CHAPTER 7

TRANSMISSION PLAN

CHAPTER 7 TRANSMISSION PLAN

7.1 Supply and Demand of Power in Northern Thailand

Peak load in the northern part of Thailand (Power Service District No. 4 of EGAT) is almost equivalent to 20 percent of peak demand in the E.G.A.T.'s wholesale to P.E.A., recorded at 220 MW in 1980 and projected at 900 MW and 1,300 MW in 1990 and 1995 respectively. The major generating facilities now in operation are Bhumibol Hydroelectric Power Station (684 MW at ultimate output), Sirikit Hydroelectric Power Station (375 MW) and Lignite-fueled Mae Moh Thermal Electric Power Station (1,725 MW at ultimate output) being partially operated, which will later be added by Kud Hydroelectric Power Station (100 MW) now under construction and, furthermore hydropower development projects now under study on Pai and Chaem Rivers. At present, power being generated from the existing power stations is transmitted by the 230 kV transmission lines into the metropolitan area of Bangkok through Nakhon Sawan Substation. Mae Moh Thermal Electric Power Plant is operated as the base-load station, notwithstanding it is situated more than 500 km apart from Bangkok, mainly because of its reducible generating cost by use of fuel priced at only one-quarter of the heavy oil. However, it is anticipated that with future expansion of Mae Moh Thermal Electric Power Station transmission loss may increase more and more on the existing 230 kV transmission lines, a plan is now being worked out to construct the 500 kV transmission line between Mae Moh and Bangkok. The existing power transmission system diagram is shown in Fig. 7-1.

7.2 Construction Projects for Connected Transmission and Substation Network

Future progress of transmission and substation construction projects is assumed as follows at the time of implementation of the present project:

Kud Hydro Power Project	Completed
Chiang Mai No. 3 Substation	Completed
Lamphun No. 2 Substation	Completed
230 kV, 2-circuit transmission line	
Kud Power Station ~ Chiang Mai No. 3	Completed
Chiang Mai ~ Mae Moh	Completed
115 kV, 2-circuit transmission line	
Lamphun No. 2 ~ Mae Moh	Completed
Lamphun No. 2 ~ Chiang Mai No. 3	Completed

On the assumption as listed above, each of these hydro construction projects should include the following transmission lines and substations at the time of execution: (See Fig. 7-2)

(1) Facilities for Mae Pai No. 6 Power Station
230 kV 2-circuit transmission line, 95 km length
230 kV 2-circuit outgoing facilities in Kud Power Station
Tele-communication system (complete set)

(2) Facilities for Mae Pai No. 1 Power Station
230 kV 2-circuit spur transmission line, 10 km length
Tele-communication system (complete set)

(3) Facilities for Mae Chaem No. 5 Power Station

115 kV 2-circuit transmission line, 40 km length

115 kV 2-circuit transmission line, 54 km length

Chom Thong Substation

2-circuit outgoing facilities in Lamphun No. 2 Substation

Tele-communication system (complete set)

(4) Facilities for Mae Chaem No. 4 Power Station

115 kV 2-circuit transmission line, 50 km length

2-circuit outgoing facilities in Chom Thong Substation

Tele-communication system (complete set)

Fig. 7-1 · CONCEPTUAL LONG-RANGE DEVELOPMENT BY EGAT

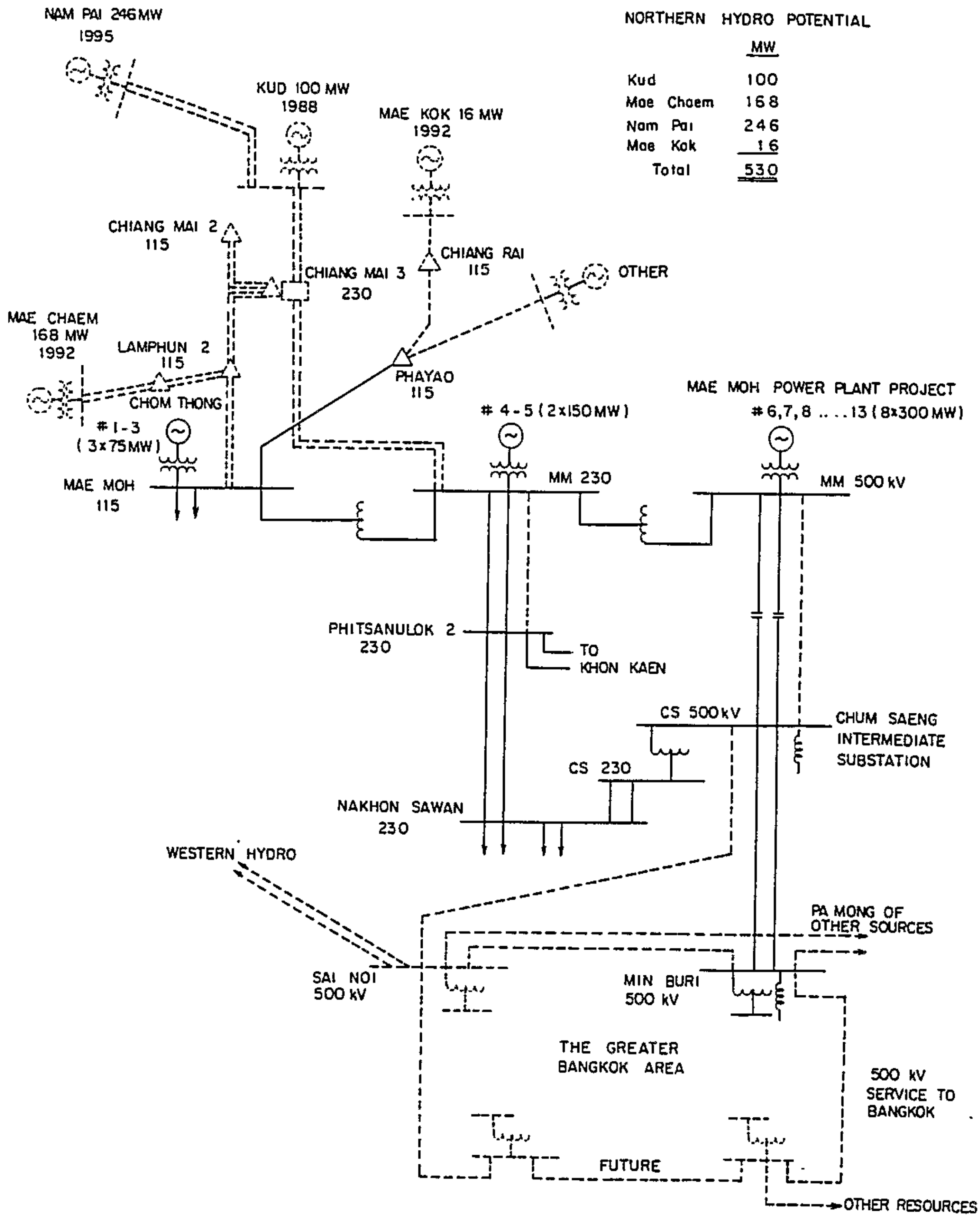


Fig. 7-2 RELATED TRANSMISSION LINE SYSTEM

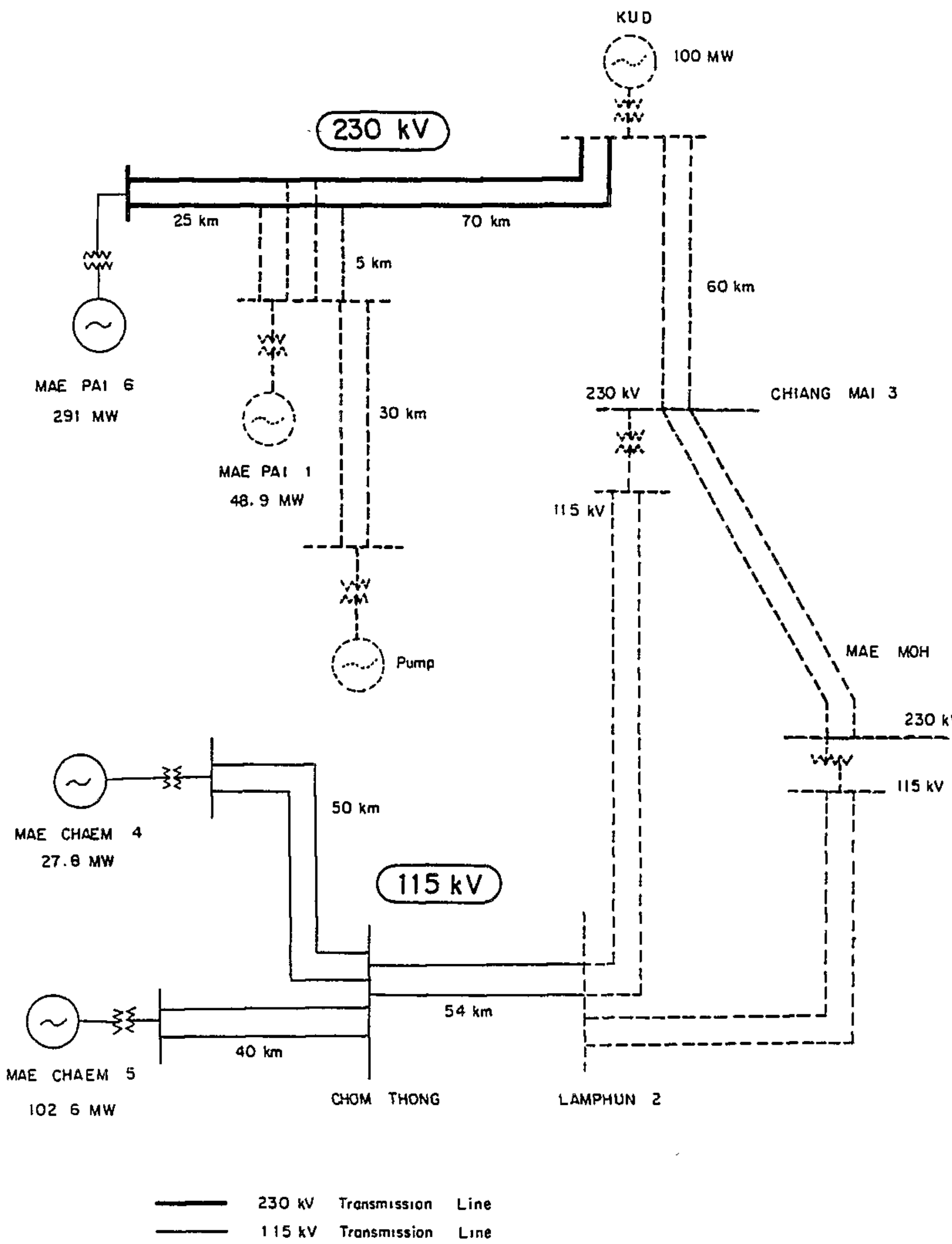
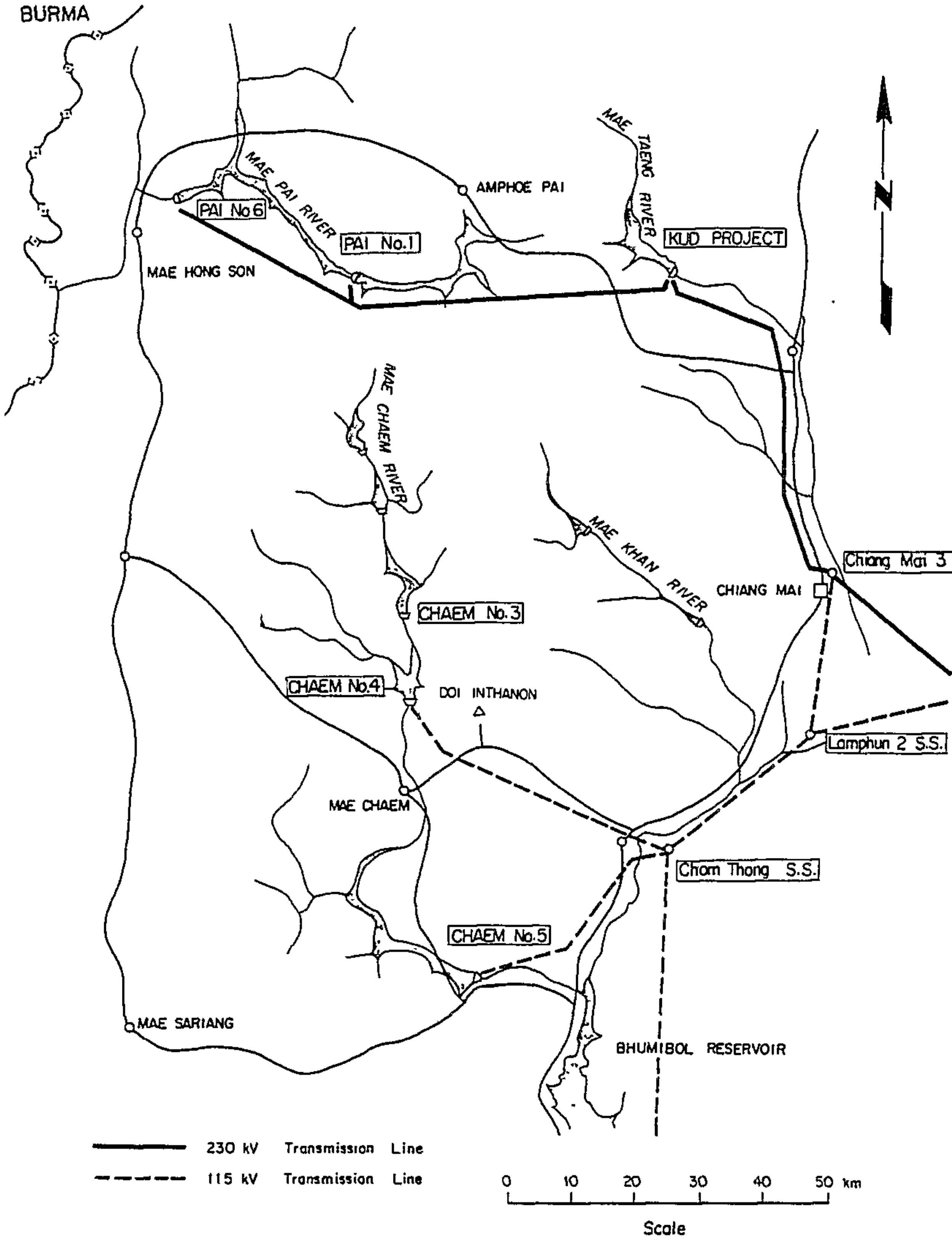
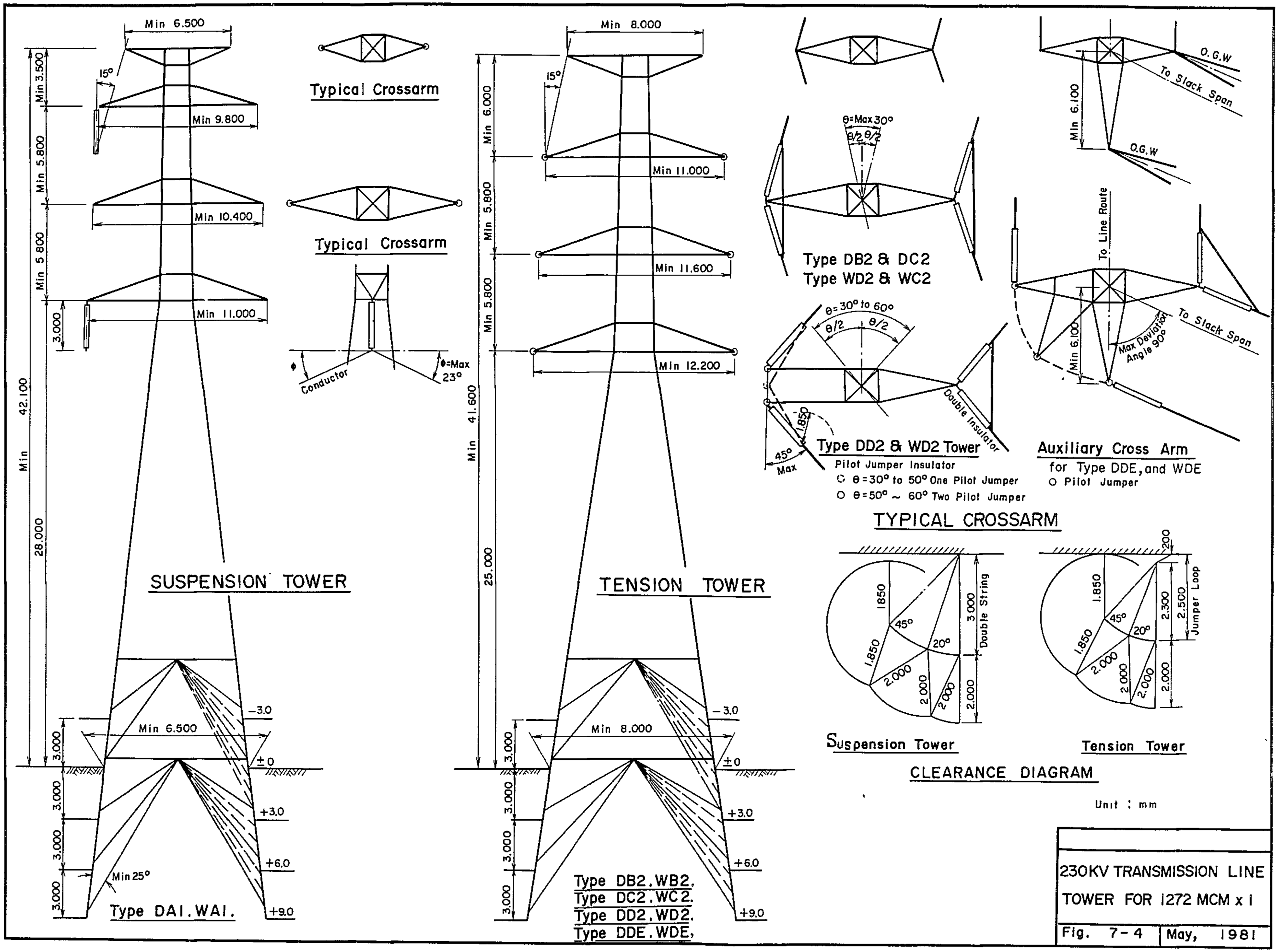


Fig. 7-3 TRANSMISSION LINE ROUTE




SUSPENSION TOWER
Type DA1.WA1.
TENSION TOWER
Type DB2.WB2.
Type DC2.WC2.
Type DD2.WD2.
Type DDE.WDE,
Typical Crossarm
Typical Crossarm
Conductor
ϕ=Max 23°
Type DB2 & DC2
Type WD2 & WC2
θ=Max 30°
Type DD2 & WD2 Tower
Pilot Jumper Insulator
θ=30° to 50° One Pilot Jumper
θ=50° ~ 60° Two Pilot Jumper
Double Insulator
Auxiliary Cross Arm
for Type DDE, and WDE
O Pilot Jumper
To Slack Span
To Line Route
O.G.W
Max Deviation Angle 90°
TYPICAL CROSSARM
Suspension Tower
Tension Tower
Double String
Jumper Loop
CLEARANCE DIAGRAM
Unit : mm
230KV TRANSMISSION LINE
TOWER FOR 1272 MCM x 1
Fig. 7-4
May, 1981

CHAPTER 8

IRRIGATION AREA – PRESENT CONDITION AND WATER DEMAND

CHAPTER 8 IRRIGATION AREA - PRESENT CONDITION AND WATER DEMAND

8.1 Rice Cultivation in Thailand

As described in Chapter 3, the agriculture sector of Thailand is playing an important role in the national economy of steady supply of food, gross domestic products and trade balance.

Rice is one of the core agricultural export items in Thailand, and out of 15 to 16 million ton (rice)[1) annual production, 1.8 to 2.9 million ton[2) are being exported annually to countries like Singapore and Malaysia, and the quantity is expected to increase to 2.3 to 3 million ton[3) in future.

According to the statistics for 1978/79[4), the planted area of the second rice is only 4,257 thousand rai, or much less than 10%[5) of the planted area for the major rice crop which is 58,410 thousand rai.

While increase of rice crop is one of the very important policies for the national economy, expansion of the planted area can be no longer expectable because of needs for forest conservation and keeping environmental balance. Accordingly, effort is being made in the direction of improving the productivity by increasing the land-use intensity of the existing planted area for higher production of rice.

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1) Selected Economic Indicators relating to Agriculture 1979 (Refer to as SEI) Table II-10
2) " Table II-2
3) The Nation on Dec. 2, 1980
4) Agricultural Statistics of Thailand, crop year 1978/79 (Refer to as AST) Tables 17 and 18
5) SEI Table II-11

8.2 Current Agricultural Situation in Chiang Mai - Lamphun Basin

8.2.1 General

Paddy, mungbeans, soybeans, garlic and other vegetables are cultivated as economic crops in the Chiang Mai - Lamphun basin spreading along both sides of the Ping River with Chiang Mai City in the center. In addition to dry season paddy, similar field crops to the one in wet season are being cultivated in the areas close to the Ping River and its tributaries and in areas where ground water is economically available even during the dry season of November/December through April/May.

General information on agriculture prepared by statistic materials and interview obtained during the last survey mission is given in Table 8-1, and yield and ex farmhouse prices on major crops are given in Table 8-2.

The soil map of the Chiang Mai - Lamphun basin prepared by the Department of Land Development is given in Fig. 8-1 for reference.

8.2.2 Existing Chiang Mai Irrigation Projects

There are 4 large scale irrigation systems constructed by RID in the Chiang Mai Province, as shown in Table 8-3. The beneficial area from these systems extends from Amphoe Mae Taeng to Ban Pa Bong in the Ping River right side and up to the provincial border with Lamphun in the left side of the river.

In addition to these large irrigation systems, there are primitive but numerous diversion facilities and irrigation canals which are collectively called "people's irrigation projects".

Since the irrigation sources are dependent on natural run-off of rivers not only for the people's irrigation but also for the RID Project systems, the cropping intensity is not always high even in areas related to these irrigation systems.

Therefore RID is enforcing plans to construct reservoirs to go with each of the existing irrigation projects so as to increase the cropping intensity by utilizing excess water resource from the wet season for irrigation during the dry season, as shown in Table 8-4. At the same time, improvement and integration of all irrigation systems inclusive of people's irrigation projects in the Chiang Mai - Lamphun basin.

Fig. 8-2 is a schematic review of major rivers and representative irrigation projects in the Chiang Mai - Lamphun basin.

8.2.3 Cham Thong - Ban Hong Area

The Amphoe Cham Thong area is located at about 60 km southwest of Chiang Mai City. It is at the right side of the Ping River, and paddy field covering the area of 60,000 rai is estimated at the Nam Mae Klang River both sides, a tributary of the Ping River. A fairly large size of agricultural area, Ban Hong Area, exists in the opposite side of the Cham Thong area beyond the Ping River, belonging to Lamphun Province and along the Nam Mae Li River, a tributary of the Ping River.

Both of these areas, Cham Thong and Ban Hong, are out of the beneficial area of the aforementioned Chiang Mai irrigation systems, and they are left as non-irrigated areas except some small scale local people's irrigations.

An irrigation project covering about 200,000 rai is being planned for the Ban Hong Area, according to RID Regional Office No. 1 in Chiang Mai. According to RID's preliminary study, annual run-off of the Nam Mai Li, which supplies water for this project, is 620 MCM/yr (basin area of 1,890 sq. km), and in this project dams and reservoirs having the capacity equivalent to about one third of the annual run-off are to be built, thereby adding paddy field of about 140,000 rai in the dry season.

8.3 Current Agricultural Situation in Kamphaeng Phet Plain

8.3.1 General

The Kamphaeng Phet plain is located at the fan top of the central granary zone of Thailand. Left side of the Ping River is a low and flat area contacting with the Mae Nam Yom basin and the right side (west) is hilly or terrace land up to the Khao Waphoepricho -Khao Mokochu mountains with a narrow paddy field running along the Ping River.

Agricultural situation of the Kamphaeng Phet Province is given in Tables 8-5 and 8-6.

Fig. 8-3 schematically reviews the Ping main river and its tributaries and representative irrigation projects in the Kamphaeng Phet plain.

Table 8-7 shows run-off of the Ping River at the Kamphaeng Phet Gauging Station (P-7A). Run-off at this point is greatly influenced by the power discharge of the Bhumibol Power Station. The average run-off in the decades of 1970 through 1979 is about 320 cu.m/sec, among which about 215 cu.m/sec is power discharge of the Bhumibol Power Station.

The average run-off during 4 months of the dry season, from December through March, is about 230 cu.m/sec, but its majority is flow for water demand in the downstream area.

The soil map of the Kamphaeng Phet plain prepared by the Department of Land Development is given in Fig. 8-1 for reference.

8.3.2 Kamphaeng Phet Plain at Ping River Left Side

The following 4 large scale irrigation projects having intake facilities in the Ping River are being constructed by RID. The beneficial area will amount to about 480,000 rai.

RID is also constructing laterals and tertiary canal networks for irrigation and drainage within the area in succession to the 4 irrigation projects.

Table 8-8 Irrigation Projects Executed by RID in the Left-side Area of the Ping in Kamphaeng Phet Plain

Irrigation Project	Potential Irrigable Area	Design Capacity of Canal Head	Water Resource
	(rai)	(cu.m/s)	
(i) Tho Tong Daeng Project	30,000		the Ping
(ii) Khlong Wong Bua Project	270,000 (25,000)1/	50.0	"
(iii) Khlong Wong Yan Project	100,000 (10,000)1/	12.5	"
(iv) Khlong Nong Khwan Project	79,900 (10,000)1/		"
Total	479,000		

Source: RID Construction Office in Kamphaeng Phet
1/: Figures in parenthesis indicate irrigable area in dry season.

As shown in 1/50,000 scale topographical maps, numeral natural streams and creeks run at the left side and at present irrigation water taken through these natural streams is led to paddy field and these streams are also functioning as drainage canals during the wet season. In ordinary years, ponding is only for quantity of 2 to 3 days in the wet season, and inundation hardly occurs to crops.

The monthly target of irrigable area during the dry season is about 10% of the total potential area depending on the water resources that are currently available, as shown in Table 8-8, but from what can be estimated from Table 8-6, it is only about 3%.

Run-off during the dry season, from December through March, is about 230 cu.m/sec, but since the Chai Nat Barrage at the downstream requires some amount of run-off, the cropping intensity of the abovementioned 4 projects can be increased only when some steps are taken to increase the Ping River run-off at this point.

8.3.3 Kamphaeng Phet Plain at Ping River Right Side

The low and flat area of 60 to 80 m high at the Ping River right side expands from Khlong Suan Mak at the north to the provincial border at the south. Majority of this flat area is used as paddy field. Terrace area higher than 60 to 80 m high extends to the Khao Waphoepricho - Kao Mokochu mountains in the west of the Kamphaeng Phet Province, and generally cassave, sugar cane, cereals and other field crops are cultivated.

As is clear in Fig. 8-3, it does not seem to be economically advantageous to introduce the water resources of the Ping main river for irrigation at the right side where there are a number of RID irrigation projects from topographical viewpoint. Therefore, among all the irrigation projects that RID has completed or being in construction or being palnned, emphasis is placed on developing plans of tributaries that are not large in scale.

Table 8-9 lists main RID irrigation projects and Table 8-10 lists the Ping River pumping station projects that NEA is planning at present.

8.4 Chai Nat Region - The Greater Chao Phraya Irrigation Project -

8.4.1 General

The Chai Nat Barrage which is the key structure of the Greater Chao Phraya Irrigation Project was completed in 1957[1)] and it supplies irrigation water to a huge rice growing area of about 6.2 million rai through the 5 main canals.

Table 8-11 outlines the Chai Nat Barrage.

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1) Project Completion Report, October 1978
Chao Phya Irrigation Improvement Project, Stage I prepared by ILACO

Table 8-11 Main Features of Chai Nat Barrage

(i)	Crest length		237.5 m with 12 sluice gates
(ii)	Crest elevation		EL. 9.0 m
(iii)	Upstream side	Flood level	EL. 18.0 m
		Retention level	EL. 16.5 m
(iv)	Downstream side	Retention level in dry season	EL. 7.5 m
(v)	Gater operation	To maintain a level difference of 9 m between (iii) and (iv) constantly	

(vi) Irrigation for left-side area
(In charge of RID Regional Office No. 8)

Wet season paddy: 3.1 ∿ 3.4 million rai in 1977 ∿ 1979

Dry season paddy: max. 550,000 rai in 1976 ∿ 1979

Main canal and its capacity	:		
		Chai Nat - Pasak Canal	210 cu.m/sec
		Chai Nat - Ayutthaya Canal	70 cu.m/sec

(vii) Irrigation for right-side area
(In charge of RID Regional Office No. 7)

Wet season paddy: 2.6 ∿ 2.8 million rai in 1977 ∿ 1980

Dry season paddy: 1.4 ∿ 2.0 million rai in 1977 ∿ 1979

Main canal and its capacity	:		
		Noi River	260 cu.m/sec
		Makham - Uthong Canal	32 cu.m/sec
		Suphan River	318 cu.m/sec

RID is proceeding with a land consolidation project[1),2)] of the beneficial area aiming at improvement of cropping intensity and productivity, and in this project, improvement of canal works, leveling or when necessary, re-parcelling are being conducted.

In the Botommathat and Chanasutr regions located in the northern part, Stage I[1)] of the land consolidation project covering 17,000 ha was completed in 1978 and a feasibility study is being made for Stage II[2)] covering 63,000 ha in succession.

In the Stage I area, local variety of rice paddy was changed to high yield variety, and broadcasting was changed to transplanting, resulting in productivity improvement.

Cropping intensity in 1978 was 195%[1)], but it reduced to 135% in 1979, and based on interview or hearing investigation, it is anticipated that the cropping intensity will substantially drop in 1980 due to decrease of usable water.

Shortage of usable water at the Chai Nat Barrage point decisively deteriorates rice crop in the beneficial area of the Greater Chao Phraya Irrigation Project, and increase of usable water is very much desired.

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1) Project Completion Report, October 1978
Chao Phraya Irrigation Improvement Project, Stage I prepared by ILACO
2) Basic Information, October 1979
Chao Phraya Irrigation Improvement Project prepared by ILACO/EMPIRE M&T

8.4.2 Hydrology in Chai Nat Barrage

Inflow to the Chai Nat Barrage is estimated to be about 26,196 MCM (830 cu.m/sec) per annum for the period of 1973 through 1979 based on data (C-2 of RID) of the Chao Phya flow at Nakhon Sawan, that was shown in Table 8-12. On the other hand, as shown in Table 8-13, total diversion water of the 5 main canals is about 11,027 MCM (9,350 cu.m/sec) per annum, and about 42% of the total annual inflow is taken for irrigation.

As shown in the hydrographs of Table 8-12 and Fig. 8-4, the average run-off is reduced to 300 cu.m/sec in the dry season, from November/December through April/May, and the water level drops almost to the restricted retention water level.

In the Chai Nat Barrage, 25 cu.m/sec water for supply in Bangkok and 70 cu.m/sec water for prevention of salinity problem are supposed to be discharged even during the dry season. Therefore, water resources are definitely in shortage to increase the cropping intensity (RID aims average 30% increase) in the irrigation area during the dry season, and RID is studying and planning water resource development in the related river systems to increase the water resources.

8.5 Calculation of Water Requirement for Irrigation

8.5.1 Estimation of Cropping Pattern

In all of Chiang Mai - Lamphun basin, Kamphaeng Phet plain and Chai Nat region, wet season, from May/June through November/December and dry season, from December/January through April/May are clearly distinctive.

In the wet season, paddy is generally cultivated through broadcasting or transplanting in low flat field, and vegetables are grown in areas with effective drainage.

In the dry season, dry season paddy and vegetables of larger profit are cultivated only in areas where irrigation water is available or surface or ground water is economically available.

Estimated cropping patterns that are common and universal to these areas are given in Fig. 8-5, and planting and harvesting periods for wet and dry season paddies are as follows:

	Planting	Harvesting
Wet season paddy	June/July	November/December
Dry season paddy	January/February	April/May

8.5.2 Estimation of Potential Evapo-transpiration

Potential Evapo-transpiration (PET) in the Chom Thong, Kamphaeng Phet and Chai Nat area was estimated using the Blaney-Criddle formula, under the following conditions:

Area	Latitude	Temperature
(i) Chom Thong	N 18°25'	Average temperature by month in Chiang Mai during 1951-75[1)]
(ii) Kamphaeng Phet	N 16°20'	Average temperature by month in Nakorn Sawan during 1951-75[1)]
(iii) Chai Nat	N 15°00'	Same as the above

1): Climatological Data of Thailand 25 year period (1951-75) Meteorological Department, Ministry of Communications

As shown in Table 8-14, the calculation results are that annual PET is 1960 to 2,120 mm exceeding the annual rainfall of about 1,200 mm greatly.

8.5.3 Water Required by Wet and Dry Season Paddies

Based on the potential evapo-transpiration, monthly rainfall and estimated cropping patterns, monthly water requirements per 1,000 ha of wet and dry season paddies in the three areas of Chom Thong, Kamphaeng Phet and Chai Nat were calculated. Conditions used in these calculations are as follows:

(i)	Cropping pattern	:	As shown in Fig. 8-5
(ii)	Monthly PET	:	Table 8-14
(iii)	Nursery area	:	5% of paddy field
(iv)	Nursery water	:	10 mm/day
(v)	Paddling water	:	200 mm at a time
(vi)	Consumptive-use coefficient of paddy	:	0.8 to 1.2
(vii)	Percolation	:	2 mm/day
(viii)	Rainfall	:	Monthly minimum rainfall during 1970-78 in Chiang Mai and Nakhon Sawan (regarded to be about 1/10 probability)
(ix)	Effective rainfall	:	75% of the (viii) rainfall, and 0 for months where effective rainfall is no greater than 10 mm/month
(x)	Conveyance efficiency	:	70%

Calculation results are shown in Table 8-15, and amounts to water consumption per ha by wet and dry season paddies are shown below.

