8-2-2. Project Crop Production

1) Crop Selection

The followings are fully considered to select the crops to be proposed by the subject Project :

- to be exportable
- to suit domestic consumption
- to meet extensible production
- to meet available cultivation technic
- to be productive
- to meet available labour
- to be effectual for irrigation
- to be adaptable for soil character

Paddy, maize, soybean, groundnuts, mungbean, mango and vegetable are consequently selected as the primary crops to meet the above requirements.

2) Cropping Pattern

Basically double cropping is introduced. The cropping patterns are classified into the following five categories depending on kinds and characters of second crops to be applied.

Field Character	Wet Season	Dry Season
- Paddy field	Paddy	Paddy
	Paddy	Soybean, Groundnuts Mungbean, Maize, Vegetables
- Upland field	Maize	Soybean, Groundnuts, Mungbean
	Vegetables	Vegetables
- Orchard	Mango	Mango

TABLE 8-2 CROPPING AREA BY IRRIGATION BLOCK

Unit: ha

Name of Irrigation Block	Wet Season					Dry Season							
	Paddy	Maize	Orchard	Vegetable	Total	Paddy	Maize	Soybean	G. Nuts	Mung	Orchard	Vegetable	Total
Existing Tha Lat	21,100	-	-	-	21,100	4,220	-	2,040	1,200	1,380	-	1,310	10,150
												(1,980)	(10,820)
Existing Bang Pakong	9,900	-	2,210	190	12,300	1,980	-	280	920	1,780	2,210	1,370	8,540
												(2,060)	(9,230)
Tha Lat Expansion	3,400	700	3,000	-	7,100	680	460	1,030	810	-	3,000	150	6,130
												(230)	(6,210)
Bang Pakong Expansion	-	-	1,950	50	2,000	-	-	-	-	-	1,950	50	2,000
												(80)	(2,030)
Total	34,400	700	7,160	240	42,500	6,880	460	3,350	2,930	3,160	7,160	2,880	26,820
												(4,350)	(28,290)
Crop Intensity					100.0%								49.7 %

Note: Parenthesis stands for the total planted area.

Crop intensity in dry season $= \frac{28,290 - 7,160}{42,500} = \times 100 = 49.7\%$

3) Cropping Area by Crop

Cropping areas by crop and by irrigation sub-basin are proposed in consideration of availability of irrigation water, farmer's intention, crop productivity, etc, as shown in Table 8-2 and as summarized in the following :

Crop	Wet Season (ha)	Dry Season (ha)	Total (ha)
Paddy	34,400	6,880	41,280
Maize	700	460	1,160
Soybean	-	3,350	3,350
Groundnuts	-	2,930	2,930
Mungbean	-	3,160	3,160
Vegetables	240	4,350	4,590
Mango	7,160	(7,160)	7,160
Total	42,500	21,130	63,630

Crop Intensity 149.7 % (present 101.5 %)

4) Cropping Calendar

Recommendable cropping calendar for paddy, maize, soybean, groundnuts, mungbean, vegetable and mango is shown in Figure 8-1. However, maize of rainy season is not irrigated.

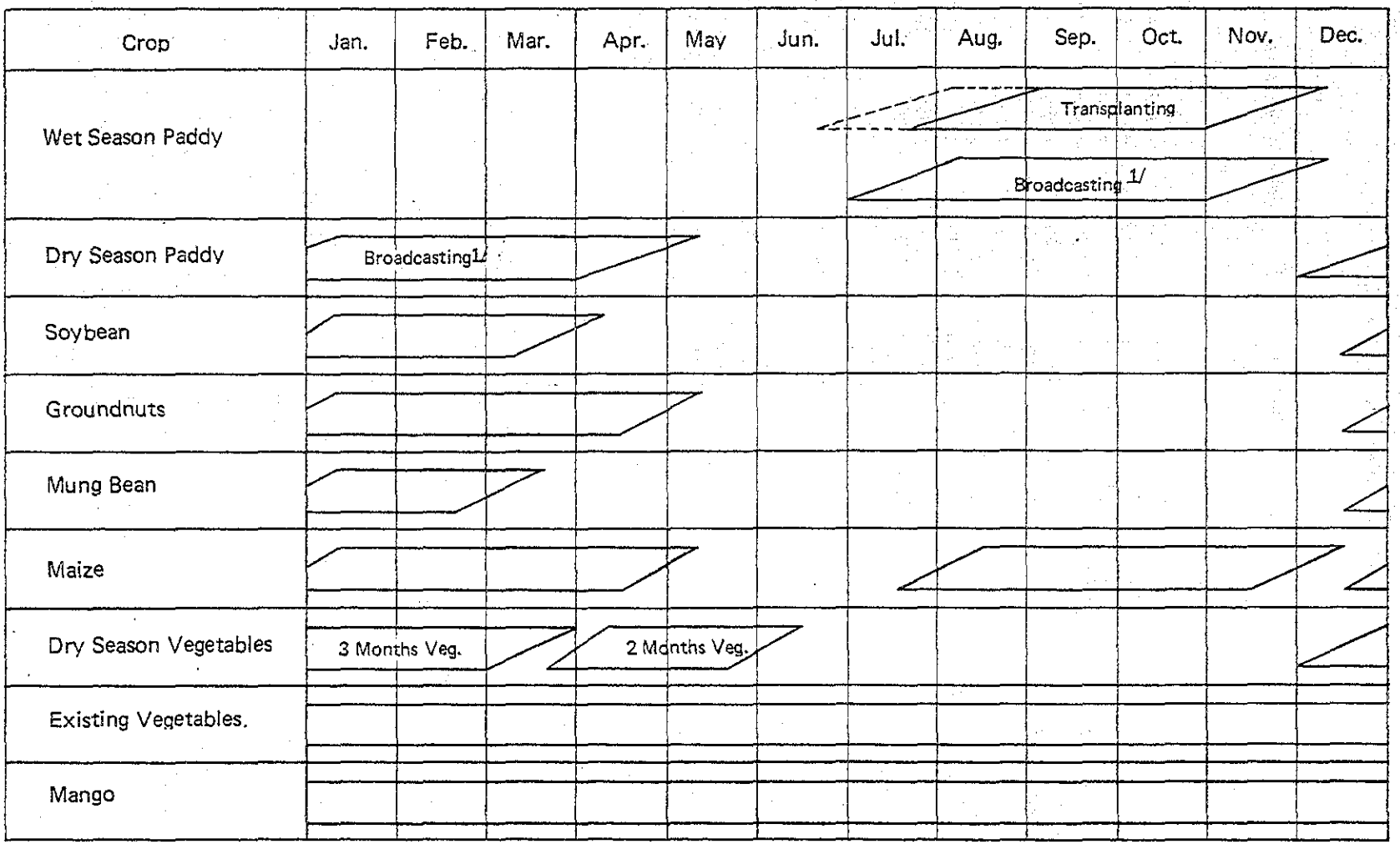
5) Crop Production

Crop	Area (ha)	Yield (kg/ha)	Production(t)
Paddy wet season	34,400	4,000	137,600
dry season	6,880	4,500	30,960
Maize wet season	700	2,100	1,470
dry season	460	2,500	1,150
Soybean	3,350	1,500	5,025
Groundnuts	2,930	1,500	4,395
Mungbean	3,160	1,100	3,476
Vegetables	4,590	14,300	65,626 /2
Mango	7,160	13,800 /1	98,808

Full development year is estimated as follows, and transitional cropping area and crop production are shown in Table 8-3.

	Full Development Year
Phase I	
Existing Bang Pakong Area	2002
Bang Pakong Expansion Area	1989
Phase II	
Existing Tha Lat Area	2001
Tha Lat expansion Area	2008

FIGURE 8-1 CROPPING CALENDAR



Note: 1/ Germinated seed broadcasting

TABLE 8-3 TRANSITION OF CROP YIELD

Unit : kg/ha

Item	Present	Number of years after completion of Project 1	2	3	4	5
Paddy						
Wet Season						
Exs. Tha L.	2,141	3,210	3,850	4,000	4,000	4,000
Exs. Bang.P.	2,079	3,120	3,740	4,000	4,000	4,000
Tha L. Expa.	1,947	2,920	3,500	4,000	4,000	4,000
Dry Season	3,750	3,920	4,280	4,500	4,500	4,500
Soybean	-	1,200	1,400	1,500	1,500	1,500
Groundnuts	-	1,200	1,400	1,500	1,500	1,500
Mungbean	-	900	1,000	1,100	1,100	1,100
Maize (D.S)	-	2,300	2,400	2,500	2,500	2,500
Chili	-	10,500	13,500	15,000	15,000	15,000
Tomato	-	12,600	16,200	18,000	18,000	18,000
Sweet Corn	-	7,900	10,200	11,300	11,300	11,300
Baby Corn	-	4,400	5,700	6,300	6,300	6,300
Chinese Cabbage	-	13,200	16,900	18,800	18,800	18,800
Green Bean	-	10,900	14,000	15,600	15,600	15,600
Mango New Plant Area /1	-	1,560	2,340	4,690	9,380	15,630
Exis. Bang P.	5,210	7,300	9,380	15,630	15,630	15,630
Bang P. Expa.	3,020	4,690	9,380	15,630	15,630	15,630

/1 1,560 kg/ha : yield of 4 years old mango.

6) Agricultural Input Material

A field husbandry plan has been established as given in Table 8-4, and the requirements of agricultural input material by crop per year are summarized from the said table, as follows:

Recommended Agricultural Input

Unit : ton

Item	Seed	Comp.F	Urea	Dung	Lime	P_2O_5	Agro.Che.
Paddy	2,920	11,696	2,600	-	75,680	20,640	1,073
Maize	22	192	-	-	-	-	-
Soybean	147	523	-	-	-	-	-
Groundnuts	147	457	-	-	-	-	-
Mungbean	60	493	-	-	-	-	-
Vegetables	64	1,744	-	45,900	528	144	15,300 ℓ
Mango	861,800 tree	788	995	50,120	-	-	39,380 ℓ
Total	3,360	15,893	3,595	96,020	76,208	20,784	1,073 t 54,680 ℓ

TABLE 8-4 FIELD HUSBANDRY PLAN

	Planting Period	Seed Quantity (kg/ha)	Crop Distance (cm)	Fertilizer (kg/ha or kg/tree) Compound	Urea	Dung (t/ha)	Acid Lime (t/ha)	Soil P2 O5 (kg/ha)	Pesticide (kg)	Harvest Period
Paddy										
Wet S.T.P.	Jul. Sep.	63	25 × 30	280 (16-20-0)	63	-	1.9~2.5	600	26	Nov. Dec.
G.B.C.	Jul. Aug.	94	-	280 (16-20-0)	63	-	do	600	26	Nov. Dec.
Dry G.B.C.	Dec. May.	94	-	300 (16-20-0)		-		-	26	Apr. May.
Maize					-					
Wet Season	Jul. Dec.	19	30 × 75	150 (20-20-0)	-	-	do	-	-	Nov. Dec.
Dry Season	Dec. May	19	30 × 75	190 (20-20-0)	-	-	-	-	-	Apr. May.
Soybean	Dec. Apr.	44	25 × 25	156 (12-24-12)	-	-	-	-	-	Mar. Apr.
Groundnuts	Dec. May	50	20 × 30	156 (12-24-12)	-	-	-	-	-	Apr. May.
Mungbean	Dec. Mar	75	20 × 50	156 (12-24-12)	-	-	-	-	-	Feb. Mar.
Vegetables										
Chili	all month	1.7	60 × 60	440 (15-15-15)	-	10	-	-	-	70 90 days
Tomato	Dry S.	0.6	50×80 100	500 (15-15-15)	-	10	-	-	4.8~7.21	70 80
Sweet Corn	all month	19.0	30×50 75	280 (20-20-20)	-	10	-	-	4.8	90
Baby Corn	all month	30.0	30 × 75	250 (20-20-20)	-	10	-	-	-	50
Chinese Cabbage	all month	5.0	40 × 60	500 (20-10-10)	-	10	-	-	2.4~4.8	60 90
Green Bean	all month	25.0	50 × 80	312 (6-12-12)	-	10	-	-	2.4~4.8	60 90
Mango		278tree	68 × 68	110 (15-15-15)	0.5	20~30 kg/tree	-	-	5.0~6.0	

T.P. : Transplanting, G. B. C. : Germinated seed Broadcasting
Application of p2.05 : 600 kg/ha/5year, 120 kg/ha/year
Application of Lime : 9.4~12.5 t/ha/5 year, 1.9~2.5 t/ha/year

7) Labor Requirement

The Project area has 14,800 farm household and available farm labors are estimated by irrigation block as follows :

Project Area	No. of farm household	Population / household	Available labor man/day
Existing Tha Lat Area	7,326	4.76	20,923
Existing Bang Pakong Area	5,091	5.27	16,098
Tha Lat Expansion Area	1,776	5.00	5,328
Bang Pakong Expansion Area	607	5.27	1,919

Note : Available labor rate assumed at 60 percent
Available labor = farm family member × 0.6 × number of household × 25 days/month × 12 months

TABLE 8-5 LABOR REQUIREMENT BY CROP

Unit : hour/ha

Crop			Labor requirement	Remark
Paddy	W.S	Transplanting	779.5	
		Broadcasting	649.5	
	D.S	Broadcasting	729.5	
Maize			378.0	
Soybean			369.0	
Groundnuts			560.0	
Mungbran			348.0	
Chili			801.0	
Tomato			1,678.0	
Baby Corn			339.0	
Mango			740.0	bearing age.

8-2-3. Agricultural Supporting Services

The present extension services require some improvements. Furthermore the intensified and scheduled extension is indispensable for the transitional period of agriculture from traditional farming to modernized one. The following measures should be taken for improving and intensifying the present extension services carried out in the Project area.

- **Increase in Extension Works**

The number of farm household to be charged by one extension staff should be reduced to 500 from the current duty of 800~1,900 by increasing the extension staff in number.

- **Quality Extension Service**

It is necessary to establish an effective extension program by strengthened training and education of the extension staff and by introducing the Subject Matter Specialist system in Amphoe extension office under the close coordination with the Agricultural Research Center.

- **Strengthening the functions of Extension Offices**

It is necessary to expand extension offices with farmers' meeting rooms and extension staff should be provided with transportation facilities such as jeep, and audio-visulal education equipments for effective services.

- **Seed service**

After the Project, the seed requirement is estimated to be about 3,400 t together with about 862,000 of mango nursery stocks.

Therefore, the Provincial Agricultural Extension Office will have to provide these crop seeds and nursery stocks. Requirement of seeds is as follow:

Item	Seed requirement	4 years renewal
	t	t
Paddy	2,920	730
Maize	22	6
Soybean	147	37
Groundnuts	147	37
Mungbean	60	15
Vegetables	64	every year
Mango	861,800 stocks	1/ 215,450 stocks/year

1/ planting period 4 year

8-2-4. Agricultural Cooperatives and Farmers Group

1) Agricultural Cooperatives

Each District related to the Project area has one or two agricultural cooperatives. The works of these agricultural cooperatives are not always active in spite of an earnest administrative direction by the provincial agricultural cooperative office.

In general, the works of the agricultural cooperative are classified into the purchasing of fertilizer, agricultural chemical, seeds, machinery, living materials, etc., the selling of rice and maize, the warehouse business/rice milling and credit.

According to the results of the socio-agro economic survey, an utilization of the agricultural cooperatives works by the membership is found in the sectors of credit and purchasing.

However, sample farmers purchase about 66% of applied volume of chemical fertilizer and about 83% of agricultural chemical from the merchant in villages or town. The ratios of rice, mango and coconuts purchasedby the merchant occupy 71%, 100% and 100% respectively. The ratio of membership used the credit works is only 2.5%. These figures indicate that a low utilization of the agricultural cooperative works is still low level.

In the integrated agricultural development plan, an application volume of chemical fertilizer of 200 kg per ha of rice and other crops per rai at present is projected to increase by 580 kg per ha of total cultivating area at the full development stage. The agricultural production volume would be expanded from about 135,000 tons at present to about 348,000 tons in the future. Credit money for input material and hired labor would be enlarged.

In the Six National Economic and Social Development Plan (1987 - 1991), major works plan under the programme for development of the production system, marketing and employment have been executed. The integrated agricultural development plan in this study should be executed in consideration of major works plan, particularly, developing the system of production for sale, restructuring agricultural production, developing agro-industries, crop diversification and developing agricultural know-how and technology.

The key factors to be indispensable for successful realization of the integrated agricultural development plan are the supply of input materials at cheaper prices, the expansion of institutional credit at low interest and the assurance to keep so profitable prices to be received by farmers as to be realized through high quality of products and technical improvement in post-harvest and packing process.

The agricultural cooperative would play an important role for realization of the key factors as mentioned above. In order to meet this expectation, an increase in the membership of the existing agricultural cooperatives, establishment of new cooperatives and training of excellent management staff are indispensable.

Consequently, development of the agricultural cooperative would be realized through not only strong support by the Government but also the success of farm economy of membership.

Repayment of membership's debts will become stable because of rich farm economy. The agricultural cooperative will be able to control their funds smoothly. As a result, the works would be active.

2) Farmers' Group

The farmers' groups are established in each District and under the jurisdiction of Department of Agricultural Extension. The numbers of the farmers' groups amount to 38 in Chachoengsao and 15 in Chonburi in the Project area.

The main works of the farmers' groups are to give loans/credits, to distribute agricultural input materials, to collects agricultural products for processing and marketing, to promote agricultural occupations and to give technical assistance. Types of occupations are divided into rice farmers, gardeners, agronomists (field crops), livestock raisers, fishermen, etc. The majority is rice farmers.

As a result of the socio-agro-economic survey, purchasing of fertilizer and agricultural chemical is carried out by the farmers' group.

In order to realize successfully the integrated agricultural development plan, the farmers' group would play the same important role as that of the agricultural cooperatives.

Specially, a cooperative spirit will be easily strengthened owing to a small number of membership. Consequently, the works of the farmers' group should be actively promoted through cooperation, marketing research and technical transfer.

8-3. Water Resources Development Plan

8-3-1. Irrigable Area and Irrigation Water Demand

The agricultural land of 42,500 ha (265,625 rai) to be irrigated by the subject Project involves the existing Tha Lat and Bang Pakong Left Bank irrigation project area and proposed expansion area of the Tha Lat and Bang Pakong Left Bank. The Project envisages to extend irrigation area by introducing double croppings in dry season to a level of some 150% of the cropping intensity. The Project also intends to supply fresh water to shrimp ponds, freshwater fishponds, industry and domestic water supply.

Considering the water availability and agronomic aspect as well, irrigation scheme was established as shown below :

Sub-Project	Season	Irrigation Service Area and Proposed Crops						
Existing Tha Lat Irrigation Project Area	Wet	Paddy (21,100ha)						
	Dry	Paddy (4,220ha)	Upland Crops (4,620ha)	Vegetables 1310ha				
Existing Bang Pakong Left Bank Project Area	Wet	Orchard (2210ha)	Paddy (9,900ha)	Veg. (190 ha)	Net Area = 12,300ha			
	Dry	Orchard (2210ha)	Upland Crops (2,980ha)	Paddy (1980ha)	Vegetables 1370ha			
Proposed Tha Lat Expansion Area	Wet	Orchard (3,000ha)	Maiz (700 ha)	Paddy (3,400ha)	Net Area = 7,100ha			
	Dry	Orchard (3,000ha)	Upland Crops (1840ha)	Maiz (460 ha)				
Proposed Bang Pakong Left Bank Area	Wet	Orchard (1950ha)	Vegt (50 ha)	Net Area = 2,000ha				
	Dry	Orchard (1950ha)	Vegt (50 ha)					

: Not planted

Cropping Intensity = 150 %

Parameters and assumptions, as previously mentioned in section 4.3.5 and as briefed below, were used to estimate crop water consumption and on-farm and diversion requirements.

Cropping Calendar

Cropping calendar was prepared in accordance with the field survey on farming practice and with recommendations from agronomic point of view, as given in Figure 8-1.

Reference Crop Evapotranspiration and Kp/Kc Values

Modified Penman Method was employed to estimate water consumption of paddy, vegetables and fruit crops, while Pan-Evaporation Method was used for upland crops.

Field Water Requirement

Percolation rate of 2.0 mm/day was applied in consideration of soil condition in the Project area, As for the requirements for both initial leaching and land preparation for paddy cultivation, respectively 50 mm and 150 mm were used.

Effective Rainfall

RID's rating curve showing relationship between monthly rainfall and monthly effective rainfall was applied. In each irrigation block, areal rainfalls were calculated by use of Thiessen Method.

Irrigation Efficiency

Overall efficiencies were taken at $0.85 \times 0.70 = 0.595$ and $0.70 \times 0.70 = 0.49$, respectively for paddy rice and upland crop cultivations.

Irrigation diversion requirement varies from time to time and from place to place depending on the availability of effective rain. Computations were made with a 10-day time step combining the above parameters and assumptions, as summarized in the following :

Irrigation Water Demand (MCM)

Area	Season	Maximum	Minimum	Average
Existing Tha Lat	wet	175.2 (1979)	80.0 (1983)	119.3
	dry	115.6 (1968)	79.0 (1975)	106.8
	annual	287.4 (1979)	180.3 (1983)	226.1
Existing & Proposed Expansion of Bang Pakong	wet	81.5 (1979)	39.4 (1983)	57.2
	dry	196.8 (1968)	178.2 (1973)	186.3
	annual	274.1 (1979)	224.2 (1983)	243.5
Tha Lat Expansion	wet	27.2 (1979)	12.8 (1983)	18.7
	dry	58.9 (1968)	46.6 (1984)	52.0
	annual	84.1 (1979)	59.9 (1969)	70.7
Whole Service Area	wet	283.9 (1979)	132.2 (1983)	195.3
	dry	371.3 (1968)	322.3 (1973)	345.0
	annual	645.6 (1979)	465.5 (1983)	540.3

8-3-2. Fishery Water Demand

About 4,000 rai of shrimp pond extends over the lower reaches of the Bang Pakong river mainly in amphoes Bang Pakong and Ban Pho. Supported by tidal movement in the river, high salinity water is deverted during flood tide and on the contrary low salinity water from the river surface during ebb tide. They are then mixed each other to produce brackish water of suitable salinity content for shrimp raising. Although the suitable salinity varies with growing stage of shrimps, it is generally said to be 15 to 25 ppt. According to the annual report issued by the Chanthaburi Brackish Water Fishery Station of Department of Fishery, however, raising of shrimp in a tank with salt water mixed with fresh water at a level of 30 to 31 ppt has achieved a great success.

In case that a diversion dam is constructed on the Bang Pakong river upstream of the shrimp farming zone, the river salinity would increase to a constant level of 33.5 ppt during dry season, due to decrease of fresh water release from upstream of the dam. Fresh water demand to keep the river salinity contents on a level of 30 ppt, at a maximum, can be estimated as follows:

- Dimension of a typical shrimp pond in the area is given as 40m(W) ×80m(L)×1.5m(D), with a capacity of 4,800 cu.m. A ratio of the net water surface area to the gross area of shrimp farm is also estimated at about 65%.

- The depth of water in a pond is usually adjusted as shrimps grow. Such depths vary from 50% of the standard depth of 1.5m for the initial one month, 75% for a succeeding month and 100% for the third and fourth months, resulting an average depth of about

1.2 m. It is also important to change as much water as possible in accordance with bailability of oxygen and plankton as well as depending on growing stage of shrimp. The following assumptions were employed :

- The pond water is freshened every two days.
- Amount of water to be changed at a time is taken at 20% of the currently stored water in a pond.

