JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

ROYAL IRRIGATION DEPARTMENT
MINISTRY OF AGRICULTURE AND COOPERATIVES
KINGDOM OF THAILAND

THE DETAILED DESIGN STUDY ON THE BANG PAKONG DIVERSION DAM PROJECT

BASIC DESIGN REPORT

MAIN REPORT

FEBRUARY 1993

SANYU CONSULTANTS INC.

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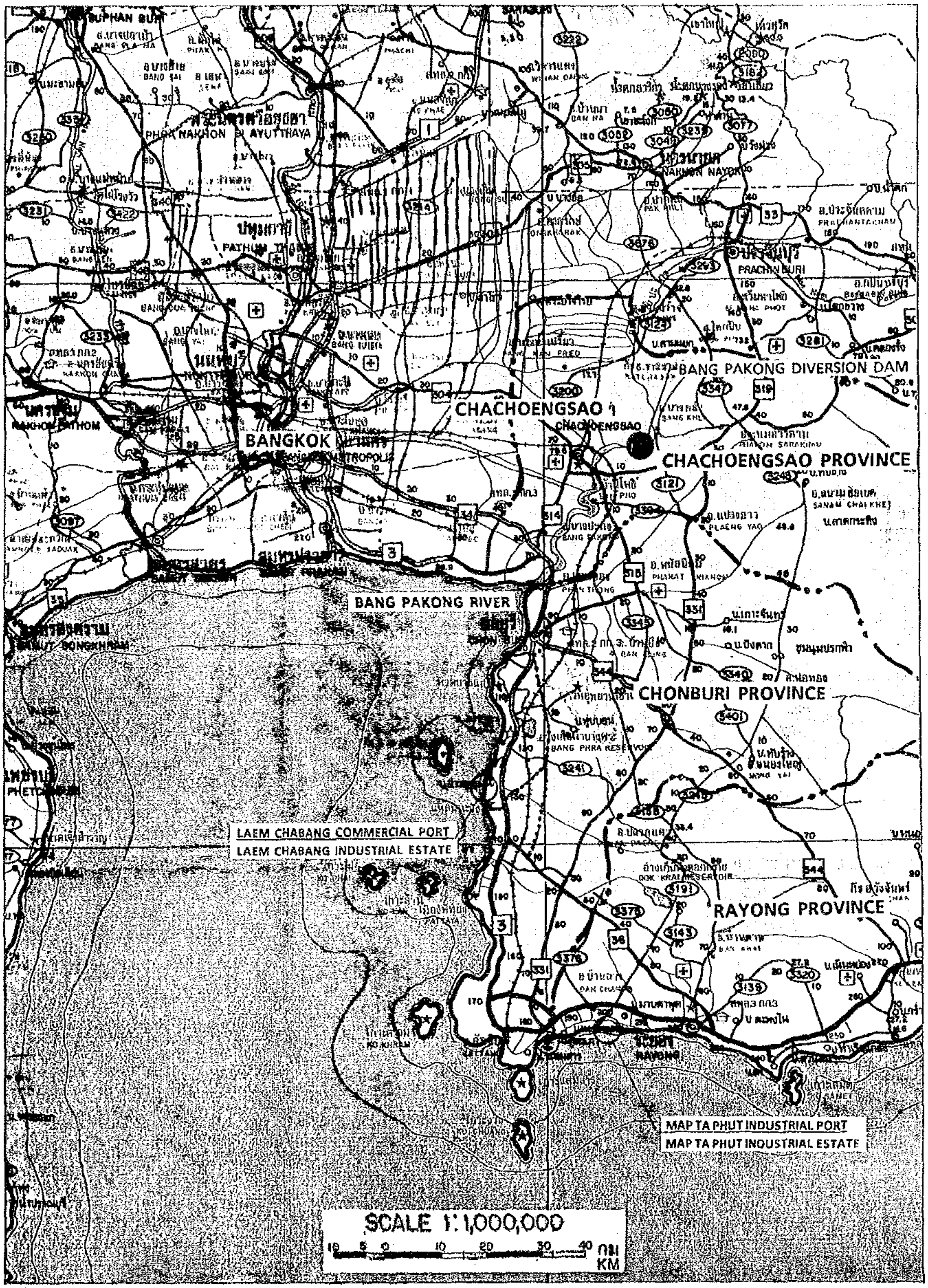
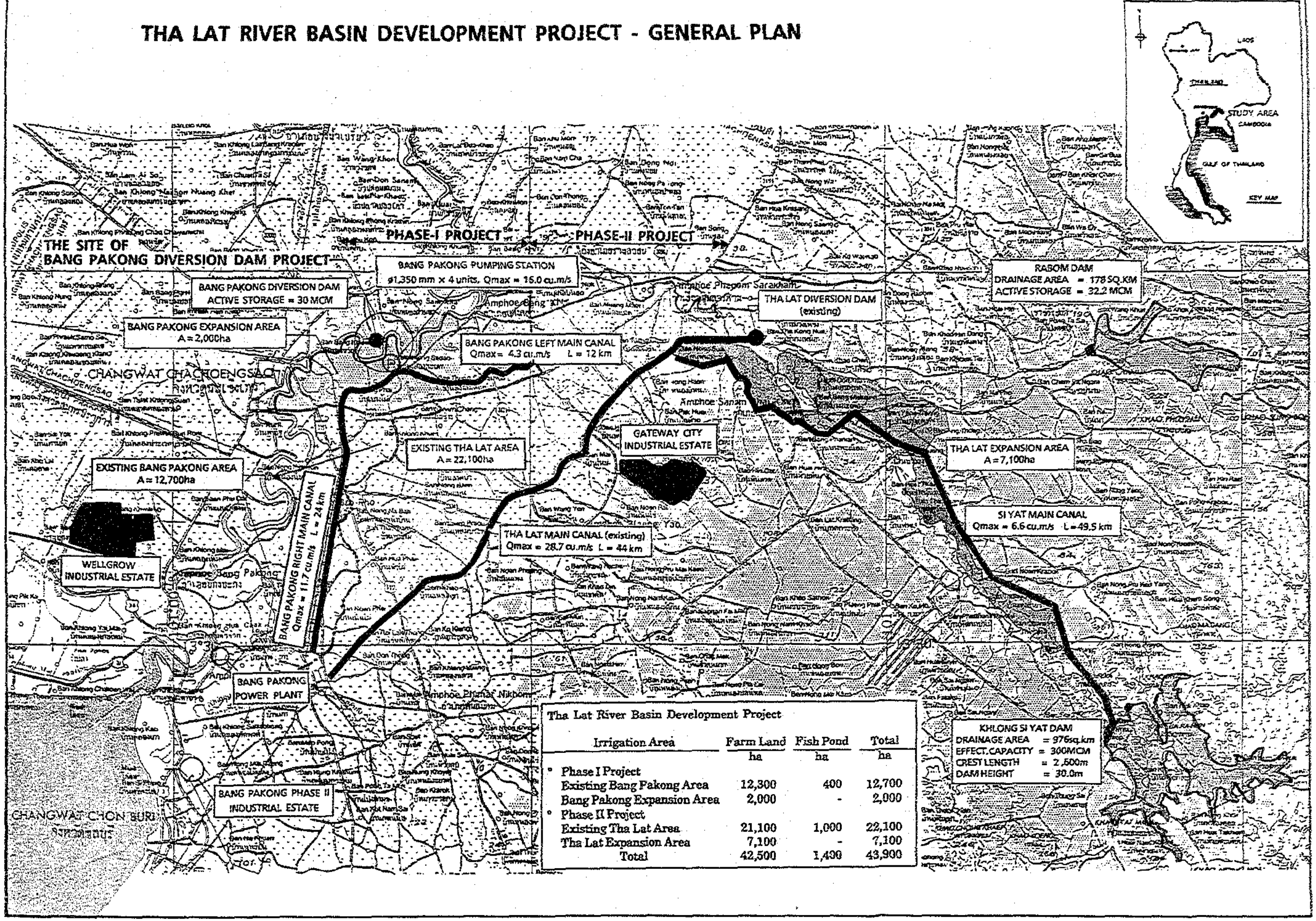
LOCATION MAP



THA LAT RIVER BASIN DEVELOPMENT PROJECT - GENERAL PLAN



The Lat River Basin Development Project

Irrigation Area	Farm Land	Fish Pond	Total
	ha	ha	ha
° Phase I Project			
Existing Bang Pakong Area	12,300	400	12,700
Bang Pakong Expansion Area	2,000	-	2,000
° Phase II Project			
Existing Tha Lat Area	21,100	1,000	22,100
Tha Lat Expansion Area	7,100	-	7,100
Total	42,500	1,400	43,900

BANG PAKONG DIVERSION DAM PROJECT - GENERAL PLAN

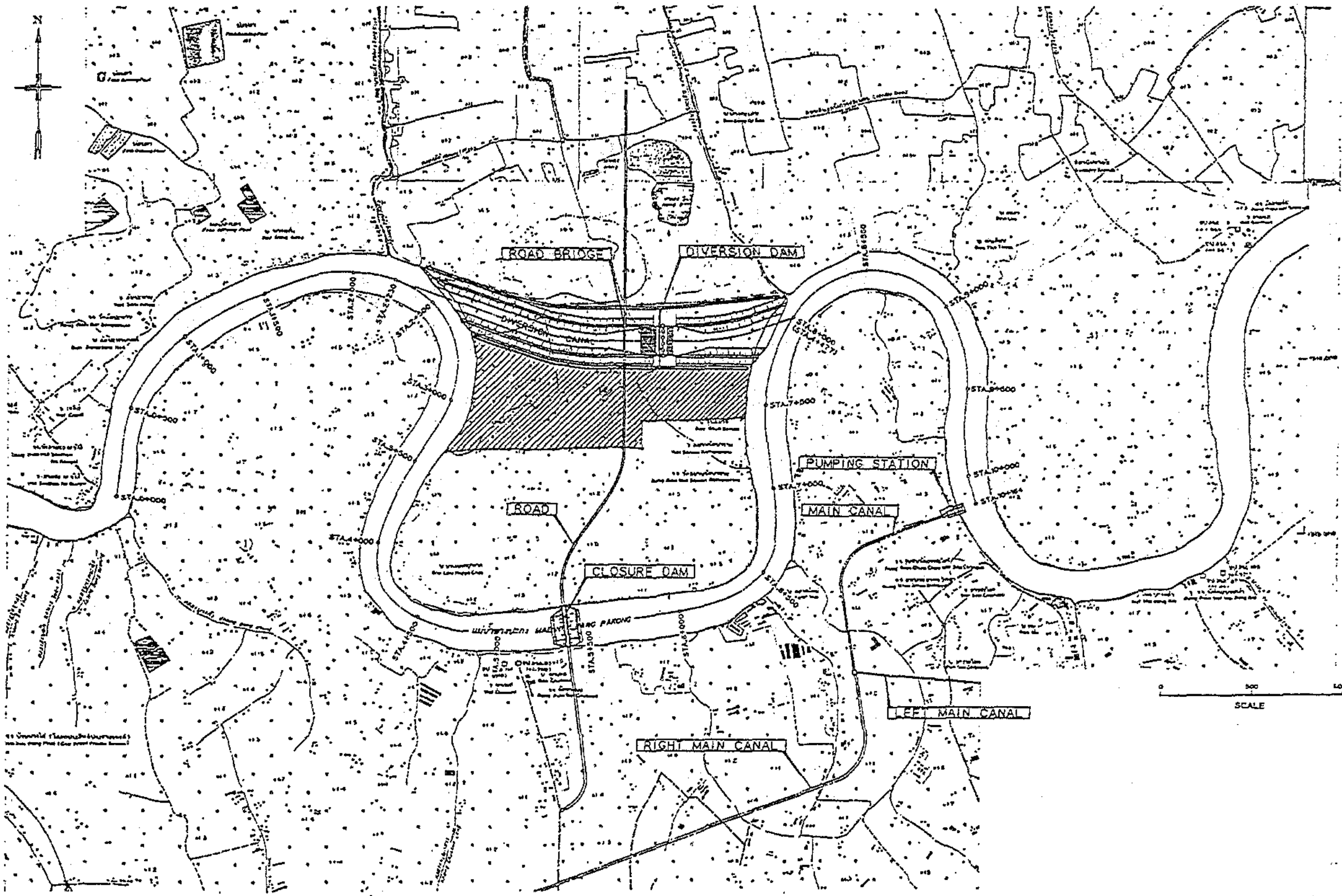


TABLE OF CONTENTS

Page

Page

Page

CHAPTER 10. BASIC DESIGN OF CONTROL SYSTEM

CHAPTER 11. BASIC DESIGN OF ELECTRICAL FACILITIES

CHAPTER 12. CONSTRUCTION PLAN

Page

LIST OF TABLES

LIST OF FIGURES

Page

PART I INTRODUCTION

PART II THA LAT RIVER BASIN DEVELOPMENT PHASE I PROJECT

PART III BANG PAKONG DIVERSION DAM PROJECT

Page

PART IV ENVIRONMENTAL CONSIDERATION

ABBREVIATIONS AND ACRONYMS USED

THAI GOVERNMENT

DOH	:	Department of Highway, MOC
DTEC	:	Department of Technical and Economic Cooperative
HD	:	Harbor Department, MOC
LDD	:	Livestock Development Department, MOAC
MD	:	Meteorological Department, MOC
MOAC	:	Ministry of Agriculture and Cooperatives
MOC	:	Ministry of Communications
MOI	:	Ministry of Industry
MOSTE	:	Ministry of Science, Technology and Environment
NEB	:	National Environment Board
NESDB	:	Office of National Economic and Social Development Board, Office of the Prime Minister
OEPP	:	Office of Environmental Policy and Planning
ONEB	:	Office of National Environment Board
PEA	:	Provincial Electricity Authority, Ministry of Interior
PWA	:	Provincial Waterworks Authority, Ministry of Interior
RID	:	Royal Irrigation Department, MOAC
RTSD	:	Royal Thai Survey Department
TOT	:	Telephone Organization of Thailand

GENERAL

B	:	Baht
BM	:	Bench Mark
EIRR	:	Economic Internal Rate of Return
EL	:	Elevation above Mean Sea Level
JICA	:	Japan International Cooperation Agency
M.	:	Million
W. L	:	Water Level
cu.m, m^3	:	Cubic meters
MCM	:	Million cubic meters
kw	:	Kilowatt
kwH	:	Kilowatt hour
l	:	Liter
ha	:	Hectare
m	:	Meter
kg	:	Kilograms
km	:	Kilometer
sq.km, km^2	:	Square kilometers
sq.m, m^2	:	Square meters
ton	:	Metric ton

p. a.	:	per annum
Yr.	:	Year
hr	:	Hour
min	:	Minute
sec	:	Second
°C	:	Degree Centigrade
HP	:	Horsepower
PS	:	French Horsepower
ppt	:	part per thousand
P. C.	:	Prestressed Concrete
R. C.	:	Reinforced Concrete
ITV	:	Industrial television system

GLOSSARY

Changwat	:	Province
Ampoe	:	District
Tambon	:	Sub-District
Muban	:	Village
Mae Nam	:	A large river
Sungai	:	A medium-sized river
Khlong	:	A tributary of the large river

THAI FISCAL YEAR

October 1 to September 30, next year

THAI WATER YEAR

April 1 to March 31, next year

PART - I. INTRODUCTION

CHAPTER 1. BACKGROUND OF THE STUDY

Bang Pakong river is one of Thailand's larger rivers with a drainage area of 17,660 sq.km and an average annual runoff of 7,900 MCM. It flows down through Chachoengsao Province situated north of the Eastern Seaboard Development Area and adjoining the eastern margin of the Bangkok Metropolitan Circle.

