitted in June of 1965 suggested the necessity of constructing large-scale reservoirs on the Nam Sai Yai as in Thailand there is characteristically a great difference in runoff during dry and rainy seasons and a tendency for dry years to exist several years in succession. A rock-fill dam was proposed to be constructed to provide the No.2 Reservoir with a high water level of EL 591 m and an effective storage capacity of 140 million cu.m, and together with the No.1 Dam to be constructed upstream, secure a total effective capacity of 300 million cu.m.

At that time, because of the difficulties of access to the site, it was impossible to make a sufficient reconnaissance of the waterway site. From aerial photographs and 1/50,000 scale topographical maps, a proposal for diversion to the Sai Noi River was made and it was suggested that if the geological conditions of the waterway and power plant were sufficiently good and water leakage during excavation were small, construction of an underground power plant was conceivable.

Therefore, on the occasion of the present field investigation, in consideration of the above circumstances, the focal point was to ascertain whcih of the two was superior, a waterway along the main stream or the diversion plan proposed for the Sai Noi River. Hereafter, a brief discussion will be made of the two, the former designated Plan A and the latter Plan B.

First, regarding the No.2 Power Station of the two plans, the waterways would both be pressure tunnels approximately 1,700 m long with penstock lines approximately 700 m long. Other than a difference in tailrace elevations of 15 m, there would be no great difference in the plans or in structural aspects. The water used at the No.2 Power Station would enter a regulating pond. In the present study, instead of the waterway assumed in the reconnaissance study by which the discharge from the No.2 Power Station would directly enter the headrace tunnel of the No.3 Power Station, it was considered that a regulating pond should be provided by an diversion dam to make possible some degree of regulation of the discharge of No.3 Power Station, at same time shortening the length of the tunnel to make construction easier.

In Plan A, the pressure tunnel of the No.3 Power Station will be approximately 550 m long and the penstock line approximately 1,400 m long; it is believed there will be no special difficulties involved. In comparison, the headrace of Plan B would have to be build underground after going down from the intake by a inclined tunnel of about 45 m because of the topogrophical conditions. Therefore, the length of the headrace would be approximately 2,600 m, the construction period quite long, and the work considerably more difficult than open construction. In other words, two work adits for excavation of the tunnel would be provided, one each at upstream and downstream locations. For the downstream work adit it will be easy to excavate a horizontal tunnel so that there will be no special problems. However, for the upstream adit, if a horizontal adit which would make work easy were to be adopted, the adit itself would be more than 1,000 m long so that for all practical purposes this would be impossible. Even in the case of a inclined tunnel of 1:3.5 gradient by which it would be possible to haul out excavation much, the length will be approximately 350 m which is not desirable in view of the construction period and the construction work itself.

From a structural point of view, it would be a pressure tunnel subjected to a hydraulic pressure of 55 m at all times, and at the time of load cut-off, the surging would cause a section to be subjected to a hydraulic pressure of approximately 70 m. Reinforcement with steel bars or steel liner would give rise to a difficulty in the construction cost. Therefore, upon calculation of the benefit of the basin plan, the Plan A was adopted. (See Fig. 7.1)

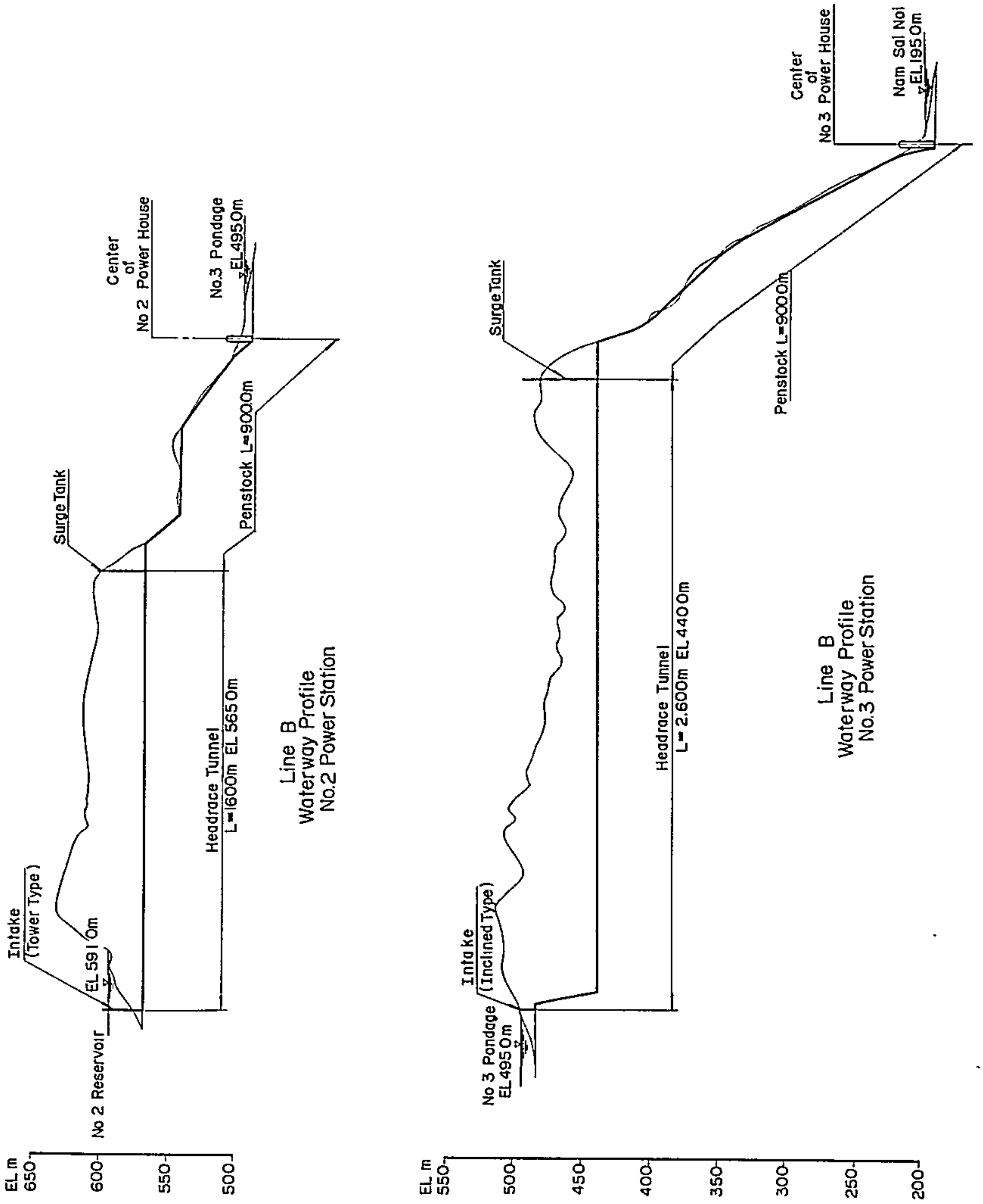
An alternative plan for the two-step, No.2 and No.3 Power Stations consisting of a single plant, either an underground or conventional type, was contemplated. The conventional type power plant was first studied, then comparison made with an underground type under the same conditions.

The waterway profile in the case of construction of a conventional type power plant would be similar to that of the No.3 Power Station in Plan B. The intake will be at the intake of the No.2 Power Station of the two-step Plan (Plan A) and the Power Station at the site of No.3 Power Station of two-step plan (Plan A) creating a headrace of approximately 4,900m. Since this headrace would pass the vicinity of the regulating pond in the two-step plan, the elevation of the headrace center would be approximately 470m. Because of this, the design hydraulic pressure of the headrace will constantly amount to approximately 120 m. Adding to this the rise in water level in the surge tank at the time of load cut-off, it is clear the increased cost of reinforcement with steel bars, steel liner or grouting against this high degree of pressure will amount to a considerable sum. It is judged that an underground power plant with a long tailrace will naturally be disadvantageous in view of construction costs.

When such an underground power plant is planned, the headrace will be an embedded inclined penstock approximately 600 m long, and construction of this pipeline will require work adits at the top, middle and bottom sections. Also, approximately 20,000 cu.m of excavation and 7,000 cu.m of concrete will be necessary. The underground work of this power plant will also require two work adits including a access tunnel for equipment. In view of the topography, it will be almost impossible to provide these work adits economically. Also, since the flow velocity of a tailrace is generally smaller than that of a headrace, the cross section of the former will usually be greater than that of the latter. With addition of a tailrace surge tank, the construction cost will not be cheap. Therefore, it was judged that the two-step plan for the waterway system downstream of the Nam Sai Yai No.2 Dam would be the most economical.

An outline of the No.2 Dam and the No.2 and No.3 Power Stations are given in the following.

FIG. 7-1 WATERWAY PROFILE OF B-LINE



7.2 NAM SAI YAI NO.2 DAM AND POWER STATION

7.2.1 No.2 Dam

Upon studies based on various data concerning topography, geology, dam construction materials and hydrology obtained from subsequent investigations, it was found the type and site proposed in the reconnaissance study for the No.2 Dam will be the most economical.

The Sai Yai River joins the Sai Noi River in the vicinity of Ban Sapanhin Gauging Station, and about 30 km upstream from this confluence, the river drops approximately 20 m in a waterfall. The site of the No.2 Dam is approximately 350 m above this waterfall where there is a wide pocket making it suitable for a dam site. The project area, except for the river bed, is covered with jungle with large trees as tall as 25 m so that the visibility is extremely bad. Moreover, since the length of the dam will be great in comparison with the height, it was difficult to immediately comprehend the topography of the entire dam site. Because the line of the dam axis had been cut open by NEA, and as a result of the study of 1/20,000-scale topographical maps and of core borings and auger borings, it was possible, however, to obtain a fairly accurate idea.

The dam at the river portion will have a height of 40 m, but since both left and right banks are gently sloped tablelands, the greater part of the dam will be low. Outcrops of rock are seen over a fairly wide area in the river section, but the mountain slopes of both banks are all covered by fairly well-compacted topsoil 4.0 to 9.0 m thick under which there is a partial distribution of weathered rock. The results of permeability tests are roughly in the order of 10^{-4}, and it appears there is no stratum of marked permeability at the base of the dam site.

As for concrete aggregate, there is only a scattering of small deposits of fine sand and cobblestones not only at the dam site, but also in the entire project area, except for some fine aggregate on the Nam Huai Yang, and it is impossible to gather natural aggregate within an economical carrying distance. To manufacture concrete aggregate by crushing is probably also not possible. Investigation of the outcrops in the vicinity of the river bed and at the quarry site and of borings proved that the rock is not of sufficient hardness.

In the event the dam is selected to be a fill-type, there will be a problem of the type of material to be used. Downstream of the dam on the left bank, boring has continued at the quarry site since the previous reconnaissance study and it has been found that weathering action has progressed fairly deeply so that the rock is not hard enough. Although it is questionable whether massive blocks can be obtained, it is not impossible to secure some amount of rock.

Regarding impervious material, test pits were excavated in the present field reconnaissance for investigation purposes, but further investigation should be made on future surveys. Dam construction material which is usable although not of very good quality is distributed in a fairly wide area over the entire right bank upstream of the dam site.

Cement is expensive in Thailand, and the cost of transportation to the project site would be high.

There would be no question, therefore, that a fill-type dam would be the most economical; however the problem of whether a rock-fill dam or an earth-fill dam would be superior still exists.

This question can be answered according to the method of combining materials and the method of construction. Although further detailed study is required regarding the properties of rock and earth materials so that it will be difficult to reach a conclusion at this point, as stated previously, the rock material is weathered to a considerable depth from the ground surface and is not of sufficient hardness. From the standpoint of construction costs, the excavation of rock material will be more costly than that of earth materials. However, there are many advantages such as construction not being governed by weather conditions and the work being rapidly accomplished. Problems due to pore water pressure will not arise, and compared to an earth dam, the volume of the dam will be smaller. On the other hand, soil materials are distributed widely over the entire right bank upstream area of the dam and can be obtained relatively easily and inexpensively.

Next, considering the method of construction, it is needless to say this will have a close relationship with how river handling will be performed. At the site of the No.2 Dam, the elevation of the mountainside on both right and left banks are high, and construction can be performed without regard to river handling throughout the year. Therefore,the most economical method of river handling is to divide the construction into two parts: the river bed and the mountainsides. For the river bed, a temporary diversion channel designed for the runoff of the dry season would be provided and this portion embanked during one dry season after diversion of the flow. For this purpose, a temporary diversion tunnel would be constructed during the first dry season after start of construction. This tunnel would be provided on the right bank and have an inner diameter of 3.0 m, length of approximately 300 m, and volume of water passing through it, approximately 45 c.m.s. at the upstream water level of 570 m, above mean sea level.

In the event the No.2 Dam is to be constructed continuously including the river bed section, a temporary diversion tunnel with an inner diameter of about 6 m would be necessary in order to discharge 180 c.m.s., the past maximum run-off corresponding to a 20-year design flood discharge. Therefore, if it were possible to embank the middle portion during the dry season only, it would be desirable for construction of this portion to be as fast as possible. In other words, for the middle portion, a rockfill type which will involve a smaller volume of embankment and which can be embanked more rapidly will be of greater advantage.

At the mountainside on both banks, as previously stated, the bed rock lines ascertained by boring are at 4.0 to 9.0 m below ground surface, but as a fairly compact layer of soil is on top of the bed rock, it is thought this earth need not be excavated except for 0.5 to 1.0 m of topsoil. Also, since these portions can be constructed at any time without particular regard to river handling, it will be more economical to build an earth-fill dam embanked mainly with soil materials existing over a wide area on the right bank upstream of the dam. For the above reasons, it is thought a dam with soil mainly used for the mountainside portions on both banks and rock material mainly used for the middle river bed portion will be the most economical.

As for the optimum scale of the reservoir, the elevation of high water level will be at 591.0 m as stated in Chapter 5 and the dam crest elevation corresponding to this will be 595.0 m. For this reason, on the left and right banks of the reservoir, earth-fill type dikes will be constructed.

7.2.2 Spillway

As described in Chapter 4, the design flood discharge at the dam site is 780 c.m.s. Before completion of the No. 1 Reservoir, 380 c.m.s. of the above can be retained in the reservoir by raising the water level a constant 1.75 m above the high water level of 591.0 m and the remaining 400 c.m.s. would be discharged downstream from the spillway. After completion of the No. 1 Reservoir, a peak cut of 100 c.m.s will become possible at the No. 1 Dam and the design will be for 280 c.m.s to be retained at the No. 2 Reservoir by raising the water level a constant 1.50 m above the high water level of 591.0 m, discharging the remaining 300 c.m.s downstream from the spillway. The spillway will be of the chute-type provided in the concave section on the left bank of the dam with an overflow crest elevation of 591.0 m, an overflow width of 85.0 m and no gates. It will be necessary to provide open channels both upstream and downstream of the concrete portion of the spillway, but it is judged that protective work will not be required except in a limited area. The excavation from the open channel will be utilized in embankment.

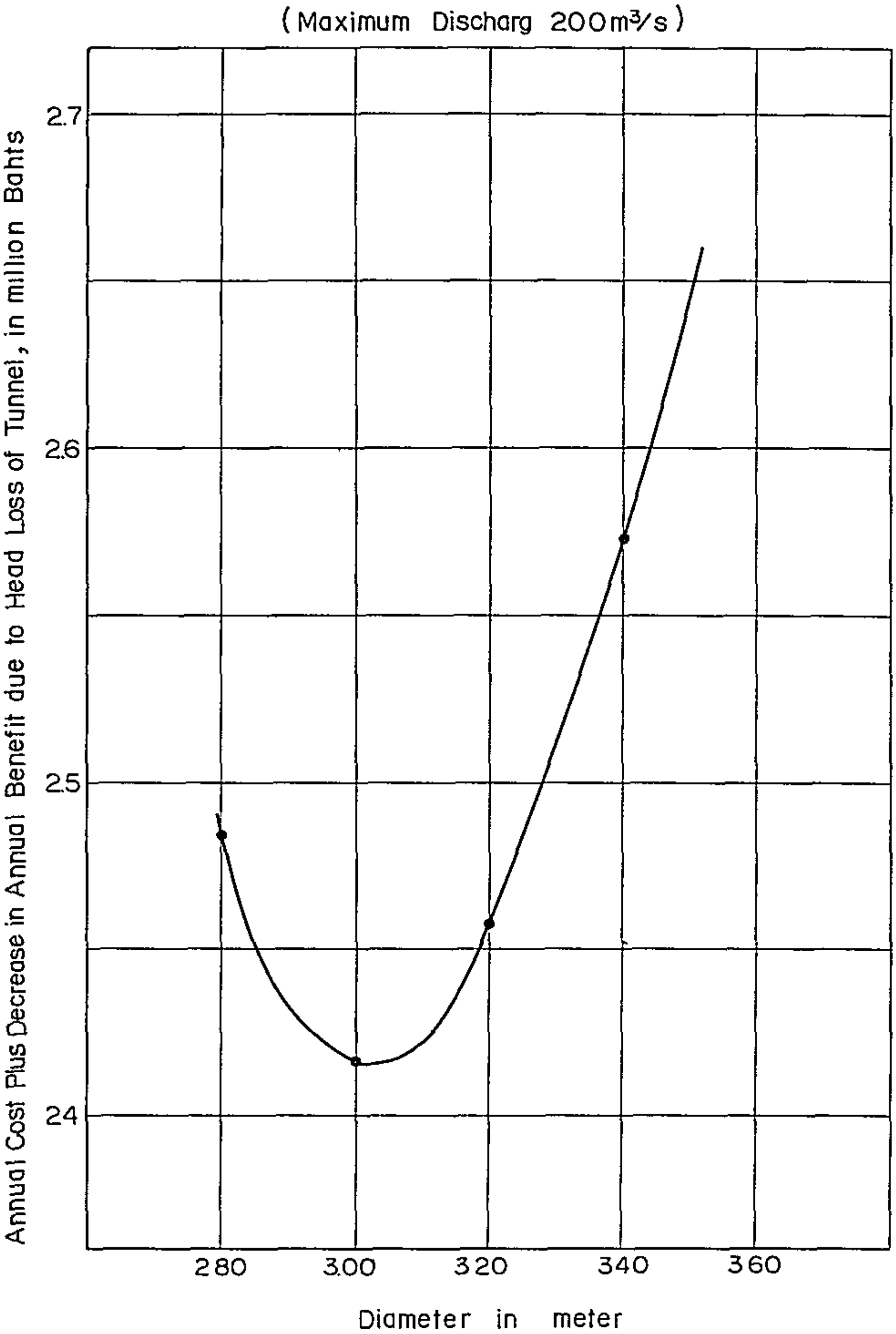
Besides the above type of spillway, chute-type spillways on the left bank of the dam or at No. 3 dike sections were considered, but as a result of comparisons based on preliminary designs, it was found that a spillway provided at the concave portion approximately 590 m on the left bank dam axis would be the most economical.

For handling the flood discharge, the method by which the spillway structure would be made as small as possible was studied. One method would be to discharge the surplus 100 c.m.s, which would later be retained by the No. 1 Reservoir, at the dike sections. However, upon consideration of the topography and geology of the dike sections and the necessity of reinforcing the downstream portions of both banks down which the flood water would be discharged, it was judged more economical and safe to handle the 100 c.m.s with a difference in surcharge of 0.25 m.