- Taking salinity of river water at 33.5 ppt, fresh water at 0 ppt and mixed water at 30 ppt, the required amount of fresh water (α) to produce a unit volume of mixed water is given as :

$$\alpha = (33.5 - 30.0)/33.5 = 0.1045$$

- Unit water requirement is thus calculated as :

$$1{,}000 \text{ ha} \times 0.65 \times 10^4 \times 1.2\text{m} \times 0.2 \times 0.1045 \times 1/2$$

$$= 0.0815 \text{ MCM/day/1,000 ha}$$

- Existing extent of 4,000 rai in the project area is expected to be expanded to about 8,300 rai at a maximum. The fresh water requirement is thus estimated approximately at 14.50 MCM annually.

Besides, about 8.750 rai (1,400 ha) of freshwater fishpond has been cultivated receiving water from irrigation canals and natural streams, mainly in the existing irrigation project areas of Tha Lat (1,000 ha) and Bang Pakong Left Bank (400 ha). Water demand was estimated under the following assumptions :

- Period of fish raising was estimated at 3.5 months as a cycle.
- Three cycles of cultivation per year was assumed to be in progress.
- Initial water requirement for preparation of the pond was assumed at 700mm
- After once the pond is filled with water, only limited volume of water corresponding to losses due to evaporation and percolation is supplemented.
- The above procedures are shown in Figure
- Net water surface area was assumed at 65% of the farming area.

- Water consumption was thus estimated at 4,359 mm/year based on the daily water demand estimation as below :

Month	Daily Demand	Monthly Demand
4	20.9	627
5	14.2	440
6	6.8	204
7	6.1	189
8	19.3	598
9	13.5	405
10	6.5	202
11	6.7	201
12	19.9	617
1	14.2	440
2	7.6	213
3	7.2	223
Total		4,359

Water demand for fishery so estimated is summarized as follows :

Fishery Water Demand (MCM)

Area	Season	Maximum	Minimum	Average
Existing Tha Lat	wet	3.2 (1979)	2.6 (1983)	3.0
	dry	3.7 (1971)	3.4 (1983)	3.0
	annual	6.9 (1979)	6.0 (1983)	6.4
Existing & Proposed	wet	2.0 (1979)	1.6 (1983)	1.8
Expansion of Bang	dry	11.2 (1968)	11.0 (1983)	11.0
Pakong	annual	13.1 (1979)	12.6 (1983)	12.8
Tha Lat Expansion	annual			
Whole Service Area	wet	5.2 (1979)	4.2 (1983)	4.8
	dry	14.8 (1979)	14.4 (1973)	14.3
	annual	20.0 (1979)	18.7 (1983)	19.1

8-3-3. Domestic and Industrial Water Supply Demand

Based on the findings as summarized in Table E-1-8, Appendix E, water demands to be required for the subject Project from industrial water supply and domestic water supply sectors are extracted and totaled as given in Table 8-6.

Irrigation Service Area	Amphoe	Water Source	Water Demand		
			Industry	Domestic	Total
			(MCM/yr)	(MCM/yr)	(MCM/yr)
Tha Lat, Existing	Phnom Sarakan	Existing Tha Lat Weir	9.798	3.810	13.609
	Plaeng Yao		36.304	1.519	37.822
	Sub-total		46,103	5.329	51.432
Bang Pakong, Existing	Ban Pho	Bang Pakong Diversion Dam	9.350	1.760	11.109
	Bang Pakong		61.950	4.596	66.546
	Sub-total		71.300	6.356	77.656
Tha Lat, Expansion	Sanamchai Ket	Rabom Dam & Si Yat Dam	1.480	7.416	8.896
	Sub-total		1.480	7.416	8.896
Bang Pakong, Expansion	Bang Khra	Bang Pakong Diversion Dam	19.217	2.849	22.066
	Chachoengsao		22.653	10.735	33.388
	Sub-total		41.870	13.584	55.454
Total			160.753	32.685	193.438

8-3-4. Overall Water Demand

Overall water demand including irrigation, fishery, industry and domestic water supply is thus evaluated as follows :

TABLE 8-6 INDUSTRIAL AND DOMESTIC WATER DEMAND BY IRRIGATION BLOCK

Amphoe	Irrigation Block	Industrial		Domestic Water		Total Quantity
		Sharing	Quantity	Sharing	Quantity	
		(%)	(MCM)	(%)	(MCM)	(MCM)
(1) Tha Lat Existing Area						
Phanom Sarakam	LBP- 3	30	2.939	30	1.143	4.082
Phanom Sarakam	LBP-16	20	1.960	20	0.762	2.722
Phanom Sarakam	LBP-17	20	1.960	20	0.762	2.722
Phanom Sarakam	KTL- 2	20	1.960	20	0.762	2.722
Phanom Sarakam	KTL- 3	10	0.980	10	0.381	1.361
Plaeng Yao	LBP- 3	50	18.152	50	0.759	18.911
Plaeng Yao	LBP-13	20	7.261	20	0.304	7.565
Plaeng Yao	LBP-14	10	3.630	10	0.152	3.782
Plaeng Yao	LBP-15	20	7.261	20	0.304	7.565
Total			46.103		5.329	51.432
(2) Bang Pakong Left Bank Existing Area						
Ban Pho	LBP- 3	50	4.675	50	0.880	5.555
Ban Pho	LBP-13	20	1.870	20	0.352	2.222
Ban Pho	LBP-14	10	0.935	10	0.176	1.111
Ban Pho	LBP-15	20	1.870	20	0.352	2.222
Bang Pakong	LBP- 1	10	6.195	10	0.460	6.655
Bang Pakong	LBP- 2	30	18.585	30	1.379	19.964
Bang Pakong	LBP- 3	40	24.780	40	1.838	26.618
Bang Pakong	LBP- 4	20	12.390	20	0.919	13.309
Total			71.300		6.356	77.656
(3) Tha Lat Expansion Area						
Sanamchai Ket	LBP-16	10	0.148	10	0.742	0.890
Sanamchai Ket	KTL- 4	40	0.592	40	2.966	3.558
Sanamchai Ket	KTL- 5	20	0.296	20	1.483	1.779
Sanamchai Ket	KTL- 6	10	0.148	10	0.742	0.890
Sanamchai Ket	KTL- 7	20	0.296	20	1.483	1.779
Total			1.480		7.416	8.896
(4) Bang Pakong Expansion Area						
Bang Khra	LBP- 2	10	1.922	10	0.285	2.207
Bang Khra	LBP- 3	60	11.530	60	1.709	13.239
Bang Khra	KTL- 1	10	1.922	10	0.285	2.207
Bang Khra	UBP- 1	20	3.843	20	0.570	4.413
Chachoengsao	LBP- 2	40	9.061	40	4.294	13.355
Chachoengsao	LBP- 3	60	13.592	60	6.441	20.033
Total			41.870		13.584	55.454
Grand Total			160.753		32.685	193.438

Overall Water Demand (MCM)

Area	Season	Maximum	Minimum	Average
Existing Tha Lat	Wet	205.7 (1970)	109.9 (1983)	149.6
	Dry	146.3 (1968)	127.5 (1975)	136.8
	Annual	348.6 (1979)	240.6 (1983)	286.4
Existing & Proposed Expansion of Bang Pakong	Wet	166.6 (1979)	124.1 (1983)	142.2
	Dry	291.4 (1968)	272.1 (1973)	278.9
	Annual	453.3 (1979)	402.9 (1983)	421.1
Tha Lat Expansion	Wet	31.8 (1979)	17.4 (1983)	23.3
	Dry	63.5 (1968)	51.2 (1984)	56.6
	Annual	93.4 (1979)	69.2 (1969)	79.9
Whole Service Area	Wet	404.0 (1979)	251.4 (1983)	315.0
	Dry	501.2 (1968)	451.3 (1973)	472.3
	Annual	895.2 (1979)	713.8 (1983)	787.3

8.3.5. Water Balance

Prior to the water balance simulation study, a hydrological review study was conducted on the monthly distribution pattern of the basin runoff.

Hydrological Review Study

Since the estimation of basin runoff was primarily based on the basin rainfall, the monthly distribution pattern of runoff also has had a close correlation with that of basin rainfall. River runoffs actually measured at gauging stations, however, show a considerably different pattern of seasonal flows due mainly to seasonal variation of the rate of runoff against basin rainfall. Monthly distributions of river runoff were, hence investigated at several representative gauging stations, and finally three stations, i.e. Kgt.3, Ny.1 and Kgt.18, were selected to represent personal pattern of runoff from sub -basin located upstream of the Bang Pakong river basin. Runoff patterns estimated directly from the basin rainfall were also used for sub-basins in the lower reaches of the river system where no actual measurement of discharge is available and where river runoff would show a different pattern as compared with those from mountainous catchment.

Type of Runoff Pattern	Description
Type - 1	Seasonal pattern observed at Kgt.3 station
Type - 2	Seasonal pattern observed at Ny.1 station
Type - 3	Seasonal pattern observed at Kgt.18 station
Type - 4	Seasonal pattern of basin rainfall

Figure 8-2 illustrates the application of runoff pattern, and typical runoff patterns in terms of monthly average are presented in Figure 8-3.

FIGURE 8-2 APPLICATION OF MONTHLY DISTRIBUTION OF RUNOFF

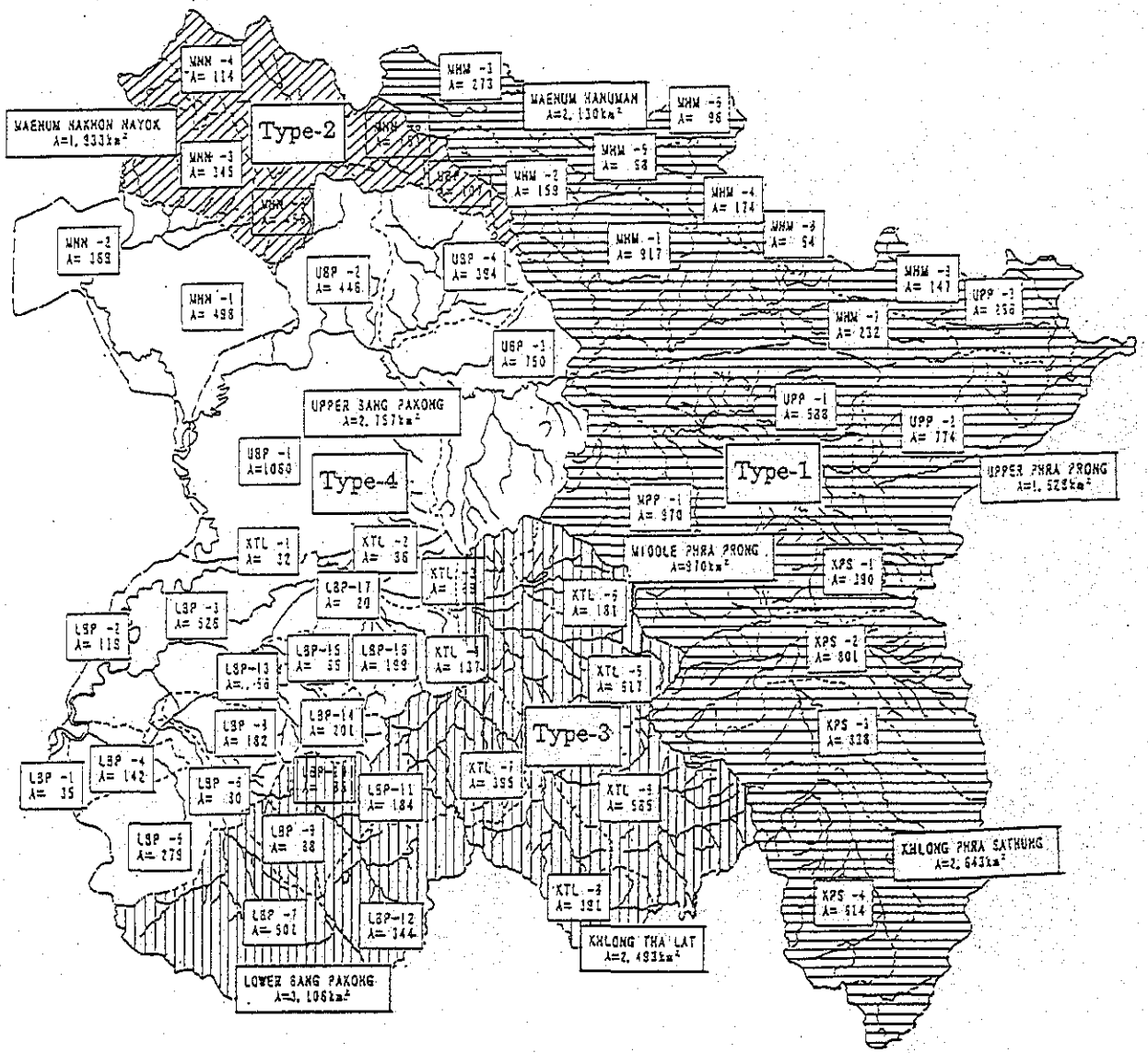
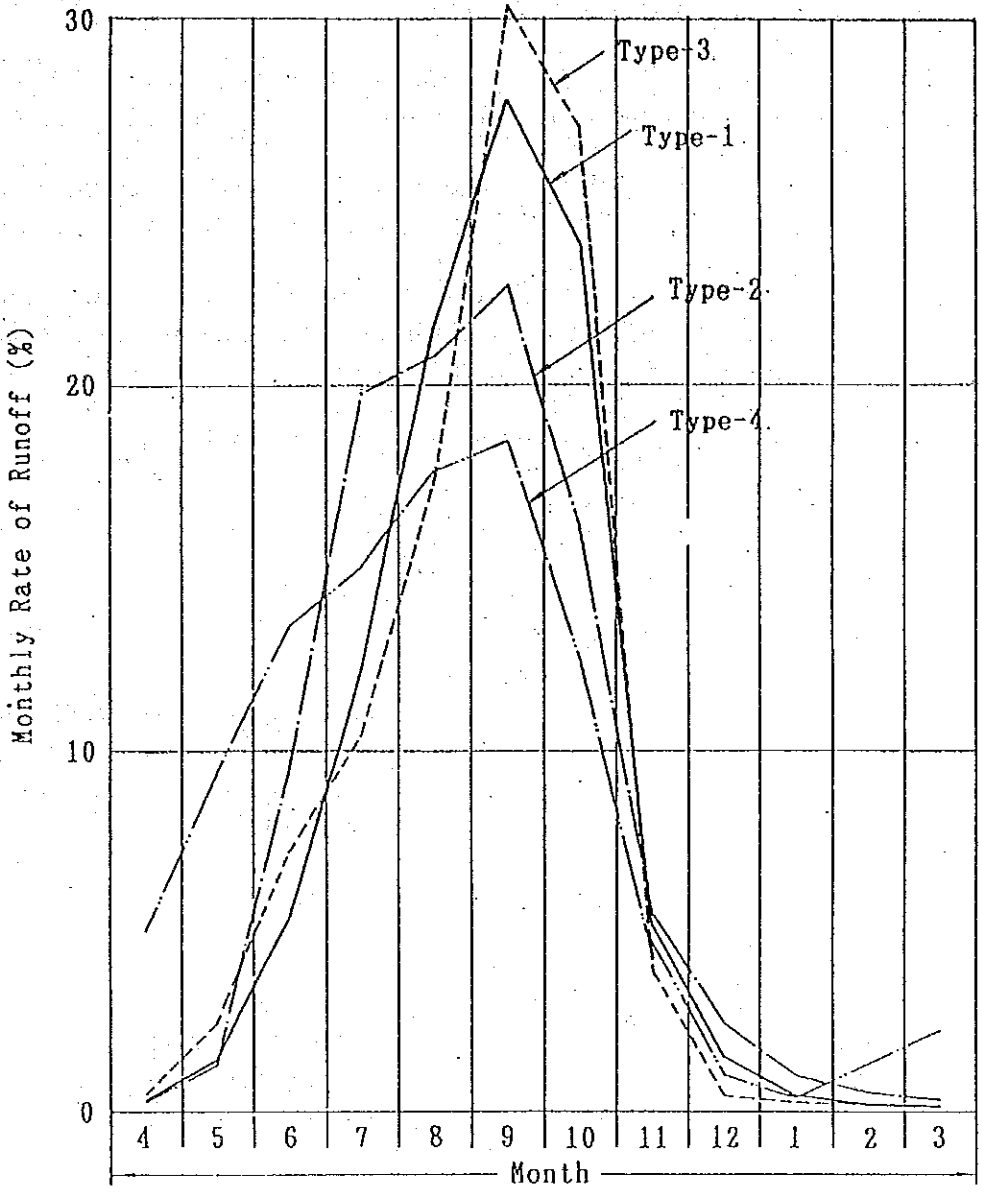


FIGURE 8-3 REPRESENTATIVE MONTHLY PATTERN OF RUNOFF



Monthly Pattern of Runoff (%)

Station	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Type
Kgt.3	0.29	1.42	5.42	12.23	21.54	27.81	23.79	5.14	1.52	0.46	0.22	0.19	Type-1
Hy.1	0.26	1.29	9.59	19.75	20.79	22.66	15.97	5.43	2.42	0.98	0.53	0.33	Type-2
Kgt.18	0.47	2.40	7.26	10.45	17.23	30.34	26.98	3.86	0.42	0.25	0.19	0.15	Type-3
Rainfall	5.01	9.38	13.38	14.96	17.48	18.40	12.48	4.19	1.02	0.41	1.09	2.19	Type-4

All computations for water balance simulation were made with a 10-day time step for the recent 20 years from 1968 up to 1987, during which a complete set of hydrological data are available.

Two alternative cases of water balance study were undertaken as visualized in Figures 8-4 and 8-5. Brief explanations are as follows :

Case-1 : Proposed condition after completion of the Khlong Rabom Dam, Bang Pakong diversion dam and Khlong Si Yat Dam.

Case-2 : Transitional condition after completion of Khlong Rabom Dam and Bang Pakong diversion Dam, but before completion of Khlong Si Yat Dam

The following assumptions were employed in computations :

- Live storages of reservoirs
  - Khlong Rabom Dam : 40 MCM
  - Khlong Si Yat Dam : 300 MCM
  - Bang Pakong diversion Dam : freshwater storage of 30 MCM between the upper (+1.0m) and lower (-1.0m) control water level
- Priority of water utilization for irrigation

  After utilizing effective rainfall within the irrigation service are as well as from the upstream drainage area is diverted from natural canals for irrigation. River channel storage is then used when water shortage occurs and whenever excess channel storage is available. Deficiency is finally depended on dam source.
- Water allocation

  In consideration of locations of the existing and proposed water sources, irrigation systems and beneficial area, water allocation among water sources and water users are preliminarily determined as follows :

FIGURE 8-4 ALTERNATIVE CASE STUDIES OF WATER BALANCE

(Case - 1 : Bang Pakong Diversion Dam + Si Yat Dam + Rabom Dam)

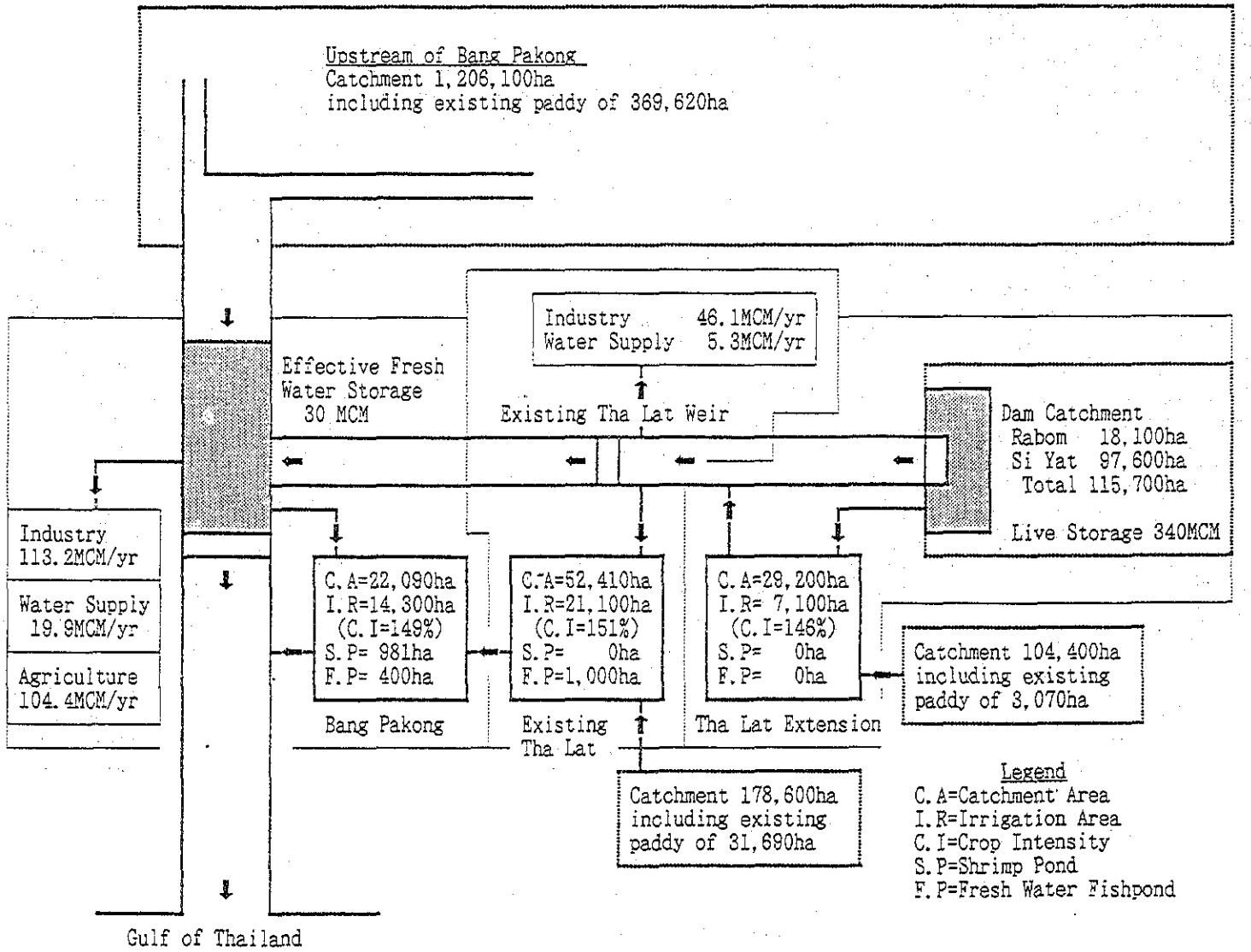


FIGURE 8-4-add. DIAGRAM FOR WATER BALANCE STUDY
(FOR CASE-1 OF WATER BALANCE SIMULATION)