In Chonburi and Rayon Provinces in the Eastern Seaboard Development Area, and in the Bangkok Metropolitan Circle, there is nowhere that further development of water resources could be carried out on a large scale. In the proximity of these two areas regarded as the industrial and economic centers of Thailand, the Bang Pakong river passing through Chachoengsao Province is the only river leaving undeveloped water resources in the drainage area and allowing future development of water resources on a large scale.

The Bang Pakong river, however, is a tidal river, and sea water usually comes up 120 km from the estuary in a dry season with small river runoff. Therefore, the construction of a diversion dam to prevent sea water intrusion will be essential for efficient utilization of the river water.

Paddy cultivation is made in the wet season, but the farmers frequently suffer from drought resulting in a low income level. There is no cultivation in the dry season because few dams have been built.

In the lowest area of the Bang Pakong river basin, very favourably located 40 - 50 km both from the Bangkok Metropolitan Circle and from the commercial port of Laem Chabang, and well-treated as the second area of investment promotion, factory and industrial estate construction is flourishing. The total estate area has already surpassed the areas of Map Ta Phut Industrial estate and Laem Chabang Industrial Estate which are typical industrial estates in the Eastern Seaboard Development Area. However, the necessary domestic and industrial water is supplied under very unstable conditions from the terminal irrigation canals. Considering the present agriculture in the basin and the domestic and industrial water supply conditions for the factories and industrial estates constructed in and around the lowest area of the Bang Pakong river basin, the water resources development project in the Bang Pakong river basin, which aims to introduce irrigated agriculture in order to raise the farmers' income and to secure the domestic and industrial waters, is very urgent and indispensable. It is to be promoted as a top priority national development project.

In 1988 the Thai Government requested the Japanese Government to prepare a master plan for an agricultural water utilization development project for the Bang Pakong river basin and to conduct a feasibility study of the area selected for such a project. The Government of Japan agreed to the study which was carried out by JICA from 1989 - 1990. The final report was presented to the Thai Government in October 1990.

According to this report, the development plan for the overall river basin is to secure a total of 3,950 MCMs of water, including 3,610 MCMs of irrigation water for 410 thousand ha, 320 MCMs of domestic and industrial water and 20 MCMs of water for fisheries. In order to ensure the water to be developed, construction of 12 storage dams with active storage capacities of 2,260 MCM in total, use of the existing Rabom dam with active storage of 40 MCM and construction of the Bang Pakong diversion dam are proposed. The project on which the feasibility study was carried out is the Tha Lat river basin development project aiming at strengthening water utilization for 42,500 ha of agricultural land in the lower area of the Bang Pakong river basin and securing domestic and industrial water which is in high demand.

The project area of the Tha Lat River Basin Development Project is classified into two sub-areas, the area to be supplied water from the Khlong Si Yat dam and the area to be supplied water from the Bang Pakong diversion dam, according to the difference of main water sources.

At the time of project implementation, construction works are divided into Phase I and II according to urgency. The area to be supplied water from the Bang Pakong diversion dam will be developed first as the Phase I project and subsequently the area to be supplied water from Khlong Si Yat dam will be developed as the Phase II project.

The project facilities required for satisfying the Phase I project are as follows:

TABLE 1-1 PHASE I PROJECT FACILITIES

	Facilities	Facilities Scale	Project Executing Body
①	Bang Pakong Diversion Dam	166 m in length	RID
②	Appurtenant Facilities		RID
	(a) Diversion Canal	approx. 2,200 m in length	
	(b) Closure Dam	approx. 250 m in crest length	
	(c) Road	approx. 2,600 m in length	
	(d) Road Bridge	approx. 250 m in length	
	(e) O/M Building	approx. 60 ha building site	
③	Irrigation Facilities		RID
	(a) Pumping Station	240 cu.m/min × 4 units	
	(b) Irrigation Canal	36 km in length	
	(c) Drainage Canal	30 km in length	
④	Purification Plants and Distribution Facilities for Domestic and Industrial Water	Annual water supply amount: 66.5 MCM (net)	PWA

Of the facilities to be constructed by RID, the Government of Thailand requested the Government of Japan to prepare a detailed design study for ① Bang Pakong diversion dam, ② Appurtenant facilities and Pumping station in ③ Irrigation facilities in June 1991, JICA is due to carry out this study.

The Government of Thailand entrusted the implementation of an Environmental Impact Assessment of the project area to a third party, Kasetsart University. They started in July 1991 and submitted the draft report on the environmental impact assessment of the Bang Pakong Diversion Dam Project in March 1992.

After receiving the report, the Government of Japan dispatched a preparatory study team for the detailed design of the Bang Pakong Diversion Dam Project in April 1992. The study team confirmed the Thai government's conclusions drawn from the contents and results of the environmental impact assessment conducted by Kasetsart University, and discussed the JICA detailed design study implementation with the government. The scope of work (S/W) for the detailed design study was then agreed upon and signed by RID and JICA Thai Office in July 1992. According to the S/W, JICA organized and dispatched a study team to the Kingdom of Thailand to commence the detailed design study in October 1992.

CHAPTER 2. OBJECTIVES OF THE STUDY

The objectives of the study are to carry out the detailed design on the Bang Pakong diversion dam and pumping station as shown in the study reports on the Agricultural Water Development Project of Bang Pakong River Basin, for which a study of the Project was made between September 1989 and October 1990 by the JICA Study Team.

The study on the Bang Pakong Diversion Dam Project is composed of Phase I study and Phase II study, and is completed in two years. The objectives of the study are to prepare the basic design reports and pre-qualification document for the Phase I study, and detailed design reports and bidding documents for the Phase II study.

In addition, the technology transfer from the JICA study team to Thai counterparts is made during the course of the study.

CHAPTER 3. REPORTS

The Phase I study is to be included in the following volumes;

(1) Basic Design Report - Main Report
(2) Basic Design Report - Drawings
(3) Basic Design Report - Appendix
(4) Prequalification Documents
(5) Evaluation Criteria for Prequalification Documents

CHAPTER 4. ORGANIZATION OF THE STUDY

JICA organized the study team to carry out the detailed design study and RID organized the advisory committee and the working group to facilitate the smooth conduct of the study.

(1) JICA Study Team

1)	Dr. Jun'ichi KITAMURA	Team Leader
2)	Mr. Satoshi SHOJI	Hydrological & Hydraulic Analysis (1)
● 3)	Mr. Noriaki TAKEDA	Hydrological & Hydraulic Analysis (2)
4)	Mr. Kazuyoshi OHSAWA	Geology and Soil Mechanics
5)	Mr. Takeshi MATSUNAMI	Environmental Considerations (1)
6)	Mrs. Vipa PUNPRAW	Environmental Considerations (2)
7)	Mr. Hiroshi MORIYAMA	Design (1) / Co-Team Leader (Diversion Dam & Closure Dam)
● 8)	Mr. Kiyonori HAYASHI	Design (2) (Diversion Dam & Diversion Canal)
9)	Mr. Fumihiko KOMADA	Design (3) (Road & Road Bridge)
● 10)	Mr. Futoshi KUROMI	Design (4) (Assistant of Design (3) & (5))
11)	Mr. Eiji ADACHI	Design (5) (Pumping Station)
● 12)	Mr. Harumitsu NISHITANI	Mechanical & Electrical Facilities Design (1)
13)	Mr. Hideo KOIZUMI	Mechanical & Electrical Facilities Design (2)
14)	Mr. Masao SENJU	Building Design (1)
15)	Mr. Alongkorn TRACHOO	Building Design (2)
16)	Mr. Tsunesuke HIWATASHI	Control System Design
17)	Mr. Etsuji TANAKA	Construction Planning
● 18)	Mr. Takashi KATSU	Construction Cost Estimation
10)	Mr. Satoshi USUKI	Bidding Documents
20)	Miss Sachie Oikawa	Coordination

● : Home Office Work only.

(2) RID Advisory Committee

Name	Section
Chairman	
1) Mr. Chamroon Chindasanguan	Deputy Director General for Engineering
Committee	
2) Mr. Sawet Yasaravana	Director of Design Division
3) Mr. Narong Sopak	Director of Topographical Survey Division
4) Mr. Chaiwat Prechawit	Director of Geotechnical Division
5) Mr. Prasert Milintangul	Director of Hydrology Division
Committee and Secretary	
2) Mr. Sanan Sirion	Director of Bang Pakong River Basin Development Project Office

(3) RID Working Group

Name	Section
Chairman	
1) Mr. Montri Onvimol	Bang Pakong River Basin Development Project Office
Staff	
2) Mr. Vorapote Nandhanapote	Hydrology Division
3) Mr. Wichit Udomrattanasiri	Design Division
4) Mr. Rang Champanoi	Topographical Survey Division
5) Mr. Rungroj Chumthong	Geotechnical Division
6) Mr. Suwit Thanopanuwat	Project Planning Division
7) Mr. Phitak Paksanond	Foreign Finance Project Administration Division
8) Mr. Manop Boonyaprasit	Bang Pakong River Basin Development Project Office
Staff and Secretary	
9) Mrs. Neowarat Damrongsak	Bang Pakong River Basin Development Project Office

6)	Mr. Suwit Thanopanuwat	Project Planning Division
7)	Mr. Phitak Paksanond	Foreign Finance Project Administration Division
8)	Mr. Manop Boonyaprasit	Bang Pakong River Basin Development Project Office

Staff and Secretary

9)	Mrs. Neowarat Damrongsak	Bang Pakong River Basin Development Project Office

PART - II. THA LAT RIVER BASIN DEVELOPMENT PHASE I PROJECT

CHAPTER 1. OUTLINE OF THE PROJECT

1.1 Objectives of the Project

Tha Lat River Basin Development Project aims at water supply for irrigation, domestic use, industrial use and fish culture, and is developed in two phases of implementation, Phase I project and Phase II project, as shown in Table 1-1.

TABLE 1-1 OBJECTIVES OF THHA LAT RIVER BASIN DEVELOPMENT PROJECT

Objectives		Phase I	Phase I + II
(1) Irrigation			
a) Irrigation Service Area			
Existing Bang Pakong Area		12,300 ha	12,300 ha
Bang Pakong Expansion Area		2,000 ha	2,000 ha
Existing Tha Lat Area		-	21,100 ha
Tha Lat Expansion Area		-	7,100 ha
Total		14,300 ha	42,500 ha
b) Cropping Intensity		150 %	150 %
(2) Domestic Water Supply	: annual demand	18.9 MCM	32.3 MCM
(3) Industrial Water Supply	: annual demand	69.7 MCM	89.7 MCM
(4) Fish Culture Water Supply			
a) fresh water fish culture		400 ha	1,400 ha
b) Shrimp culture		980 ha	980 ha
(5) Compensatory Water Supply for Agriculture in Bang Pakong Right Bank Area during dry season		-	104.4 MCM
(6) Surplus Water	: annual amount	60 MCM	90 MCM

1.2 Project Facilities and Allocation of Construction Works

The project facilities of the Tha Lat River Basin Development Project are shown in Table 1-2. In the project facilities of Phase I project, the Bang Pakong diversion dam, the appurtenant facilities and irrigation facilities are constructed under the control of RID and the facilities for domestic and industrial water supplies are constructed under the control of PWA. All of the project facilities of Phase II project are constructed under the control of RID.

The construction works of the project facilities to be constructed under the control of RID in the Tha Lat River Basin Development Project are divided into four construction works as shown in Table 1-3.

TABLE 1-2 PROJECT FACILITIES OF THA LAT RIVER BASIN DEVELOPMENT PROJECT

1. Phase I Project	
1) Dam and Diversion Dam (Executing Body : RID)	
a) Rabom Dam (Existing)	Storage Dam, Active Storage 32.2 MCM
b) Bang Pakong Diversion Dam & Its Appurtenant Facilities	
- Bang Pakong Diversion Dam	Active Storage 30 MCM, 30 m × 5 spans
- Diversion Canal	about 2.2 km in length
- Closure Dam	about 250 m in crest length
- Road & Road Bridge	about 2.6 km in road length, about 250 m in road bridge length
- O/M Buildings	about 60 ha in building lot
2) Irrigation Facilities (Executing Body : RID)	
a) Pumping Station	Pump Discharge 16 m^3/sec (960 m^3/min) ϕ1,350 mm × 4 units
b) Main Irrigation Canal	36 km in length
c) Drainage Canal	30 km in length
3) Facilities for Domestic and Industrial Water Supplies (Executing Body : PWA)	
- Net Amount of Annual Water Supply	66.5 MCM (8,860 MCM × 0.75)
2. Phase II Project	
1) Dam and Diversion Dam (Executing Body : RID)	
a) Khlong Si Yat Dam	Storage Dam, Active Storage 300 MCM
b) Tha Lat Diversion Dam	Improvement of Existing Diversion Dam
2) Irrigation Facilities (Executing Body : RID)	
- Main Irrigation Canal	Improvement : 44 km New Construction : 50 km

Note : This table does not show farm facilities.

TABLE 1-3 ALLOCATION OF CONSTRUCTION WORKS OF RID's PROJECT FACILITIES

Construction Works	Details of Works
Phase I Project	
① Bang Pakong Diversion Dam Project	Construction of Bang Pakong Diversion Dam, its Appurtenant Facilities and Pumping Station
② Phase I Irrigation and Drainage Canals Project	Construction of Irrigation and Drainage Canals in Existing Bang Pakong Area and Bang Pakong Expansion Area
Phase II Project	
③ Khlong Si Yat Dam Project	Construction of Khlong Si Yat Dam
④ Phase II Irrigation Canal Project	Improvement of Existing Tha Lat Diversion Dam, Improvement and Construction of Irrigation Canals in Existing Tha Lat Area and Tha Lat Expansion Area

CHAPTER 2. PRESENT CONDITIONS OF THE PROJECT AREA

2.1 Location

As shown in Figure 2-1, the Tha Lat River Basin Development Project has an irrigation service area of 14,300 ha situated on the left bank of the lower area of the Bang Pakong river basin and a service area of domestic and industrial water supplies situated along main roads Nos. 304, 314 and 34.

The project area exists mainly in Chacheongsao province with a part of the project area belonging to Chonburi province. Chacheongsao province is located in the north part of the Eastern Seaboard Development Area and adjoins the eastern margin of the Bang Pakong Metropolitan Circle. The project area has an elevation of 0.8 meters to 1.5 meters on a flat alluvial plain.