	Wet Season Paddy (cu.m/ha)	Dry Season Paddy (cu.m/ha)
Chom Thong	15,650	14,040
Kamphaeng Phet	15,560	14,860
Chai Nat	15,560	14,930

8.6 Estimation of Agricultural Benefit

8.6.1 General

The Mae Pai and Mae Chaem River Hydroelectric Power Development Project requires transbasin of about 700 MCM annually (23 cu.m/sec) out of the Pai River to the Chaem River. The increased run-off from the transbasin seems to be large enough to increase the Ping River run-off during the dry season after being regulated by the group of reservoirs of the Chaem River and Bhumibol reservoir.

As mentioned in Clauses 8.3 and 8.4 of Chapter 8, while irrigation facilities have been constructed in the Kamphaeng Phet plain and Chai Nat region at the left side of the Ping River, since the river run-off decreases in the dry season, enough diversion water is unobtainable to achieve the scheduled cropping intensity.

Therefore, it is judged that the most efficient use of the increased run-off of the Ping River resulting from the Mae Pai and Mae Chaem River Hydroelectric Power Development Project and being available additionally as explained above, should be planned in the existing irrigated area of the Kamphaeng Phet or Chai Nat which have land potential large enough for the utilization during the dry season. The agricultural benefit resulting from the project should be evaluated based on the yield of the dry season paddy that is realized with cropping intensity increase during the dry season, in line with this judgement.

8.6.2 Estimation of Incremental Yield

The average yield of the dry season paddy (non-glutionous) being harvested in the Chiang Mai -Lamphun basin and Kamphaeng Phet plain is estimated to be about 500 kg/rai (unhulled).

We have learned through interviews or hearing investigations that some farm houses in areas where water is controllable during the dry season are making high yield such as 700 to 900 kg/rai by applying fertilizer. Also, as shown in Table 8-6, there is an example of obtaining a yield of 724.6 kg/rai in the large scale experiment conducted in the Kamphaeng Phet Province.

In the northern area of the Chai Nat region where a land consolidation project was completed, yield of 262 to 1,018 kg/rai (averaging to 691 kg/rai) of dry season paddy is recorded[1].

From these factors, we estimated 650 kg/rai (unhulled), or about 4 tons/ha, as an average expected yield for dry season paddy to be used in calculating the future agricultural benefit.

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1) Results of Benefit Monitoring in the Pilot and Stage I Area Technical Report No. 50, Jan. 1980, ILACO/EMPIRE M&T

8.6.3 Estimation of Economic Paddy Price

The ex farmhouse price of paddy based on governmental support (guarantee) as of January 1981 is 3.2 to 3.8 Baht/kg. At the same time, FOB Bangkok price of rice being exported from Thailand is US$407 to 410[1] per ton, as approved by the government. There is a report that the price was US$363 to 430[2] in April 1980.

Existing study reports[3] indicate that economic ex farmhouse price of paddy is equivalent to about 60 ∿ 65% of FOB price of rice. Accordingly, we use a figure of 5,000 Baht/ton (US$250/ton) as the economic ex farmhouse price in the project evaluation.

8.6.4 Estimation of Farm Expenses and Net Revenue

Results of the investigation conducted by the Ministry of Agriculture and Co-operatives in the Chai Nat region (the beneficial area of the Greater Chao Phya Irrigation Project) are effective for use in studies of this clause[4] with regard to the ratio of expenses and net revenue in the gross revenue. Summary of the investigation results are given in Table 8-16.

Based on the results, expense ratio and net revenue ratio of 40% and 60% respectively are used in calculating the agricultural benefit.

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1) Nation on Dec. 3, 1980. The export price of rice fixed by the Foreign Trade Department, Ministry of Commerce
2) Monthly Bulletin (May 1980) issued by Bank of Thailand
3) Project Completion Report, Oct. 1979
Chao Phya Irrigation Improvement Project, Stage I, ILACO
Feasibility Report on the Kamphaeng Saen Irrigated Agriculture Development Project in the Mae Klong River Basin, Oct. 1979, JICA
4) Results of Benefit Monitoring in the Pilot and Stage I Areas
Technical Note No. 50, 1978/79
Ministry of Agriculture and Co-operatives, ILACO/EMPIRE M&T, Bangkok
Jan. 1980

Table 8-16 Crop Budgets Monitored in Chai Nat Region[1)]

Unit: Baht/rai

		Wet Season	Dry Season
(1) Pilot area	Total value of production	1,215 ∿ 1,348	1,698 ∿ 1,963
	Variable cost (Physical cost)	363 ∿ 402	394 ∿ 473
	Gross margin (% of total value of production)	67 ∿ 73%	73 ∿ 80%
(2) Chanasutr	Total value of production	1,151 ∿ 1,267	1,652 ∿ 1,788
	Variable cost	455 ∿ 464	511 ∿ 574
	Gross margin (% of total value of production)	60 ∿ 63%	66 ∿ 71%
(3) Boromdhart	Total value of production	996 ∿ 1,185	1,456 ∿ 1,569
	Variable cost	277 ∿ 321	352 ∿ 413
	Gross margin (% of total value of production)	71 ∿ 74%	74 ∿ 76%

1) Results of Benefit Monitoring in the Pilot and Stage I Areas
Technical Note No. 50, 1978/79
Ministry of Agriculture and Co-operatives, ILACO/EMPIRE M&T, Bangkok, Jan. 1980

8.6.5 Estimation of Agricultural Benefit

Based on assumption that flow condition on the Ping River is improved by the Mai Pai and Mae Chaem River Hydroelectric Power Development Project and that the increased run-off is utilized to increase the cropping intensity of dry season paddy in any of the existing irrigation project area of the Kamphaeng plain and Chai Nai region, obtainable agricultural benefit after implementing the project is estimated to be about 12,200 Bahts (US$610) per ha, as shown in Table 8-17.

Water consumpted in the dry season paddy is estimated to be about 15,000 cu.m/ha crop, as reviewed in Clause 8.5.3. This makes the agricultural benefit to be about 0.8 Baht/cu.m.

Water increase resulting from implementing the Mae Pai and Mae Chaem River Hydroelectric Power Development Project is estimated to be about 700×10^6 cu.m/year. Cropping area of dry season paddy is increased by about 46,700 ha resulting from the increase of usable water, and this makes the total agricultural benefit to about 569×10^6 Bahts.

8.7 Project Cost

8.7.1 Additional Investment

Most of or part of diversion facilities and main canals has been completed in the existing irrigated area of the Ping River left side Kamphaeng Phet plain and Chai Nat region. Completion of the main works and improvement of canal networks are essential to increase the productivity of the area.

Actual cost of the land consolidation project conducted by RID in the Chai Nat region northern area (Stage I area in the Chanasutr and Boromdhart area) is reported to be US$1,000/ha as of end of 1978, but this is estimated to be US$1,200/ha at present.

Therefore, additional investment required to obtain the above mentioned agricultural benefit is estimated to US$2,500/ha, including expenses for additional main canal and land consolidation expenses.

8.7.2 Annual Amortization Cost and O&M Expenses

Based on factors of 12% for general opportunity cost of capital in Thailand and 50 years for service life of the irrigation facilities, the annual amortization cost of the above mentioned project cost is US$301.

Using a figure of US$30/ha as the average annual maintenance and administration expenses required for the irrigation facilities, annual total expenses per ha is US$331.

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1) Chao Phya Irrigation Improvement Project Basic Information, Oct. 1979, RID, ILACO/EMPIRE M&T

8.8 Ratio of Cost and Benefit

Under the conditions that the water resources improved by the Mae Pai and Mae Chaem River Hydroelectric Power Development Project are utilized for cropping intensity of dry season paddy in the irrigated areas at the left side of the Kamphaeng Phet and in the Chai Nat region, the estimated annual benefit is about US$610/ha and annual expense about US$331/ha. Accordingly, the ratio of cost and benefit is 1.84.

8.9 Future Irrigation Plan in the Right Side Plain of Kamphaeng Phet

8.9.1 General

As described in Clause 8.3.3 of Chapter 8, extensive hilly land or terrace is left without irrigation in the Kamphaeng Phet plain at the right side of the Ping River. Area of comparative flat terrace located at EL 80 to 120 m is as wide as 900 sq.km between Khlong Suan Mak to Nam Wang Ma. Because of topography, to irrigate this area with water from the Ping River does not seem to be economically advantageous.

This clause describes future plan of using water resources of 4 tributaries; Khlong Wang Chao, Khlong Suan Mak, Khlong Khlung and Nam Mae Wong, to irrigate the Kamphaeng Phet right side plain (refer to Fig. 8-6).

Run-offs of the tributaries that can be utilized are recorded as follows, and the average specific run-off per 100 sq.km is 1.1 to 1.3 cu.m/sec.

	Period	Location	Basin	Average Annual Run-off
(i) K. Suan Mak (P-26)	Apr. 1964 ∿ Mar. 1975	Lat. 16-26-54 Long. 99-25-57	968 sq.km	10.4 cu.m/s
(ii) K. Khlung (P-35)	Apr. 1974 ∿ Mar. 1980	Lat. 16-04-22 Long. 99-24-18	730 sq.km	9.2 cu.m/s
(iii) N. Mae Wong (Ct'-5)	Apr. 1969 ∿ Mar. 1980	Lat. 15-54-10 Long. 99-28-45	?	10.3 cu.m/s

8.9.2 Khlong Wang Chao and Khlong Suan Mak

The Khlong Wong Chao River starts in the mountainous area at the northwestern part of the Kamphaeng Phet plain of the Ping River right side, and joins with the Ping River at about 40 km upstream of Kamphaeng Phet City.

The basin area of the planned dam and reservoir site (approximate longitude 99°07' and latitude 16°29') is about 230 sq.km. If the same specific discharge as P-16 is assumed, the annual run-off at this point is about 790 MCM (2.5 cu.m/sec). If a dam is constructed in this point (about 330 m river bed EL), about 90 to 110 MCM impound capacity is obtainable.

If water requirement for paddy per one season is estimated to be about 15,000 cu.m/sec, the annual discharge at this point is usable in a potential planting area of about 5,300 ha.

The Khlong Suan Mak River flows through the northern part of the Ping River right side plain toward east and joins the Ping River at Kamphaeng Phet City.

The narrow area (approximate longitude 99°16' and latitude 16°20') while the Khlong Suan Mak River flows from mountainous area to middle part is a very promising point for dam construction. The basin area of this point is about 530 sq.km, and if the same specific discharge as P-26 is assumed, annual run-off at this point is estimated to be about 180 MCM (5.7 cu.m/sec). At this point (about 130 m river bed EL), obtainable impound capacity is about 100 MCM with 180 m H.W.L. and about 200 MCM with 195 m H.W.L.

The annual run-off at this point can be used in a potential paddy planting area of 12,000 ha, and if irrigation facilities are installed at about 10 km downstream, irrigation of farm land below EL 100 m is possible.

Water of the Khlong Wang Chao reservoir mentioned earlier flows down for about 20 km and reaches the confluence with the Khlong Mae Ya Ma River. If this water is not led for irrigation of the terrace in the Tak area, it can be flown into the Khlong Khayang, a tributary of the Khlong Suan Mak, at about 1.5 km downstream (basin area of 543 sq.m), increasing the Khlong Suan Mak water resource.

8.9.3 Khlong Khlung Irrigation Project

As shown in Fig. 8-6, RID is already planning constructing a dam and reservoir in this point (approximate longitude 99°24', latitude 16°14')[1], and if the RID plan is realized, an irrigated land (about 14,700 ha) of about 92,000 rai in the terrace land of EL 80 to 100 m is developed in the both sides of the Khlong Khlung River.

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1) Hearing investigation at RID Regional Office No. 3 at Phitsanulok

8.9.4 Muang Dam Project on Nam Mae Wong

RID is planning to construct a dam and reservoir in the narrow part of the Nam Mae Wong River (approximate longitude 99°27', latitude 15°54'), as shown in Fig. 8-6[1]. The main purposes of the plan are said to be flood control of the Nam Mae Wong basin and development and securing of water resources for the Chai Nat Barrage.

Dry season inflow to the Chai Nat Barrage is greatly declining in recent years, and various large scale transbasin schemes are being studied to increase the inflow.

Judging from 1/50,000 topographical maps, water resources stored in the Muang Dam are suitable to be led to the terrace, lower than EL 100 to 120 m, in both sides of the Nam Mae Wong River. Accordingly, when the transbasin schemes to the Chai Nat Barrage, as mentioned above, are realized, the water resources created by the Muang Dam Project may be transferred to the Nam Mae Wong basin of the Kamphaeng Phet plain.

1) Hearing investigations at RID Regional Office No. 7 at Chai Nat

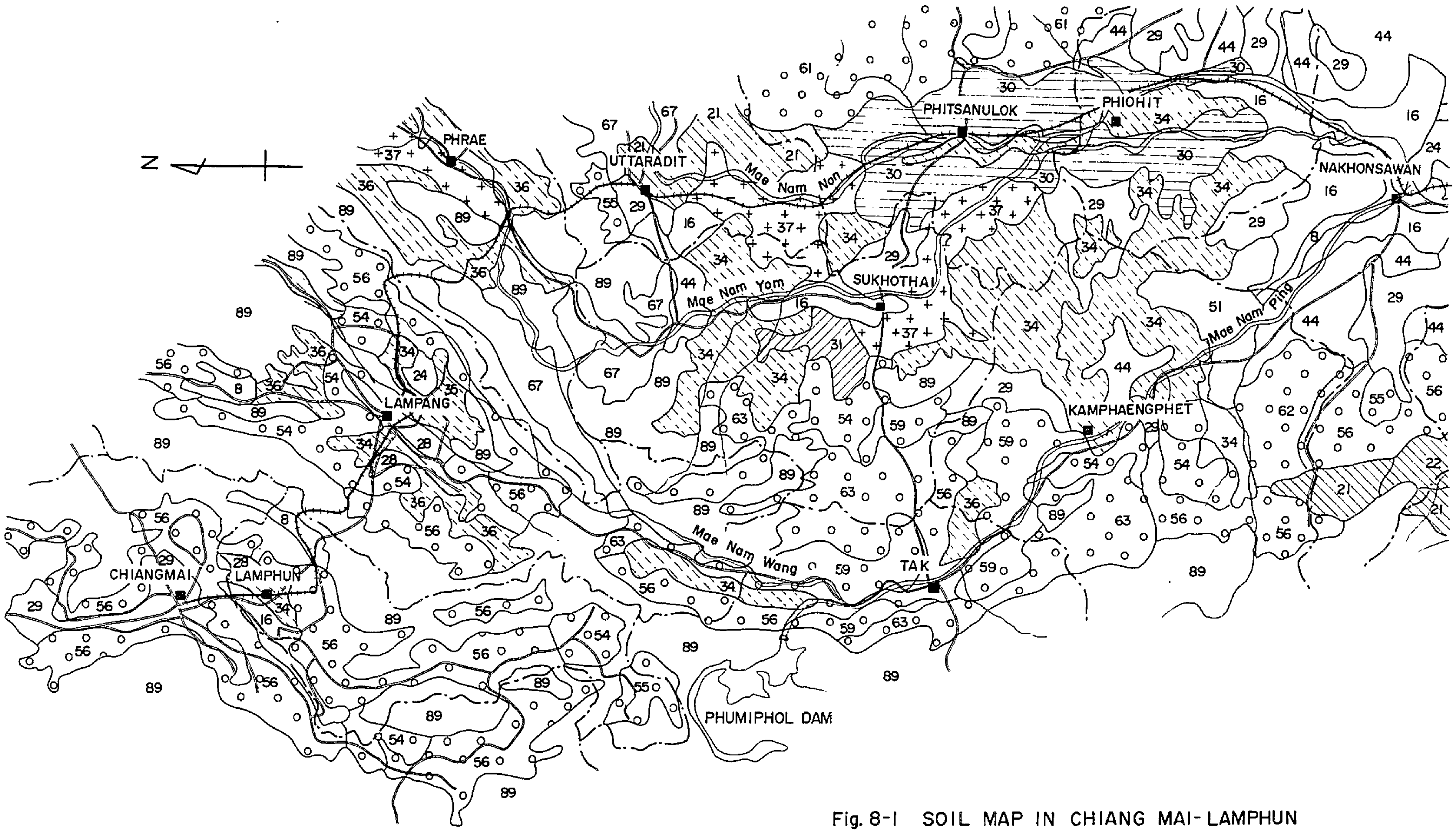


Fig. 8-1 SOIL MAP IN CHIANG MAI-LAMPHUN BASIN AND KAMPHAENG PHET PLAIN

SOIL LEGEND (Scale 1: 1,000,000)

ORDERS	SUBORDERS	MAPPING NUMBER	SOIL NAMES
ENTISOLS	FLUVENTS	8	LOAMY USTIFLUVENTS
INCEPTISOLS	AQUEPTS	16	CLAYEY TROPAQUEPTS
	TROPEPTS	21	LOAMY DYSTROPEPTS
ALFISOLS	AQUALFS	28	LOAMY TROPAQUALFS
		29	CLAYEY TROPAQUALFS
	AQUALFS/AQUEPTS	30	CLAYEY TROPAQUALFS/CLAYEY TROPAQUEPTS
	AQUALFS/USTALFS	31	CLAYEY TROPAQUALFS/CLAYEY HAPLUSTALFS
	USTALFS	34	LOAMY HAPLUSTALFS
		35	CLAYEY HAPLUSTALFS
		36	SKELETAL HAPLUSTALFS
	USTALFS/AQUALFS	37	LOAMY HAPLUSTALFS/CLAYEY TROPAQUALFS

ORDERS	SUBORDERS	MAPPING NUMBER	SOIL NAMES
ULTISOLS	AQUULTS	44	CLAYEY PALEAQUULTS
	AQUULTS/AQUALFS	51	CLAYEY PALEAQUULTS/CLAYEY TROPAQUALFS
	USTULTS	54	LOAMY PALEUSTULTS
		55	CLAYEY PALEUSTULTS
		56	SKELETAL PALEUSTULTS
		59	SKELETAL HAPLUSTULTS
		62	CLAYEY PALEUSTULTS/LOAMY PALEUSTULTS
		63	SKELETAL PALEUSTULTS/SKELETAL HAPLUSTULTS
	USTULTS/USTALFS	67	SKELETAL PALEUSTULTS/SKELETAL HAPLUSTALFS
		89	SLOPE COMPLEX

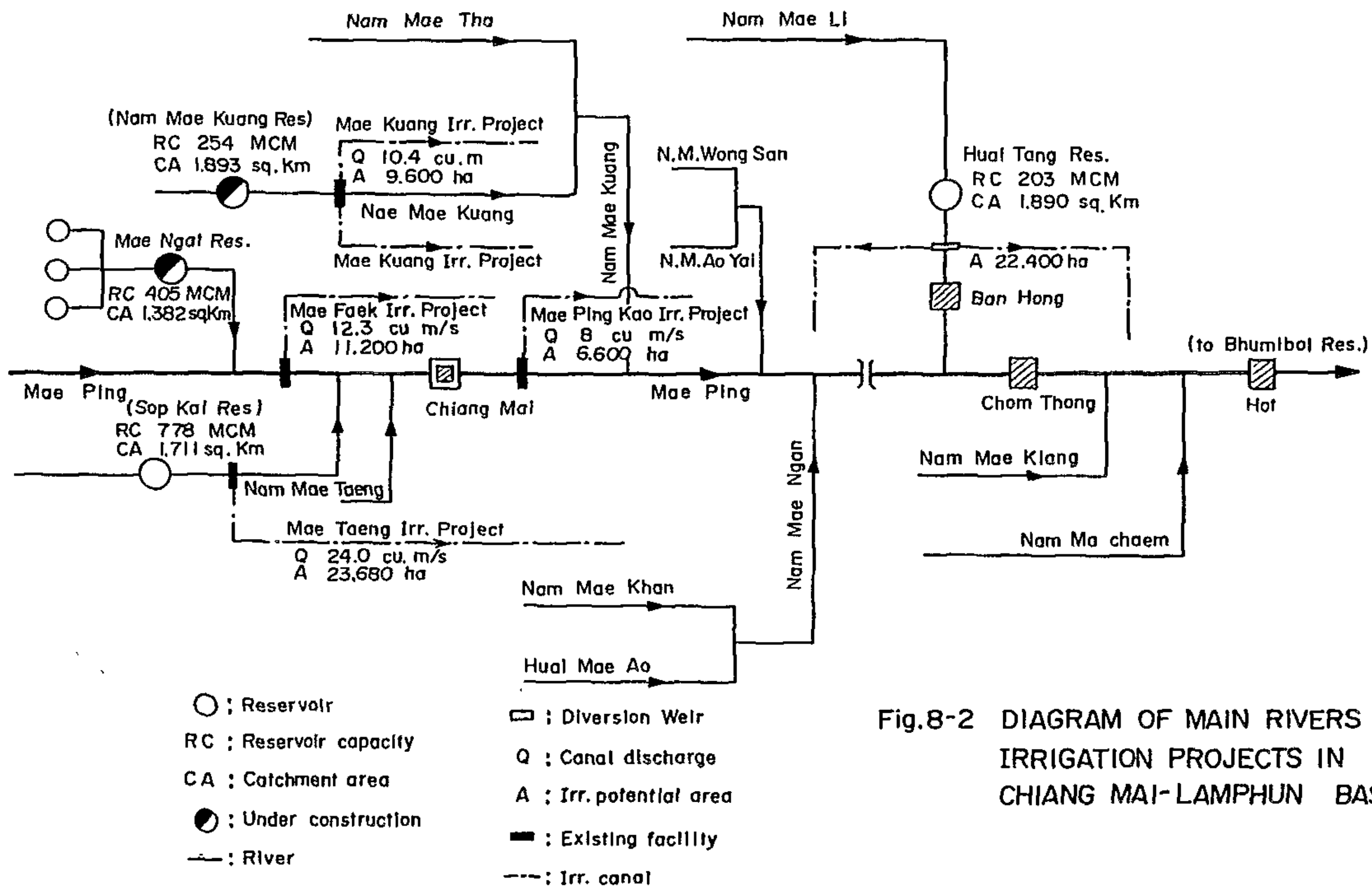


Fig.8-2 DIAGRAM OF MAIN RIVERS AND IRRIGATION PROJECTS IN CHIANG MAI-LAMPHUN BASIN

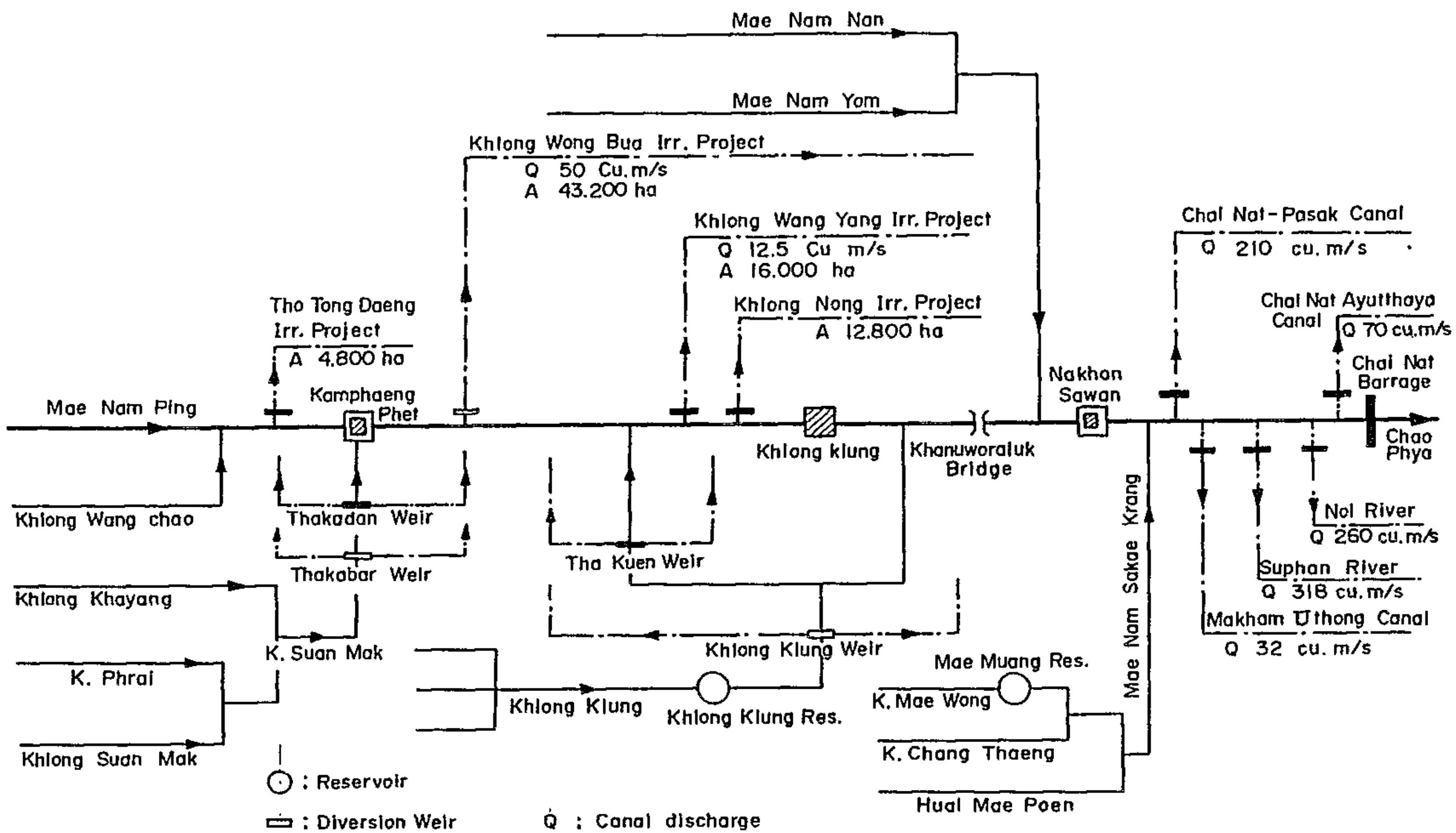
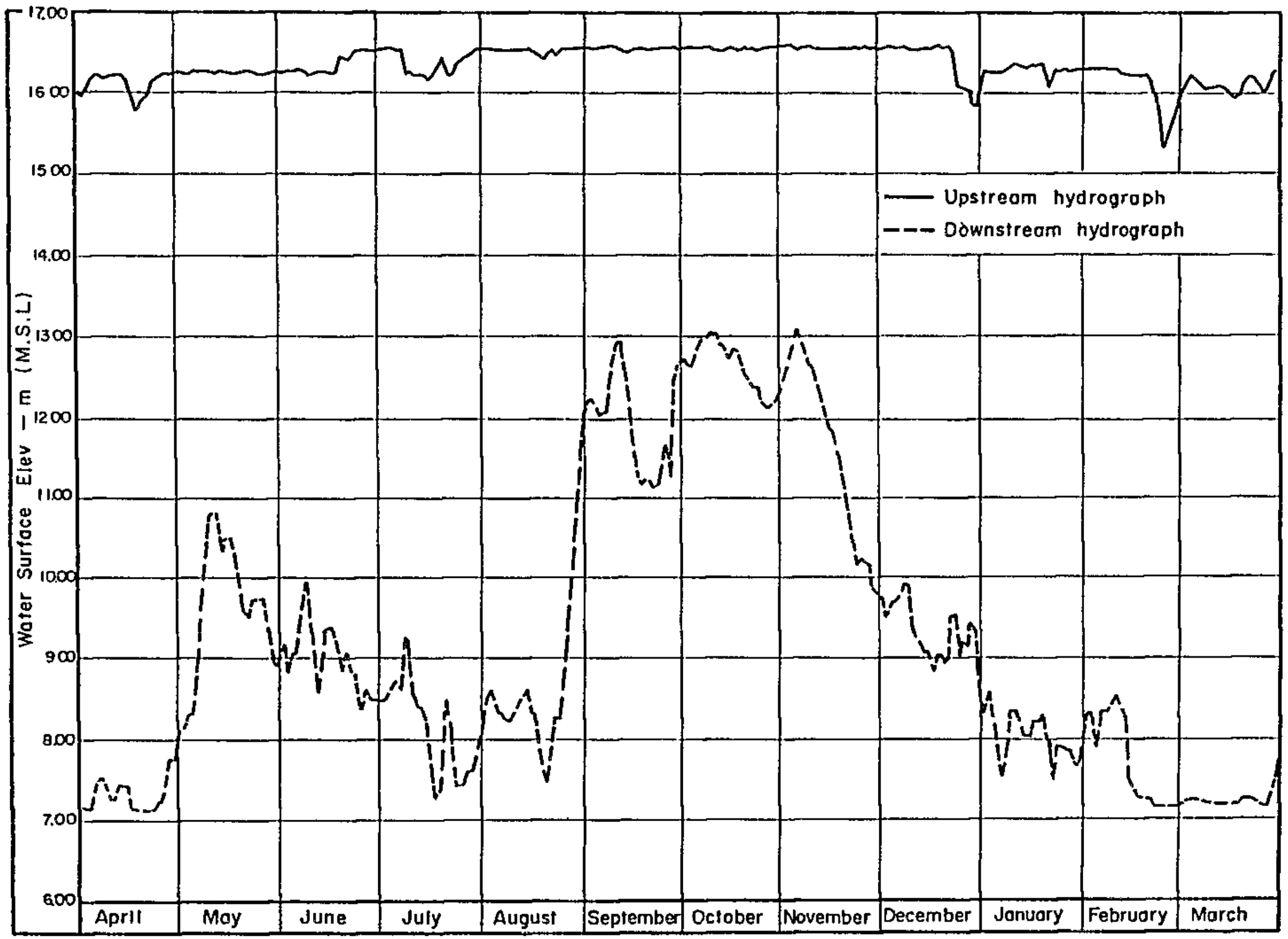


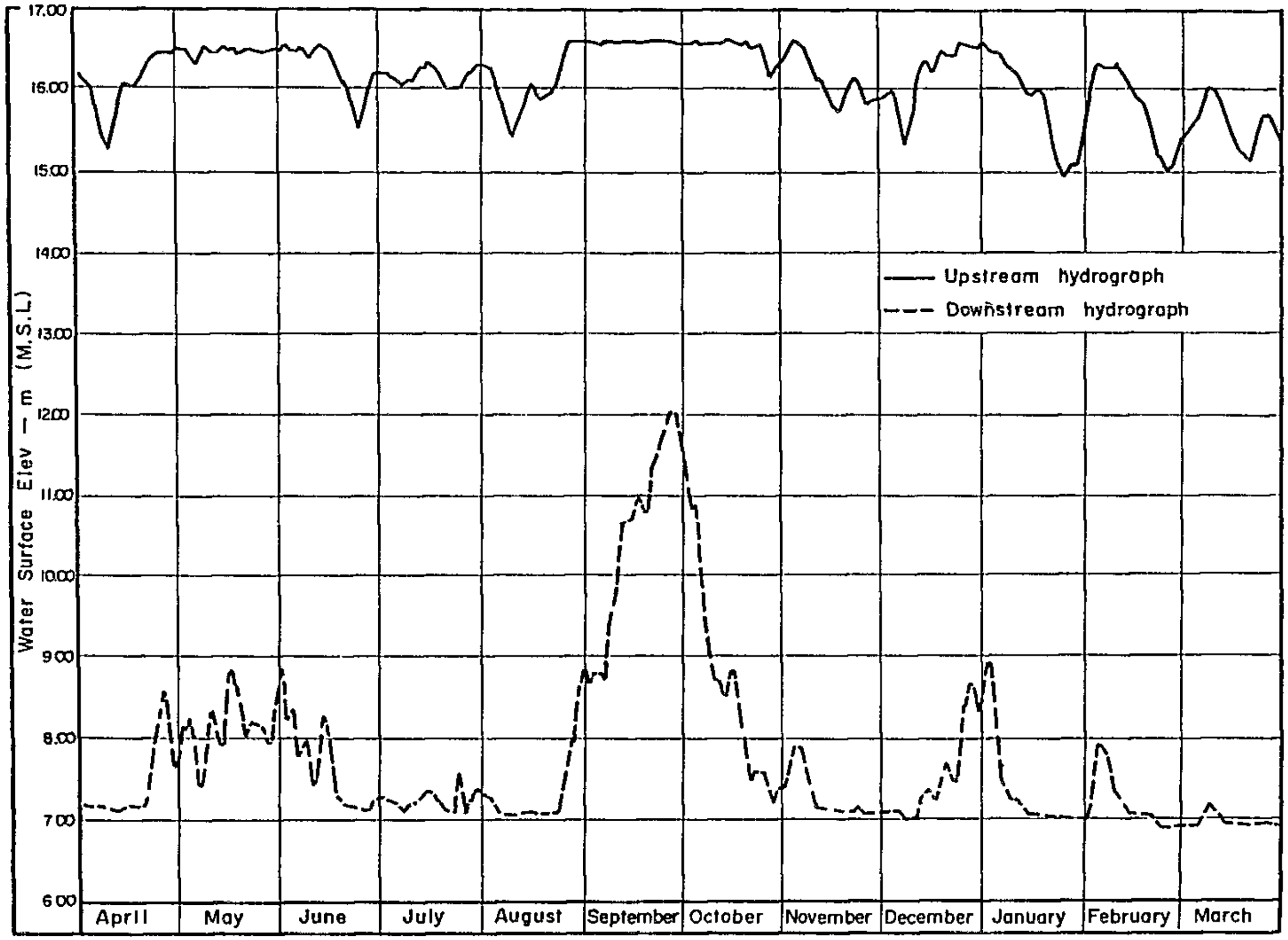
Fig.8-3 DIAGRAM OF MAIN RIVERS AND IRRIGATION PROJECTS IN KAMPHAENG PHET PLAIN

Fig. 8-4 (1) HYDROGRAPH AT CHAI NAT BARRAGE IN 1976



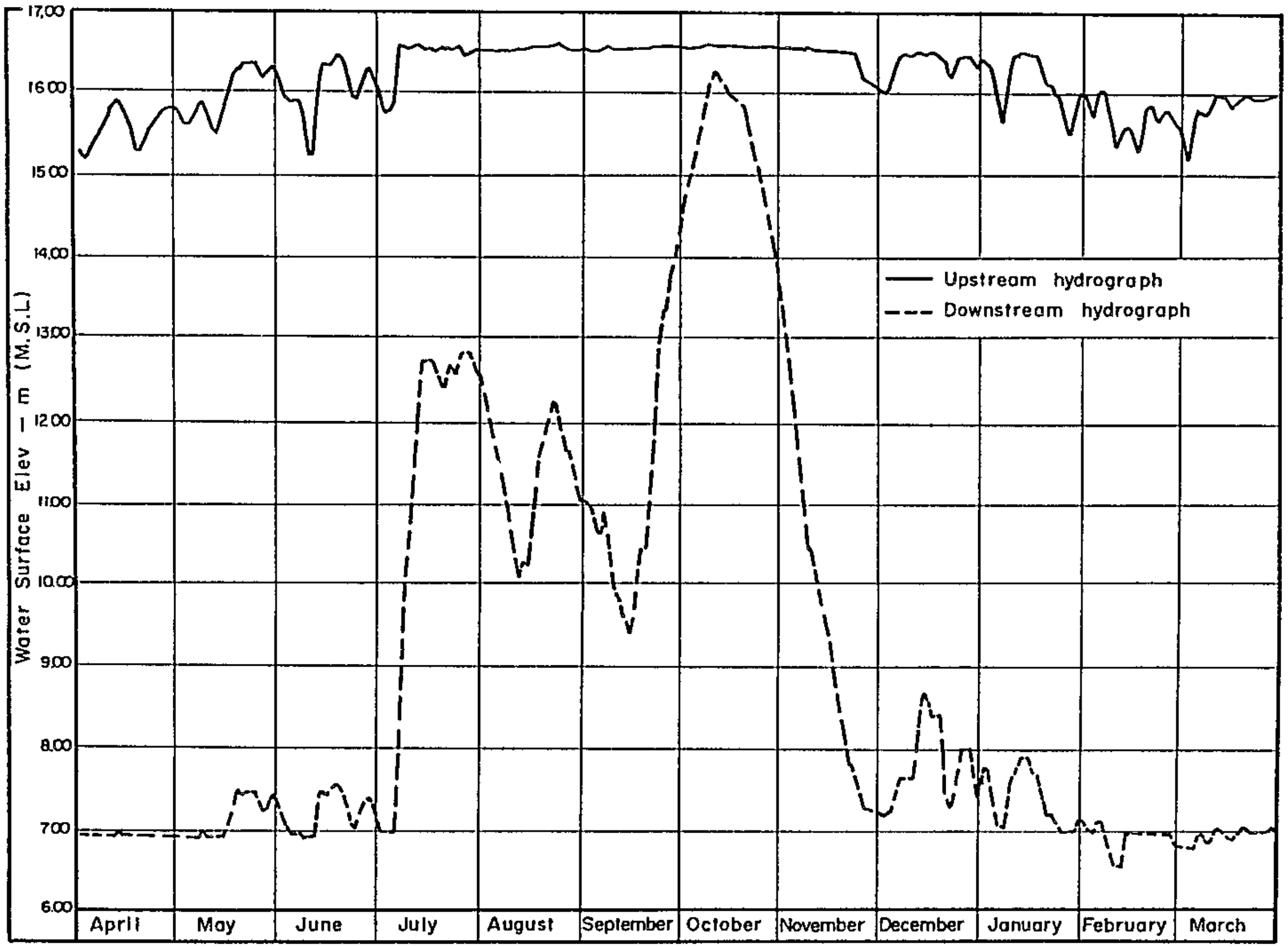
Source; Royal Irrigation Department,
Ministry of Agriculture and Co-operatives.