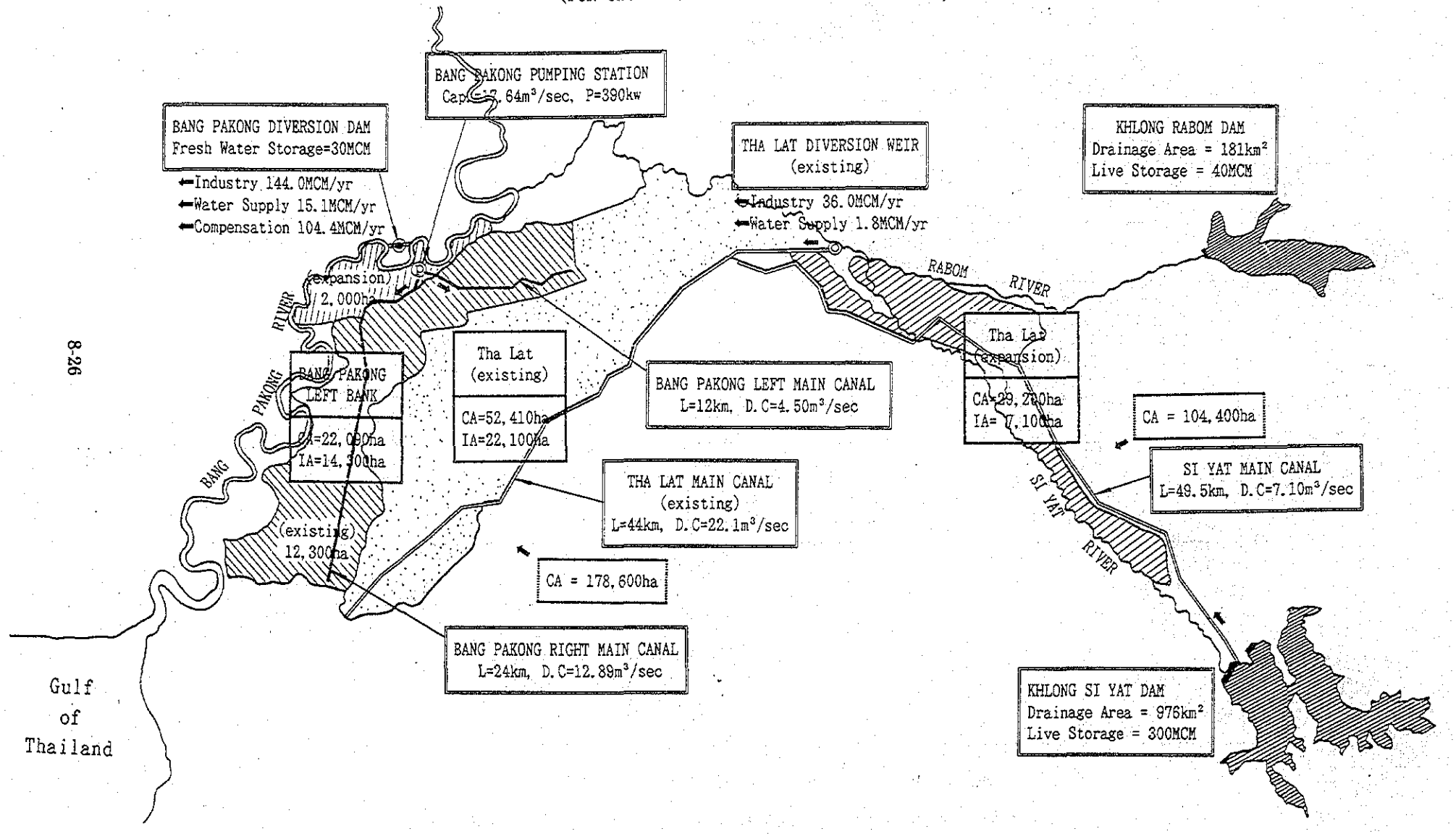
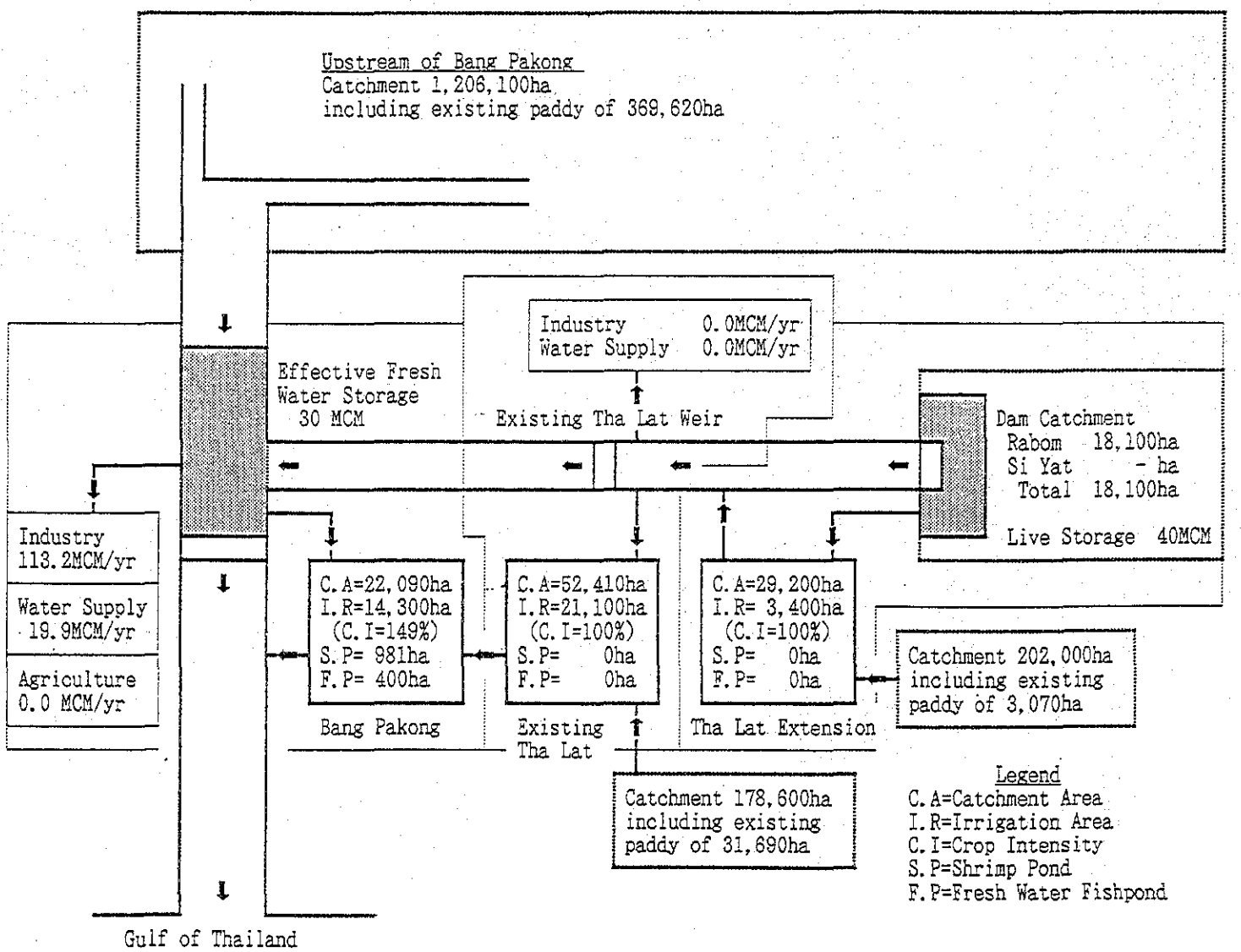


FIGURE 8-5 ALTERNATIVE CASE STUDIES OF WATER BALANCE

(Case-2 : Bang Pakong Diversion Dam + Rabom Dam)



Water Sources	Water Users	
Bang Pakong diversion dam	Irrigation :	Existing and proposed extension of Bang Pakong Left Bank plus compensatory water supply to the Bang Pakong Right Bank area
	Industry and domestic water supply	
Existing Tha Lat weir	Irrigation :	Existing Tha Lat area
	Industry and domestic water supply	
Rabom and Si Yat dam	Irrigation :	Proposed Tha Lat expansion

- Dam Operation

  The Bang Pakong diversion dam is so operated as to keep the upper limit of control water level (+1.0m) whenever possible. This means that water is released from the upstream Robom and Si Yat dams in order to restore the diversion dam storage if the inflow into the diversion dam is less than the demand required and when excess storage is available in upstream dams.

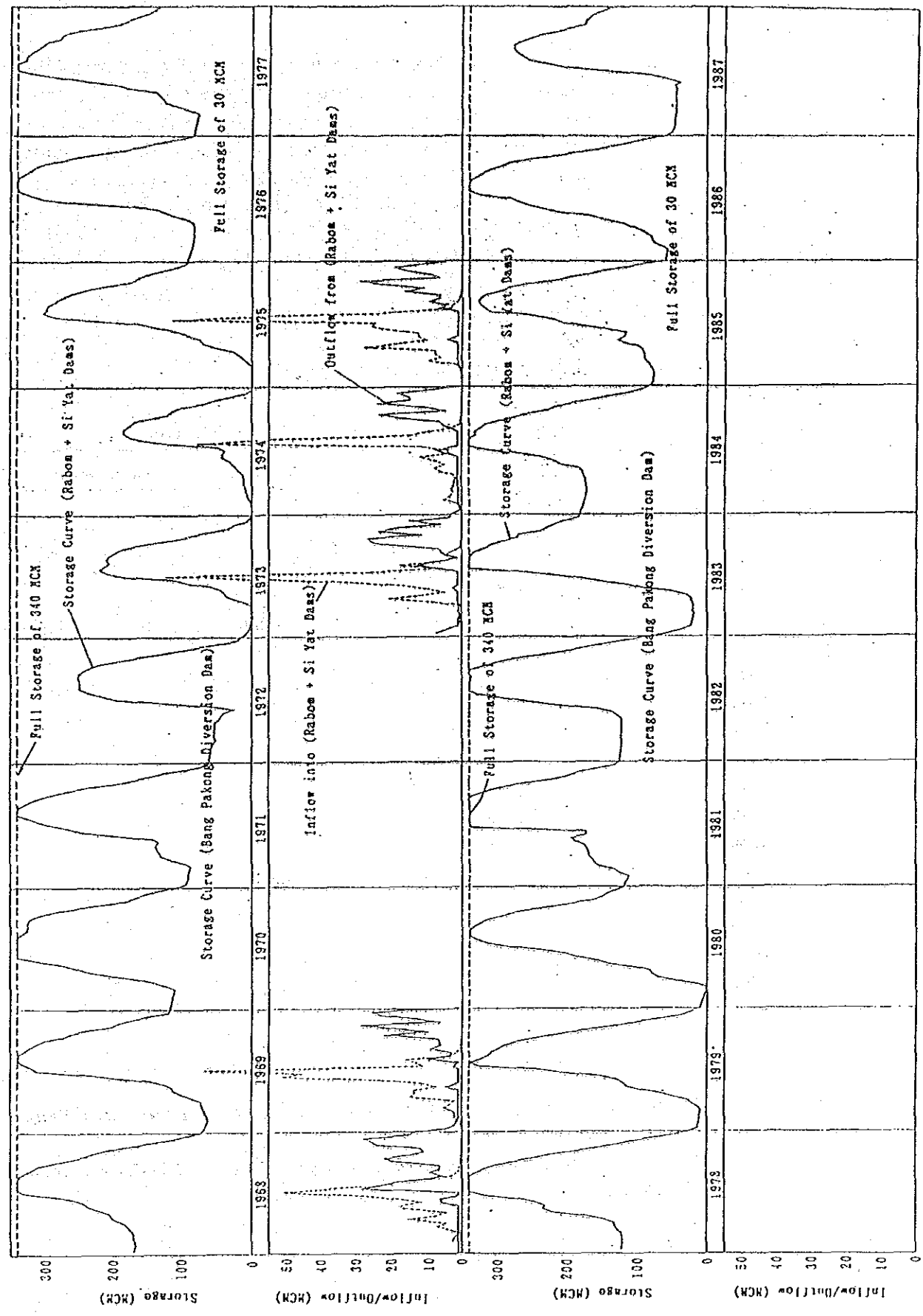
Computed results of water balance including dam operation for case-1 of alternative studies are then summarized as follows :

Summary of Water Balance Computation (CASE-1)

	Shortage in Irrigation Area			Minimum Storage (MCM)	
Year	Area (1)	Area (2)	Area (3)	Diversion Dam	Upstream Dam
1968	0.000	0.000	0.000	30.000	75.739
1969	0.000	0.000	0.000	30.000	64.370
1970	0.000	0.000	0.000	30.000	110.482
1971	0.000	0.000	0.000	30.000	61.979
1972	0.000	0.000	0.000	30.000	17.245
1973	0.000	0.000	0.000	30.000	1.000
1974	0.000	6.716	4.553	30.000	1.000
1975	0.000	6.863	2.180	30.000	4.000
1976	0.000	0.000	0.000	30.000	83.084
1977	0.000	0.000	0.000	30.000	79.217
1978	0.000	0.000	0.000	30.000	25.918
1979	0.000	0.000	0.000	30.000	9.048
1980	0.000	0.000	0.000	30.000	0.000
1981	0.000	0.000	0.000	30.000	112.364
1982	0.000	0.000	0.000	30.000	76.541
1983	0.000	0.000	0.000	30.000	19.527
1984	0.000	0.000	0.000	30.000	82.670
1985	0.000	0.000	0.000	30.000	60.999
1986	0.000	0.000	0.000	30.000	57.578
1987	0.000	0.000	0.000	30.000	38.471

Note : Area (1) = Existing and proposed expansion of Bang Pakong
(2) = Existing Tha Lat
(3) = Proposed Tha Lat expansion

FIGURE 8-6 WATER BALANCE SIMULATED (CASE-1 OF ALTERNATIVE STUDY)



For about 2 to 3 years of transitional period after construction of the Bang Pakong diversion dam but before completion of the Khlong Si Yat dam, the diversion dam linked with the Khlong Rabom dam would provide irrigation water to the service areas of existing and proposed expansion of Bang Pakong Left Bank with a reduce cropping intensity of 130% as well as compensatory water of 104.4 MCM during dry season to the Right Bank area and water to be conveyed to the beneficiaries of industrial and water supply sectors. During this period, other irrigable areas, such as existing Tha Lat and proposed Tha Lat expansion, would be left undeveloped. Water balance computation under this situation is summarized as follows:

Shortage in Irrigation Service Area (MCM)

Year	Existing & Expansion of Bang Pakong Left Bank	Tha Lat	
		Existing	Expansion
1968	-	-	-
1969	-	-	-
1970	-	-	-
1971	-	-	-
1972	-	17.386	-
1973	-	-	-
1974	-	-	-
1975	-	-	-
1976	-	-	-
1977	-	-	-
1978	25.569	-	-
1979	41.936	-	-
1980	-	-	-
1981	-	4.090	-
1982	-	-	-
1983	-	-	-
1984	-	-	-
1985	-	0.188	-
1986	-	-	-
1987	-	3.606	-

Note: (1) Tentative cropping intensity for the existing and proposed expansion of Bang Pakong Left Bank is 130%.

(2) Compensatory water supply of 580,000 m^3/day (=104.4 MCM for dry season) is fully considered.

CHAPTER 9. PROJECT FACILITIES

CHAPTER 9. PROJECT FACILITIES

9-1. Khlong Si Yat Dam

9-1-1. General

Khlong Si Yat dam consists of main and saddle dams, outlet works and spillway. The main dam is on the Si Yat river about 40 km upstream from the confluence of the Rabom river. The dams are of homogeneous type earthfill dams with impervious blanket, containing about 3,600,000 cu.m of embankment in total. The main dam is 2,600 m long at the crest elevation of 67.5 m, and has a maximum height of 30 m above the lowest point of the foundation.

The material for the impervious zone of the dam is obtained from the borrow area and required structures excavation, and the quarry and required spillway excavation can provide riprap materials of the dam. The filter materials will be purchased from the sand and gravel production company in Chonburi or other neighborhood.

Khlong Si Yat dam raises the water surface about 20 m and forms a reservoir. The reservoir cover 45.5 sq.km at the normal water level of EL.63.1 m, and has a total capacity of 325 MCM, of which 300 MCM are usable.

About the damsite the Si Yat river has a drainage area of 976 sq.km. The maximum runoff was 487 MCM in 1981and the minimum was 182 MCM in 1974 with an average yield of 286 MCM.

The side channel spillway with a capacity of 1,030 cu.m/sec is provided on the left abutment of the saddle dam. The spillway crest elevation is 63.1 m, and the crest length is 150 m.

A cut-and-cover conduit type outlet work is provided under the right abutment of the main dam. The outlet works serve to release stored water into the Si Yat Main Canal (Qmax = 7.81 cu.m/sec) and the river of Khlong Si Yat (Qmax = 34.17 cu.m/sec).

TABLE 9-1. KHLONG SI YAT RESERVOIR AND DAM FEATURES

Reservoir		
Average annual rainfall	1,343	mm
Drainage area	976	sq.km
Maximum annual runoff	487	MCM
Minimum annual runoff	182	MCM
Average annual runoff	286	MCM
Maximum water level	65.4	m
Normal water level	63.1	m
Minimum operating level	51.5	m
Reservoir area (at normal water level)	45.5	sq.km
Active storage	300	MCM
Dead storage	25	MCM
Gross storage	325	MCM
Dam		
Type	Homogeneous earthfill dam	
Crest length	Main dam 2,600	m
	Saddle dam 620	m
Maximum height	Main dam 30	m
	Saddle dam 12.5	m
Crest elevation	67.5	m
Embankment volume	approx. 3,600,000	cu.m
Spillway		
Type	Side channel spillway	
Crest length	150	m
Crest elevation	63.1	m
Spillway capacity	1,030	cu.m/s
Inflow design flood (1,000 year frequency flood)	2,037	cu.m/s

Outlet Works

Type: Concrete-encased pressure pipe conduit

Function

- to release stored water into Si Yat Main Canal (Qmax = 7.81 cu.m/s)
- to release stored water into Khlong Si Yat for supplemental water supply to the downstream areas excluding Tha Lat Expansion Area. (Qmax = 34.17 cu.m/s)

9-1-2. Site Selection

Comparative study was made carefully for two alternative sites of Khlong Si Yat dam, Si Yat No.1 and No.2 site, as summarized in the following table.

Dams		Si Yat Dam (No.1)	Si Yat Dam (No.2)
Active Storage	(MCM)	396	300
Embankment Volume	(cu.m)	8,200	3,740
Active Storage / Embankment Volume		48.3	80.2
Rough Estimate of Construction Cost			
Embankment	('000 Baht)	820,000	374,000
Spillway	(〃)	266,000	206,000
Compensation	(〃)	293,000	221,000
Total		1,379,000	801,000
Water Cost	(Baht/cu.m)	3.48	2.67
Acquisition Area	(ha)	9,760	7,370

The comparison as made above clarifies that Si Yat No.2 site is advantageous because of lower in water cost and less in acreage of land acquisition.

As the result of the comparative study on damsite selection, Si Yat No.2 site was recommended by the JICA Study Team at the meeting held on May 10, 1990 and it was selected finally with the RID's assent later.

9-1-3. Site Topography, Geology and Fill Materials

1) Site Topography

The damsite is located on the topographic boundary between the undulated hill and the mountainous terrain.

Three major topographic units, the alluvial flood plain, the undulated hill and the mountainous terrain, are distributed in the damsite.

The Si Yat river of about 20 m in riverbed width flows to the west-northwest in the flood plain and a tributary joins from the left bank 700 m upstream of the damsite.

The alluvial flood plain extends 300 m in width on the left bank and 800 m in width on the right bank. An altitude of the flood plain ranges from 45 to 48 m while the bottom of riverbed indicates 39.7 m.

The undulated hill is distributed on the left bank where two discernible height of flat terrains are traceable. The flat terrains with an altitude of 50 to 54 and 60 to 80 m are of terrace origin and the latter develops extensively 8 km in width. The undulated hill shifts into 200 m in height of mountainous terrain in the eastern divide.

The alluvial flood plain shifts into the mountainous terrain through the transitional detritus zone in the right abutment where the highest peak attains 158 m.

2) Site Geology

The following geological investigation was conducted by RID.

- Core drilling include standard penetration tests and permeability tests.

  Main dam: 5 holes Total 100 m
  Spillway : 2 holes Total 25 m

- Seismic refraction survey along main dam axis: 3 km

- Electrical resistibility exploration

The mountainous terrain, which forms the right abutment of the main dam and also the left abutment of the saddle dam, is mainly underlain by sandstone and siltstone of Tanaosi Group of the Carboniferous in the basement. Although no outcrops of the rocks are found in the area, rock fragments of fresh siltstone are found on the mountain slope on the right abutment.

The riverbed has a maximum thickness of 3 m and is composed of clay and sand with gravels in the base. The alluvial deposits in the flood plain which is extensively distributed on the right bank has a maximum thickness of 18 m and is composed of clay and silt of 3 to 5 m thick and gravels of 4 to 9 m thick in the base.

The thick unconsolidated formation underlying the alluvial and terrace deposits is extensively distributed at the damsite except right abutment. Thickness of the formation ranges from 6 to 10 meters and the faces of it changes irregularly and laterally.

The formation is composed mainly of silty gravels and is characterized by the presence of rock fragments. The rock fragments and silty gravel on the left bank grade into clay in the riverbed and, sand and silty gravel on the right

bank. The geologic age of the formation may infer to the early Pleistocene to Pliocene because it underlies the terrace deposits of the Pleistocene age.

Two kinds of terrace deposits, the lower and higher, are distributed on the left bank and the former consists of gravel beds of 3 m thick and the latter consists of gravel beds of more than 3 m thick.

The detritus deposits are distributed in both the abutments and are composed mainly of rock fragments on the right bank and they change into clay and sand on the left bank.

The permeability of the beds were determined by the Open-End Test in respective drilling holes. The figure shows that the layer of more than 10^{-2} cm/sec permeability is distributed in the flood plain on the right bank and in the lower terrace deposits, and thickness of these layers are 2 to 6 and 7 m respectively. Another layers underlaying at the damsite indicate less permeability of 10^{-3} cm/sec in any place.

The N-values in the drilling holes are determined by Standard Penetration Test.

The figure shows that the layer with less than 10 blows largely distributes near the surface with a maximum thickness of 4.5 m. The layer of less than 20 blows distributes mainly on the alluvial flood plain and attains 11 m.

3) Fill Materials

The following soil tests were made by RID.

Soil Tests for Fill Materials of Khlong Si Yat Dam

- Earth Materials		
Specific gravity	4	Samples
Field moisture	4	
Grain size analysis	18	
Atterberg limits	18	
Proctor compaction test	4	
Permeability test	2	
Triaxial shear test UU	2	
Triaxial shear test CU	2	
- Rock Material		
Specific gravity	2	Samples
Absorption	2	

The proposed borrow area for earth materials are located about 1 km upstream of the damsite. The area is underlain by impervious materials which

could be satisfied in terms of quantity and quality for the embankment materials. More than 70% of available earth materials from the borrow area is classified as CL.

The proposed quarry of rock materials for a riprap is located in Khao Ba Ra Run 3 km far from the damsite. The quarry is underlain by the solid granite which has a enough quality for the riprap.

9-1-4. Preliminary Design

1) Reservoir Plan

- Active storage ..... 300 MCM, nearly same as the average annual runoff of 286 MCM
- Dead storage ..... 25 MCM (= 250 cu.m/km/year × 976 sq.km × 100 year)
- Gross storage ..... 325 MCM

The design water level of reservoir is obtained from Height -Area and Height-Capacity Curves as shown in Figure 9-3.

- Normal water level ..... 63.1 m
- Minimum operating level . 51.5 m
- Reservoir area ..... 45.5 sq.km at Normal Water Level

2) Dam

As shown in Figure 9-2 the earthfill dam of a homogeneous type is proposed for Khlong Si Yat dam by the following reasons;

Topography

The topographic feature of the proposed site of Khlong Si Yat dam is characterized with the prevalence of gentle but discernible low hill and widely extended flood plain.

The main dam is 2,600 m long at the dam crest 67.5 m in elevation, with a maximum height of approximately 23 m above the streambed.

An earthfill dam is recommendable due to the location in low plain and low dam height from an economic point of view.