2.2 Climate

The climate over the lower area of the Bang Pakong river basin is tropical and monsoonal. Two distinct seasons, the dry season with a northeast monsoon from November to April and the wet season with a southwest monsoon from May to October, are recognized in the area.

Annual rainfalls in the passed twenty years have ranged widely from a minimum of 880 mm in 1979 to a maximum of 1,660 mm in 1983, with 1,240 mm on an average. The peak of the wet season generally falls in September.

Temperature shows slight seasonal variation between a minimum of 26.2 °C in December and a maximum of 29.8°C in April, while the minimum relative humidity is recorded in December at 68% and the maximum in October at 81%.

Major climate features observed at the Chacheongsao station are summarized as shown in Figure 2-2.

FIGURE 2-1 THA LAT RIVER BASIN DEVELOPMENT PHASE I PROJECT - GENERAL PLAN

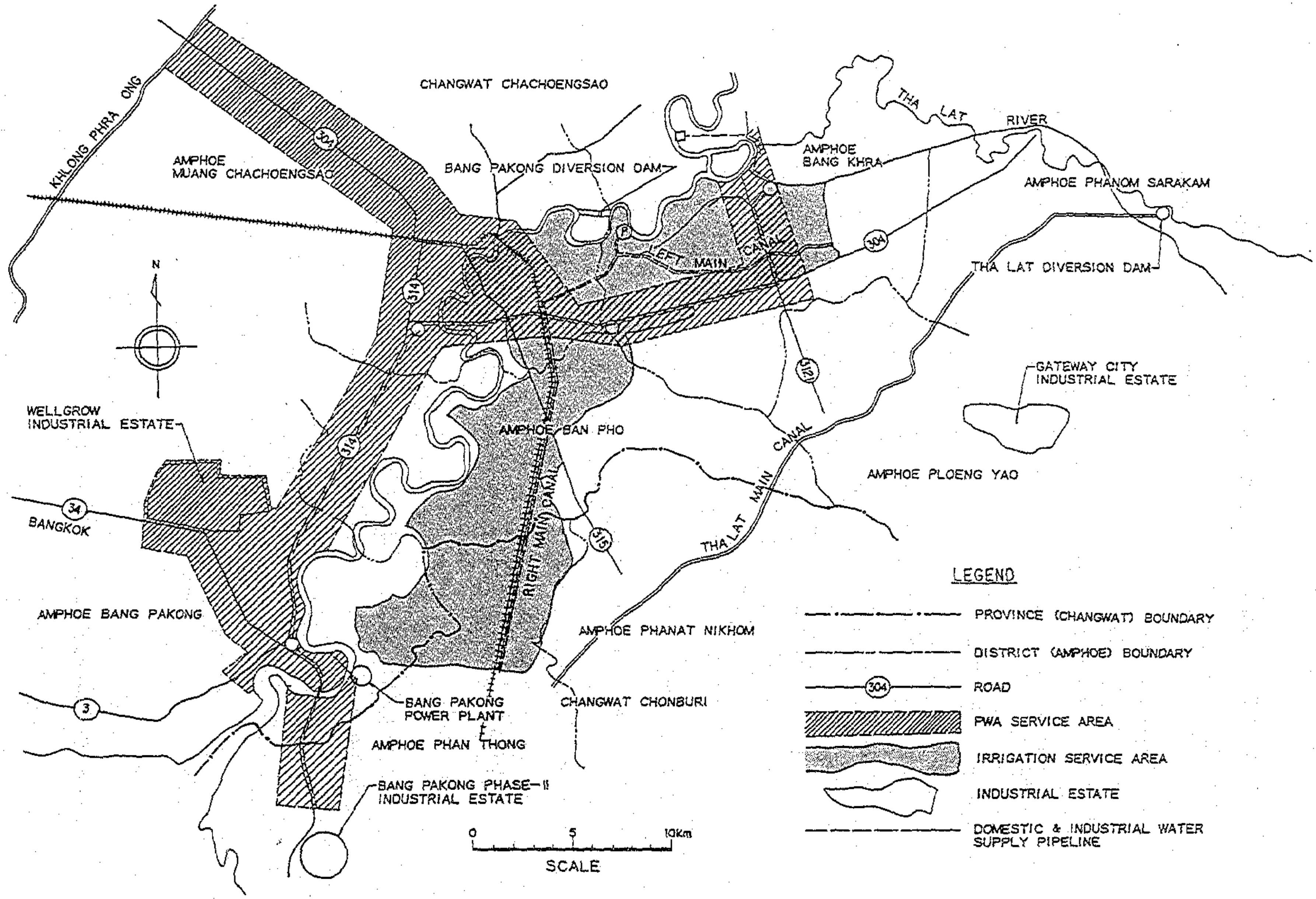


FIGURE 2-2 CLIMATIC CHARACTERISTICS AT CHACHOENGSAO

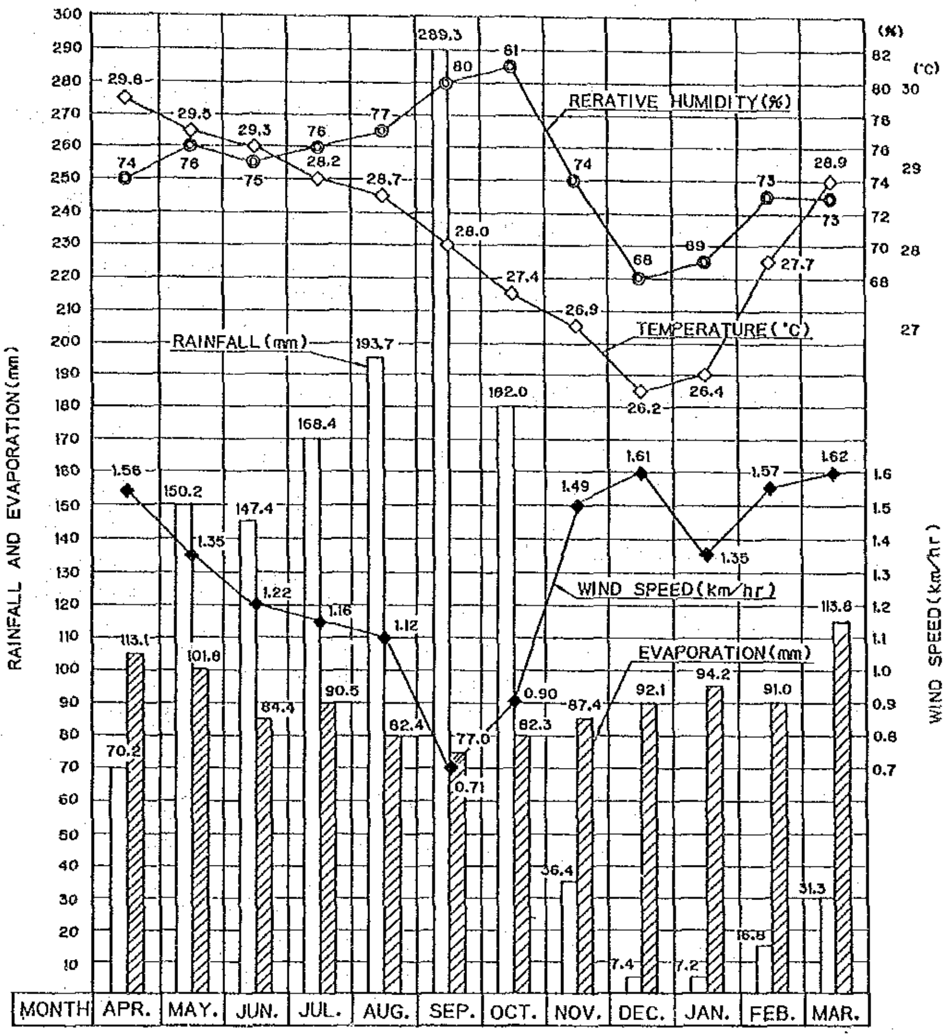
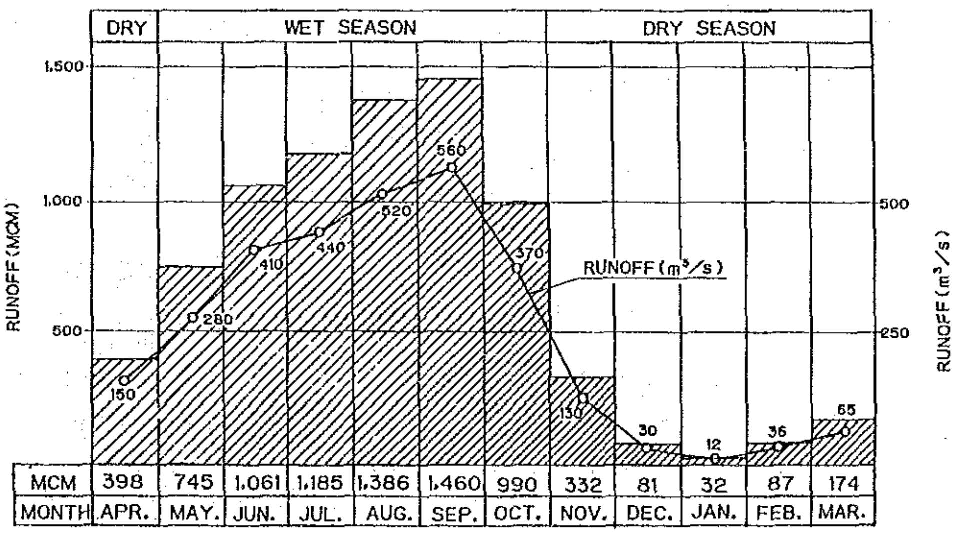


FIGURE 2-3 AVERAGE MONTHLY RUNOFF OF BANG PAKONG RIVER



2.3 Water Resources

The major water resource of the Tha Lat River Basin Development Phase I project is the Bang Pakong river with a drainage area of 17,660 km^2 and an average annual runoff of 7,900 MCM. As shown in Figure 2-3, the average monthly runoff varies from a maximum of 1,460 MCM (560 m^3/sec) in September to a minimum of 32 MCM (12 m^3/sec) in January.

2.4 Social and Economic Situation

The relative values of the Gross Provincial Product of Chacheongsao and Chonburi provinces are as follows;

TABLE 2-1 SOCIAL AND ECONOMIC SITUATION

Item	Whole Thailand	Chacheongsao	Chonburi
Gross Provincial Product (GPP)			
- Agriculture (million Baht)	198,300	3,470	3,530
- Other Sectors (million Baht)	1,035,700	12,650	44,160
- Total (million Baht)	1,234,000	16,120	47,690
Population (1,000 people)	53,600	510	760
per Capita GPP (Bahts)	23,000	31,500	60,400

Present land use in the irrigation service area of 14,300 ha includes 10,000 ha of paddy field, 4,060 ha of orchard land and 240 ha of upland, and the cropping intensity is 100 percent.

CHAPTER 3. DEVELOPMENT PLAN

3.1 Agricultural Development Plan

1) Proposed Land Use

Proposed cropping plan and estimated yield are as follows;

TABLE 3-1 PROPOSED CROPPING PLAN AND ESTIMATED YIELD

Crops	Wet Season	Dry Season	Total	Yield
	(ha)	(ha)	(ha)	(ton)
Paddy	9,900	1,980	11,880	48,150
Soybean	-	280	280	420
Groundnuts	-	920	920	1,380
Mungbean	-	1,780	1,780	1,958
Vegetables	240	2,140	2,380	34,034
Mango	4,160	(4,160)	4,160	57,408
Total	14,300	7,100	21,400	143,710

Note : The cropping intensity is 150 percent.

2) Irrigation Water Demand

The amount of irrigation water required for the cultivation of 14,300 ha of land in the wet season and of 7,100 ha in the dry season was computed for the twenty years from 1968 to 1987, and the results are summarized in the following table.

TABLE 3-2 IRRIGATION WATER DEMAND (MCM)

Season	Maximum	Minimum	Average
Wet Season	84.0 (1979)	40.8 (1983)	58.6
Dry Season	100.4 (1986)	79.1 (1987)	91.6
Annual	182.1 (1979)	130.0 (1983)	150.5

3) Fish Culture Water Demand

Fish culture water requirements include 980 ha of fresh water for brackish water shrimp culture and 400 ha of fresh water fish pond. The amount of water required is estimated as follows.

TABLE 3-3 FISH CULTURE WATER DEMAND (MCM)

Season	Maximum	Minimum	Average
Wet Season	4.7 (1979)	40.1 (1983)	4.4
Dry Season	12.3 (1986)	10.5 (1987)	12.1
Annual	17.1 (1979)	14.9 (1987)	16.5

3. 2 Domestic and Industrial Development Plan

Domestic and industrial water demands in the year 2005 are estimated by PWA as shown below.

- Domestic Water Demand : annual demand 18.9 MCM
- Industrial Water Demand : annual demand 69.7 MCM

3. 3 Water Resources Development Plan

1) Overall Water Demand

Overall water demand including surplus water of 60 MCM/year are as follows;

TABLE 3-4 OVERALL WATER DEMAND (MCM)

Season	Maximum	Minimum	Average
Wet Season	166.6 (1979)	122.8 (1983)	140.9
Dry Season	190.4 (1986)	141.6 (1987)	180.5
Annual	355.1 (1979)	289.4 (1987)	321.4

2) Water Balance Computation

The results of water balance computation for the twenty years from 1968 to 1987 are shown in Figure 3-1. As shown below, water shortage occurs three years out of twenty years.

TABLE 3-5 YEARS OF WATER SHORTAGE

Year of Water Shortage	Amount of Water Shortage
1978	18.0 MCM
1977	38.7 MCM
1983	11.8 MCM

FIGURE 3-1 WATER BALANCE COMPUTATION (AFTER COMPLETION OF PHASE I PROJECT, SURPLUS WATER : 60 MCM)

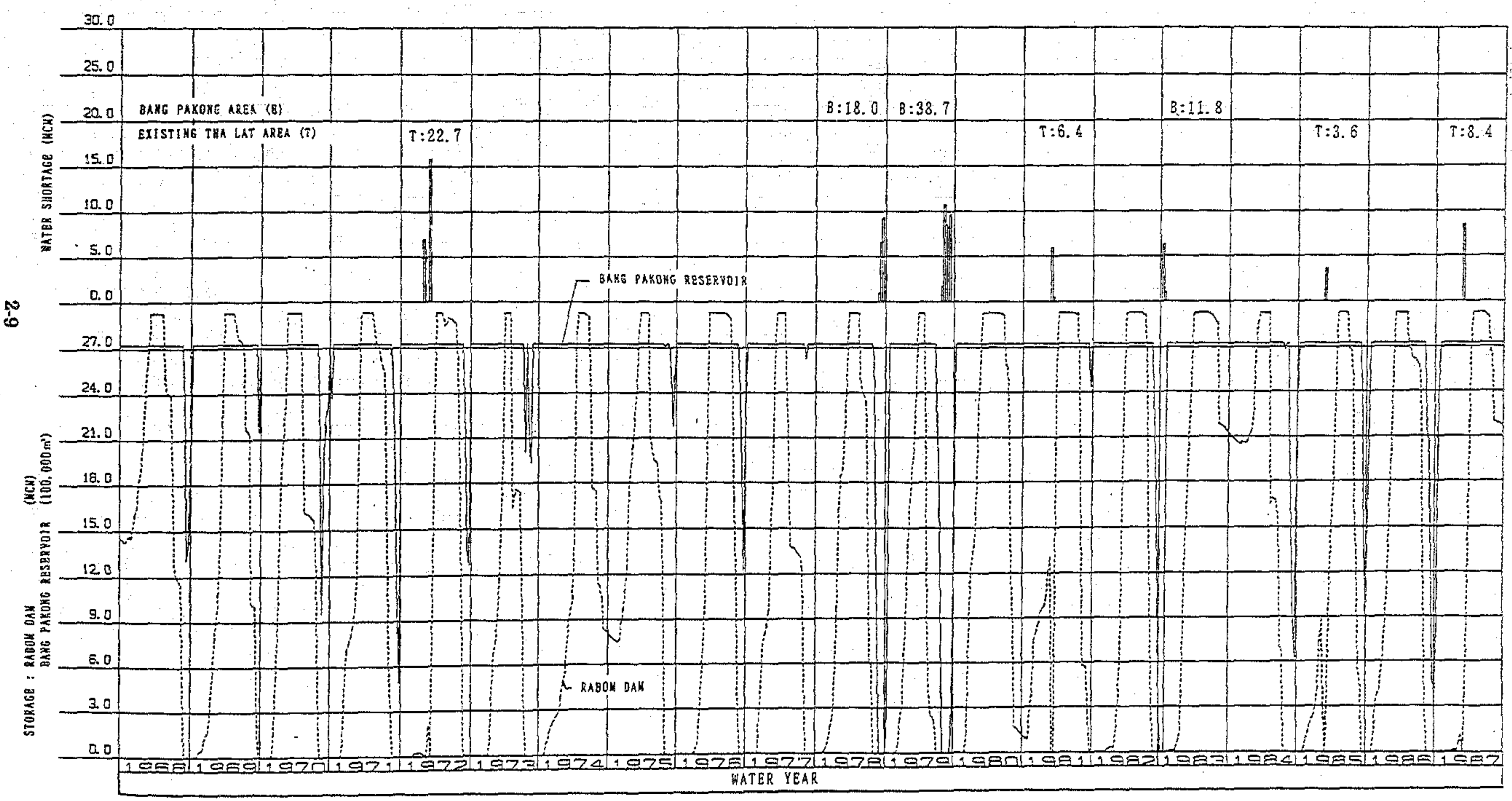


FIGURE 3-2 WATER BALANCE COMPUTATION (AFTER COMPLETION OF PHASE I PROJECT, SURPLUS WATER : 20 MCM)

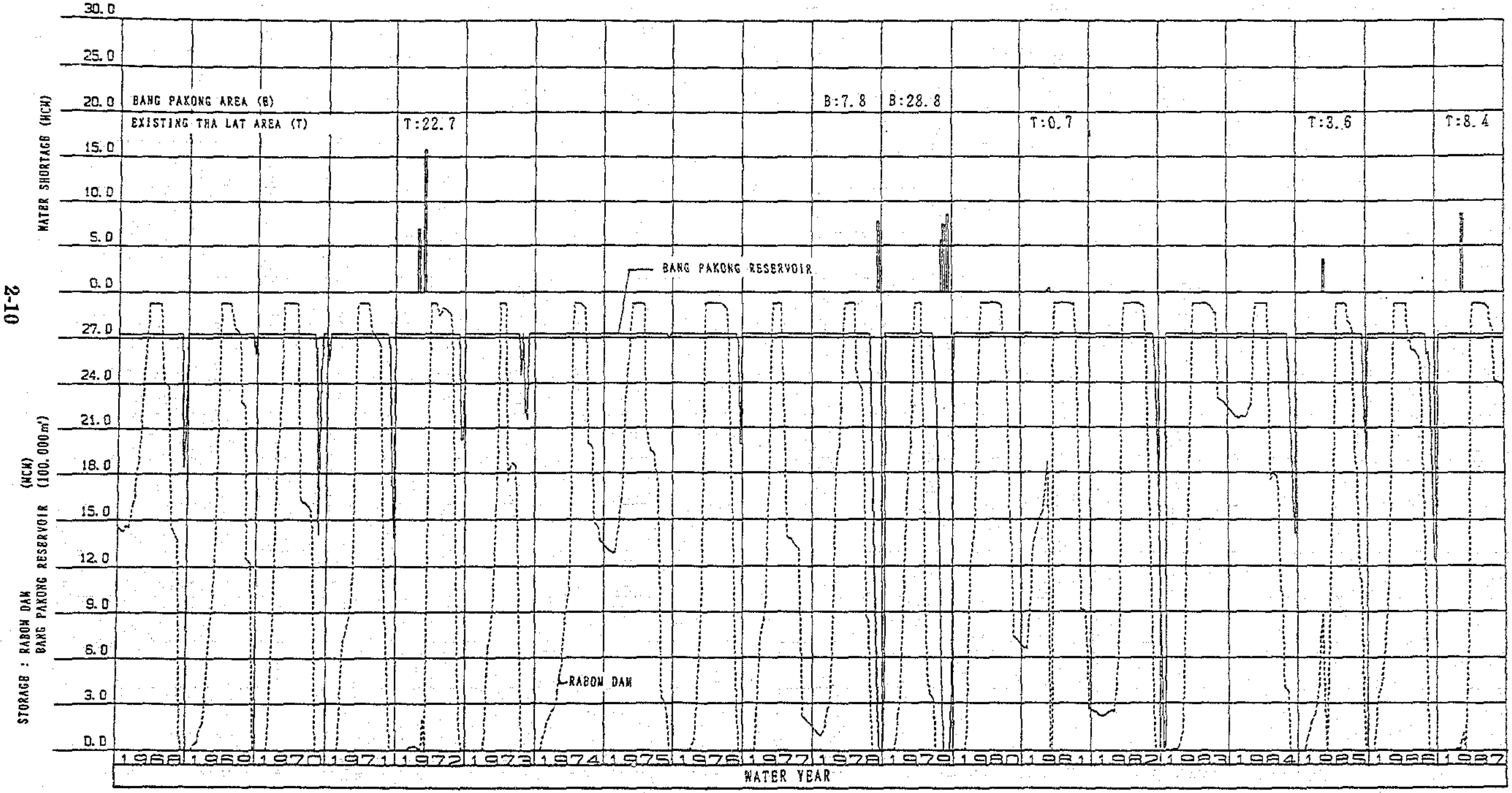
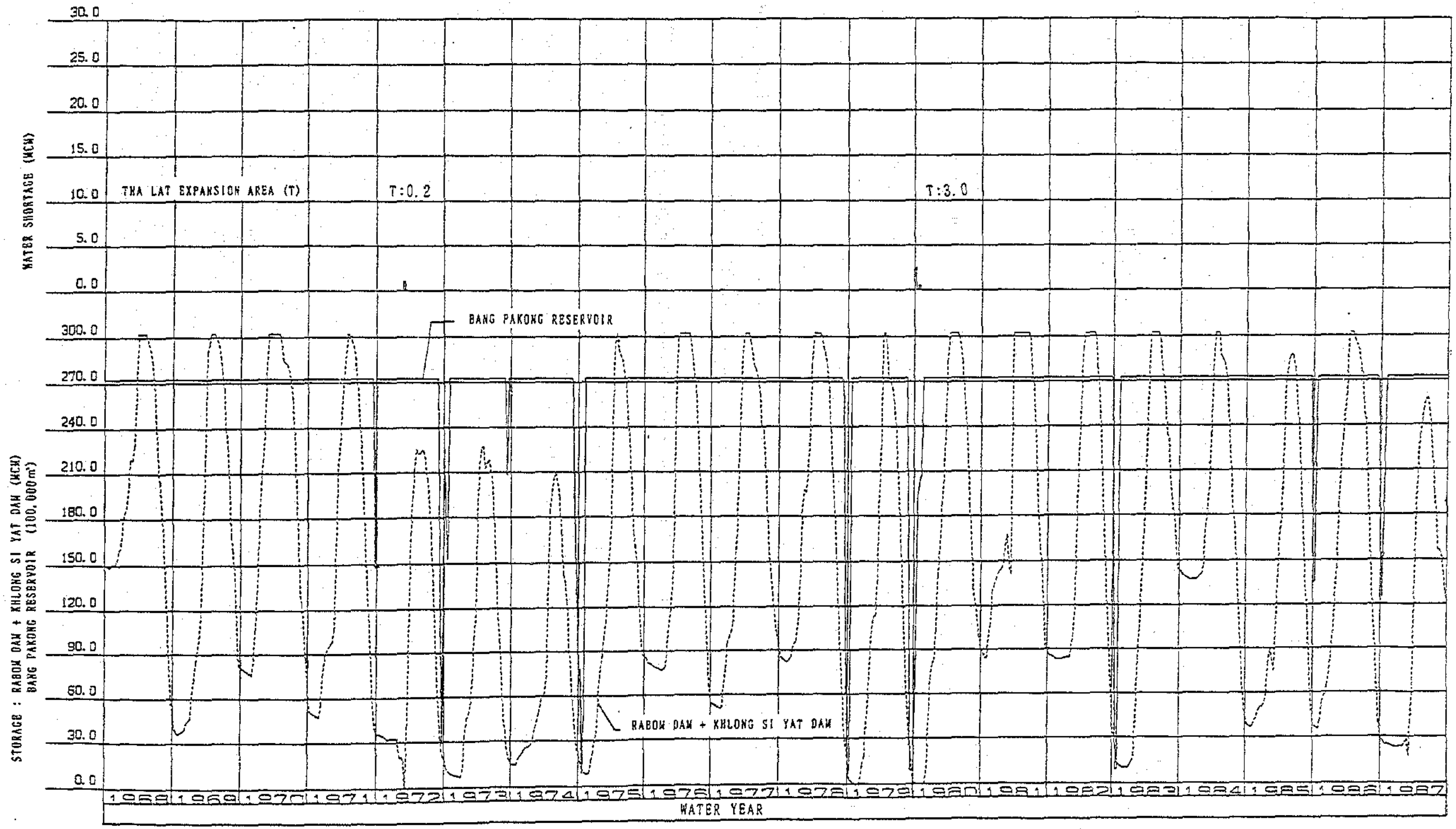


FIGURE 3-3 WATER BALANCE COMPUTATION (AFTER COMPLETION OF PHASE I & II PROJECTS, SURPLUS WATER : 90 MCM)



If there had been a surplus of 20 MCM of water, the water shortage would have occurred only two years out of the twenty years because the water shortage would not have occurred in 1983 as shown in Figure 3-2.

After the Khlong Si Yat dam has been completed in Phase II project, the water shortage will not occurr in the project area of Phase I project, and surplus water will increase form 60 MCM to 90 MCM. The results of water balance computation after completion of the Phase II project is shown in Figure 3-3.

3.4 Project Justification

1) Economic Analysis

a) Project Cost

The disbursement schedule for the project cost of the Tha Lat River Basin Development Phase I Project is estimated as shown in Table 3-6.

TABLE 3-6 DISBURSEMENT SCHEDULE OF PROJECT COST

(Unit: million Bahts)

Year	Financial Cost: RID's Facilities (Diversion Dam & Irrigation Facilities)	Financial Cost: PWA's Facilities (Facilities for Domestic & Industrial Water Supplies)	Financial Cost: Total	Economic Cost (90% of Financial Cost)
1992	179 [1]	157	336	302.4
1993	219	471	690	621.0
1994	496	785	1,281	1,152.9
1995	1,058	942	2,000	1,800.0
1996	1,279	785	2,064	1,857.6
1997	873	-	873	785.7
1998	254	-	254	228.6
Total	4,358	3,140	7,498	6,748.2

Note : 1) The project cost of 120 million Bahts for Rabom dam construction is included.

b) Operation and Maintenance Cost

The annual operation and maintenance cost is shown in Table 3-7.

TABLE 3-7 ANNUAL OPERATION AND MAINTENANCE COST

(Unit: million Bahts)

Facility	Financial Cost	Economic Cost
RID's Facilities	17.0	15.3
PWA's Facilities	94.2 [1]	84.8
Total	111.2	100.1

Note : 1) The annual operation and maintenance cost for PWA's facilities is estimated to be 3% of the project cost.

c) Replacement Cost

The irrigation pumps to be set up by RID and the purification plant, etc. to be installed by PWA are planned to be replaced once every twenty years. The replacement cost is shown in Table 3-8.

TABLE 3-8 REPLACEMENT COST

(Unit: million Bahts)

Facility	Financial Cost	Economic Cost
RID's Facilities (Pumps)	170.0	153.0
PWA's Facilities (Purification Plants, etc.)	628.2 [1]	565.2
Total	798.0	718.2

Note : 1) The replacement cost for the PWA's facilities is planned to be 20% of the project cost

d) Incremental Benefit

The incremental benefit for the Phase I project is shown in Table 3-9.

TABLE 3-9 INCREMENTAL BENEFIT

(Unit: million Bahts)

Agricultural sector (Agriculture : 440.6 + Fisheries : 5.3)	= 445.9
Domestic & industrial water supplies sector	
- Domestic & industrial water supply by PWA	
66.5 MCM × 10 Baht/cu.m	= 665.0
- Future demand for domestic & industrial water	
60.0 MCM × 0.75 × 3 Baht/cu.m	= 135.0
Total	1,245.9

e) Economic Internal Rate of Return

The economic internal rate of return of the Phase I project is analyzed to be 11.0%. The results of the sensibility analyses are shown below.

Case -1:	In the case of surplus water of 20 MCM ...	10.7%
Case -2:	10% increase in the project cost	10.2%
Case -3:	10% decrease in the project benefit	10.0%

2) Project Evaluation

The Tha Lat River Basin Development Phase I Project can be evaluated as follows;

a) The Phase I project is of great importance and urgency to Thailand, and is useful for the national economy judging from the feasible and viable value of 11.0% in the economic internal rate of return.

b) In the irrigation service area, the farming population amounts to about 30 thousand in 5,700 farming households, the net farm income per household, the off farm income per household and the total income per household are estimated as 26,800 Baht, 59,000 Baht and 85,800 Baht respectively, at present. By implementing the Phase I project, the net farm income per household is expected to reach 81,600 Baht corresponding to three times the existing income resulting in stabilization of the farmers' lives and a rise in their standard of living.

c) By implementing the Phase I project, domestic water supply for about 250 thousand persons will be possible, contributing to an improvement of the sanitary conditions and the living life environment of the inhabitants in the project area.

d) The domestic and industrial water supply to the factories and industrial estates in the project area situated in the northern part of the Eastern Seaboard Development Area, has been unstable. Since a stable water supply is possible and will stabilize factory operation with the implementation of the Phase I project, new factories will be attacted to the industrial estates under construction and employment opportunities will be created.

e) By implementing the Phase I project, it will be possible to provide a surplus of 60 MCMs of domestic and industrial water once the planned capacities of irrigation water, fisheries water and domestic and industrial water, have been confirmed. The project area is favorably located near the Bangkok Metropolitan Circle and Laem Chabang commercial port, and the infrastructure of roads, electricity, communication, railways, etc., has been consolidated. Therefore, if a stable domestic and industrial water supply is available, it will be much easier to attract factories to the area. By constructing light industrial factories of the labour-intensive type in the project area and creating new employment opportunities, the concentration of economic activity and new population in the Bangkok Metropolitan Circle will be curbed.