Fig. 8-4 (2) HYDROGRAPH AT CHAI NAT BARRAGE IN 1977



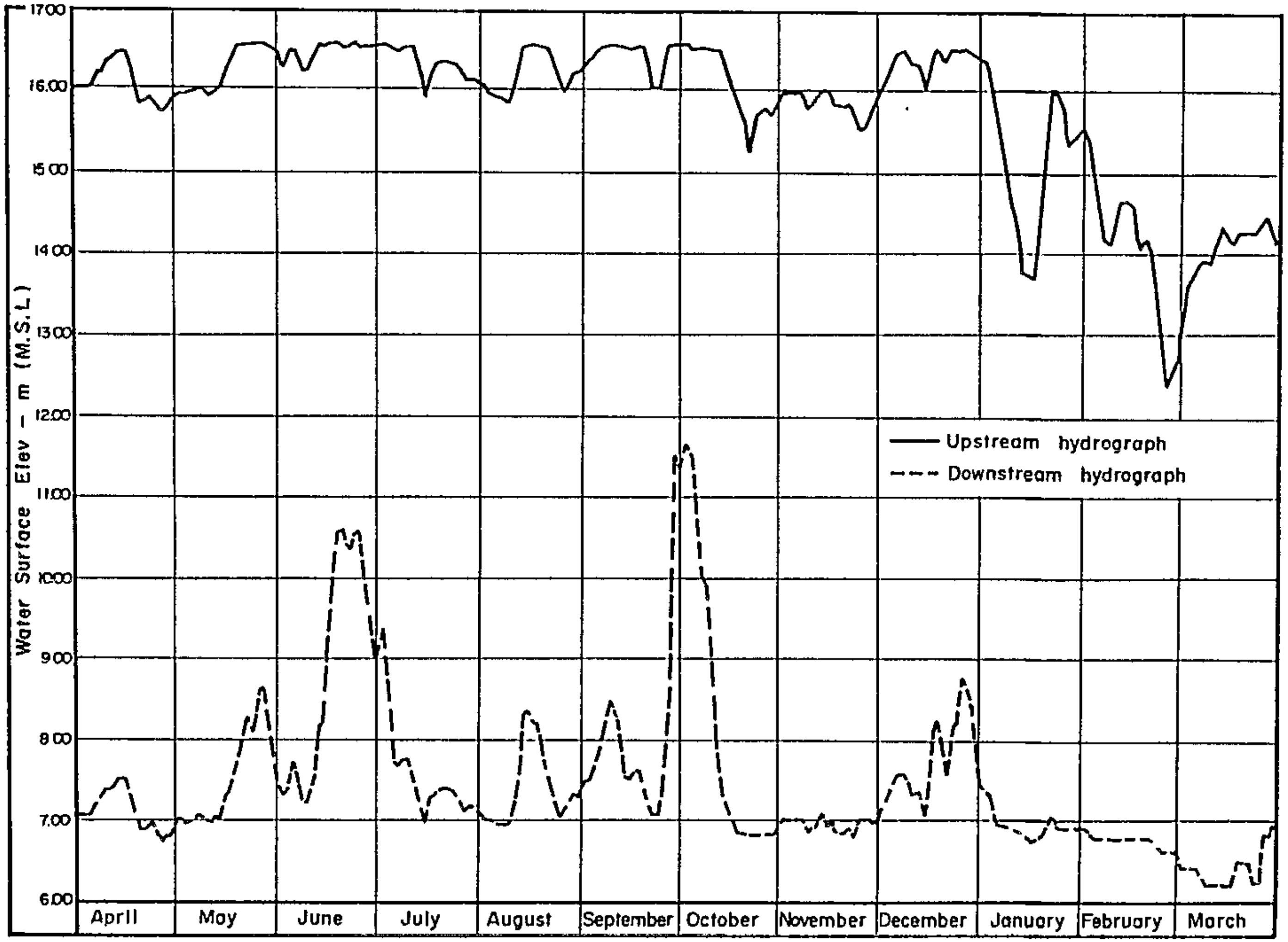
Source; Royal Irrigation Department,
Ministry of Agriculture and Co-operatives.

Fig. 8-4 (3) HYDROGRAPH AT CHAI NAT BARRAGE IN 1978



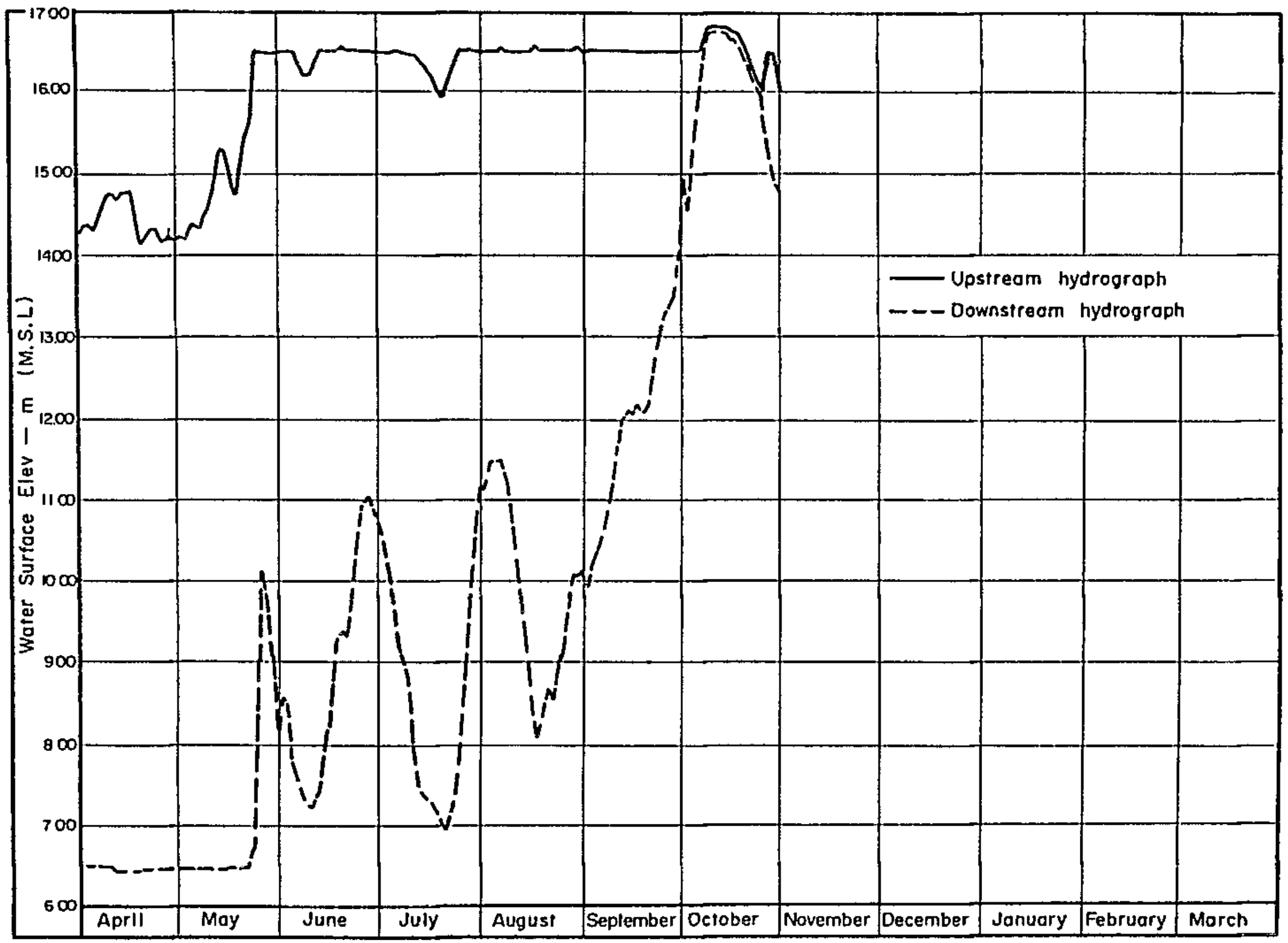
Source; Royal Irrigation Department,
Ministry of Agriculture and Co-operatives.

Fig. 8-4 (4) HYDROGRAPH AT CHAI NAT BARRAGE IN 1979



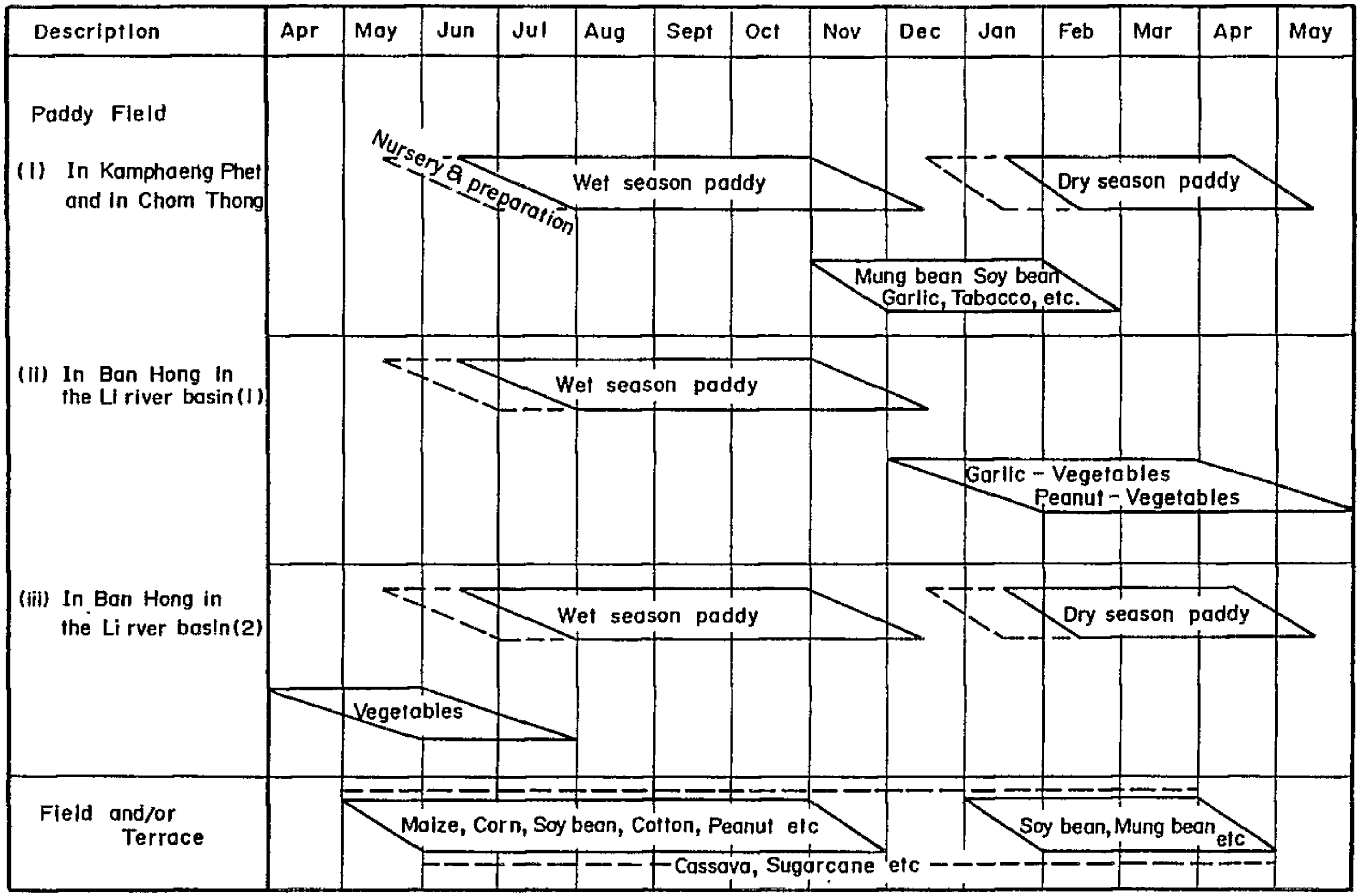
Source; Royal Irrigation Department,
Ministry of Agriculture and Co-operatives.

Fig. 8-4 (5) HYDROGRAPH AT CHAI NAT BARRAGE IN 1980



Source; Royal Irrigation Department,
Ministry of Agriculture and Co-operatives.

Fig. 8-5 TYPICAL CROPPING PATTERN IN CHIANG MAI – LAMPHUN BASIN AND KAMPHAENG PHET PLAIN



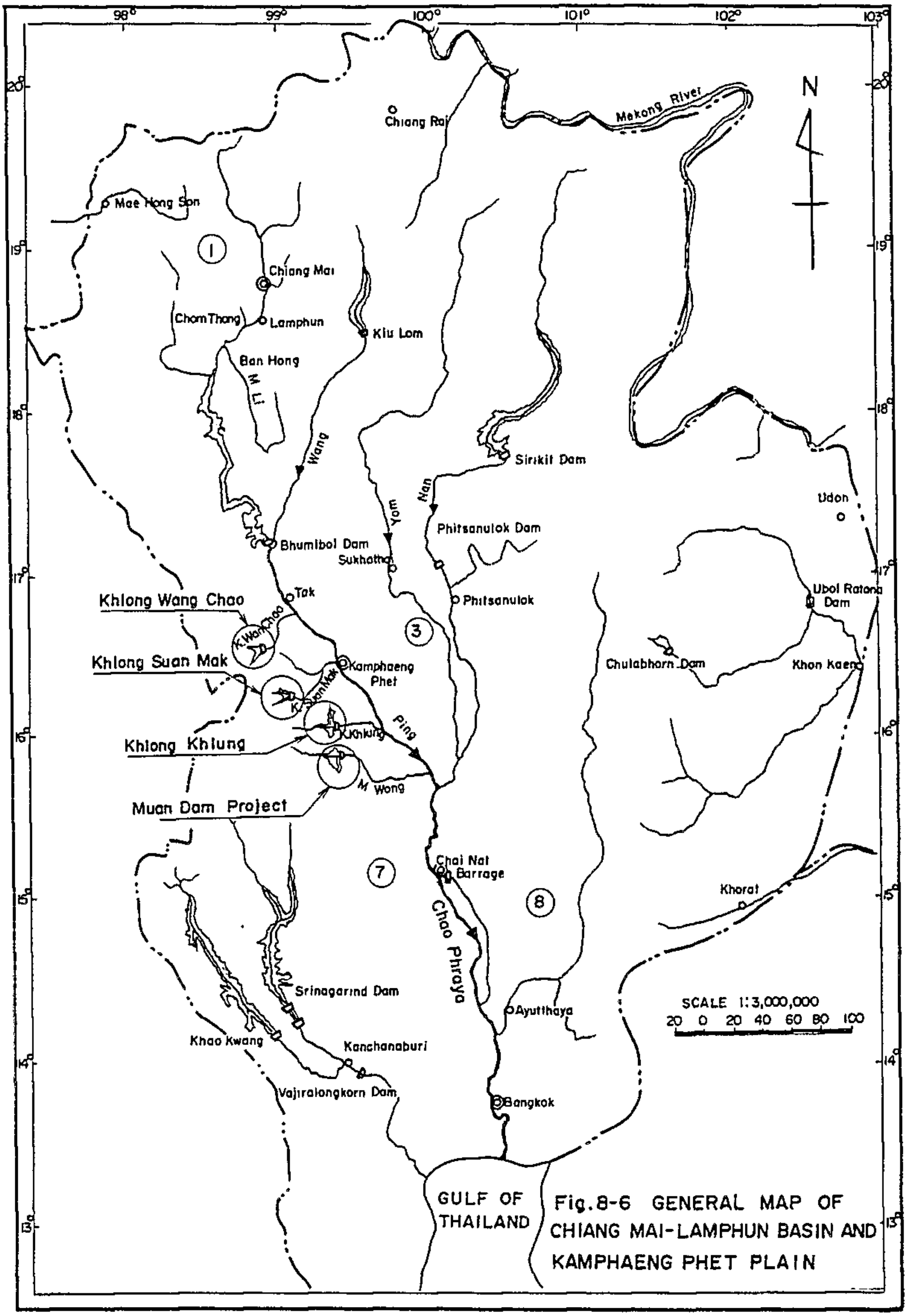


Fig.8-6 GENERAL MAP OF CHIANG MAI-LAMPHUN BASIN AND KAMPHAENG PHET PLAIN

Table 8-1 General Information on Agriculture in Chiang Mai-Lamphun Basin

		Chiang Mai[1] Province	Lamphun[2] Province
Cultivated Area	(rai)	1,503,061	963,000
Farmer's Household	(No.)	232,007	49,157
Farmer's Population	(person)	1,321,568	
Landownership	(rai/H.H)	6.5(7.2)	6.7
Annual Av. Temperature	(°C)	25	27
Annual Rainfall	(mm)	1,271	1,023

Source 1): Provincial Agricultural Extension Office, Chiang Mai Province

2): Agricultural Office Lamphun Province

Table 8-2 Planted Area, Average Yield and Farm-gate Price of Major Economic Crops in 1978/79 in Chiang Mai and Lamphun Provinces

Economic Crops	Chiang Mai Province		Lamphun Province		Farm-gate[1)] price (Baht/rai)
	Planted Area (rai)	Yield (kg/rai)	Planted Area (rai)	Yield (kg/rai)	
Major Rice (Wet season)	759,599	518 (580 ∿ 600)	217,114	434 (560)	2.3 ∿ 2.6 Non-gluti. 2.1 Glutinous
Dry season Rice	(48,794)	(530 ∿ 880)	(27,381)	(470)	
Mung bean	4,629	101 (150 ∿ 174)	15,693	137 (130)	4.2 ∿ 5.7 (5 ∿ 7)
Soy bean	154,688	192 (155)	3,570	211 (183)	4.7 ∿ 5.7 (5 ∿ 6)
Ground nut	61,114	254 (123 ∿ 360)	13,975	252 (320)	5.4 in shell, dried
Maize	15,974	214 (378)	-	-	
Garlic		(1,500 ∿ 2,000)			7.5∿11.5 dried
Onion		(800 ∿ 1,200)			
Tabacco (flesh leaves)		(2,000 ∿ 3,000)			2.5 ∿ 2.6

Source: AST Tables 19 ∿ 32
1): Table 1
Price of Agricultural Product in 2522 (Office of Agricultural Economics 2523)
Figures in parenthesis; Interviewed in December 1980

Table 8-3 Typical RID Irrigation Projects in Chiang Mai Province

Project	Potential Area (ha)	Capacity of Canal (cu.m/sec)	Water Resource	Additional Reservoir
(i) Mae Taeng Project	23,680	24.0	Mae Taeng	Sop Kai Res.[1)]
(ii) Mae Faek Project	11,200	12.3	Mae Ngat	Ngat Res.[2)]
(iii) Mae Kuang Project	9,600	10.4	Mae Kuang	Kuang Res.[2)]
(iv) Mae Ping Kao Project	6,600	8	Mae Ping	-

1): Under studying by RID.
2): Under construction by RID.

Table 8-4 Planting Area of Wet and Dry Paddy in 1979 in Irrigation Areas in Chiang Mai and Lamphun Provinces

Amphoe	Wet Paddy (rai)	Dry Paddy (rai)	Ratio (%)
(i) San Sai & Doi Saket (Region V)	122,282	9,080	7.4
(ii) Sara-pee (Region IV)	41,430	8,092	19.5
(iii) Hong Dong & Sanpa Tong (Region VI)	101,365	27,799	27.4
(iv) Chom Thong[1)]	56,199	15,497	27.6
(v) Hot[1)]	31,197	2,853	9.1
(vi) Lamphun Province[1)]	217,850	27,381	12.6

1): Out of the existing RID project areas.

Source: Record of Aug., 1979.

Table 8-5 General Information on Agriculture in Kamphaeng Phet Province

Cultivated Area	(rai)	3,036,741
Farmer's Household	(No.)	84,189
Landownership	(rai/H.H)	36
Annual Ave. Temperature	(°C)	29 1)
Annual Rainfall	(mm)	1,174 1)

1): At Nakhon Sawan,

Source: Climatological Data of Thailand, 25yr Period (1957 - 75)

Table 8-6 Statistics of Economic Crops in 1979 in Kamphaeng Phet Province

Economic Crop	Planted Area (rai)	Yield (kg/rai)	Farm-gate Price (Baht/kg)
Wet season paddy	1,364,000	360 (400 ∿ 500) 1)	2.9 (3 ∿ 3.5) 1)
Dry season paddy	36,868	-	
ditto inerperimental farm		724.6 (in vast scale) (1,000 with fertilizer) 1)	
Maize	254,992	400	2.0
Soy bean	67,654	210	6.0
Mung bean	186,903	110	5.0
Sugar cane	194,200	7,000	0.41
Cassava	94,983	2,700	0.75
Sorghum	7,460	260	1.9

Source: Agricultural Extension Report of Provincial Agriculture (Office of Kamphaeng Phat, 1979.

1): Interviewed in Dec., 1980.

Table 8-7 Discharge of the Ping River at Kamphaeng Phat Bridge (p.7A)
(Lat. 16°28'38", Long. 99°31'06" Drainage Area 42,700 sq.km)

Water Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual Runoff mcm	Annual Mean cms	Bhumibol Power Discharge mcm
1970	749	1,001	1,073	979	1,461	1,330	1,387	984	957	721	684	783	12,109	384	(7,392)
1971	763	809	757	893	1,324	1,470	1,515	1,038	824	698	624	740	11,457	362	(7,392)
1972	611	734	685	714	724	821	1,062	692	562	519	513	668	8,306	263	(7,326)
1973	824	755	891	882	1,272	2,093	1,540	774	709	670	828	983	12,222	387	(6,499)
1974	702	841	729	730	877	1,213	1,330	1,379	420	430	518	759	9,930	315	(6,947)
1975	832	706	745	813	1,020	1,558	1,897	1,340	646	470	512	758	11,325	358	(5,753)
1976	852	874	1,023	1,136	807	1,083	1,206	933	519	490	550	825	10,297	326	(8,190)
1977	875	898	656	728	724	1,110	780	893	490	271	496	633	8,533	271	(6,964)
1978	678	621	635	976	823	1,027	1,151	378	455	383	475	818	8,420	267	(5,634)
1979	866	816	824	733	747	853	746	914	597	312	267	327	8,002	253	(6,378)
Average	775	806	802	858	978	1,255	1,261	933	618	496	547	732	10,060	319	(6,787)

---- Average -----
598 mcm (231 cms)

(215 cms)

Table 8-8 Irrigation Projects Executed by RID in the Left-side Area of the Ping in Kamphaeng Phet Plain

Irrigation Project	Potential Irrigable Area (rai)	Design Capacity in Canal Head (cu, m/s)	Water Resource
(i) Tho Tong Daeng Project	30,000		the Ping
(ii) Khlong Wong Bua Project	270,000 (25,000)[1)]	50.0	"
(iii) Khlong Wang Yon Project	100,000 (10,000)[1)]	25.5	"
(iv) Khlong Nong Khwan Project	79,900 (10,000)[1)]		"
Total	479,000		

Source: RID Construction Office in Kamphaeng Phet.

1): Figures in parenthesis indicate irrigable area in dry season.

Table 8-9 Typical RID Irrigation Projects in Right-side Area of the Ping in Kamphaeng Phet Plain

Irrigation Project	Stage[1)]	Water Resource
(i) Thakadan Weir	C	Khlong Suan Mak
(ii) Khlong Nong Canal	UC	"
(iii) Thaka Bank	P	"
(iv) Khlong Lan	C	Khlong Khayang
(v) Khlong Kayang	C	"
(vi) Wangsai Weir	P	Khlong Wang Chum
(vii) Thakuen Weir	C	"
(viii) Khlong Klung Dam	P	Khlong Klung
(ix) Khlong Klung Weir	P	"
(x) Mae Muang Dam	P	Khlong Mae Wong

1) C : Completed
UC: Under construction
P : Planning stage

Source: Location Maps of RID Irrigation Projects

Table 8-10 Pumping Station Project[1)] Executed by NEA

(i) Ban Lam Dok Mai Nua;	at the right bank of the Ping
(ii) Ban Rai Tai;	"
(iii) Ban Hui Yang;	"
(iv) Ban Hui Koh;	"
(v) Ban Thong Kung;	at the left bank of the Ping
(vi) Ban Tha Mae-Kua;	"

1): Project area: approximate 3,000 rai per unit
Canal length: 25 km including main, lateral and sub-lateral canals

Source: Location map provided by Electrical Pumping Project, NEA.

Table 8-11 Main Features of Chai Nat Barrage

(i)	Crest Length	237.5 m with 12 sluice gates
(ii)	Crest Elevation	EL 9.0 m
(iii)	Upstream side Flood Level	 EL 18.0 m
	Retension Level	EL 17.5 m
(iv)	Down stream side Retension Level in Dry Season	 EL 7.5 m
(v)	Gater Operation	To maintain a level difference of 9 m between (iii) and (iv) constantly.
(vi)	Irrigation for Left-side Area (Incharge of RID Regional Office No.8)	
	Wet season paddy;	3.1 ∿ 3.4 million rai in 1977 ∿ 1979
	Dry season paddy;	max. 550,000 rai in 1976 ∿ 1979
	Main canal and ; its capacity	Chai Nat-Pasak Canal 210 cu.m/sec Chai Nat-Ayutthaya Canal 70 cu.m/sec
(vii)	Irrigation for Right-side Area (Incharge of RID Regional Office No.7)	
	Wet season paddy;	2.6 ∿ 2.8 million rai in 1977 ∿ 1980
	Dry season paddy;	1.4 ∿ 2.0 million rai in 1977 ∿ 1979
	Main canal and ; its capacity	Noi River 260 cu.m/sec Makham-Uthong Canal 32 cu.m/sec Suphan River 318 cu.m/sec

Table 8-12 Discharge of the Chao Phya at Nakhon Sawan (C-2)
(Lat. 15°40'15", Long. 100°06'45", Drainage Area 110,569 sq·km
After Jointing of the Nan and the Wang) 1/

Water Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual Runoff mcm.	Annual Mean cms.
1973	893	895	1,242	1,428	2,489	4,035	5,584	2,455	1,108	729	768	977	22,602	717
1974	1,025	1,208	1,108	1,118	2,086	3,040	3,850	3,990	1,651	833	725	1,073	21,709	688
1975	1,275	1,277	1,543	1,929	2,831	7,376	10,419	4,528	1,989	1,092	1,158	1,487	36,907	1,167
1976	1,625	2,088	2,081	1,847	2,374	4,716	6,436	4,859	1,881	1,174	1,027	1,401	31,508	999
1977	1,591	1,907	1,537	1,524	1,839	4,072	3,302	2,073	1,166	671	727	961	12,371	678
1978	1,063	1,020	1,014	3,213	4,262	4,730	8,077	2,968	1,401	1,022	973	1,517	31,240	991
1979	1,606	1,643	2,130	1,737	1,972	2,164	2,202	1,673	1,290	619	447	552	18,036	570
Average	1,296	1,434	1,522	1,828	2,550	4,304	5,695	3,220	1,498	874	832	1,138	26,196	830

1/ : Sirikit dam on the Nan River: 10,550 mcm in reservoir capacity
Kiu Lom dam on the Wang River: 112 mcm

Table 8-13 Monthly Hydrometric Data at Chai Nat Barrage (1970 ∿ 1979)

Unit: cu·m/sec

	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Annual Average
1. Chainat - Pasak Canal													
Max.	155	168	189	191	211	258	257	203	121	154	102	139	
Min.	40	50	59	77	141	90	48	137	9	17	21	36	
Mean	99	96	124	140	173	199	191	172	61	59	71	86	123 (3,875) 1/
2. Chai Nat - Ayuthaya Canal													
Max.	15	14	15	39	63	76	69	62	11	9	18	17	
Min.	0	0	0	4	54	46	41	26	0	0	0	0	
Mean	4	4	7	26	55	61	59	47	5	1	4	5	23 (725) 1/
3. Noi River													
Max.	142	114	72	114	188	249	255	229	98	49	62	116	
Min.	31	33	31	43	115	140	129	147	29	22	33	41	
Mean	73	17	55	78	145	186	207	204	59	34	46	68	101 (3.182) 1/
4. Makham - Uthong Canal													
Max.	30	23	25	22	27	28	29	27	20	3	9	26	
Min.	0	4	6	3	12	4	1	0	0	0	1	2	
Mean	15	14	16	17	22	16	13	19	7	1	5	13	13 (410) 1/
5. Suphan River													
Max.	162	141	142	121	160	249	262	220	84	50	72	145	
Min.	60	42	31	21	59	39	5	28	11	4	26	48	
Mean	105	86	88	76	106	118	152	138	43	26	51	90	90 (2,835) 1/
6. Released discharge toward downstream at Chai Nat Barrage													
Max.	124	557	557	1,069	1,338	2,416	3,572	1,414	615	274	214	156	
Min.	71	79	100	70	98	220	327	74	144	117	71	66	
Mean	91	184	249	325	442	1,069	1,671	660	349	180	115	89	451 (14,213) 1/

1/ : Figures in the parenthesis indicates in MCM.

Table 8-14 Potential Eavapotranspiration in Chom Thong, Kamphaeng Phet and Chai Nat (by Blaney-Criddle Method)

	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Remarks
1. Chom Thong (N 18°25')													
Daytime-hours (%)	8.50	9.10	8.94	9.19	8.92	8.29	8.21	7.63	7.74	7.81	7.29	8.43	
Average temperature (°C)	28.3	28.0	27.1	26.7	26.2	26.2	25.5	23.4	20.6	20.0	22.2	25.6	Average at Chiang Mai (1951-75)
Potential ET by Blaney-Criddle (mm)	179.1	190.5	183.4	186.9	179.4	166.7	162.4	143.6	135.8	134.9	133.2	167.2	1,963.1 mm/yr
ref: Class A Pan Evaporation (1951-75) (mm)	197.2	176.2	136.7	128.5	117.8	126.4	129.1	104.4	99.7	108.4	137.0	180.6	1,642.0 mm/yr
2. Kamphaeng-Phet (N 16°20')													
Daytime-hours (%)	8.46	9.03	8.85	9.10	8.86	8.28	8.26	7.70	7.81	7.89	7.33	8.43	
Average temperature (°C)	31.9	30.7	29.6	29.1	28.4	28.1	27.9	26.8	25.2	25.5	28.4	30.7	Average at Nakhon Sawan (1951-75)
Potential ET by Blaney-Criddle (mm)	192.1	200.1	191.7	195.0	187.1	173.7	172.0	156.9	153.5	156.1	154.8	186.8	2,198 mm/yr
ref: Class A Pan Evaporation (1951-75) (mm)	237.3	199.8	172.5	165.3	149.5	125.0	131.0	122.5	128.5	137.2	156.6	206.0	1,931.2 mm/yr
3. Chai Nat (N 15°00')													
Daytime-hours (%)	8.44	8.98	8.80	9.05	8.83	8.28	8.26	7.75	7.88	7.94	7.36	8.43	
Average temperature (°C)	31.9	30.7	29.6	29.1	28.4	28.1	27.9	26.8	25.2	25.5	28.4	30.7	Average at Nakhon Sawan (1951-75)
Potential ET by Blaney-Criddle (mm)	191.8	199.1	190.8	194.1	186.4	173.7	172.5	158.0	154.9	157.2	155.4	186.9	2,120.8 mm/yr

Table 8-15 (1) Monthly Water Requirement for Paddy per 1,000 ha in Chom Thong and Ban Hong Area

	Description	Unit	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
			Wet Season Paddy							Dry Season Paddy					
Consumptive-use	1. Nursery stage	mm/day	10.0	10.0	10.0					10.0	10.0				
	Amount required	10^3m^3/M	50.0	50.0	50.0					50.0	100.0				
	2. Land preparation	mm	200	200	200					200	200				
	Amount required	10^3m^3/M	666.7	666.7	666.7					666.7	1,333.3				
	3. Potential ET	mm/M		191.7	195.0	187.1	173.7	172.0	156.9	153.5	156.1	154.8	186.8	192.1	200.1
	Crop coeff. (kc)			0.8	1.0	1.1	1.2	1.1	1.0	0.8	0.8	0.9	1.2	1.0	0.8
	Consumptive-use	mm/M		153.4	195.0	205.8	208.4	189.8	156.9	122.8	124.9	139.3	224.2	192.1	160.1
	Percolation	mm/M		60	60	60	60	60	60	60	60	60	60	60	60
	4. Total amount req. (1+2+3)	10^3m^3/M	716.7	1,072.7	2,417.0	2,658.0	2,684.0	2,493.0	1,446.0	304.7 (716.7)	(1,741.5)	(1,993.0)	(2,842.0)	(2,521.0)	(733.7)
Rainfall	5. Rainfall at Kamphaeng Phet	mm/M	20.1	50.8	(68.5)	80.8	152.9	42.4	2.7	0	0	0	0	0	20.1
	6. Effective rainfall	mm/M	15.1	38.1	51.4	60.5	114.7	31.8	-	-	-	-	-	-	15.1
	7. Acreage	Ha	350	683	1,017	1,000	1,000	1,000	667	333					667.0
	8. Amount available	10^3m^3/M	52.9	260.2	522.7	605.0	1,147.0	318.0	-	-					100.7
Water req.	9. Net water req.	10^3m^3/M	663.0	812.5	1,894.3	2,053.0	1,537.0	2,130.0	1,446.0	304.7 (716.7)	(1,691.5)	(1,993.0)	(2,842.0)	(2,521.0)	(633.7)
	10. Gross water req.	10 m /M	Total for wet paddy 15,559							Total for dry paddy 14,854					

Table 8-15 (2) Monthly Water Requirement for Paddy per 1,000 ha in Kamphaeng Phet Area

	Description		May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
			Wet Season Paddy							Dry Season Paddy					
Consumptive-use	1. Nursery stage	mm/day	10.0	10.0	10.0					10.0	10.0				
	Amount required	$10^3m^3/M$	50.0	50.0	50.0					50.0	100.0				
	2. Land preparation	mm	200	200	200					200	200				
	Amount required	$10^3m^3/M$	666.7	666.7	666.7					666.7	1,333.3				
	3. Potential ET	mm/M		191.7	195.0	187.1	173.7	172.0	156.9	153.5	156.1	154.8	186.8	192.1	200.1
	Crop coeff. (kc)			0.8	1.0	1.1	1.2	1.1	1.0	0.8	0.8	0.9	1.2	1.0	0.8
	Consumptive-use	mm/M		153.4	195.0	205.8	208.4	189.8	156.9	122.8	124.9	139.3	224.2	192.1	160.1
	Percolation	mm/M		60	60	60	60	60	60	60	60	60	60	60	60
	4. Total amount req. (1+2+3)	$10^3m^3/M$	716.7	1,072.7	2,417.0	2,658.0	2,684.0	2,493.0	1,446.0	304.7 (716.7)	(1,741.5)	(1,993.0)	(2,842.0)	(2,521.0)	(733.7)
Rainfall	5. Rainfall at Kamphaeng Phet	mm/M	20.1	50.8	(68.5)	80.8	152.9	42.4	2.7	0	0	0	0	0	20.1
	6. Effective rainfall	mm/M	15.1	38.1	51.4	60.5	114.7	31.8	-	-	-	-	-	-	15.1
	7. Acreage	Ha	350	683	1,017	1,000	1,000	1,000	667	333					667.0
	8. Amount available	$10^3m^3/M$	52.9	260.2	522.7	605.0	1,147.0	318.0	-	-					100.7
Water req.	9. Net water req.	$10^3m^3/M$	663.0	812.5	1,894.3	2,053.0	1,537.0	2,130.0	1,446.0	304.7 (716.7)	(1,691.5)	(1,993.0)	(2,842.0)	(2,521.0)	(633.7)
	10. Gross water req.	10 m /M	Total for wet paddy 15,559								Total for dry paddy 14,854				

Table 8-15 (3) Monthly Water Requirement for Paddy per 1,000 ha in Chai Nat Area

	Description	Unit	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
			Wet Season Paddy								Dry Season Paddy				
Consumptive-use	1. Nursery stage	mm/day	10.0	10.0	10.0					10.0	10.0				
	Amount required	$10^3m^3/M$	50.0	50.0	50.0					50.0	100.0				
	2. Land preparation	mm	200	200	200					200	200				
	Amount required	$10^3m^3/M$	666.7	666.7	666.7					666.7	1,333.3				
	3. Potential ET	mm/M		190.8	194.1	186.4	173.7	172.5	158.0	154.9	157.2	155.4	186.9	191.8	199.1
	Crop coeff. (kc)			0.8	1.0	1.1	1.2	1.1	1.0	0.8	0.8	0.9	1.2	1.0	0.8
	Consumptive-use	mm/M		152.6	194.1	205.0	208.4	189.8	158.0	123.9	125.8	139.9	224.3	191.8	159.3
	Percolation	mm/M		60	60	60	60	60	60	60	60	60	60	60	60
	4. Total amount req. (1+2+3)	$10^3m^3/M$	716.7	1,071.1	2,411.7	2,650.0	2,684.0	2,498.0	1,453.3	306.5 (716.7)	(1,743.0)	(1,999.0)	(2,843.0)	(2,518.0)	(731.0)
Rainfall	5. Rainfall at Kamphaeng Phet	mm/M	20.1	(50.8)	(68.5)	80.8	152.9	42.4	2.7	0	0	0	0	0	20.1
	6. Effective rainfall	mm/M	15.1	38.1	51.4	60.5	114.7	31.8	-	-	-	-	-	-	15.1
	7. Acreage	Ha	350	683	1,017	1,000	1,000	1,000	667	333					667
	8. Amount available	$10^3m^3/M$	52.9	260.2	522.7	605.0	1,147.0	318.0	-	-					100.7
Water req.	9. Net water req.	$10^3m^3/M$	663.0	810.9	1,889.0	2,045.0	1,537.0	2,180.0	1,453.3	281.6 (716.7)	(1,743.0)	(1,999.0)	(2,843.0)	(2,518.0)	(631.0)
	10. Gross water req.	$10^3m^3/M$	Total for wet paddy 15,551								Total for dry paddy 14,929				

Table 8-16 Crop Budgets Monitored in Chai Nat Region[1)]

(Unit: Baht/rai)

		Wet Season	Dry Season
(1) Pilot Area	Total value of Production	1215 ∿ 1348	1698 ∿ 1963
	Variable Cost (Physical Cost)	363 ∿ 402	394 ∿ 473
	Gross Margin (% of total value of production)	67 ∿ 73%	73 ∿ 80%
(2) Chandsutr	Total Value of Production	1151 ∿ 1267	1652 ∿ 1788
	Variable Cost	455 ∿ 464	511 ∿ 574
	Gross Margin (% of total value of production)	60 ∿ 63%	66 ∿ 71%
(3) Boromdbart	Total Value of Production	996 ∿ 1185	1456 ∿ 1569
	Variable Cost	277 ∿ 321	352 ∿ 413
	Gross Margin (% of total value of production)	71 ∿ 74	74 ∿ 76

1): Results of Benefit Monitoring in the Pilot and Stage I Areas Technical Note No.50 1978/79,

Ministry of Agriculture and Co-operatives, ILACO/EMPIRE M&T Bangkok, January 1980.

Table 8-17 Estimated Agricultural Benefit with Project per Ha

(i) Yield of dry season paddy	(kg/rai)[1)] (kg/ha)	650 (4,063)
(ii) Economic farm-gate price of paddy	(Baht/kg)[2)]	5
(iii) Gross production value	(Baht/ha)	20,315
(iv) Rate of production expenses	(%)[3)]	40
(v) Rate of net revenew	(%)	60
(vi) Net production value per Ha	(Baht/ha)	12,189
(vii) Water Requirement for dry paddy	(cu.m/ha)	15,000
(viii) Net production value per cu.m	(Baht/cu.m)	0.813

1), 2) & 3): Refer to 6.2, 6.3 and 6.4.

CHAPTER 9

CITY WATER SUPPLY

CHAPTER 9 CITY WATER SUPPLY

9.1 Present Status of City Water Supply

9.1.1 Introduction

In Thailand, more than 40 public service agencies undertake construction, operation and maintenance of the existing waterworks. Of them all, the Metropolis Water Works Authority (MWWA) provides its service to Bangkok Metropolis and its adjoining provinces of Nonthaburi and Samut.

Traditionally, the water supply system in Bangkok was blessed abundantly with ground water of good quality. Recently, however, surface water, i.e., river water, treated by chemicals has become only dependable supply source, as the result of declining of ground water level as the increase of the number of drilled wells and deterioration in water quality with saline water content. The distribution pipeline has been suffered from severe hurt or damage because of long negligence in maintenance care, being contaminated increasingly inside the pipe by lack of water pressure due to insufficiency of water supply. In 1979, however, water supply has turned to an increasing tendency with completion of Bangkhen Purification Plant. It is, therefore, expected that the waterworks will be improved gradually in a long run with continuing effort for maintenance and repair, even though there may be damage or leakage on the pipeline due to excessive inside water pressure.

The service area for which the MWWA is responsible covers a total expansion of 3,100 km^2. Total population in this region reached about 5,800,000, about 55 percent of which, that is 3,200,000, is served by the

MWWA at present. The service area covering this population is no more than only 273 km^2. Total number of consumers served by the MWWA as of September end in 1979 amounts to 355,707 on a metered-contract basis, an increase of 14,623 or 4.3 percent over the preceding year. The greater majority of total, or 348,154, is contracted by central metering system and only a few, or 2,257, are contracted by separate metering system (in Bangkhen and Bank Kapi). Large consumers number to 5,296. The service area of the MWWA is mapped out in Fig. 9-1.

9.1.2 Raw Water Production

The MWWA's water production consists of surface water withdrawn from Chao Phya River and ground water pumped up from deep wells scattered over in Bangkok Metropolis, Nonthaburi Province and Samut Prakarn Province. Yearly production of raw water up to 1979 and daily average production in fiscal year 1979 are shown in Tables 9-1 and 9-2 respectively.

Production of 308×10^6 m^3, which corresponds to 63.6 percent of the MWWA's total 485×10^6 m^3 produced for fiscal year 1979, is shared by surface water from Chao Phya River and production of 177×10^6 m^3 corresponding to 36.4 percent comes from ground water by operation of 131 deep wells. Surface water withdrawn from Chao Phya River is pumped up directly at the pumping station (Fig. 9-2) situated at Sam Lae 32 km north of Bangkok Metropolis, transfered into Bank Luang Reservoir and Sam Sen or Thonburi Treatment Plant through the canal, and supplied, through each distribution pipeline, to either Bangkok or Thonburi. In 1979, with completion of the waterwork expansion project of Stage I - Phase 1 Bangkhen Treatment Plant was newly entered into operation in addition to the preceding two treatment plants.

The MWWA completed, in 1970, its master plan for future water supply system expansion envisaged up to the year 2000 within the Bangkok Metropolis service area by cooperation of Camp Dresser and Mckee, the U.S. - based consulting firm. Daily average water demand as forecast under such master planning is as shown in Table 9-3. Although Stage I of the city water improvement project under the master plan started in 1974, the work program had to be revised inevitably in the face of worldwide inflationary tendency resulting from the previous oil crisis, as the result of which the Stage I project was splitted into Phase 1 and Phase 2. The system and service area in both Phase 1 and Phase 2 are shown in Fig. 9-3. Phase 1 covers the part of the project as far as financing of fund from abroad afforded, which includes construction of Bangkhen Water Treatment Plant, transmission and distribution networks, deep wells and other appurtenant facilities at total construction cost of $4,789.4 \times 10^6$ Bahts. With completion of Phase 1, production capacity has increased up to 2,000,000 m^3 per day, or a rise of 800,000 m^3 per day as compared with the preceding level, and the service area has spread from 242 km^2 to 273 km^2 by an expansion of 31 km^2 with total population of 3,200,000 being served. The present operating capacity of each treatment plant is as follows:

Sam Sen Treatment Plant	600,000 m^3/day
Thonburi Treatment Plant	150,000 "
Bangkhen Treatment Plant	800,000 "
Deep wells	450,000 "
Total	2,000,000 "

9.1.3 Stage I - Phase 2

The demand forecast assures that the present supply capacity of 2,000,000 m^3 per day would fully cover water demand increase toward the end of 1982. However, in order to cope with further increase of demand after 1982 and, besides that, to restrict full operation of deep wells to prevent possible sinkage of the urban ground level by excessive pumping-up of ground water, the supply capacity must be increased at Phase 2 in continuity with the preceding Phase 1. Thus, Phase 2 project is now under way toward scheduled to be completed by 1983 in order to cope with future demand increase in the central supply system serving Bangkok Metropolis and its adjoining densely-populated districts in Nonthaburi Province and Samut Prakarn Province. When Phase 2 will have been completed, the future daily supply capacity will reach 2,400,000 m^3 by an increase of 400,000 m^3 per day and the service area will spread up to 430 km^2 by expansion of 157 km^2 with total population of some 4,200,000 to be served.

The scope of works at Phase 2 covers the following items:

1. Construction of raw water improvement facilities for expansion of the 508 km open canal from San Lae Pump Station to Ban Poon with increased water discharge to 42 m^3 per second

2. Construction of Bang Luang Siphon to be capable of water discharge at a rate of 42 m^3 per second

3. Improvement of the existing 9 km open canal starting from Bang Khen Water Treatment Plant and leading to Bang Suc Pump Station

4. Construction of water treatment and other associated facilities capable to accept additional water of 400,000 m^3 per day at Bang Khen Water Treatment Plant

5. Construction of MWWA headquarters at 12,000 m^2 lot within the premises of Bang Khen Water Treatment Plant

6. Additional construction of 7.4 km long tunnel of 2.0 × 2.5 m inner size, together with installation of three (3) butterfly valves at each valve room of Phahol Yothin and Klong Toey

7. Construction of four (4) distribution pumping stations at Bang Khen, Phahol Yothin, Klong Toey and Rot Burane

8. Construction of three (3) regulating basins such as Klong Toey, Rot Burane and Phahol Yothin of 30,000 m^3, 10,000 m^3 and 40,000 m^3 storage capacity respectively

9. Installation of the 215 km main of 400 ∿ 1,500 mm diameter

10. Installation of the 880 km distribution pipeline of 100 ∿ 300 mm diameter

11. Drilling of 15 deep wells, each capable of 200 m^3 per hour in water supply

12. Other works

Construction period is projected over about three (3) years at total construction cost of 5,396.6 × 10^6 Bahts. The domestic currency portion includes the MWWA's own investment fund, domestic loan and governmental finance while the foreign currency portion includes loan funds financed by OECF, ADB and IBRD.

Initial Category	Cost Million Baht
Raw water	417.5
Treatment plant	363.5
Transmission tunnels	928.1
Pump stations and reservoirs	862.7
Trunk mains	1,456.0
Distribution pipelines	784.0
Deep wells	38.3
Metering	194.7
Design and construction supervision	215.5
Land	60.9
Miscellaneous	75.4
Total	5,396.6

Source of Fund	Million Baht
OECF	881.9
ADB	1,860.0
IBRD	316.7
Government equity, MWWA revenue and other loans	2,838.0
Total	5,396.6

9.2 Future Water Supply Expansion Program

9.2.1 Water Demand and Supply Plan

Demand forecast by the MWWA predicts 1,900,000 m^3 by 1982, 2,100,000 m^3 by 1983 and 2,400,000 m^3 by 1985 respectively. Demand for further future by the year 2000 is forecasted as indicated in Fig. 9-3. Possible water withdrawal from Chao Phya River is defined to be 25 m^3 per second at maximum as mutually agreed between the MWWA and the RID (Royal Irrigation Department). It is also provided under the agreement that river water of Chao Phya should be discharged at a minimum flow rate of 70 m^3 per second at Chinat Dam for city water supply, navigation and salinity damage protection. Of total discharge, water withdrawal of 25 m^3 per second, should be made available for city water supply at Sam Lae Pump Station.

The present volume of water withdrawal available by the MWWA amounts roughly to 21 m^3 per second will be increased up to 25 m^3 per second upon completion of Stage I - Phase 2 in total capability of facilities. Therefore, if the project at Stage I - Phase 2 can be completed as scheduled, no shortage of water supply would be threatened up to 1985. Nevertheless, further review should be made on additional increase after 1985 of water supply allocation from Chao Phya over the presently planned level, or any other alternative plan to meet future water demand. Unless any suitable plan is executed, there would be a fear of causing grave consequence in water supply after 1985.

As the measures to be taken to increase future water supply there are some alternatives under-studied, including the plan to withdraw water from Quae Noi River and Mae Klong River or to construct a dam in Pasak River. However no conclusion has been reached yet for final choice. In fact, however, the MWWA makes its study about the future expansion program by the year 2000 according to the following stages.

Stage I - Phase 2 (1985)	Raw water requirement, estimated at 2,160,000 m^3 per day (25 m^3 per second).
Stage II (1990)	Raw water requirement, estimated at 3,600,000 m^3 per day (42 m^3 per second). Construction of water treatment plant capable of 1,200,000 m^3, four (4) pump stations and water transmission tunnel of 25 km length.
Stage III (1995)	Raw water requirement, estimated at 4,800,000 m^3 per day (56 m^3 per second). Construction of water treatment plant capable of 1,200,000 m^3, four (4) pump stations and water transmission tunnel of 32 km length.
Stage IV (2000)	Raw water requirement, estimated at 6,000,000 m^3 per day (70 m^3 per second).

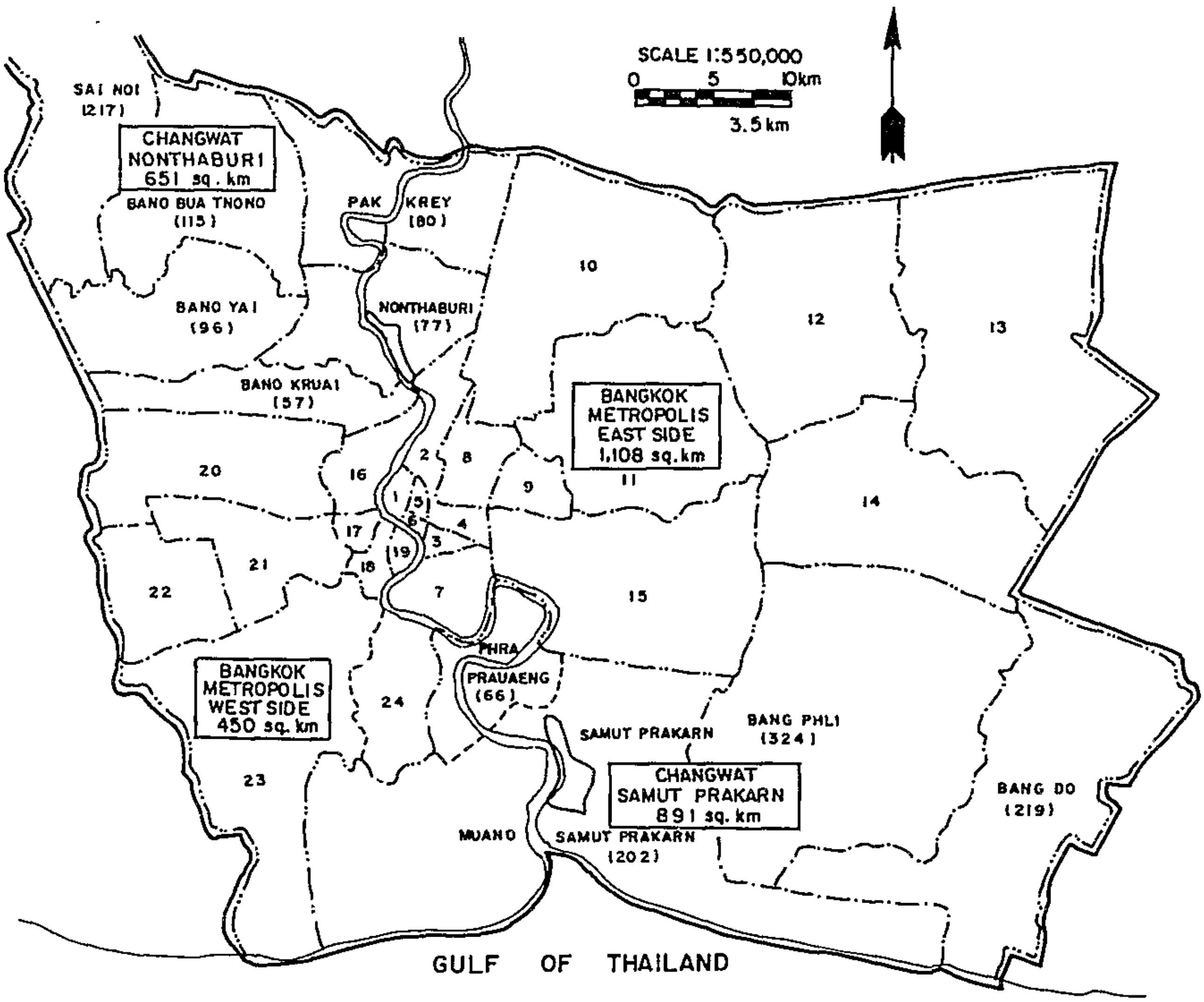
9.2.2 Mae Pai River Diversion Project

In case of river water diversion by pumping from Mae Pai River into Mae Chaem River, annual diversion estimated at some 700 × 10^6 m^3 would be about 1,900,000 m^3 (22 m^3 per second) at daily average after regulated in the future reservoir to be constructed on Mae Pai River and the existing Bhumibol reservoir. At present, future raw water shortage is estimated at 17 m^3 per second by 1990, 31 m^3 per second by 1995 and 45 m^3 per second by 2000 on a basis of possible water intake at 25 m^3 per second from Chao Phya River. From this estimate it is expected that this diversion plan from Mae Pai River would help partly to resolve the shortage problem of city water supply in Metropolis Bangkok.

However, any data for cost comparison in relation to the alternative project on withdrawal of water from Quai Noi River or Mae Klong River are not available. Besides that, as can be estimated from the construction cost at Stage I - Phase 2 now under way, it may be most probable that construction cost to be required for intake facilities, treatment plants, transmission tunnels and channels, pump stations, distribution pipelines and others as may be required for execution of the diversion plan should exceed largely the benefit to be gained from the project.

For this reason stated above, this master plan will be studied on such assumed condition that total water available from diversion would be used for irrigation purpose only.

Fig. 9.1 DISTRICTS AND PROVINCES IN THE MWWA AREA



DISTRICTS WHOLLY WITHIN BANGKOK METROPOLIS

BANGKOK METROPOLIS	AREA sq km	BANGKOK METROPOLIS	AREA sq. km
1 PHRA NAKORN	5.5	13 NONG CHOK	236.3
2 DUSIT	12.0	14 LAY KRABANG	123.9
3 BANG RAN	5.5	15 PHRA KANONG	143.6
4 PATHUM WAN	8.4	16 BANGKOK NOI	23.0
5 PUMPRAS	1.9	17 BANGKOK YAI	6.2
6 SAMPANTAWONG	1.4	18 THONBURI	8.6
7 YANAWA	36.9	19 KLONG SAN	6.1
8 PHYA THAI	21.1	20 TALNG CHAN	79.7
9 HUEY KHWANG	9.5	21 PHASI CHAROEN	84.0
10 BANG KHEN	149.3	22 NONG KHAEM	49.3
11 BANG KAPI	188.6	23 BANG KHUN THIAN	101.2
12 MIN BURI	174.3	24 RAT BURANA	42.9

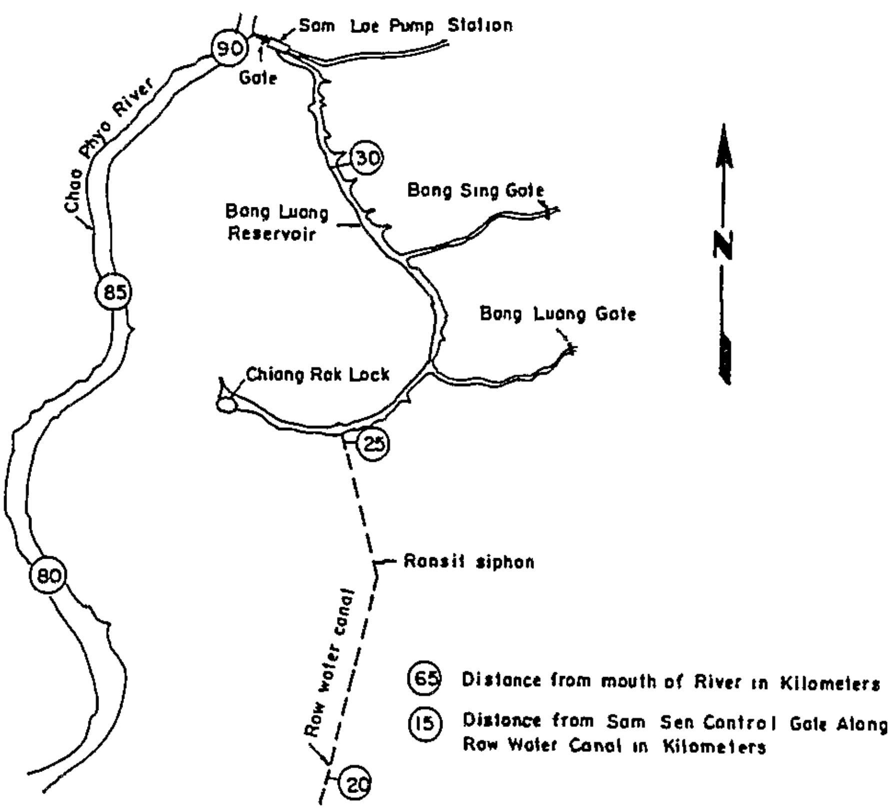


Fig. 9. 2 SAM LAE PUMP STATION

MWWA WATER PRODUCTION AND DEMAND

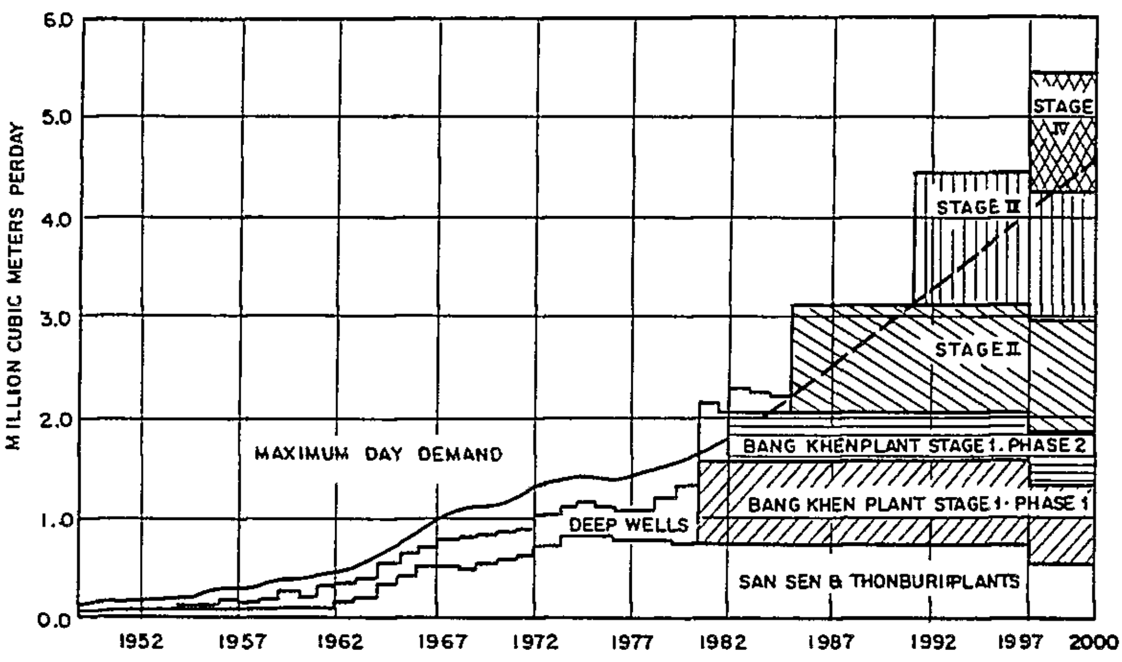


Fig. 9.3

MWWA FACILITIES AND SERVICE AREA IN PHASE 1 & PHASE 2

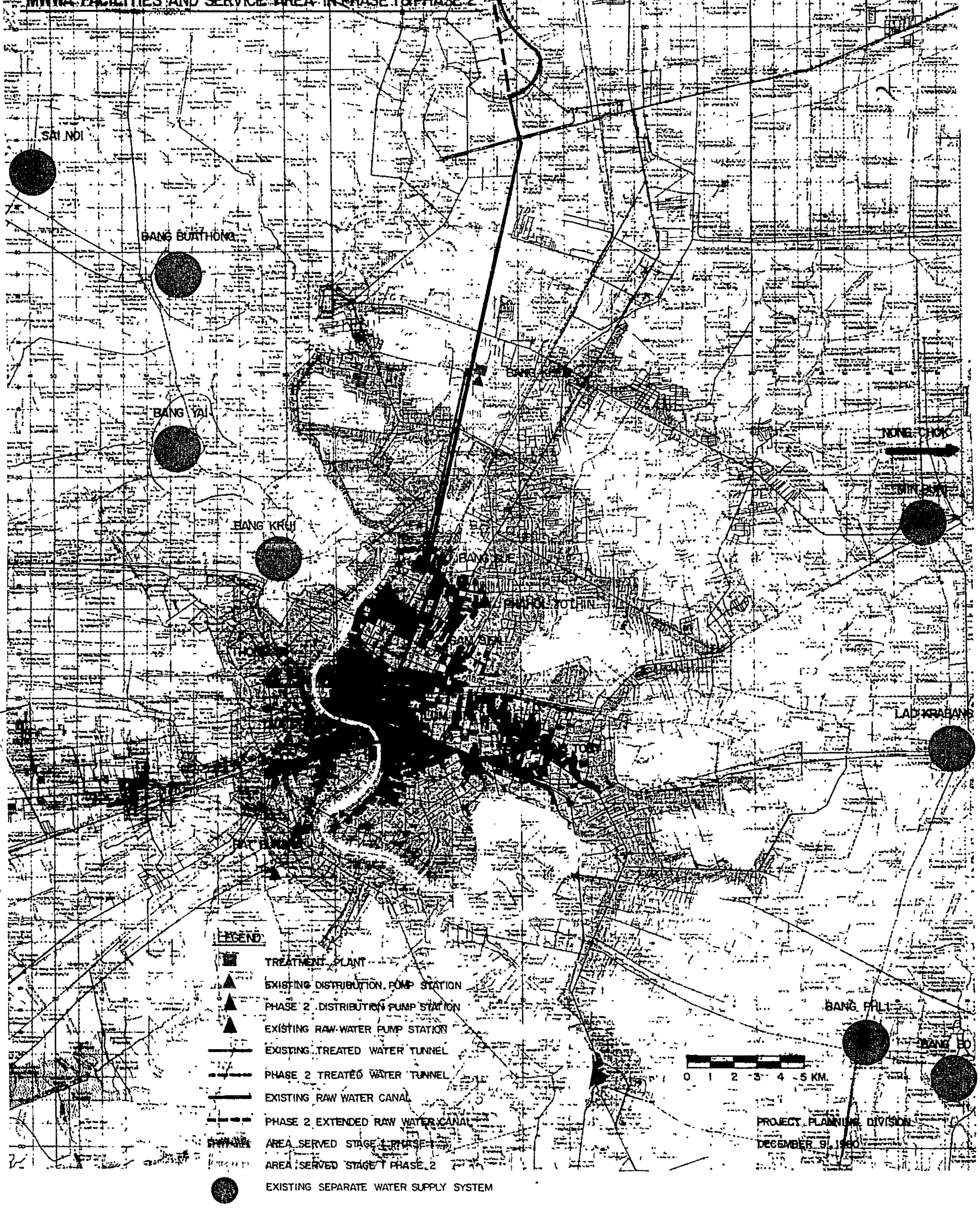


Table 9-1 Yearly Production ($10^6 m^3$)

Year	Treatment Plant			Dead Wells	Total
	Samsen	Thonburi	Sub-total		
1968	182	29	211	125	336
1969	184	29	213	114	327
1970	195	28	223	112	335
1971	196	32	228	121	349
1972	200	71	271	116	387
1973	238	71	309	132	441
1974	241	70	311	135	446
1975	245	68	313	128	441
1976	242	70	312	120	432
1977	240	70	310	120	430
1978	242	70	312	148	460
1979	240	68	308	177	485

Table 9-2 Average Water Production in 1979

Source of Supply	Yearly Production m^3	Average Production m^3/day	Percentage to Total
Treatment Plants			
Samsen	240,107,400	657,830	49.5
Thonburi	68,232,670	186,935	14.1
Sub-total	308,340,070	844,765	63.6
Deep wells			
Bangkok Metropolis		392,605	29.5
Nontaburi		65,495	4.9
Samut Prakarn		25,965	2.0
Sub-total	176,684,490	484,065	36.4
Total	485,024,560	1,328,830	100.0

Table 9.3 Annual Average Daily Water Requirements, 1,000 CMD

Year	Domestic	Commercial & Institution	Industrial	Free Public & System Leakage	Total
1952	50	12	-	31	93
1953	52	15	-	38	105
1954	88	20	-	46	154
1955	96	20	-	47	163
1956	108	35	-	50	193
1957	108	28	-	54	190
1958	105	60	-	58	223
1959	178	67	-	78	323
1960	132	58	4	86	280
1961	145	103	7	93	348
1962	155	104	22	95	376
1963	180	122	38	104	444
1964	282	143	62	129	616
1965	295	149	84	171	699
1966	347	185	113	166	811
1967	446	206	156	132	940
1968	499	241	215	103	1,058
1969	530	260	260	82	1,132
1970	563	286	301	122	1,272
1971	575	318	328	141	1,362
1972	579	342	359	160	1,440
1973	581	357	381	206	1,525
1974	576	372	404	180	1,532
1975	568	387	425	140	1,520
1980	703	481	554	185	1,923
1985	955	601	708	221	2,485
1990	1,212	739	875	249	3,075
1995	1,548	905	1,078	289	3,820
2000	1,960	1,108	1,300	368	4,736

CHAPTER 10

PRELIMINARY DESIGN

CHAPTER 10 PRELIMINARY DESIGN

10.1 Civil Works

Preliminary design has been carried out for Mae Pai Projects Nos. 6 and 1 and Mae Chaem Projects Nos. 5 and 4 which were determined to be 'feasible' after study in the preceding Chapter 6 Development Plan. Topographic maps used for this study were on a reduced scale from 1/2,000 to 1/5,000 for Mae Pai Project No. 6 and Mae Chaem Project No. 5 and on enlarged scale from 1/50,000 to 1/5,000 for Mae Pai Project No. 1 and Mae Chaem Project No. 4 respectively. Any future supplement to those topographic maps or the new mapping scope is specified in Table 1-1.

The basic factors for preliminary design are based primarily upon the development project scale as may be deemed as optimum at the present stage after the study in the preceding Chapter 6. They are shown in Table 6-18. Preliminary design drawings are shown in Dwg. Nos. 10-1 to 10-4. Those basic figures and preliminary design drawings should require further review at the next advanced stage.

With regard to the pumped-up diversion scheme, this Chapter deals only with indication of the diversion route in the topographic map at a scale of 1/50,000 and the scale of underground-type pump station.

Stated hereunder is the preliminary design outline at each project site.

Mae Pai Project No. 6

The Project undertakes construction of a rockfill dam of 185 m height, 400 m crest length and 13,500 × 10^3 m^3 volume on the axis alongside which boring test was carried out by NEA.

Upstream and downstream faces are sloped at 1:2.5 and 1:2.0 respectively. The left bank of dam is provided with a spillway of 30 m width, 620 m length, which is capable to release the probable maximum flood (PMF) of 3,000 m^3/sec. The right bank is provided with a diversion tunnel capable to pass the 20-year return period discharge of 820 m^3/sec. This diversion tunnel will be converted to an outlet structure in the future.

An intake with the maximum intake volume of 202 m^3/sec is provided on the right bank upstream of the dam axis. From the intake, two (2) headrace with 5.6 m inner diameter expands for 660 m, leading to the power house by way of a surge tank and a penstock for power generation of normal maximum output of 291,000kW and average annual energy production of about 620GWh.

Mae Pai Project No. 1

The Project undertakes construction of a rockfill dam of 100 m height, 230 m crest length and 2,450 × 10^3 m^3 volume. Upstream and downstream faces are sloped the same as designed for Mae Pai No. 6.

The left bank is provided with a spillway of 30 m width, 340 m length, which is capable to release the PMF of 2,200 m^3/sec, and also provided with two (2) diversion tunnels with the capacity of 600 m^3/sec for 20-year return period discharge. The right bank is provided, on it upstream, with an intake capable of 85.4 m^3/sec at maximum intake volume, with a single headrace channel of 5.2 m inner diameter and 350 m length, leading to the power house by way of a penstock for power generation of normal maximum output of 68,900kW and average annual energy production of about 110GWh.

Installation of a surge tank was omitted in this preliminary design because of relatively short length of the headrace. However, its necessity must be reviewed in further study.

Mae Chaem No. 5

The project plans construction of a rockfill dam of 140mm height, 555 m crest length and 10,120 × 10^3 m^3 volume on the dam axis now under test by NEA.

The left bank is provided with a spillway of 30 m width, 670 m length and 3,000 m^3/sec of PMF. The right bank is provided with two (2) diversion tunnel capable of 820 m^3/sec release of 20-year return period, and also provided with an intake, on its upstream, capable of 116 m^3/sec at maximum intake volume, from which one (1) headrace tunnel of 5.9 m inner diameter and 320 m length conveys water to the power house by way of a penstock for power generation of normal maximum output of 102,600kW and average annual energy production of about 288GWh.

Mae Chaem Project No. 4

The Project plans construction of a rockfill dam of 95 m length, 440 m crest length and 4,110 × 10^3 m^3 volume on the upstream dam axis,

The left bank is provided with a spillway for PMF discharge of 2,300 m^3/sec with size of 30 m width and 440 m length, together with two (2) diversion tunnels for 630 m^3/sec of 20-year return period discharge.

The right bank is provided, on its upstream side, with an intake of 51.6 m^3/sec at maximum volume and also with a headrace tunnel of 4.2 m inner diameter and 320 m length for conveyance of water into the power house by way of the pressure tunnel for power generation of normal maximum output of 27,600kW and average annual production of about 100GWh.

10.2 Electrical Equipment

10.2.1 Mae Pai No. 6 Power Station

(1) Main equipment of power station

This power station is planned for normal effective head of 163.1 m, maximum available discharge of 202 m^3/sec and power plant output of 291MW.

For this development scale, the number of units is to be two, each unit consisting of a combination of a 145.8MW vertical-shaft Francis turbine, 160MVA synchronous generator and a 160MVA main transformer.

The unit system where the two generators and main transformers are connected one on one is to be adopted for the main circuits, with the generators and main transformers to be installed outdoors connected by metal enclosed buses.

(2) Switchyard equipment

Two main transformers and other necessary equipment are to be installed at the outdoor switchyard. The switchyard equipment is planned for nominal voltage of 230kV.

The 230kV buses are of the double-bus system, and two transmission lines are to be connected.

In adopting GIS type, consideration was given to the fact that it would be difficult to secure a lot with the required area for a conventional type switchyard in the vicinity of this power station.

The outlined specifications of the main equipment at Mae Pai No. 6 Power Station aggregating the above are as listed below, while the single-line diagram, plan and cross-sectional drawings of the power station are as indicated in Fig. 10-1.

Specifications of Main Equipment for Mae Pai No. 6 Power Station

Power Plant Output	291,000kW
Turbines	
Type	Vertical-shaft Francis turbine
Number of units	2
Normal effective head	163.1 m
Max. discharge	101 m^3/sec
Output	145,800kW (at normal effective head)
Revolving speed	188 rpm
Generators	
Type	3-phase, AC, synchronous generator
Number of units	2
Capacity	160,000kVA (power factor 0.9, lagging)
Frequency	50 Hz
Main Transformers	
Type	3-phase, outdoor, oil-immersed
Number of units	2
Capacity	160,000kVA
Voltage	230/13.8kV
Switchyard Equipment	
Type	Outdoor switchgear
Bus connection system	Double-bus system
Number of transmission lines	2

10.2.2 Mae Chaem No. 5 Power Station

(1) Main equipment of power station

This power station is planned for normal effective head of 104.1 m, maximum available discharge of 116 m^3/sec and power plant output of 102.6MW.

The number of turbine-generator units of this power station is two, each unit consisting of a combination of a 53.5MW vertical-shaft Francis turbine and a 58.6MVA synchronous generator, and the number of main transformer is one having 117.2kVA in its capacity.

(2) Switchyard equipment

The switchyard equipment is planned to be conventional types of nominal voltage of 115kV.

The generated electric power is to be sent to Lanphun 2 substation through Chom Thong substation by 115kV 2-circuit transmission line.

The outlined specifications of the main equipment at Mae Chaem No. 5 Power Station aggregating the above are as listed below, while the single-line diagram, plan and cross-sectional drawings are as indicated in Fig. 10-2.

Specifications of Main Equipment for Mae Chaem No. 5 Power Station

Power Plant Output	102,600kW
Turbines	
Type	Vertical-shaft Francis turbine
Number of units	2
Normal effective head	104.1 m
Max. discharge	58 m^3/sec
Output	53,500kW (at normal effective head)
Revolving speed	250 rpm
Generators	
Type	3-phase, AC, synchronous generator
Number of units	2
Capacity	58,600kVA (power factor 0.9, lagging)
Frequency	50 Hz
Main Transformers	
Type	3-phase, outdoor, oil-immersed
Number of units	1
Capacity	117,200kVA
Voltage	115/13.8kV
Switchyard Equipment	
Type	Outdoor switchgear
Bus connection system	Double-bus system
Number of transmission line	2

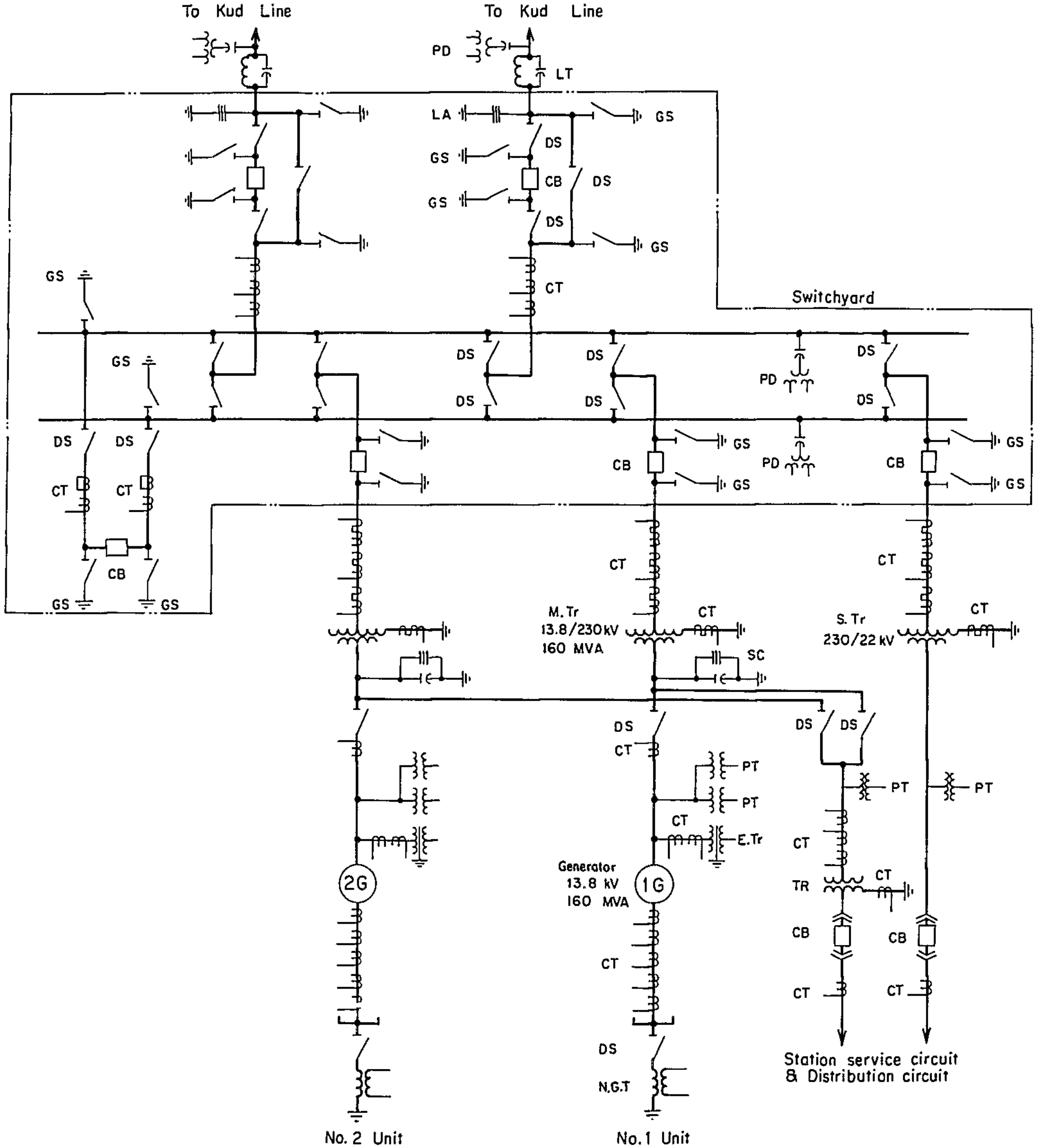
10.2.3 Mae Pai No. 1 Project (Mae Pai No. 1 Power Station) and Mae Chaem No. 4 Project (Mae Chaem No. 4 Power Station)

Specifications of Main Equipment for Mae Pai No. 1 Power Station

Power Plant Output	48,900kW
Turbines	
Type	Vertical-shaft Francis turbine
Number of units	2
Normal effective head	67.3 m
Max. discharge	42.7 m^3/sec
Output	25,300kW (at normal effective head)
Revolving speed	300 rpm
Generators	
Type	3-phase, AC, synchronous generator
Number of units	2
Capacity	27,200kVA (power factor 0.9, lagging)
Frequency	50 Hz
Main Transformers	
Type	3-phase, outdoor, oil-immersed
Number of units	1
Capacity	54,400kVA
Voltage	230/13.8kV
Switchyard Equipment	
Type	Outdoor switchgear
Bus connection system	Double-bus system
Number of transmission line	4

Specifications of Main Equipment for Mae Chaem No. 4 Power Station

Power Plant Output	27,600kW
Turbines	
Type	Vertical-shaft Francis turbine
Number of units	2
Normal effective head	62.9 m
Max. discharge	25.8 m^3/sec
Output	14,300kW (at normal effective head)
Revolving speed	375 rpm
Generators	
Type	3-phase, AC, synchronous generator
Number of units	2
Capacity	16,000kVA (power factor 0.9, lagging)
Frequency	50 Hz
Main Transformers	
Type	3-phase, outdoor, oil-immersed
Number of units	1
Capacity	32,000kVA
Voltage	115/13.8kV
Switchyard Equipment	
Type	Outdoor switchgear
Bus connection system	Double-bus system
Number of transmission line	2

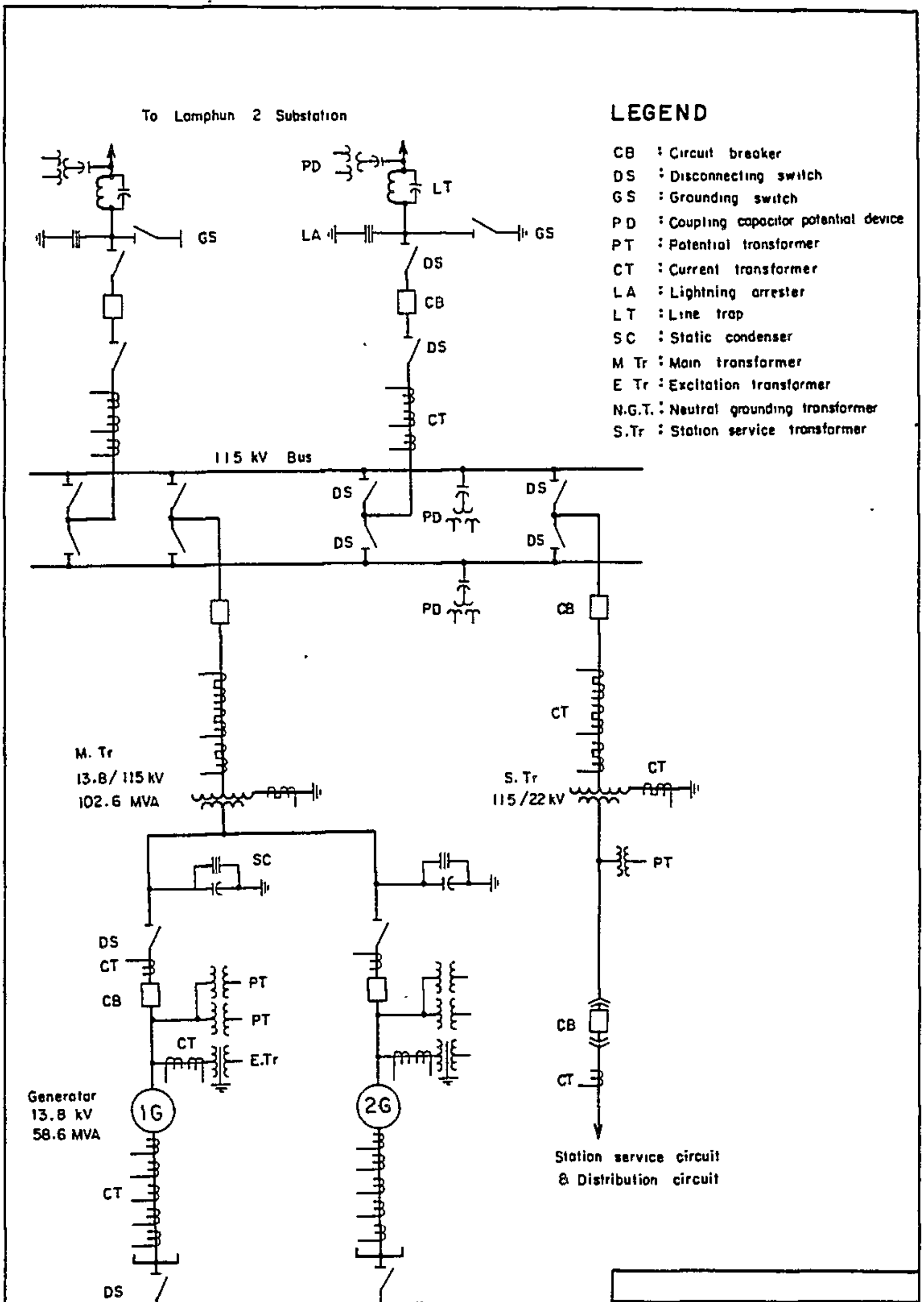


LEGEND

CB : Circuit breaker
DS : Disconnecting switch
GS : Grounding switch
PD : Coupling capacitor potential device
PT : Potential transformer
CT : Current transformer
LA : Lightning arrester
LT : Line trap
SC : Static condenser
M. Tr : Main transformer
E. Tr : Excitation transformer
N.G.T. : Neutral grounding transformer
S. Tr : Station service transformer

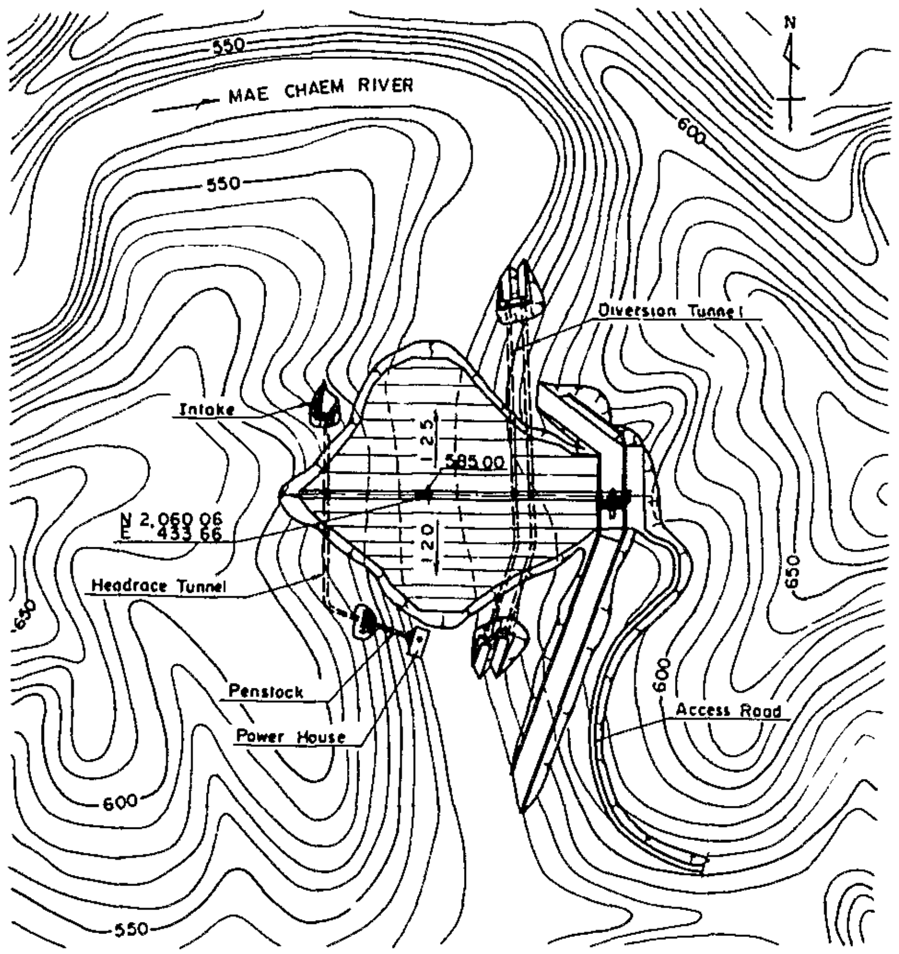
SINGLE LINE DIAGRAM
MAE PAI No. 6 P/S

Fig. 10-1	May, 1981

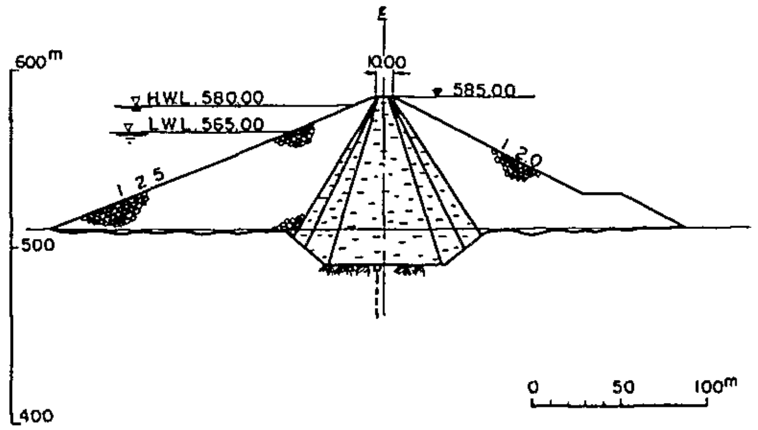


SINGLE LINE DIAGRAM
MAE CHAEM No. 5 P/S

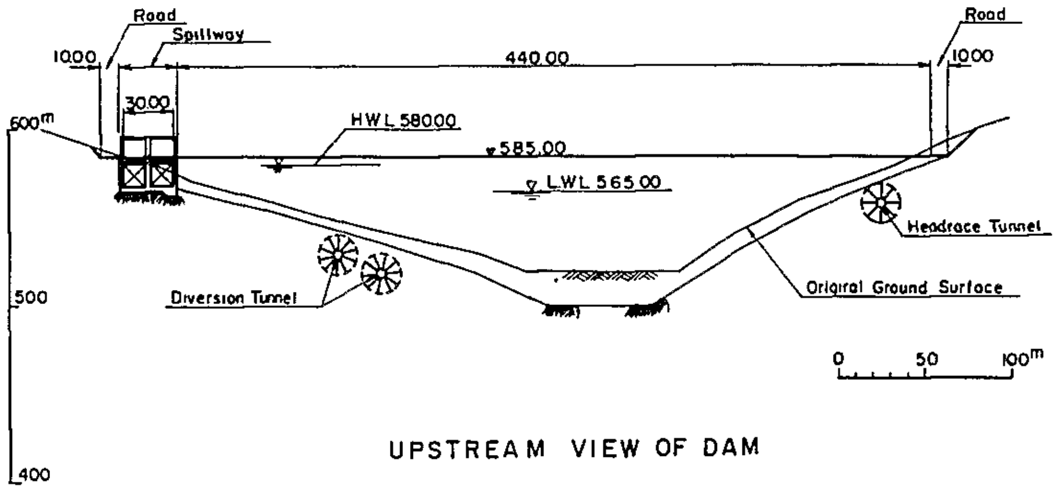
Fig. 10-2 | May, 1981



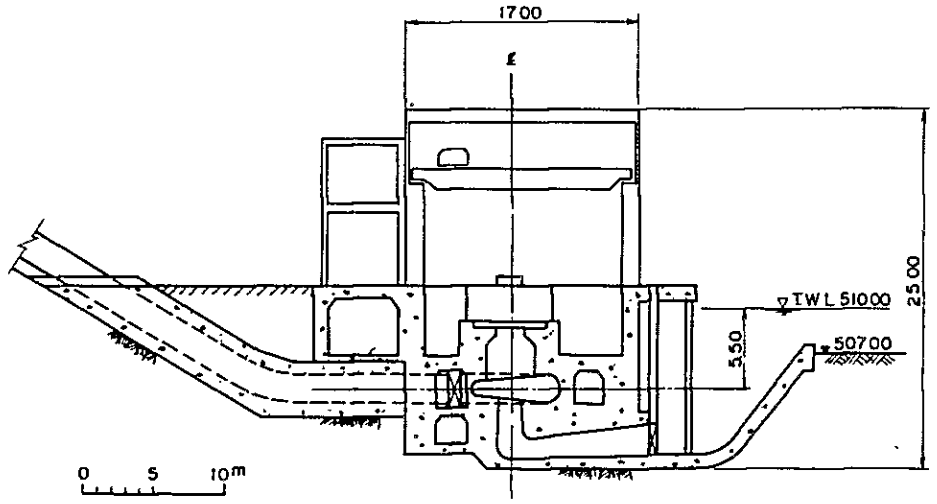
PLAN



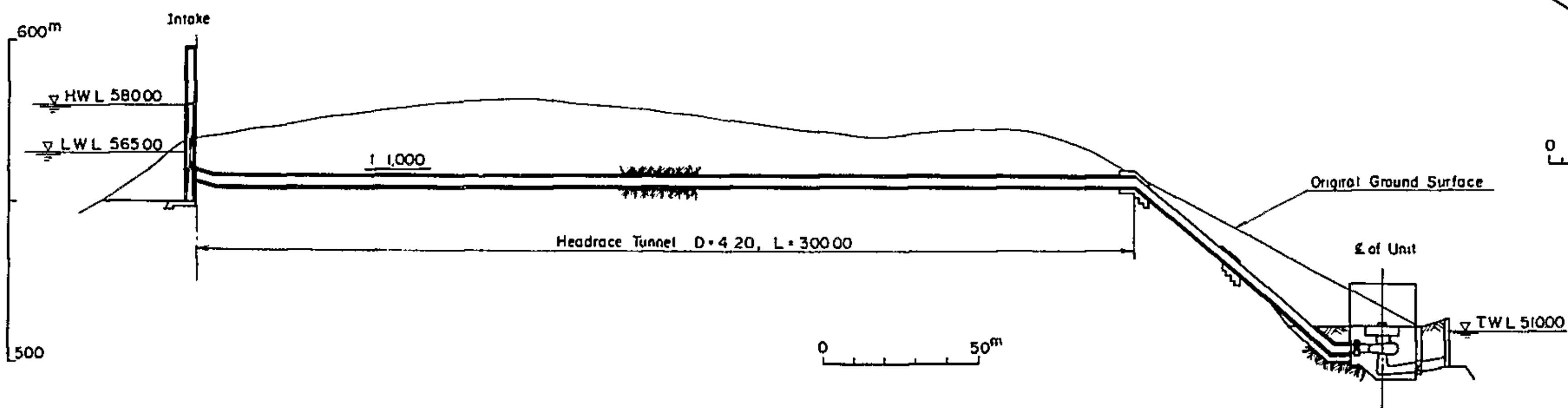
TYPICAL CROSS SECTION OF DAM



UPSTREAM VIEW OF DAM



CROSS SECTION OF POWERHOUSE

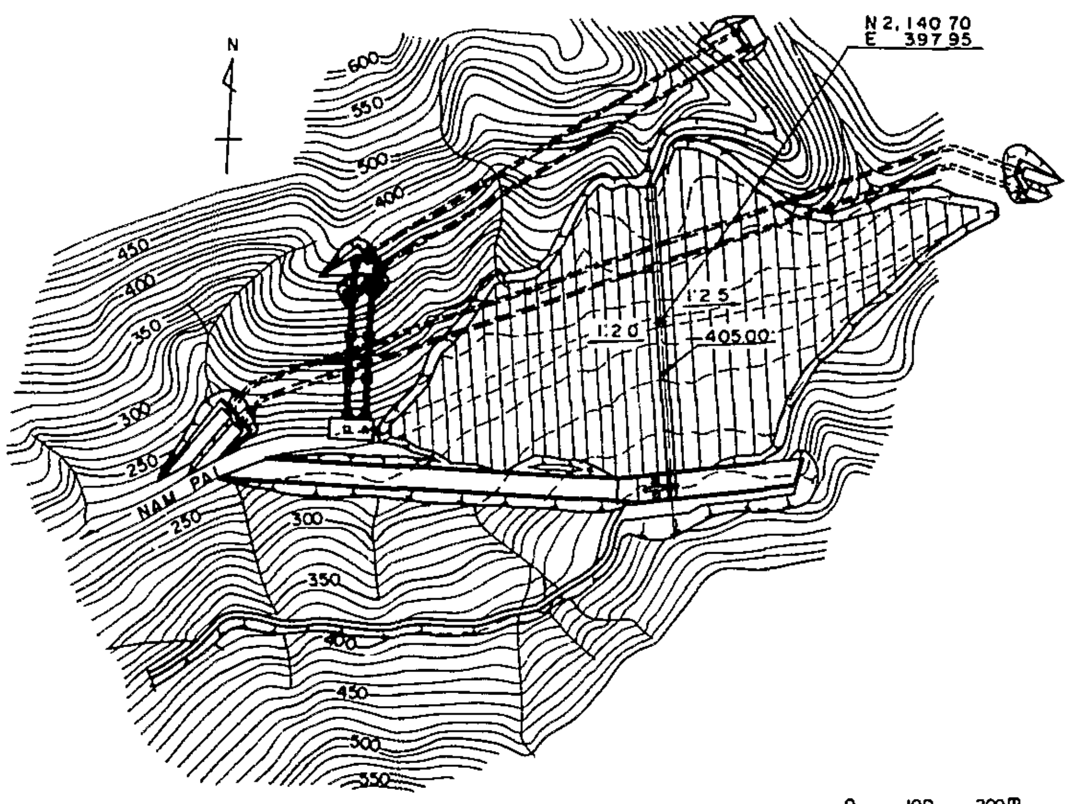


PROFILE OF WATERWAY AND POWERHOUSE

MAE PAI AND MAE CHAEM PROJECT MASTER PLAN	
MAE CHAEM RIVER No.4 SITE	
Dwg. 10-1	ELECTRIC POWER DEVELOPMENT CO., LTD TOKYO, JAPAN
	DR. SUBMITTED.
	TR. RECOMMENDED.
	CK. APPROVED.
	June 1981

LOCATION	DATE	DESCRIPTION	BY
REVISION			

SHEET NO. OF



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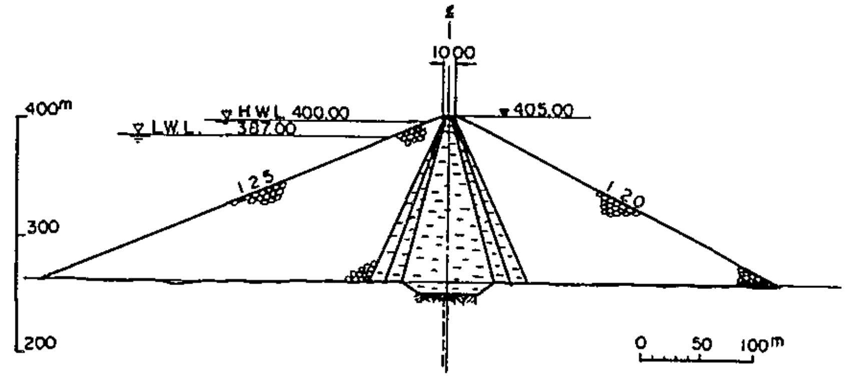
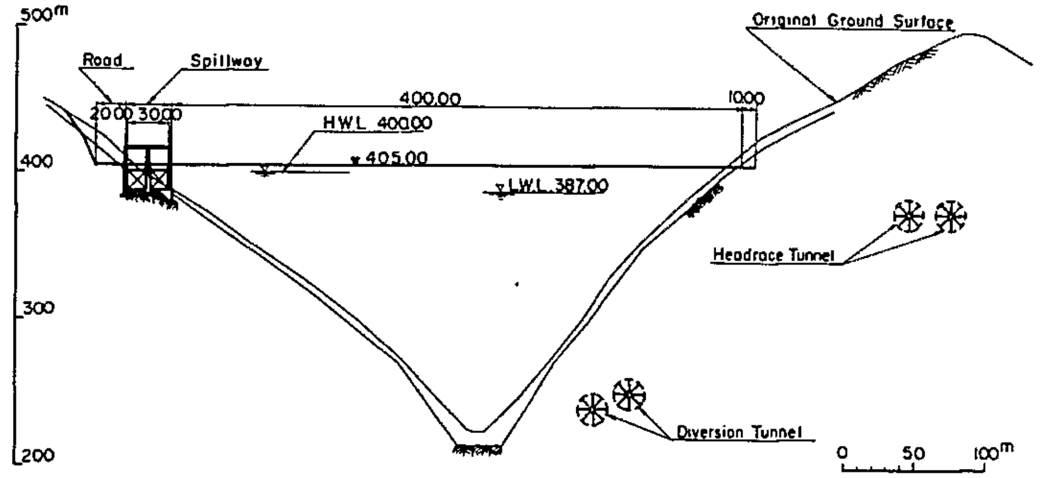
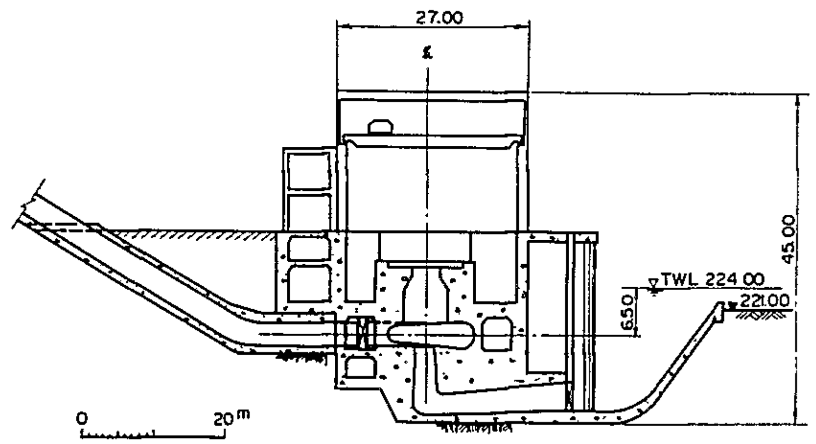


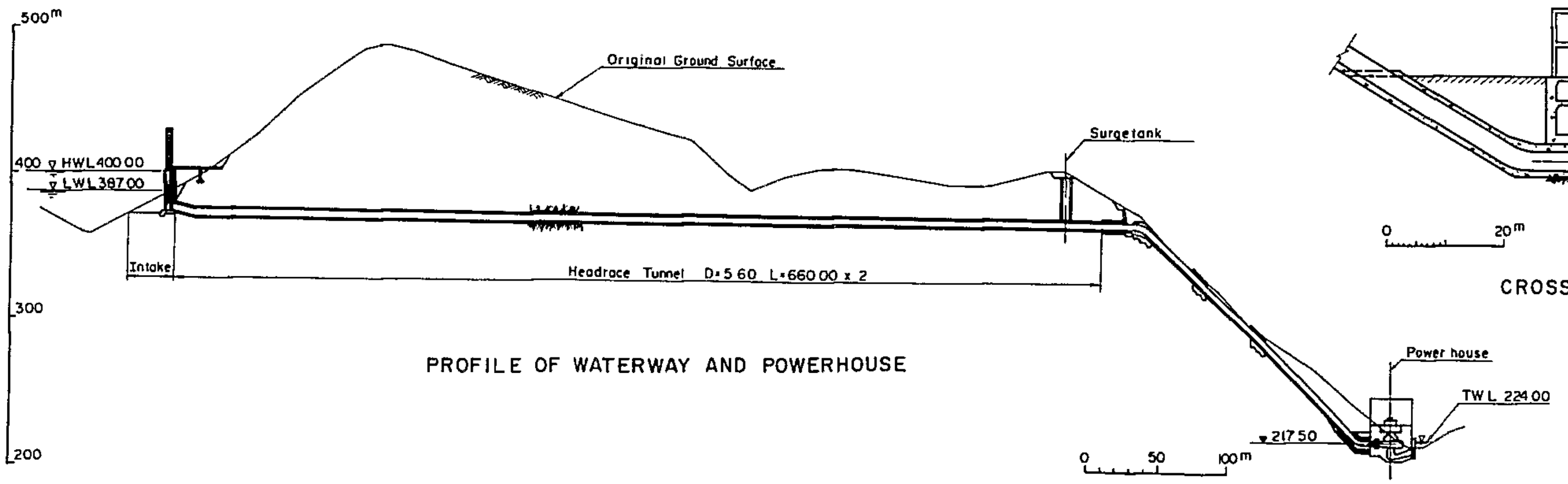
TYPICAL CROSS SECTION OF DAM



UPSTREAM VIEW OF DAM



CROSS SECTION OF POWERHOUSE



PROFILE OF WATERWAY AND POWERHOUSE

LOCATION	DATE	DESCRIPTION	BY
REVISION			

MAE PAI AND MAE CHAEM PROJECT
MASTER PLAN

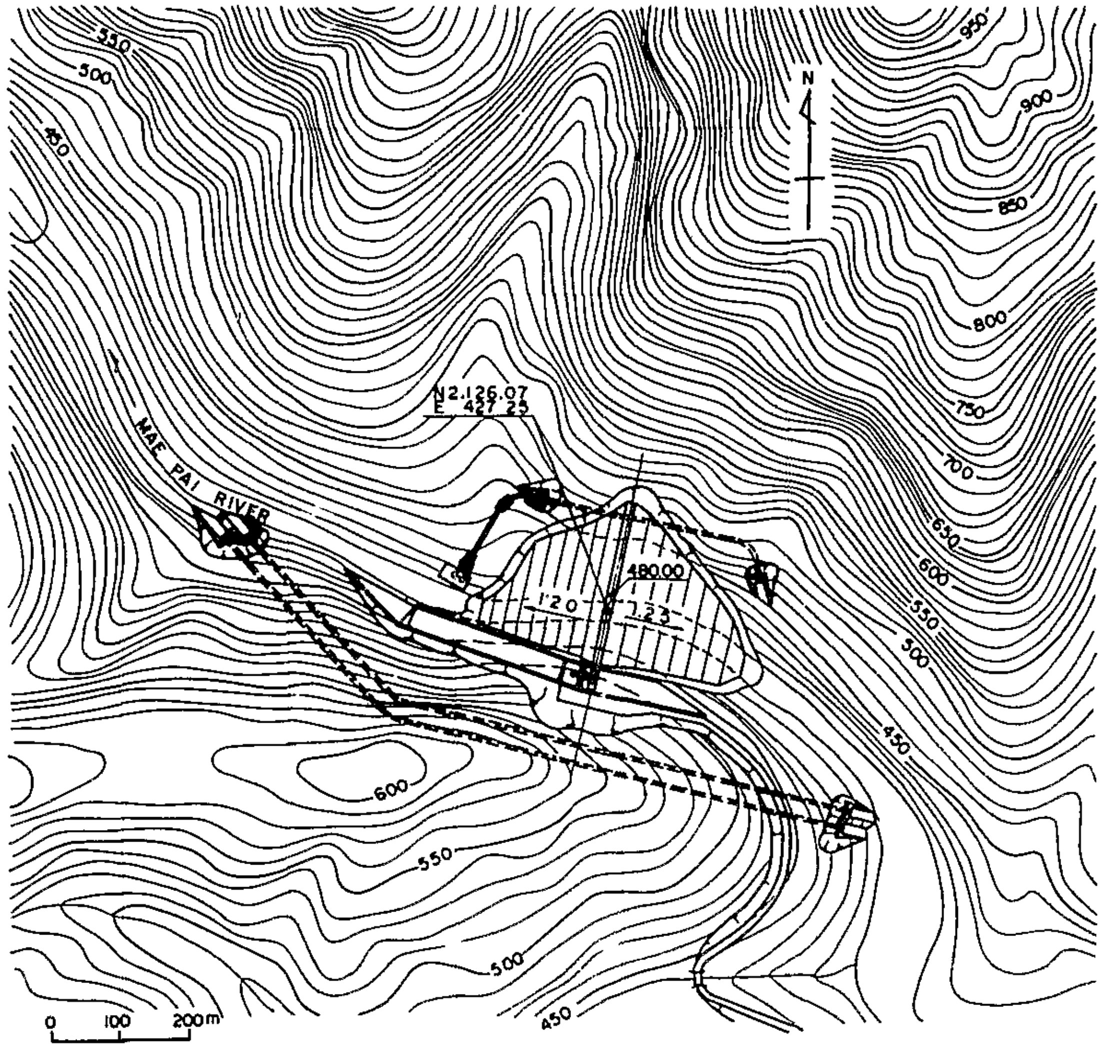
MAE PAI RIVER No. 6 SITE

ELECTRIC POWER DEVELOPMENT CO., LTD
TOKYO, JAPAN

Dwg. 10-2

DR. SUBMITTED.
TR. RECOMMENDED:
CK. APPROVED

June 1981



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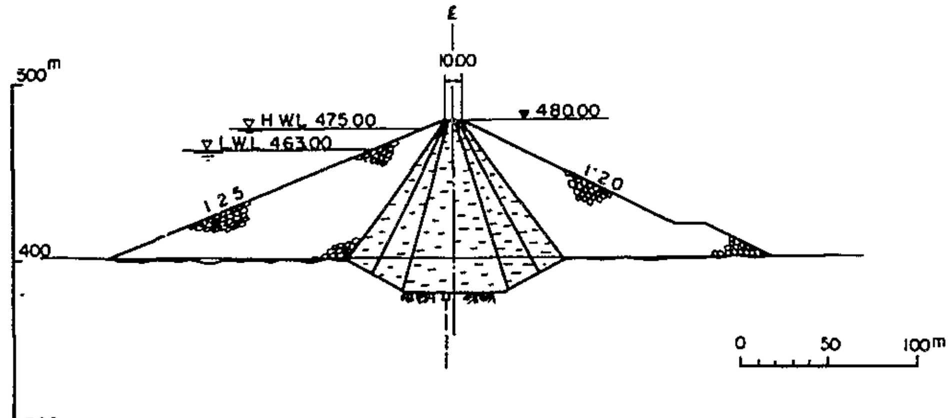
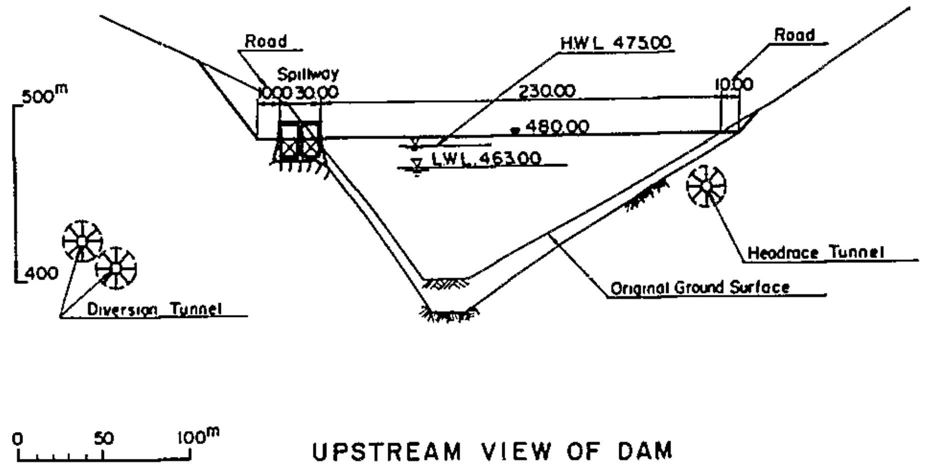
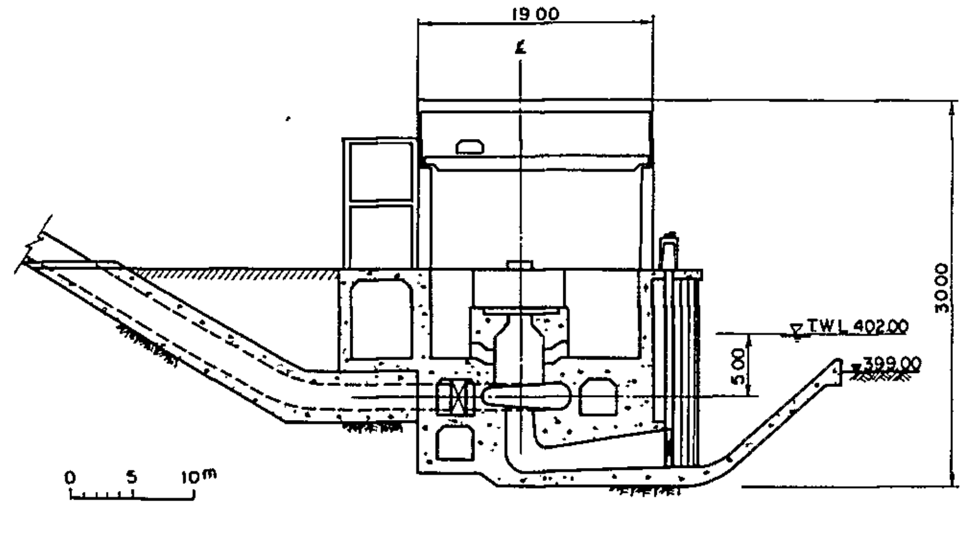


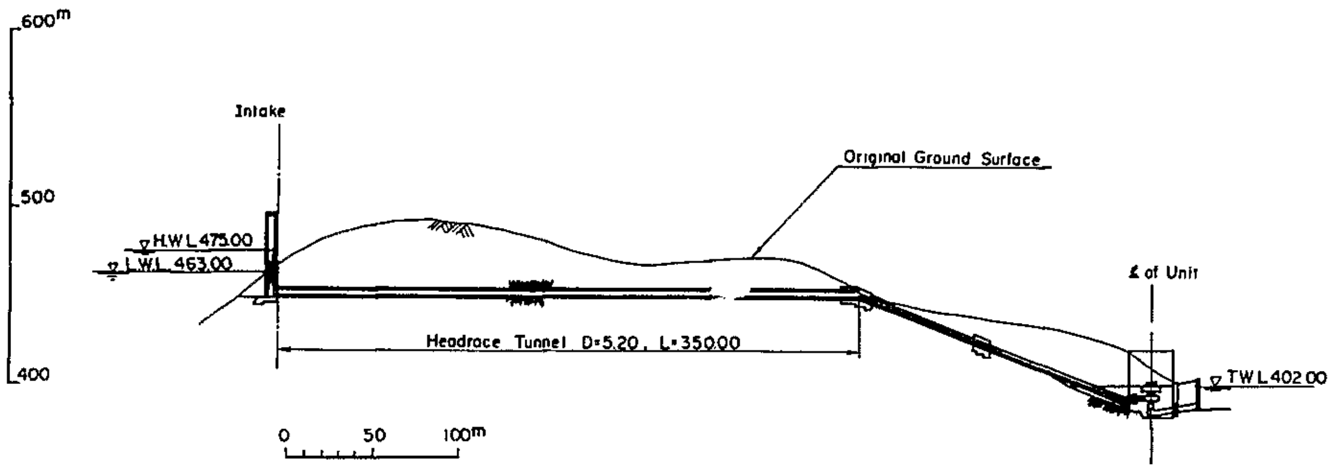
TYPICAL CROSS SECTION OF DAM



UPSTREAM VIEW OF DAM



CROSS SECTION OF POWERHOUSE



PROFILE OF WATERWAY AND POWERHOUSE

MAE PAI AND MAE CHAEM PROJECT
MASTER PLAN

MAE PAI RIVER No I SITE

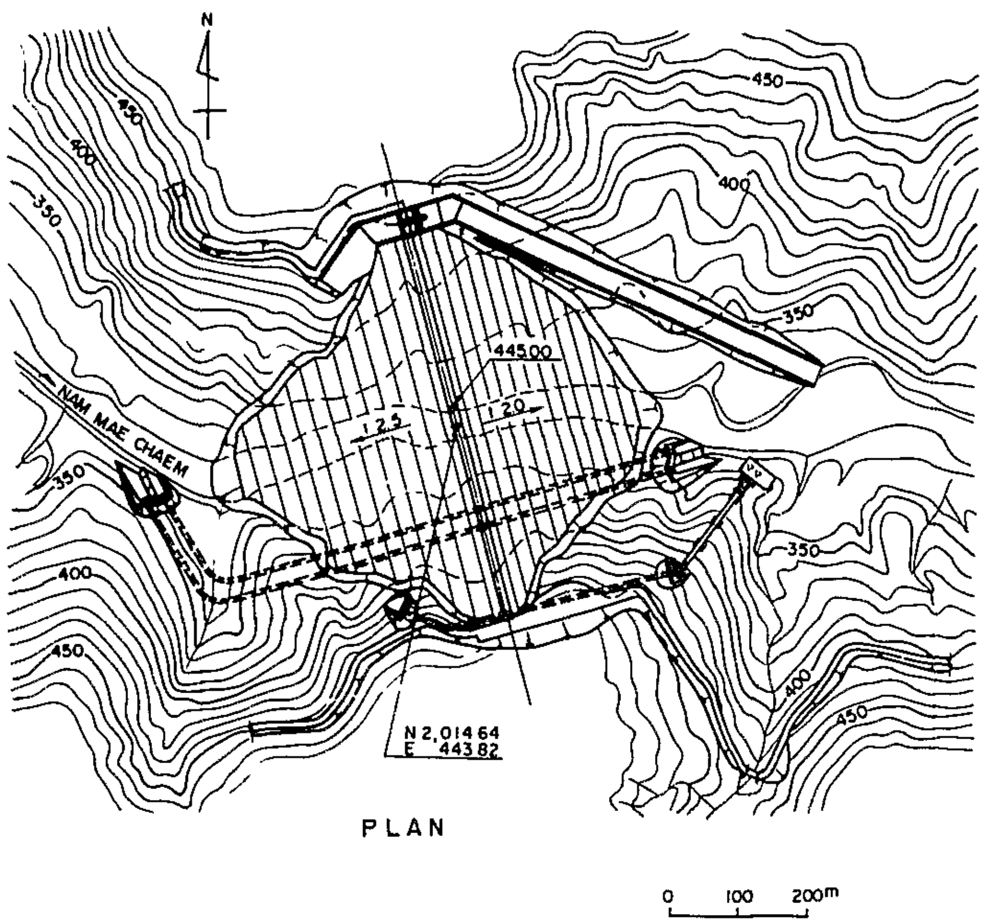
ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

DR :	SUBMITTED :		
TR :	RECOMMENDED.		
CK :	APPROVED.		
–	–	–	June, 1981

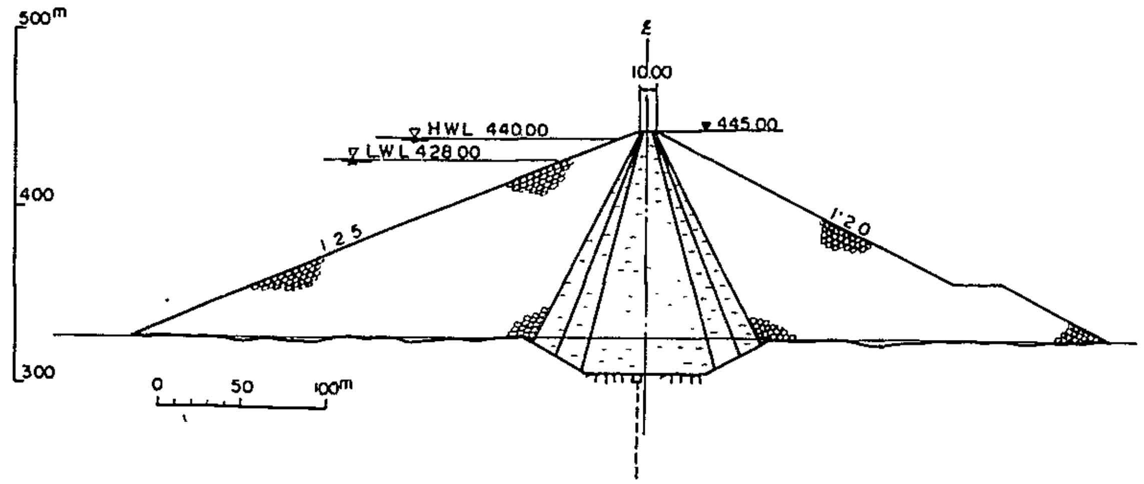
Dwg. 10-3

LOCATION	DATE	DESCRIPTION	BY
REVISION			

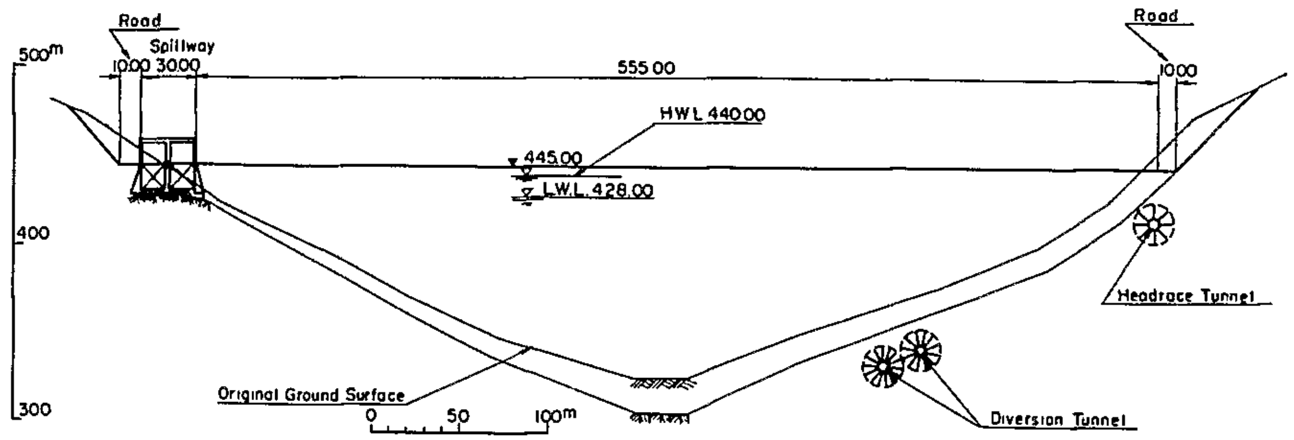
SHEET NO. OF



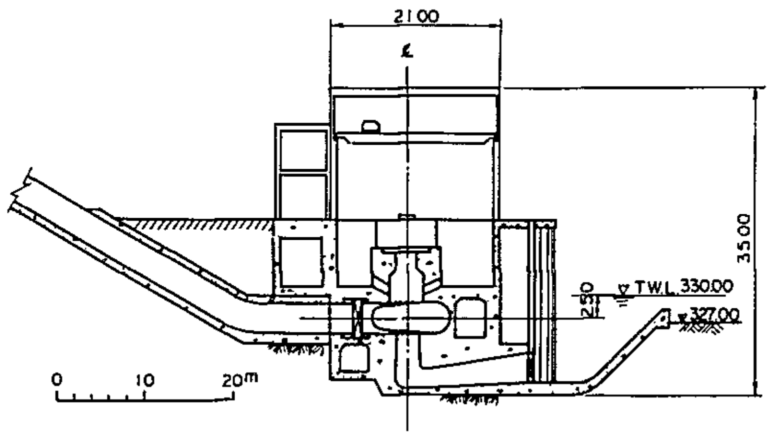
PLAN



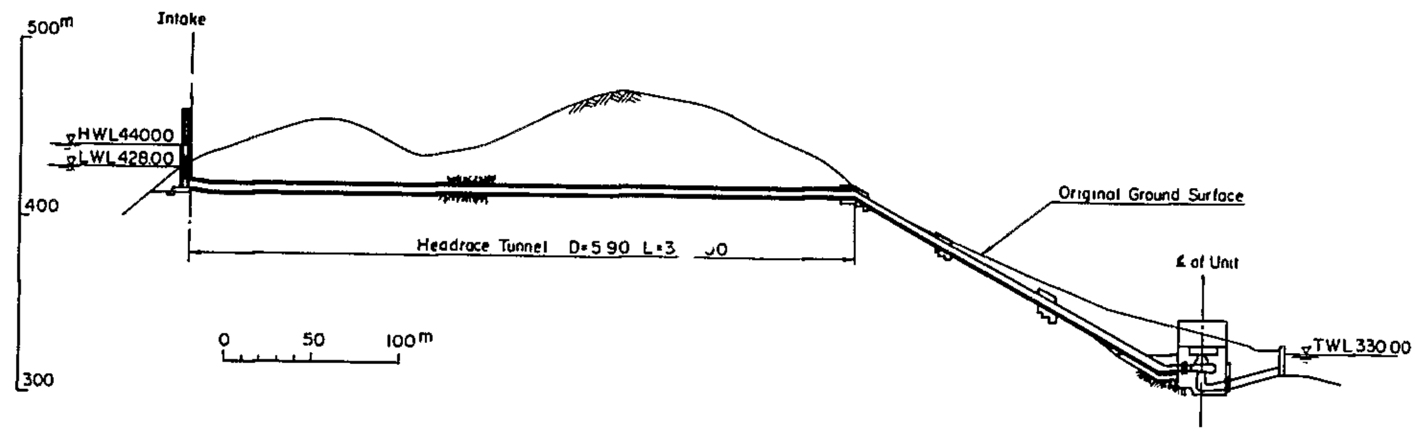
TYPICAL CROSS SECTION OF DAM



UPSTREAM VIEW OF DAM



CROSS SECTION OF POWERHOUSE



PROFILE OF WATERWAY AND POWERHOUSE

LOCATION	DATE	DESCRIPTION	BY
REVISION			

MAE PAI AND MAE CHAEM PROJECT MASTER PLAN

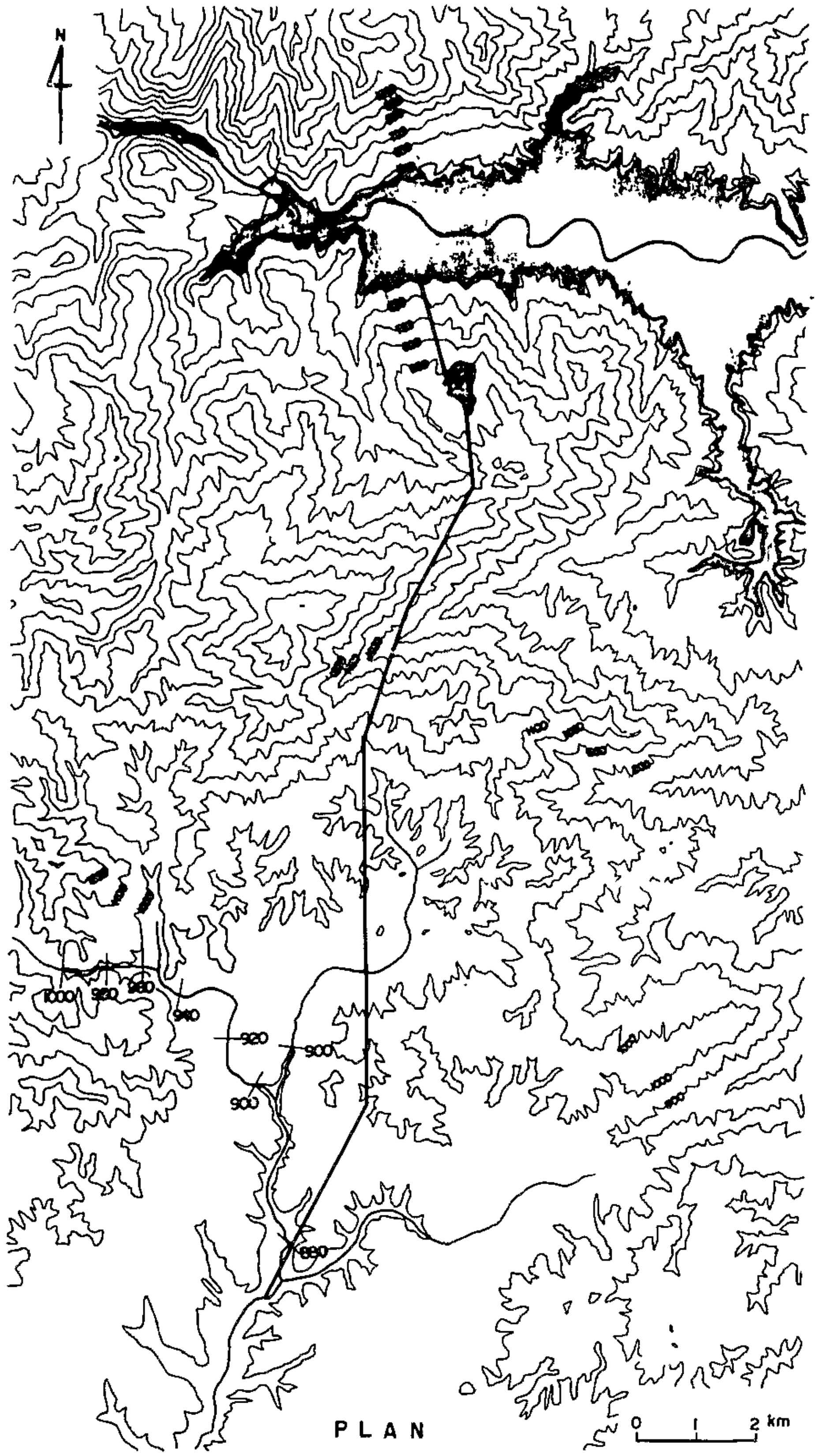
MAE CHAEM RIVER No 5 SITE

ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO, JAPAN

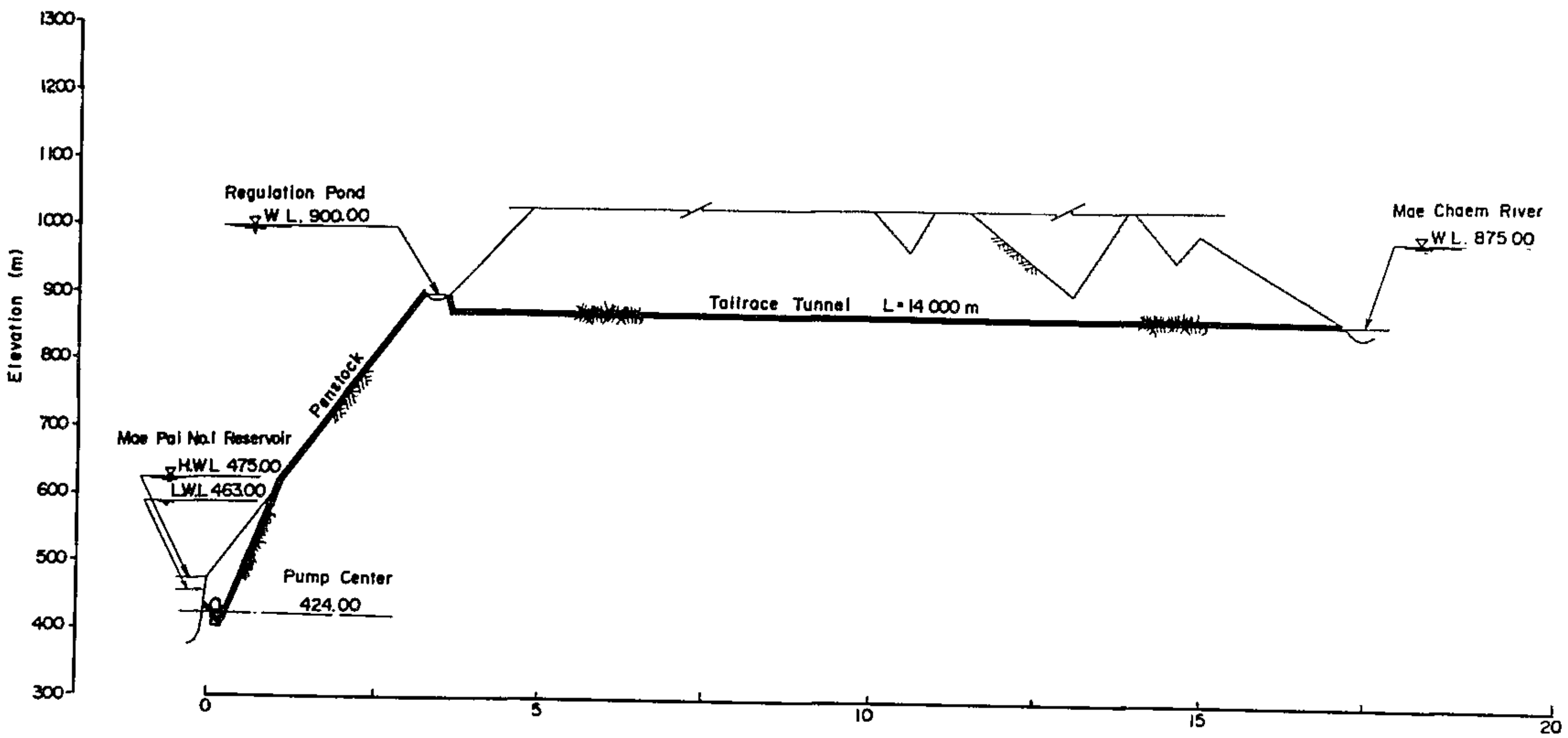
Dwg. 10-4

DR. SUBMITTED.
TR. RECOMMENDED
CK. APPROVED.