Foundation Condition

The foundation at almost all the parts of the proposed damsite consists of fine-grained material such as silt, clay, silty clay etc. These foundation layer must be good for the support of earthfill dam but not suitable for concrete gravity dam nor for rock fill dam.

The seepage control is made by provision of an impervious blanket, because application of the grouting is not realistic for the foundations composed largely of unconsolidated fine materials.

Material Availability

Available embankment material from the borrow area, which is located about 1 km upstream of the damsite, are impervious ones that will be classified as CL, SC or GC, and it is assumed that pervious or semipervious materials are not obtained at low cost. Accordingly a homogeneous type is recommended for the dam under these local conditions.

Riprap materials will be obtained from the excavation materials of required spillway and quarry site as shown in Figure 9-1 and filter materials will be purchased from the sand and gravel production Co. in Chonburi or other neighborhood.

3) Spillway

Spillway Capacity

In this consideration of the project scale and the site conditions, a 1,000 year frequency flood with a peak of 2,037 cu.m/sec shall be adopted as the inflow design flood according to the criteria for storage dams of the Project Planning Division, RID.

As the proposed damsite has a large reservoir area of 45.5 sq.km at the normal water level of 63.1 m, the surcharge storage is relatively large. Accordingly the spillway capacity can be reduced considerably.

The spillway capacity is determined at 1,030 cu.m/sec from flood routing as shown in Figure 9-4.

Location and Type

Rock foundation is only found on the mountainous terrain which forms the right abutment of the main dam and also the left abutment of the saddle dam.

The location of spillway is selected on the left abutment of the saddle dam in consideration of topographic feature, foundation conditions and the location of the outlet works. Taking into account the topography and foundation conditions of the site, the side channel spillway is recommendable.

Profile of the spillway is shown in Figure 9-2.

4) Outlet Works

Main functions required for the outlet works are as follows:

i) to release stored water into Si Yat Main Canal (Qmax = 7.81 cu.m/sec).

ii) to release stored water into Khlong Si Yat for supplemental water supply to the downstream areas excluding Tha Lat Expansion Area (Qmax = 34.17 cu.m/sec).

The outlet works will be classified structurally into two types, one is tunnel type and the other is cut-and-cover conduit type. As a tunnel is not contact directly with the dam embankment, it may be safer than a cut-and-cover conduit. However, a cut-and-cover conduit type outlet works is recommended because it is more economical compared with a tunnel outlet works.

Profile of the outlet works is shown in Figure 9-2.

9-1-5. Construction Plan and Schedule

1) Workable Day and Work Volume

A) Workable Day

The workable days of each work will be as follows;

Item of Works	Workable Day per Month	
	Wet Season	Dry Season
Fill of Impervious Zone	16	25
Common Earth Work	21	25
Concrete Works	25	25

B) Work Volume

The work volume for construction of Khlong Si Yat dam is as follows;

Item of Works	Work Volume
Fill of Impervious Zone	3,200,000 m^3
Fill of Filter Zone and Riprap	390,000 m^3
Excavation, Dams	700,000 m^3
〃 , Spillway	2,000,000 m^3
〃 , Outlet Works	250,000 m^3
Concrete	41,000 m^3

2) Construction Method

A) Diversion Works

The diversion of river flow during dam construction period will be carried out through temporary diversion channel constructed under the dam body. The outlet works will be used as the diversion way during the period of the final stage of dam construction when the temporary diversion channel is closed.

B) Excavation Works

Excavation works are categorized as follows:

i) Stripping and Common Excavation

Main machinery used for stripping and common excavation works is as follows;

Excavation	:	32 ton Bulldozer
Loading	:	3.3 cu.m Tractor Shovel or 3.3 cu.m Wheel Loader
Hauling	:	10 - 20 ton Dump Truck

ii) Rock Excavation

Main machinery used for rock excavation is as follows;

Excavation	:	Blast (bench cut method)
Gathering	:	32 ton Bulldozer
Loading	:	3.3 cu.m Wheel Loader
Hauling	:	10 - 20 ton Dump Truck

C) Fill Work

After completion of the stripping and key trench excavation, the fill works are commenced. The utilization plan of fill materials is as follows;

Fill Materials	Utilization Plan
Impervious	Materials from borrow area and required structures excavation
Filter	Purchase
Riprap	Materials from quarry and required spillway excavation
Sand & gravel bedding for riprap	Purchase

The compaction manner of fill materials is planned tentatively as shown below; however, the actual compaction method should be decided after performing the field test embankment.

Compaction Manner

Fill Zone	Thickness of Spread (cm)	No. of Pass	Compaction Machinery
Impervious	20	8	20 ton Tamping Roller
Filter Drain	30	5	10 ~ 15 ton Vibrating Roller

D) Concrete Works

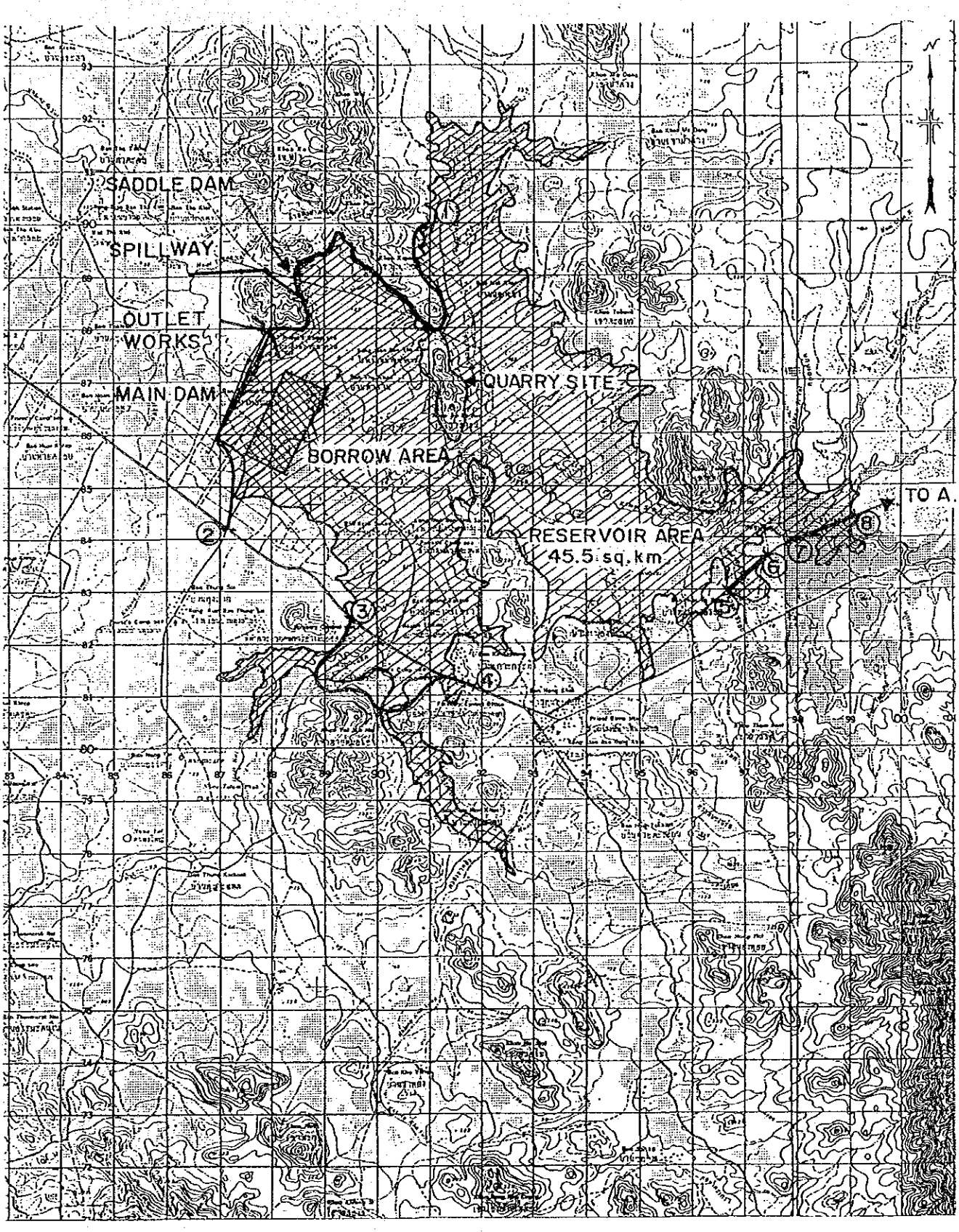
The total concrete volume required for the construction of spillway and outlet works is approximately 41,000 cu.m.

The concrete works are carried out by batching plant installing two mixers with a capacity of 0.75 cu.m. The performance of the plant is planned to be 26 cu.m/hr (0.75 × 2 × 20 batches × 85%).

E) Construction Schedule

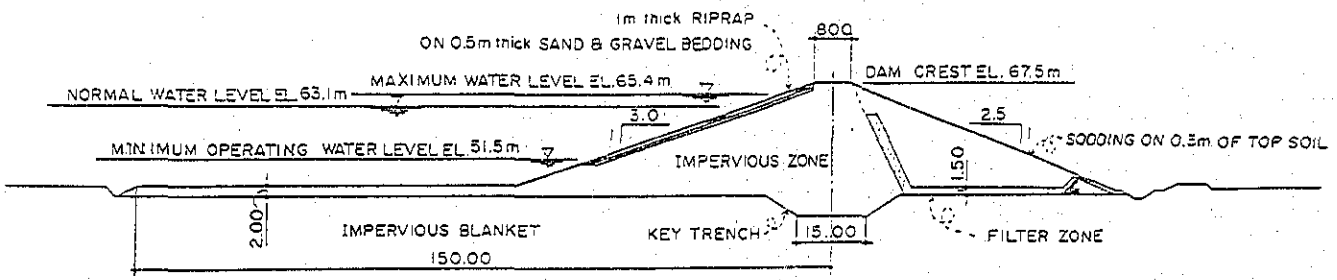
Construction schedules is planned based on quantities of earth works and concrete works, and is shown in Figure 10-2.

FIGURE 9-1 LOCATION MAP OF KHLONG SI YAT DAM

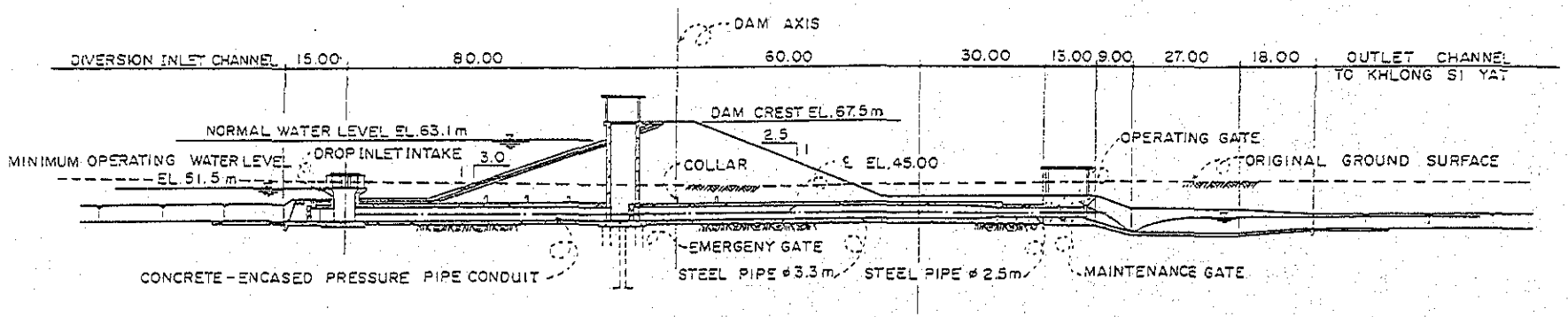


SCALE 1: 100,000

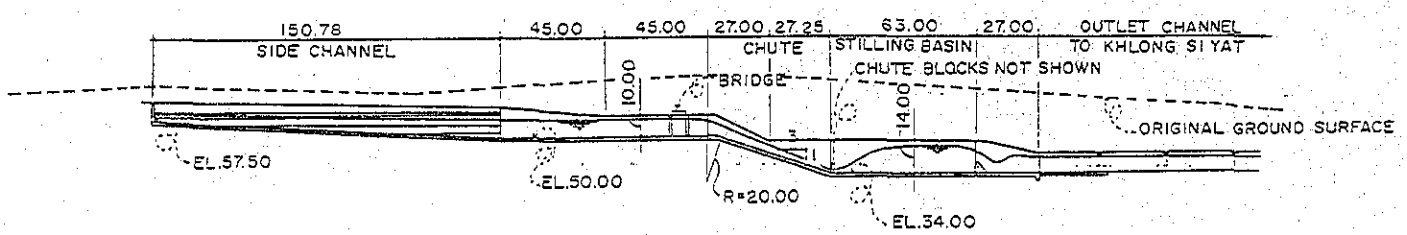
FIGURE 9-2 SECTION OF KHLONG SI YAT DAM, OUTLET WORKS PROFILE AND SPILLWAY PROFILE



TYPICAL CROSS SECTION OF DAM
SCALE 1 : 1,000



PROFILE ON ℄ OUTLET WORKS
SCALE 1 : 1,000



PROFILE ON ℄ SPILLWAY
SCALE 1 : 2,000

FIGURE 9-3 HEIGHT-AREA AND HEIGHT-CAPACITY CURVES

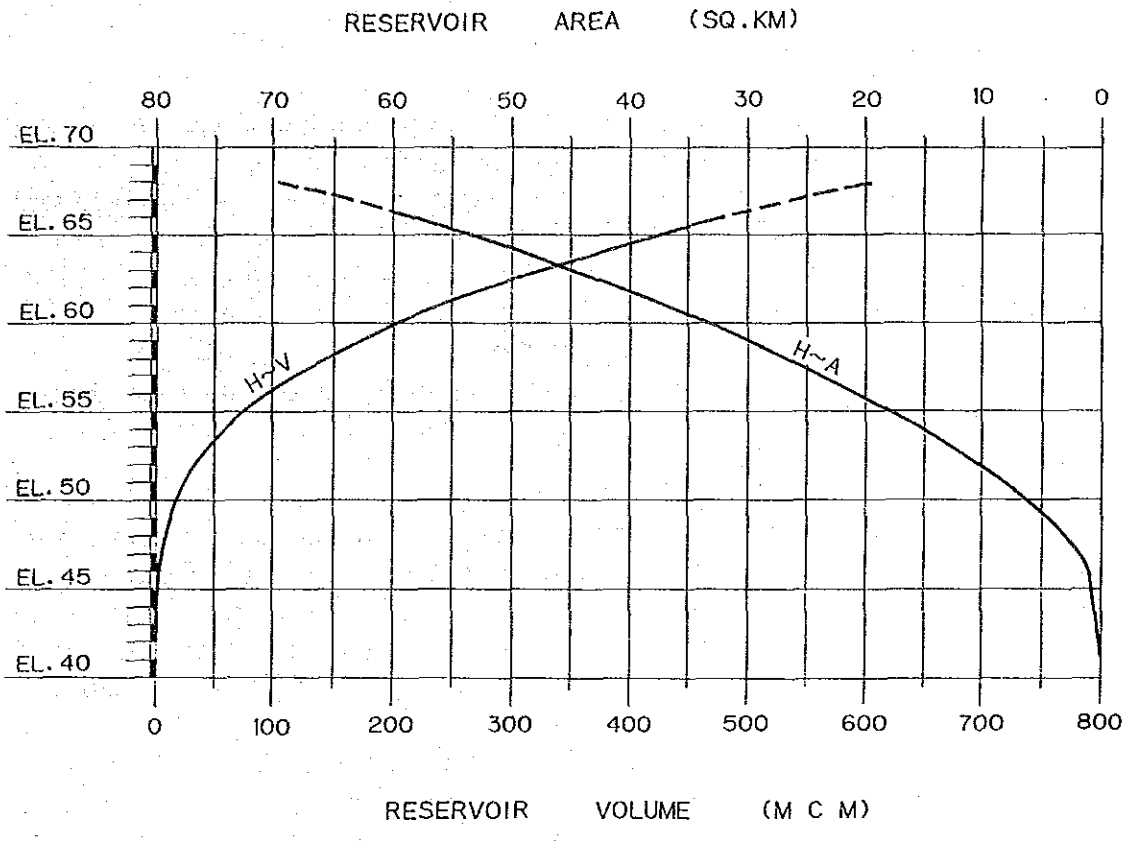
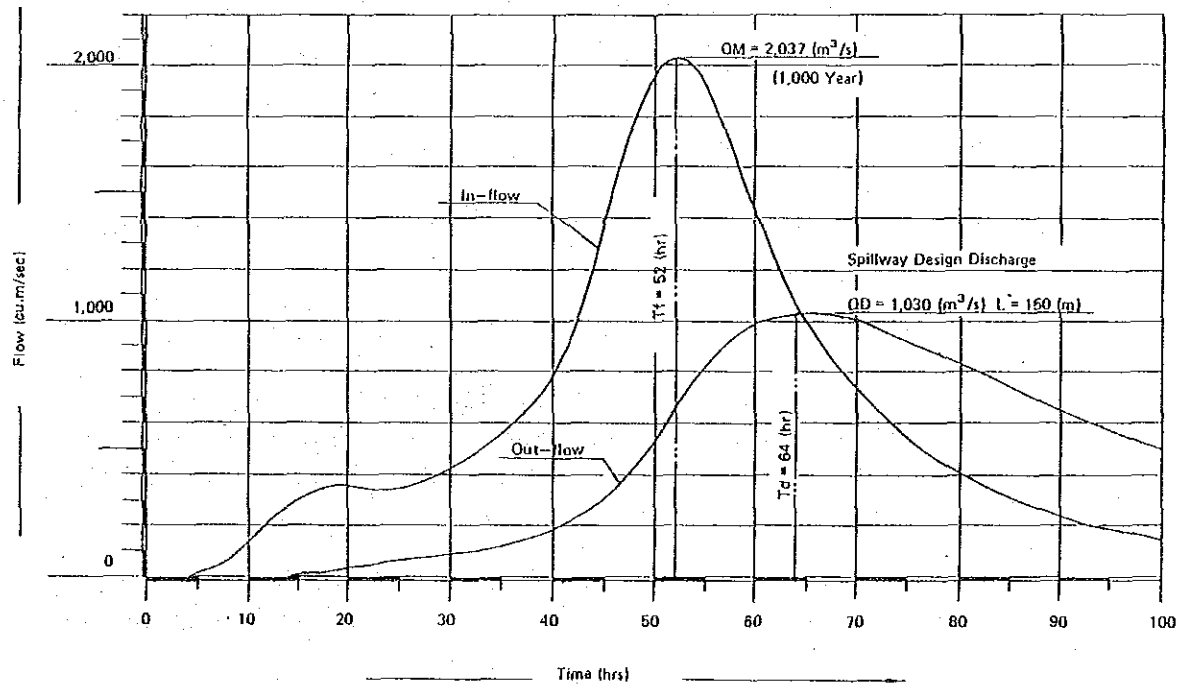


FIGURE 9-4 FLOOD ROUTING CURVES FOR KHLONG SI YAT DAM SPILLWAY



9-2. Bang Pakong Diversion Dam

9-2-1. *General Concept*

The land use for agriculture on the bank area along the Bang Pakong river are categorized roughly as shrimp pond downstream of the City of Chachoengsao located around 50 km upstream from the river mouth, and orchard upstream of Chachoengsao. The length of the Bang Pakon river is about 150km from the river mouth up to the Amphoe Bang Sang and the river has several tributaries including the Nakong Nayok and Prachin rivers. The water surface slope of the river is considered to be very gentle at around 1/100,000 in dry season and 1/40,000 in wet season, due to the meandered river course and topographic features. For this reason, saline water from the sea enters considerably upstream.

As regards the manner of river water use, the shrimp farmers divert brackish water from the river during dry season downstream of the Chachoengsao City and, on the contrary, the fruit plantation keeps away from the saline water at the upstream site. For this reason the proposed site of diversion dam is recommendable to be located upstream of Chachoengsao City to minimize disadvantages to be possibly brought by the diversion dam construction. The proposed construction site should also be near from the industrial complexes to be located along the route 304 in consideration of industrial water supply. Severe pollution of river water due to the wastewater drained from municipal area of Chachoengsao will be realized if the diversion damsite is proposed downstream of the City.

The proposed diversion dam will be placed outside of the meandering river course for the convenience of construction works and the river route will be replaced after completion of the dam. Accordingly, conditions to be considered in selection of the proposed diversion damsite are summarized as follows:

- to be located upstream of Chachoengsao City.
- to minimize the replacement cost of houses which are located within the proposed construction site, and
- to minimize the length of the diversion channel route

Considering the conditions above mentioned, the proposed diversion damsite was selected on the Bang Pakong river at the point of 70 km from the river mouth, based on the careful studies on the 1/10,000 scale map and the field investigations.

The water levels of the Bang Pakong river at the proposed site of the diversion dam are under tidal influence. The normal high water level during

high tide is observed some 0.6 to 0.7 m lower than the embankment height on both banks. There are no other artificial embankment or river protection and, according to an interview survey, there is no significant rise of river water even during wet season. A few floods only were observed in the past, of which the most severe one occurred in 1983 with the highest flood levels of around 2.0 m above mean sea water level. Due to this small freeboard and very flat bottom slope of the river, the diversion dam should be proposed to be all-section movable type of weir, in order to avoid the rise of flood water levels after the project.

No excess water head will be allowed during the flood flow and hence it is not recommendable to reduce the river section. Accordingly the width of the proposed dam will be the same as the existing width of the river.

A slide type gate capable of opening completely is recommended in due consideration of operation and maintenance. The gate span is to be as wide as possible and the width of 30 m will be standard.

General features of the Bang Pakong diversion dam are shown in Table 9-2.

TABLE 9-2. GENERAL FEATURES OF BANG PAKONG DIVERSION DAM

DIVERSION DAM	
TYPE	ALL-SECTION MOVABLE TYPE
GATE	
CONTROL GATE (Double Leaf Gate)	
2 sets × 30 m width × (3.7 m + 7.5 m) height	
FLOOD GATE (Single Leaf Gate)	
3 sets × 30 m width × 10.3 m height	
DAM LENGTH	280 m
BOTTOM SEAL ELEVATION	(-) 9.0 m
CONNECTING BRIDGE	
ACTUAL WIDTH	9.70 m
LENGTH	167.00 m
CLOSURE DAM	
TYPE	EARTH FILL DAM
CREST LENGTH	250.0 m
MAXIMUM HEIGHT	13.0 m
CREST ELEVATION	(+) 3.0 m
EMBANKMENT VOLUME	150,000 Cu.m

9-2-2. Site Selection

The Bang Pakong diversion damsite will be located downstream of the confluence with the Tha Lat river when the most effective utilization of the Tha Lat river water is considered. In total, five possible sites of the diversion dam were preliminarily investigated and compared as shown in Figure 9-5. More comprehensive examination on the selection of diversion damsite was discussed in the Appendix H-4 to the main report.