PART - III. BANG PAKONG DIVERSION DAM PROJECT

CHAPTER 1. FEATURES OF THE PROJECT FACILITIES

The project facilities of the Bang Pakong Diversion Dam Project are shown in Table 1-1 and Figure 1-1, in which the detailed design of the O/M buildings is prepared by RID and the other facilities are designed in detail by the JICA study team.

TABLE 1-1 FEATURES OF THE PROJECT FACILITIES

1) <u>Facilities to be designed by JICA study team</u>		
① Bang Pakong Diversion Dam		
Design Flood	:	1,600 m^3/sec
Length of Diversion Dam	:	166 m
Tide Protection Gates		
- Regulating Gate	:	Double Leaf Wheel Type Gate, 30 m span × 2 sets, Height of Upper Gate 3. 1 m Height of Lower Gate 6.9 m
- Flood Gate	:	Single Leaf Wheel Type Gate, 30 m span × 3 sets, Height of Gate 10 m
Pier	:	Height 26.5 m, Length 19.0 m, Thickness 4 m
O/M Bridge	:	Width 5 m, Prestressed Concrete Box Girder Bridge span length 33.15 m × 5 spans
Foundation Works	:	P.C. Pile Foundation
Concrete Volume	:	approx. 38,000 m^3
② Diversion Canal		
Bottom Width	:	80 m
Slope of Bank	:	1 : 7.5
Excavation Depth	:	approx. 11 m
Length of Canal	:	approx. 2. 2 km (including the section of the Bang Pakong diversion dam)
Excavation Volume	:	approx. 3,500,000 m^3 (including an excavation for Bang Pakong diversion dam)
③ Closure Dam		
Crest Length	:	approx. 250 m
Dam Height	:	15.9 m (not including height of camber)
	:	12.0 m
Width of Dam Crest	:	1 : 5.0
Slope of Embankment	:	approx. 310,000 m^3 (rock material 60,000 m^3,
Embankment Volume		coarse-grained soil material 250,000 m^3)

④ Road

Road Width	:	Total Width 9 m, Width of Asphalt Pavement 6 m
Road Length	:	approx. 2. 6 km

⑤ Road Bridge

Bridge Class	:	First Class
Width of Bridge	:	9.0 m
Type of Bridge	:	Prestressed Concrete Box Girder Bridge
Length of Bridge	:	span length 30.6 m × 8 spans

⑥ Pumping Station

Pump Discharge	:	16 m^3/sec (960 m^3/min)
Actual Pump Head	:	5. 4 m
Pump	:	Vertical Shaft Type Mixed Flow Pump, ø1,350 mm × 4 units
Prime Mover	:	Electric Motor 350 kw × 3 units Diesel Engine 500 PS × 1 unit
Pump House	:	R.C. made, Total Floor Area approx. 500 m^2
Concrete Volume	:	approx. 3,000 m^3

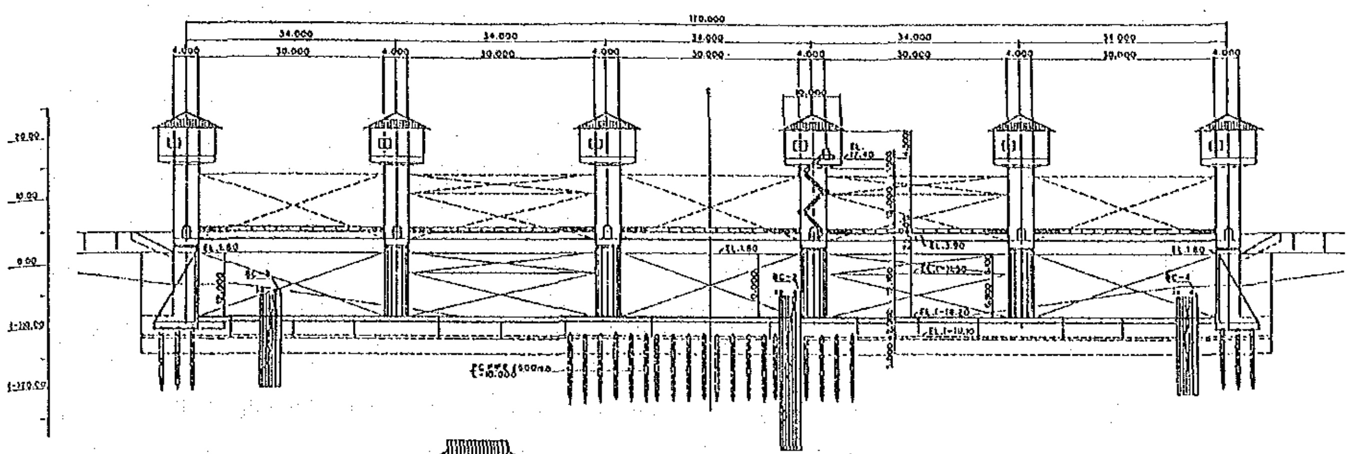
⑦ Control System & Electrical Facilities

Control System	:	Remote Control System for Tide Protection Gates & Pumps, ITV Monitoring System, Two River Water Level Gauging Stations, etc.
Electrical Facilities	:	Incoming Electrical Works, Substations, Distribution Lines, etc.

2) Facilities to be designed by RID

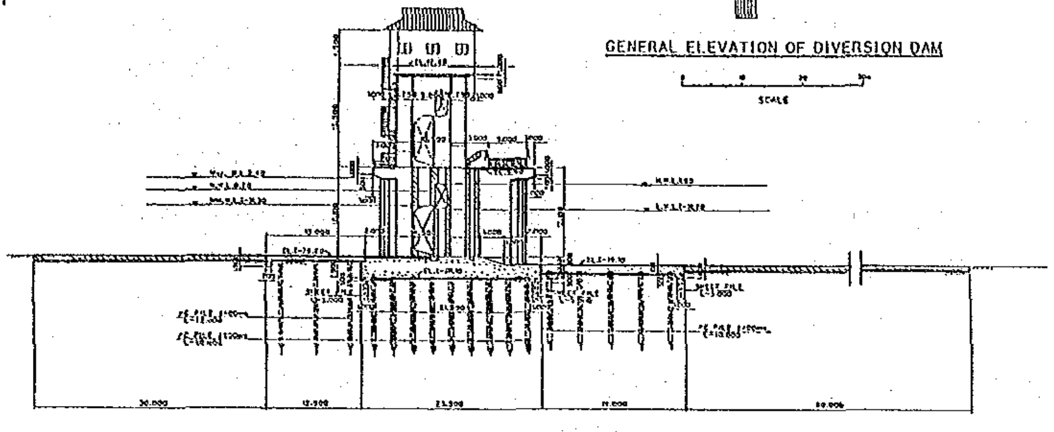
⑧ O/M Building	:	Area of Building Lot approx. 60 ha, Control House, Training Center Building, Residential Houses, etc.

FIGURE 1-1 FEATURES OF THE PROJECT FACILITIES



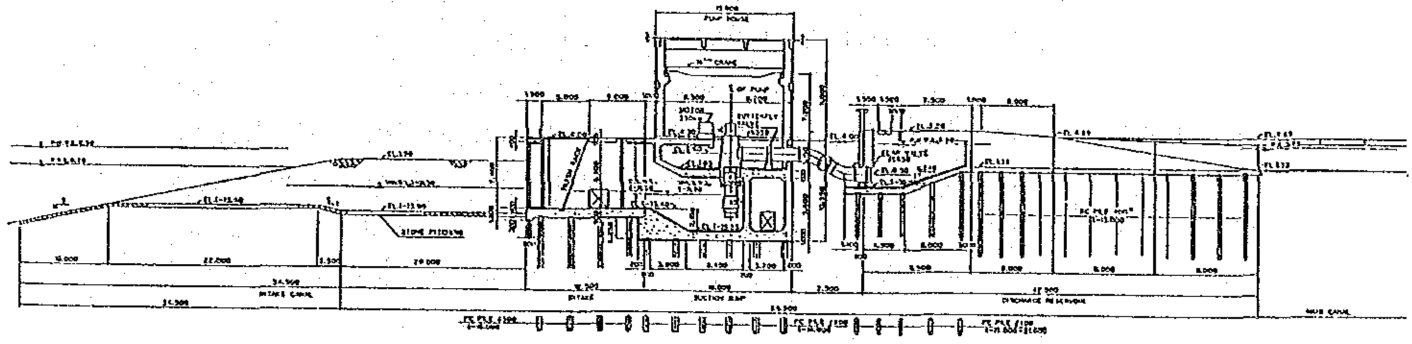
GENERAL ELEVATION OF DIVERSION DAM

SCALE

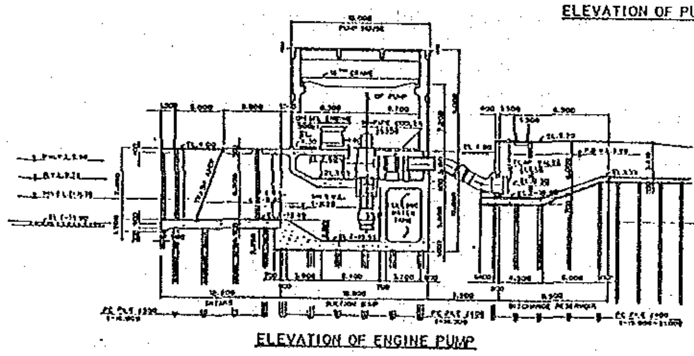


TYPICAL SECTION OF DIVERSION DAM

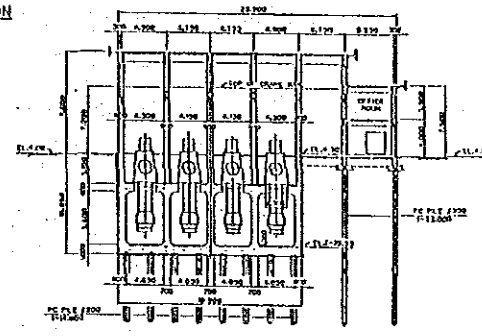
SCALE



ELEVATION OF PUMPING STATION

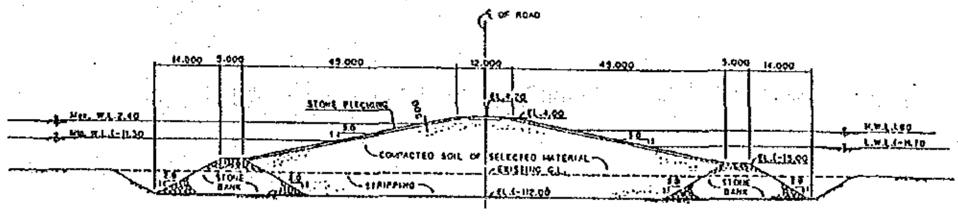


ELEVATION OF ENGINE PUMP



CROSS SECTION OF PUMPING STATION

SCALE



CLOSURE DAM

SCALE

CHAPTER 2. TOPOGRAPHY AND GEOLOGY

2.1 Topography

The Bang Pakong diversion damsite is located about 76 km upstream from the estuary, 0.8 to 1.3 m in ground elevation and with flat topography. The cropping area is composed mostly of mango, banana, and coconut, orchards. There are paddy fields, however, north of the diversion channel, and shrimp ponds interspersed through the area. The Bang Pakong river meanders from east to west near the diversion damsite 230 m in mean width, and about 11 m in depth. The meandering line of the river has about 2.7 km in mean wave length and about 1.2 km in mean amplitude.

2.2 Geology

The facilities construction sites are located on an alluvial plain formed by the conveying and accumulating actions of the Bang Pakong river. The alluvial layer in this area is a typical weak ground composed of flood plain deposit mainly with such fine particles as silt, clay, etc. According to the boring investigation results, the geology in this area is classified into the following 4 layers, and it is found that each layer is distributed more or less in a horizontal structure.

1st layer: Brown clay layer (corresponding to topsoil layer)
(1 to 2 m in thickness)

2nd layer: Blackish gray - brown clay and silt layer
(17 to 19 m in thickness)

3rd layer: Yellowish brown fine - coarse sand layer
(1 to 2 m in thickness)

4th layer: Yellowish brown - reddish brown silty clay and fine sand layer
(more than 10 m in thickness)

The geological features of each layer are as follows;

1st layer : The 1st layer consists of somewhat compacted silty clay corresponding to the topsoil and indicates 2 to 4 in the N-values.

2nd layer: The clay and silt layer belonging to the 2nd layer consists of very fine particles classified as CL and ML under the Unified Soil Classification System.

The upper half of the layer shows less than 4 in the N-value (mostly 0 to 1) making for an extremely weak layer (compressive strength ranging between 0.3 to 1.1 kg/cm^2). The depth of this weak layer from ground surface reaches 7.0 to 8.5 m at the diversion damsite, 8.0 to 10.5 m along the diversion channel and 13.0 m at the right abutment of the closure dam.

The lower half of the layer indicates 10 to 30 in the N-value and 1.2 to 4.8 kg/cm^2 in compressive strength, and a somewhat compacted nature in comparison with the upper half of the layer. The N-values of this layer are widely distributed with a considerable variation in depth and location. Since 10 to 15 in the N-value are found here and there in the lower half of the layer even at a depth of more than 16 m below the ground surface, it is impossible to regard it as a stable bearing layer.

3rd layer : The fine and coarse sand layer belonging to the 3rd layer is classified as SC to SM and distributed almost horizontally in the whole area with good continuation, indicting 24 to 50 in the N-value partly well compacted. Therefore, it can be recognized as a sufficient bearing layer in some parts.

4th layer : The 4th layer consisting of silty clay and fine sand shows more than 40 in the N-value. This fine sand layer is intercalated between clay layers with a lenticular shape and its continuation is not clear. The silty clay layer is well compacted and consolidated as a whole and distributed evenly. As a result, it can be judged to have has sufficient bearing capacity.

2. 3 Soil Mechanics Property of Alluvial Deposit

A series of soil tests on samples of materials taken from bore-holes and test pits was executed in order to clarify the physical and mechanical properties of the alluvial deposits extending around the diversion damsite.