7.2.3 Outlet

The temporary diversion channel will be converted to serve as an outlet by providing a valve chamber at the plug. Considering the dissipation of water pressure by the inner walls of the tunnel, a Howell-Bunger valve should be the most suitable type of valve. This outlet will be provided for emergency discharge from the dam, but since the sediment at this site is estimated to amount to 100,000 c.m.s per year with the reservoir capacity approximately 6 million

FIG. 7-2 STUDY ON HEADRACE TUNNEL DIAMETER FOR NAM SAI YAI NO. 2 AND NO. 3 POWER STATIONS



cu.m at the intake orifice bed at EL 566.0 m, the outlet will be urgently needed for sediment flushing also. An underground gallery to the valve chamber in the outlet will be provided separately.

7.2.4 Intake

The intake will be a tower-type in consideration of the topography and will be provided at the right bank approximately 300 m upstream of the dam. In the vicinity of this site, it is thought a sloping type reinforced concrete intake will not be economical. As the slope of the mountainside near the intake is gentle and the distance between the right bank of the reservoir and the intake is great, although it would be desirable to provide a bridge, the construction cost would be too great. Therefore, contact for maintenance and inspection will be made by a servicing beat. A steel stairway will be provided at the dam and a simple which crane will be provided on the slab of the winch base at 595.0 m. The minimum water elevation of the reservoir is 575.0 m, and to guard against entrance of air from the intake, the elevation of the intake will be at 566.0 m. The volume of excavation in front of the intake will accordingly be increased, but all of the excavated material can be used for embankment of the dam. Trash screens will be provided in front of the intake orifice. Also, at the headrace tunnel orifice a roller gate will be installed for the purpose of maintenance and inspection of the tunnel.

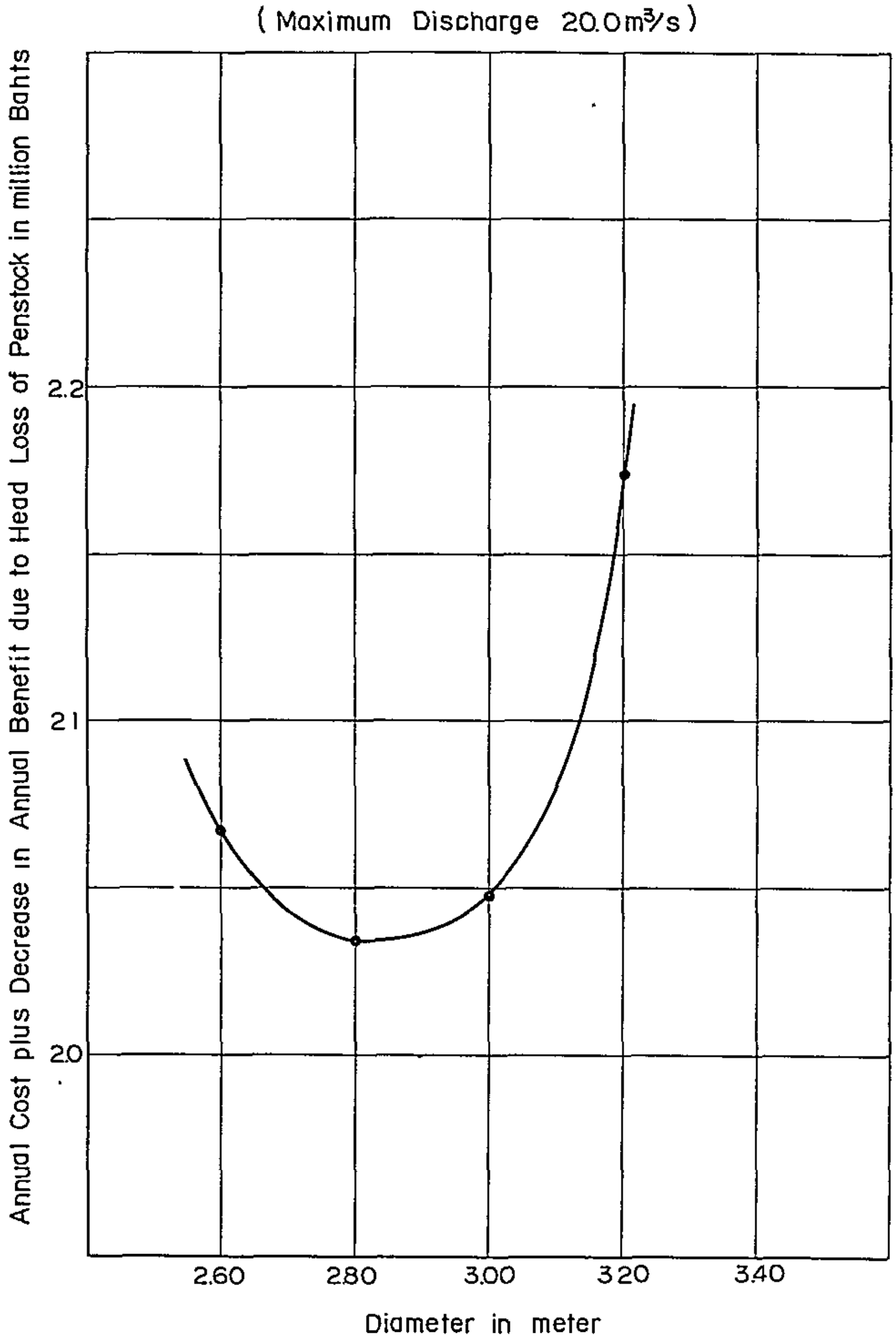
7.2.5 Headrace Tunnel

The headrace tunnel will be a pressure tunnel with a horseshoe-type cross section. Various inner diameters were studied for the tunnel cross section and the one for which the sum of the annual cost and the decrease in annual benefit due to head loss would be the smallest was selected. The results of this study are as shown in Fig. 7-2, and the inner diameter of the tunnel was decided to be 3.1 m. The calculations were made considering the No. 2 and No. 3 Power Stations as one entity and the inner diameters of tunnels for both power stations were made identical for convenience of construction.

The route of the headrace tunnel was selected to provide adequate depth from the ground surface to the tunnel. It will be necessary to line the entire length of the tunnel with concrete, and at points where there is little overburden or the ground is loose, the concrete must be reinforced with steel. In the section near the base of the surge tank to the exposed penstock line, the variation in pressure is considered great so that it will be necessary to line the tunnel with steel tubes.

As stated previously, there is no problem in particular concerning the geology of the route of the headrace tunnel, and it is judged there will be no springing of water. Therefore, there should be no special difficulties in construction of the tunnel, but care will be needed regarding the thickness of the ground above the tunnel as it will be driven through roughly horizontal strata. Work adits will be provided at two locations near the intake and the surge tank taking into consideration the schedules of related civil engineering works, while excavation and concreting will be performed from both entrances.

FIG. 7-3 STUDY ON PENSTOCK DIAMETER FOR NAM SAI YAI NO. 2 POWER STATION



Two kinds of grouting, low-pressure and high-pressure, will be thoroughly carried out.

7.2.6 Surge Tank

For stability of the water surface and convenience of construction, the surge tank, will be a differential type comprised of a vertical shaft with an expanded upper section and a riser with all cross sections circular. The surge tank was so designed that detrimental effects would not occur at the headrace tunnel when the full load is cut off at high water level of the reservoir and when half-load is suddenly increased at low water level of the reservoir. The inner walls of the tunnel downstream from the base of the surge tank will be lined with steel plate.

7.2.7 Penstock

One penstock will be provided, and it will be of welded steel tube. The material of the barrel of the pressure pipe will be mainly rolled steel for welded structure of SM 41 and SM 50 or equal grade and the pipe will be supported by concrete anchor blocks and ring girders. The cross section of the penstock, as in the case of the headrace tunnel, was selected by obtaining the smallest sum of the annual cost and decrease in the annual benefit due to head loss. The results of the calculations are as indicated in Fig. 7-3 and it was decided that an average inner diameter of 2.8 m should be used for the steel pipe. In design of the penstock, the internal pressure was considered as being the sum of the hydrostatic head plus surging head or water hammer pressure whichever is the greater.

At the horizontal section at the bottom part of the penstock, a discharge line branching from the main line will be provided to enable power to be generated No. 3 Power Station even when the No. 2 Power Station is not in operation.

7.2.8 Powerhouse and Tailrace

The powerhouse will be a surface, indoor-type in consideration of topography and geology. L-type draft tubes will be installed and gates will be provided at the tailrace.

A tailrace will be provided between the powerhouse and regulating pond and it will be an open channel type. In consideration of the geology of this area, the tailrace must be protected with concrete to a height approximately 0.75 m above the water surface level. An outdoor switchyard will be located adjacent to the powerhouse where a repair shop, warehouse, emergency engine room, etc. will be provided.

7.2.9 Generating Facilities

As shown in Fig. 7-4, the Nam Sai Yai No. 2 Power Station will be connected to the Nam Sai Yai No. 3 Power Station by a 115-kV, 1-circuit transmission line. Considerations have also been given to make possible connection with the Nam Sai Yai No. 1 Power Station by a 115-kV transmission line. There will be a one-man control from the control room for a turbine and a generator and it will be possible to change to a remote control system with the No. 3 Power Station as the master station. It is thought a reexamination will be necessary at the time construction is to be carried out. The turbine will be a vertical-shaft Francis type for a rated effective head of 70 m, maximum discharge of 20 c.m.s, and the output of 12.4 MW.

For this head and output, a diagonal flow turbine as well as a Francis turbine can be considered as suitable. However, since the drawdown at this power station is 15 m which is 21 % of the rated head, this range can be adequately covered by a Francis turbine. Moreover, as is seen in the study of the kW balance, the power station will be operated as a peak power plant and there will be little operation at partial load, therefore, there is little merit in adopting a diagonal flow turbine. The Francis type was selected as it is a simpler structure, easier to install, maintain and inspect, and less expensive.

The generator will be a vertical-shaft, synchronized generator with a capacity of 14 MVA and 333 rpm, to be installed on a concrete barrel.

The main transformer will be an outdoor 3-phase, oil-immersed, self-cooled type to be installed at the outdoor switchyard.

A 35-ton crane will be provided for assembling the turbine and disassembling the turbine and generator.

7.3 NO. 3 POWER STATION

7.3.1 Dam and Regulating Pond

After passing the open channel tailrace, the discharge of No. 2 Power Station immediately enters a regulating pond. The regulating pond, was so scaled that the expense of the pond would be lower than the sum of the expense of the alternative tunnel and the lost benefit due to head loss in the tunnel. The plan for the pond will have the following merits over the plan for a tunnel.

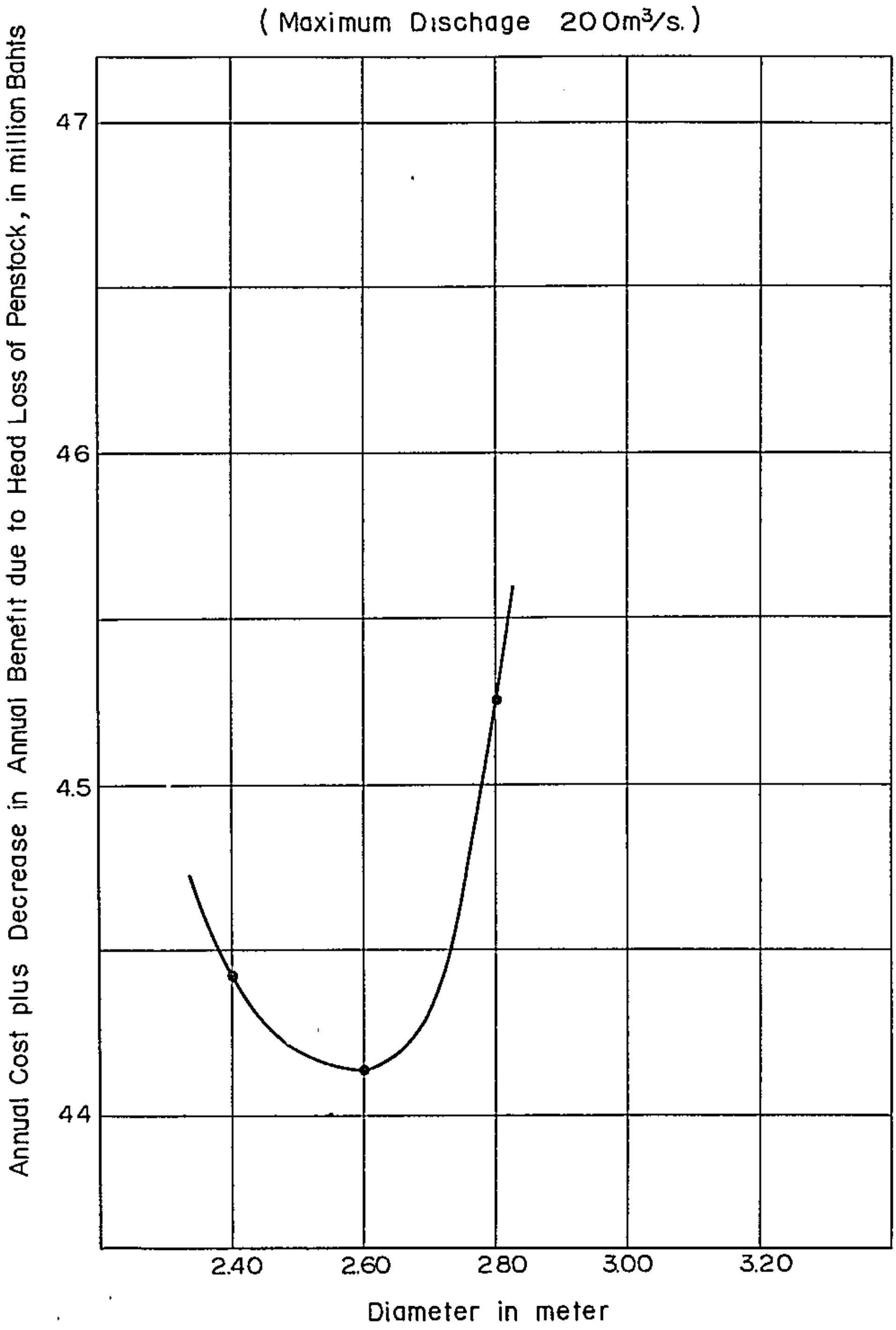
(1) If an drawdown of approximately 3 m corresponding to a regulating capacity of 1.6 million cu.m were to be provided for the pond, it will be possible to regulate the difference of the discharge and generating periods of the No. 2 and No. 3 Power Stations.

(2) Generally, construction of a dam of this type and magnitude is easier than construction of a waterway such as a tunnel.

(3) The head loss due to a waterway such as a tunnel will be negligible in the case of a regulating pond.

From the aspect of design, the dam would be roughly the same type as the dikes and dam in the case of the No. 2 Reservoir, and the soil and rock

FIG. 7-4 STUDY ON PENSTOCK DIAMETER FOR NAM SAI YAI NO. 3 POWER STATION



materials to be used for embankment are readily available, around the pond area.

A spillway with a discharge capacity of approximately 20 c.m.s will be provided at the right bank portion of the dam.

7.3.2 Intake

The intake will be a sloping type to be provided on the right bank approximately 300 m downstream of the dam. Trash screens will be provided in front of the intake and a sluice gate will be installed at the headrace tunnel orifice for maintenance and inspection of the tunnel.

The intake bed elevation is at 500.0 m which will mean a large volume of excavation for the front of the intake, but the excavated material can be used for embankment of the dam.

7.3.3 Headrace Tunnel

The headrace tunnel, as previously stated, will be the same horseshoe-type pressure tunnel with an inner diameter of 3.10 m as the tunnel for the No. 2 Power Station for convenience of construction. The route was selected with consideration given to providing adequate depth from the ground surface to the tunnel. The tunnel will have to be lined with concrete throughout its entire length, and at sections where there is little overburden, poor geological conditions or great fluctuation in pressure, it will be reinforced with steel bars or steel plate. Two types of grouting, low-pressure and high-pressure, will be performed with special care.

As an added note, since the tunnel is relatively short, it is thought excavation and concrete placement can progress from one entrance.

7.3.4 Surge Tank

The surge tank will be a differential type as in the case of the No. 2 Power Station, and the inner walls approximately 2/3 of the length of the tunnel downstream from the surge tank will be lined with steel plate.

7.3.5 Penstock

The 1,390 m long penstock and the total head of 340 m are special features of the No. 3 Power Station. Materials for the barrel of the pipe will mainly be rolled steel for welded structure of SM 50 and SM 58-grade. The cross sectional dimension of the penstock, as in the case of the headrace tunnel, was selected for an inner diameter at which the sum of the annual cost and the annual lost benefit due to head loss would be a minimum. The results of the calculations are indicated in Fig. 7-4 and the average inner diameter of the pipe will be 2.6 m. As in the case of the No. 2 Power Station, the design of the penstock was based on the assumption of internal pressure equalling the sum of the hydrostatic head plus surging head or water hammer pressure, whichever is the greater.

7.3.6 Powerhouse and Tailrace

The powerhouse will be a surface indoor type in consideration of topography and geology. This power plant will discharge water directly to the main stream of the Sai Yai River and considerations will be given to the powerhouse, outdoor steel structures and access roads so that they will be amply safe against the 300 c.m.s discharge made up of the 100-year probability flood discharge of approximately 210 c.m.s at the Nam Sai Yai No. 2 Dam and 60 c.m.s at the remaining catchment area plus a margin of safety. Also, the powerhouse site including appurtenant facilities should have a layout which gives adequate consideration to displacement of earth and sand down the steep slope of the mountainside.

The L-type draft tubes will be used, and gates will be provided at outlets. Outdoor steel structures will be installed on the upstream side of the powerhouse.