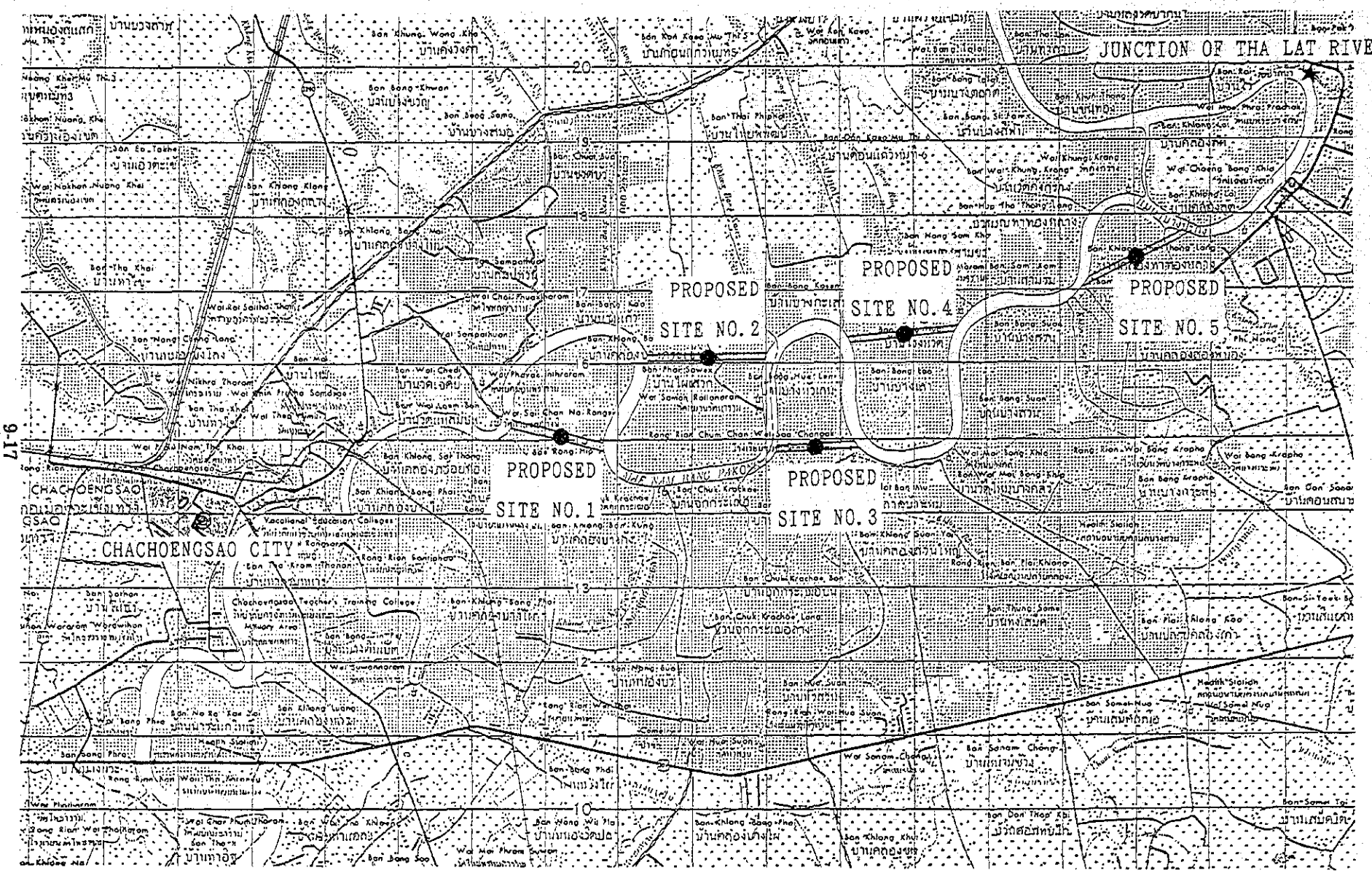
Possible sites were comparatively studied on the basis of 1/10,000 scale map, as follows:

Item	No.1	No.2	No.3	No.4	No.5
Length of Diversion Channel (km)	1.3	1.6	1.0	1.4	1.4
Nos. of Houses to be Replaced	32	30	31	48	35
Nos. of Houses to be Compensated	25	12	20	12	18
Length of Road to be Constructed (km)	4.0	2.0	3.0	3.0	5.0
Length of Road Rehabilitated (km)	4.0	7.0	7.0	9.5	5.0
Distance from Chachoengsao (km)	5	8	12	14	21

The proposed site No.3 as primarily selected due to the low construction cost from the above comparison was excluded since there exists an important temple (Wat Sao Changok) within the vicinity of the construction site. The site No.2 and No.4 were further studied and the site No.2 was selected by taking into account the following reasons:

- Despite that the construction cost at the No.2 site will be slightly higher having relatively longer diversion channel, replacement and compensation costs for houses will be much lower than No.4.
- Moreover an important temple (Wat Samarum) exists very closely to the No.4 site.
- Connection or access road to be constructed or rehabilitated is also shorter if the site No.2 is selected.
- Storage volume of fresh water and distance from beneficiaries are advantageous when the site is selected more downstream.

FIGURE 9-5 LOCATION OF PROPOSED DIVERSION DAM SITE



9-2-3. Site Topography, Geology and Fill Materials

The diversion dam is located in the pinched flood plain surrounded by a meandering river course of the Bang Pakong river about 8 km east of Chachoengsao City. The terrain shows generally but slightly elevated natural bank formed along the meandering river course. The diversion channel will be excavated to connect the both bends of meandering river course with the diversion dam in the midway. The closure dam will be located at about 1.3 km south of the diversion dam.

The site is underlain by alluvial unconsolidated clay, sand, and sand and gravel of several 10 m thick and these beds are subject to saline water intrusion. Foundation for the diversion dam is expected on a hard sandy clayey bed in the alluvial formation and estimated depth of the bed is about 25 to 30 m below ground surface.

The excavated material of the diversion channel can be provided for the closure dam. Quantity and quality of the material are supposedly good enough to adopt the embankment of the dam. Sand borrow is located in Ban Na near Chonburi, about 50 km south-southwest of the site. Materials for coarse aggregate and riprap can be procured from the existing quarry in Khao Kwang Thong, 50 km south-southeast of the site.

9-2-4. Preliminary Design

1) Decision of Sectional Area of Diversion Dam

Width and sectional area of the river are estimated according to the river survey conducted by RID.

The sectional area of the proposed diversion dam is recommended as 1,500 m^2 equivalent to the average sectional area within the 10 km distance between the points 5 km downstream and 5 km upstream of the damsite.

2) Hydraulic Design Condition

Depending on the hydraulic situation, the design condition of structures and gates are as follows:

A) Water Level at the Diversion Damsite

- Case-1: Upstream = 1.30 m (control water level : CWL) + 0.50 m (height of wave) = (+) 1.80 m

Downstream = (-) 1.50 m (mean low water level: MLWL)

- Case-2: Upstream = (-) 1.50 m (CWL)

  Downstream = 1.30 m (mean high water level: MHWL) + 0.50 m (height of wave) = (+) 1.80 m

B) Bottom Elevation and Depth at the Diversion Dam

- Bottom Elevation : (-) 9.0 m
- Depth : Maximum 1.3 - (-) 9.0 = 10.3 m
  Minimum (-) 1.5 - (-) 9.0 = 7.5 m

3) Gate Size

The span of gate is determined at 30 m for both the main and regulating gates according to the following general concepts:

For main gate;

- Maximum span of the gate is not more than 50 m and not less than that of regulating gate

For regulating gate;

- More than two spans due to safety operation of gates
- Effective gate span shall be more than 25% of river channel
- Maximum span is not more than 45 m from the technical view point

The heights of both the upper and lower leaves are be determined based on design conditions on the water level at the proposed diversion damsite and operation/maintenance capability of the gates. The following proposals are most reasonable for the proposed dam.

Specification	Upper Leaf	Lower Leaf
- Top of the leaf	MSL (+) 1.80 m Same as design high water level of upstream side	MSL (-) 1.50 m Same as design low water level of downstream side
- Bottom of the leaf	MSL (-) 1.90 m 0.40 lower than design low water level	MSL (-) 9.00 m Proposed sill elevation of the diversion dam
- Height of gate	3.70 m	7.50 m

4) Gate Type

The types and names of commonly used hydraulic gates are as below:

- Fixed wheel gate
- Radial gate/sector gate/drum gate
- Slide gate
- Roller gate
- High pressure slide gate/ring follower gate
- Ring scale gate

The above-mentioned hydraulic gates generally consist of gate leaves, bearings, gate guides, and anchorage and gate hoists. Hydraulic gate with appurtenant parts are designed in accordance with the following conditions.

- Safety against unpredictable load
- Sufficient watertightness
- Easy and reliable operation
- High durability
- No harmful vibrations during operation
- Easy maintenance

From the above mentioned basic concept of the regulating gate designing the following gate types are recommendable for irrigation, industrial and drinking water supplies as well as for prevention of saline water intrusion.

Item	Double Shell Type Roller Gate		Shell Type with Flap Roller Gate	
	Normal	Reverse	Normal	Reverse
- Height of Gate	Hg > 1/15L		Hf < 1/3H or 3.0 m	
- Downpull of Lower Leaf	Small	Large	Large	Small
- Effect of Tidal Wave	Small	Medium	Large	Small
- Adherence of Sea Animals	Inside of Upper Leaf	Inside of Lower Leaf	Flap and Lower Leaf	Flap and lower Leaf
- Stability of Water Flow	Smooth	Smooth	Unsteady	Unsteady

Although the cost of double shell type roller gate is slightly higher than that of shell type with flap gate, they have more advantages than the latter, such as stability of gate and reliability of gate operation. Accordingly the double shell type roller gate with normal system is recommendable for regulating gate. Beside this, the single shell type roller gate is adopted as the type of main gate.

5) Fish Way

A fish way is not installed from the structural view point due to intrusion of saline water when the tide level is higher than the upstream water level. No fish ladder is necessary during rainy season due to the full opening of the gates. While during dry season, the regulating gates function as the fish ladder because fishes can move upstream through the flowing water over the leaf of the gate.

6) Navigation Lock

Basically no navigation lock is installed. If a navigation lock is installed, it is not effectible because the operation times and hours are very limited due to the tide fluctuation. Passengers will change boats up and downstream of the diversion dam or land transportation may take the place of navigation feature.

7) Diversion Channel

The section of diversion channel shall be determined depending on the study of river sections between up and downstream of the proposed diversion dam. However, the bottom width of the channel is decided to meet the flow width of the diversion dam considering its construction and the stability of side slope.

The stability of side slope must be studied carefully by using the result of boring test and soil mechanical test. And, if the side slope is taken at 1:5, the water flow area becomes 2,240 m^2 which is bigger than the existing cross sectional area of river channel and is therefore adequate to pass the flood flow.

The site of dambody is selected near the access road as the most appropriate site among several alternatives. The left bank upstream of the diversion dam is designed as straight line and the right is considered with smooth curve as the transition to make steady water flow. The opening of transition will be 20°depending on the hydraulic view point and the radius of the curve shall be more than 5 times of the channel width (around 800 m).

The channel line immediately downstream of the dambody shall be straight line with at least the same length of its width to make gate operation and river flow steady, and then the diversion channel will be connected to the Bang Pakong river smoothly.

The desirable angle of curve of the channel to connect the river is also 20 ° to make river flow smooth and the radius of the curve will be 800 m more or less or the same as inlet transition.

The operation road will be provided on both banks. The dike of about 1.0 m high will be arranged outside of the operation road and the ditch will also be arranged along the foot of the dike.

8) Closure Dam

The side slope of 1:5 is applied for the closure dam section to stabilize the river flow. The top elevation of the dam will be EL (+) 3.00 m which is estimated as the flood level in 1983 (MSL (+) 2.03 m) plus 0.5 m of wave and 0.5 m of free board.

Due to the construction in water, the section of closure dam is so designed that the rock material will be deposit on both sides of the section and the excavating material of the diversion channel will be used for the filling material of the closure dam.

The slope of closure dam is covered by the filter with clashing stone and rock material. The size of rock material used for deposit shall be big enough in the size which will not be flushed by the river flow.

For the borrow site of the rock material, the industrial estate at Bang Nong Krock is considered as the appropriate site from its distance. However, it is not desirable because the size of rock is irregular and easily weathered due to the laterite character, furthermore the material is scattered and the construction period may different from that of development of the industrial estate.

The borrow-site of Chonburi, where is located at about 50 km south from the proposed damsite, is recommendable. Although the borrow-site is little bit far from the damsite, any size of rock materials are available there. And no other borrow site can be found within 50 km from the proposed diversion damsite.

9) Connecting Road

The connecting bridge will be installed on the dambody for the purpose of operation of gates and connection of right and left bank transportations. The connecting road will also be provided linking the bridge and the closure dam. It will be used as the trunk road instead of navigation.

9-2-5. Construction Plan

1) Construction Base Site

Around 10,000 sq.m of the area is proposed for the construction office, quater, warehouse and working site. It will be located on the north side of the proposed diversion dam along the access road. The area is low and marshy, so that filling by laterite material will be necessary to prevent flooding.

2) Power Supply for Construction

A substation for the future gate operation will be installed at the right foot of the diversion dam. The power for construction will be supplied by the substation, while a standby generator shall be installed at the base site and construction site for use during black out.

3) Water Supply for Construction

A water tank with a capacity of 100 cu.m shall be provided for the mixture of concrete production and the water shall be carried from Chachoengsao City by a tank lorry because the water from the Bang Pakong river can not be expected for the mixture of concrete due to salt content and the good quality of well water surrounding the site is also not available.

4) Excavation Plan of Damsite

The depth of excavation is 13.5 m from the natural ground elevation to the basement of concrete slab. Open excavation method will be applied with construction equipment of a 1.0 cu.m backhoe and 11 ton dumptruck. The excavation work of dam shall be conducted concentratedly during the dry season from December to May. The excavation slope will be 1:3.5 and the maximum excavation depth is around 4.0 m. A flat terrace shall be provided between upside slope and downside slope for the stabilization of the slope.

Typical specification of excavation equipments are as follows:

Backhoe 1.0 cu.m	450 m^3/day	10 hr/day
Dumptruck 11 t	120 m^3/day	average hauling distance 1.0 km
Marshy Bulldozer	1,500 m^3/day	leveling

Assuming the construction period of 5 months with workable days of 100 days, the following equipments will be necessary;

Backhoe	1.0m^3	12 unit
Dumptruck	11 t	46 unit
Marshy Bulldozer		4 unit
Bulldozer		2 unit

5) Dump Area of Excavation Material

The excavated material of diversion dam and channel shall be thrown to certain dump area except filling material to be used for the closure dam. The excavation of diversion channel will be conducted by a pump dredger, therefore the dump area is enclosed by a dike with the height of 2 m where the excavated materials are discharged through pipe line. Large scale of land is necessary for the dump area and the paddy field along the access road, north side of the proposed damsite, is appropriate.

6) Excavation Method of Diversion Channel

A pump dredger will be used for the excavation of diversion channel. Maximum excavation depth is 10.5 m and distance of discharge pipe is 1.5 km. The maximum ability of dismantled type pump dredger is 1,000 ps for the main pump. It is transported through the Bang Pakong river. The capacity and numbers of dredgers are estimated as follows:

Working hours per a month	425 hr/month
Capacity of dredger 1,000 ps	180 m^3/h
Capacity of dredger per month	180 m^3/h × 425 hr/month = 76,500 m^3/month
Total dredger/ month	
4,064,000 m^3/76,500 m^3/m	53.1 months
Assumed excavation period	18 months
Units of dredger	53.1 m/18 m = 3 unit

Accordingly 3 units of dredgers are applied.

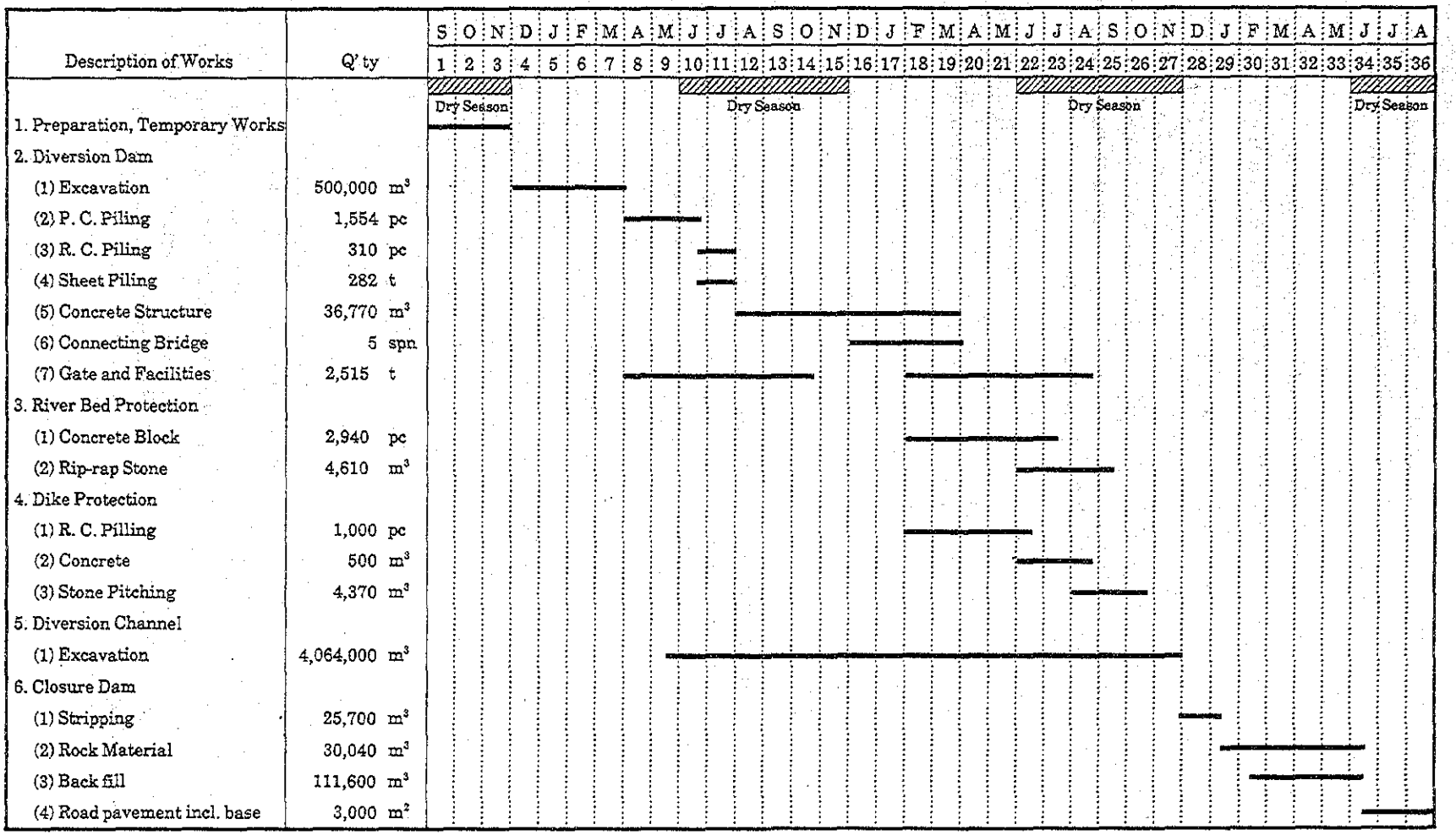
Tentative construction schedule is shown in Figure 9-6.

9-2-6. Hydraulic Simulation

Hydraulic analyses on the Bang Pakong river with conditions before and after construction of the proposed diversion dam should be conducted in order to clarify hydraulic function of the Bang Pakong river during the periods of probable floods and low river flows. Objectives of the study are summarized as follows:

- To simulate hydraulic phenomenon on the river during the period of historical flood(s) ever recorded.
- To simulate hydraulic phenomenon on the river during the period of probable floods with given frequency of occurrence.

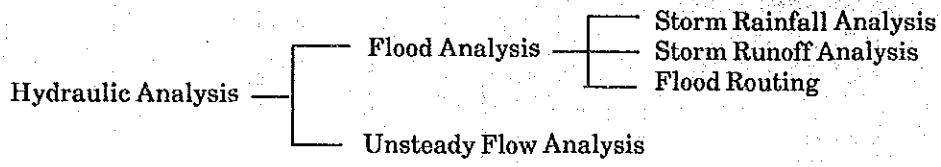
FIGURE 9-6 TENTATIVE CONSTRUCTION SCHEDULE FOR BANG PAKONG DIVERSION DAM



- To simulate hydraulic phenomenon on the river with small/medium floods probably be occurred during the period of gate operation.

- To simulate hydraulic phenomenon on the river with gate operation and with no inflow from the upstream river basin.

Hydraulic analysis comprises flood analysis covering the whole Bang Pakong river basin and unsteady flow analysis on the river. Flood analysis also consists of storm rainfall analysis, storm runoff analysis and flood routing on the river from the upstream end up to, at least, the confluence of the Prachin and Nakhon Nayok river with Bang Pakong river.



Flood Analysis

No one knows, until the date, the exact discharges of flood along the river in the lower reaches because the river system is under the tidal influence. It is, therefore, very important to analyze firstly the existing situation of the river with flood runoffs.

The Bang Pakong river basin has a catchment of 17,660 sq.km over which various storm rainfalls in time and space have been observed. Storm runoffs caused by such storm rainfalls in various parts of the catchment flow down on the slope into the stream, join at places and are finally concentrated into the main stream of Bang Pakong river. Numbers of flood hydrographs of small streams with various patterns of runoff and time lags are accordingly accumulated to create the flood hydrograph of the river.

In the lower and middle-lower reaches of the river system which is characterized by flat bed slope, meandering channel of limited small flow capacity and low banks, floods sometimes flow over the banks to inundate the neighboring paddy areas. Rainfalls on these areas are also stored on paddy surface, and drained gradually in accordance with flowing capacities of outlet, internal natural drain and external river water stage. This function greatly contributes to the mitigation of flood damage or reduction of peak flood in the downstream area.

This kind of hydraulic function can only be solvable when the "Method of Characteristics with Consideration on Effect of Storage on a Paddy Plot" (cf. Appendix D.4) is introduced.

Unsteady Flow Analysis

A solution of hydraulics on the river, in terms of river stages, flow discharges and velocities, is obtainable through the unsteady flow analysis. River systems between the river mouth and the confluence of the Prachin and Nakhon Nayok rivers with Bang Pakong river are schematized as shown in Figure 9-7. Computation will be made with an appropriate time step and by giving initial and boundary conditions such as hydrographs of flood inflow to each of the blocks and tidal heights at the river mouth.

In order to determine important parameters for computation, works of model verification should be made. Parameters to be determined are:

- Hydrological parameters to determine runoff capacities from paddy field, or averaged values of size, height and commanded area of paddy notch (outlet of paddy plot) and sizes and capacity of farm drain or small drainage canal. These parameters are determinable through flood analysis.

- Hydraulic parameters such as Manning's roughness coefficient and others, determinable from unsteady flow analysis.