The results of the soil tests refer to Table 2-1 to 2-3 and the brief descriptions for the physical and mechanical properties of the alluvial deposit are as follows;

1) Physical Properties

Specific gravity:

The distribution of specific gravity in depth according to the distributed samples from the bore-holes is shown in Figure 2-1.

The specific gravity is erratically distributed in a range of 2.60 to 2.84 with considerable irregularity in depth, however, this is not inconsistent with the data obtained in previous similar tests.

Field moisture content:

The distribution of field moisture content in depth is shown in Figure 2-2, in which the widely distributed values range between 20 and 100%, however, it can be divided into 2 layers at a depth of about 8 m.

The field moisture content in the upper layer decreases significantly with an increase of depth, and finally may reach about 50% at a depth of 8 m. On the other hand, the lower layer decreases gradually in depth and approaches a value of about 20% around a depth of 22 m.

Liquid limit and plastic limit:

According to liquid limit and plastic limit in depth as shown in Figure 2-2, the value approximately corresponds to the range of 35 to 55% in the liquid limit and of 20 to 40% in the plastic limit, having the same tendency to decrease gradually in accordance with the depth from the ground surface.

Plastic chart: The relationship between the plastic index and liquid limit is shown in the plastic chart of Figure 2-3.

The greatest value is distributed in the upper part along the A line which indicates that the deposits consist mainly of organic clay belonging to CL (ML and OL partially distributed) under the Unified Soil Classification System with low plasticity and less fat.

Plastic index: The distribution of plastic index (PI = LL - PL) in depth is indicated in Figure 2-4, in which there is no extreme variation in depth and almost distributes in a range of 10 to 20%.

Consistency index: Regarding the distribution of consistency index (Ic = LL wf/PI) in depth, it can be classified into 2 layers at a depth of about 8 m as shown in Figure 2-4. The upper layer corresponds to the values below zero in the consistency index, in which it is generally known that the soil state induces to the liquid state by remolding and disturbance because the field moisture content exceeds the liquid limit, resulting in an unstable condition. On the contrary in the lower layer, the values of consistency index shows within the range of 0.5 to 1.5 having the stable condition.

Liquidity index: As for the liquidity index (IL = wf - PL/PI), the distribution in depth is mainly divided into 2 layers with the same tendency for the consistency index as shown in Figure 2-4. The upper layer of about an 8 m thickness is shown to be generally over 3.0 in the liquidity index indicating very weak ground with extreme sensitivity.

On the other hand, the lower layer corresponds to a value of less than 1.0 m liquidity index indicating stable condition.

2) Mechanical Properties

Shear strength: The distribution of shear strength (shear strength means cohesion) in depth by the in-situ vane test, triaxial compression test and unconfined compression test is shown in Figure 2-5, in which the values are widely distributed ranging between 0.1 to 2.5 kgf/cm^2. However, it seems to be classified into 2 layers at a depth of about 8 m below the ground surface. The upper layer corresponds to the value of 0.1 to 0.5 kgf/cm^2, in which there is no definite tendency in depth and mostly distributes in a range of 0.2 to 0.4 kgf/cm^2. On the contrary the lower layer, shows a range of 0.5 ~2.5 kgf/cm^2 and the value in creases gradually in accordance with an increase of depth.

Pre-consolidation stress: As for the pre-consolidation stress of the alluvial deposits, Figure 2-6 shows a relationship between the consolidation yield stress and overburden load in depth.

In the above figure, the relationship in depth is comparatively well correlated, therefore, the alluvial deposits can be recognized as a normal consolidated clay layer.

TABLE 2 - 1 RESULT OF PHYSICAL SOIL TEST (DISTURBED SAMPLES BY BORING CORES)

No. of Hole	Depth (m)	Unified, Soil Classification System	Field Moisture Content, Wf (%)	Specific Gravity, Gs	Gradation Distuibution (%)			Liquid Limit LL (%)	Poastic Limit PL (%)	Plastic INdex, PI	Consestency Index,IC	Liquidity Index, IL	N - Value
					Sand	Silt	Clay						
BC - 2	1.00 ~ 4.45	ML, OL	77.1	2.77	4.2	95.6		42.5	29.2	13.3	- 2.60	3.60	1
	5.00 ~ 7.45	CL	40.0	2.71	14.8	85.2		46.0	26.6	19.4	0.31	0.69	1 ~ 2
	9.00 ~ 15.45	CL	30.5	2.70	9.6	90.4		37.7	24.3	13.4	0.54	0.46	12 ~ 23
	19.00 ~ 23.45	CL	15.3	2.80	20.6	79.4		35.9	18.7	17.2	1.20	- 0.20	24 ~ 50
	24.00 ~ 27.45	SC	12.9	2.72	59.5	40.5		28.0	16.6	11.4	1.32	- 0.32	30 ~ 50 <
BU - 1	0.00 ~ 6.45	ML, OL	72.3	2.70	6.6	93.4		41.3	29.5	11.8	- 2.63	3.63	1
	8.00 ~ 11.45	CL	35.3	2.77	13.2	86.8		41.0	23.5	17.5	0.33	0.67	5 ~ 14
BU - 2	2.00 ~ 4.45	CL	70.6	2.74	7.4	92.6		41.5	24.7	16.8	- 1.73	2.73	1 ~ 2
	6.00 ~ 9.45	CL	26.2	2.69	10.6	89.4		32.0	19.2	12.8	0.45	0.55	1 ~ 5
BD - 1	0.00 ~ 6.45	CL	66.9	2.76	5.5	71.1	24.4	34.9	22.2	12.7	- 2.52	3.52	1 ~ 3
	8.00 ~ 8.45	CH	30.4	2.77	0.9	31.8	67.3	63.5	28.5	35.0	0.95	0.05	14
BD - 2	0.00 ~ 6.45	ML, OL	90.2	2.64	2.7	58.5	38.8	46.7	32.5	14.2	- 3.06	4.06	0 ~ 1
	8.00 ~ 11.45	CL	19.4	2.65	11.0	41.1	47.9	35.0	19.0	16.0	0.98	0.03	2 ~ 16
BD - 3	1.00 ~ 6.45	MH, OH	95.1	2.74	1.4	53.5	45.1	52.9	32.5	20.4	- 2.07	3.07	0
	8.00 ~ 11.45	CL	25.0	2.76	7.0	35.5	57.5	42.5	22.0	20.5	0.85	0.15	0 ~ 10
BCD - 2	1.00 ~ 6.45	MH, OH	31.9	2.69	0.3	52.3	47.4	55.8	40.3	15.5	1.54	- 0.54	1
	14.00 ~ 20.45	CL	20.0	2.80	16.0	34.1	49.9	42.6	22.3	20.3	1.11	- 0.11	13 ~ 45
BPS - 1	11.00 ~ 16.45	CL	25.9	2.73	8.9	31.2	59.9	45.4	23.1	22.3	0.87	0.13	14 ~ 38
	19.00 ~ 23.45	CL	23.6	2.79	13.4	29.8	56.8	43.1	21.3	21.8	0.89	0.11	32 ~ 50 <
	26.00 ~ 27.30	SC	12.5	2.70	69.9	12.8	17.3	26.5	17.1	9.4	1.49	- 0.49	23
BPS - 2	1.00 ~ 7.45	ML, OL	70.6	2.69	7.6	50.4	42.0	41.0	30.1	10.9	- 2.72	3.72	1
	10.00 ~ 15.45	CL	29.2	2.74	11.2	30.6	58.2	41.3	22.6	18.7	0.65	0.35	1 ~ 21
	17.00 ~ 22.40	CL	-	2.84	13.7	31.5	54.8	41.2	21.1	20.1	-	-	33 ~ 50 <
BD - 1R	2.00 ~ 6.45	ML, OL	95.3	2.60	0.9	40.1	59.0	49.2	37.2	12.0	- 3.84	4.84	0 ~ 2
	11.00 ~ 18.45	CL	21.5	2.67	7.5	29.1	63.4	42.0	24.1	17.9	1.15	- 0.15	10 ~ 27

Note ; consistency Index IC = (LL - Wf) / (LL - PL) = (LL - Wf) / PI

Liquidity Index IL = (Wf - PL) / (LL - PL) = (Wf - PL) / PI

TABLE 2 - 2 RESULT OF SOIL TEST (DISTURBED SAMPLES AT TEST - PITS)

1. Physical Tests

No, of Hole	Depth (m)	Unified, Soil Classification System	Feld Moisture Content, Wf (%)	Specific Gravity, Gs	Gradation Distribution (%)			Liquid Limit LL (%)	Plastic Limit PL (%)	Plastic Index, PI
					Sand	Silt	Clay			
SM - 1	1.70 ~ 0.20	ML, OL	3.6	2.64	2.2	66.1	31.7	34.3	24.4	9.9
	0.20 ~ - 0.08	ML, OL	57.6	2.67	6.2	50.3	43.5	40.4	26.1	14.3
SM - 3	1.50 ~ 0.00	ML, OL	4.8	2.61	1.9	46.7	51.4	33.7	25.7	8.0
	0.00 ~ - 1.00	MH, OH	91.1	2.61	0.1	63.7	36.2	55.9	34.2	21.7
SM - 4	1.32 ~ 0.20	ML, OL	4.0	2.61	3.4	46.2	50.4	32.1	23.1	9.0
	0.20 ~ - 1.00	MH, OH	66.8	2.61	0.5	59.5	40.0	51.8	33.9	17.9

2. Mechanical Tests

No, of Hole	Depth (m)	Compaction Test		Gradation Test			Triaxial Compression Test						Coefficient of Permeability K, (cm/sec)
		max - γd 1/ (grf / cm3)	Wopt 2/ (%)	Ranging of Void - ratio (%)	Cv 3/ (cm^3/sec)	Compression Index, Cc	U - U Condition 4/		C - U Condition 7/		C - U Condition 8/		
							C (kgf/cm^2) 5/	ϕ (°) 6/	C (kgf/cm^2)	ϕ (°)	C (kgf/cm^2)	ϕ (°)	
SM - 1	1.70 ~ 0.20	-	-	-	-	-	-	-	-	-	-	-	-
	0.20 ~ - 0.08	1.513	22.7	0.92 ~ 0.58	$5.2 \sim 1.4 \times 10^{-4}$	0.30	0.64	13.4	0.06	18.1	0.12	29.6	1.13×10^{-3}
SM - 3	1.50 ~ 0.00	-	-	-	-	-	-	-	-	-	-	-	-
	0.00 ~ - 1.00	1.394	28.0	0.99 ~ 0.65	$9.9 \sim 1.7 \times 10^{-4}$	0.32	0.58	14.1	0	21.4	0.10	32.8	2.82×10^{-3}
SM -	1.32 ~ 0.20	-	-	-	-	-	-	-	-	-	-	-	-
	0.20 ~ - 1.00	1.486	26.1	0.90 ~ 0.52	$8.4 \times 10^{-4} \sim 9.3 \times 10^{-5}$	0.31	0.68	11.7	0.16	16.3	0.17	24.4	1.58×10^{-3}

Note ; The consolidation, triaxial compression and permeability tests have been carried out at 95% of the maximum dry density condition with 2% wet side of the optimum moisture content.
1/ maximum dry density, 2/ optimum moisture content, 3/ coefficient of consolidation, 4/ unconsolidated-undrained condition under the total stress method, 5/ cohesion, 6/ internal friction angle, 7/ consolidated-undrained condition under the total stress method, 8/ consolidaled-undrained condition under the effective stress method.

TABLE 2-3 RESULT OF SOIL TEST (UNDISTURBED SAMPLES AT BORE-HOLES)

1. Physical Tests

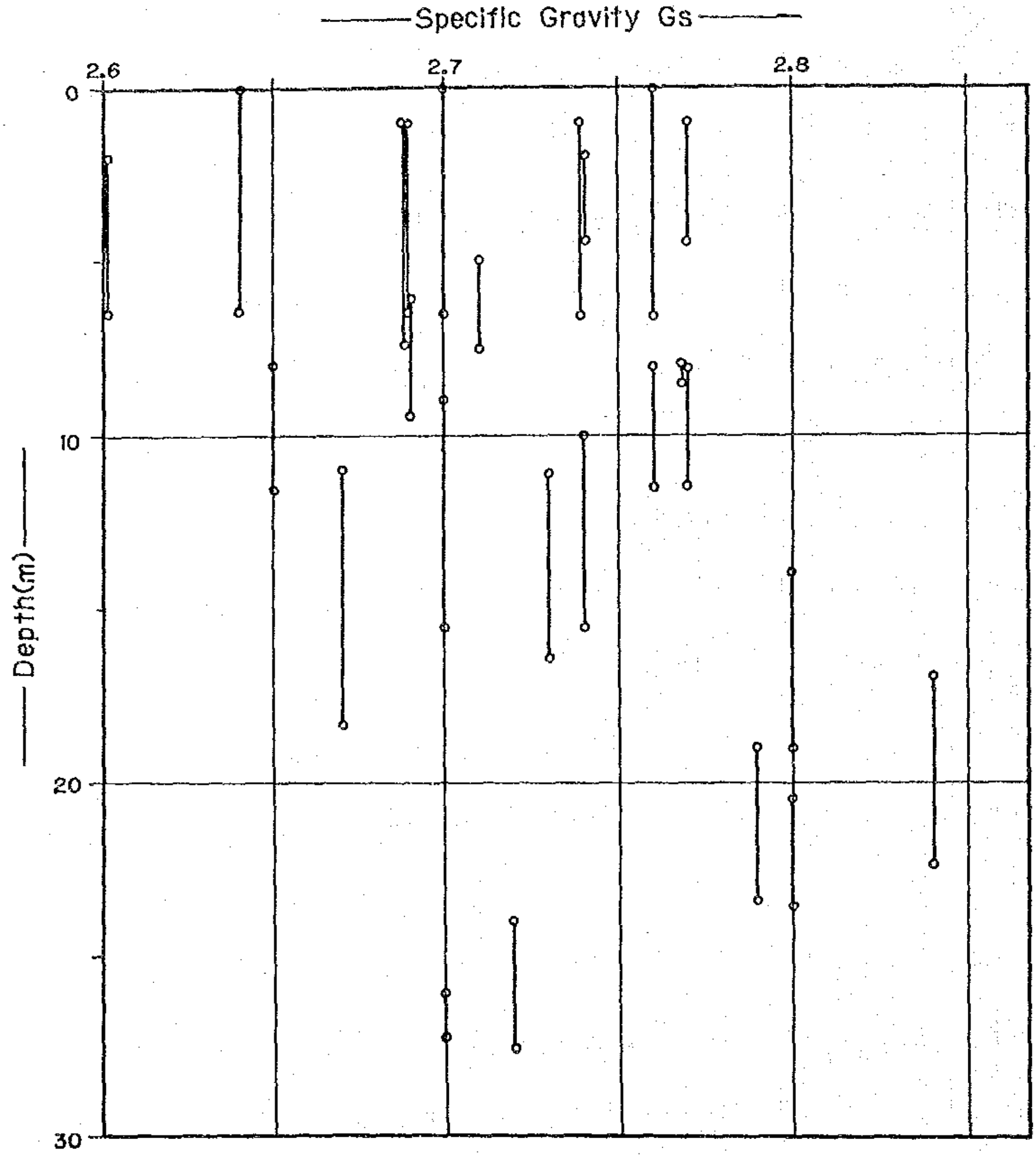
No, of Hole	Depth (m)	Unified, Soil Classification System	Feld Moisture Content, Wf (%)	Gradation Distribution (%)			Liquid Limit LL (%)	Plastic Limit PL (%)	Plastic Index, PI	Shrinkage Limit SL (%)
				Sand	Silt	Clay				
SR	1.70 ~ 0.20	-	42.1	29.8	51.4	18.8	-	-	-	-
	0.20 ~ -0.08	CL	21.3	5.2	47.6	47.2	35.0	20.4	14.6	13.2
SL	1.50 ~ 0.00	CL	89.3	1.8	70.8	27.4	46.3	31.7	14.6	13.6
	0.00 ~ -1.00	CH	25.5	13.9	36.3	49.8	63.6	30.9	32.7	19.3
	1.32 ~ 0.20	CL	21.0	7.7	54.6	37.7	30.7	21.1	9.6	11.7
	0.20 ~ -1.00	CL-ML	13.6	45.8	22.8	31.4	21.8	15.3	6.5	9.8

2. Mechanical Tests

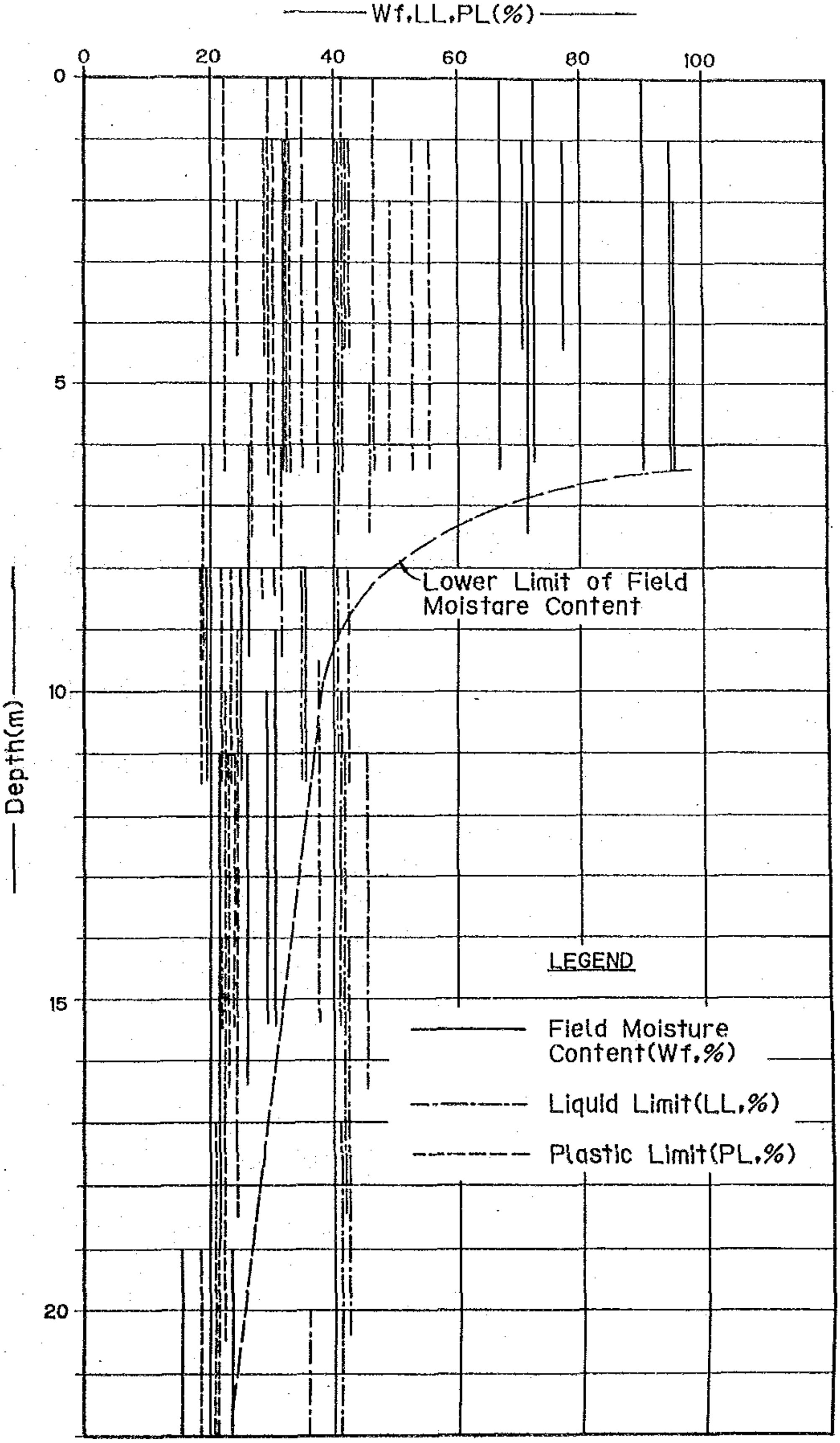
No, of Hole	Unconfined Compression Test					Consolidation Test						Triaxial Compression Test						
	Depth (m)	Wf (%) 1/	Unit Weight γt (grf/cm³)	qu 2/ (kgf/cm²)	Cu 3/ (kgf/cm²)	Depth (m)	Ranging of void-ratio (%)	Pc 4/ (kgf/cm²)	Cv 5/ (cm²/sec)	Cc 6/	Mv 7/ (cm²/kgf)	Depth (m)	U-U Condition 8/ C (kgf/cm²) 9/	U-U Condition 8/ ø (°) 10/	C-U Condition 11/ C (kgf/cm²)	C-U Condition 11/ ø (°)	C-U Condition 12/ C (kgf/cm²)	C-U Condition 12/ ø (°)
SR	2.0~3.0	44.9	1.752	0.851	0.43													
		47.0	1.727	0.903	0.45													
	3.0~4.0	92.3	1.452	0.461	0.23													
	4.5~5.5	50.0	1.641	0.747	0.37	4.5~5.5	1.40~0.78	0.83	$1.1\times10^{-3}\sim3.5\times10^{-4}$	0.39	$1.1\times10^{-1}\sim9.8\times10^{-3}$	4.5~5.5	0.39	7.9	0.10	12.5	0.08	28.5
	6.0~7.0	55.2	1.614	0.502	0.25													
	9.0~9.6	32.8	1.906	0.917	0.46							7.5~8.5			0.08	15.3	0.12	32.1
		36.2	1.887	0.924	0.46													
	10.5~11.2	27.8	1.551	6.291	3.15							10.5~11.0			0.10	15.5	0.05	18.8
	12.5~13.0	26.5	2.008	1.460	0.73													
		27.1	1.974	1.500	0.75													
	14.0~14.5	18.7	2.116	4.787	2.39													
	15.0~15.5	21.7	2.059	4.067	2.03													
		21.2	2.088	3.780	1.89													
	17.0~17.5	17.7	2.087	8.562	4.28							16.5~17.5	0.63	9.0	0.33	23.7	0.25	29.2
SL	1.0~2.0	-	1.740	1.065	0.53	1.0~2.8	1.31~0.78	0.98	$2.0\sim1.2\times10^{-4}$	0.44	$5.1\sim1.2\times10^{-2}$	1.0~2.8	0.43	1.7	0.43	8.9	0.32	18.6
	2.0~3.0	105.2	1.438	0.480	0.23													
	3.0~4.0	98.0	1.442	0.281	0.14													
		98.1	1.473	0.300	0.15													
	4.5~5.0	95.4	1.462	0.377	0.19	4.5~5.0	2.49~0.95	0.80	$2.7\times10^{-3}\sim7.5\times10^{-5}$	1.11	$1.7\times10^{-1}\sim1.9\times10^{-2}$	4.5~5.0	0.27	3.7	0.06	9.9	0.15	15.5
	6.0~7.0	79.1	1.477	0.363	0.18													
		85.2	1.487	0.367	0.18													
	7.5~8.0	37.6	1.652	0.264	0.13	7.5~8.0	0.88~0.64	1.30	$9.7\sim6.2\times10^{-4}$	0.22	$2.8\times10^{-2}\sim6.8\times10^{-3}$	7.5~8.0			0.26	18.4	0.20	28.2
	9.0~9.5	33.2	1.940	1.196	0.60													
	11.0~11.5	21.8	1.700	3.112	1.56							11.0~11.5	0.86	2.9	0.55	12.5	0.50	17.0
	12.5~13.0	19.4	2.113	4.563	2.28													
	14.0~14.5	18.6	2.164	1.546	0.77							13.5~14.0			0.23	21.6	0.19	26.4
	15.0~15.5	20.6	2.107	2.043	1.02													

Note ; 1/ field moisture content, 2/ unconfined compressive strength, 3/ strength constants Cu = 1/2 qu, 4/ ;reconsolidation stress, 5/ coefficient of consolidation, 6/ compression index, 7/ coefficient of volume compressibility, 8/ unconsolidated-undrained condition under the total stress method, 9/ cohesion, 10/ internal friction angle, 11/ consolidated-undrained condition under the total stress method, 12/ consolidated-undrained condition under the effective stress method

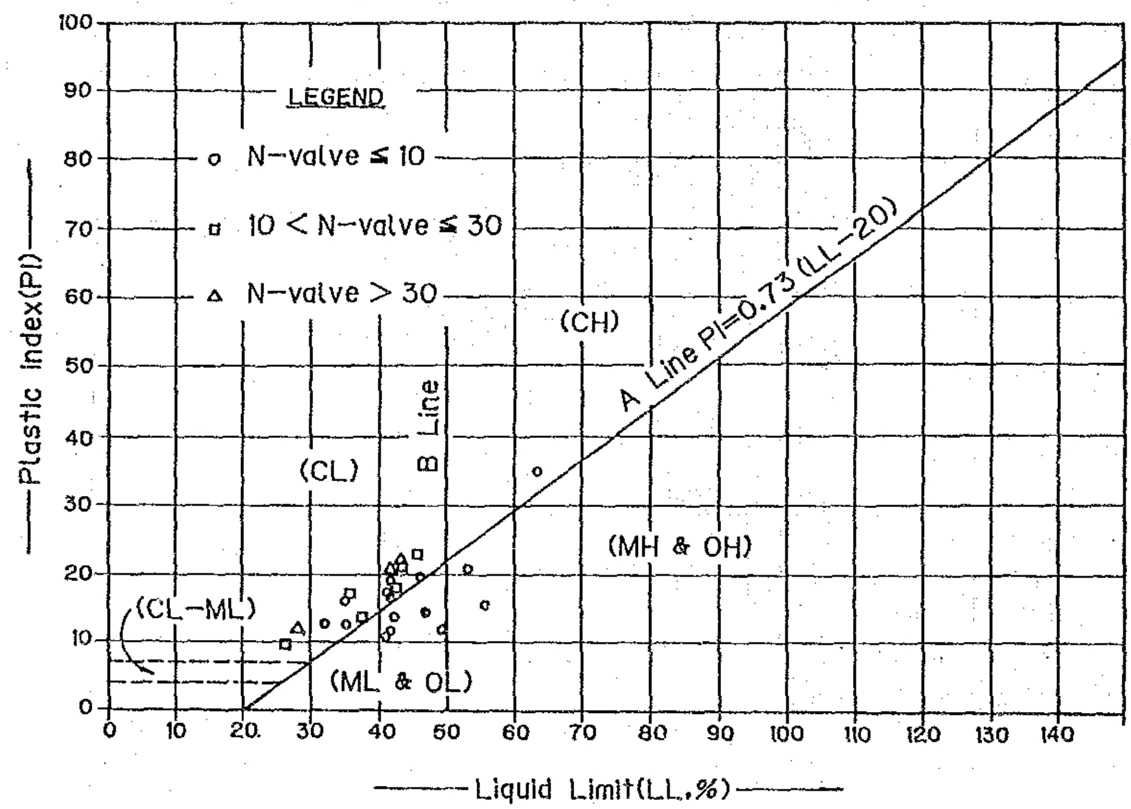
FIGURES 2-1 RELATIONSHIP BETWEEN SPECIFIC GRAVITY AND DEPTH
(DISTURBED SAMPLES BY BORING CORES)



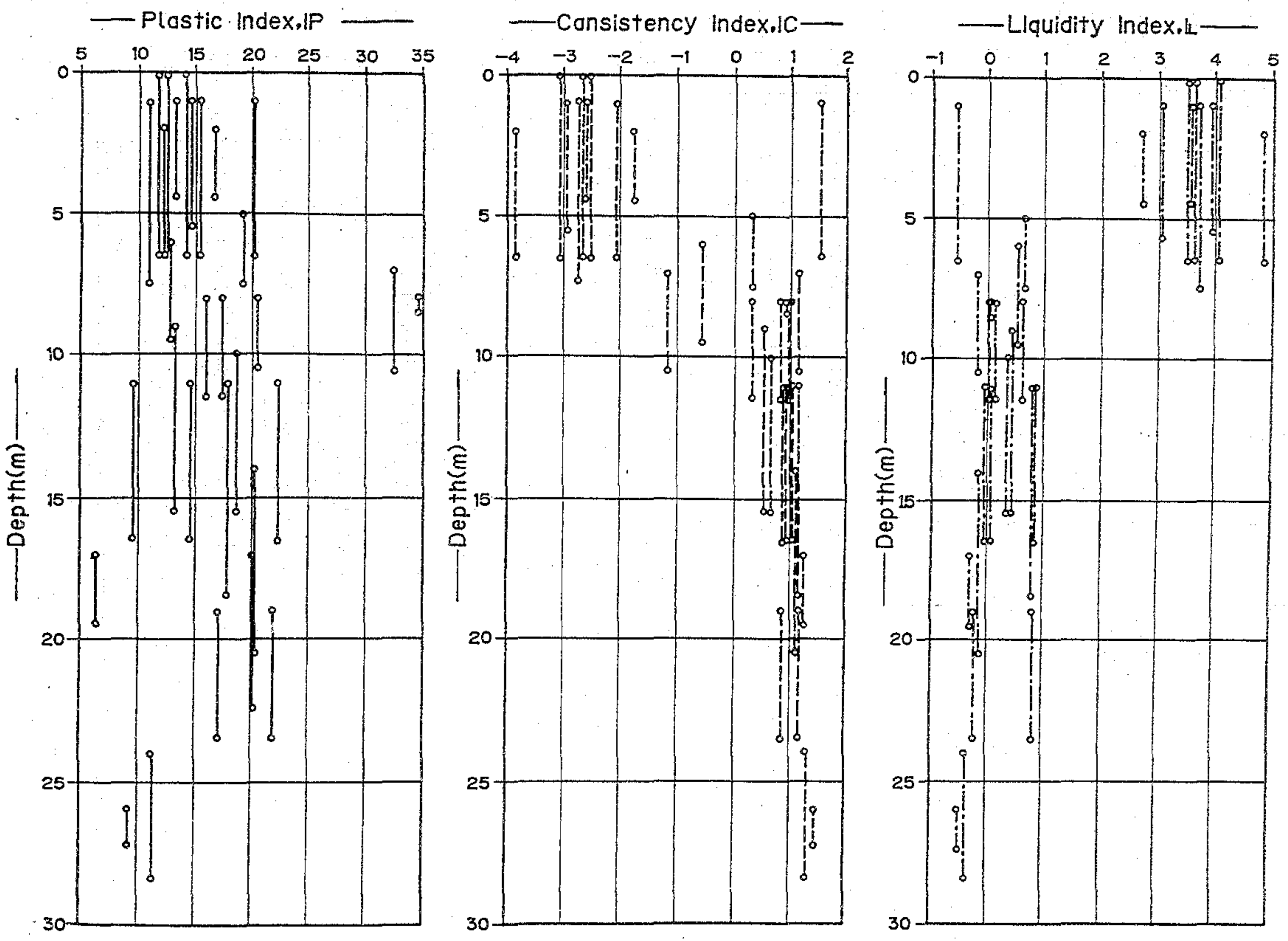
FIGURES 2-2 RELATIONSHIP BETWEEN PHYSICAL PROPERTIES AND DEPTH (DISTURBED SAMPLES BY BORING CORES)



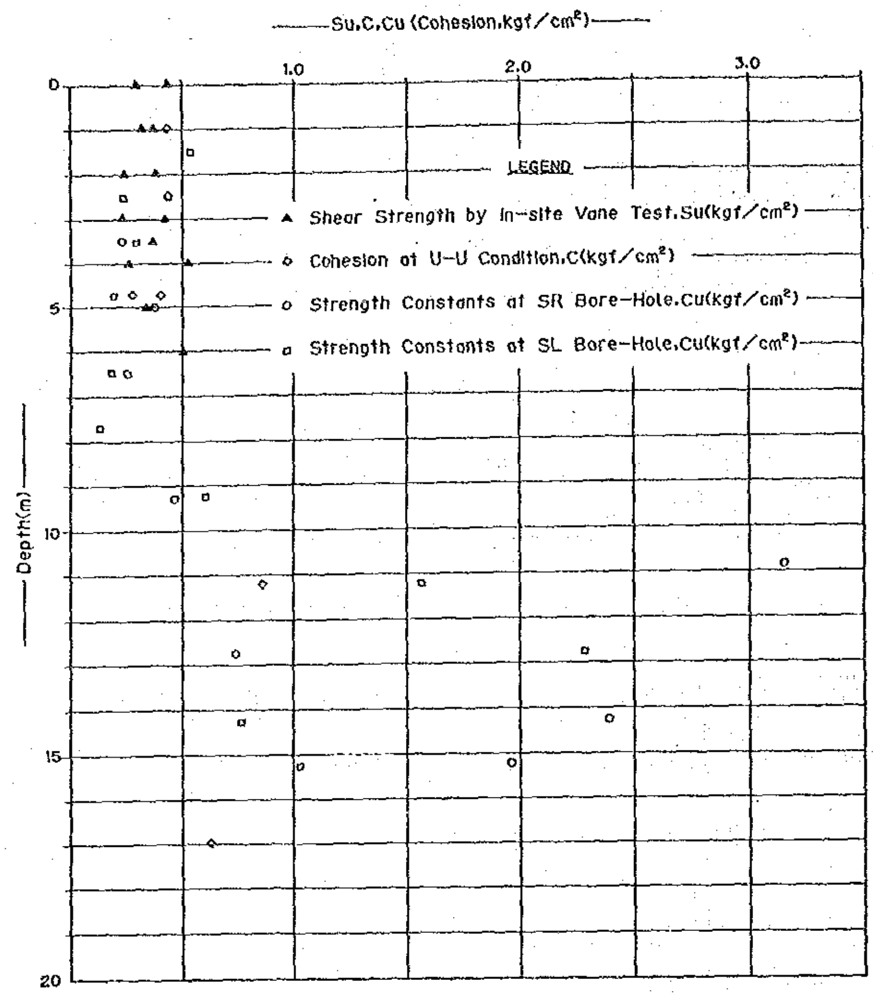
FIGURES 2-3 PLASTICITY CHART



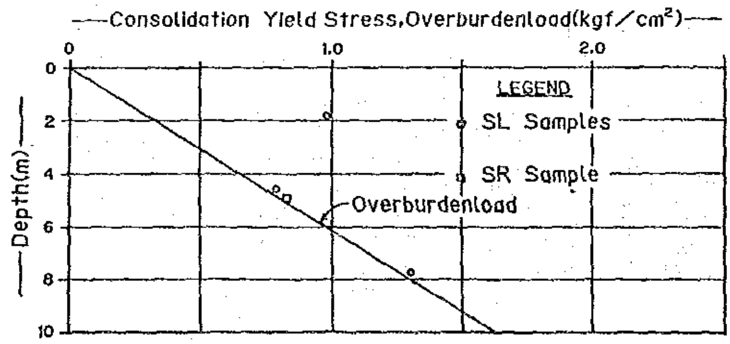
FIGURES 2- 4 RELATIONSHIP BETWEEN PLASTIC INDEX, CONSISTENCY INDEX, LIQUIDITY INDEX AND DEPTH
(SAMPLES BY BORE-HOLES)



FIGURES 2-5 RELATIONSHIP BETWEEN SHEAR STRENGTH(COHESION) AND DEPTH



FIGURES 2-6 RELATIONSHIP BETWEEN PRE-CONSOLIDATION STRESS AND DEPTH



CHAPTER 3. DESIGN CRITERIA

3.1 General

The project facilities are designed according to the design information given in this chapter. The other design information necessary for the complete design of the project facilities should be found in the following design standards.

- Design standards for headworks, filldam, pump facilities and canal works in land improvement projects, established by Agricultural Structure Improvement Bureau, Ministry of Agriculture, Forestry and Fisheries of Japan.
- Japanese government ordinance for road structures and Japanese design standard for road bridges.
- Design standard of roads and standard drawings of road structures, established by the Highway Department of Thailand.

In designing the project facilities based on these design standards, the design standards of Thailand should be applied preferentially over the Japanese design standards.

3.2 General Design Information for Structure

1) Allowable Stresses of Construction Materials

a) Allowable Stress of Reinforced Concrete

Allowable Stress (kg/cm^2)		28 day Concrete Strength (kg/cm^2)		
		180	210	240
Bending Compressive Stress		81	94.5	108
Shear Stress	Beams	4	4.2	4.5
	Slabs	8	8.5	9
Bond Stress	Round Bar	7	7.5	8
	Deformed Bar	14	15	16
Bearing Stress		54	63	72
Structures to be applied		Others	Slabs, walls and piers of main structures	Slab of bridge

The modular ratio (modulus of elasticity of steel/modulus of elasticity of concrete) of 10 will be used for the design of the project facilities.

b) Allowable Stress of Plain Concrete

Allowable Stress (kg/cm^2)	28 Day Concrete Strength (kg/cm^2)	
	180	140
Bending Compressive Stress	45	35
Bending Tensile stress	2.5	2
Bearing Stress	54	42

c) Allowable Tensile Stress of Steel

- Deformed bar (SD30) $\sigma sa = 1{,}400\ kg/cm^2$
- Round bar (SR24) $\sigma sa = 1{,}200\ kg/cm^2$
- Structural steel (SS41) $\sigma sa = 1{,}200\ kg/cm^2$
- Steel sheet pile (SY30) $\sigma sa = 1{,}400\ kg/cm^2$

2) Loadings

a) Dead Loads

The dead-load weights are as follows;

- Reinforced concrete $\gamma c = 2.4\ t/m^3$
- Plain concrete $\gamma c = 2.2\ t/m^3$
- Water $\gamma w = 1.0\ t/m^3$
- Sea water $\gamma e = 2.4\ t/m^3$
- Dry earth $\gamma e = 1.6\ t/m^3$
- Wet earth $\gamma e = 1.8\ t/m^3$
- Saturated earth $\gamma e = 2.0\ t/m^3$
- Steel $\gamma s = 7.85\ t/m^3$

b) Live Loads

Structures on which heavy wheels pass through the side of the structure should be designed for the wheel loads, and where heavy wheels do not pass through the side of the structure, a live load of $300\ kg/m^2$.

c) Seismic Loads

The seismic loads are not considered for the design of the project facilities.

3) Bang Pakong Reservoir Plan

- Design flood	:	1,5000 m^3/s
- Maximum Water Level (Max. W.L.)	:	EL. 2.40 m
- Normal Water Level (N.W.L.)	:	EL. 0.70 m
- Minimum Operating Level (Min. O.L.)	:	EL. - 1.30 m
- Active Storage	:	30 MCM

4) Sea Level

- High Water Level (H.W.L.)	:	EL. 1.30 m
- Low Water Level (L.W.L.)	:	EL.-1.00 m
- Highest High Water Level (H.H.W.L.)	:	EL.2.10 m
- Lowest Low Water Level (L.L.W.L.)	:	EL.-1.70 m

3.3 Diversion Dam

The general design considerations for the diversion dam are as follows;

a) No navigation lock is provided. Boats and ships are prohibited from passing through the diversion dam even when the gates open. The two jetties are planned on the left bank of Bang Pakong river. One is constructed upstream of the closure dam and the another is downstream.

b) No fish ladder is constructed in the Bang Pakong Diversion Dam Project. However, the approximate location of a fish ladder will be selected and preliminary design drawings will be provided for future implementation.

c) A floating net system is provided upstream from the diversion dam.

d) The O/M bridge will be designed for a live load of TL-20t and its width will be 5 meters or more for the passage of a truck crane for maintenance and repair work on the tide protection gates.

e) A stop log necessary for maintenance and repair work on the tide protection gates will be provided.

f) An emergency generator is provided for the operation of the tide protection gates even in the time of power failure.

3.4 Pumping Station

The general design considerations for the pumping station are as follows;

a) The discharge water level is determined as EL. 3.80 m by adding a head loss due to the increased length of the canal and a difference in water level in the transitional section, to the designated water level of EL. 3.70 m at the beginning of the main canal shown in the F/S report.

- Head loss due to an increased length of canal:

  $= \text{(increased length of canal)} \times \text{(gradient of canal invert)}$

  $= 600\text{ m} \times (1/12{,}000) = 0.05\text{ m}$

- Difference in water level in transitional section:

  $= (1 + fgc) \times \text{(velocity head)}$

  $= 1.3 \times (0.815^2/(2 \times 9.8)) = 0.05\text{ m}$

  (fgc: coefficient of head loss due to change of canal section)

b) The floating net system will be provided in front of the entrance of the intake canal, and also trash racks will be provided in the intake canal.

c) The pump house will be designed to have enough space for disassembling and repairing the pump facilities in addition to the space for the main pumps, incoming/distribution facilities, office, etc. The area of the office should be enough for a staff of more than three. A bedroom is not required.

d) At least one of the main pumps should be designed to be operated even in a power failure.

e) The site of the pumping station includes the sites of the intake canal, pump house and discharge reservoir. The layout plan should take into account the space required for the above mentioned structures and for maintenance.

3.5 Road and Road Bridge

The general design considerations for road and road bridge are as follows;

a) The width of the road and road bridge will be 9 meters. The road section is composed of a 6 meter wide roadway and two shoulders of 1.5 meters wide each.

b) The road and road bridge should be designed for the design speed of 60 ~ 80 km/hr.

c) The road is planned to be paved with asphalt and the cross grade will be 3.5%.

d) Drainage ditches along the road are not required.

e) The road bridge is designed for a live load of TL-20t.

f) Because the passage of boats and ships under the road bridge is prohibited, it is not necessary to determine a clearance level.

g) Lighting facilities will be installed along the road and road bridge.

3.6 Buildings

The general design considerations for buildings are as follows;

a) The allowable stresses of the construction materials in building works are as shown in chapter "3.2 General Design Information for Structure".

b) The wind load factors for various height zones are as follows;

less than 10 m high	50 kg/m^2
10 to 20 m high	80 kg/m^2
20 to 40 m high	120 kg/m^2

c) The design loads on the floor for various types of building are as follows;

garages, machine room	500 kg/m^2
office	300 kg/m^2
residence	150/m^2

d) Fire extinguisher will be provided in the buildings. For every 100 m^2 of floor area there will be one fire extinguisher. A floor area less than 100 m^2 will have at least one fire extinguisher.

CHAPTER 4. HYDROLOGICAL AND HYDRAULIC ANALYSIS

4. 1 Scale of the Planned Facilities

No large-scale flood control facilities have been implemented in the subject river system, so the existing high water condition is therefore assumed as the design high water level. The scale of the subject facilities is, as applied by RID, planned as 1/50 exceeding probability.

4. 2 Design Flood and Maximum Water Level

4. 2. 1 Rainfall Analysis

1) Rainfall Stations Representing Watershed

A large number of rainfall gauging stations are distributed in the subject watershed. Similar to the approaches in F/S, 20 stations, which represent similar areas of Thiessen polygons and show similar rainfall patterns, have been selected for analysis.

2) Design Rainfall Duration

Duration of the design rainfall has been determined through the study of 5 previous major floods at Kgt. 3 which represents about 45% of the watershed.

Studies on a series of daily rainfall records with flood peaks at the 20 stations indicate that 80% of rainfall of over 1.0 mm/day lasts for 7 days while 95% of that over 5.0 mm/day lasts for the same period. The duration of the design rainfall has therefore been decided at 7 days.

3) Design Rainfall Distribution Pattern

Among the selected 20 stations, hourly rainfall records are available only at 4 stations though they have not been processed yet.

The design rainfall distribution pattern has accordingly been thus projected. From the recorded 7-day rainfall at the 20 stations during the major floods, a distribution pattern of the maximum rainfall intensity in the 7 days has been projected, and the hourly rainfall for each day has then been given by dividing the daily rainfall by 24.

4) Effective Rainfall

Similar to F/S, the effective rainfall has been worked out from the relationship between cumulative rainfall and loss rainfall, which was derived from the observed runoff records and rainfall records in the watershed during major floods.

4. 2. 2 Runoff Analysis

1) Method of Analysis

Methods for the analysis are the unit hydrograph method, the storage function method and the characteristic curve method.

The watershed is characterized by relatively low-elevated rolling hills with gentle slopes in the upper reaches and by flat low land of paddy fields with ground slope of 1/30,000 - 1/60,000 in the downstream reaches of the Bang Pakong River. By taking account of the water storage effect in paddy fields, the combined characteristic curve method has been employed for the analysis.

2) Blocking of Watershed and Runoff Model Constants

By taking account of the water resources development plans in the whole river system, the watershed has been divided into 54 blocks in 8 sub-systems.

The model constants for the flood runoff models have been decided from land use classification in the watershed, based on 1 : 50,000 topo-maps.