7.3.7 Generating Facilities

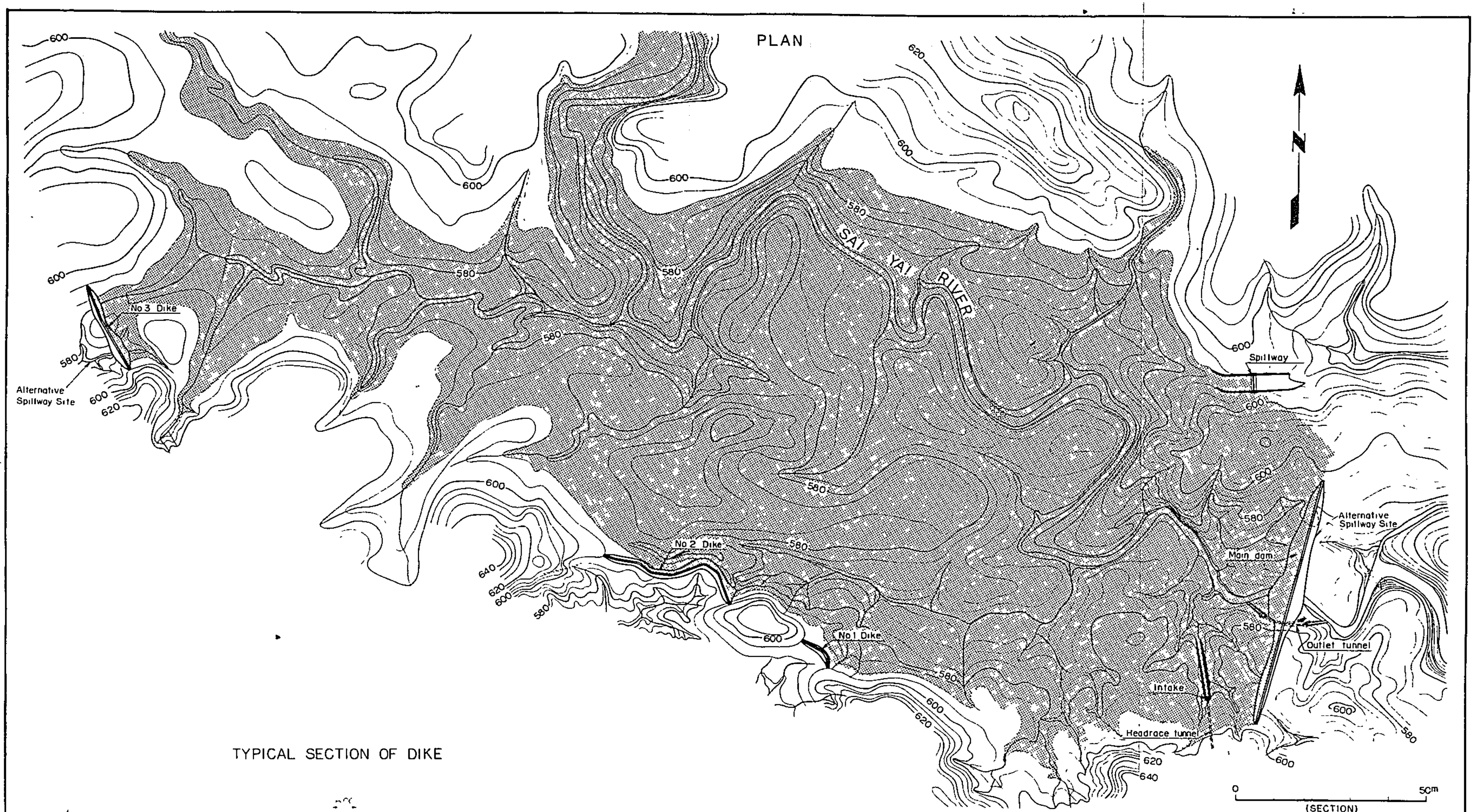
The Nam Sai Yai No. 3 Power Station will be the major station of the Nam Sai Yai System and the 115-kV, 2-circuit transmission line connecting Korat Substation with the Nam Sai Yai System will be led out from the outdoor switchyard of this No. 3 Station. As shown in Dwg. 7-11, when the No. 4 Power Station is completed, it will be connected to the 115-kV bus line of the No. 3 Power Station by a 115-kV, 1-circuit line, and additional space for this has been considered. The outdoor switchyard will be provided upstream of the power station along the river. As the terrain is steep, the arrangement is long and narrow to minimize the amount of excavation. The powerhouse will be a surface type, and the two turbine-generator units and the equipment in the outdoor switchyard will be controlled from the control room.

Each turbine will be a vertical Francis type for rated head of 333 m, maximum discharge of 20 c.m.s with output of 29.7 MW.

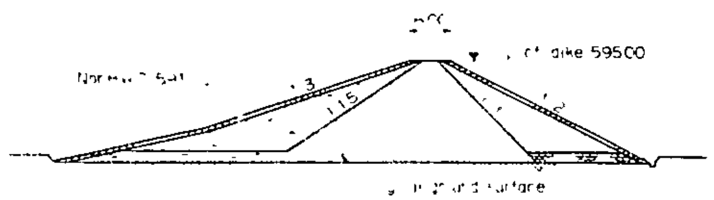
Head is slightly high for a Francis type, but in recent years the Francis type has made remarkable inroads into the high-head field, and at present, since it is being used with heads of more than 500 m, it is judged there will be no problems.

For this head and output, it is possible to use a Pelton type but it is thought the head is slightly too low. With a Pelton type turbine the revolutions will be 375 rpm or approximately 60% of a Francis type so that the equipment will need to be of a large, making both turbine and generator expensive.

Also, since this station will be operated as a peak power plant, seldom operating at partial load, Francis type turbines which have good maximum efficiency are superior. However, as it will be possible to suppress the rise of hydraulic pressure at a low level with Pelton type turbines using deflectors, there are cases when overall economy can be obtained for such power stations with long penstocks as the No. 3 Power Station.



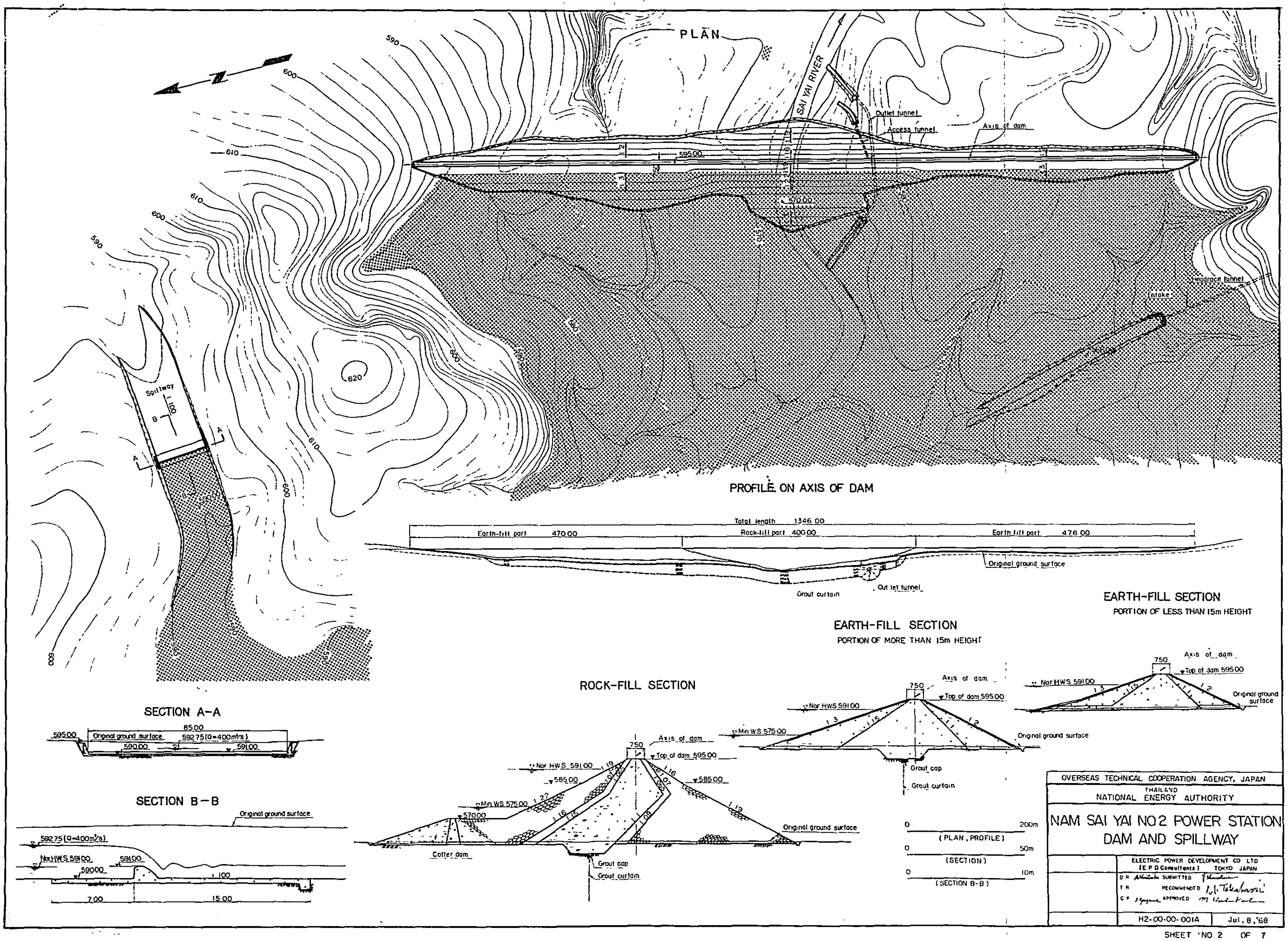
TYPICAL SECTION OF DIKE

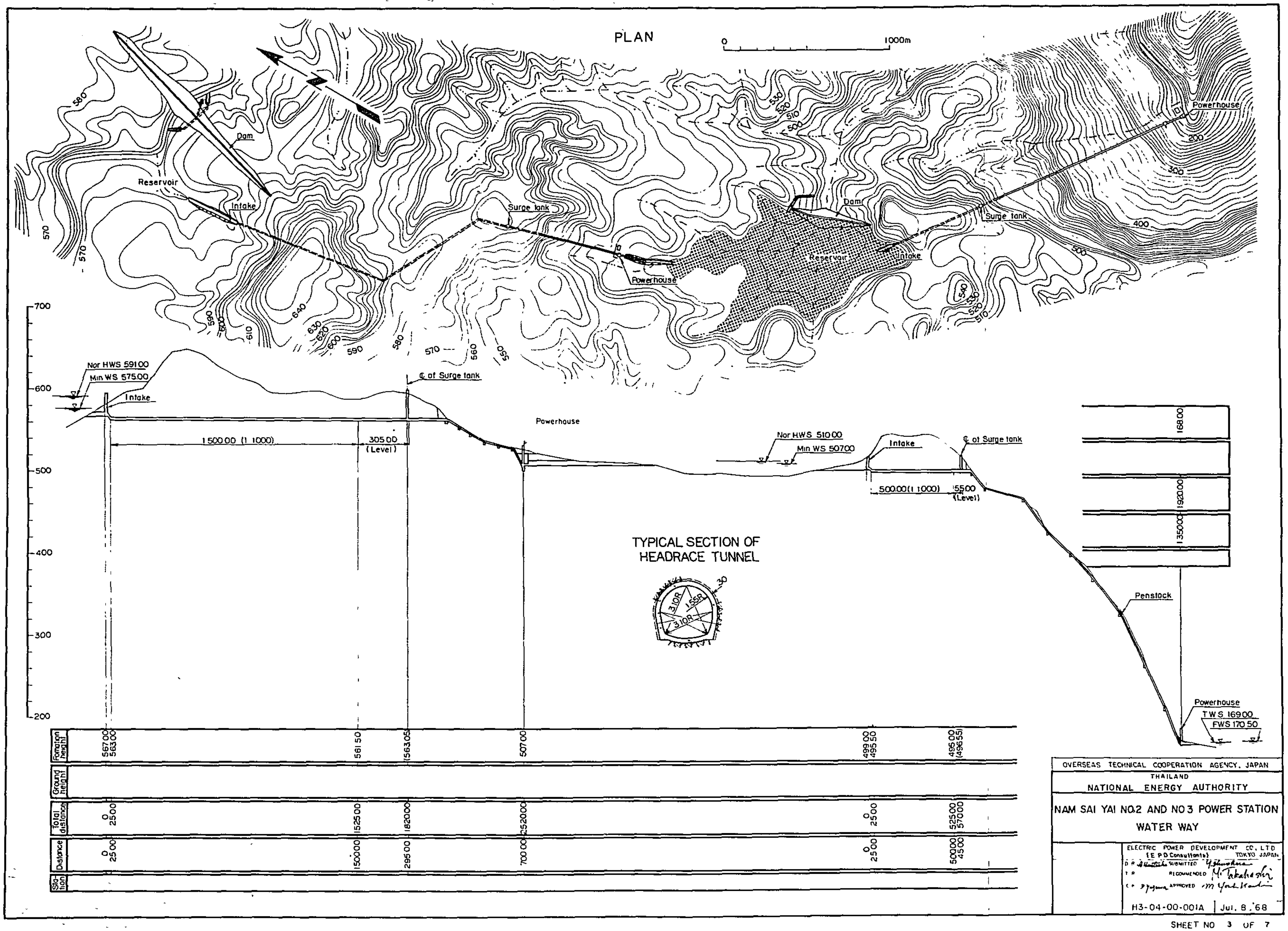


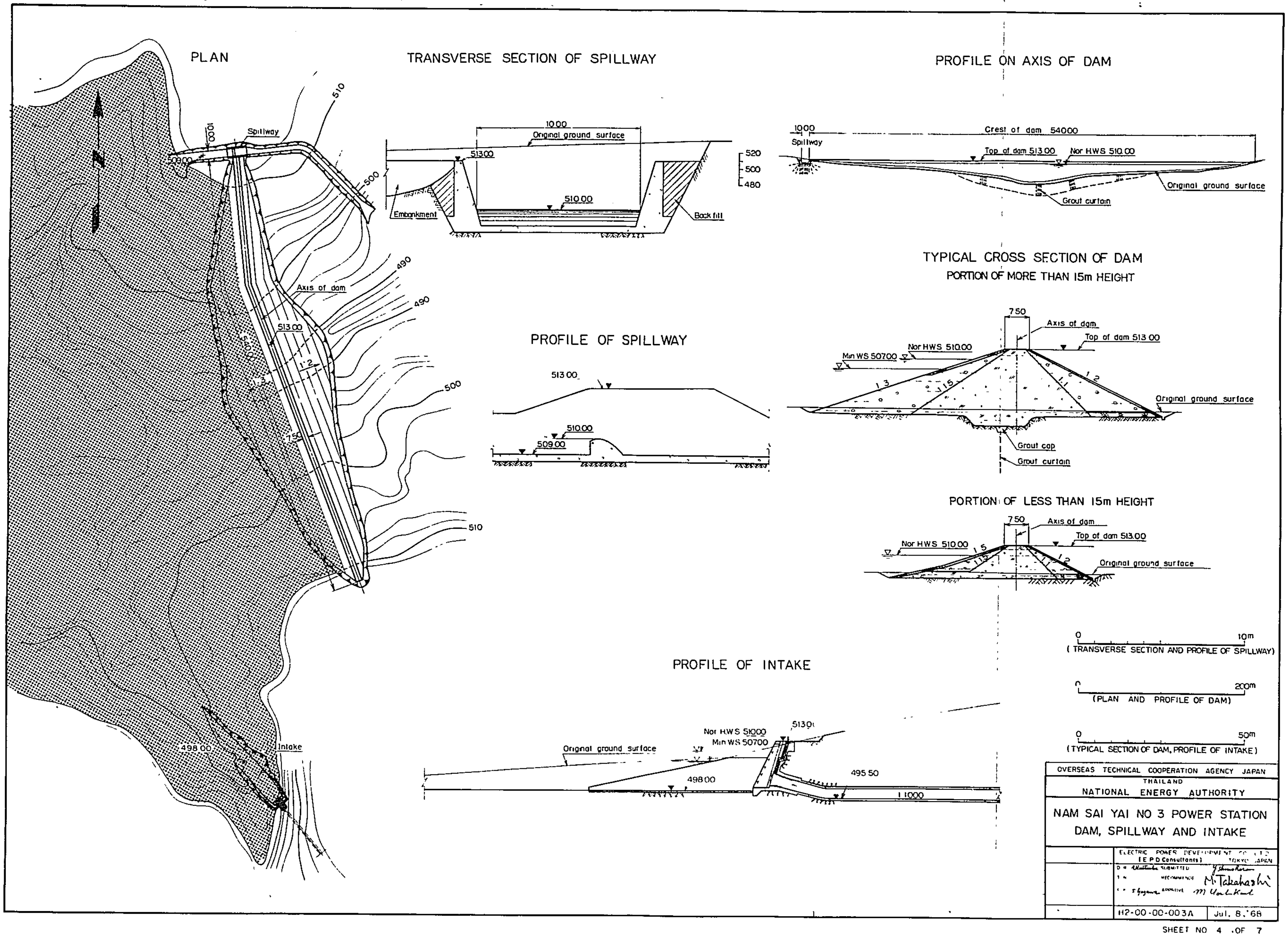
OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN
THAILAND NATIONAL ENERGY AUTHORITY
NAM SAI YAI NO 2 POWER STATION DIKE
ELECTRIC POWER DEVELOPMENT CO., LTD (E P D Consultants) TOKYO JAPAN
SUBMITTED / RECOMMENDED M. Takahashi / APPROVED
H2-00-00-002A Jul. 8, '68

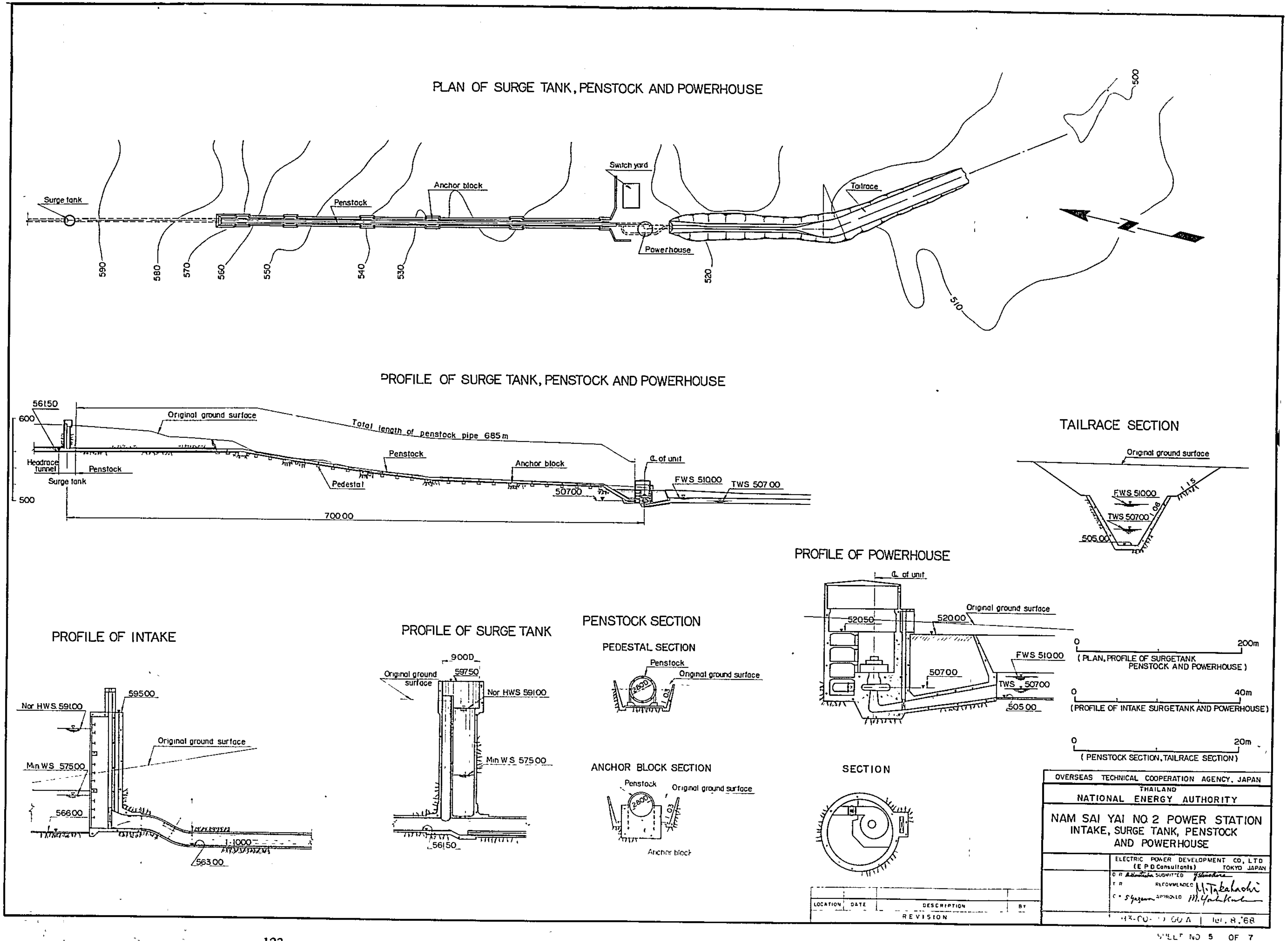
LOCATION	DATE	DESCRIPTION	BY
REVISION			

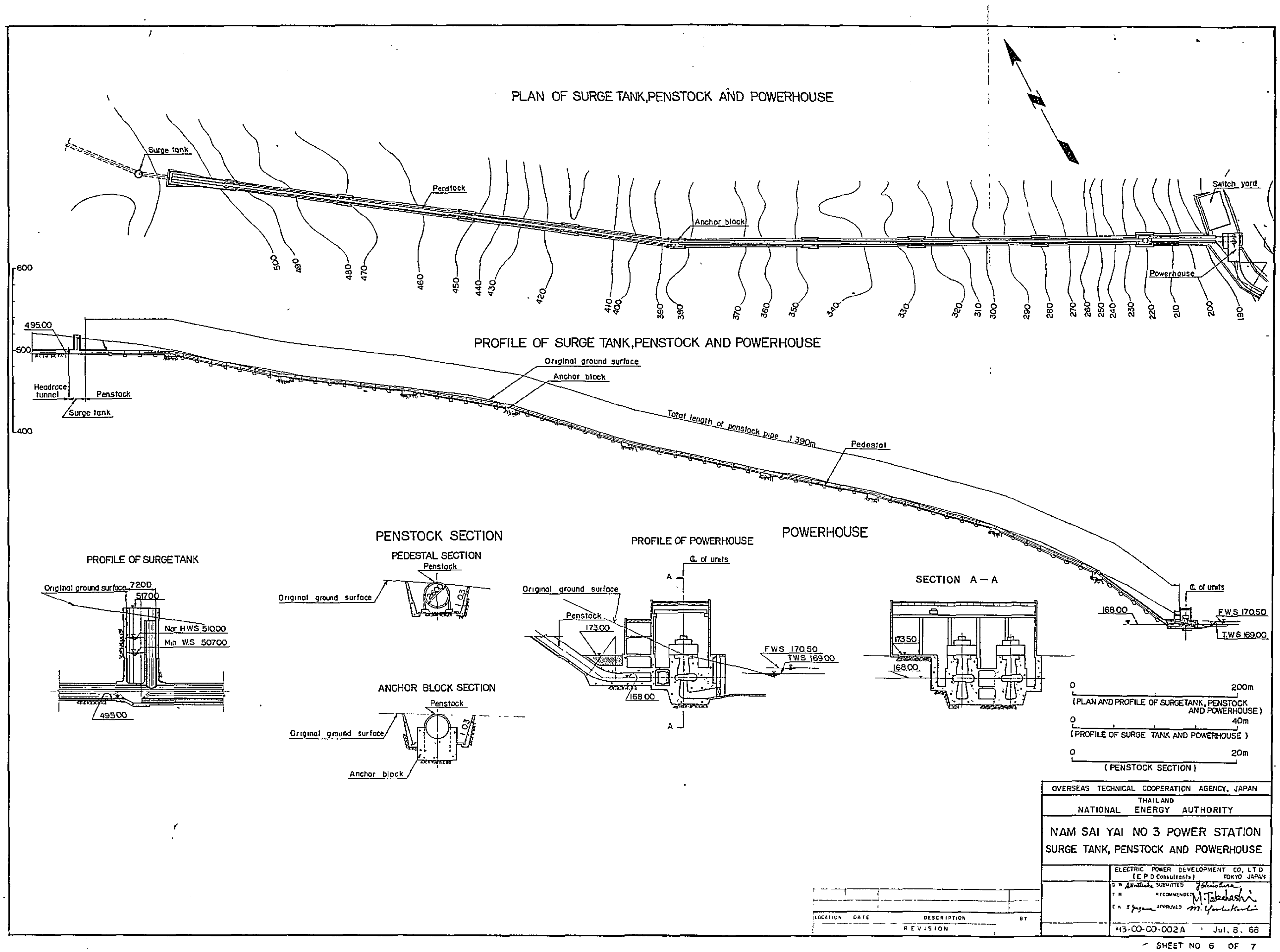
SHEET NO 1 OF 7


PLAN
SAI YAI RIVER
Outlet tunnel
Access tunnel
Axis of dam
595.00
570.00
Headrace tunnel
Intake
Spillway
620
PROFILE ON AXIS OF DAM
Total length 1346.00
Earth-fill part 470.00
Rock-fill part 400.00
Earth-fill part 476.00
Original ground surface
Grout curtain
Out let tunnel
EARTH-FILL SECTION
PORTION OF LESS THAN 15m HEIGHT
EARTH-FILL SECTION
PORTION OF MORE THAN 15m HEIGHT
ROCK-FILL SECTION
SECTION A-A
85.00
595.00
Original ground surface
592.75 (Q=400m³/s)
590.00
591.00
SECTION B-B
Original ground surface
592.75 (Q=400m³/s)
Nor.HWS 591.00
590.00
591.00
7.00
15.00
Axis of dam
7.50
Top of dam 595.00
Nor.HWS 591.00
585.00
Min.WS 575.00
570.00
Cofferdam
Grout cap
Grout curtain
Original ground surface
(PLAN, PROFILE)
(SECTION)
(SECTION B-B)
200m
50m
10m
OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN
THAILAND
NATIONAL ENERGY AUTHORITY
NAM SAI YAI NO.2 POWER STATION
DAM AND SPILLWAY
ELECTRIC POWER DEVELOPMENT CO. LTD
(E.P.D.Consultants) TOKYO JAPAN
SUBMITTED
RECOMMENDED
APPROVED
H2-00-00-001A
Jul. 8, '68
SHEET NO 2 OF 7


PLAN
0
1000m
Dam
Reservoir
Intake
Surge tank
Powerhouse
TYPICAL SECTION OF HEADRACE TUNNEL
Nor HWS 591.00
Min WS 575.00
℄ of Surge tank
1500.00 (1:1000)
305.00 (Level)
Nor HWS 510.00
Min WS 507.00
500.00 (1:1000)
55.00 (Level)
Penstock
TWS 169.00
FWS 170.50
Formation height
Ground height
Total distance
Distance
Station
OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN
THAILAND
NATIONAL ENERGY AUTHORITY
NAM SAI YAI NO.2 AND NO.3 POWER STATION
WATER WAY
ELECTRIC POWER DEVELOPMENT CO., LTD
(E.P.D.Consultants) TOKYO JAPAN
SUBMITTED
RECOMMENDED
APPROVED
H3-04-00-001A
Jul. 8. '68
SHEET NO 3 OF 7


PLAN
Spillway
509.00
513.00
Axis of dam
540.00
1:3
1:2
7.50
510
500
490
498.00
Intake
TRANSVERSE SECTION OF SPILLWAY
10.00
Original ground surface
513.00
510.00
Embankment
Back fill
520
500
480
PROFILE OF SPILLWAY
513.00
510.00
509.00
PROFILE ON AXIS OF DAM
10.00
Spillway
Crest of dam 540.00
Top of dam 513.00
Nor HWS 510.00
Original ground surface
Grout curtain
TYPICAL CROSS SECTION OF DAM
PORTION OF MORE THAN 15m HEIGHT
7.50
Axis of dam
Top of dam 513.00
Nor HWS 510.00
Min WS 507.00
1:3
1:1.5
1:2
Original ground surface
Grout cap
Grout curtain
PORTION OF LESS THAN 15m HEIGHT
7.50
Axis of dam
Top of dam 513.00
Nor HWS 510.00
1:5
1:1.5
1:2
Original ground surface
PROFILE OF INTAKE
Original ground surface
Nor HWS 510.00
Min WS 507.00
513.00
498.00
495.50
1:1000
0 10m
(TRANSVERSE SECTION AND PROFILE OF SPILLWAY)
0 200m
(PLAN AND PROFILE OF DAM)
0 50m
(TYPICAL SECTION OF DAM, PROFILE OF INTAKE)
OVERSEAS TECHNICAL COOPERATION AGENCY JAPAN
THAILAND
NATIONAL ENERGY AUTHORITY
NAM SAI YAI NO 3 POWER STATION
DAM, SPILLWAY AND INTAKE
ELECTRIC POWER DEVELOPMENT CO., LTD.
(E P D Consultants) TOKYO JAPAN
M. Takahashi
H2-00-00-003A
Jul. 8, '68
SHEET NO 4 OF 7


PLAN OF SURGE TANK, PENSTOCK AND POWERHOUSE
Surge tank
Penstock
Anchor block
Switch yard
Powerhouse
Tailrace
590
580
570
560
550
540
530
520
510
500
PROFILE OF SURGE TANK, PENSTOCK AND POWERHOUSE
56150
600
500
Original ground surface
Total length of penstock pipe 685m
Headrace tunnel
Penstock
Surge tank
Pedestal
Anchor block
℄ of unit
FWS 51000
TWS 507.00
50700
700.00
TAILRACE SECTION
Original ground surface
FWS 51000
TWS 50700
505.00
PROFILE OF POWERHOUSE
℄ of unit
Original ground surface
52050
52000
FWS 51000
50700
TWS 50700
505.00
0
200m
(PLAN, PROFILE OF SURGETANK PENSTOCK AND POWERHOUSE)
0
40m
(PROFILE OF INTAKE SURGETANK AND POWERHOUSE)
0
20m
(PENSTOCK SECTION, TAILRACE SECTION)
PROFILE OF INTAKE
Nor HWS 59100
59500
Original ground surface
Min WS 57500
56600
1:1000
563.00
PROFILE OF SURGE TANK
9000
Original ground surface
59750
Nor HWS 59100
Min WS 57500
56150
PENSTOCK SECTION
PEDESTAL SECTION
Penstock
Original ground surface
2600
ANCHOR BLOCK SECTION
Penstock
Original ground surface
2600
Anchor block
SECTION
LOCATION
DATE
DESCRIPTION
BY
REVISION
OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN
THAILAND
NATIONAL ENERGY AUTHORITY
NAM SAI YAI NO. 2 POWER STATION
INTAKE, SURGE TANK, PENSTOCK AND POWERHOUSE
ELECTRIC POWER DEVELOPMENT CO., LTD
(E P D Consultants)
TOKYO JAPAN
SUBMITTED
RECOMMENDED
APPROVED
SHEET NO 5 OF 7


PLAN OF SURGE TANK, PENSTOCK AND POWERHOUSE
Surge tank
Penstock
Anchor block
Switch yard
Powerhouse
500 490 480 470 460 450 440 430 420 410 400 390 380 370 360 350 340 330 320 310 300 290 280 270 260 250 240 230 220 210 200 190
PROFILE OF SURGE TANK, PENSTOCK AND POWERHOUSE
600
500
400
495.00
Headrace tunnel
Penstock
Surge tank
Original ground surface
Anchor block
Total length of penstock pipe 1,390m
Pedestal
℄ of units
168.00
F.W.S 170.50
T.W.S 169.00
PROFILE OF SURGE TANK
Original ground surface
7.200
5.1700
Nor HWS 510.00
Min W.S 507.00
495.00
PENSTOCK SECTION
PEDESTAL SECTION
Penstock
Original ground surface
ANCHOR BLOCK SECTION
Penstock
Original ground surface
Anchor block
POWERHOUSE
PROFILE OF POWERHOUSE
℄ of units
Original ground surface
Penstock
173.00
168.00
FWS 170.50
TWS 169.00
A
A
SECTION A — A
173.50
168.00
0 200m
(PLAN AND PROFILE OF SURGETANK, PENSTOCK AND POWERHOUSE)
0 40m
(PROFILE OF SURGE TANK AND POWERHOUSE)
0 20m
(PENSTOCK SECTION)
OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN
THAILAND
NATIONAL ENERGY AUTHORITY
NAM SAI YAI NO 3 POWER STATION
SURGE TANK, PENSTOCK AND POWERHOUSE
ELECTRIC POWER DEVELOPMENT CO., LTD
(E P D Consultants) TOKYO JAPAN
SUBMITTED
RECOMMENDED
APPROVED
LOCATION DATE DESCRIPTION BY
REVISION
H3-00-00-002A Jul. 8. 68
SHEET NO 6 OF 7

The results of economic comparison showed the construction cost using Francis turbines to be approximately 4 million Baht lower, since it was shown that this difference would be increased even more in regard to efficiency, Francis type was adopted.

The generators will be 33-MVA capacity, 600-rpm, vertical shaft, synchronized generators. The main transformers will be 11/115-kV, 33-MVA capacity, outdoor, 3-phase, forced-oil, air-cooled type and the generators and transformers will be connected by a metal enclosed bus. A 40-ton crane will be provided for assembling and dissembling the turbines and generators.

7.4 TRANSMISSION LINE

7.4.1 Transmission Line Route

The transmission line with a length of 109 km starts from Sai Yai No. 2 Power Station, passes the No. 3 Power Station and ends at Korat Substation.

Approximately 15 km of this route on the power station side is a mountainous area at an elevation of around 800 m, while the remainder is almost all a gently undulating plateau at an elevation of 400 to 500 m. Approximately 80 km on the Korat Substation side runs along an existing road, for convenience of the construction work and maintenance. In order to avoid of damage from dust raised by passing vehicles, the transmission line will be located on the windward side (the most frequent wind direction throughout the year) or be set at a distance of at least about 200 m from the road.

7.4.2 Scale of Transmission Line

In consideration of interconnection with the existing NEEA System, the transmitting voltage was selected to be 115 kV between the No. 3 Power Station and Korat Substation.

For the line between the Sai Yai No. 2 and No. 3 Power Stations, voltages of 66 kV and 115 kV were compared and as the former would require 66/115-kV interconnection facilities and relating switchgears, it was found to be uneconomical, though cost of transmission lines is cheaper and therefore 115 kV was adopted.

The 105 km between the No. 3 Power Station and Korat Substation was made to be 2 circuits for transmission of 70 MW of power. This will also provide ample capacity to transmit 99 MW in the future when the No. 1 and No. 4 Power Stations are developed. Between the No. 2 and No. 3 Power Stations, a 1-circuit, 115-kV line will be sufficient.

For a conductor, 160-sq.mm to 410 sq.mm ACSR were compared for such properties as transmission capacity, voltage drop, transmission loss, required reactive capacity, etc. and for economics, a 240-sq.mm ACSR was found to be the most superior and was therefore selected.

Insulators will be 250-mm ball-and-socket type standard suspension insulators with both suspension and strain types to be single string.

For support, it is possible to use of steel towers, steel poles or concrete poles, but because of the importance of this transmission line, steel towers of galivanized steel assembled with bolts which are durable and safe were selected. Concrete footings (without reinforcement) will be used as foundations. Dwg. 7-7 and 7-8 shows a standard suspension and tension type steel tower.

7-4-3 Insulation Design

Since abnormal voltages in the transmission line will occur due to switching surges and line overvoltages, the number of insulators and spacing of grounding were determined to prevent flashovers.

As this transmission line will be a direct grounding system, the switching surge was considered to be 2.8 times normal phase crest voltage value.

From the above, it was decided that the number of insulators should be 7 standard 250-mm suspension types per string, including a reserve insulator for maintenance purposes with a horn gap of 0.77 m and standard insulation spacing of 1.10 m. The allowance of dielectric strength for switching surges will be 1.22.

Overhead ground wires at shielding angles of 30° will be provided throughout the transmission line to prevent direct hits on conductors by lightning.

In order to prevent inverse flashover, the grounding resistance of steel towers will be not more than 10 ohms and counterpoises will be provided. Insulator apparatuses will be provided with arcing horns to prevent damage to insulators in case of inverse flashover.

The minimum height from ground of the conductors will be 6.0 m.

7.5 SUBSTATION

The transmission line from the Nam Sai Yai Power Stations will be connected to the 115-kV transmission line of the NEEA and YEA System at Korat Substation. The 115-kV, 2-circuit transmission line from the Nam Sai Yai Power Stations will be led in adjacent to and on the east side of the Surin lead in line of the Korat Substation and it is planned to add equipment necessary for this, such as disconnecting switches, circuit breakers and outdoor steel structures etc.

The bus line arrangement, as shown in Dwg. 7-11, will be a double bus line system as planned by NEEA to improve reliability because the Korat Substation occupies an exceedingly important position in the power system.

7.6 COMMUNICATIONS FACILITIES

The arrangement of telecommunications circuits were based on the following fundamental conditions.

(1) The load dispatching center of this system will be provided at Kohn Kaen Substation as planned by NEEA.

(2) The general administration and line maintenance work of the Nam Sai Yai Power Stations will be centered at Korat Substation.

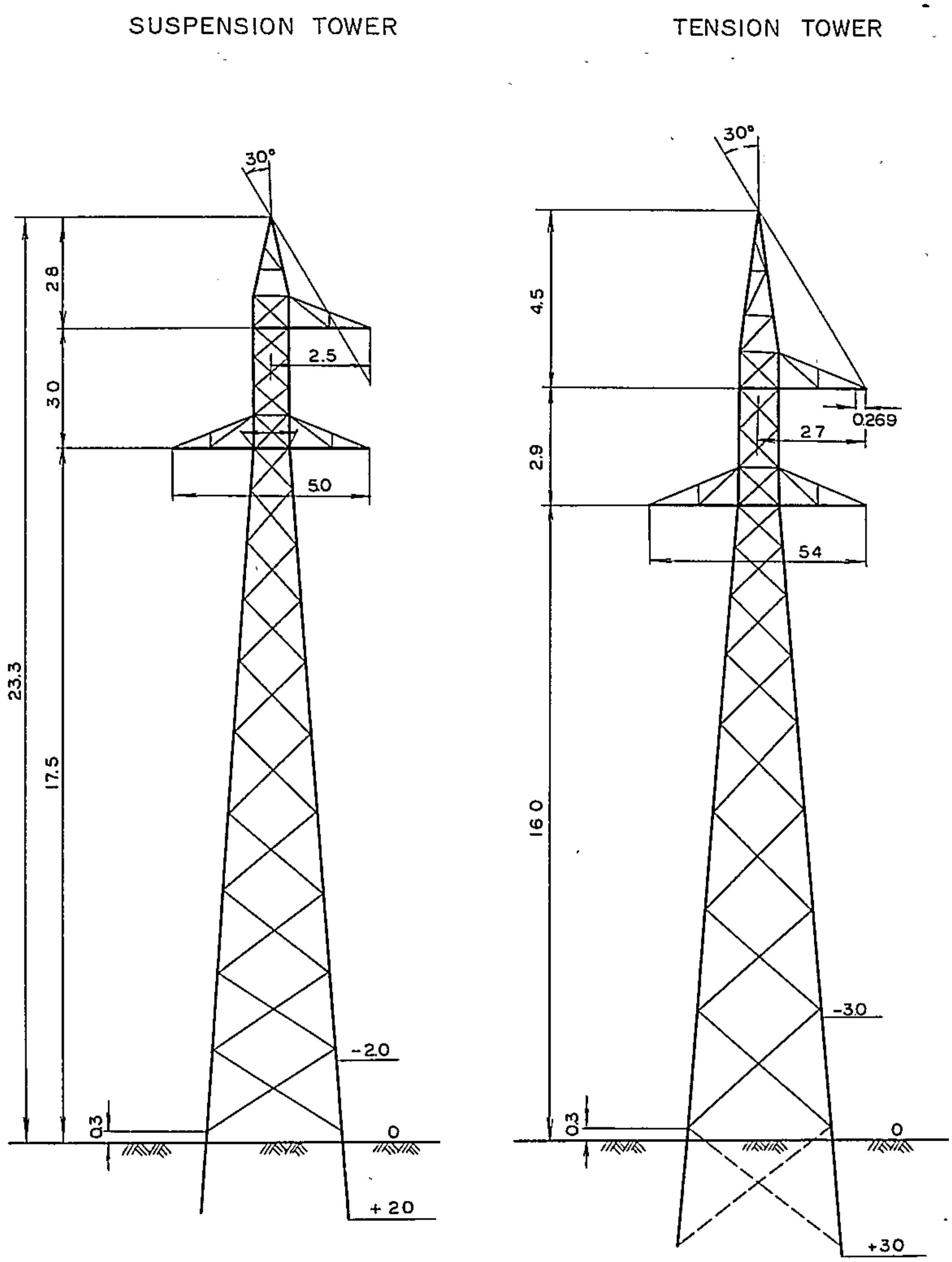
For load dispatching, 1 circuit of a power line carrier telephone will be provided between Korat Substation and the Nam Sai Yai No. 2 and No. 3 Power Stations. The connection with existing circuits at Korat Substation will be performed by manual key. However, when the circuit between Korat Substation and Kohn Kaen Substation becomes congested in the future, it is recommended to install an exclusive telephone circuit.

Besides the above, for general business, 1 circuit of a power line carrier telephone will be provide and a telephone exchanger will be installed to facilitate smooth operations at No. 3 Power Station.

In order to expedite line maintenance between Korat Substation and Nam Sai Yai No. 3 Power Station, a telecommunication circuit for line maintenance will be provided. VHF base stations will be provided inside the Korat Substation compounds and along the transmission line route, while VHF mobile stations for line inspection and maintenance will be assigned to Korat Substation and Nam Sai Yai No. 3 Power Station.

Between the VHF Base Station along the transmission line route and Korat Substation, 1 circuit of a power line carrier telephone will be provided. With this, the VHF mobile station inspecting the lines near relay stations can communicate with the Korat Substation through the relay station by the press-to-talk method.

To expedite the restoration of order within transmission lines, a transmission line fault locator will be provided at Korat Substation.



OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN

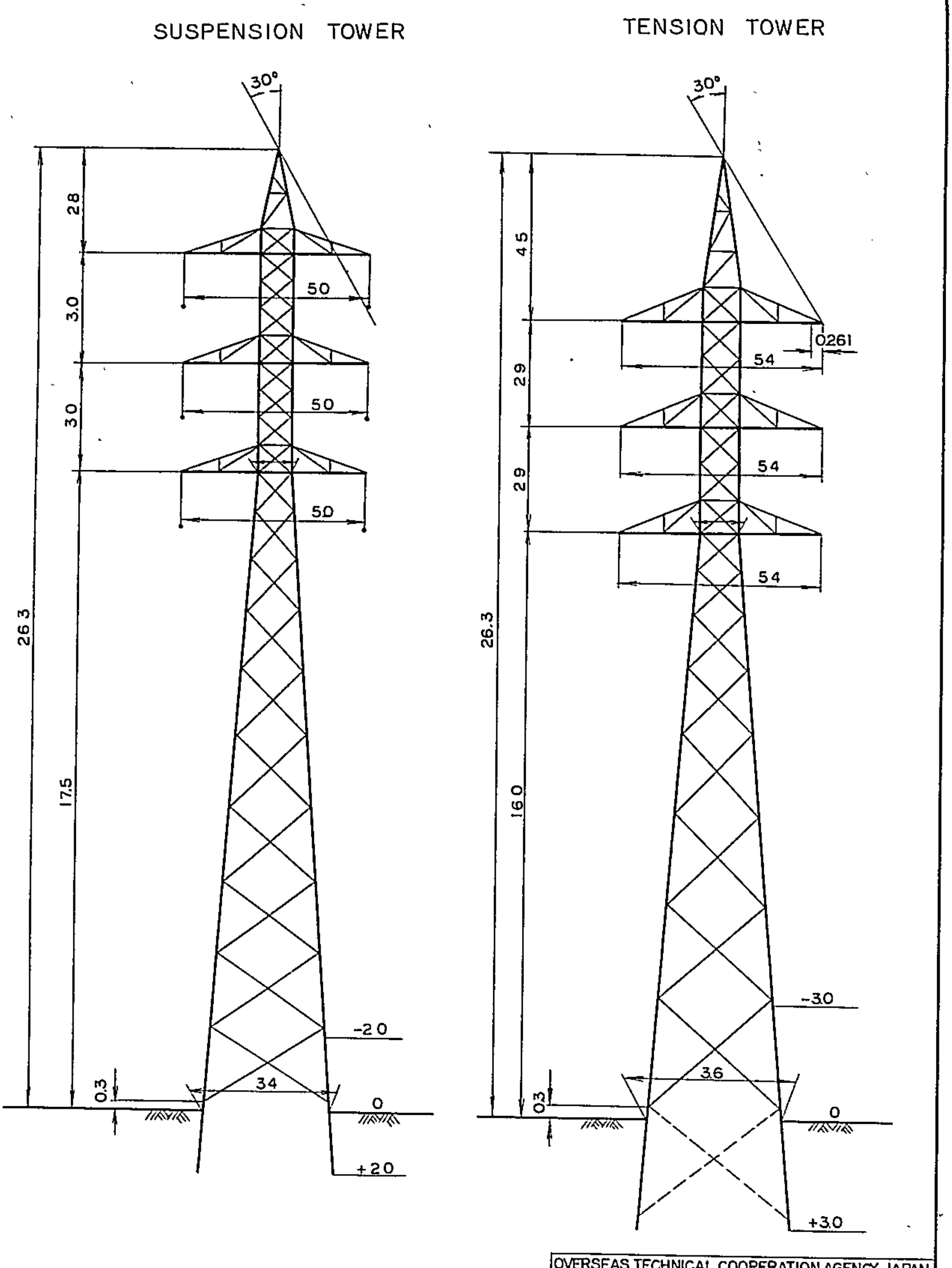
THAILAND NATIONAL ENERGY AUTHORITY

TRANSMISSION LINE
STANDARD TOWERS
(FOR 1 CIRCUIT)

ELECTRIC POWER DEVELOPMENT CO., LTD
(E.P.D Consultants) TOKYO JAPAN

DR.: [signature] SUBMITTED. [signature]
TR., RECOMMENDED:
CK. [signature] APPROVED: [signature]

SHEET NO. 7 OF 7



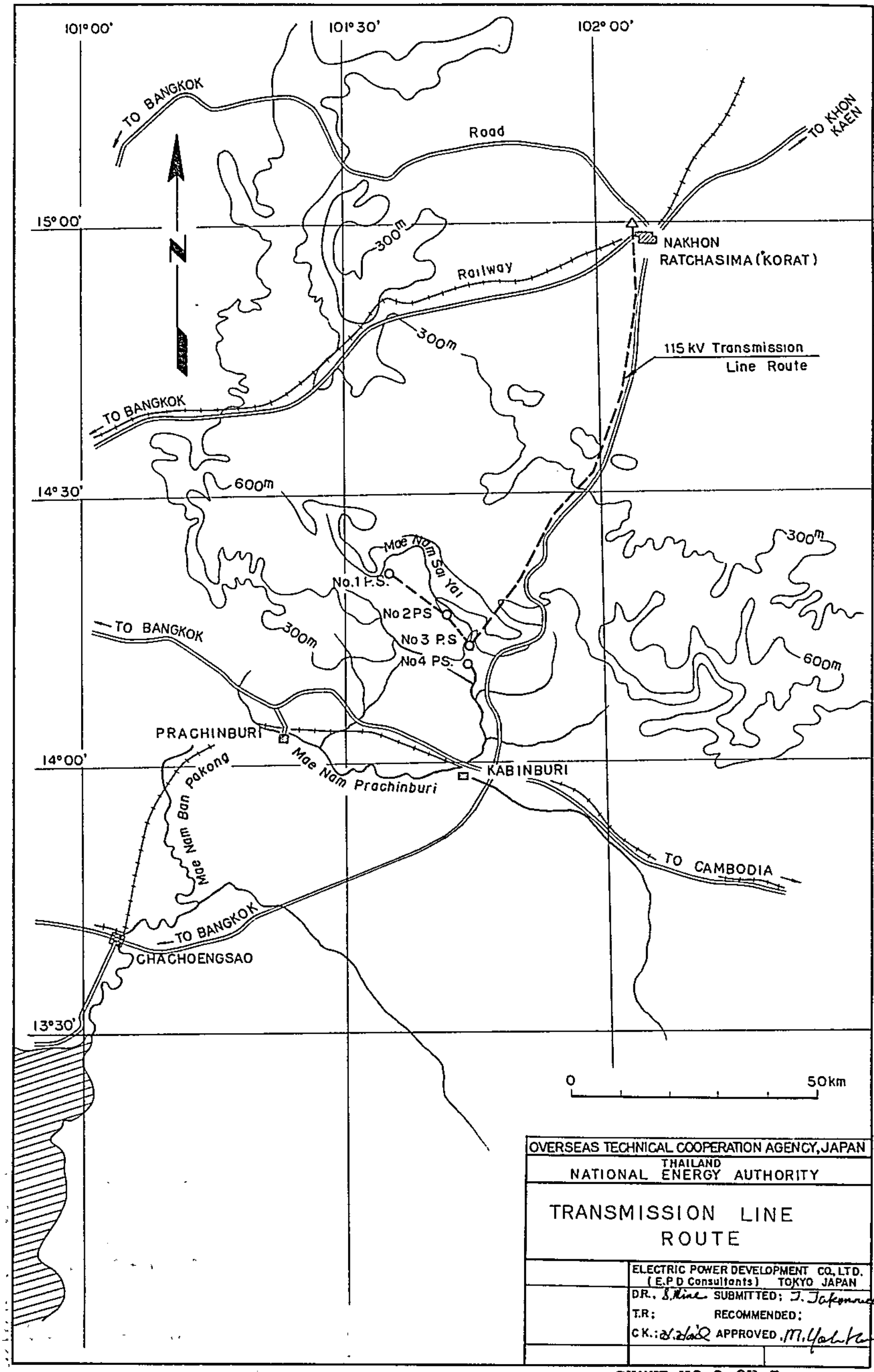
OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN

THAILAND
NATIONAL ENERGY AUTHORITY

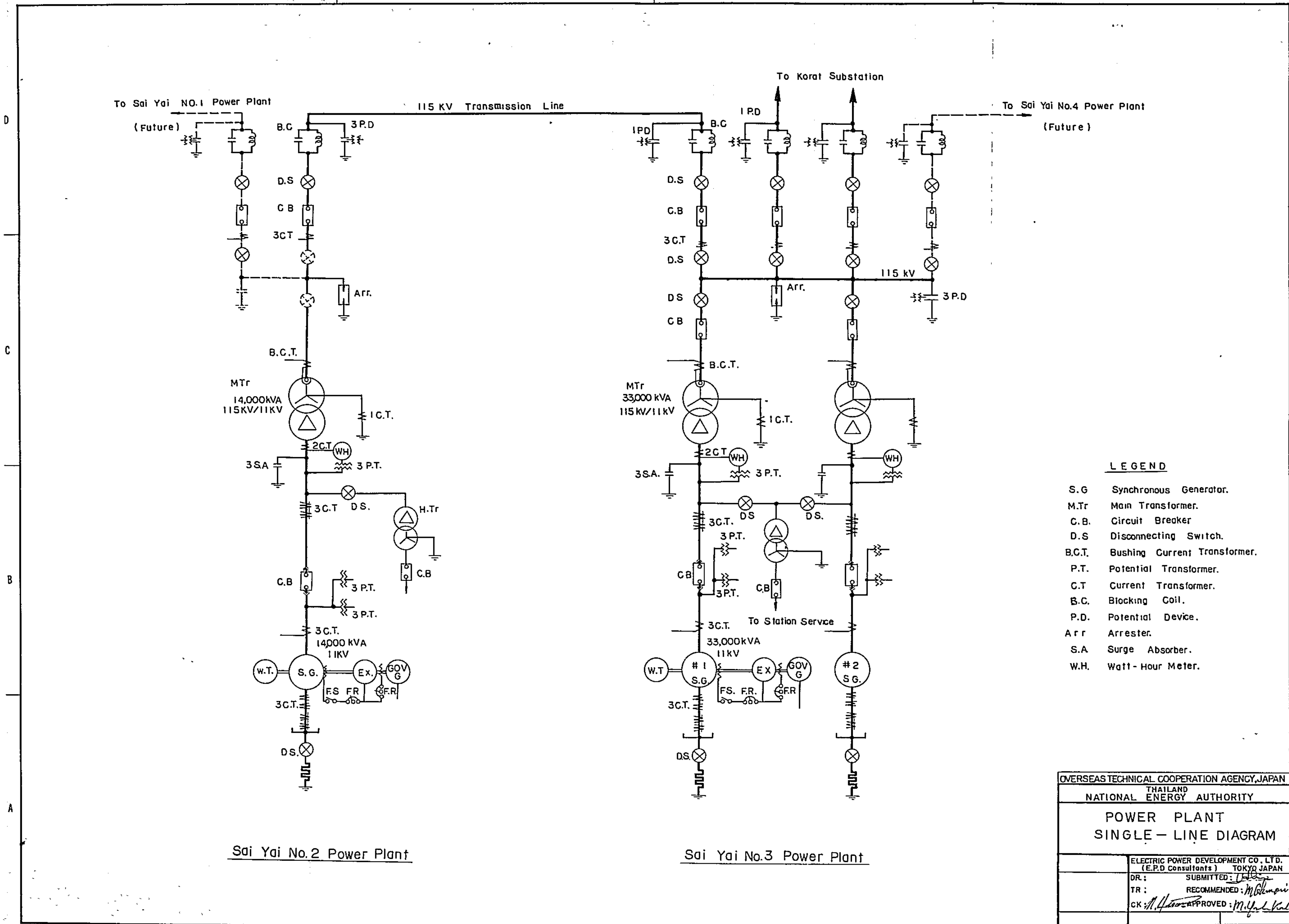
TRANSMISSION LINE
STANDARD TOWERS
(FOR DOUBLE CIRCUIT)

ELECTRIC POWER DEVELOPMENT CO., LTD.
(E.P.D. Consultants) TOKYO JAPAN
DR. S. Mine SUBMITTED: T. Takenouchi
TR. RECOMMENDED.
CK. [illegible] APPROVED M. Yabuta

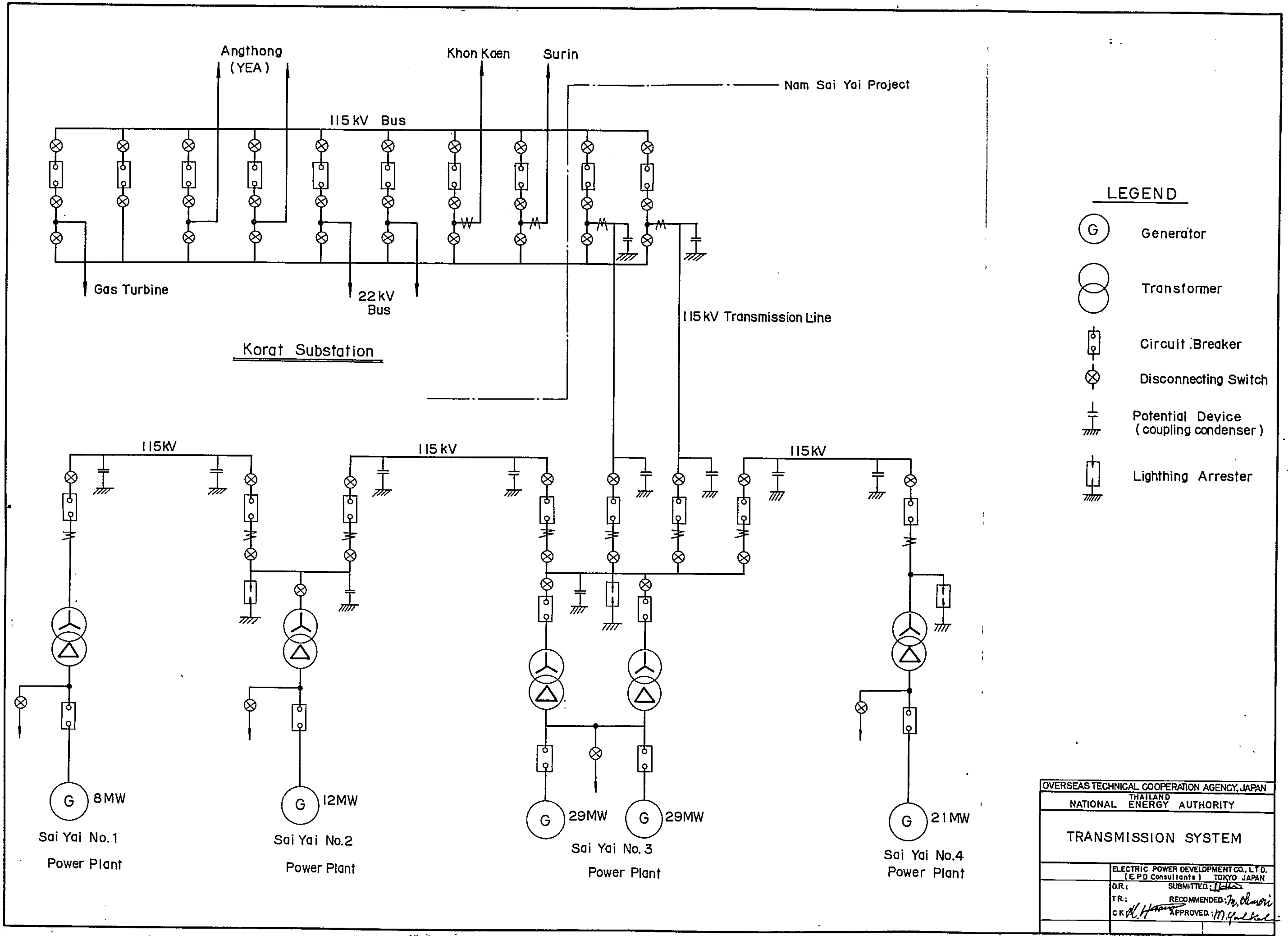
SHEET NO. 8 OF



101° 00'
101° 30'
102° 00'
15° 00'
14° 30'
14° 00'
13° 30'
TO BANGKOK
TO KHON KAEN
Road
Railway
300m
600m
NAKHON RATCHASIMA (KORAT)
115 kV Transmission Line Route
Mae Nam Sai Yai
No.1 P.S.
No 2 PS
No 3 P.S
No 4 PS.
PRACHINBURI
Mae Nam Prachinburi
KABINBURI
TO CAMBODIA
Mae Nam Ban Pakong
CHACHOENGSAO
0
50km
OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN
THAILAND NATIONAL ENERGY AUTHORITY
TRANSMISSION LINE ROUTE
ELECTRIC POWER DEVELOPMENT CO., LTD. (E.P.D Consultants) TOKYO JAPAN
DR.
SUBMITTED:
T.R:
RECOMMENDED:
CK.:
APPROVED.



SHEET NO. 10 OF 7


Angthong
(YEA)
Khon Kaen
Surin
Nam Sai Yai Project
115 kV Bus
Gas Turbine
22 kV
Bus
115 kV Transmission Line
Korat Substation
LEGEND
Generator
Transformer
Circuit Breaker
Disconnecting Switch
Potential Device
(coupling condenser)
Lighthing Arrester
115kV
115 kV
115kV
G
8MW
Sai Yai No.1
Power Plant
G
12MW
Sai Yai No.2
Power Plant
G
29MW
G
29MW
Sai Yai No.3
Power Plant
G
21MW
Sai Yai No.4
Power Plant
OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN
NATIONAL THAILAND ENERGY AUTHORITY
TRANSMISSION SYSTEM
ELECTRIC POWER DEVELOPMENT CO., LTD.
(E.P.D Consultants) TOKYO JAPAN
D.R.:
SUBMITTED:
TR.:
RECOMMENDED:
CK.
APPROVED:

CHAPTER 8

CONSTRUCTION SCHEDULE AND PROCEDURE

DRAWINGS

CHAPTER 8. CONSTRUCTION SCHEDULE AND PROCEDURE

8.1 BASIC CONSTRUCTION SCHEDULE

For the construction period for Nam Sai Yai No. 2 Dam and the No. 2 and No. 3 Power Stations, a duration of 40 months after completion of the access road is thought to be most suitable in consideration of the works, the arrangement of the structures, the construction capabilities that can be expected of contractors and the various conditions of the project area. To avoid concentration of works, there will be a difference of 9 months between start-up of the No. 2 Power Station including the No. 2 Dam and that of the No. 3 Power Station. Considering the requirements of power demand and supply and the necessity to store water during the rainy season, the start of water storage at the No. 2 Dam is aimed for July 1973 and operation start-up of the No. 2 and No. 3 Power Stations for October 1973 and June 1974 respectively. Therefore, counting back 40 months from this time, the construction will have to begin in February 1971 at the latest.

In 1971, the first year, after moving onto the site and finishing preliminary works such as construction roads, construction buildings, construction power facilities, etc., most of the No. 2 Power Station works such as the temporary diversion tunnel, excavation and embankment of the dam except for the river bed portion, excavation and embankment of the dikes, driving of work adits and main tunnel of the headrace and excavation for the penstock will be begun.

In the second year, the temporary diversion tunnel will be completed in the dry season at the beginning of the year, and the construction of the spillway and dikes also will be completed. Driving of the headrace tunnel and penstock, will be mostly completed, and concrete lining and installation of penstock line will be started. Simultaneously with the end of the rainy season, excavation and embankment of the river bed portion of the dam will begin, and in order to finish embankment of this portion during one dry season it will be necessary to pay attention to efficiency and concentration of the work. Work on the intake, surge tank and power station will also be started. Regarding the No. 3 Power Station, the penstock line will be the major item of works, and it will be necessary to start work at the beginning of the year. Other work will be started at the end of the year.

Embankment of the No. 2 Dam will be completed during the first half of the third year, and on July 1 the temporary diversion tunnel will be plugged and storage of water begun with power generation started in October. The middle of August through September will be used for water passage tests. The tunnel, penstock and powerhouse which are the main works of the No. 3 Power Station will be at their peaks of construction during this year, and by the end of the year, except for installation of equipment and machinery and internal finishing of building works, most of the work will be completed.

In the fourth year, power generation at the No. 3 Power Station will be started with July 1 as the target date.

In order for the above work to proceed smoothly, the construction of transportation roads, various preliminary works, purchase contracts for construction machinery and various equipments must progress smoothly according to the schedule indicated in DWG 8-1.

8.2 CONSTRUCTION PROCEDURE

8.2.1 Transportation Road

The town nearest the construction site is Kabinburi. At the time of the field survey, the existing road from Kabinburi was not in a condition which would make it usable as a construction road except for short stretches. However, construction of an access road was started from February 1968 and by the time work on the project is begun, the stretches between Kabinburi and the No. 3 Dam Site (about 30 km), and between the No. 3 Dam Site and the No. 2 Dam Base Camp (about 25 km) will present no problems for construction vehicles.

Up to Kabinburi, transportation of materials can be made by trailer, truck, or railroad freight cars. The method of transportation up to this point should be decided upon by the weight and dimensions, whether the material is domestic or imported, and by urgency. But in principle, it should be by railroad freight. For this purpose, the junction of the railroad approximately 5 km towards Combodia from Kabinburi with the highway leading towards Korat will be utilized to provide a sidetrack just before the junction where simple unloading and storage facilities will be located. Transportation will be by rail up to this point and by automobile thereafter.

8.2.2 Electric Power for Construction

Inside the project area, there is no power system at present which can be used for construction purposes. Therefore, equipment and facilities used for construction should be selected so that internal combustion engines can be used as much as possible, while facilities such as electric motors and illumination which require electric power will be limited to the necessary minimum, electricity being supplied by diesel generators.

Permanent distribution lines between power plants, dams, intakes, etc. will be built in advance as shown in DWG. 8-2 and branch lines installed from these lines as necessary will be distribute power to demand areas such as the various entrances of the headrace tunnels, aggregate plants and dam material borrow areas.

8.2.3 Water Supply Facilities

The water for construction and drinking will be taken at upstream of the coffer dams. This water will be pumped up and supplied to the dams, spillways, the various entrance of the headrace tunnels, powerhouses, aggregate plants, offices, living quarters and other facilities.

8.2.4 Procurement of Construction Materials

The materials to be used in construction will amount approximately to the following quantities:

Item	Unit	Main Work	Preliminary Work	Total
Cement	ton	15,200	1,100	16,300
Reinforcing Steel	ton	1,240	300	1,540
Steel	ton	460	630	1,090
Explosives	ton	430	—	430
Oils	kl	—	—	4,000
Lumber	cu.m	3,600	11,500	15,100

Such materials as cement, lumber, nails and wire which are produced in Thailand will be procured domestically. Oils such as kerosene, heavy oil and gasoline, although not produced in Thailand, will be procured on the general Thai market. Steel materials such as reinforcing steel, steel plates and shaped steel; fabricated steel such as rods, bits, steel forms, supports, gates, steel tubes and outdoor steel structures, and blasting materials such as explosives, detonators and fuses will be imported.

Regarding concrete aggregate, as river deposits of the necessary quantity and quality are not found in the vicinity of the project area, fine aggregate will be obtained from the sand deposit where the Huai Yang River joins the Sai Yai River about 5 km downstream of the latter's confluence with the Sai Noi River. Coarse aggregate will be purchased from the quarries existing at the right bank of the Hanuman River or the left bank of the Phra Phong River. As an added note concerning these aggregates, further investigations will be necessary regarding quality, grading and available quantities, while prices must also be negotiated.

8.2.5 Method for Constructing Main Structures

(a) Construction of No. 2 Dam

The mountainsides on both the left and right banks of the No. 2 Dam, are at high elevations, and construction can be carried out throughout the year without regard to river handling. Therefore, the most economical way to construct the No. 2 Dam is to divide the work into two parts, the river bed portion and the mountainside portion, and to embank the river bed portion in one dry season after diverting the river by a temporary diversion tunnel designed to handle the dry season runoff. The mountainside portions on the left and right banks will be worked throughout the construction period, while the diversion of the river will be carried out immediately after the end of the rainy season of 1971. In general, the excavation of the dam foundation will be carried out downward in order from the parts at higher elevations after treatment of the ground surface. Especially for the bed rock which will be the foundation of the soil material imprevious core, thorough grouting will be performed to prevent permeation of water. Also, grouting will be performed at places where it is necessary to increase the bearing strength and improve the ground, as well as stop water leakage.

The volume of embankment for the dam involves 800,000 cu. m of previous materials and 600,000 cu. m of imprevious materials or a total of 1,400,000 cu. m. As described in the section on materials, the previous material will be obtained from the borrow area indicated in DWG. 8-2 and excavated muck from the temporary diversion tunnel, dam foundation, spillway and tunnels. The impervious materials can be obtained from the borrow area indicated in the same DWG 8-2. It should be noted that the borrow areas, upon future investigations to be made on the properties and available qualities of materials, may be fixed at other locations which are of greater advantage. The schedule for embankment of the dam was decided upon according to embankment volume, heavy equipment to be used, carrying distances, weather conditions and schedules of related works.

The major heavy equipment to be used for embankment will consists of shovels of 1.2 to 2.0 cu. m dipper capacities, 10 to 20 ton dump trucks, 20 ton bulldozers and 10 cu. m motor scrapers. The roads from all borrow areas will be made sufficiently wide and gently graded to permit two-way passage of trucks at high speeds.

Heights of embankment lifts and methods of compaction will be selected after carrying out test embankments to determine at the best results.

In order to start power generation in October 1973, it will be necessary to store the water of the rainy season of that year. Therefore, final plugging of the temporary diversion tunnel must be carried out before the start of the rainy season, in other words by the end of June. Prior to final plugging, it will be desirable to first close the temporary diversion tunnel to be used as a outlet and finish installation of the tailrace tube and valve.

(b) Construction of Headrace Tunnel

In order to construct the headrace tunnel of the No. 2 Power Station which will have a total length of 1,785 m within the projected schedule, it is thought necessary to provide two work adits: towards the intake and towards the surge tank. The tunnel will be excavated by full-face methods throughout most of its length. Upon excavation, in sections where unstableness is expected, supports or temporary lining will be provided and the real concrete lining laid after excavation is fully completed. Concrete will be placed at one time for the full cross section using movable steel forms. After lining with concrete, mortar grouting and high-pressure grouting will be performed in order. Upon the progress of the intake and tunnel construction, the work adit near the intake will be closed and further construction of the tunnel will be made from the intake. The cross section and layout of the work adit near the surge tank will have to be given special consideration, as towards the end of construction the work on the tunnel, surge tank and penstock will overlap. After completion of the works, the downstream work adit, will be left as an inspection gallery for the tunnel and a manhole will be provided at the plug.

Driving of the headrace tunnel of the No. 3 Power Station, as in the case of the No. 2 Power Station will be performed by full-face methods from both ends providing work adits near the intake and the surge tank. However, since the tunnel is short, the concrete lining will be laid from only one entrance. The cross section of the tunnel is the same for both the No. 2 and No. 3 Power Stations, and the construction periods staggered for the two so that tunnel driving machinery and movable steel forms for placing concrete used for the tunnel of the No. 2 Power Station can be used in construction of the No. 3 Power Station tunnel. As for the work adits, as in the case of the No. 2 Power Station, the upstream work adit portal will be plugged and thoroughly grouted while the downstream work adit will be left as an inspection gallery for the tunnel.

(c) Construction of Other Structures

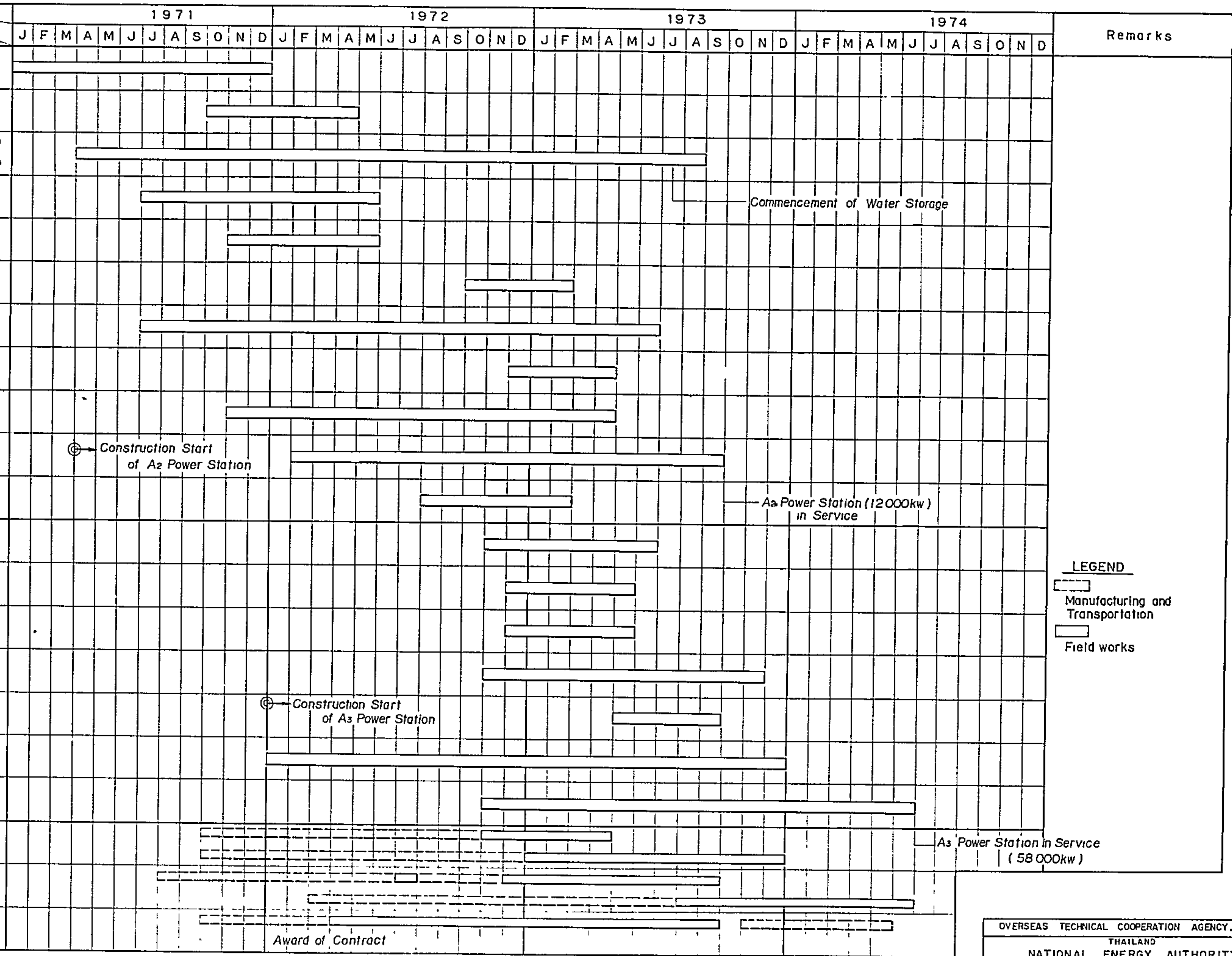
The construction of the No. 3 Dam will be performed in one dry season and no special diversion by a temporary tunnel will be carried out, the work being performed while drainage is accomplished with pumps. Although the construction method of the No. 3 Dam will follow the methods of the No. 2 Dam and the dikes, embankment will be started after careful foundation treatment by curtain and consolidation grouting. The materials for the dam body, besides being hauled from the designated borrow areas, will also be made available from excavation muck of the No. 2 and No. 3 Power Station. By the time embankment of the No. 3 Dam is completed, structures which will be affected by water storage in the No. 3 Regulating Pond must be completed or be in a condition that when the gate are closed no water will enter.

Since the penstock of the No. 3 Power Station is extremely long and will be constructed on a steep slope, it will be necessary for excavation to be begun simultaneously with the start of works for the No. 3 Power Station. Also, during the period of this excavation, it will be impossible to carry on work for the power-house located at the bottom of the penstock. Therefore, in order for the powerhouse works to be carried out according to schedule, the civil engineering works of the penstock line which have an effect on safety below must be hurried as much as possible. The penstock line will be excavated from the top, while installation of the pipe line will be started simultaneously from the top and the middle to meet the construction schedule.

Excavation of the vertical shaft of the surge tank will be carried out by first digging an advance vertical shaft with a cross section of 6 to 8 sq. m from below and then finishing by widening successively from the upper part, following this by excavation of the lower water chamber. Concrete will be placed after completion of excavation.

Although there will be no special problems in construction of the No. 2 Power Station, for the No. 3 Power Station, excavation of the foundation will be started immediately after the end of the rainy season of 1973 and the structures at the lower parts will be completed before the start of the rainy season of the following year, 1974. By closing the draft gates the danger of water entering the powerhouse will be eliminated.

Works		Quantities
A2 Power Station	Preparatory Works	
	Diversion Works	Tunnel Length 230.00m
	Dam	Ex 60,100 m³ Em 1,399,600 m³
	Spillway	Ex 124,000 m³ Conc 1,270 m³
	Dike	Em 296,600m
	Intake	Ex 60,000 m³ Conc 880 m³
	Tunnel (L=1785.0m)	Ex 20,850 m³ Conc 7,350 m³
	Surge Tank	Ex 2,790 m³ Conc 1,290 m³
	Penstock (L=6850m)	Ex. 30,000 m³ Conc. 5,010 m³
	Powerhouse	Ex 11,960 m³ Conc. 3,810 m³
	Tailrace	Ex 99,800 m³ Conc 1,800 m³
A3 Power Station	Dam	Ex 17,700 m³ Em 403,400 m³
	Spillway	Ex 9,700 m³ Em 370 m³
	Intake	Ex 15,700 m³ Conc 620 m³
	Tunnel (L=535.0m)	Ex 6,900 m³ Conc 2,450 m³
	Surge Tank	Ex 1,990 m³ Conc 745 m³
	Penstock (L=1390.0m)	Ex 83,450 m³ Conc 9,730 m³
	Powerhouse	Ex 31,000 m³ Conc. 4,540 m³
Equipment etc	Penstock Equipment	A2PS 680 t A3PS 1,920 t
	Turbine & Generator	1 set 2 set
	Transmission Line etc	



OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN

THAILAND
NATIONAL ENERGY AUTHORITY

NAM SAI YAI NO.2 AND NO.3 POWER STATION
CONSTRUCTION SCHEDULE

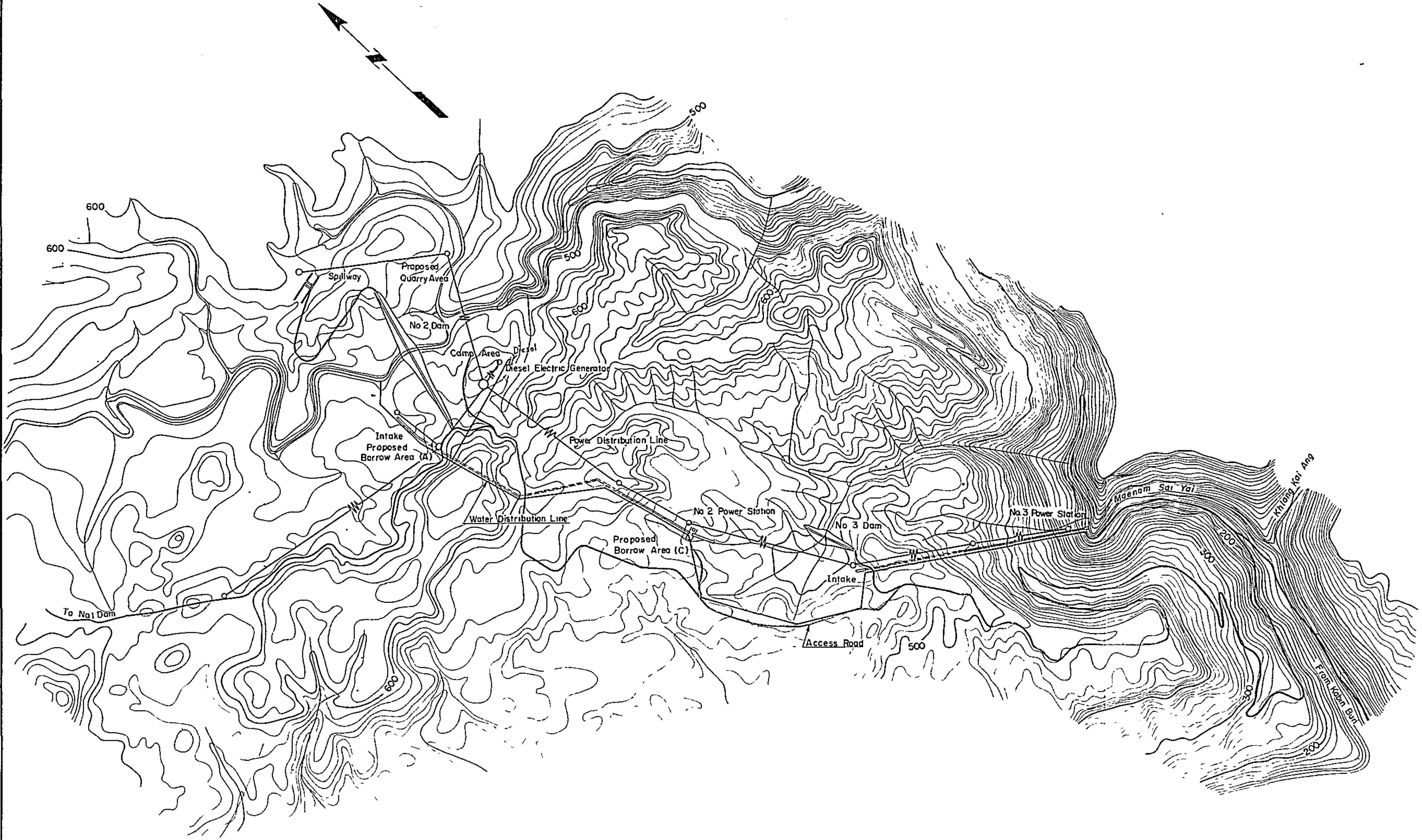
ELECTRIC POWER DEVELOPMENT CO., LTD (E.P.D. Consultants) TOKYO JAPAN

DR. SUBMITTED RECOMMENDED APPROVED

LOCATION DATE DESCRIPTION BY
REVISION

[illegible] Jul. 6, '68

SHEET NO 1 OF 8



OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN

THAILAND
NATIONAL ENERGY AUTHORITY

CONSTRUCTION ROADS LANDS AND TEMPORARY WORKS

ELECTRIC POWER DEVELOPMENT CO., LTD (E P D Consultants) TOKYO JAPAN

LOCATION	DATE	DESCRIPTION	BY
REVISION			

Jul. 8, '68

SHEET NO 2 OF 8

CHAPTER 9

COST ESTIMATE

TABLES

CHAPTER 9. COST ESTIMATE

9.1 BASIC ASSUMPTIONS

In estimating construction costs, the natural conditions and regional conditions of the project site, the scale of the works and the technological standards which can be counted on at present were taken into consideration, and calculations were made based on the commodity prices as of March 1968.

The basic assumptions for estimation of construction costs are as described below.

(1) Scope of Construction Cost Estimates

The scope of construction cost estimates covers the Nam Sai Yai No. 2 and No. 3 Power Stations, the transmission line from these power stations to Korat and up to the expansion in the switching facilities at Korat Substation for leading in the transmission line. Further, the communication facilities to be provided between the No. 2, No. 3 Power Stations and Korat Substation, and the construction roads to the various structures and the power stations branching from the access road presently being built are also included.

(2) Construction Costs of Civil Engineering Works

(a) Work quantities were estimated from the preliminary design drawings attached to this Report and when necessary from still more detailed preliminary design drawings.

(b) Regarding basic prices, the expenses for materials to be procured in Thailand and for labor were based on the prices in March 1968 while the prices of imported construction machinery were based on March 1968 CIF prices.

(c) Construction costs were calculated on performance in Thailand, information obtained from experience with similar works in Japan and the effects of regional conditions. The unit costs of major works such as excavation of dam foundation, dam embankment, tunnel excavation, aggregate manufacturing, and concreting were estimated by daily quantity methods. In other words, the types of construction machinery and periods of use were first determined according to the construction schedule and work quantities. Next, based on the results, the necessary labor, material and equipment costs were calculated to obtain the direct construction costs. Following this, the cost of temporary facilities necessary for smooth operation of various equipment and facilities and the administrative costs of the various contractors were added to the direct construction costs to obtain the unit construction costs.

(d) The cost for preliminary works such as construction road, power facilities for construction, cutting trees and camping facilities is included in the civil work cost.

(e) Customs duties on imported materials and imported construction machinery were all included in the unit construction costs.

(f) A contingency reserve of 15% was included for the civil engineering works construction costs.

(3) Costs of Equipment and Machinery

(a) Equipment and machinery such as gates, penstock pipe, electrical machinery and equipment, transmission facilities, substation equipments were all assumed to be of Japanese manufacture and furnished from Japan.

(b) The costs of various equipment and machinery were calculated by adding ocean freight, insurance, customs duties, landing costs, overland transportation costs in Thailand and field installation costs to the F O B price in Japan.

(c) A contingency reserve of 5% of the cost of equipment and machinery was included.

(4) Engineering Fees

5% of the construction cost were included as engineering fees for detailed designing and supervising costs.

(5) Administrative cost

The field allowances of NEA personnel dispatched to the project site and the expenses of offices, living quarters and automobiles required by NEA and the Consulting Engineer and of other necessary facilities were included as administrative cost at 4% of construction cost.

(6) Land Acquisition Costs

All locations at which power generation facilities will be provided are on state-owned land so that the cost of land acquisition is not involved. As the part of the transmission line will pass through privately owned land, the compensation for this is included in the estimate.

(7) Interest during Construction

Interest during construction was calculated based on annual construction fund requirements indicated in Table 10-2. The interest rate, was assumed at 6.0% per annum for both foreign and domestic currency payments.

(8) Domestic and Foreign Currency

Construction costs were divided into domestic and foreign currency payments. Wages of indigenous labor, on-site living expenses of foreign labor and engineers, cost of materials procured in Thailand, customs duties of imported materials and construction machinery and freight costs in Thailand are included under domestic currency. Other expenses are included under foreign currency. Exchange rates were calculated to be the official rates of U.S.$1.00 = ฿ 20.8 = ¥360.

9.2 SUMMARY OF CONSTRUCTION COST

The total construction cost required for execution of works for the Nam Sai Yai No. 2 and No. 3 Power Stations is calculated to be 490 million Baht. Of this amount, the equivalent of 292 million Baht will be paid in foreign currency while the payments in domestic currency will amount to 198 million Baht.

Of the total construction cost, 421 million Baht will be the construction cost of power generating facilities of which the foreign currency payments will be equivalent to 243 million Baht and 178 million Baht will be paid in domestic currency. The transmission line construction cost will be 69 million Baht of which the equivalent of 49 million Baht will be paid in foreign currency and 20 million Baht will be paid in domestic currency.

The summary of construction costs is given in Table 9-1. The annual fund requirements based on the construction schedule are indicated in Table 9-2. The terms of payment in this case are considered as described below. For civil engineering works, payments will be based on monthly work totals of which 10% monthly would be withheld, and in the month that half of work is completed, one-half of the payments withheld will be released. Upon completion of work, one-half of the remaining payments withheld would be released and the balance paid one year after completion of the power station. The payment schedule for equipment and machinery will be 5% at time of signing of contract, 35% at time of arrival at project site, 30% at time of completion of work and 30% at time of start-up.

TABLE 9-1 SUMNARY OF ESTIMATED CONSTRUCTION COST

(Unit: Thousands of Baht)

	Item	Total Cost	Foreign Currency	Domestic Currency
1.	Generating Facilities	353,700	204,900	148,800
	No.2 Power Station	195,200	106,900	88,300
	No.3 Power Station	158,500	98,000	60,500
2.	Transmission Line, Substation and Telecommunication	57,900	42,600	15,300
3.	Engineering Fee	20,700	20,700	–
4.	Administration Cost	16,500	–	16,500
5.	Compensation	1,000	–	1,000
6.	Interest during Construction	40,000	24,100	15,900
	Total	487,800	292,300	197,500

TABLE 9-1, (1) COST OF GENERATING FACILITIES

(Unit: Thousands of Bahts)

Item	No.2 Power Station			No.3 Power Station		
	Total Cost	Foreign Currency	Domestic Currency	Total Cost	Foreign Currency	Domestic Currency
1. Generating Facilities	195,200	106,900	88,300	158,500	98,000	60,500
Civil Works	153,200	77,000	76,200	59,800	28,400	31,400
Dam	86,800	44,600	42,200	17,600	8,900	8,700
Waterway and Powerhouse	46,400	22,400	24,000	34,400	15,800	18,600
Contingencies	20,000	10,000	10,000	7,800	3,700	4,100
Hydraulic Equipments	17,000	11,900	5,100	45,400	31,800	13,600
Gates	1,100	1,000	100	900	800	100
Penstocks	8,800	7,800	1,000	26,000	23,200	2,800
Outlet-valve	300	200	100	–	–	–
Installation Cost	3,500	2,500	1,000	9,200	6,500	2,700
Import Taxes	2,600	–	2,600	7,100	–	7,100
Contingencies	700	400	400	2,200	1,300	900
Electric Equipment	25,000	18,000	7,000	53,300	37,800	15,500
Turbines	4,300	4,000	300	9,100	8,400	700
Generator	4,800	4,500	300	11,300	10,500	800
Transformer	1,300	1,200	100	4,600	4,300	300
Accessories	6,200	5,900	300	10,000	9,600	400
Installation Cost	2,600	1,800	800	6,400	3,700	2,700
Import Taxes	4,600	–	4,600	9,300	–	9,300
Contingencies	1,200	600	600	2,600	1,300	1,300

TABLE 9-1, (2) COST OF TRANSMISSION LINE, SUBSTATION AND TELECOMMUNICATION

(Unit: Thousands of Baht)

Item	Total Cost	Foreign Currency	Domestic Currency
2. Transmission Line, Substation and Telecommunication	58,900	42,600	16,300
Transmission Line	38,700	35,700	3,000
Substation	2,400	2,200	200
Telecommunication	3,400	3,300	100
Import Taxes	10,600	–	10,600
Contengencies	2,800	1,400	1,400
Compensation	1,000	–	1,000

TABLE 9-2 FUND REQUIREMENT IN EACH YEAR

(Unit: million Baht)

Item	Total Fund Requirement		1970		1971		1972		1973		1974		1975	
	Foreign Currency	Domestic Currency	Foreign Currency	Domestic Currency	Foreign Currency	Domestic Currency	Foreign Currency	Domestic Currency	Foreign Currency	Domestic Currency	Foreign Currency	Domestic Currency	Foreign Currency	Domestic Currency
(A) Generating Facilities														
(A−1) No.2 Power Station														
Civil Works	77.0	76.2	–	–	19.6	18.5	36.4	35.8	18.5	19.4	2.5	2.5	–	–
Hydraulic Equipments	11.9	5.1	–	–	1.0	0.5	6.9	3.1	4.0	1.5	–	–	–	–
Electric Equipments	18.0	7.0	–	–	0.9	0.4	6.3	2.4	10.8	4.2	–	–	–	–
Engineering Fee	9.8	0	7.8	0	1.0	0	1.0	0	–	–	–	–	–	–
Administration Cost	0	7.8	–	0.1	0	1.7	0	3.7	0	2.3	–	–	–	–
Sub-total	116.7	96.1	7.8	0.1	22.5	21.1	50.6	45.0	33.3	27.4	2.5	2.5	–	–
Interest during Construction	10.7	8.2	0.2	0	1.1	0.6	3.3	2.5	6.0	5.0	0.1	0.1	–	–
Total	127.4	104.3	8.0	0.1	23.6	21.7	53.9	47.5	39.3	32.4	2.6	2.6	–	–
Cumulative Total	–	–	8.0	0.1	31.6	21.8	85.5	69.3	124.8	101.7	127.4	104.3	–	–
(A−2) No.3 Power Station														
Civil Works	28.4	31.4	–	–	–	–	7.1	8.2	18.1	19.8	2.3	2.4	0.9	1.0
Hydraulic Equipments	31.8	13.6	–	–	1.5	1.0	10.0	4.0	10.3	4.6	10.0	4.0	–	–
Electric Equipments	37.8	15.5	–	–	–	–	1.9	0.8	13.2	5.4	22.7	9.3	–	–
Engineering Fee	7.7	0	5.2	0	0.5	0	0.5	0	0.5	0	–	–	–	–
Administration Cost	0	6.3	–	–	0	0.1	0	1.3	0	2.9	0	2.0	–	–
Sub-total	105.7	66.8	6.2	0	2.0	1.1	19.5	14.3	42.1	32.7	35.0	17.7	0.9	1.0
Interest during Construction	10.1	6.3	0.2	0	0.4	0	1.0	0.5	2.9	1.9	5.6	3.9	0	0
Total	115.8	73.1	6.4	0	2.4	1.1	20.5	14.8	45.0	34.6	40.6	21.6	0.9	1.0
Cumulative Total	–	–	6.4	0	8.8	1.1	29.3	15.9	74.3	50.5	114.9	72.1	115.8	73.1
(A−1) + (A−2)														
Total	243.2	177.4	14.4	0.1	26.0	22.8	74.4	62.3	84.3	67.0	43.2	24.2	0.9	1.0
Cumulative Total	–	–	14.4	0.1	40.4	22.9	114.8	85.2	199.1	152.3	242.3	176.4	243.2	177.4
(B) Transmission Line														
Transmission Line, Substation and Telecommunication	42.6	16.3	–	–	–	–	30.3	11.4	12.3	4.9	–	–	–	–
Engineering Fee	3.2	0	–	–	–	–	2.0	0	1.2	0	–	–	–	–
Administration Cost	0	2.4	–	–	–	–	0	1.4	0	1.0	–	–	–	–
Sub-total	45.8	18.7	–	–	–	–	32.3	12.8	13.5	5.9	–	–	–	–
Interest during Construction	3.3	1.4	–	–	–	–	0.9	0.4	2.4	1.0	–	–	–	–
Total	49.1	20.1	–	–	–	–	33.2	13.2	15.9	6.9	–	–	–	–
Cumulative Total	–	–	–	–	–	–	33.2	13.2	49.1	20.1	–	–	–	–
(C) Sum of Generating Facilities and Transmission Line														
Total	292.3	197.5	14.4	0.1	26.0	22.8	107.6	75.5	100.2	73.9	43.2	24.2	0.9	1.0
Cumulative Total	–	–	14.4	0.1	40.4	22.9	148.0	98.4	248.2	172.3	291.4	196.5	292.3	197.5

CHAPTER 10

ECONOMIC JUSTIFICATION

TABLES

CHAPTER 10. ECONOMIC JUSTIFICATION

10.1 SALABLE ENERGY

As described in Chapter 6, the available energy per annum possible at the Nam Sai Yai No. 2 and No. 3 Power Stations is estimated to be 40 million kWh and 190 million kWh respectively or a total of 230 million kWh at the sending end. This all energy will be used effectively immediately upon start-up of the stations.

Since it is estimated the transmission losses from Nam Sai Yai No. 2 and No. 3 Power Stations to Korat Substation will be 2.3%, the salable energy at Korat Substation will be 39.1 million kWh and 185.6 million kWh respectively or a total of 224.7 million kWh.

10.2 ANNUAL COST AND ENERGY COST

10.2.1 Annual Cost

As described in Chapter 9, the total construction cost of Nam Sai Yai No. 2 and No. 3 Power Stations including the transmission line to Korat will be 490 million Baht.
The construction cost by facility and the respective serviceable years are as shown in Table 10-1.

Applying the equalized annual cost factor at an interest rate of 6% for both foreign and domestic currency, as shown in Table 10-1, the uniformly distributed annual cost over 50-years serviceable life of this Project is given in Table 10-2. As can be seen in this table, the annual cost of the Nam Sai Yai No. 2 and No. 3 Power Stations is 37,570 million Baht.

Various taxes and levies are not considered for the Project, because it is thought the Nam Sai Yai No. 2 and No. 3 Power Stations will be transferred to the jurisdiction of NEEA upon completion. In Thailand, authorities such as NEEA are exempt from taxes. However, after deduction of interest and various expenses, a contribution corresponding to the business tax on net profit is to be made to the Government. Since the electric power industry in Thailand is state-owned, it is thought the first objective of NEEA would be to establish as low a power rate as possible instead of attempting to produce net income by raising the rate. Therefore, in calculating the above annual cost, it was assumed NEEA would not gain any net profit so that there would be no contribution.

10.2.2 Energy Cost

The annual cost obtained above divided by the salable energy produces the energy cost per kWh at Korat Substation of the Nam Sai Yai No. 2 and No. 3 Power Stations, which will be 0.167 Baht per kWh.

10.3 ANNUAL BENEFIT

10.3.1 Basic Concepts of Economic Evaluation

As stated in Chapter 3, it has been made definite that the NEEA and the YEA Systems will be interconnected by a transmission line in 1970 and power will be interchanged between the two systems by means of this transmission line. Under such circumstances, it is thought appropriate to consider a standard thermal power station for comparison purposes, rather than alternative facilities, for economic evaluation of the Nam Sai Yai Power Stations.

10.3.2 Selection of Standard Thermal Power Plant

The following basic conditions were used in selecting a standard thermal power station:

(1) It should be of appropriate scale viewed from the points of sizes of power demand, growth rates and structure of supply capabilities within the YEA and NEEA Systems.

(2) It should be a modern thermal station which would occupy a major position in the supply capacity in the near future.

(3) It should be at the most favorable location for a new thermal power station.

Taking into account the above conditions, an exclusively heavy oil burning thermal station of 400 MW (200 MW x 2 units) to be constructed in the environs of Bangkok was selected as the standard thermal power station.

10.3.3 Construction Cost and Annual Cost of Standard Thermal Power Plant

The construction cost in Thailand of the 400-MW heavy-oil burning thermal power plant selected above is estimated as shown in Table 10-3.

Next, the annual cost of this thermal power station was calculated dividing into fixed and variable cost (Table 10-4).

The fixed cost are 262 Baht per kW and the variable cost 0.112 Baht per kWh. For the same reason given in 10.2.2, taxes, levies and contributions were considered to be zero, but import duty on fuel has been included.

10.3.4 Unit Value of Benefit

The annual benefit of a hydroelectric power station is calculated from benefit per kW and benefit per kWh. The benefit per kW is the annual fixed cost of a standard thermal power station multiplied by a kW adjustment factor. The reason for this multiplication by the kW adjustment factor is that thermal stations tend to have more outages due to faults and periodical repairs than hydro-power station. Therefore, in order to supply power with the same dependability as a hydroelectric plant, when a thermal plant is added to a power system, the thermal plant would require a capacity increase corresponding to this outage factor. This increased capacity requirement should be looked on as a benefit of a hydroelectric plant. The coefficient for inclusion of this benefit in the calculations is the kW adjustment factor. In this case, the customary 1.15 used in Japan was taken as the factor.

The kWh benefit is the annual variable expense per kWh of a standard thermal power plant compared with the energy produceable annually.

Therefore, the benefit per kW and the benefit per kWh will be as follows:

Benefit per kW	262 x 1.15 = 300 Baht
Benefit per kWh	0.112 Baht

10.3.5 Annual Benefit of Nam Sai Yai No. 2 and No. 3 Projects

The annual benefit of the Nam Sai Yai Project was calculated using the benefits per kW and per kWh.

The effective capacities of Nam Sai Yai No. 2 and No. 3 Power Stations are given in Table 10-5 and 10-6. These effective capacities are the amounts obtained from the kW balance based on the load forecast by EPDC described in Chapter 3.
As can be seen from this table, approximately 6 years after start-up of the Nam Sai Yai power stations, the entire capacities will become effective and will reach dependable peak output.

The transmission losses between the Nam Sai Yai power stations and Korat Substation were considered to be cancelled by the transmission losses of the standard thermal power station which would be constructed in the vicinity of Bangkok and therefore were not included in the calculations.

The annual benefit of the Nam Sai Yai power stations obtained in the manner is expected to be 44.1 million Baht as indicated in Table 10-5 and 10-6.

10.4 BENEFIT-COST RATIO AND INTERNAL RATE OF RETURN

The annual cost of Nam Sai Yai No. 2 and No. 3 Power project is 37.6 million Baht as shown in Table 10-2 and the annual benefit is 44.1 million Baht as shown in Table 10-5 and 10-6.

Therefore, the annual surplus benefit will be 6.5 million Baht and the benefit-cost ratio will be 1.17.
Moreover, the internal rate of return (the interest rate at which cost equals to benefit) based on above figures is estimated to be 7.7%. (See Appendix. G)

10.5 BENEFIT-COST RATIO ACCOUNTING FOR EFFECT ON DOWNSTREAM CULTIVATED LAND

The benefit to downstream cultivated land when the upstream reservoir is constructed, as stated in 5.3.2 and 5.3.3, will be 9.4 million to 15.3 million Baht annually including the benefit from flood control, while the annual cost for irrigation facilities required exclusively for this purpose is 7.7 million to 7.9 million Baht. Therefore, the surplus benefit is 1.7 million to 7.4 million Baht.

If the annual benefit of agriculture is assumed to be 15.3 million Baht and annual cost for irrigation facilities 7.9 million Baht, adding these figures to the benefit and cost of power generation, the benefit-cost ratio will be 1.28.

Regarding the reservoir as a dual-purpose facility for power generation and irrigation (including flood control), the cost allocation by the alternative justifiable cost method will be as given in Table 10-7.

The annual cost and benefit-cost ratio for power generation are 35.5 million Baht and 1.24 respectively and for irrigation 10.5 million Baht and 1.46.

TABLE 10-1 CONSTRUCTION COST AND EQUALIZED ANNUAL COST FACTOR OF NAM SAI YAI NO. 2 AND NO. 3 PROJECTS

Item	Generating Plant	Transmission Line, Substation and Telecommunication
Construction Cost (1,000 Baht)	420,600	69,200
Serviceable Years	50	40
Equalized Annual Cost Factor (per cent)	7.35	9.65
1. Interest and Depreciation	6.35	6.65
2. Operation and Maintenance	0.70	2.50
3. Administration	0.30	0.50

TABLE 10-2 ANNUAL COST OF NAM SAI YAI NO. 2 AND NO. 3 PROJECTS

Unit: 1,000 Baht

Item	Generating Facilities	Transmission Line, Substation and Telecommunication	Total
1. Interest and Depreciation	26,680	4,600	31,280
2. Operation and Maintenance	2,940	1,730	4,670
3. Administration	1,270	350	1,620
4. Total	30,890	6,680	37,570

TABLE 10-3 CONSTRUCTION COST AND GENERAL FEATURES OF STANDARD THERMAL PLANT

Item	Unit	Value
Installed Capacity	MW	400
Unit Capacity x Number of Unit	MW x unit	200 x 2
Annual Capacity Factor	%	70
Thermal Efficiency at Sending End	%	35.9 (0.242 liters/kWh)
Annual Energy Supply	Million kWh	2,453
Fuel and Lubricants	Million liters	593.6
Construction Cost	Million Baht	1,100

TABLE 10-4 ANNUAL COSTS AND UNIT COST OF STANDARD THERMAL POWER PLANT

Unit: 1,000 Baht

Item	Fixed Costs	Variable Costs	Remarks
1. Interest and Depreciation	79,916		Capital Recovery (1) Factor: 0.07265
2. Operation and Maintenance Costs	23,160	4,400	
Labour Costs	3,360		120 men x 28,000 ฿/man
Repair Expenses	17,600	4,400	Construction Cost x 2%
Miscellaneous Expenses	2,200		Construction Cost x 0.2%
3. Administration Costs	1,764	411	O & M Cost x 8% (2)
4. Fuel Costs		207,088	0.455 ฿/liter x 593.6 million liters
5. Total	104,840	274,929	
6. Annual Costs at Sending Ehd			
Power Cost (฿/kW)	262		
Energy Cost (฿/kWh)		0.112	

Note:

(1) Annual interest rate: Foreign Currency : 6%
Domestic Currency : 6%
Serviceable life: 30 years

(2) The costs were allocated according to the following ratio:
Fixed Cost : 80%
Variable Cost : 80%

TABLE 10-5 ANNUAL BENEFIT OF NAM SAI YAI NO. 2 POWER STATION

Year	(1) Salable Annual Energy in MWh	(2) Dependable Capacity in MW	Annual Benefit in 1,000 Baht		
			(3) For kWh (1) x 0.112	(4) For kW (1) x 300	(5) Total (3) + (4)
1974	40,000	7.3	4,480	1,590	6,070
1975	40,000	7.3	4,480	2,190	6,670
1976	40,000	7.3	4,480	2,190	6,670
1977	40,000	7.3	4,480	2,190	6,670
1978	40,000	8.6	4,480	2,580	7,060
1979	40,000	9.2	4,480	2,760	7,240
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
2023	40,000	9.2	4,480	2,760	7,240
Present Worth in 1974	–	–	70,620	41,130	111,810
Annual Benefit for 50 years	{Capital recovery factor for 50 years = 6.34%}		4,480	2,610	7,090

TABLE 10-6 ANNUAL BENEFIT OF NAM SAI YAI NO. 3 POWER STATION

Year	(1) Salable Annual Energy in MWh	(2) Dependable Capacity in MW	Annual Benefit in 1,000 Baht (3) For kWh (1) x 0.112	(4) For kW (1) x 300	(5) Total (3) + (4)
1974	190.0	31.6	21,280	9,480	30,760
1975	190.0	35.8	21,280	10,740	32,020
1976	190.0	39.1	21,280	11,730	33,010
1977	190.0	39.1	21,280	11,730	33,010
1978	190.0	53.3	21,280	15,990	37,270
1979	190.0	56.4	21,280	16,920	38,200
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
2023	190.0	56.4	21,280	16,920	38,200
Present Worth in 1974	–	–	335,650	248,010	583,660
Annual Benefit for 50 years	{Capital recovery factor for 50 years = 6.34%}		21,280	15,730	37,010

TABLE 10-7 COST ALLOCATION

Unit: million Baht

Item		Power	Irrigation	Total
1.	Benefit	44,100	15,270	59,370
2.	Alternate cost	44,100	16,600	–
3.	Benefit limited alternate cost (lesser of 1 or 2)	44,100	15,270	59,370
4.	Specific costs	30,770	7,870	38,640
5.	Remaining benefit (3–4)	13,400	7,400	20,800
6.	Allocated joint costs	4,680	2,580	7,260
7.	Total costs (4 + 6)	35,450	10,450	45,900
8.	Surplus benefits	8,650	4,820	13,470
9.	Benefit-cost ratio	1.24	1.46	1.29

CHAPTER 11

FINANCIAL PROGRAM

TABLES

CHAPTER 11 FINANCIAL PROGRAM

11.1 FUND REQUIREMENT

The total construction cost of this Project as stated in Chapter 9 will be foreign currenty equivalent to be 292,300,000 Baht and 197,500,000 Baht in domestic currency or a total of 489,800,000 Baht and the annual fund requirement will be as given below.

Unit: 1,000 Baht

Year	Foreign Currency	Domestic Currency	Total
1970	(400) 14,400	(-) 100	(400) 14,500
1971	(1,500) 26,000	(-) 22,800	(1,500) 48,800
1972	(5,200) 107,600	(3,400) 75,500	(8,600) 183,100
1973	(11,300) 100,200	(7,900) 73,900	(19,200) 174,100
1974	(5,700) 43,200	(4,000) 24,200	(9,700) 67,400
1975	(-) 900	(-) 1,000	(-) 1,900
Total	(24,100) 292,300	(15,300) 197,500	(39,400) 489,800

Note: Figures in parentheses indicate interest during construction included in annual fund requirements.

11.2 FINANCING OF FUNDS

11.2.1 Source of Funds

In general, it is desirable for electric power development projects with slow speed of capital rotation'to be carried out using long-term, low-interest funds. However, since it is difficult to procure such long-term, low-interest funds in the domestic financial market of a developing nation such as Thailand, it was assumed that for this Project foreign currency fund requirements would be met by foreign loans and domestic currency requirements by Thai Government funds. As the owner of the Project, NEA, is the Thai Government agency responsible for electric power development of the country, and in the light of the purpose of the Project, it would be possible for foreign loans and government funds to be secured.

11.2.2 Interest and Amortization

(1) Foreign Currency Requirement

Examples of loans obtained from foreign countries for projects of this type in Thailand in the past, are the World Bank loans and the U.S. Export-Import Bank loans to YEA and the West German Government loans to NEEA. The terms of these loans have generally been 4 to 5% interest with the amortization period including period of deferment being 15 to 20 years. On the other hand, the Nam Pung Project carried out by NEA under the supervision of EPDC was financed entirely with domestic funds for which interest rates were 4 to 5%. The Lam Dom Noi Project which NEA is about to initiate is probably finianced by loans from the Japanese Government Economic Cooperation Fund with the terms contemplated to be an interest rate of 4.5% and the amortization period 20 years including a deferment of 5 years.

As stated above, foreign loans to Thailand in the past have been made at fairly favorable terms, but it cannot be concluded that loans in the future can be secured at such terms. For this Project, taking into consideration the recent raise in World Bank interest rates on loans, the terms were assumed to be as indicated below.

Interest rate:	6%
Amortization period:	20 years after start-up, principal and interest amortized in equal installments.

(2) Domestic Currency Requirement

The terms for borrowing government funds in Thailand depend on the nature and urgency of the project, and the nature and reliability of the project owner, but for electric power enterprises, the interest rate is generally 6% with the period of amortization to be within the service life of the project.

Therefore, the terms for loans of domestic funds for this Project were assumed to be as given below.

Interest rate:	6%
Amortization period:	50 years after start-up, principal and interest amortized in equal installments.

11.3 DEBT FINANCING

11.3.1 Revenues From Sale of Electricity

(1) Substation Unit Sales Price

As the electric power generated in this Project is assumed to be delivered at Korat Substation, it is necessary to determine the unit sales price of electricity at this substation. At present the unit price of energy in the Nam Pong System of NEEA at the low-tension side of substation is 0.35 Baht per kWh while it is 0.40 Baht per kWh in the Nam Pung System.

While, wholesale rate of YEA to NEEA and PEA is 0.315 Baht per kWh at the monthly load factor of 60% and 0.27 Baht per kWh at 80%.

Since the electric power industry is a public utility and the owner of this Project is a government agency, it would be inappropriate to gain special profit. A proper rate would be one at a level that would provide operation and maintenance expenses, administration expenses and interest charges and also enable complete repayment of foreign currency loans in 20 years. In calculating the energy cost of this Project, a figure of approximately 0.20 Baht per kWh at Korat Substation is obtained.

An allowance of approximately 10% was provided and the financial schedule was prepared at a unit sales price of 0.22 Baht/kWh. The actual unit sales price should be considered from the point of view of the power system as a whole. In any event, the sales price of this Project can be set at a rate considerably below the rates of existing systems and still enable repayment of foreign currency loans in 20 years. After that period the charge can be reduced even further.

(2) Salable Energy at Korat Substation

The salable energy at Korat Substation of the Nam Sai Yai No. 2 Power Station (start of operation, October 1973) and the Nam Sai Yai No. 3 Power Station (start of operation, July 1974), as described in Chapter 10, is 39.1 million kWh and 185.6 million kWh respectively. Judging from the situations prevailing in the System, this power quantities should all be consumed immediately upon start-up without any becoming latent.

(3) Income

Income from electric power charges at the low-tension side of Korat

Substation is calculated in Table 11-1.

11.3.2 Operation and Maintenance Costs

The ratio of operation and maintenance costs of this Project to the construction cost of generating facilities and transmission lines including engineering fees, administration expenses and interest during construction was calculated as indicated below.

Generating facilities:	Construction cost x 0.7%
Transmission lines:	Construction cost x 2.5%

11.3.3 Depreciation

As the method of depreciation generally adopted in the electric power industry of Thailand is a 10% residual value fixed amount method, this was also adopted for this Project with serviceable years to be as indicated below.

Generating facilities:	50 years
Transmission lines:	40 years

11.3.4 Administration Costs

The administration costs of the head office of the owner to be allocated to this Project were calculated to be the following:

Generating facilities:	Construction cost x 0.3%
Transmission lines:	Construction cost x 0.5%

11.3.5 Net Income

Deducing operation and maintenance costs depreciation, administration costs and interest payments on foreign and domestic currency loans from the annual income of this Project calculated based on the various abovementioned conditions, net income as indicated in Table 11-1 is obtained.

11.4 AMORTIZATION SCHEDULE

(1) The funds to be applied to repayment of loans will be the net income and depreciation reserve obtained from current income.

(2) Based on the loan terms of 11.2.2, the amounts of foreign currency and domestic currency to be repaid will be as indicated in Table 11-2.

(3) The results of calculation of cash balance based on the above are as shown in Table 11-3.

(4) As is clearly seen from this table, the cash balance will be favorable at all times from 1975, and the repayment of foreign and domestic currency loans according to the various conditions assumed will be easily possible. Therefore, Nam Sai Yai Project not only is highly economical, but also is quite feasible from the standpoint of funds.

TABLE 11-1 STATEMENT OF INCOME

Unit: Million Baht

Item	1 1974	2 1975	3 1976	4 1977	5 1978	6 1979	7 1980	8 1981	9 1982	10 1983	11 1984	12 1985	13 1986	14 1987	15 1988	16 1989	17 1990	18 1991	19 1992	20 1993	21 1994	Total
(A) Revenues																						
Salable energy (Gwh)	85.6	224.7	224.7	224.7	224.7	224.7	224.7	224.7	224.7	224.7	224.7	224.7	224.7	224.7	224.7	224.7	224.7	224.7	224.7	224.7	224.7	
Cost per kwh (Baht)	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	
Total Operating Revenues	18.8	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	1,006.8
(B) Operating Expenses																						
Operation & Maintenance Generating Facilities	1.95	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	
Transmission Line	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	
Depreciation	6.58	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	
Administration	1.19	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	
Total Operating Expenses	11.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	319.4
(C) Operating Income (C = A − B)	7.4	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0	687.4
(D) Financial Expenses																						
(Interest)																						
Foreign Loans	10.59	17.25	16.75	16.23	15.68	15.09	14.47	13.80	13.10	12.36	11.57	10.74	9.85	8.91	7.92	6.86	5.75	4.56	3.31	1.98	0.53	217.30
Domestic Loans	7.46	11.82	11.78	11.74	11.69	11.64	11.58	11.52	11.46	11.40	11.33	11.26	11.18	11.10	11.02	10.93	10.83	10.73	10.62	10.50	10.38	231.97
Total Financial Expenses	18.1	29.1	28.5	27.9	27.3	26.7	25.9	25.3	24.6	23.8	22.9	22.0	21.0	20.0	19.0	17.8	16.6	15.3	13.9	12.5	10.9	449.1
(E) Net Income	−10.7	4.9	5.5	6.1	6.7	7.3	8.1	8.7	9.4	10.2	11.1	12.0	13.0	14.0	15.0	16.2	17.4	18.7	20.1	21.5	23.1	238.5

TABLE 11-2 (1) AMORTIZATION SCHEDULE - DOMESTIC CURRENCY

(Unit: Million Bahts)

Year	Borrowing			Redemption			Outstanding Balance	Remarks
	Generating Facilities	Transmission Line	Total	Principal	Interest	Total		
1973	104.3	20.1	124.4				124.40	Interest Rate: 6%
1974	73.1		73.1	0.43	7.46	7.89	197.07	
1975				0.71	11.82	12.53	196.36	Redeemable in equal annual installments in 50 years.
1976				0.75	11.78	12.53	195.61	
1977				0.79	11.74	12.53	194.82	
1978				0.84	11.69	12.53	193.98	
1979				0.89	11.64	12.53	193.09	Amortization Rate: 0.063444
1980				0.95	11.58	12.53	192.14	
1981				1.01	11.52	12.53	191.13	
1982				1.07	11.46	12.53	190.06	
1983				1.13	11.40	12.53	188.93	
1984				1.20	11.33	12.53	187.73	
1985				1.27	11.26	12.53	186.46	
1986				1.35	11.18	12.53	185.11	
1987				1.43	11.10	12.53	183.68	
1988				1.51	11.02	12.53	182.17	
1989				1.60	10.93	12.53	180.57	
1990				1.70	10.83	12.53	178.87	
1991				1.80	10.73	12.53	177.07	
1992				1.91	10.62	12.53	175.16	
1993				2.03	10.50	12.53	173.13	
1994				2.15	10.38	12.53	170.98	

TABLE 11-2 (2) AMORTIZATION SCHEDULE - DOMESTIC CURRENCY

Unit: Million Baht

Year	Borrowing			Redemption			Outstanding Balance	Remarks
	Generating Facilities	Transmission Line	Total	Principal	Interest	Total		
1973	127.4	49.1	176.5				176.50	Interest Rate: 6%
1974	115.8		115.8	4.80	10.59	15.39	287.50	
1975				8.23	17.25	25.48	279.27	Redeemable in equal
1976				8.73	16.75	25.48	270.54	annual installments
1977				9.25	16.23	25.48	261.29	in 20 years.
1978				9.80	15.68	25.48	251.49	
1979				10.39	15.09	25.48	241.10	Amortization Rate:
1980				11.01	14.47	25.48	230.09	0.087184
1981				11.68	13.80	25.48	218.41	
1982				12.38	13.10	25.48	206.03	
1983				13.12	12.36	25.48	192.91	
1984				13.91	11.57	25.48	179.00	
1985				14.74	10.74	25.48	164.26	
1986				15.63	9.85	25.48	148.63	
1987				16.57	8.91	25.48	132.06	
1988				17.56	7.92	25.48	114.50	
1989				18.62	6.87	25.48	95.88	
1990				19.73	5.75	25.48	76.15	
1991				20.92	4.56	25.48	55.23	
1992				22.17	3.31	25.48	33.06	
1993				23.50	1.98	25.48	9.56	
1994				9.56	0.53	10.09	0	

TABLE 11-3 STATEMENT OF CASHFLOW

Unit: Million Baht

Item	1 1974	2 1975	3 1976	4 1977	5 1978	6 1979	7 1980	8 1981	9 1982	10 1983	11 1984	12 1985	13 1986	14 1987	15 1988	16 1989	17 1990	18 1991	19 1992	20 1993	21 1994	Total
(A) Cash from Income																						
Net Income	-10.7	4.9	5.5	6.1	6.7	7.3	8.1	8.7	9.4	10.2	11.1	12.0	13.0	14.0	15.0	16.2	17.4	18.7	20.1	21.5	23.1	238.5
Depreciation	6.58	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	9.13	189.1
(B) Proceed from Finance																						
Foreign Loans	43.2	0.9																				44.1
Domestic Loans	24.2	1.0																				15.2
(C) Total																						
(C = A + B)	63.3	15.9	14.6	15.2	15.8	16.4	17.2	17.8	18.6	19.4	20.2	21.1	22.1	23.1	24.2	25.3	26.6	27.9	29.2	30.7	32.3	496.9
(D) Capital Expenditure																						
Construction Cost	67.4	1.9																				69.3
(E) Repayment of Borrowing																						
Foreign Loans	4.8	8.23	8.73	9.25	9.80	10.39	11.01	11.68	12.38	13.12	13.91	14.74	15.63	16.57	17.56	18.62	19.73	20.92	22.17	23.50	9.56	292.3
Domestic Loans	0.43	0.71	0.75	0.79	0.84	0.89	0.95	1.01	1.07	1.13	1.20	1.27	1.35	1.43	1.51	1.60	1.70	1.80	1.91	2.03	2.15	26.5
(F) Total																						
(F = D + E)	72.63	10.84	9.48	10.04	10.64	11.28	11.96	12.69	13.45	14.25	15.11	16.01	16.98	18.00	19.07	20.22	21.43	22.72	24.08	25.53	11.71	388.1
(G) Cash Balance																						
Total	-9.3	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.2	5.2	5.1	5.1	5.2	5.1	5.2	5.1	5.2	5.2	5.1	5.2	20.5	108.8
Accumulated Total		-4.2	0.9	6.0	11.1	16.2	21.3	26.4	31.6	36.8	41.9	47.0	52.2	57.3	62.5	67.6	72.8	78.0	83.1	88.3	108.8	