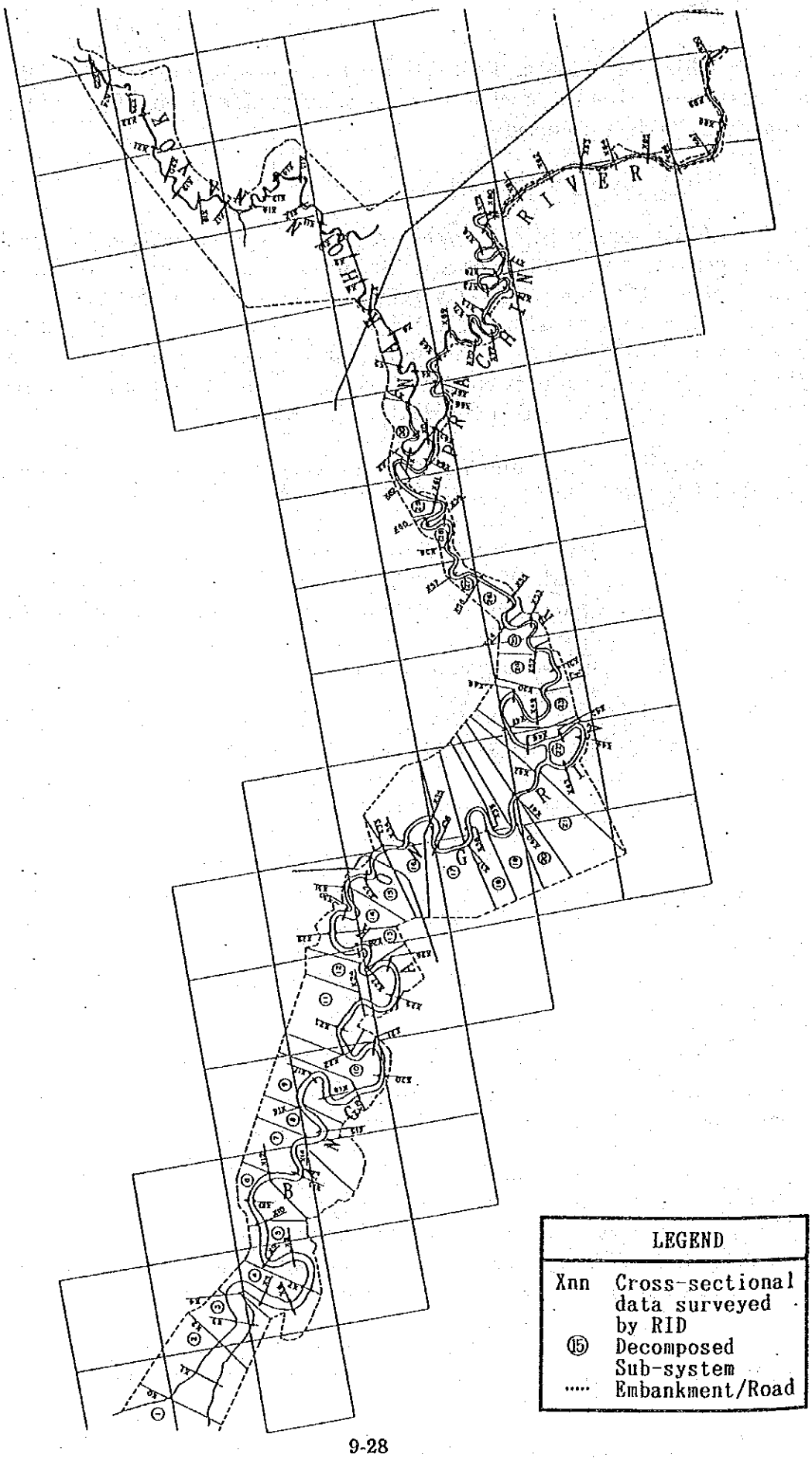
A historical record of flood occurred in 6th to 23rd of October, 1983 will be used to determine the above parameters. During this period, various patterns of rainfall were recorded as given in Table 9-3. These values were treated to generate basin rainfalls in runoff blocks as presented in Table 9-4. Hourly measurements of tide during this period at the river mouth were also collected from the Harbor Department, Ministry of Communication, as shown in Table 9-5. Observations of peak stage of flood are available at stations on the Bang Pakong river.

Numbers of computation are to be made with various combinations of assumed values of hydrological and hydraulic parameters until the computed results, particularly river stages, coincide the observed values.

Since the diversion dam is so planned and designed as to ensure the existing flowing capacity and is to be kept full open during the period of flood (throughout the wet season), no significant change of flooding situation on the river will be cause by the construction of the dam, as far as river hydraulics is concerned and unless the river improvement works are accompanied upstream.

Analyses will, however, be made on the basis of probable floods of given frequencies (say, 10,50 and 100 year recurrence periods) to compare

FIGURE 9-7 SCHEMATIC DIAGRAM OF BANG PAKONG RIVER SYSTEM



hydraulic situations before and after the construction of the proposed diversion dam.

The diversion dam is operated conceptionally as follows:

- Gates are full open during wet season when most of floods occur.
- Gates are full closed during dry season when inflows are mostly negligibly small or less than the amount of water to be diverted.
- Gates are occasionally open or closed during the transitional period between wet and dry seasons.

More important is to analyze hydraulic phenomenon during the transitional period, when gates are closed and occasional small or medium scale of floods occur. It is, however, presumed that no serious damage will happen if the gate operations are made in concert with rainfall and river stage observations in the basin and if a preliminary release of stored water is made in advance, since the traveling time of flood has been estimated considerable.

Environmental impacts possibly be caused by waste waters from the municipal areas of Chachoengsao are concerned especially during the period of no or less inflow into the diversion dam when no or only the minimum volume of water is released downstream of the dam. It is, however, presumed that the flow generated by the tidal motion will be great enough to flash out the waste water far downstream of the river into the sea. It is also presumed that the river stage downstream of the dam will be raised slightly by the construction of the diversion dam, since the dam will prevent the tidal water intruding upstream of the river channel. Analysis to be made under this condition will reveal the above fact and will also indicate the hydraulic differences before and after construction of the proposed Bang Pakong diversion dam.

The further study will be made during the course of the detailed design for the Project.

TABLE 9-3 RAINFALL RECORDED AT STATIONS DURING 1983 FLOOD

Daily Rainfall in (1983 October) (1)

Day	0304	0308	0321	0322	0606	0901	0916	0917	2204	2207
6	-	-	-	6.2	7.4	-	-	2.6	-	0.9
7	-	13.0	-	-	8.1	-	-	-	-	-
8	-	12.4	-	9.1	17.6	3.2	7.4	-	14.5	-
9	-	24.0	-	1.0	16.0	13.0	4.5	63.1	22.5	43.2
10	35.1	38.6	30.4	44.1	12.7	13.2	18.7	21.8	62.5	70.5
11	16.2	45.6	40.4	49.3	6.4	15.6	7.8	25.6	26.6	92.3
12	8.2	5.7	-	2.8	48.8	18.8	-	0.3	35.8	9.5
13	0.0	18.7	40.0	36.7	2.3	40.1	-	10.0	22.6	56.2
14	14.5	10.0	15.5	21.0	14.7	-	36.8	0.7	10.2	-
15	0.0	8.4	-	-	7.4	10.3	7.6	-	16.2	27.5
16	40.1	-	6.5	2.7	-	-	-	-	12.1	-
17	0.0	11.5	-	-	48.4	6.0	17.6	26.1	5.2	28.2
18	25.6	40.0	45.5	41.1	39.4	50.1	132.0	37.6	22.3	73.9
19	56.6	3.3	40.4	44.9	28.7	25.8	6.9	1.5	8.6	-
20	0.0	-	8.5	-	25.1	0.1	2.6	7.8	29.5	4.2
21	-	-	0.5	-	-	14.5	0.9	-	6.2	-
22	-	-	-	-	-	0.9	9.6	11.0	15.8	-
23	-	-	-	3.3	-	4.2	27.9	51.5	8.5	-
24	-	-	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-	51.2	-
Total	196.3	231.2	277.7	262.2	283.0	215.8	280.3	259.6	324.3	406.4

Daily Rainfall in October, 1983 (2)

Day	2215	2517	2553	4402	4404	4406	4408	4412	4413	2515
6	-	-	0.8	-	-	-	-	-	-	1.0
7	5.7	-	-	10.0	-	-	-	-	-	-
8	2.4	7.9	4.8	-	6.0	5.8	6.7	26.0	25.3	6.0
9	22.8	3.9	2.3	35.5	2.9	11.2	13.1	31.8	4.0	2.9
10	83.2	111.0	55.1	40.0	51.3	60.2	49.5	97.5	88.0	69.4
11	16.7	59.0	2.4	60.0	1.0	-	2.8	4.9	-	3.0
12	5.6	110.0	41.0	15.0	8.2	-	48.5	1.8	51.0	51.7
13	22.4	136.7	5.7	20.5	5.2	-	33.3	43.9	26.3	7.2
14	22.6	8.3	0.4	-	2.9	15.0	-	-	52.6	0.5
15	107.4	33.5	21.3	15.0	21.8	16.5	-	24.5	3.7	26.8
16	-	-	-	-	2.6	-	8.0	-	3.0	-
17	35.5	-	27.7	30.5	55.3	-	65.9	35.3	37.6	34.9
18	31.4	49.6	21.7	-	34.1	23.0	5.0	18.8	9.0	27.3
19	42.3	-	-	-	0.7	30.5	-	-	1.3	-
20	-	-	5.7	-	6.7	25.0	6.8	25.6	7.2	7.2
21	-	1.3	-	-	-	-	-	-	7.1	-
22	-	3.2	7.0	-	0.8	-	-	66.0	0.4	8.8
23	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	8.3	-	-
25	-	-	-	-	-	-	-	-	-	
Total	398.0	524.4	195.9	226.5	199.5	187.2	239.6	434.4	316.5	246.7

TABLE 9-4 BASIN STORM RAINFALLS ANALYZED (OCTOBER 1983)

		OCTOBER 1983																		
	NO.	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	TOTAL
LBP	1	0.0	0.0	3.2	13.0	13.2	15.6	18.8	40.1	0.0	10.3	0.0	6.0	50.1	25.8	0.1	14.5	0.9	4.2	215.8
	2	0.0	1.3	1.3	2.8	34.8	19.1	8.3	3.1	13.6	1.1	34.9	1.3	27.8	49.3	0.0	0.4	0.0	0.1	199.9
	3	0.0	0.0	0.0	0.0	49.6	23.9	5.6	12.8	14.8	0.0	29.3	0.0	32.0	51.0	2.7	0.2	0.0	0.0	221.9
	4	0.0	0.0	2.0	8.2	21.3	15.8	14.9	25.3	5.4	6.5	14.8	3.8	41.0	37.0	0.1	9.1	0.6	2.6	208.4
	5	0.4	0.0	2.9	20.1	14.8	16.7	15.1	33.6	1.9	8.6	0.0	3.6	52.3	21.2	1.4	11.6	2.8	12.5	225.6
	6	1.5	0.0	0.0	35.3	27.7	21.5	3.8	5.6	6.8	0.0	17.6	14.6	32.3	25.5	4.4	0.0	6.2	28.8	231.5
	7	1.8	0.0	2.1	46.1	20.9	20.4	0.2	7.1	11.2	2.2	0.0	23.6	65.0	3.1	6.3	0.3	10.6	44.7	265.6
	8	1.7	0.0	0.0	40.4	26.6	22.2	3.1	6.4	5.7	0.0	14.4	16.7	33.3	21.1	5.0	0.0	7.0	33.0	236.6
	9	2.6	0.0	0.0	63.1	21.8	25.6	0.3	10.0	0.7	0.0	0.0	26.1	37.6	1.5	7.8	0.0	11.0	51.5	259.6
	10	2.6	0.0	0.0	63.1	21.8	25.6	0.3	10.0	0.7	0.0	0.0	26.1	37.6	1.5	7.8	0.0	11.0	51.5	259.6
	11	2.8	0.0	0.5	60.0	22.9	26.8	0.4	11.3	1.7	0.0	0.1	24.8	37.8	3.7	7.4	0.0	10.4	49.1	259.7
	12	3.1	0.0	1.2	55.0	24.7	28.7	0.6	13.5	3.3	0.0	0.4	22.7	38.1	7.1	6.8	0.0	9.6	45.2	259.9
	13	0.0	0.0	0.0	0.0	43.3	20.6	6.7	7.2	14.7	0.0	34.1	0.0	29.2	53.2	1.5	0.1	0.0	0.0	210.5
	14	2.5	0.0	0.0	59.9	24.7	26.3	0.3	11.5	1.4	0.0	0.3	24.8	38.0	3.4	7.8	0.0	10.4	48.9	260.5
	15	0.3	0.0	0.0	6.9	74.0	38.8	0.0	36.7	13.9	0.0	5.8	2.9	44.6	36.1	8.4	0.4	1.2	5.7	275.7
	16	1.0	0.0	0.9	9.6	68.0	39.1	0.3	35.2	13.8	0.0	5.1	3.9	43.9	35.0	7.5	0.4	1.6	8.1	273.4
	17	0.0	0.0	0.0	0.0	80.4	40.4	0.0	40.0	15.5	0.0	6.5	0.0	45.5	40.4	8.5	0.5	0.0	0.0	277.7
KTL	1	0.0	0.0	0.0	0.0	80.4	40.4	0.0	40.4	15.5	0.0	6.5	0.0	45.5	40.4	8.5	0.5	0.0	0.0	277.7
	2	0.0	0.0	0.0	0.0	80.4	40.4	0.0	40.4	15.5	0.0	6.5	0.0	45.5	40.4	8.5	0.5	0.0	0.0	277.7
	3	0.0	0.0	0.0	0.0	80.4	40.4	0.0	40.4	15.5	0.0	6.5	0.0	45.5	40.4	8.5	0.5	0.0	0.0	277.7
	4	3.6	0.0	5.3	0.6	59.3	45.6	1.6	38.1	18.7	0.0	4.3	0.0	42.9	43.0	3.6	0.2	0.0	1.9	268.7
	5	5.4	0.0	7.9	1.2	44.9	48.7	2.5	35.5	19.8	0.1	4.0	0.1	42.2	44.0	0.7	0.4	0.0	2.9	260.3
	6	4.5	0.0	6.6	2.4	32.6	49.9	2.3	28.7	16.6	0.8	8.0	0.7	45.1	41.9	0.2	1.9	0.0	2.6	244.6
	7	5.8	0.0	8.0	8.5	41.4	46.5	2.5	33.5	18.6	0.0	2.4	3.1	40.7	39.7	0.9	0.0	1.3	9.1	261.9
	8	6.2	0.0	9.1	1.0	44.1	49.3	2.8	36.7	21.0	0.0	2.7	0.0	41.1	44.9	0.0	0.0	0.0	3.3	262.2
	9	6.2	0.0	9.1	1.0	44.1	49.3	2.8	36.7	21.0	0.0	2.7	0.0	41.1	44.9	0.0	0.0	0.0	3.3	262.2
UBP	1	0.0	4.2	2.8	13.9	61.2	38.6	4.4	25.1	10.9	7.7	2.9	8.9	29.8	23.7	8.2	0.2	0.0	0.0	242.6
	2	0.2	3.4	3.4	25.9	56.1	40.3	6.4	19.9	7.3	18.2	0.0	15.2	30.7	13.7	12.0	0.0	0.0	0.0	252.7
	3	0.0	0.0	2.4	6.9	28.5	34.4	2.1	9.3	10.3	6.5	13.8	2.7	44.0	32.7	8.4	4.3	0.0	0.5	206.6
	4	0.0	0.0	6.8	10.8	61.6	0.0	2.5	1.3	16.9	15.9	0.1	1.9	22.3	29.0	24.1	0.4	0.0	0.0	193.7
	5	0.0	0.0	9.3	9.9	65.2	0.0	9.2	4.7	21.8	14.2	0.5	6.8	20.5	25.2	21.8	1.3	0.1	0.0	210.5
MNN	1	0.5	4.2	1.4	31.9	57.3	60.5	20.4	31.2	0.3	21.9	0.2	30.0	33.0	0.2	3.5	0.1	2.0	0.2	298.8
	2	0.6	1.0	6.6	14.8	62.1	23.2	37.9	16.8	2.7	22.1	2.9	25.3	26.9	2.1	11.2	1.5	8.4	2.0	268.2
	3	0.3	0.0	9.6	29.5	65.2	48.9	26.9	34.0	6.7	20.0	8.0	13.0	39.8	5.7	20.9	4.1	10.4	5.6	348.8
	4	0.0	0.0	11.9	15.2	81.4	39.2	64.7	67.1	9.5	22.9	7.4	3.2	32.9	5.2	18.0	4.3	10.9	5.2	399.1
	5	0.7	0.0	2.3	33.7	79.1	82.3	32.7	72.6	2.2	28.4	0.5	21.1	66.5	0.3	4.3	0.5	1.3	0.3	428.9
	6	0.3	0.0	3.7	22.9	65.0	35.3	5.7	23.5	9.3	20.9	0.0	10.4	42.4	18.6	16.8	0.0	0.1	0.0	275.0
NPP	1	0.4	0.0	13.4	18.3	52.1	28.4	1.5	27.7	3.8	13.3	9.8	42.9	36.4	18.1	12.9	2.9	32.3	0.6	314.9
NHM	1	0.0	0.2	22.7	8.6	82.4	5.3	38.7	27.2	40.5	9.7	4.0	41.4	14.7	5.0	9.0	5.9	9.5	0.1	324.9
	2	0.0	0.0	21.0	5.6	81.9	0.0	39.8	20.5	44.3	6.5	2.3	29.3	12.1	7.7	11.1	5.5	0.3	0.0	288.1
	3	0.0	2.4	7.0	13.5	85.6	21.8	35.5	46.5	20.7	57.5	0.3	19.0	31.6	24.6	6.3	1.1	0.8	0.0	374.3
	4	0.0	4.7	6.3	19.6	84.0	13.9	13.3	23.1	27.7	89.8	0.5	35.9	27.6	35.3	1.2	1.2	0.1	0.0	384.1
	5	0.0	5.7	2.4	22.8	83.2	16.7	5.6	22.4	22.6	107.4	0.0	35.5	31.4	42.3	0.0	0.0	0.0	0.0	398.0
	6	0.0	5.7	2.4	22.8	83.2	16.7	5.6	22.4	22.6	107.4	0.0	35.5	31.4	42.3	0.0	0.0	0.0	0.0	398.0
	7	0.0	0.0	26.0	31.8	97.5	4.9	1.8	43.9	0.0	24.5	0.0	85.3	18.8	0.9	25.6	0.0	66.0	0.0	426.1
	8	0.0	3.1	13.2	24.7	89.0	10.9	7.8	30.9	16.4	67.6	0.2	54.6	24.8	22.9	10.3	0.6	25.1	0.0	402.1
	9	0.3	0.0	19.0	22.1	83.5	4.1	14.7	31.3	0.1	23.4	0.0	66.3	19.8	0.0	19.0	0.0	46.5	0.0	350.1
KPS	1	0.0	0.0	19.6	25.6	81.7	4.2	17.2	40.4	0.0	16.4	2.6	78.9	14.2	0.0	19.4	0.0	44.2	0.0	370.1
	2	1.8	0.0	8.9	11.1	51.8	16.5	31.5	35.1	6.1	2.0	5.8	48.3	16.6	13.0	6.3	0.0	5.3	1.0	364.5
	3	3.3	2.8	10.8	12.8	36.0	9.2	43.6	22.8	7.5	2.6	4.6	52.5	21.0	15.0	12.5	0.0	0.0	0.4	257.3
	4	5.7	4.7	13.6	12.0	25.9	15.6	38.2	16.1	13.4	4.3	2.1	40.6	33.3	27.0	15.8	0.0	0.0	0.8	270.0
UPP	1	0.0	0.0	23.9	29.7	92.2	4.7	6.9	42.7	0.0	21.8	0.9	83.2	17.3	0.0	23.5	0.0	58.7	0.0	405.6
	2	0.0	0.0	11.1	17.4	60.5	3.3	37.8	35.7	0.0	5.6	6.2	70.4	8.2	0.0	11.1	0.0	15.2	0.0	282.5
	3	0.4	0.0	7.9	10.2	57.4	2.8	39.9	21.8	0.2	12.5	3.4	50.5	14.2	0.0	8.4	0.0	10.5	0.0	240.0
MEAN		1.2	0.8	6.5	18.9	55.7	26.3	12.7	26.9	11.3	14.8	5.3	22.6	34.0	22.3	8.4	1.4	8.0	7.9	285.2

TABLE 9-5 HOURLY HEIGHTS OF TIDE AT BANG PAKONG (OCTOBER 1983)

Time (Hour)	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0	1.78	2.86	1.99	2.08	2.28	2.28	2.44	2.47	2.47	2.52	2.68	2.16	2.08	1.86	1.76	1.72
1	1.60	2.67	1.76	1.84	1.98	2.00	2.22	2.32	2.36	2.59	2.71	2.35	2.31	1.91	1.70	1.61
2	1.49	2.54	1.61	1.67	1.78	1.81	1.99	2.18	2.30	2.64	2.84	2.67	2.75	2.20	1.96	1.57
3	1.48	2.45	1.52	1.56	1.63	1.68	1.80	2.00	2.25	2.63	2.84	2.92	3.18	2.78	2.50	1.91
4	2.18	2.67	1.47	1.49	1.54	1.57	1.70	1.88	2.14	2.43	3.01	3.09	3.48	3.30	3.12	2.74
5	2.96	2.58	1.92	1.67	1.52	1.52	1.67	1.76	2.05	2.42	2.91	3.10	3.51	3.56	3.52	3.37
6	3.44	3.34	2.73	2.33	1.84	1.59	1.68	1.76	1.96	2.17	2.72	2.99	3.51	3.60	3.69	3.73
7	3.64	3.72	3.36	3.00	2.39	2.03	1.89	1.80	1.87	2.08	2.36	2.72	3.16	3.39	3.67	3.85
8	3.61	3.85	3.61	3.48	2.93	2.55	2.26	1.97	1.89	1.97	2.19	2.40	2.76	3.08	3.48	3.83
9	3.33	3.87	3.76	3.74	3.28	3.00	2.65	2.18	1.95	2.01	2.09	2.18	2.41	2.72	3.09	3.51
10	2.92	3.59	3.72	3.88	3.52	3.31	2.94	2.53	2.16	1.99	2.00	1.99	2.17	2.43	2.74	3.12
11	2.47	3.12	3.49	3.81	3.58	3.52	3.21	2.84	2.46	2.41	2.03	1.98	1.99	2.13	2.45	2.72
12	2.15	2.75	3.09	3.57	3.65	3.58	3.41	3.12	2.73	2.74	2.40	2.08	1.93	2.07	2.25	2.45
13	1.93	2.44	2.74	3.29	3.32	3.64	3.47	3.37	3.00	3.24	2.86	2.47	2.28	2.24	2.21	2.31
14	1.87	2.36	2.54	3.05	3.16	3.54	3.53	3.52	3.28	3.65	3.27	3.04	2.79	2.68	2.41	2.30
15	2.16	2.39	2.52	2.96	3.04	3.40	3.52	3.59	3.46	3.88	3.60	3.52	3.32	3.12	2.76	2.56
16	2.65	2.76	2.70	2.96	2.96	3.50	3.43	3.52	3.53	3.95	3.70	3.75	3.63	3.52	3.27	2.99
17	3.26	3.20	2.96	3.04	3.02	3.24	3.34	3.51	3.44	3.98	3.80	3.84	3.80	3.67	3.57	3.35
18	3.59	3.55	3.27	3.27	3.12	3.24	3.28	3.31	3.25	3.68	3.62	3.74	3.68	3.57	3.59	3.49
19	3.68	3.73	3.45	3.49	3.20	3.16	3.22	3.08	3.12	3.44	3.31	3.40	3.36	3.40	3.40	3.40
20	3.52	3.56	3.43	3.44	3.28	3.04	3.21	2.87	2.87	3.17	2.88	2.98	2.92	2.97	3.01	3.07
21	3.01	3.16	3.22	3.40	3.12	2.99	3.11	2.75	2.68	2.86	2.62	2.58	2.56	2.52	2.56	2.68
22	2.64	2.96	2.80	2.96	2.92	2.78	2.96	2.60	2.51	2.76	2.35	2.29	2.27	2.18	2.18	2.28
23	2.20	2.36	2.52	2.61	2.63	2.72	2.68	2.52	2.48	2.62	2.23	2.09	2.04	1.95	1.92	1.98

9-3. Irrigation and Drainage Facilities

9-3-1. General Concept

The Project area is composed of three major irrigation systems; namely Si Yat Irrigation System (Tha Lat Expansion area), Tha Lat Irrigation System (Tha Lat Existing area) and Bang Pakong Irrigation System (Bang Pakong Left Bank Irrigation area and Bang Pakong Expansion area).