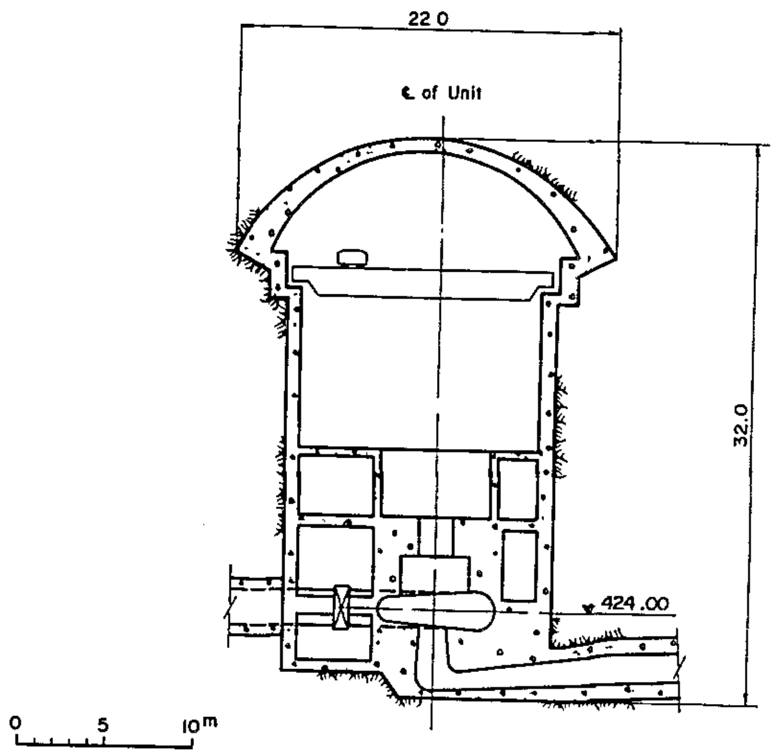
SHEET NO. OF



PLAN



PROFILE OF WATERWAY



CROSS SECTION OF UNDER GROUND PUMP STATION

MAE PAI AND MAE CHAEM PROJECT
MASTER PLAN

TRANS-BASIN SCHEME
FROM PAI RIVER TO
CHAEM RIVER

ELECTRIC POWER DEVELOPMENT CO., LTD
TOKYO, JAPAN

Dwg. 10-5

DR:	SUBMITTED:	
TR:	RECOMMENDED	
CK	APPROVED:	

LOCATION	DATE	DESCRIPTION	BY
REVISION			

SHEET NO. OF

CHAPTER 11

CONSTRUCTION COST

CHAPTER 11 CONSTRUCTION COST

The approximate construction costs referring to the various project sites are calculated in accordance with the following procedure.

The approximate calculation formula prepared based upon the results of construction of many dams and power stations undertaken in the past is used for the purpose of determination of the volume of construction work.

The unit prices of the construction work are determined by referring to the construction costs of projects enforced in the Kingdom of Thailand or by referring to the unit prices adopted in reports of similar projects prepared recently. The cost calculation refers to 1981. As for the classification of the costs into either the domestic currency or foreign currency, all items which can be domestically procured in the Kingdom of Thailand are included in domestic currency, while large sized construction machinery, hydraulic equipment, electric equipment, etc., are calculated in foreign currency.

The scope of calculation of the construction costs covers the civil construction costs, the hydraulic equipment, the electrical equipment, the transmission lines and substations, the engineering fee and interest during construction.

The import duties referring to the imported equipment are not taken into consideration in the present calculation.

Details like the construction plan, construction work schedule and yearly financial program are regarded to be analyzed at Pre-feasibility Study and Feasibility Study levels, and are not taken into consideration in the prsent report.

Approximate construction costs are shown in Tables 11-1 to 11-4, corresponding to the four (4) suitable sites derived by the present investigation of the master plan.

Table 11-1

Case: Chaem 4 (580 m)

Unit: 10^3B

Item	F.C.	D.C.	Total
(A) Generating Facilities			
I. Preparation works	-	87,200	87,200
II. Civil works	549,700	711,200	1,260,900
III. Hydraulic equip.	60,000	9,000	69,000
IV. Electrical equip.	93,400	49,400	142,800
Sub-total	703,100	856,800	1,559,900
(B) Transmission Line	52,000	28,000	80,000
Sub-total	755,100	884,800	1,639,900
(C) Engineering Fee	45,300	44,300	89,600
(D) Interest During Const.	128,000	148,500	276,500
Grand total	928,400	1,077,600	2,006,000

Table 11-2

Case: Chaem 5 (440 m)

Unit: 10^3B

Item	F.C.	D.C.	Total
(A) Generating Facilities			
I. Preparation works	-	230,500	230,500
II. Civil works	1,267,500	1,473,800	2,741,300
III. Hydraulic equip.	101,100	13,400	114,500
IV. Electrical equip.	251,300	133,100	384,400
Sub-total	1,619,900	1,850,800	3,470,700
(B) Transmission Line	142,000	76,500	218,500
Sub-total	1,761,900	1,927,300	3,689,200
(C) Engineering Fee	105,300	96,100	201,400
(D) Interest During Const.	373,400	405,000	778,400
Grand total	2,240,600	2,428,400	4,669,000

Table 11-3

Case: Pai 1 (475 m)

Unit: 10^3B

Item	F.C.	D.C.	Total
(A) Generating Facilities			
I. Preparation works	-	154,700	154,700
II. Civil works	360,200	618,100	978,300
III. Hydraulic equip.	69,500	10,100	79,600
IV. Electrical equip.	146,100	77,300	223,400
Sub-total	575,800	860,200	1,436,000
(B) Transmission Line	18,800	10,200	29,000
Sub-total	594,600	870,400	1,465,000
(C) Engineering Fee	35,700	43,800	79,500
(D) Interest During Const.	100,800	146,700	247,500
Grand total	731,100	1,060,900	1,792,000

Table 11-4

Case: Pai 6 (400 m)

Unit: 10^3B

Item	F.C.	D.C.	Total
(A) Generating Facilities			
I. Preparation works	-	323,000	323,000
II. Civil works	2,031,600	2,358,400	4,390,000
III. Hydraulic equip.	191,600	19,700	211,300
IV. Electrical equip.	555,900	294,300	850,200
Sub-total	2,779,100	2,995,400	5,774,500
(B) Transmission Line	173,500	93,500	267,000
Sub-total	2,952,600	3,088,900	6,041,500
(C) Engineering Fee	176,800	154,000	330,800
(D) Interest During Const.	626,000	648,700	1,274,700
Grand total	3,755,400	3,891,600	7,647,000

CHAPTER 12

ECONOMIC EVALUATION

Table 11-4

Case: Pai 6 (400 m)

Unit: 10^3B

Item	F.C.	D.C.	Total
(A) Generating Facilities			
I. Preparation works	-	323,000	323,000
II. Civil works	2,031,600	2,358,400	4,390,000
III. Hydraulic equip.	191,600	19,700	211,300
IV. Electrical equip.	555,900	294,300	850,200
Sub-total	2,779,100	2,995,400	5,774,500
(B) Transmission Line	173,500	93,500	267,000
Sub-total	2,952,600	3,088,900	6,041,500
(C) Engineering Fee	176,800	154,000	330,800
(D) Interest During Const.	626,000	648,700	1,274,700
Grand total	3,755,400	3,891,600	7,647,000

CHAPTER 12

ECONOMIC EVALUATION

CHAPTER 12 ECONOMIC EVALUATION

12.1 Economic Evaluation Method

Economic evaluation of the power generation project can be made in comparison with the alternative project which provides service at an equal level to the planned project. The applicable method of worldwide acceptance to the case of hydro power development project is first to select a thermal power plant as the alternative project, regarding its generating unit cost as the equivalent benefit cost for the proposed hydro power project and then to compare that cost with the generating cost estimated for the proposed project. Economic evaluation for this project follows the conventional method as aforestated.

This master plan covering power development projects on Pai and Chaem Rivers is based upon such assumption that the sequential order of development would start from downstream toward upstream with due consideration to the present rate of survey progress and accessibility to the project sites.

Comparative study for economic evaluation has been made on four alternative power stations, such as Mae Chaem No. 5, Mae Chaem No. 4, Mae Pai No. 6 and Mae Pai No. 1, of final choice after formulation of the development scheme. Since this project is still at a preliminary level of master planning and the time of completion for individual power development scheme remains uncertain, the annual expense method (the normal-year expense method) has been taken up as the suitable approach to economic evaluation.

The basic case of economic evaluation takes into account the shadow price factor, as agreed upon by NEA, same as in the case of feasibility study conducted by EGAT for Upper Quai Yai Project. Since fuel cost and interest rate in recent years are very hard to foresee, sensitivity analysis has been made, in addition to the basic case study, with regard to those factors in order to look into what influence will be exerted upon economy of this project by variation of such fuel cost and interest rate.

Table 12-1 shows the standards used for economic evaluation.

12.2 Proposed Project Outline for Economic Evaluation (1)

	Mae Pai No. 6	Mae Pai No. 1
River	Mae Pai	Mae Pai
Catchment area	3,725 km^2	1,817 km^2
Annual discharge	1,578 × 10^6 m^3	729.07 × 10^6 m^3
Reservoir		
High-water level	EL. 400 m	EL. 475 m
Gross storage capacity	2,421 × 10^6 m^3	765 × 10^6 m^3
Effective capacity	571 × 10^6 m^3	290 × 10^6 m^3
Impounding area	48.0 km^2	29.4 km^2
Dam		
Type	Rockfill	Rockfill
Height crest length	185 × 400 m	100 × 230 m
Volume	13,500 × 10^3 m^3	2,450 × 10^3 m^3
Power generation	Dam type	Dam type
Generating capacibility		
Max. output	291MW	48.9MW
Annual energy production		
Primary	495.98 × 10^6kWh	82.36 × 10^6kWh
Secondary	123.97 × 10^6kWh	30.06 × 10^6kWh
Generating facilities		
Installed capacity	291MW	48.9MW
No. of generating unit	2 units	2 units
Standard effective head	169.2 m	67.3 m
Max. water requirement (per unit)	101 m^3/s	42.7 m^3/s
Transmission facilities (including telecommunication)		
Transmission voltage	230kV	230kV
Construction costs (10^6฿)		
Generating facilities	5,774,500	1,436,000
Transmission facilities	267,000	29,000
Engineering fee	330,800	79,500
Interest accrual during	1,274,700	247,500
Total	7,647,000	1,792,000

12.2 Proposed Project Outline for Economic Evaluation (2)

	Mae Chaem No. 5	Mae Chaem No. 4
River	Mae Chaem	Mae Chaem
Catchment area	3,735 km^2	1,955 km^2
Annual discharge	1,206 × 10^6 m^3	698.34 × 10^6 m^3
Reservoir		
High-water level	EL. 440 m	EL. 580 m
Gross storage capacity	2,141 × 10^6 m^3	196 × 10^6 m^3
Effective capacity	500 × 10^6 m^3	100 × 10^6 m^3
Impounding area	37.7 km^2	8.2 km^2
Dam		
Type	Rockfill	Rockfill
Height crest length	140 × 555 m	95 × 440 m
Volume	10,120 × 10^3 m^3	4,110 × 10^3 m^3
Power generation	Dam type	Dam type
Generating capacibility		
Max. output	102.6MW	27.6MW
Annual energy production		
Primary	173.63 × 10^6kWh	46.86 × 10^6kWh
Secondary	114.29 × 10^6kWh	52.56 × 10^6kWh
Generating facilities		
Installed capacity	102.6MW	27.6MW
No. of generating unit	2 units	2 units
Standard effective head	104.1 m	62.9 m
Max. water requirement (per unit)	58 m^3/s	25.8 m^3/s
Transmission facilities (including telecommunication)		
Transmission voltage	115kV	115kV
Construction costs (10^6฿)		
Generating facilities	3,470,700	1,559,900
Transmission facilities	218,500	80,000
Engineering fee	201,400	89,600
Interest accrual during	778,400	276,500
Total	4,669,000	2,006,000

12.3 Selection of Alternative Power Plant

This project envisages power generation for supply to meet partial demand across the whole country of Thailand through the transmission line to be connected to the existing power system network. Therefore, the alternative power plant for economic comparative study has been selected on an assumption that it should be installed in the outskirt of the metropolitan area of Bangkok, the largest consuming center of the country.

For economic study of this Project, evaluation has been made on the basis of the normalized annual expenses for two thermal power units of 250MW output each, with due consideration to the probable size of the project. Thus, beneficial costs per kW, kWh and secondary kWh of the project have been calculated for economic evaluation.

As a general practice, a power generating unit fueled with heavy oil was selected conventionally as the alternative to the hydro power project. However, such oil-fueled power plant has been excluded from this comparative study for the following reasons:

(1) Oil price is too expensive.

(2) It has become impossible to forecast future oil price because of unreasonable uplift of petroleum on the OPEC side.

(3) Stabilized supply of heavy oil in the perspective future is projected with uncertainty.

(4) The EGAT's power development program does not include any construction project of heavy oil fueling power plant.

(5) The International Energy Agency (in Paris) of OECD has recommended its member countries to refrain from construction plan of new oil-fueled power plants by reason that petroleum should no longer be consumed for fueling but should only be used effectively for petro-chemical and other industrial purposes.

In Thailand there are alternative resources of local availability to the proposed project, such as natural gas, lignite, nuclear energy and imported coal.

For instance, natural gas now being exploited in the Union Mining Area of the Siam Bay is planned for industrial allocation with reduced share in the power generation sector, though at the early stage of development it may be fueled for South Bangkok and Ban Pakong Thermal Power Plants. Therefore, it has no marginal surplus as fuel for new power plants.

The Mae Moh Thermal Power Project now under way for construction is planned to consume full amount of lignite being produced in the Mae Moh area. This does not, therefore, permit any future expansion of the thermal power generating capacity.

In Thailand, effort is being pursued to look into potential reserve of lignite and natural gas in the Siam Bay. As of this date, however, no progress has yet been achieved in the estimation of potential energy re-sources and cost for exploitation. It is not advisable, therefore, to plan any such alternative thermal power generating unit by use of fuel with uncertainties.

As for nuclear power generation, aside from its own technical problem it contains not a few problems of complexity such as security of fuel supply source, disposal of spent fuel and other political involvements both at home and abroad. Since there is no definite prospect for earliest construction of the nuclear power plant under the present circumstance, it is neither advisable to take up the power unit of this type as the alternative for comparative study.

Recently, since attack of oil crisis coal has been coming into revival as the alternative energy resources still in abudant reserve in the earth. Therefore, for this comparative study it is considered most opportune to the current needs of times and most realistic, indeed, to take up the thermal power plant fueled with imported coal.

In fact, coal still remains in sufficient reserve enough to meet total worldwide demand. However, it is confronted at present with such problems as transportation means, port of coal handling and carriage vessel. If the coal supplier can be assured of purchase on a long-term stabilized basis by the purchaser, it can be imported at a reasonable international price level. Main coal-exporting countries with the sphere of free trade are Australia, United States, Canada and South Africa. Among them, coal to be imported from Australia and South Africa is most practicably suited for stabilized consumption in Thailand, especially when consideration is given to hedge possible risk from strike or labor dispute in coal mining.

All those things, therefore, lead to the decision that the two thermal power units, each of 250MW capacity, to be fueled with imported coal have been taken up for study as the alternative to the power generating facility under this project. The site of construction is assumed to be at the proposed construction site of Ao Phai Nuclear Power Plant about 100 km southeast from Bangkok. For the port of coal unloading it is also assumed that the extended portion of the deep water port now being planned as a part of the industrial complex at Rangchaban could be used for this purpose.

12.4 Benefit from Project

12.4.1 Alternative Thermal Power Generating Unit

The alternative thermal power generating unit selected as the comparable standard for economic evaluation under this project is outlined as follows:

(1) The construction site is within the proposed land area for construction of Ao Phai Nuclear Power Plant.

(2) Construction cost is of equivalent conversion at a 1981 price level from construction unit cost of Ban Pakong Thermal Power Plant recently entered into contract by EGAT after international competitive bidding, allowing for 20 percent additional cost to compensate for a greater number of auxiliary equipment being provided for a coal-fired power plant and 30 percent addition for pollution control cost. Thus, total cost is estimated at 150 percent of construction cost to be required for a heavy-oil fueled power plant.

(3) According to the operating record of thermal power plants within the EGAT's power system for the period from 1975 to 1978, it is registered that the mean value of dependable capacity for existing thermal power plants (heavy oil/natural gas/lignite) is 95 percent after adjustment by diversity factor for each unit. Therefore, the beneficial cost of this project has been calculated with this mean value taken into account.

Design specifiations of the alternative thermal power plant selected on the foregoing conditional basis are shown in Table 12-2.

12.4.2 Fuel Resources for Alternative Thermal Power Plant

Since coal may be imported from Australia on similar conditions to Japan, especially with regard to its carriage distance to the port of delivery in Thailand, this study is made on assumption that it is purchased from Australia. Australian coal is produced mainly from the State of New South Wales. It is, however, expected that the State of Queens Land will become the export center of bulk coal in the future with further exploitation of coal mining.

Australian coal was priced at 31 to 33 U.S. dollars per ton on a long-term contract FOB prices in early 1980. It has been jumped up to as high as 50 to 56 U.S. dollars per ton as of February 1981. It is really an unprecedent case of sudden price rise by more than 10 U.S. dollars per ton in December 1980. It is said that the real cause for such acute rise may be attributable to rapid demand increase from European countries involved in rapid decline of ordinary coal import from Poland in consequence of its nationwide general strike, in addition to the current upward tendency of demand for ordinary coal on a global scale. Though the future market situation is hard to foresee, it is nevertheless anticipated that the price once soared would not fall down to the original level so easily, even though the labor dispute in Poland has been settled, but rather remain at a stabilized high level as it is now. For this reason, this study makes estimated of imported coal price at 50 U.S. dollars per ton on a FOB price (in 1981) basis and 75 U.S. dollars per ton on delivery to the plant allowing for extra costs such as marine transport and insurance.
In view of the fact that the price would be cheaper if imported from South Africa while it would be higher if purchased from the west coast of the

United States, the price of Australian coal as estimated under this study may be considered reasonably moderate for economic evaluation.

Incidentally, those major coal exporting countries belong to the free trade economic bloc and many of the coal mines are privately owned and operated far and wide all over the world. Therefore, unlike the case of OPEC where oil price is cartelized to higher rise, any future price rise of coal may depend solely upon the principle of free economy through the operating mechanism of demand and supply.

Imported Coal Price

Coal Price (FOB)	50 U$/t
Freight	14 U$/t
Demurrage for 30 days	6 U$/t
Mics. Cost (Insurance, Commission, etc.)	5 U$/t
Total	75 U$/t

12.4.3 Beneficial Costs for Hydro Power Development Project

Beneficial costs for the hydro power project are calculated as follows from the normalized annual expenses as may be required for the alternative power plant selected for comparative study (see Table 12-2 for further details).

Power Generation Beneficial Costs

(Interest rate = 10%)

Beneficial unit cost per kW	3.089฿
Beneficial unit cost per kWh	0.6995฿
Secondary beneficial unit cost per kWh	0.6796฿

12.5 Annual Expense for Hydro Power Project

Annual expense for the hydro power project is calculated for annual normalized cost on the economic evaluation basis as shown in Table 12-1. Annual expense for each project is as shown in Tables 12-8, 12-9, 12-10 and 12-11 respectively.

Economic project costs are as shown in the Table below, as adjusted by use of the shadow-price factor for correction of the investment sum to be required for each project as the standard for calculation of such annual expense.

Project Cost

(Unit: 10^6฿)

Projects	Project Financial Cost	Project Economic Cost	Remarks
Mae Pai No. 6	7,647,000	7,474,000	
Mae Pai No. 1	1,792,000	1,694,000	
Mae Chaem No. 5	4,669,000	4,552,500	
Mae Chaem No. 4	2,006,000	1,924,000	
Total	16,114,000	15,644,000	

12.6 Economic Evaluation

12.6.1 Benefit-Cost Analysis

The following results have been sought from benefit-cost analysis for each project by due reference to annual benefit to be gained from each power generation project as estimated from the preceding 12.4.3 and annual expense as estimated from the preceding 12.5.

Benefit-Cost Analysis (1)
(Shadow price factor being taken into account)

Interest rate: 10%

Project	Annual Benefit(B) (10^6฿)	Annual Cost (C) (10^6฿)	B - C (10^6฿)	B/C
Mae Pai No. 6	1,321.10	866.42	454.68	1.525
Mae Pai No. 1	228.10	196.30	31.80	1.162
Mae Chaem No. 5	495.23	528.00	-32.77	0.938
Mae Chaem No. 4	150.60	223.00	-72.40	0.675

Benefit-Cost Analysis (2)
(Shadow price factor not being taken into account)

Interest rate: 10%

Project	Annual Benefit(B) (10^6฿)	Annual Cost(C) (10^6฿)	B - C (10^6฿)	B/C
Mae Pai No. 6	1,257.00	887.00	370.00	1.417
Mae Pai No. 1	217.40	207.70	9.70	1.047
Mae Chaem No. 5	473.59	541.00	-67.41	0.875
Mae Chaem No. 4	144.70	232.60	-87.90	0.622

12.6.2 Sensitivity Analysis

Sensitivity study has been made on Mae Pai No. 6 Project and Mae Chaem No. 5 Project which are at an advanced stage of study and found to be relatively favorable in economy after benefit-cost analysis.

Sensitivity analysis has been made on the varied basis of fuel cost for the alternative power plant, its construction cost and each project construction cost and its interest rate, just to look into the effect to be exerted upon economy of the project by such varied factors.

The results of study are as shown in Figs. 12-1, 12-2, 12-3, 12-4, 12-5, 12-6, 12-7 and 12-8 respectively.

12.6.3 Consideration

From the result of benefit-cost analysis, it has been considered that both of Mae Pai No. 6 Project and Mae Pai No. 1 Project are most economically beneficial than any others. Mae Pai No. 6 Project, which is now under site survey, should be advanced further into the stage of feasibility study at the earliest possible opportunity. With regard to Mae Pai No. 1 Project, the site survey work should start, because of the encouraging prospect for its economy, so as to study feasibility of the construction project.

The sensitivity analysis result concludes, as far as analysis is concerned, that Mae Chaem No. 5 Project should require immediate steps for feasibility study, in view of urgent need for energy supply in Thailand, since the project has economic advantage from the financial aspect if fuel price for the alternative power plant rises up and the project can be financed by the loan fund with the favorable condition of interest payment applicable to developing countries.

With regard to Mae Chaem No. 4 Project, it appears to be of no urgent need at the present stage because of low economy and small scale. However, because of the high potentiality for future development, it is recommended that the survey work should continue as it has been.

12.6.4 Economic Evaluation by Alternative Thermal Power Plants than Imported-Coal-Fired Thermal Power Plant (Reference)

In this chapter, we discussed the project economy based on an imported coal fired thermal as the alternative power plant. In addition to the above, we have studied the project economy based on various alternative thermal power plants including Oil-Fired, Natural Gas-Fired and Lignite-Fired thermal power plant as the alternative power plant and the results were summerized in the "Supplementary Study of Economic Evaluation which is bounded followed to this chapter for reference.

Fig. 12-1 SENSITIVITY ANALYSIS FOR MAE PAI No.6 PROJECT (1)

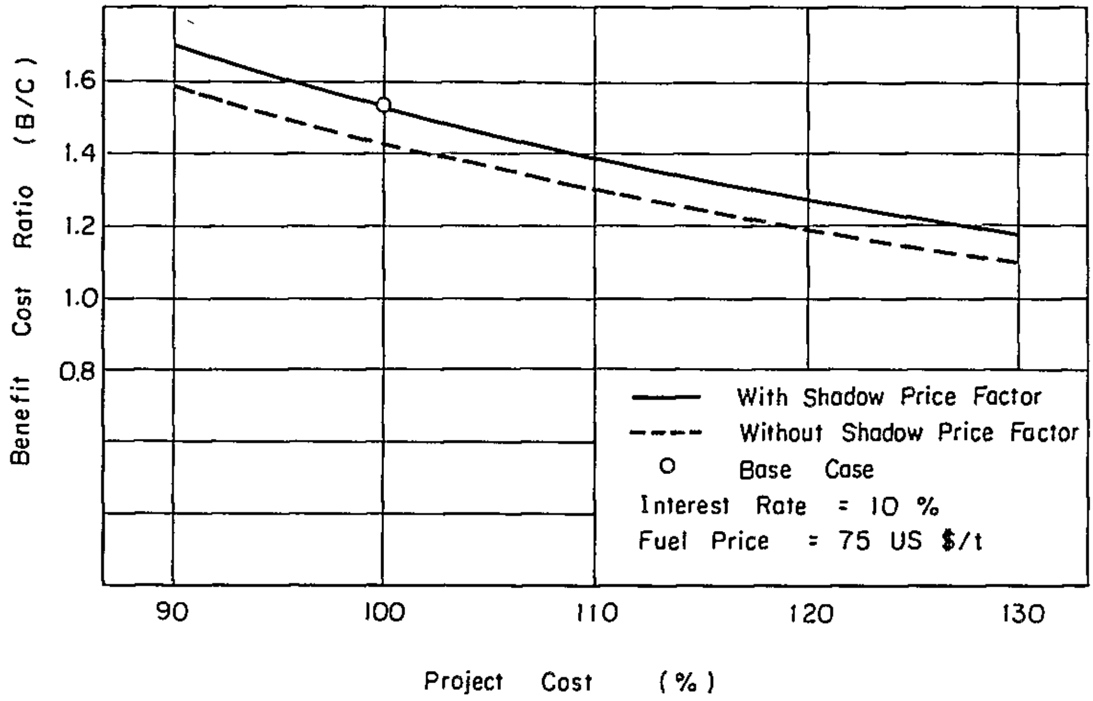


Fig. 12-2 SENSITIVITY ANALYSIS FOR MAE PAI No.6 PROJECT (2)

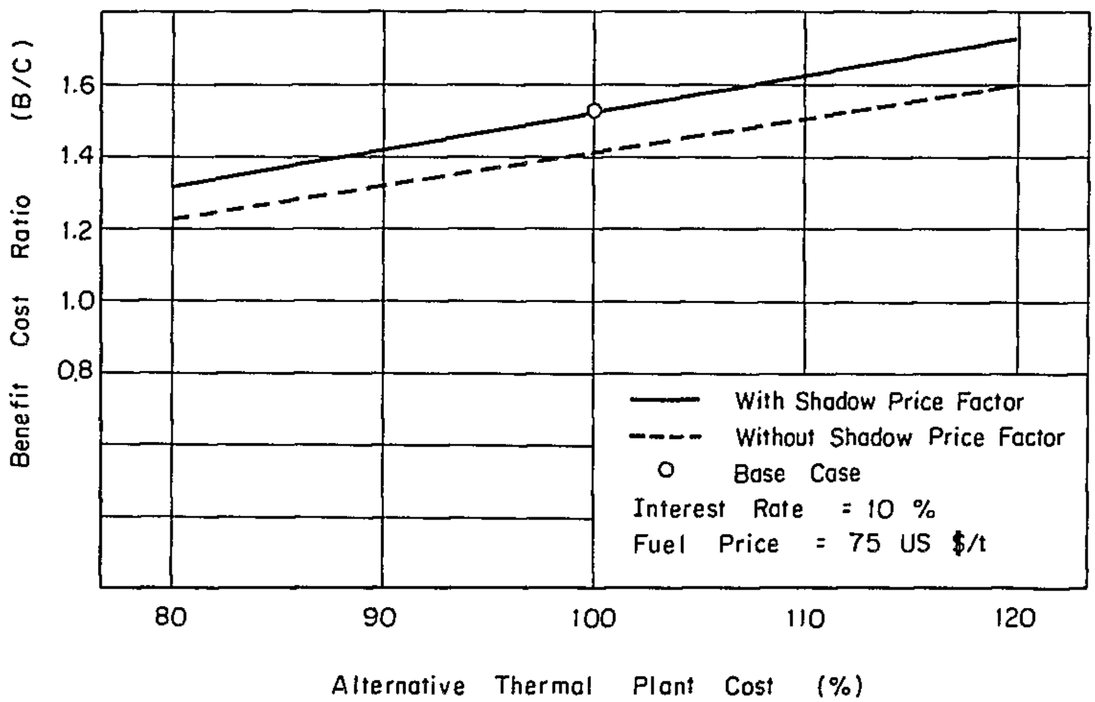


Fig. 12-3 SENSITIVITY ANALYSIS FOR MAE PAI No.6 PROJECT (3)

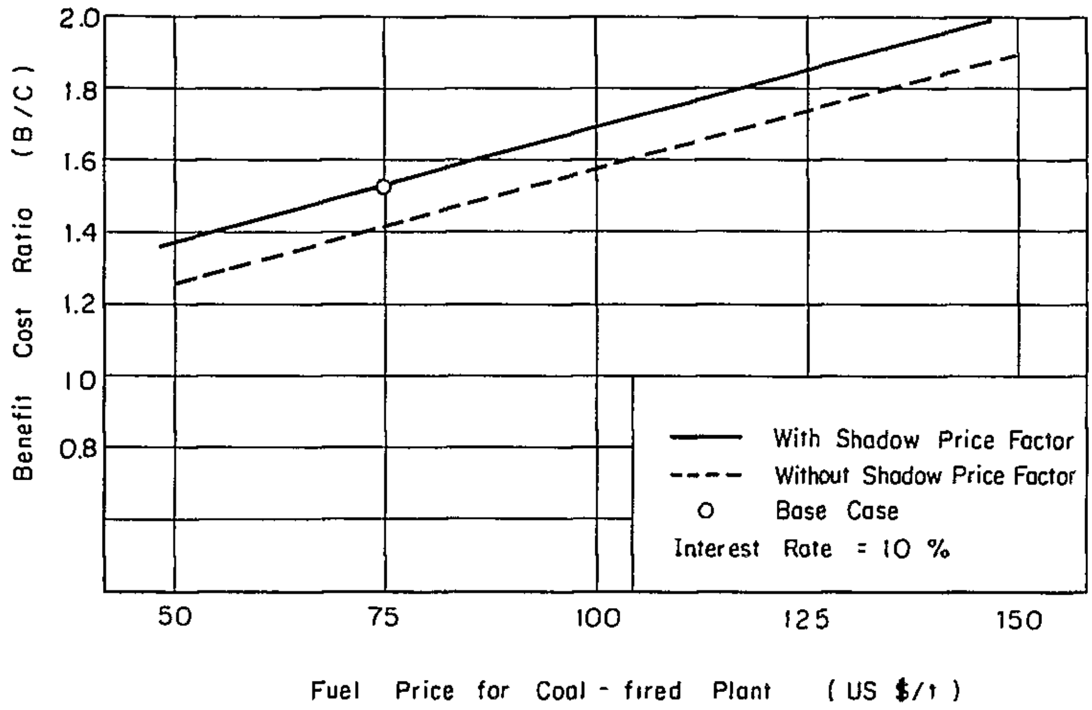


Fig. 12-4 SENSITIVITY ANALYSIS FOR MAE PAI No.6 PROJECT (4)

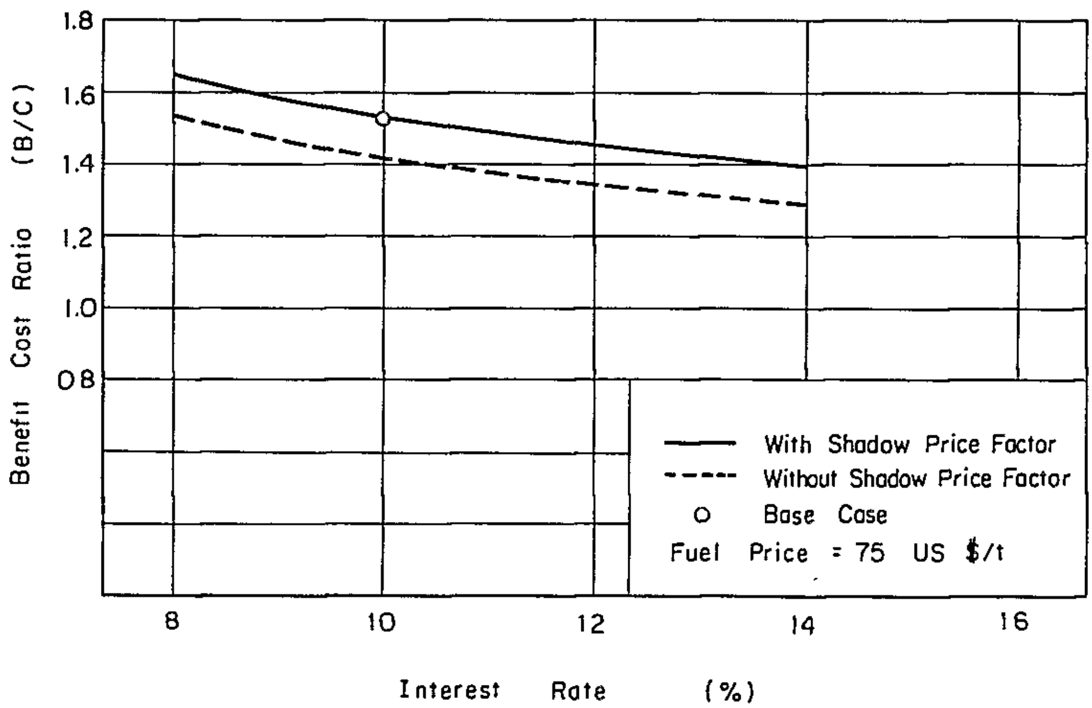


Fig.12-5 SENSITIVITY ANALYSIS FOR MAE CHAEM No.5 PROJECT (1)

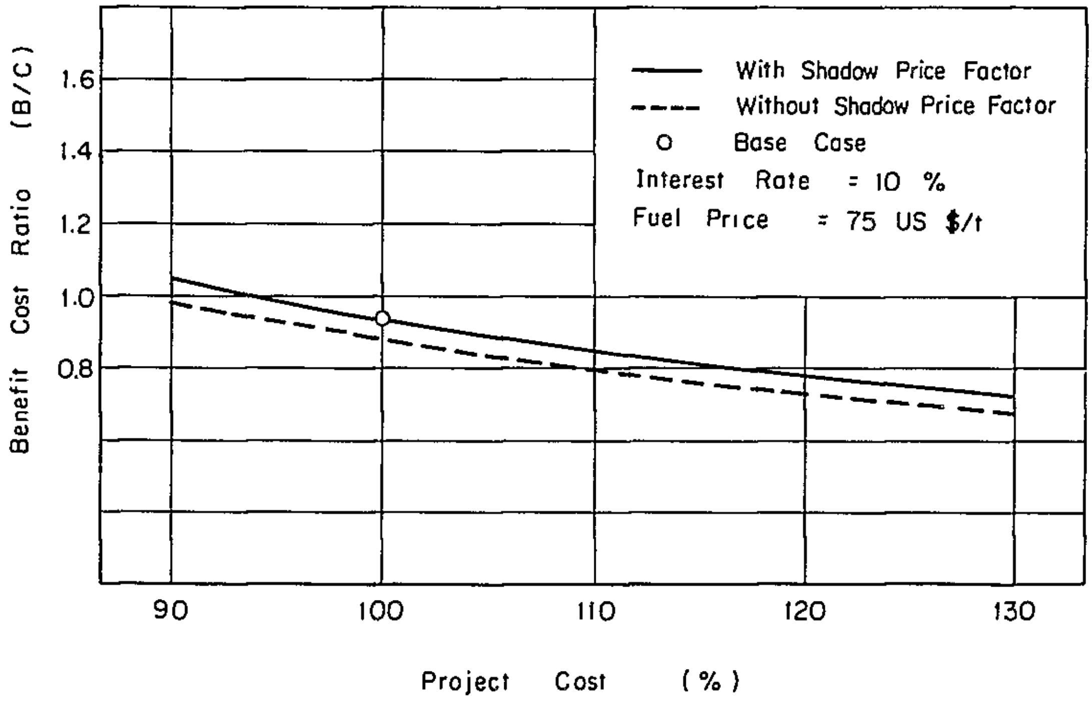


Fig.12-6 SENSITIVITY ANALYSIS FOR MAE CHAEM No.5 PROJECT (2)

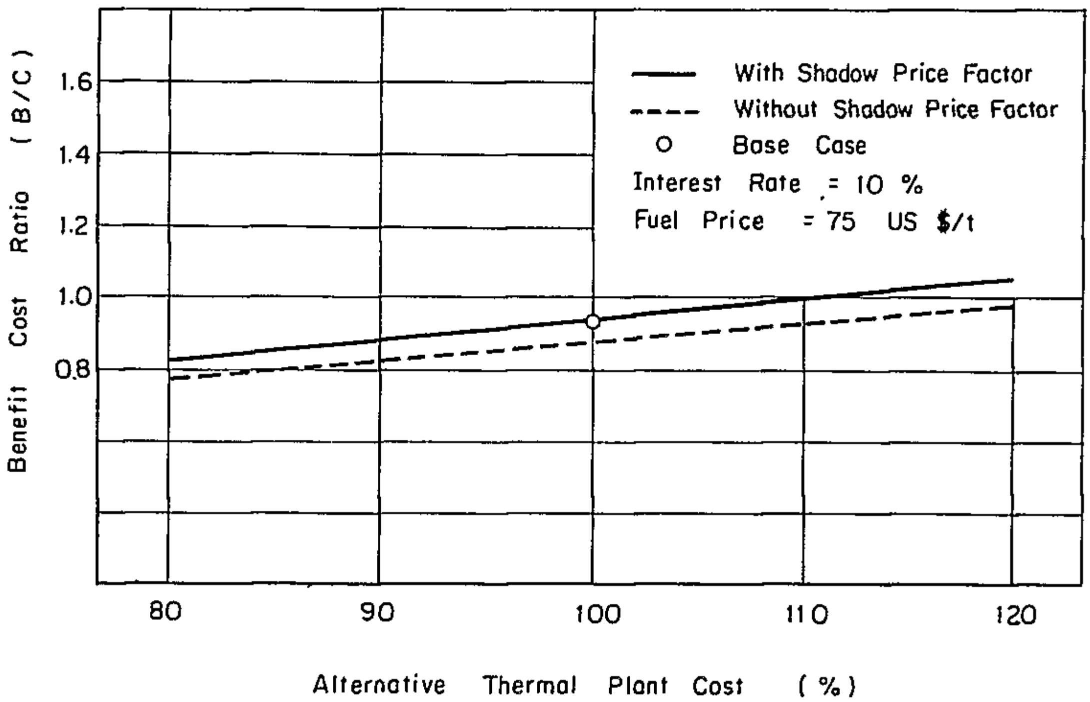


Fig. 12-7 SENSTIVITY ANALYSIS FOR MAE CHAEM No.5 PROJECT (3)

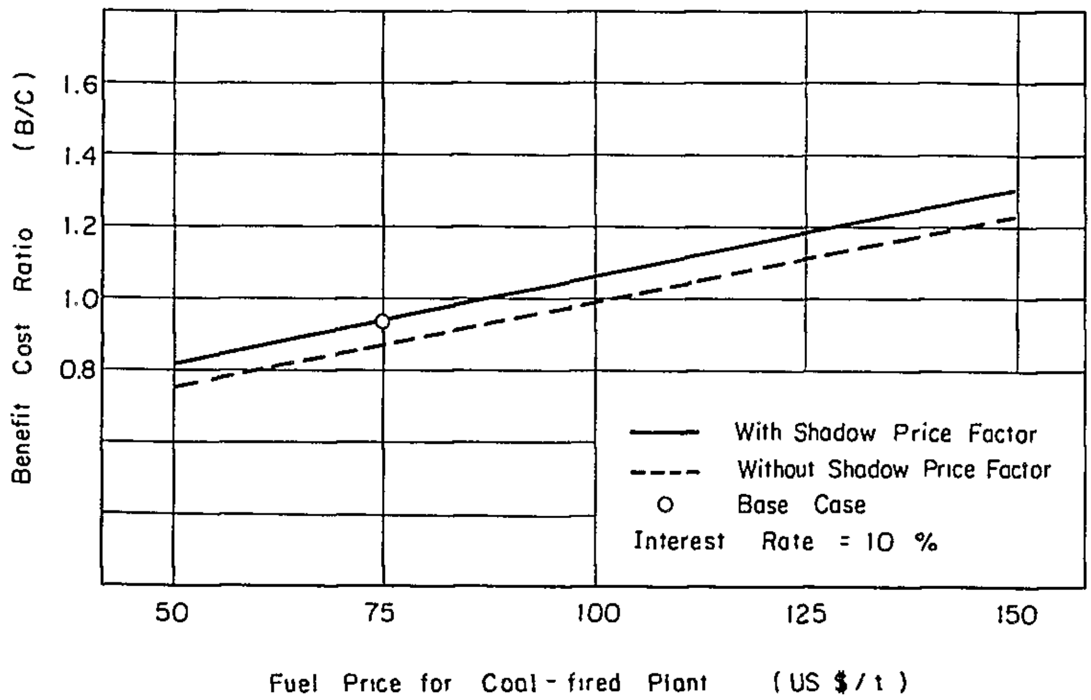


Fig. 12-8 SENSITIVITY ANALYSIS FOR MAE CHAEM No.5 PROJECT (4)

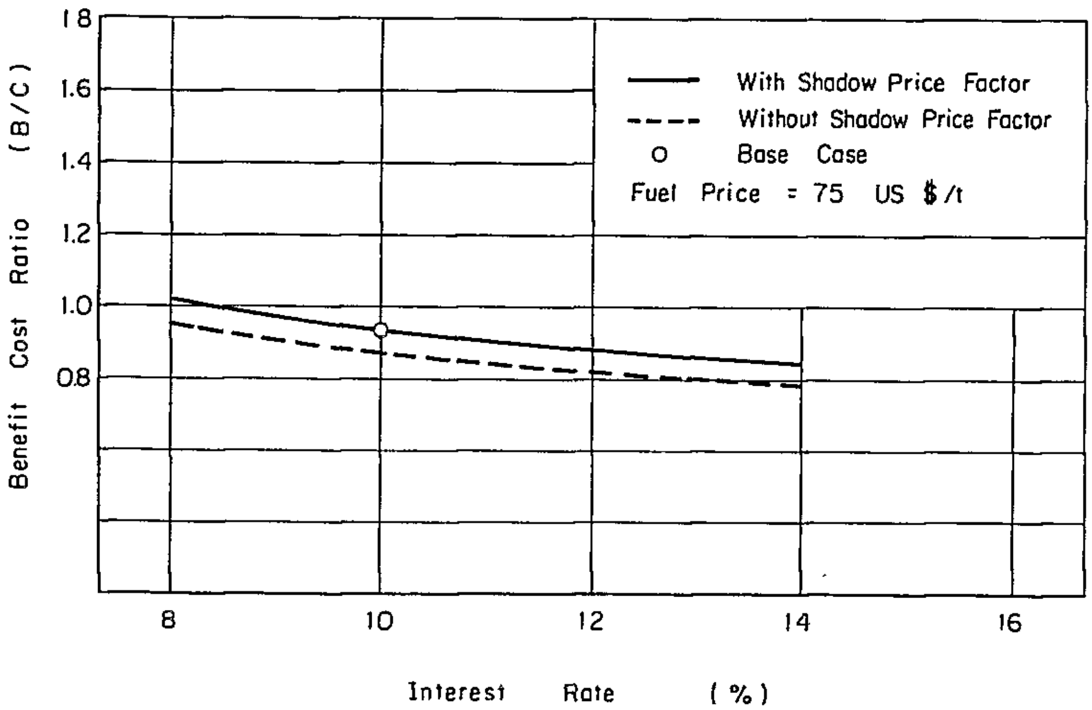


Table 12-1 Basic Criteria for Economic Study

Method of Analysis:	Benefit-Cost Analysis (Annual Cost Method)
Interest Rate:	10%
Escalation:	Not considered
Shadow Price Factor:	
Foreign Currency	1.10
Local Currency	0.85
Local Currency for Thermal	0.95
Fuel Price	1.0
Service Life of Facilities:	
Dam and Hydropower Plant	50 years
Coal-fired Thermal Power Plant	25 years
Related Transmission facilities	40 years
Operation and Maintenance:	
Dam and Hydropower Plant	1.5%
Coal-fired Thermal Power Plant	3.0%
Related Transmission Facilities	1.5%
Conversion Rate of Currency:	US$1.00 = 20.5฿

Table 12-2 Estimation of Power Benefits of Hydropower Project (1)
(Study on Alternative Thermal Power Plant)

-- Without Shadow Price Factor --

Interest Rate: 10%

1981 Price Level

			Remarks
Installed Capacity		250 MW x 2	
Dependable Capacity	(MW)	475.0	
Annual Plant Factor	(%)	70	
Annual Energy Production	(10^6 kWh)	3,066	
Station Service Use	(%)	7	
Annual Available Energy	(10^6 kWh)	2,851	
Unit Construction Cost			
Net Cost	(US$/kW)	800	
Cost with IDC	(US$/kW)	927	
Construction Cost with IDC	(10^6 US$)	464	
Service Life	(Year)	25	
Capital Recovery Factor	(p.u.)	0.11017	
O & M Cost Rate without Fuel	(%)	3	
Fuel Consumption Rate	(kg/kWh)	0.395	
Unit Fuel Cost	(US$/kg)	0.0806	

Annual Cost (10^6 US$)	Fixed Cost	Variable Cost	Remarks
Capital Cost	51.12	-	
O & M Cost w/o Fuel	11.14	2.78	
Fuel Cost	-	97.50	
Sub-total	62.26	100.28	
Total	162.54		

Cost of Alternative Thermal Power Project			Remarks
kW Cost	(฿/kW)	2,688	
kWh Cost	(฿/kWh)	0.721	
Fuel Cost	(฿/kWh)	0.7011	
Averaged Generating Cost	(฿/kWh)	1.1687	

Table 12-2 (Cont.)

Power Befenit of Hydropower Project			Remarks
kW Benefit			
Compensation Coefficient	(p.u.)	1.067	
kW Benefit	(฿/kW)	2,868	
kWh Benefit			
Compensation Coefficient	(p.u.)	0.9694	
kWh Benefit	(฿/kWh)	0.6989	
Secondary kWh Benefit	(฿kWh)	0.6796	

Note:

Compensation Factor (for kW Benefit)

$$= \frac{(1 - FOh)(1 - TLh)(1 - OHh)}{(1 - FOt)(1 - TLt)(1 - OHt)}$$

$$= \frac{(1 - 0.05)(1 - 0.02)}{(1 - 0.02)(1 - 0.11)} = 1.067$$

Compensation Factor (for kWh Benefit)

$$= \frac{(1 - FOh)(1 - TLh)}{(1 - FOt)(1 - TLt)}$$

$$= \frac{(1 - 0.05)}{(1 - 0.02)} = 0.9694$$

where,

Forced outage rate:

Hydro (FOh)	5%
Thermal (FOt)	Considered separately at the calculation of the dependable capacity

Transmission line loss rate:

Hydro (TLh)	Considered separately
Thermal (TLt)	2%

Overhaul rate:

Hydro (OHh)	2%
Thermal (OHt)	11% (40 days a year)

Table 12-3 Estimation of Power Benefits of Hydropower Project (2)
(Study on Alternative Thermal Power Plant)

-- With Shadow Price Factor --

Interest Rate: 10%
1981 Price Level

			Remarks
Installed Capacity		250 MW x 2	
Dependable Capacity	(MW)	475.0	
Annual Plant Factor	(%)	70	
Annual Energy Production	(10^6 kWh)	3,066	
Station Service Use	(%)	7	
Annual Available Energy	(10^6 kWh)	2,851	
Unit Construction Cost			
Net Cost	(US$/kW)	800	
Cost with IDC	(US$/kW)	927	
Construction Cost with IDC	(10^6 US$)	500 *	* Shadow Price Factors are considered.
Service Life	(Year)	25	
Capital Recovery Factor	(p.u.)	0.11017	
O & M Cost Rate without Fuel	(%)	3	
Fuel Consumption Rate	(kg/kWh)	0.395	
Unit Fuel Cost	(US$/kg)	0.0806	

Annual Cost (10^6 US$)	Fixed Cost	Variable Cost	Remarks
Capital Costs	55.09	-	
O & M Cost w/o Fuel	12.00	3.00	
Fuel Cost	-	97.50	
Sub-total	67.09	100.50	
Total	167.59		

Cost of Alternative Thermal Power Project			Remarks
kW Cost	(฿/kW)	2,892	
kWh Cost	(฿/kWh)	0.7216	
Fuel Cost	(฿/kWh)	0.7011	
Averaged Generating Cost	(฿/kWh)	1.205	

Table 12-3 (Cont.)

Power Benefit of Hydropower Project			Remarks
kW Benefit			
Compensation Coefficient	(p.u.)	1.067	
kW Benefit	(฿/kW)	3,089	
kWh Benefit			
Compensation Coefficient	(p.u.)	0.9694	
kWh Benefit	(฿/kWh)	0.6995	
Secondary kWh Benefit	(฿/kWh)	0.6796	

Note:

Compensation Factor (for kW Benefit)

$$= \frac{(1 - FOh)(1 - TLh)(1 - OHh)}{(1 - FOt)(1 - TLt)(1 - OHt)}$$

$$= \frac{(1 - 0.05)(1 - 0.02)}{(1 - 0.02)(1 - 0.11)} = 1.067$$

Compensation Factor (for kWh Benefit)

$$= \frac{(1 - FOh)(1 - TLh)}{(1 - FOt)(1 - TLt)}$$

$$= \frac{(1 - 0.05)}{(1 - 0.02)} = 0.9694$$

where,

Forced outage rate:

- Hydro (FOh) 5%
- Thermal (FOt) Considered separately at the calculation of the dependable capacity

Transmission line loss rate:

- Hydro (TLh) Considered separately
- Thermal (TLt) 2%

Overhaul rate:

- Hydro (OHh) 2%
- Thermal (OHt) 11% (40 days a year)

Table 12-4 Power Benefit of Mae Pai No.6 Project

1. Power and Annual Energy Production

	at Generator End	Loss Rate	at Primary Substation
Maximum Output	291,000 kW	0.75%	288,800 kW
Firm Energy	495.98×10^6 kWh	0.5%	493.50×10^6 kWh
Secondary Energy	123.97×10^6 kWh	0.5%	123.35×10^6 kWh

2. Unit Benefit

Interest Rate: 10%

	With Shadow Price Factor	Without Shadow Price Factor
kW Benefit	3,089 ฿/kW	2,868 ฿/kW
kWh Benefit (Firm)	0.6995 ฿/kWh	0.6989 ฿/kWh
kWh Benefit (2ndry)	0.6796 ฿/kWh	0.6796 ฿/kWh

3. Benefits of Project (10^6 ฿)

	With Shadow Price Factor	Without Shadow Price Factor
kW Benefit	892.1	828.3
kWh Benefit (Firm)	345.2	344.9
kWh Benefit (2ndry)	83.8	83.8
Total Benefit	1,321.1	1,257.0

Table 12-5 Power Benefit of Mae Pai No.1 Project

1. Power and Annual Energy Production

	at Generator End	Loss Rate	at Primary Substation
Maximum Output	48,900 kW	0.5%	48,660 kW
Firm Energy	82.36×10^6 kWh	0.3%	82.11×10^6 kWh
Secondary Energy	30.06×10^6 kWh	0.3%	29.97×10^6 kWh

2. Unit Befenit

Interest Rate: 10%

	With Shadow Price Factor	Without Shadow Price Factor
kW Benefit	3,089 ฿/kW	2,868 ฿/kW
kWh Benefit (Firm)	0.6995 ฿/kWh	0.6989 ฿/kWh
kWh Benefit (2ndry)	0.6796 ฿/kWh	0.6796 ฿/kWh

3. Benefits of Project (10^6 ฿)

	With Shadow Price Factor	Without Shadow Price Factor
kW Benefit	150.3	139.6
kWh Benefit (Firm)	57.4	57.4
kWh Benefit (2ndry)	20.4	20.4
Total Benefit	228.1	217.4

Table 12-6 Power Benefit of Mae Chaem No.5 Project

1. Power and Annual Energy Production

	at Generator End	Loss Rate	at Primary Substation
Maximum Output	102,600 kW	5%	97,470 kW
Firm Energy	173.63 x 10^6 kWh	2.5%	169.29 x 10^6 kWh
Secondary Energy	114.29 x 10^6 kWh	2.5%	111.43 x 10^6 kWh

2. Unit Benefit

Interest Rate: 10%

	With Shadow Price Factor	Without Shadow Price Factor
kW Benefit	3,089 ฿/kW	2,868 ฿/kW
kWh Benefit (Firm)	0.6995 ฿/kWh	0.6989 ฿/kWh
kWh Benefit (2ndry)	0.6796 ฿/kWh	0.6796 ฿/kWh

3. Benefits of Project (10^6 ฿)

	With Shadow Price Factor	Without Shadow Price Factor
kW Benefit	301.08	279.54
kWh Benefit (Firm)	118.42	118.32
kWh Benefit (2ndry)	75.73	75.73
Total Benefit	495.23	473.59

Table 12-7 Power Benefit of Mae Chaem No.4 Project

1. Power and Annual Energy Production

	at Generator End	Loss Rate	at Primary Substation
Maximum Output	27,600 kW	2.5%	26,910 kW
Firm Energy	46.86×10^6 kWh	1.5%	46.16×10^6 kWh
Secondary Energy	52.56×10^6 kWh	1.5%	51.77×10^6 kWh

2. Unit Benefit

Interest Rate: 10%

	With Shadow Price Factor	Without Shadow Price Factor
kW Benefit	3,089 ฿/kW	2,868 ฿/kW
kWh Benefit (Firm)	0.6995 ฿/kWh	0.6989 ฿/kW
kWh Benefit (2ndry)	0.6796 ฿/kWh	0.6796 ฿/kWh

3. Benefits of Project (10^6 ฿)

	With Shadow Price Factor	Without Shadow Price Factor
kW Benefit	83.1	77.2
kWh Benefit (Firm)	32.3	32.3
kWh Benefit (2ndry)	35.2	35.2
Total Benefit	150.6	144.7

Table 12-8 Annual Cost of Mae Pai No. 6 Project

(1) Case with Shadow Price Factor

Description	Unit	Generating Facilities	Related Transmission Facilities	Total	Remarks
Construction cost (incl. IDC)	10^6฿	7,130	344	7,474	
Serviceable year	Years	50	40	-	
Interest rate	%	10	10	-	
Capital recovery factor	p.u.	0.10086	0.10226	-	
Interest and depreciation	10^6฿	719.13	35.18	754.31	
Operation and maintenance cost	10^6฿	106.95	5.16	112.11	1.5%
Annual cost	10^6฿	826.08	40.34	866.42	

(2) Case without Shadow Price Factor

Description	Unit	Generating Facilities	Related Transmission Facilities	Total	Remarks
Construction cost (incl. IDC)	10^6฿	7,309	338	7,647	
Serviceable year	Years	50	40	-	
Interest rate	%	10	10	-	
Capital recovery factor	p.u.	0.10086	0.10226	-	
Interest and depreciation	10^6฿	737.70	34.60	772.30	
Operation and maintenance cost	10^6฿	109.60	5.10	114.70	1.5%
Annual cost	10^6฿	847.30	39.70	887.00	

Table 12-9 Annual Cost of Mae Pai No. 1 Project

(1) Case with Shadow Price Factor

Description	Unit	Generating Facilities	Related Transmission Facilities	Total	Remarks
Construction cost (incl. IDC)	10^6฿	1,658.2	35.8	1,694	
Serviceable year	Years	50	40	-	
Interest rate	%	10	10	-	
Capital recovery factor	p.u.	0.10086	0.10226	-	
Interest and depreciation	10^6฿	167.2	3.7	170.9	
Operation and maintenance cost	10^6฿	24.9	0.5	25.4	1.5%
Annual cost	10^6฿	192.1	4.2	196.3	

(2) Case without Shadow Price Factor

Description	Unit	Generating Facilities	Related Transmission Facilities	Total	Remarks
Construction cost (incl. IDC)	10^6฿	1,758.1	33.9	1,792	
Serviceable year	Years	50	40	-	
Interest rate	%	10	10	-	
Capital recovery factor	p.u.	0.10086	0.10226	-	
Interest and depreciation	10^6฿	177.3	3.5	180.8	
Operation and maintenance cost	10^6฿	26.4	0.5	26.9	1.5%
Annual cost	10^6฿	203.7	4.0	207.7	

Table 12-10 Annual Cost of Mae Chaem No. 5 Project

(1) Case with Shadow Price Factor

Description	Unit	Generating Facilities	Related Transmission Facilities	Total	Remarks
Construction cost (incl. IDC)	10^6 ฿	4,271	281.5	4,552.5	
Serviceable year	Years	50	40	-	
Interest rate	%	10	10	-	
Capital recovery factor	p.u.	0.10086	0.10226	-	
Interest and depreciation	10^6 ฿	430.9	28.8	459.7	
Operation and maintenance cost	10^6 ฿	64.1	4.2	68.3	1.5%
Annual cost	10^6 ฿	495.0	33.0	528.0	

(2) Case without Shadow Price Factor

Description	Unit	Generating Facilities	Related Transmission Facilities	Total	Remarks
Construction cost (incl. IDC)	10^6 ฿	4,392	277	4,669	
Serviceable year	Years	50	40	-	
Interest rate	%	10	10	-	
Capital recovery factor	p.u.	0.10086	0.10226	-	
Interest and depreciation	10^6 ฿	442.70	28.30	471.0	
Operation and maintenance cost	10^6 ฿	65.80	4.20	70.0	1.5%
Annual cost	10^6 ฿	508.50	32.50	541.0	

Table 12-11 Annual Cost of Mae Chaem No. 4 Project

(1) Case with Shadow Price Factor

Description	Unit	Generating Facilities	Related Transmission Facilities	Total	Remarks
Construction cost (incl. IDC)	10^6฿	1,822.5	101.5	1,924	
Serviceable year	Years	50	40	-	
Interest rate	%	10	10	-	
Capital recovery factor	p.u.	0.10086	0.10226	-	
Interest and operation	10^6฿	183.8	10.4	194.2	
Operation and maintenance cost	10^6฿	27.3	1.5	28.8	1.5%
Annual cost	10^6฿	211.1	11.9	223	

(2) Case without Shadow Price Factor

Description	Unit	Generating Facilities	Related Transmission Facilities	Total	Remarks
Construction cost (incl. IDC)	10^6฿	1,908.1	97.9	2,006	
Serviceable year	Years	50	40	-	
Interest rate	%	10	10	-	
Capital recovery factor	p.u.	0.10086	0.10226	-	
Interest and depreciation	10^6฿	192.5	10	202.5	
Operation and maintenance cost	10^6฿	28.6	1.5	30.1	1.5%
Annual cost	10^6฿	221.1	2.5	232.6	

SUPPLEMENTARY STUDY OF ECONOMIC EVALUATION

CHAPTER A SUPPLEMENTARY STUDY OF ECONOMIC EVALUATION

A.1 Introduction

In this report, an import-coal fired thermal power plant is considered as the alternative thermal power plant.

In addition to the economic studies in Chapter 12, economic studies for the selected hydropower projects were made based on the alternative thermal power plants (Oil-fired, Natural gas-fired and Lignite-fired).

A.2 Fuel Cost of Alternative Thermal Power Plant

Price of Bunker C oil was estimated at 40 US$/barrel taking consideration of the current international market price, price of Natural gas is 75.04 Baht/million Btu which is agreed between EGAT and Petroleum Authority of Thailand (PTT) in March 1981, and the price of lignite could not be found, therefore, we estimated the price at 30 US$/t.

(1981 Price)

	Bunker C oil	Natural gas	Imported coal	Lignite
Fuel calorie	10,200 kcal/kg (10,000 kcal/ℓ)	-	6,300 kcal/kg	3,500 kcal/kg (6,300 Btu/ℓb)
Annual thermal efficiency (at pf=0.7)	37% × 0.96	37% × 0.96	36% × 0.96	35% × 0.96
Required calorie	2,421 kcal/kWh	2,421 kcal/kWh	2,488 kcal/kWh	2,560 kcal/kWh
Fuel consumption rate	0.242 ℓ/kWh	0.0096×10^6 Btu/kWh	0.395 kg/kWh	0.731 kg/kWh
Fuel price (FOB)	-	-	50US$/t	-
Fuel price (CIF)	40US$/Barrel (0.252$/ℓ)	-	75US$/t	-
Fuel price at plant	0.252$/ℓ	75.04 ฿/million Btu	0.0806$/kg	30US$/t
Fuel cost for power generation	0.0610$/kWh (=1.25฿/kWh)	0.0352$/kWh (=0.721฿/kWh)	0.0318$/kWh (=0.652฿/kWh)	0.0219$/kWh (=0.45฿/kWh)

A.3 Unit Construction Cost of Alternative Thermal Power Plants

(1981 price)

Oil-fired thermal	535US$/kW
Natural gas-fired thermal	535US$/kW
Imported coal-fired thermal	800US$/kW
Lignite-fired thermal	830US$/kW

Note: Interest during construction is not included in the above cost.

A.4 Unit Benefits of Hydropower Projects (Interest Rate: 10%)

A.4.1 Oil-fired Thermal as the Alternative

Cost of Alternative Thermal Power Project		
kW Cost	(฿/kWh)	1,882
kWh Cost	(฿/kWh)	1.3563
Fuel Cost	(฿/kWh)	1.3443
Average Generating Cost	(฿/kWh)	1.6699

Benefit of Hydropower Project		
kW Benefit		
Compensation coefficient	(p.u.)	1.067
kW benefit	(฿/kW)	2,008
kWh Benefit		
Compensation coefficient	(p.u.)	0.9694
kWh benefit	(฿/kWh)	1.3148
Secondary kWh Benefit	(฿/kWh)	1.3032

A.4.2 Natural Gas-fired Thermal as the Alternative

Cost of Alternative Thermal Power Project		
kW Cost	(฿/kW)	1,882
kWh Cost	(฿/kWh)	0.7874
Fuel Cost	(฿/kWh)	0.7754
Average Generating Cost	(฿/kWh)	1.101

Benefit of Hydropower Project		
kW Benefit		
Compensation coefficient	(p.u.)	1.067
kW benefit	(฿/kW)	2,008
kWh Benefit		
Compensation coefficient	(p.u.)	0.9694
kWh benefit	(฿/kWh)	0.7633
Secondary kWh Benefit	(฿/kWh)	0.7517

A.4.3 Lignite Fired Thermal as the Alternative

Cost of Alternative Thermal Power Project		
kW Cost	(฿/kW)	3,011
kWh Cost	(฿/kWh)	0.5064
Fuel Cost	(฿/kWh)	0.4839
Average Generating Cost	(฿/kWh)	1.008

Benefit of Hydropower Project		
kW Benefit		
Compensation coefficient	(p.u.)	1.067
kW benefit	(฿/kW)	3,213
kWh Benefit		
Compensation coefficient	(p.u.)	0.9694
kWh benefit	(฿/kWh)	0.4909
Secondary kWh Benefit	(฿/kWh)	0.4691

A.5 Benefit of Hydropower Project (Interest Rate: 10%)

A.5.1 Annual Benefit of Mae Pai No. 6 Project (10^6฿)

	Oil-fired	Natural gas	Lignite
kW Benefit	579.91	579.91	927.91
kWh Benefit (Firm)	648.85	376.69	242.26
kWh Benefit (2ndry)	160.75	92.72	57.86
Total Benefit	1,389.51	1,049.32	1,228.03

A.5.2 Annual Benefit of Mae Pai No. 1 Project (10^6฿)

	Oil-fired	Natural gas	Lignite
kW Benefit	97.71	97.71	156.34
kWh Benefit (Firm)	107.96	62.67	40.31
kWh Benefit (2ndry)	39.06	22.53	14.06
Total Benefit	244.73	182.91	210.71

A.5.3 Annual Benefit of Mae Chaem No. 5 Project (10^6฿)

	Oil-fired	Natural gas	Lignite
kW Benefit	195.72	195.72	313.17
kWh Benefit (Firm)	222.58	129.22	83.10
kWh Benefit (2ndry)	145.22	83.76	52.27
Total Benefit	563.52	408.7	448.54

A.5.4 Annual Benefit of Mae Chaem No. 4 Project (10^6฿)

	Oil-fired	Natural gas	Lignite
kW Benefit	54.04	54.04	86.46
kWh Benefit (Firm)	60.69	35.23	22.66
kWh Benefit (2ndry)	67.47	38.92	24.29
Total Benefit	182.2	128.19	133.41

A.6 Economic Evaluation

A.6.1 Benefit-Cost Analysis

Based on the annual benefits of the selected hydropower projects estimated in the previous Clause A.5 and the annual cost of the selected hydropower projects estimated in the Clause 12.5 of the Chapter 12, benefit-cost analysis was made, and the following results were obtained. In these studies, the shadow price factors are taking into consideration.

(1) In the case of oil fired thermal as the alternative

(Interest Rate: 10%)

Project	Annual benefit (B) (10^6฿)	Annual cost (C) (10^6฿)	B − C (10^6฿)	B/C
Mae Pai No. 6	1,389.51	866.42	523.09	1.604
Mae Pai No. 1	244.73	196.3	48.43	1.247
Mae Chaem No. 5	563.52	528.0	35.52	1.067
Mae Chaem No. 4	182.2	223.0	-40.8	0.817

(2) In the case of natural gas-fired thermal as the alternative

(Interest Rate: 10%)

Project	Annual benefit (B) (10^6฿)	Annual cost (C) (10^6฿)	B - C (10^6฿)	B/C
Mae Pai No. 6	1,049.32	866.42	182.9	1.211
Mae Pai No. 1	182.91	196.3	-13.39	0.932
Mae Chaem No. 5	408.7	528.0	-119.3	0.774
Mae Chaem No. 4	128.19	223.0	-94.81	0.575

(3) In the case of lignite-fired thermal as the alternative

(Interest Rate: 10%)

Project	Annual benefit (B) (10^6฿)	Annual cost (C) (10^6฿)	B - C (10^6฿)	B/C
Mae Pai No. 6	1,228.03	866.42	361.61	1.417
Mae Pai No. 1	210.71	196.3	14.41	1.073
Mae Chaem No. 5	448.54	528.0	-79.46	0.85
Mae Chaem No. 4	133.41	223.0	-89.59	0.598

A.6.2 Comparison of Benefit-cost Ratios by Various Alternative

Seeing from the Clause A.6.1, the project economic indeces are changed by alternative thermal power plant and are summarized below:

Fuel of alternative thermal / Project	Bunker C oil	Natural gas	Imported coal	Lignite
Mae Pai No. 6	1.604	1.211	1.525	1.417
Mae Pai No. 1	1.247	0.932	1.162	1.073
Mae Chaem No. 5	1.067	0.774	0.938	0.850
Mae Chaem No. 4	0.817	0.575	0.675	0.598

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