1) Tha Lat Irrigation System

The Tha Lat Irrigation System was constructed in 1953. The intake of the main canal for the Tha Lat Irrigation Project is located on the left bank 60 m upstream of the Tha Lat weir. And the main canal runs to the direction of south west in parallel with the Bang Pakong river. The regulating gates are installed at the point of 3.0 km from the intake and the discharge of main canal is controlled by these gates. According to the rehabilitation plan prepared in 1986 by RID, the design intake water level is EL5.50 m. The canal slope is very flat as 1/50,000 from the intake to the regulating gates and 1/14,000 from the regulating gates to the end.

Total length of the main canal is 44 km. Initially it was designed as concrete canal, however it was replaced by the earth canal during construction due to the budget shortage for the Project. The maximum capacity of this canal is 15.90 cu.m/sec and the flow velocity is considerably slow ranging from 0.3 to 0.5 m/s. The canal section has been reduced by scouring and silting. According to the Project plan, the canal capacity will be up-graded to 22.1 cu.m/sec so that the canal section and related structures are improved to meet the plan.

The canal section is trapezoidal having a side slope of 1 : 1.5. The main canal has six laterals and several check gates on the way. Several drain inlets are provided on the left bank as the supplemental intakes from the catchment area.

The main canal is aligned along the contour line and supply the water to the service area located on the right bank.

More than 10 laterals have been constructed by farmers except six regular laterals which were initially installed by RID. Earth canal is applied for laterals and only structures were made of concrete. The laterals are aligned at right angles to the main canal. The water level in the laterals are assumed some-what lower than the ground elevation of the service area.

2) Bang Pakong Irrigation System

A polder dike is constructed surrounding the project area and regulating gates are provided at the outlet of natural creeks to take the fresh

water when the water level of the river is higher than that of the service area and to save water to be released during low water period of the river. Those gates also function to prevent the saline water intruding into the irrigation service area during dry season. Some of them were however damaged and not functioning.

Natural creeks are connected each other forming canal net-works. The stored water in these creeks is supplied to the service area, however, it is not enough to irrigate the area in dry season.

Farmers use their own small pumps to supply the irrigation water to their paddy field due to the insufficient water level. Accordingly those creeks are used dual purposely for irrigation and drainage. The flow direction in the creeks is not constant so that check structures are not applicable.

The polder dike shall be improved at the insufficient part and used as the operation road. The regulating gates which are installed at the outlet of creeks along the polder dike shall also be rehabilitated or improved. Several regulating gates are required upstream of the proposed diversion dam to control the intake water and downstream to prevent saline water from intruding into the orchard area located outside of the polder dike. Although these creeks have a role to drain out excess water, the combined check gates shall be considered to make operation easier. There exist considerable extent of chicken and pig cultivation in the orchard area. The problem is the polluted water drained from those livestock yard. Drainage canals for those polluted water shall therefore be separated from irrigation canals. Especially, since the stored water by the proposed diversion dam will be used for industrial and drinking purposes, those polluted water must be prevented from intruding into the upstream portion of the dam.

About 37 km of main canal shall be installed to improve the irrigation network to maximize the effect of construction of the diversion dam. Irrigation water will be diverted to existing creeks through the main canal and head gates. The canal will be lined by thin concrete to reduce land acquisition and operation and maintenance costs.

3) Si Yat Irrigation System

The Si Yat Irrigation System is newly developed with service areas about 5,400 ha on the right bank and about 1,700 ha on the left bank of the Si Yat river (tributary of the Tha Lat river). The elevations of beneficial area located on the right bank area range from EL.40 m to EL.10 m and those on the left bank EL.15 m to EL.5 m.

A gravity irrigation method is recommended.

Since the elevation of right bank area is considerably high and the area is located near the proposed dam, the direct intake method will be provided for the area. As an alternative plan for the left bank area, it was considered to discharge required volume of water directly into the Si Yat river and take it from the diversion weir to be newly installed at 10 km upstream of the Existing Tha Lat diversion weir. However this method is not recommendable because a high diversion weir required to take water from the Si Yat river. Accordingly the water is conveyed crossing the Tha Lat river at the point of Wat Bang Phaniyang by a siphon extending the right bank main canal.

The capacities of the canals and structures are designed based on the diagrams illustrated in Figures 9-8, 9-9 and 9-10.

The main and lateral canals are constructed by the Project and the on-farm facilities will be consolidated by the beneficiaries.

9-3-2. Irrigation and Drainage Scheme

The existing irrigation systems are to be efficiently utilized with additional construction as well as rehabilitation of main and lateral canals and their appurtenant structures, and with consolidation of on-farm facilities, except for the Tha Lat expansion area where new systems of irrigation and drainage are constructed separately.

In the existing Tha Lat irrigation area, present farm plots and canal alignments are in principle left as they are, main and lateral canals are rehabilitated and main and supplemental drains are consolidated together with development of on-farm facilities.

In the existing and proposed Bang Pakong Left Bank irrigation areas, the main irrigation canal is provided in order to conduct water diverted from the proposed Bang Pakong diversion dam to each of natural drain, from where irrigation waters are received by farmers. The existing streams and drains function dual purposely for irrigation and drainage. They will work as drainage canals when drainage is required in and around the service area and, on the contrary will work as irrigation canal when drainage is not required, after an adequate supply of irrigation water is guaranteed by the Project. Tail-end regulating structures, which function either flood control gates during flood period or tidal gates during irrigation period, and check structures installed on such natural drains will be properly operated for the purpose of controlling irrigation and drainage.

FIGURE 9-8 IRRIGATION DIAGRAM FOR THA LAT IRRI. PROJECT AREA

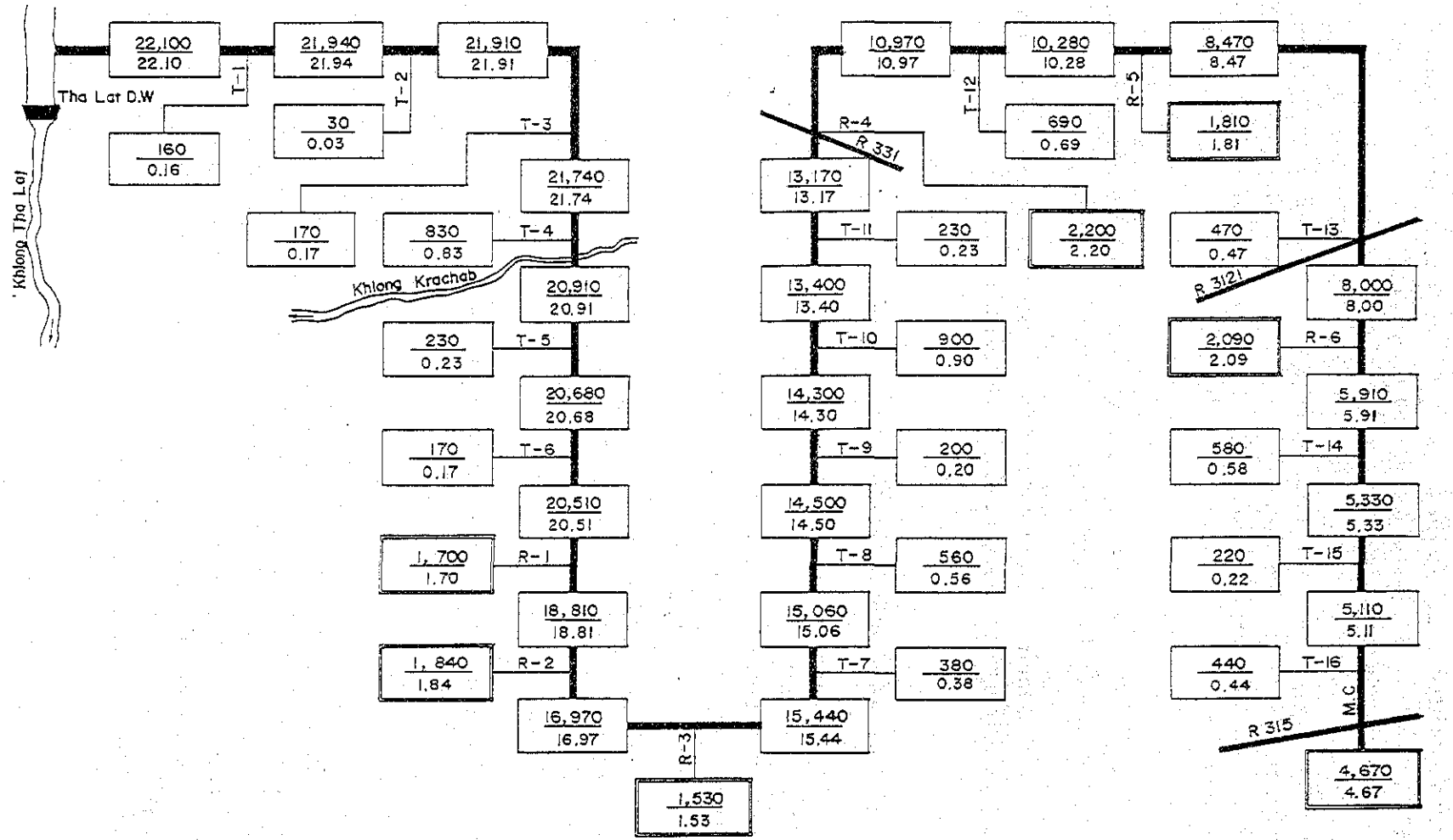


FIGURE 9-9 IRRIGATION DIAGRAM FOR BANG PAKONG LEFT BANK IRRI. PROJECT AREA

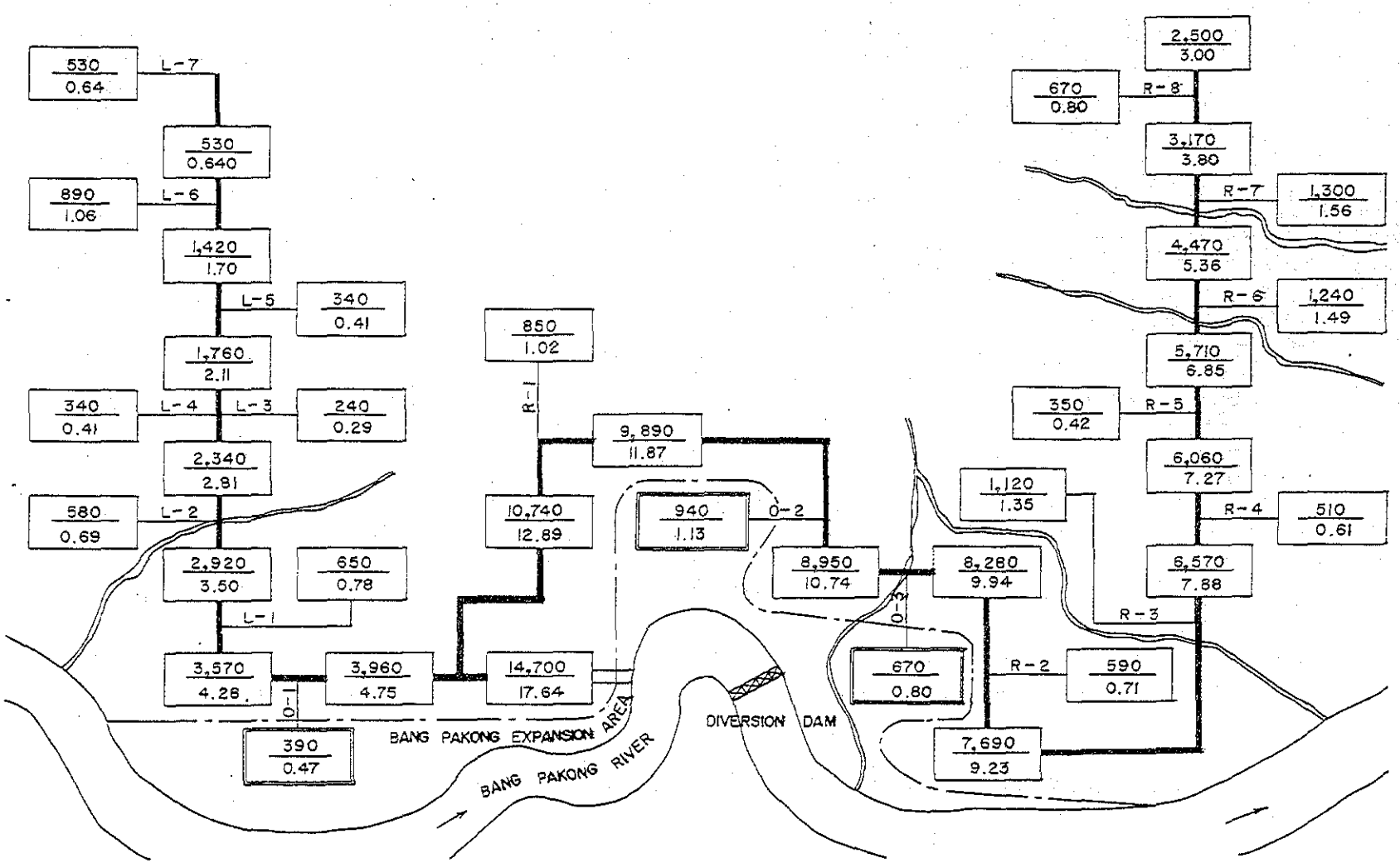
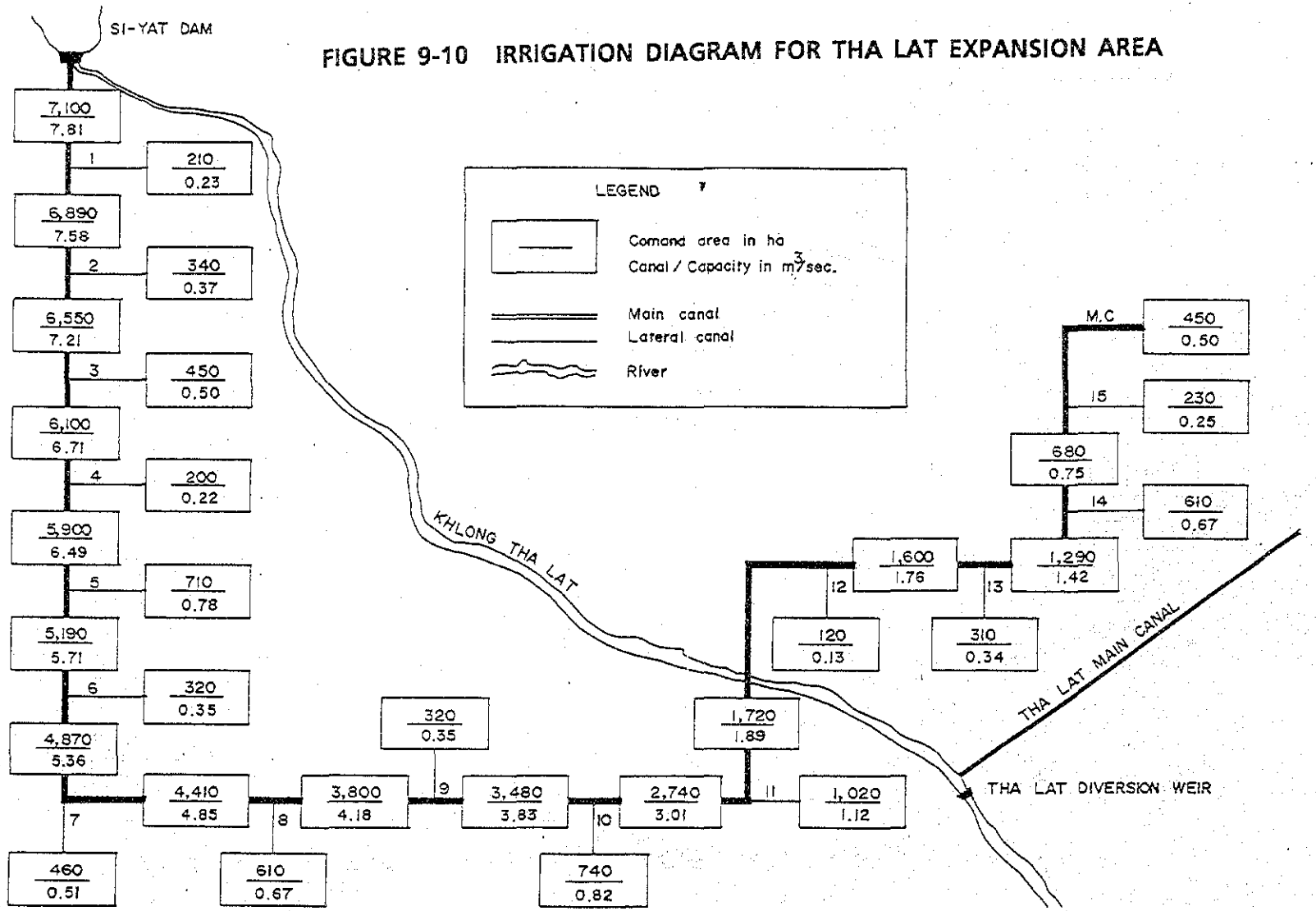


FIGURE 9-10 IRRIGATION DIAGRAM FOR THA LAT EXPANSION AREA



In the Tha Lat expansion area, irrigation and drainage systems are newly developed including main, lateral and on-farm facilities.

In order to determine irrigation method applicable in the Tha Lat expansion area, intake-rate tests were conducted. The test results, collected from the selected five sites are summarized as follows:

Result of Intake-Rate Test

Site	Dc	Ic	In	Tn
No.1	$DC = 2.549T^{0.635}$	$IC = 97.1T^{-0.885}$	13.6	219
No.2	$DC = 1.834T^{0.594}$	$IC = 85.4T^{-0.408}$	7.0	244
No.3	$DC = 9.273T^{0.382}$	$IC = 212.5T^{-0.818}$	5.5	371
No.4	$DC = 18.089T^{0.208}$	$IC = 225.8T^{-0.782}$	1.7	475
No.5	$DC = 1.870T^{0.521}$	$IC = 58.5T^{-0.479}$	3.9	287

Note:
1) Accumulated infiltration $Dc = CT^n$ (mm)
2) Cylinder intake-rate $Tc = 60CnT^{n-1}$
3) time T (min)
4) Basic intake-rate $In = 60\ Cn\{(600\ (1 - n)\}^{n-1}$ (mm/hr)
5) Time to arrive at In : $T_n = 600\ (1 - n)$ (min)

Most crops can be irrigated by the furrow method except those grown in ponded water, such as rice. The furrow method is particularly suitable for irrigating crops subject to injury if water covers the crown or stem of the plants, as the crops may be planted on beds between furrows. This irrigation method is best suited to medium to moderately fine textured soils of relatively high available water holding capacity and conductivities which allow significant water movement in both the horizontal and vertical directions, and is suitable to fine textured very slowly permeable soils on level sites which permit water impoundment.

From the above figures, basic intake-rates of not exceeding 7.8 mm/hr are observed at the sites except the No.1 site, meaning that the furrow irrigation system is mostly applicable in the area.

The level impoundment furrow system will be introduced in the area. water is applied at one end of the furrow at a rate that will provide coverage of the entire length in a relatively short time. The water is then ponded until it infiltrates. The inflow rate should be large enough to advance to the end in not greater than 1.5 times the net opportunity time required for the design application. The rate, however, must not exceed the flow capacity of the furrow nor result in excessive erosion.

The capacities of irrigation facilities are determined based on the peak irrigation requirements. The annual peak and second largest values of requirements in irrigation service areas for the subject Feasibility Study were extracted from the 20 year's water balance computation. After eliminating the annual peak values in order to save the design capacities, the second largest values were then put into probability analysis to produce the water duties for irrigation main canals. (cf. Appendix D.8)

In consideration of rotational irrigation especially during dry season, the water duty for irrigation ditches was determined on the basis of the peak on-farm irrigation requirement of 8.87 mm/day for dry season paddy during the first 10-day period of March (cf. Appendix D.1). The farm distribution losses of 15% for paddy cultivation was also considered in order to obtain the design unit discharge of irrigation ditches as gives below:

$$\frac{8.87 \text{ mm} \times 1.0 \text{ ha}}{1 - 0.15} = 1.21 \text{ lit./sec/ha (or 0.19 liter/sec/rai)}$$

Water Duties for Irrigation Canals and Ditches

(Unit: liter/sec/ha)

Service Area	Main and Lateral Canal	Ditch
Existing Tha Lat Area	1.0	1.21
Tha Lat Expansion	1.1	1.21
Existing & Proposed Bang Pakong	1.2	1.21

The paddy rice is tolerant of flooded water to some extent if the depth and duration of inundation are kept within the acceptable limit. In the subject Project area, most of the storm rainfall to cause flood is concentrated on 3 to 5 days. From the above consideration, the Project aims to set up the design intensity of storm rainfall as the 3-day consecutive rainfall of a 5-year return period, and 150 mm was obtained from the measurements collected at the 03042 station in Amphoe Ban Pho. The design modulus was then determined so as to drain the probable 3-day consecutive rainfall on the irrigated field in 3 days. Assumptions and procedures taken in determining the design modulus are as follows:

- A 3-day consecutive rainfall of a 5-year return period was selected with a value of 150 mm.
- Losses due to evaporation and percolation were disregarded for safety reason. Therefore, water to be drained is 150 mm.

- For rice and other corp cultivation, water is to be drained in 3 days, consequently the design modulus = 150 mm/3 days = 50 mm/day.
- A conversion factors from mm/day to liter/sec/ha and to liter/sec/rai are 0.1157 and 0.0185, respectively.
- The design modulus is 50 × 0.1157 = 5.79 liter/sec/ha or 50 × 0.0185 = 0.926 liter/sec/rai.
- Point rainfall was only considered. The resulted design modulus is accordingly applicable for the area of on-farm level not exceeding 2,000 rai (320 ha).
- Reduction factors to apply the design modulus for drainage areas larger than 2,000 rai are quoted from the RID's previous study as follows:

REDUCTION FACTORS FOR DRAINAGE AREAS LARGER THAN 2,000 RAI

Drainage Area in Rai		Reduction Factor
less than 2,000		1.00
2,000~	5,000	0.95
5,000~	10,000	0.90
10,000~	20,000	0.86
20,000~	50,000	0.76
50,000~	100,000	0.72
100,000~	200,000	0.68
200,000~	500,000	0.64
500、000~	1,000,000	0.60
>	1,000,000	0.58

9-3-3. Tha Lat Irrigation System (Existing Tha Lat Area)

1) Tha Lat Weir

The crest elevation of existing weir is EL.5.00 m which was heightened 1 m in 1960. Two flash gates with stop logs were installed at the both sides of the weir when it was heightened. The width of weir is 23 m at the crest and the height of the weir is 5.0 m.

There are two natural canals named Huai Muang Ploang and Hu Chang respectively 2.5 km and 600 m upstream of the weir on the right bank of the Tha Lat river. These two canals adjoin each other and are connected to the

Tha Lat river upstream and downstream of the weir. Therefore Hu Chang river functions as spillway of the Tha Lat diversion weir. A regulating gate sized 2.0 m × 1.8 m is installed in the Hu Chang river.

The crest of the weir shall be heightened to rise the capacity of the main canal and to increase effect of gravity irrigation system for the service area. In order to drain flood water safely without reduction of the width of existing weir and to maintain normal water surface, a flap type gate will be effective. A rubber gate is, therefore, recommended in consideration of above functions, and from view points of easy operation and maintenance as well as its reasonable construction cost.

The size of the weir is as follows:

Diversion Weir	
Type	Fixed with rubber gate
Length	44.0 m
Height	6.0 m
Fixed Crest Elevation	EL.3.30 m
Gate	
Type	Rubber flap gate
Length	33.5 m
Height	2.60 m
Crest Elevation	EL.6.00 m

2) Main Canal

The canal section between the intake and regulating gate has not enough capacity due to silting so that it shall be excavated to the proper size. Generally as the canal size is inadequate downstream of the regulating gates due to silting, it shall be expanded to maintain proper canal section. Rock excavation will be required for some part of canal located downstream.

Furthermore for the purpose of enforcing canal capacity from the existing 15.9 m^3/s to the proposed 22.1 m^3/s to meet the improvement plan, the main canal will be lined with concrete taking the limited land property and reduction of operation and maintenance cost into consideration.

Since the free board is also insufficient at some part of the main canal especially at the downstream portion, additional filling will be needed and both the banks will be used as trunk roads. Check gates are required immediate downstream of head gates or the tail of the canal to maintain the necessary water level. Some culverts and siphons crossing roads or natural creeks have

not enough capacity in its section especially downstream of the main canal, and therefore they shall be improved to the proper section.

The Canal length by capacity is as follows:

Capacity (m3/s)	Length (km)
22.10	6.00
20.91	3.85
18.81	2.15
16.97	2.70
15.44	8.25
10.97	2.60
8.47	2.02
5.91	10.00
4.67	6.43

3) Lateral Canal

Lateral Canal were designed with a concrete lining section initially, however the lining was not implemented due to the budget shortage. Accordingly the canal section which has been reduced by silting shall be expanded to a proper capacity. Both the banks shall be improved with required sizes and they will be used for operation and maintenance and agriculture purposes.

New construction of check gates at the proper stations, repairing of the protection up and downstream of the structures, improvement of the structures having insufficient capacity, etc. shall be required in order to maintain the sufficient irrigation water level. Several laterals are also requested to be improved for the proper irrigation distribution system in the area.

4) Farm Turn-Out

The farm turn-out will be improved into a constant head type turn-out with one gate. They are principally installed at the same stations of existing turn-outs, however, additional installation will be required so that a turn-out will cover about 50 ha of irrigation service area.

5) Drainage Canal

Usually natural streams and creeks are used for main or lateral drainage canals. Farm drains shall be constructed by the beneficiaries.

The plan of system is shown in Drawing F-12 and the profile and dimensions of main canal are shown in Drawing F-13. Typical structures are shown in the drawings of Appendix as example.

9-3-4. Bang Pakong Irrigation System (Existing and Proposed Bang Pakong Area)

1) Pumping Station

Since the control water level upstream of the proposed Bang Pakong diversion dam varies from (+) 1.30 m to (-) 1.50 m, a low head pumping station with the maximum capacity of 17.64 m^3/s shall be installed to lift the water from the division dam to the main canal.

The design condition of pump is as follows:

Design Discharge	:	Q = 17.64 m^3/sec
Lowest Suction Water Level	:	(-) 1.5 m
Discharge Water Level	:	(+) 3.70 m

Judging from the monthly water requirement shown in Table 9-6, the type and dimension of the pump are recommended as follows::

Type	:	Vertical diagonal flow pump
Unit	:	4 units
Size	:	ϕ1,500 mm
Discharge Capacity:		264.4 m^3/min
Total Head	:	6.10 m
Motor Capacity	:	390 KW

TABLE 9-6. MONTHLY WATER REQUIREMENT FOR PUMPING

Month	Requirement (m^3/sec)	Ratio (%)	
Apr.	4.91	17.8	(1/4)
May	4.23	24.0	(1/4)
Jun.	1.98	11.2	(1/8)
Jul.	4.32	24.5	(1/4)
Aug.	17.64	100.0	(4/4)
Sep.	17.64	100.0	(4/4)
Oct.	17.64	100.0	(4/4)
Nov.	6.50	36.8	(1/3)
Dec.	10.91	61.8	(3/5)
Jan.	12.94	73.4	(3/4)
Feb.	14.20	80.5	(4/5)
Mar.	12.39	70.2	(3/4)

2) Main Canal

At the point 700 m downstream of the discharge basin of pumping station, the intake canal is diverted to the Left main canal and Right main

canal. The capacity of Right main canal is 12.89 cu.m/sec with the canal size deducted according to the irrigation requirement. The canal length is as follows:

Canal Name	Capacity (m^3/sec)	Length (km)
Intake Canal	17.64	0.7
Left Main Canal	4.75	12.0
Right Main Canal	12.89	24.0

The canal section is designed as trapezoidal shape having a side slope of 1:1.5. And it is lined with the concrete to reduce the land acquisition cost and seepage.

The profile and dimensions are shown in Drawing F-18 and F-19.

3) Check Gate and Head Gate

Head gates are installed at the proper stations to deliver water to the service area through existing creeks. In order to supply proper amount of water to the service area, several check gates are arranged along the main canal.

4) Drainage System

To prevent polluted water from intruding into the proposed diversion dam, a drainage canal along the Bang Pakong river is provided. Regulating gates will be provided at the outlet of existing creeks in the upstream of the dam to control outflow of polluted water and inflow of irrigation water. So the gates work as intakes during the high water level of the dam.

On the other hand, several natural creeks are to be expanded to maintain enough capacity to release excess water. Furthermore some regulating gates with insufficient capacity shall be rehabilitated and improved.

The recommended plan is shown in Drawing F-12.

9-3-5. Si Yat Irrigation System (Proposed Tha Lat Expansion Area)

1) Main Canal

About 50 km of main canal will be installed for the irrigation of Tha Lat Expansion area.

Because that the long canal is provided in order to intake water directly from the dam and to convey water to the left bank, a concrete lined canal is recommended to save water from leakage. In order to minimize the water to be released from the dam even during wet season, the drained excess water from the catchment area will be received by the drain inlet structure or waste culvert. Adequate number of spillways and waste ways are also provided for the convenience of operation and maintenance works.

The canal slope is decided to maintain allowable velocity to avoid scouring and silting. Drop structures are provided to waste excess water head where the steep topography is predominant.

The check gate shall be provided at the immediately downstream of lateral head gates and at proper stations to maintain enough water level and to use water effectively. Both or either bank shall be used for the operation road and farm road.

The canal length by capacity is as follows:

Capacity (m^3/s)	Length (km)
7.81	16.1
6.49	9.9
4.85	3.5
3.01	2.4
1.89	7.4
0.75	10.2

The plan is shown in Drawing F-20 and the profile and dimensions are shown in Drawing F-21.

2) Lateral Canal

Lateral canals are constructed as earth canal.

Laterals are located at the proper interval so that farm ditches do not exceed 1 km and numbers of direct farm turn-out from main canal is minimized. Intake water level of farm turn-out is planed at 30 cm above the ground level of service area with installation of check gates to be arranged properly. Either bank is also used for operation and farming practice.

3) Head Gate

Sluice gate will be provided for the head gate of lateral to deliver the water to the lateral canal.

4) Farm Turn-out

A constant head turnout covering about 50 ha of irrigation service area will be newly provided or will replace the existing ϕ300 mm pipe in order to achieve better management of irrigation services. Because of unnecessity of orifice control due to the flat topography, however, the control gate only will be installed.

5) Drainage Canal

Farm drains are constructed by beneficiaries. Usually natural streams and creeks are used for main or lateral drainage canals. It will be maintained in good condition by the O & M office or beneficiaries.

Canal system of Tha Lat Expansion area is shown in Drawing F-20.

9-3-6. On-farm Work

The proposed Project provides fundamental irrigation and drainage facilities involving the main and lateral canals and their appurtenant structures, and expects that the necessary on-farm facilities be constructed by farmers themselves, in order to fulfill (1) double cropping in every part of the irrigation service area with the cultivation of a high yielding variety, (2) irrigation and drainage control, (3) application of rotational irrigation method and (4) introduction of upgraded farming technique and practice.

The on-farm facilities consist of, farm ditches, diversion boxes, checks, farm inlets, road crossings and farm drains. Farm roads are, however, not recommended to avoid reducing of farm land.

Farm Ditch

A farm ditch will be aligned along the existing paddy dike in order to convey irrigation water to a field, and be touched to every paddy plot in principle. One kilometer per 50 ha of the main farm ditch and 500 m per 10 ha of supplementary farm ditch will be needed. The ditch will have a trapezoidal cross-section with a side slope of 1:1 and the minimum bottom width and water depth of 0.3 m. Check structures of stoplog type will also be installed at the tail and proper interval.

Farm Inlet

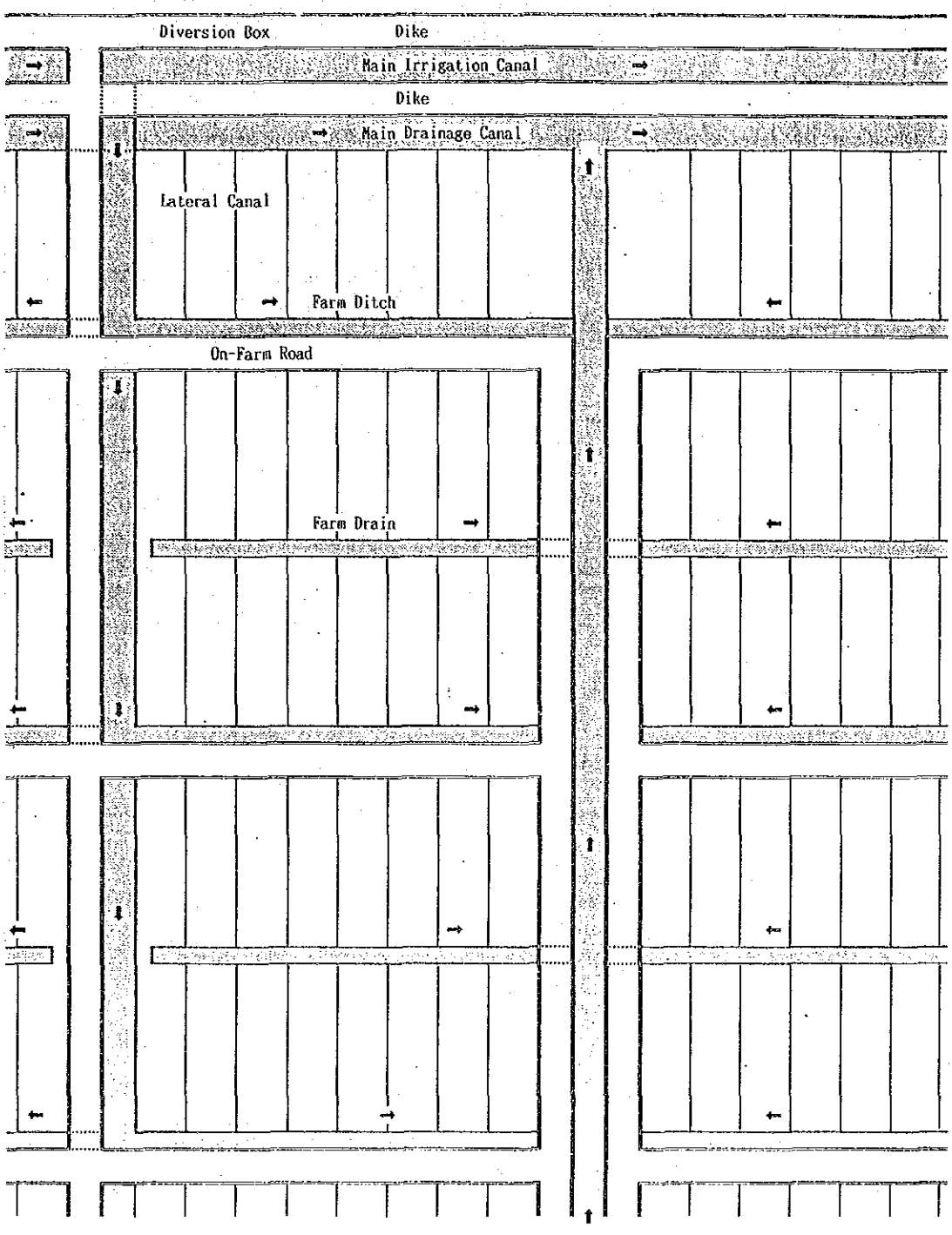
A farm inlet of a ϕ200 mm concrete pipe with a wooden stoplog will be installed to take water from the farm ditch into paddy plots.

Farm Drain

A main farm drain and supplementary farm drain will be consolidated respectively on the opposite side of the main farm ditch and between the supplementary farm ditch. The main farm ditch will be linked with the lateral drain which will be connected to the main drain. Natural streams and creeks will however be commonly used as the main and lateral drains.

An ideal layout of the on-farm facilities is shown in Figure 9-11.

FIGURE 9-11 IDEAL LAYOUT OF ON-FARM FACILITIES



CHAPTER 10. PROJECT IMPLEMENTATION PROGRAM

CHAPTER 10. PROJECT IMPLEMENTATION PROGRAM

10-1. Project Management and Implementation

10-1-1. Project Leading Agency

The water consumers in the project consist of irrigation beneficiary, industrial sector, urban and rural inhabitants, fish growers and EGAT power plant.

There are numbers of the governmental agencies which have been providing services for water resources and related agricultural development in the subject Project area. Such ministries concerned to the Project are Ministry of Agriculture and Cooperatives (MOAC), Ministry of Industry (MIND), Ministry of Interior (MOI), and Ministry of Science and Technology (MOST).

The agencies under MOAC are;

- Royal Irrigation Department (RID) responsible for design, construction and O & M of the storage dam, diversion dam, main and lateral irrigation and drainage canals as well as for providing technical assistance to the water user's groups in designing, implementing and executing, O & M of irrigation facilities and water management works within their terminal irrigation areas.

- Department of Agricultural Extension (DOAE) which would play an important role for extension services on all agricultural commodities.

- Department of Agriculture (DOA) responsible for research and institutional aspects on all field crops.

- Department of Fishery (DOF) responsible for servicing both the marine and freshwater fishery in all aspects including production and marketing.

- Cooperative Promotion Department (CPD) responsible for promotion of establishment of cooperatives and agri-creit business.

- Royal Forest Department(RFD) which is responsible to regulate development and to implement watershed management programme in the national reserved forest area.

Under the Ministry of Industry, the Industrial Estate Authority of Thailand (IEAT) has a responsibility to provide bulk industrial water to the large scale industrial complex as well as small private industrial development area. Provincial Waterwork Authority (PWA) under the MOI has a responsibility to provide domestic and drinking water to the urban and rural area. Electric Generating Authority of Thailand (EGAT) under MOST would have a responsibility to implement electric development scheme by constructing hydropower generation plants and the thermal power plants.

10-1-2. Project Executing Agency and Organization

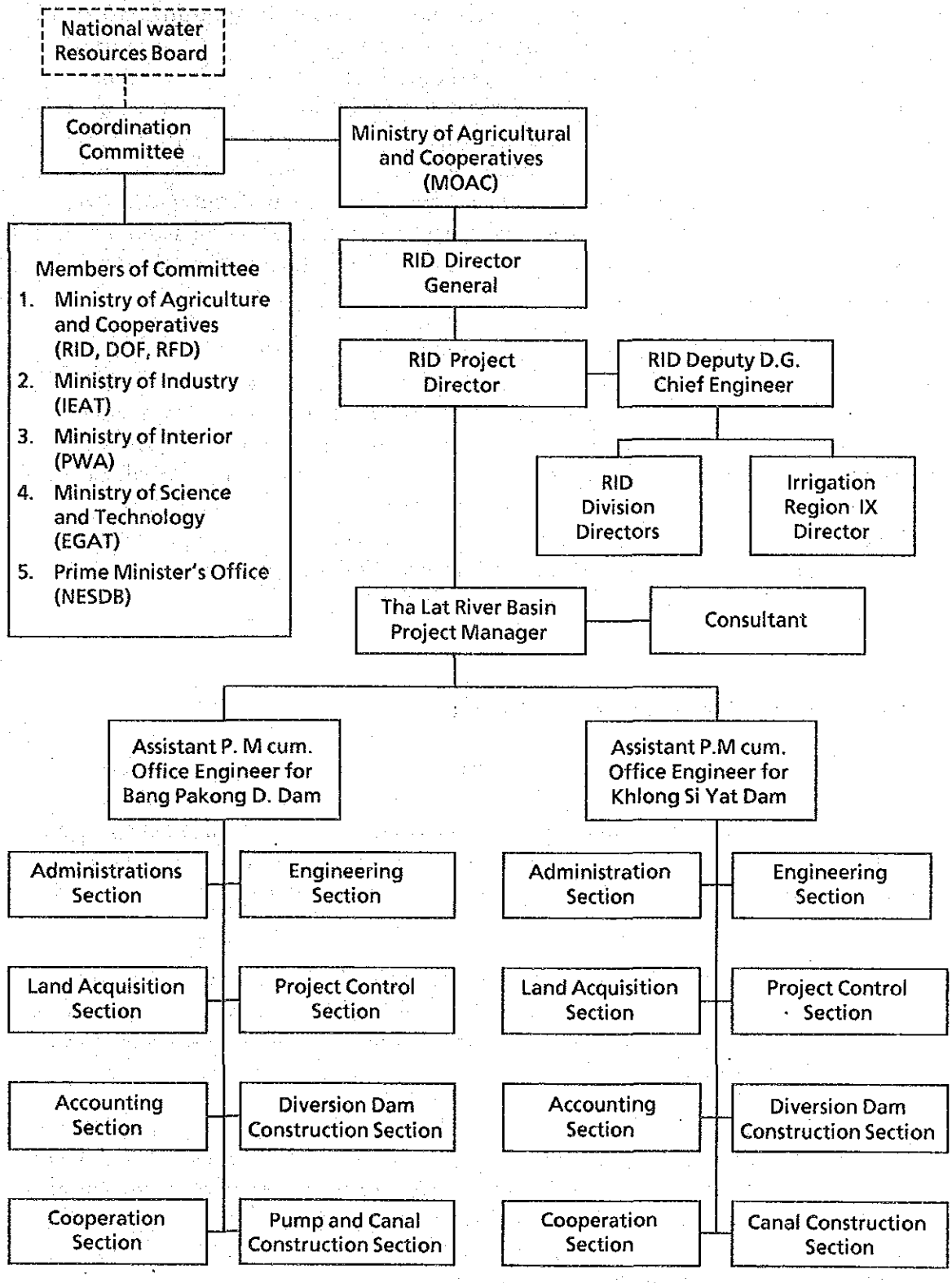
A special board to be chaired by MOAC is recommendable to be organized as the Coordinating Committee for the implementation of the proposed Tha Lat River Basin Development Project, for both overall planning and decision-making functions on the national level, especially the aspects of water resources development and well balanced water distribution management.

The committee would have its members comprising MOAC, MIND, MOI, MOST, NESDB (National Economic and Social Development Board) and Governor of Changwat Chachoengsao. Secretary group under the committee should be nominated from RID, IEAT, PWA, DOF, RFD and EGAT. Main function of the Committee would be to determine water resources development policy, water distribution management based on development progress and/or project components required from respective sectors such as irrigation, industry, drinking water, fishery and power generation. Beside the above, it would be to approve the project budgets as well as cost sharing policy, to ensure the coordination of various activities and to resolve the project implementation programmes.

Major construction works of the project for irrigation sector are composed of storage dam, diversion dam, pumping station and main irrigation canal systems of about 130 km long in total. The Royal Irrigation Department (RID), which has the prominent experience in the similar-natured projects to the Tha Lat River Basin Project (TLRBP), should be responsible for the execution of the Project. The proposed organization of execution body is illustrated in figure 10-1.

The organization of Project implementation of RID are usually lined up by the Project Director, Project manager, Office Engineer and Section Chiefs. The Project Director is comprehensively responsible for the project implementation. The project manager is, under the control of the Project Director, fully responsible for the execution of the project works. The Office Engineers are assigned to assist the Project Manager in overall project works.

FIGURE 10-1 PROPOSED ORGANIZATION OF PROJECT IMPLEMENTATION



Two positions of office engineer will be nominated separately for Phase-I and Phase-II projects as indicated in the Figure 10-1.

The Administrative Section will be responsible for administration property, personnel affairs and miscellaneous matters. Land Acquisition Section will function for land and personnel property compensation and purchasing, and implementation of resettlement. Accounting Section will function for labour recruitment, material procurements related to the construction work and its accounting services. Cooperation Section will be responsible for provision of technical assistance for on-farm development works by the project beneficiary, to cooperate other agencies concerned on the irrigated agricultural development and to train the farmers on the on-farm water management.

The Engineering Section is in charge of necessary topographic survey for design of major canal systems under the cooperation of the Survey Division, RID, detailed design of canals and relevant facilities under the supervision of the Design Division, and arrangement for land acquisition. Project Control Section is responsible for construction planning, preparation of tender documents inclusive of specifications and cost estimate, and budget allocation schedule. Dams, Pump and Canals Construction Section is in charge of construction supervision and inspections of the works on contract basis, repairing works, and water and electric supply.

10-1-3. Water Management in The Basin

Water resources to be developed in the Bang Pakong river basin are mainly river runoff with storage reservoirs and diversion dams, and there are huge amount of such development potentiality. As discussed already in the previous sections, those storage dam construction will be implemented in the prioritized development manners and based on water demands from respective consumer sectors.

As the result of overall river basin study, Tha Lat river basin with two storage dams (total live storage capacity of 340 MCM) and two diversion dams (existing Tha Lat diversion weir and Bang Pakong diversion dam) was selected as the highest priority project.

Bang Pakong diversion dam to be constructed on the Bang Pakong river has many positive functions, such as (1) to prevent saline water intrusion in dry season, (2) to store river runoff during transition period of wet and dry season, (3) to regulate water released from storage reservoirs on the upstream river and (4) to develop both the regions of the Bang Pakong on the left and right banks by providing road and bridge.

According to the Khlong Si Yat and Rabom reservoir operation rules, a water level upstream of the Bang Pakong diversion dam will usually be kept (+) 1.00m MSL until storage volumes of the reservoirs go down to the low water level. Storage reservoir on the Bang Pakong river after completion of the said diversion dam will function as an intake pool of about 50 km long up to the conjunction of Nakhon Nayak and Prachin river, where many water consumers including irrigation farmers, private factories and fishery growers compete each other for water diversion.

In order to manage developed water resources effectively and harmoniously, Water Management Board (WMB) should be established on the provincial level guided by RID Operation /Maintenance Office. The members of WMB are to be collected from all of the agencies concerned with the water utilization involving the Chachoengsao provincial governor. It is noted here that the proposed subject Project would cover the water demands for irrigation requested from the farmers within the Feasibility Study area, industrial and drinking water in Chachoengsao province, fishery water in the specified area along the lower reaches of the river and for domestic water required in the EGAT power station.

Water resources development scheme in the Tha Lat river basin is divided into two phases, first phase for Bang Pakong diversion dam and second phase for Khlong Si Yat dam.

Actual water utilizations for each development phase, however, do not meet the projected water demands. These imbalance between water demand and water supply or availability should be adjusted periodically for effective use of water resources.

Water users other than those in the project area along the Bang Pakong river will request to utilize more fresh water in dry season. In such a case, WMB should take prompt actions to adjust water distribution within an allowable level of water resources developed and/or to be developed.

10-2. Project Implementation Program

10-2-1. Implementation Program

Project implementation program shall be prepared taking into account the phased water demand, urgency of water supply, effectiveness of investment and quick development of the Project. In order to use stored water of Rabom dam effectively, the project implementation schedule is divided into two phases with beneficiaries and major facilities of the respective phases as summarized in the following: