KINGDOM OF THAILAND
THE FEASIBILITY STUDY ON
THE AGRICULTURAL WATER DEVELOPMENT
PROJECT OF BANG PAKONG RIVER BASIN
Main Report
OCTOBER 1990
JICA

KINGDOM OF THAILAND
ROYAL IRRIGATION DEPARTMENT
MINISTRY OF AGRICULTURE AND COOPERATIVES

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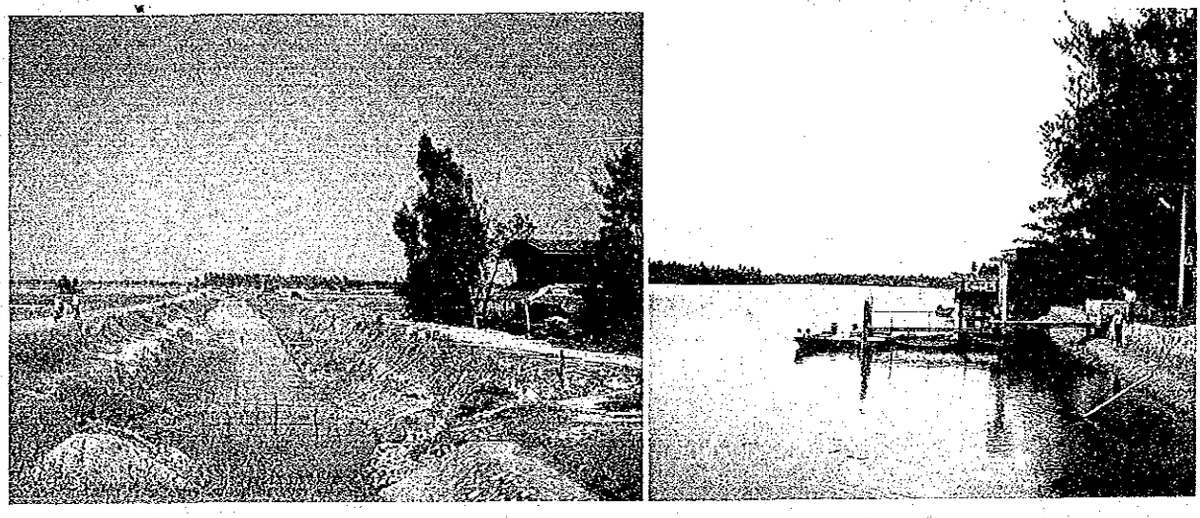
Main Report



OCTOBER 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

KINGDOM OF THAILAND

ROYAL IRRIGATION DEPARTMENT

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THE FEASIBILITY STUDY
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MAIN REPORT

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PREFACE

In response to a request from the Government of the Kingdom of Thailand, the Japanese Government decided to conduct a feasibility study on the Agricultural Water Development Project of Bang Pakong River Basin and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Thailand a study team headed by Dr. Junichi Kitamura, Sanyu Consultants Inc., three times from September, 1989 to September, 1990.

The team held discussions with the officials concerned of the Government of Thailand and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

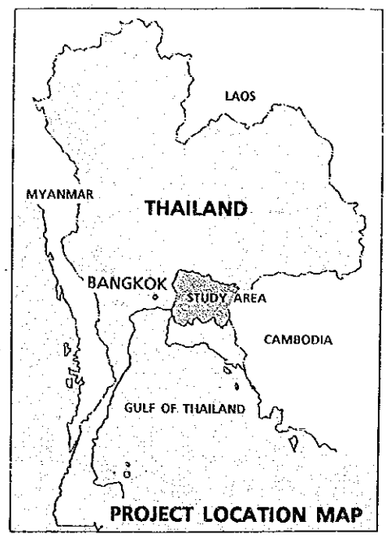
I wish to express my sincerest appreciation to the officials concerned of the Government of Thailand for their close cooperation extended to the team.

October, 1990

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

GENERAL LOCATION MAP



Maenum Nakhon Nayok Sub-Basin C. A=1,933sq. km

Maenum Hanuman Sub-Basin C. A=2,130sq. km

Upper Bang Pakong Sub-Basin C. A=2,757sq. km

Middle Phra Prong Sub-Basin C. A= 970sq. km

Upper Phra Prong Sub-Basin C. A=1,628sq. km

Lower Bang Pakong Sub-Basin C. A=3,106sq. km

Khlong Tha Lat Sub-Basin C. A=2,493sq. km

Khlong Phra Sathung Sub-Basin C. A=2,643sq. km

Khlong Khon Na Dam
Khlong Tha Dan Dam
Khlong Nong Kosee Dam
Prachantakham Irrig. P.
Tha Hoe I.P.
Lam Phraya Than Dam
Huai Sai Noi Dam
Huai Somong Dam
U. Khlong Phra Prong Dam
Khlong Phra Prong Dam
Khlong Phra Sathung Dam
Bang Phluang I. P.
Pra Ong Chaiyanuchit I.P.
Bang Pakong Left Bank Irrig. P.
Phan Thong I. P.
Ban Bung I.P.
Rabom Dam
Khlong Luang Dam
Khlong Si Yai Dam
Bang Pakong Dam
WATTHANA NAKHON

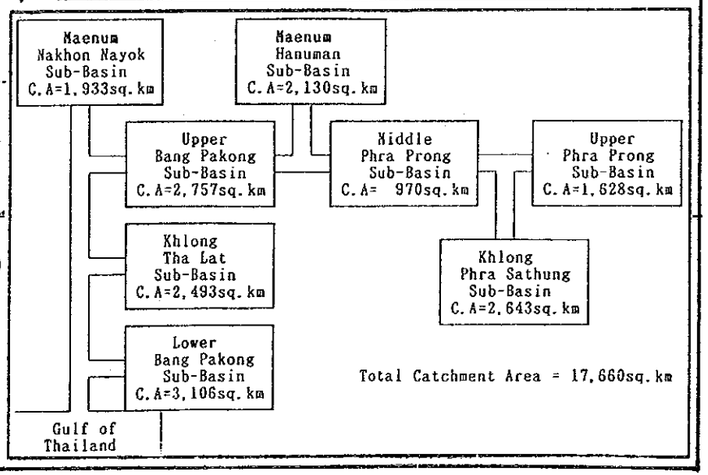
SCALE 0 5 10 15 km

EXISTING IRRIGATION PROJECT

AREA NEWLY DEVELOPED

PROPOSED DAM/RESERVOIR

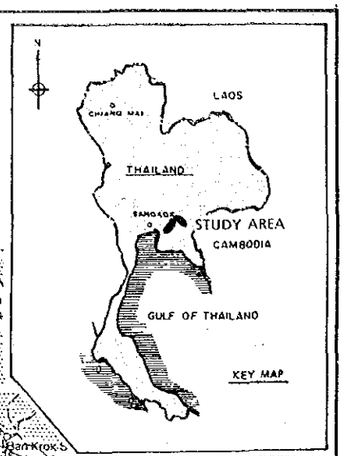
Sub-Basin	Irrigation Area (ha)	Water Requirement in MCM		
		Crop	Effect. Rain	Diversion
Upper Phra prong	62,400	377.830	211.933	310.179
Khlong Phra Sathung	43,000	261.950	146.077	216.740
Middle Phra Prong	25,000	159.574	94.342	118.959
Maenum Hanuman	39,600	230.404	128.192	191.662
Upper Bang Pakong	87,900	1,485.396	732.863	1,350.028
Maenum Nakhon Nayok	207,400	766.108	423.962	575.036
Khlong Tha Lat	8,700	54.923	19.995	64.567
Lower Bang Pakong	104,000	742.186	306.755	779.703
Whole River Basin	578,000	4,078.369	2,064.116	3,606.873



Total Catchment Area = 17,660sq. km

THA LAT RIVER BASIN DEVELOPMENT PROJECT

SCALE 1 ; 250,000



BANG PAKONG PUMPING STATION
C = 17.64cu.m/s M = 390KW

BANG PAKONG DIVERSION DAM
EFFECT. CAPACITY 30MCM

BANG PAKONG EXPANSION AREA
A = 2,000ha

BANG PAKONG LEFT MAIN CANAL
L = 12km INITIAL C = 4.50cu.m/s

THA LAT DIVERSION WEIR
(existing)

RABOM DAM
DRAINAGE AREA = 175sq.km
EFFECT. CAPACILTY = 36.5MCM

EXISTING THA LAT AREA
A = 22,100ha

PLAENG YAO
INDUSTRIAL ESTATE

THA LAT EXPANSION AREA
A = 7,100ha

EXISTING BANG PAKONG AREA
A = 12,700ha

BANG PAKONG RIGHT MAIN CANAL
L = 24km INITIAL C = 12.89cu.m/s

THA LAT MAIN CANAL (existing)
L = 44km INITIAL C = 22.1cu.m/s

SI YAT MAIN CANAL
L = 49.5km INITIAL C = 7.10cu.m/s

BANG PAKONG
INDUSTRIAL ESTATE

KHLONG SI YAT DAM
DRAINAGE AREA = 976sq.km
EFFECT.CAPACITY = 300MCM
CREST LENGTH = 2,600m
HEIGHT = 30.0m

CHANGWAT CHACHOENGSAO
จังหวัดฉะเชิงเทรา

CHANGWAT CHON BURI
จังหวัดชลบุรี

Amphoe Bang Pakong
Amphoe Bang Nam Priao
King Amphoe Ratchasan
Amphoe Phanom Sarakham
Amphoe Sanam Chai Khet
Amphoe Plan Thong
Amphoe Phanat Nikhom

THA LAT RIVER BASIN DEVELOPMENT PROJECT

IRRIGABLE AREA

Tha Lat Expansion Area	7,100 ha
Existing Tha Lat Area	22,100
Existing Bang Pakong Area	12,700
Bang Pakong Expansion Area	2,000
Total	43,900 ha

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FEASIBILITY STUDY

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ABBREVIATIONS AND ACRONYMS USED

THAI GOVERNMENT

BAAC	:	Bank of Agriculture and Agricultural Cooperatives
CDD	:	Community Development Department, MOI
CPD	:	Cooperatives Promotion Department, MOAC
DOA	:	Department of Agriculture, MOAC
DLD	:	Department of Land Development, MOAC
DOAE	:	Department of Agricultural Extention, MOAC
DOF	:	Department of Fisheries, MOAC
DOH	:	Department of Highway, MOC
DOL	:	Department of Lands, MOI
DOLA	:	Department of Local Administration, MOI
HD	:	Harbor Department, MOC
LDD	:	Livestock Development Department, MOC
MD	:	Meteorological Department, MOC
MRD	:	Mineral Resources Development, Ministry of Development
MOAC	:	Ministry of Agriculture and Cooperatives
MOC	:	Ministry of Communications
MOF	:	Marketing Organizations for Farmers, MOAC
MOI	:	Ministry of Interior
MOPH	:	Ministry of Public Health
NEA	:	National Energy Administration, Ministry of Science, Technology, and Energy
NEB	:	Natinal Environmental Board, Ministry of Science, Technology and Energy
NESDB	:	National Economics and Social Development Board, Office of Prime Minister
NICA	:	National Institute of Coastal Aquaculture, DOF
NRDC	:	National Rural Development Committee
NSO	:	National Statistical Office, Office of Prime Minister
OAE	:	Office of Agricultural Economics, MOAC
PER	:	Provincial Electricity Authority
RFD	:	Royal Forestry Department, MOAC
RID	:	Royal Irrigation Department
RTSD	:	Royal Thai Survey Department

GENERAL

B	:	Baht
BM	:	Bench Mark
EL	:	Elevation above Mean Sea Level
FAO	:	Food and Agricultre Organization of the United Nations
GDP	:	Gross Domestic Product
GNP	:	Gross National Product

JICA	:	Japan Internatinal Cooperation Agency
M.	:	Million
NPV	:	Net Produion Value
WL	:	Water Level
cu. m	:	Cubic meters
MCM	:	Million cubic meters
kw	:	Kilowatt
kwH	:	Kilowatt hour
l	:	liter
ha	:	Hectare
m	:	Meter
kg	:	Kilograms
km	:	Kilometer
sq. km	:	Square kilometers
sq. m	:	Square meters
ton	:	Metric ton
p. a.	:	per annum
Yr.	:	Year
hr	:	Hour
min	:	Minute
sec	:	Second
c	:	Degree Centigrade
ms / cm	:	Milli siemens per centimeters (same as m. mho / cm)
HP	:	Horsepower
ppt	:	part per thousand

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

UNIT OF MEASUREMENT

1 rai = 0.16 ha = 1,600 sq. m
1 ha = 6.25 rai = 10,000 sq. m

THAI FISCAL YEAR

October 1 to September 30, next year

SUMMARY

A. INTRODUCTION

A. 1. Study Objectives

The study objectives are to formulate comprehensive water resources development programs in the Bang Pakong River Basin, to put priorities on the project to be implemented in order, and to conduct a feasibility study for the project area with top priority; in which water resources facilities are constructed on the river and its tributaries, and irrigation and drainage facilities for subject project are radically modified and or constructed so as to stabilize water supply for paddy and dry cropping as well as drinkings, industries and fisheries through the year and especially in a dry season to prevent saline water from intruding into the area.

A. 2. Scope of Works

The study comprises two parts; one is "Overall Basin study" to cover the entire Bang Pakong River Basin and the other is "Feasibility Study on the Khlong Tha Lat River Basin Development Project".

B. OVERALL BASIN STUDY

B.1. Present Conditions of The Basin

B. 1. 1. Location

Being situated in the east-central part of Thailand, the Bang Pakong River Basin has a catchment of 17,660 sq.km which covers about 3.4 percent of the total national land area. The basin occupies major portions of the Changwats Chonburi, Chachoengsao, Prachinburi and Nakhon Nayok.

B. 1. 2. Climate

Two pronounced seasons, wet and dry, dominate over the basin. The southern monsoon during May through October carries tropical air from the Gulf of Thailand and the Andaman Sea providing most of annual rainfall over the area. The northwest monsoon, during November through March, generally brings dry air and high temperature. Mean annual rainfall ranges between 900 mm and 2,400 mm in the recent 20 years, with considerable differences from place to place generally increasing in proportion to the latitude from the south to the north. Monthly temperatures vary from 26 to 30°C with insignificant difference in time and space.

B. 1. 3. Social and Economic Situation (Population and GPP)

Item	Whole Kingdom	Eastern Region	Major Changwats in the Basin			
			Chonburi	Chachoe -ngsao	Nakhon Nayok	Prachin -buri
Gross Provincial Product						
- Agriculture	198,284	17,738	3,532	3,466	727	2,868
- Other Sectors	1,035,746	82,759	44,155	12,651	1,912	5,597
- Total	1,234,030	100,497	47,687	16,097	2,639	8,465
Population (1,000 person)	53,605	3,232	790	511	203	773
per Capita GPP (Bahts)	23,021	31,094	60,368	31,501	12,999	10,951

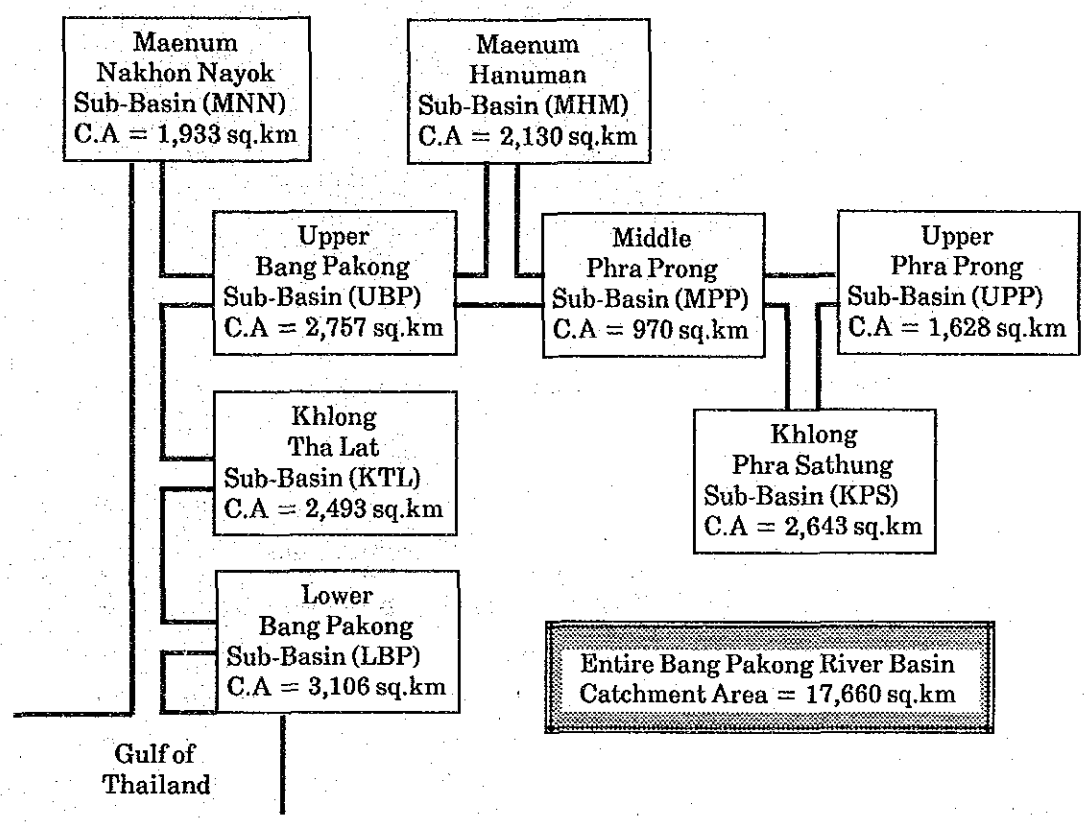
Note: GPP is given in million bahts.

B. 1. 4. River System and Sub-Basin Zoning

The two primary tributaries of the Bang Pakong river are the Nakhon Nayok and Prachin rivers which join near the western boundary of the basin.

The Prachin river originates near Kabinburi where the Hanuman and Phra Prong rivers join. Approximately 57% of the Bang Pakong basin area drains into the Prachin river, 11% into the Nakhon Nayok river and the remainder of the basin drains into the Bang Pakong river downstream of the two major tributaries. The basin was divided into 8 sub-basins as shown below:

Sub-Basin Zoning



B. 1. 5. Hydrology

Rainfall, river runoff and runoff coefficient analyzed in terms of an annual average in the recent 20 years are as follows:

Sub-basin	Catchment (sq.km)	Rainfall (mm)	Runoff (MCM)	Runoff Coefficient (%)
UPP	1,628	1,762	690	24
KPS	2,643	1,580	880	21
MPP	970	1,925	560	30
MHM	2,130	1,926	1,430	35
UBP	2,757	1,641	1,480	33
MNN	1,933	1,729	1,540	40
KTL	2,493	1,343	700	21
LBP	3,106	1,240	650	17
Whole Basin	17,660	1,590	7,930.0	27.5

B. 1. 6. Present Land Use

Existing land use by sub-basin is summarized as follows:

(Unit: ha)

Sub-Basin	Project Area	Agricultural Land					Other Land
		Paddy	Upland	Orchard	Vege.	Total	
Lower Bang Pakong	310,600	102,680	144,110	17,830	8,370	272,990	37,610
Khlong Tha Lat	249,300	3,990	61,050	700	160	65,900	183,400
Upper Bang Pakong	275,700	167,380	37,130	41,880	8,560	254,950	20,750
Mae Num Nakhon Nayok	193,300	81,680	2,550	12,110	3,380	99,720	93,580
Middle Phra Prong	97,000	19,520	21,820	-	-	41,340	55,650
Mae Num Hanuman	213,000	24,520	24,550	15,470	80	64,620	148,380
Khlong Phra Sathung	264,300	29,960	69,970	8,170	2,050	110,150	154,150
Upper Phra Prong	162.800	46,560	29,880	5,840	1,810	84,090	78,710
Whole River Basin	1,766,000	476,290	391,060	102,000	24,410	993,760	772,240

Note: Orchard includes tree crops such as para-rubber, eucalyptus, bamboo and other fruit crops.

B. 1. 7. Major Crops

Planted areas by major crops in the main four Changwat are extracted from agricultural statistics as follows:

(Unit: ha)

Crops	Chonburi	Chachoengsao	Prachinburi	Nakhon Nayok	Total
Paddy	47,900	78,800	226,700	78,900	432,300
Cassava	26,200	67,400	139,200	-	232,800
Sugarcane	29,800	7,000	-	-	36,800
Legumes	600	2,200	13,000	-	15,800
Maize	-	2,200	104,700	200	107,100
Mango	3,000	7,500	4,500	1,200	16,200

B. 2. Basic Strategy for Basin Development

B. 2. 1. Problems and Constraints Involved

Favored moderately with an annual rainfall of about 1,600 mm, paddy cultivation is dominant in the basin during wet season. Mainly for lack of interior drainage facilities combined with absolutely limited outflow capacities of rivers and tributaries, however, the existing paddy areas are often suffered from floodings and inundations. Another serious problem during wet season in the same area is frequent shortages of supplemental irrigation water. However, it has not been achieved for lack of irrigation facilities, limited river runoff and saline water intrusion. In dry season, on the contrary, the area is almost left fallow from of lack of water.

Cassava is a profitable crop and is an easy crop to grow, requiring no particular technical knowledge, extensive labour and no irrigation. It also grow in a poor soil. However, based on the agreement signed between Thailand and EEC, exports must decrease. This will lead to limiting production of cassava, and in turn crop diversification plan should be examined and irrigation development is the only basic solution to cope with this problem.

B. 2. 2. Basic Development Strategy

The land resources development depends on water supply and flood exclusion. In the lower reaches of the river basin forming wide flat paddy field zone, such cropping patterns as double paddy farming and wet season paddy plus dry season dry farmings are to be introduced by securing water by dam construction. The middle and upper reaches of the river basin, on the other

hand, are expected to be developed urgently from a security viewpoint, since the eastern border of the basin is located near the Cambodian boundary.

In the economy of Thailand, the progress of the industry has been quite remarkable. The whole reaches of Bang Pakong river situated between Chonburi and Bangkok have suddenly been highlighted as the areas suitable for industrial estates. For industrial, municipal and domestic water supplies, the tasks are to secure water source, to extend and strengthen conveying, distributing and purifying facilities.

The project areas with higher priority must be developed in order, so as to utilize water resources effectively in the whole Bang Pakong river basin, and to plan a balanced development of the areas. Firstly, multi-purpose dams are constructed to supply water stably for agriculture, industry, municipal and domestic purposes, and fishery. Concurrently, a diversion dam is built on the main Bang Pakong river just upstream of Chachoengsao City to prevent saline water from intruding in dry season, and to supply water multi-purposely by storing fresh water in the river course upstream of the diversion dam.

B. 3. Water Resources Development

B. 3. 1. Water Demands

- Irrigation Water and Crops

The areas to be irrigated, by crops are shown in the next table.

Area to be Irrigated, by Crops

Crop	In a Rainy Season	In a Dry Season	
Paddy (by transplanting)	192,520 ha	-	ha
Paddy (by direct sowing)	147,080	38,200	
Soybeans	-	70,000	(5,000)
Peanuts	-	25,000	(5,000)
Mungbeans	-	25,000	(5,000)
Fruit trees (Mangoes)	24,200	24,200	
Vegetables	28,000	28,000	
Sub-total	391,800	210,400	(15,000)
Total		602,200	(15,000)

Remarks: Figures in parentheses are existing dry field areas for which irrigation is needed only in a dry season. They are included as a part in figures in no parentheses.
Cropping rate will be (602,200 + 15,000)/(391,800 + 15,000) = 1.52

- Water Demand and Required Dam Capacities

The hydrological data used for the following water balance study are actually measured values for 20 years from 1968 till 1987

In case of drought year with 1/2 probability

-	Mean yearly outflow	6,453.1 (MCM)
-	Total water demand	3,952.8
in which	irrigation water	3,606.9
	municipal and domestic water	116.1
	industrial water	215.3
	fisheries water	14.5
	Total required dam capacities	1,645.6

Total required dam capacities in drought years with probabilities for 20 years

with	1/2 probability	1,645.6 (MCM)
	1/5 probability	1,844.6
	1/10 probability	2,094.1
	1/20 probability	2,227.9

B. 3. 2. Alternative Irrigation Plans

Combining field findings in various sectors concerned, 4 cases of alternative irrigation plans in total were established. Basic concept employed in establishing these irrigation plans are briefly explained as follows:

Irrigation Plan-1 : In addition to full irrigation of the existing wet season paddy, the feasible maximum scale of upland crops, vegetables and fruit crops is introduced. Within the allowable limit of water resources, the maximum scale of dry season paddy is also considered. This plan would correspond with the maximum sizing plan of water resources development.

Irrigation Plan-2 : In the irrigation plan-1, the cropping rate on the existing paddy field was taken at about 150% as a target. This plan would correspond to the standard sizing plan of water resources development.

Irrigation Plan-3 : The second cropping on the existing paddy field is limited to the feasible maximum scale of upland crops. No dry paddy cultivation is expected. This plan

would correspond with the reduced plan of water resources development.

Irrigation Plan-4 : Only existing scale of wet season paddy and upland crops is considered. This plan would correspond to the minimum plan of water resources development.

On the basis of crop water requirements and water demands for other sectors than irrigation, computations were made to simulate the proposed situation of water balance in irrigation blocks, and then computed results were summarized in sub-river basins as well as in the entire Bang Pakong river basin.

B. 3. 3. Optimum Water Source Plan

- Optimum Water Source Plan

The benefit-cost ratio of each plan is not so much different from others except plan-4.

Plan-2, however, is hydrologically suitable because the dam capacity corresponds to mean yearly outflow and the paddy field utilization rate is about 150%. As a result, plan-2 is adopted as the optimum water source plan.

Benefit-cost Ratio

Items	Plan-1	Plan-2	Plan-3	Plan-4
Benefit				
- Incremental benefit (1)	3,292	3,115	2,852	1,837
- O. M Cost (2)	302	301	300	299
- ((1)-(2))/0.12	24,917	23,450	21,267	12,817
Project cost				
- Project cost	26,094	25,124	24,067	22,400
Economic value (0.9)	23,484	22,611	21,660	20,160
B/C ratio	1.06	1.04	0.98	0.64

Remarks: The capital reduction rate is 12% and the durable years of facilities are assumed to be 60 years on an average.

B. 3. 4. Priority of Project Implementation

Based on the plan-2 stated above, the project area with top priority is selected from the projects in the overall river basin development plan, for the following feasibility study.

As the standard for selection, the followings are considered.

- National economy feasibility .. investment efficiency
- Technical feasibility ..... water source amount, dam construction and compensation difficulties
- Social feasibility ..... inhabitants' needs, industrial and drinking water urgencies.
- Private economy feasibility .... benefit per hectare

Name of sub-river basins	Evaluation value	General ranking
Lower Bang Pakong (LBP)	7.2	3
Khlong Tha Lat (KTL)	8.7	1
Upper Bang Pakong (UBP)	7.8	2
Maenum Nakhon Nayok (MNN)	5.0	8
Middle Phra Prong (MPP)	6.0	6
Maenum Hanuman (MHM)	6.4	5
Khlong Phra Satung (KPS)	5.9	7
Upper Phra Prong (UPP)	7.2	3

Eventually the areas irrigable with the water to be stored in Rabon Dam under construction and Si Yat Dam to be built on the tributaries of Tha Lat River, have been established in the sub-river basins of Khlong Tha Lat (KTL) and Lower Bang Pakong (LBP).

B. 3. 5. Project Implementation Schedule

In due consideration of well-balanced regional development as well as high efficiency of the project investment, staged development is considered to be recommendable. The scheme was proposed to be of three stages. The following table summarizes the staged development scheme proposed by the study.

	First Stage	Second Stage	Third Stage	Total
1. Irrigation Component				
1.1. Irrigation Area (ha)	37,900 (LBP) 8,500 (KTL)	30,300 (LBP) 29,700 (KPS) 16,600 (MPP)	136,900 (UBP) 43,300 (UPP) 28,100 (MHM) 76,400 (MNN)	
Sub-Total	46,400	76,600	284,700	406,800
1.2. Investment Cost (million baht)				
- Direct Cost	3,930	6,170	19,020	29,120
- Indirect Cost	600	850	3,780	5,230
Sub-Total	4,530	7,020	22,800	34,350
(baht/ha)	97,600	91,600	80,100	84,400
2. Water Supply/Industry Component				
2. 1. Investment Cost (million baht)				
- Raw Water Supply	2,280	210	670	3,160
Sub-Total	2,280	210	670	3,160
Total Investment	6,810	7,230	23,470	37,510

C. FEASIBILITY STUDY

C. 1. MAKING DEVELOPMENT PLAN

C. 1. 1. Definition of the Project

In the overall basin study for the agricultural water resources development project of Bang Pakong river basin, the river basin development plan was established, and the priorities to be developed were given to respective sub-basin projects. Consequently, as the project area with top priority, the Tha Lat river basin project area consisting of two sub-basins, that is, Lower Bang Pakong and Khlong Tha Lat, was selected. In these two sub-basins, the Feasibility Study area of 60,600 ha was finally fixed.

So as to supply the above-mentioned area stably with irrigation water as well as the staple cities along the river with drinking water, the industrial estates near the river with industrial water and the fish ponds and the shrimp culture with fresh water to control the salinity for the latter; such water resources development as Si Yat dam to be constructed, Rabom dam under construction by RID and Bang Pakong diversion dam to be built, new construction and rehabilitation of main irrigation and drainage canals and consolidation of facilities on farm level are major works of the Project.

C. 1. 2. Integrated Agriculture Development Plan

- Land Use Plan (ha)

Land Use	Present	Planned	Balance
Paddy Field	34,710	34,400	(-) 310
Dry Field	2,780	940	(-) 1,840
Orchard	4,060	7,160	3,100
Bush Land	2,000	450	(-) 1,550
Other Land	17,050	17,650	600
Total	60,600	60,600	0

Depending on the careful study, Paddy, Maize, Soybean, Groundnuts, Mungbean, Mango and Vegetables are recommended as adaptable crops in the Project area. Basically, double cropping pattern is adopted and the following five categories are proposed.

Field Character	Wet Season	Dry Season
- Paddy field:	1) Paddy	Paddy
	2) Paddy	Legume, Maize, Vegetables(cropping rate is about 50%)
- Upland field:	3) Maize	Legume
	4) Vegetables	Vegetables
- Orchard:	5) Mango	Mango

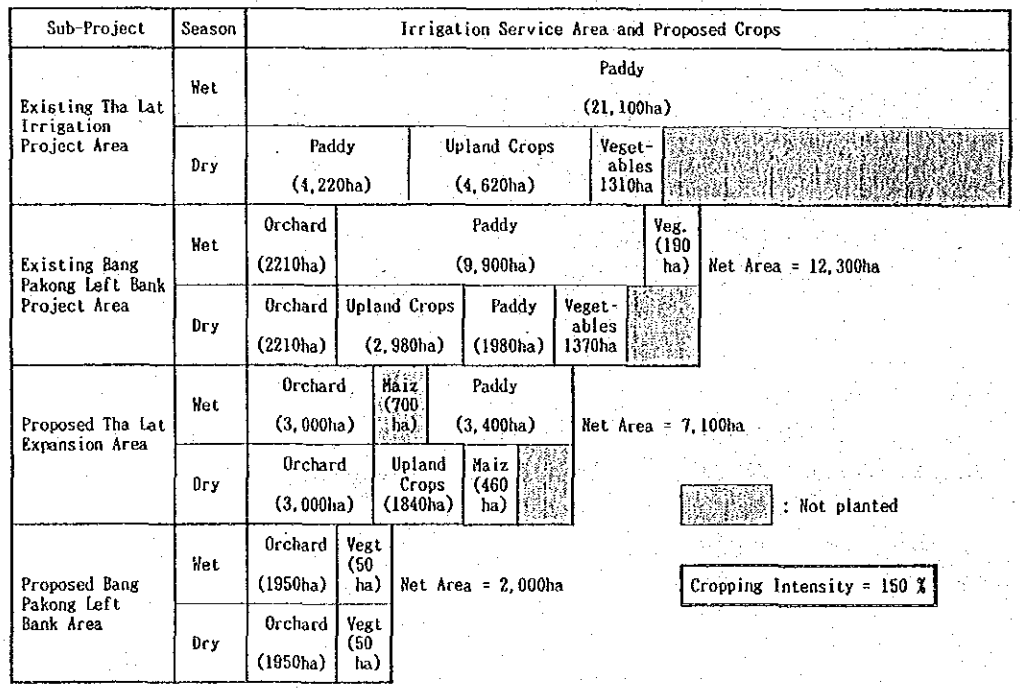
- Croppng Area (ha) and Production.

Crops	Wet Season (ha)	Dry Season (ha)	Total (ha)	Production (t)
Paddy	34,400	6,880	41,280	168,560
Maize	700	460	1,160	2,620
Soybean	-	3,350	3,350	5,023
Groundnuts	-	2,930	2,930	4,395
Mungbean	-	3,160	3,160	3,476
Vegetables	240	4,350	4,590	65,626
Mango	7,160	(7,160)	7,160	98,808
Total	42,500	21,130	63,630	348,508

The crop intensity will be 149%. (101.5% at present)

C. 1. 3. Water Resources Development Plan

- Illustration of Irrigation Plan



- Irrigation Water Demand (MCM)

Area	Season	Maximum	Minimum	Average
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

As the fisheries water, fresh water supplies for brackish water shrimp culture of 1,350 ha and fresh water fish ponds of 1,400 ha will be needed. The required water amount is estimated as follows.

- Fishery Water Demand (MCM)

Area	Season	Maximum	Minimum	Average
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

- Industrial and Domestic Water Demand

Water Demand		
Industry	Domestic	Total
(MCM/yr)	(MCM/yr)	(MCM/yr)
160.753	32.685	193.438

- Overall Water Demand (MCM)

Area	Season	Maximum	Minimum	Average
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

- Water Balance

The following two cases of water balance study were undertaken.

Case-1: Proposed final condition after completion of Rabom dam (40 MCM), Bang Pakong diversion dam (30 MCM) and Si Yat dam (300 MCM).

Case-2: Transitional condition after completion of Rabom dam and Bang Pakong diversion dam only, but before completion of Si Yat dam.

The results of water balance study in 20 years are as follows.

Case-1: Water supply for overall sectors including about 150 percent crop intensity can be provided within the allowable water shortage.

Case-2: Water supply for irrigation sectors after providing compensation of irrigation water and industrial/drinking water can be made as supplemental irrigation water in wet season as well as about 30 percent intensity in Bang Pakong area in dry season.

C. 2. Project Facilities

C. 2. 1. Khlong Si Yat Dam

The Khlong Si Yat dam is composed of a main dam, saddle dam, intake facilities and a floodway. The main dam is constructed on the Si Yat river about 40 km upstream of the conjunction of the Rabom river. An earthfill dam of homogeneous type with impermeable blanket is adopted for Khlong Si Yat dam. The dam construction cost is estimated as 1,060 million baht and the construction period will be for four years.

Major dimension of the Khlong Si Yat dam are summarized as follows:

Reservoir

Drainage area	976 sq.km
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)

C. 2. 2. Bang Pakong Diverdion Dam

The design sectional area of the proposed diversion damsite is recommended as 1,500 sq.m which is the average section of 10 km between 5 km upstream and 5 km downstream of the site.

- Water Level at the Site
  - Case-1: Upstream level = 1.30 + 0.50 = 1.80 m
    Downstream level = - 1.50 m
  - Case-2: Upstream level = - 1.50 m
    Downstream level = 1.30 + 0.50 = 1.80 m
- Bottom Elevation and Water Depth at the Site
  - Bottom elevation : - 9.0 m
  - Water depth : Max. 1.3 - (-) 9.0 = 10.3 m
    Min. (-) 1.5 - (-) 9.0 = 7.5 m

Gate Type

The double shell type roller gate with normal system is recommendable for the regulating gate. The single shell type roller gate is recommendable for the main gate.

No fishway and no navigation lock will be set up judging from environmental, social and economic studies. The dimensions of diversion dam, therefore, are as follows:

Regulating gate: 30 m span × 2 units, height 3.70 m/7.50 m

Main gate : 30 m span × 3 units, height 10.60 m

Diversion Channel

The bottom width of the channel is decided to meet the flow width of the diversion dam and the side slope is assumed as 1 : 5, considering the stability of side slope. As a result, the water flow area will be estimated at 2,240 sq.m.

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 (+) 3.0 m in elevation which is estimated as the flood level in 1983 of (+) 2.03 m plus 0.5 m of wave height and 0.5 m of free board.

C. 2. 3. Irrigation and Drainage Facilities

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

- Tha Lat Irrigation System

The Tha Lat Irrigation System was constructed in 1953. The intake of the main canal for the Project is located on the left bank 60 m upstream of the Tha Lat weir. And the main canal runs southwest in parallel with the Bang Pakong river. There regulating gates are installed 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 EL. 5.50 m. The canal slope is so flat as 1/50,000 from the intake to the regulating gates and 1/14,000 from the regulating gates to the terminal.

Total length of the main canal is 44 km. Initially it was designed as concrete canal, it, however, was replaced by the earth canal during construction for lack of the budget 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/sec. 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.

More than 10 laterals have been constructed by farmers except 6 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 somewhat lower than the ground elevation of the service area.

- 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 fresh water when the water level of the river is higher than that of the service area and to save the water to be released during low water level of the river. Those gates also function to prevent the saline water intrusion 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 networks. 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 fields due to the insufficient water level. Accordingly, those creeks are used for dual purposes of 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. There re-gulating 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 damsite 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 yards. Drainage canals for those polluted water shall therefore be separated from irrigation canals.

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, operation and maintenance costs.

- Si Yat Irrigation System

The Si Yat Irrigation System is newly developed with service areas of about 5,400 ha on the right bank and about 1,700 ha on the left bank of the Si yat river which is a tributary of the That Lat river. 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. This method, however, is not recommendable because a high diversion weir is required to take water from the Si Yat river. Accordingly the water is conveyed crossing the That Lat river at Wat Bang Phaniyang by a siphon extending the right bank main canal.

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

C. 3. Project Implementation Programme

C. 3. 1. Implementation Programme

The implementation programme should be prepared by taking into account phased water demand tendency as well as urgency of water supply policy, effectiveness of investment and quick development of the project. The project implementation programme are divided into two phases.

(1) Beneficiaries

Phase-1	Irrigation	:	Existing Bang Pakong area	(12,700 ha)
			Bang Pakong Expansion area	(2,000 ha)
	Industry	:	Bang Pakong Industrial Estate	(1,600 ha)
Phase-2	Irrigation	:	Existing Tha Lat area	(22,100 ha)
			Tha Lat Expansion area	(7,100 ha)
	Industry	:	Plaeng Yao Industrial Estate	(1,600 ha)

(2) Major Facilities

Phase-1 Common facilities : Bang Pakong diversion dam

Irrigation facilities: Rehabilitation/construction of main and lateral canals as well as related structures. Construction of pump station.

Industrial facilities: Construction of a pump station, pipelines and a regulating reservoir.

Phase-2 Common facilities: Khlong Si Yat dam

Irrigation facilities: Rehabilitation/construction of main and lateral canals as well as related structures. Dredging of drainage canals.

Industrial facilities: Construction of a pump station, pipelines and a regulating reservoir.

C. 3. 2. Optimum Construction Schedule

In consideration of construction works volume, budgetary measures, mobilization tendency of engineers, etc. the phase-1 and phase-2 projects will take 6.0 years and 6.5 years respectively from the detailed design stage until the completion of the works.

C. 4. Summary of Project Cost

(Unit: Million Baht)

Work Description	Phase I Project	Phase II Project	Total
A. Direct Project Cost			
1. Preparatory Work	20	26	46
2. Construction Cost	2,160	1,943	4,103
3. Land Acquisition / Resettlement	375	680	1,055
4. O & M Equipment	11	11	22
5. Survey and Investigation	24	15	39
6. Administration Cost	106	130	236
7. Engineering Service	216	194	410
8. Physical Contingency	291	299	590
Total (1 - 8)	3,203	3,298	6,501
9. Price Escalation	474	803	1,277
Total (1 - 9)	3,677	4,101	7,778
B. Indirect Project Cost			
1. Construction Cost	220	452	672
2. Engineering Cost	26	54	80
3. Physical Contingency	25	50	75
Total (1 - 3)	271	556	827
4. Price Escalation	51	147	198
Total (1 - 4)	322	703	1,025
Grand Total (A + B)	3,999	4,804	8,803
Foreign Currency	(2,215)	(1,980)	(4,195)
Local Currency	(1,784)	(2,824)	(4,608)

C. 5. Project Justification

The project justification is made through the study of project feasibility from economic, financial and socio-economic aspects.

The economic feasibility is studied by calculating the economic internal rate of return (EIRR). Sensitivity analysis is made in order to elucidate the economic viability of the project against the change in prices, delay in implementation, cost overrun and yield.

Financial analysis is made by typical farm budget analysis and cost recovery including joint cost allocation.

The social effects and economic impacts from the implementation of the Project are treated in intangible benefit study and environmental impact evaluation.

C. 5. 1. Benefit

1) Tangible Benefit

Economic incremental benefit for all sector at the full target year are summarized as follows:

- Irrigation	930 MB
- *Industry/Drinking*	217 MB
Total	1,147 MB

2) Intangible Benefit

In addition to the tangible benefit for agriculture and fishery, various intangible benefits and socio-economic impacts are expected from implementation of the project comprised by agricultural sector, industrial water supply sector and drinking water supply sector. The major intangible benefits are shown as follows:

1) Creation of new job opportunities
2) Improvement of local transportation
3) Improvement of sanitary condition
4) Improvement of water front environment

C. 5. 2. Cost

1) Capital Cost

The project cost consists of the direct project cost and the indirect project cost. All these costs are estimated on a financial basis.

In order to estimate the economic cost for agricultural sector, financial cost for Si Yat storage dam and Bang Pakong diversion dam are previously allocated by 63% of agricultural water sector and 37% of industrial and drinking water sectors.

- Irrigation	4,817 MB
- Industry/Drinking	1,168 MB
Total	5,985 MB

2) Annual Operation and Maintenance Cost

The financial cost does not include the depreciation cost of O & M equipment. This financial cost is converted into economic cost using conversion factor of 0.9.

(million baht)

Phase	Financial	Economic
Phase-1	17.0	15.3
Phase-2	21.8	19.7
Overall	38.8	35.0

3) Replacement Cost

Pumps proposed in Phase-1 project and Resettlement plan of Phase-2 are replaced by interval of 20 years.

(million baht)

Phase	Financial	Economic
Phase-1	170	153
Phase-2	0.08	0.07

C. 5. 3. Economic Internal Rate of Return

The economic internal rate of return for the agricultural sector is calculated on the basis of the flows of economic benefits and costs mentioned above. EIRR by phase is calculated as follows:

	Agricultural Sector	All Sector
Phase-1	14.0%	12.2%
Phase-2	9.7%	
Overall	11.7%	
Phase-1 (Tentative)	13.6%	

Sensitivity analysis is the effective measures of testing for the riskiness of the project. Analysis are made for the following cases:

Case-1: 10% increase in project cost due to unforeseen geological and topographical conditions and unexpected increase of material costs.

Case-2: 10% decrease in project benefit due to unexpected decrease in prices of commodities and in crop yield.

Case-3: Two years overrun of full-development period of project benefit.

Case-4: Two years overrun of construction period.

The EIRR of four cases are estimated as follows:

	EIRR (%)		
Case	Overall	Phase-1	Phase-2
Original	11.7	14.0	9.7
Case-1	10.8	13.0	9.0
Case-2	10.7	12.9	8.9
Case-3	11.1	13.3	9.4
Case-4	10.8	12.7	9.2

C. 5. 4. Project Justification

Economic internal rate of return (EIRR) for all sectors was estimated at 12.2 percent.

It was reported that the latest prime rate of loan interest is 15 percent at the minimum and the deposit loan rate is 12.5 to 13 percent. When the marginal productivity of capital is considered to be approximately the deposit loan rate, the economy of all sector projects is rightly justifiable. The cost benefit ratio for the agricultural sector will be considered nearly justifiable from the national economic point of view.

C. 6. Environmental Impact Evaluation

The detailed Environmental Impact Statement (EIS) is required if the main features of the proposed project exceed the following guideline:

- Effective storage : 100 MCM
- Reservoir area : 15 sq.km
- Irrigation area : 80,000 rai (12,800 ha)

The proposed Tha Lat river basin development project has been divided into two phases in view of the project implementation, and the both phases are larger than the above guideline in scale and therefore the detailed EIS will be required.

Main Feature of Tha Lat River Basin Development Project

	Phase-1	Phase-2	Overall Development
Effective Storage (MCM)	30	300	330
Reservoir Area (sq.km)	10	45.5	55.5
Irrigation Area (ha)	14,700	30,240	43,540

The environmental study comprises manifold items of environmental impact evaluations. They are primarily classified into the following four categories:

(1) Physical resources
(2) Ecological resources
(3) Human use values
(4) Quality of life values

Preliminary studies were only carried out at the current stage of the study for the purpose of pointing out the present environmental problems and constraints and the anticipated alternation in environmental resources, either positive or negative, probably be caused by the project implementation.

C. 7. Conclusion and Recommendation

C. 7. 1. Conclusion

As a result of the overall basin study for the agricultural water resources development project of Bang Pakong river basin, the Tha Lat river

basin project was selected as the one with top priority from several sub-basin development projects.

Continuously the feasibility study on the project has been made carefully. The project has multi-purposes for water resources development, that is, for irrigation, industry, drinking, and fisheries, and two sub-phased implementation schedules.

As stated above, it has been found that the project is accorded high priority and great urgency to be developed with water supply for attaining quick benefits to the project area and accelerating regional development.

It is, therefore, concluded that after its prudent findings, the Project is technically feasible and economically viable.

C. 7. 2. Recommendation

1) In the time of the implementation of the Tha Lat river basin development project with storage dam and diversion dam constructions, not only the technical and economic examinations, but also social or environmental considerations must inevitably be needed according to the result of the environmental impact study to be carried out by the third party.

2) The facilities plan and their cost estimate made in this feasibility study must be reexamined at the detailed design stage to enhance their precision.

3) The organization of the project implementation and their operation and maintenance must be strongly functioned, because of multipurpose water resources development schemes and multi-phased implementation programs.

4) Especially, the control of the water to be released from the dams and the diversion dam after construction will be quite important. It must be unifiedly controlled by the technical officials of the government.

5) The water management board on a provincial level should be organized to coordinate the water distribution plan based on the water demand request from respective sectors for effective utilization of water resources.

6) The project implementation schedule must be phased in conformity to water demand tendency, urgency of water supply policy, effectiveness of investment, etc.

7) The resettlement areas for Khlong Si Yat dam and Bang Pakong diversion dam must be finally determined after the more detailed investigation and study.

8) Based on the understanding of the basic concept in which irrigation and drainage must be separated each other, the irrigation and drainage plans must be implemented. Besides, RID should educate and cooperate farmers to be benefited to implement construction works and proper operation/maintenance of the terminal irrigation and drainage facilities in order to execute quick yielding of the proposed crop productions.

9) So as to bring the cultivation technic of diversification crops and transportation system on a higher level, administratively and financially assisting countermeasures for such agricultural supporting services as agricultural extension, farmers' organization, credit, circulating system, etc. will be required.

10) The diversion dam works to be implemented near the existing communities require the treatment of plenty of dredged soil. Acquisition of the land to fill up the soil and how to use the filled land must be seriously examined.

11) Since the construction of conducting facilities for industrial and domestic water supplies is concurred with the construction of the diversion dam and irrigation facilities, scrupulous coordination will be necessary for implementing the project harmoniously and economically.

12) The topographic survey and geological investigation must be carried out for further detailed design, land acquisition and construction works.

- Topographic surveys for storage and diversion damsites and main irrigation/drainage facilities.
- Geological investigations for storage and diversion dams and major facilities related.

13) Since the arrears of the planned construction schedule influence upon the economy of the investment, the construction works on time will be inevitably needed.

CHAPTER 1. INTRODUCTION

CHAPTER 1. INTRODUCTION

1-1. Authorization

In response to the request of the government of the Kingdom of Thailand, the government of Japan had entrusted the implementation of the Feasibility Study on the Agricultural Water Development Project of Bang Pakong River Basin (hereinafter referred to as "the Study") to the Japan International Cooperation Agency (hereinafter referred to as "JICA").

Accordingly, the Preliminary Survey Team headed by Mr. Futao YASUE was dispatched in March 1989 by JICA and Scope of Works for the Study was set forth.

Based on the Scope of Works agreed upon between JICA and the Royal Irrigation Department of the Ministry of Agriculture and Cooperatives (hereinafter referred to as "RID"), the Feasibility Study Team (hereinafter referred to as "the Team") headed by Dr. Junichi KITAMURA and the Advisory Committee headed by Mr. Toshio MORIYASU were dispatched and submitted the Inception Report to RID in September, 1989.

In the report, the Overall Basin Study was included as Phase I Study and the Feasibility Study on the project with the top priority, as Phase II Study.

Although the Inception Report was accepted in principle by Thai Officials concerned headed by Dr. Boonyok VADHANAPUTHI, Senior Expert for Water Resources Planning and Development, RID; a request for the urgent implementation of the Feasibility Study on Khlong Si Yat Dam Project as the one with the top priority was made, because the project implementation for multipurpose water utilization in the basin must be expedited to meet the increasing demand of water particularly for irrigation and industrial purposes.

The request to modify the Feasibility Study Schedule of the Project was examined prudently according to the submitted Supplementary Note, by JICA.

Eventually the request being accepted, the Feasibility Study was commenced as the Tha Lat River Development Project including Khlong Si Yat Dam in November, 1989.

Then, the Progress Report (I) was made and submitted to the Thai Government, and the main findings obtained from the first Field Survey were officially explained at RID in Bangkok in December, 1989. As a result of the

discussion following the explanation of the report, the Thai side accepted in principle the contents of the Report.

The Home Office Work was started to make the Interim Report based on the first Field Survey and according to the major comments brought up after the said discussion, in January, 1990. And the Report was completed, submitted to JICA at the end of March, sent to RID in April, and explained at the beginning of the second Field Survey in May, 1990.

As a result of the discussion, the Thai side accepted in principle the contents of the Interim Report.

Then the second Field Survey was carried out so as to summarize the results in which the major items brought up after the discussion on the overall basin study at the Interim Report explanation meeting had been studied and the remarkable topics in the feasibility study. The survey was finalized and the Progress Report (II) was made and explained at the end of June, 1990. The Thai side accepted in principle the contents of the Progress Report (II) after the discussion.

The Home Office Work was resumed to make a draft of the Final Report based on the second Field Survey and the major comments brought up after the discussion.

Eventually the draft of the final report was completed, submitted to JICA, sent to RID in August, and was explained in September, 1990.

1-2. The Study Area

The overall basin study area covers the entire Bang Pakong River Basin of about 17,660 sq.km, and its western border is located 60 km east of the capital, Bangkok. In the overall basin study, the river basin development plan was established, and the priorities to be developed were given to respective sub-basin projects.

As the project area with top priority, the two sub-basis, that is, Lower Bang Pakong and Khlong Tha Lat, were selected.

In the two sub-basins, the Feasibility Study area of 60,600 ha was chosen, in which 34,800 ha of existing and 9,100 ha of proposed irrigation areas were included. This study area is located in the western part of the whole Bang Pakong river basin and near the main river and its tributaries, favorable to receive the water to be released from Rabom dam under construction, Si Yat dam, and Bang Pakong diversion dam to be constructed.

1-3. Objectives of the Study

The study objectives are to formulate comprehensive water resources development programs in the Bang Pakong River Basin, to put forward balanced areal development, to put priorities on the projects to be implemented in order, and to conduct a feasibility study for the project area with top priority; in which dam reservoirs are constructed upstream of the river and its tributaries, a diversion dam is built on the river just upstream of Chachoengsao City, existing irrigation facilities for the irrigation projects are radically modified and new irrigation facilities are also partly built; so as to stabilize water supply for paddy and dry croppings as well as drinkings, industries and fisheries through the year and especially in a dry season to prevent saline water from intruding into the area.

1-4. Reports

The reports were compiled based on the following manners.

- Executive Summary (One volume)
- Main Report (One volume)
- Appendixes to the Main Report (Two volume)
- Drawings (One volume)

1-5. Organization for the Study

The JICA organized the Advisory Committee consisting of four members from the Government of Japan in order to give the advice to the Team. The members are shown in the following list.

1)	Mr. Toshio MORIYASU	Chairman/Generalization Ministry of Agriculture, Forestry and Fisheries, JAPAN
2)	Mr. Shiro HIRABAYASHI	Irrigation and Drainage Ministry of Agriculture, Forestry and Fisheries, JAPAN
	(Succeeded by) Mr. Hideo SEKIOKA	(Ditto)

3)	Mr. Kotaro FUJISADA	Agronomy Ministry of Agriculture, Forestry and Fisheries, JAPAN
	(Succeeded by) Mr. Kiyoshi SAWADA	(Ditto)
4)	Mr. Toru ARAI	Economic Evaluation Overseas Economic Cooperation Fund (OECF), JAPAN

The JICA organized the Team with the experts as listed in the following Table, with respect to the implementation of the Study.

Expertise	Name
Team Leader/Coordination	Junichi KITAMURA
Hydrology	Masamichi WATANABE
Geology	Hisao ANDSO
Co-Team Leader/Water Use Planning	Satoshi KADOWAKI
Irrigation/Drainage	Yoshiaki KIMURA
Facility Design	Hiroshige TOMIYAMA (Hiroshi MORIYAMA)
Facility Design/Cost Estimation	Yasuo TERAMURA
Agronomy	Chingchai Jongpukdee
Agro-Economy/Project Evaluation	Shouji YAMADA
Environment	Chagard Chumroenprouk

The RID decided the counterparts as shown in the following list, corresponding to the Team.

	Name	Section
1)	Leader	
	Dr. Boonyok Vadhanaphuti	Senior Expert for Water Resources planning and Development
2)	Assistant Leader	
	Mr. Maitri Poolsup	Director, PPD
	Mr. Sawatchai Charoento	Director, Region IX Office
3)	Secretary	
	Mr. Suthi Songvoravit	Project Planning Division (PPD)
4)	Assistant Secretary	
	Mr. Thanar Suwattana	PPD, Section-1
	Mr. Charoon Rookheb	PPD, Section-1
5)	Member	
	Mr. Narong Sopak	Topographical Survey Division
	Mr. Danai Triyadhen	Geo-Technical Division
	Dr. Thanu Harnpattanapanich	Geo-Technical Division
	Mr. Mondhian Kangsasitiam	Research and Laboratory Div.
	Mr. Vorapote Nadhanapote	Hydrology Division
	Mr. Osot Charnvej	Operation & Maintenance Div.
	Mr. Prapat Aukayanakul	Design Division
	Mrs. La-ong Rojanasoonthon	Data Processing Division
	Mr. Manus Kumnoetmanee	Program Coordination/Budget Div.
	Mr. Surasak Srikhirin	Medium Scale Project Const. Div.
	Mr. Pairoj Na Nongkhai	Laws and Lands Division
	Mr. Anan Phoonthawee	PPD, Section-1
	Mr. Thanar Suwattana	PPD, Section-1
	Mrs. Phattaporn Mekpruksawong	PPD, Section-1
	Mr. Charoon Rookheb	PPD, Section-1
	Mr. Siripong Sholsiripunlert	PPD, Section-2
	Mr. Prasert Lakshanasomya	PPD, Section-3
	Mr. Preechanun Srikeaw	PPD, Section-3
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	Mr. Bancha Sathasathuchana	Regional Irrigation Office IX
	Mr. Permsak Kidmai	Regional Irrigation Office IX

CHAPTER 2. BACKGROUND

CHAPTER 2. BACKGROUND

2-1. General

Thai government has been set up the basic policy, of which agricultural development scheme should be promoted the crop diversification and agro-industrialization through qualitative improvement of crop production from quantitative expansion, on the national economic and social development plan in the Six Five Year Plan.

At present, the Bang Pakong river basin is located at the eastern part of central plain and being planted paddy rice and traditional crop in almost of the beneficial area. The government policy on agricultural crop production trends to change gradually from placing concentration upon paddy rice to raising self-sufficiency ratio of product for domestic consumption as well as promotion of staple product for export.

Cassava production of Thailand takes place the first rank in the world. Since the expansion of export of tapioka and its' pellet has become unstable, strong promotion of more profitable upland crops should be made as convertible crop from cassava in the area where irrigation water can be supplied through out a year.

Industrial development in the Eastern Seaboard Area and Bangkok Metropolitan area are in rapid progress founded by both governmental investment for consolidation of infrastructural facility and private sectors for construction of factories and related facilities.

The study area is moderately favored with an annual rainfall, widely ranging from the highest of 2,400 mm at northern mountainous area to the lowest of around 1,000 mm in the lower reach of the Bang Pakong river. Seasonal variation of rainfall is also remarkable. In spite of such circumstances, frequent shortage of supplemental irrigation water even during rainy season as well as drinking and industrial water supply sectors is serious problem in the basin.

In this connection, establishment of overall river basin water resources development schemes including agricultural development plan with more comprehensive examination is inevitably required.

2-2. National Economy

National Land

The national land area amounts to about 51.3 million hectare, of which 46% is utilized as farm land, 28% as forest land and 26% as others. Especially the utilization of farm land in 1988 is represented by paddy land of 50.20%, field crops land of 24.17% and fruit tree & tree crops land of 13.22%.

Population

Annual growth rate of population has been decreasing in recent years as shown in the following table:

Trend of Population

unit : 1,000 persons, %

Year	Population	Growth rate
1979	45,460	
1980	46,718	2.76
1981	47,735	2.18
1982	48,741	2.11
1983	49,734	2.04
1984	50,714	1.97
1985	51,683	1.91
1986	52,654	1.88
1987	53,605	1.81
1988	54,536	1.74

Source : Agricultural Statistics of Thailand, 1988/89, MOAC, Originally by NESDB.

Economic Growth

The national economy has been achieving a satisfactory development in recent years. The kingdom of Thailand conquered a state of depression which had occurred due to falling of international prices of agricultural products from 1985 to 1986. This steady development is owing to the high economic growth in the non-agriculture sector as shown in the following table.

Values of Gross Domestic Products at Prices in 1972

Unit : million bahts, %

Year	Agriculture		Non-Agriculture		Total	
	GDP	Growth rate	GDP	Growth rate	GDP	Growth rate
1979	60,726		225,071		285,797	
1980	61,770	1.7	237,702	5.6	299,472	4.8
1981	65,093	5.4	253,346	6.6	318,439	6.3
1982	67,082	3.1	264,298	4.3	331,380	4.1
1983	70,061	4.4	285,347	8.0	355,408	7.3
1984	73,977	5.6	380,738	33.4	454,715	27.9
1985	78,539	6.2	394,113	3.5	472,652	3.9
1986	78,725	0.2	411,814	4.5	490,539	3.8
1987	77,163	- 0.2	446,361	3.9	523,524	6.7
1988	83,772	8.6	495,374	11.0	579,146	10.6

Source : Agricultural Statistics of Thailand, 1988 / 89, MOAC. Originally from NESDB.

Price Level

The price level in Thainland has been steady in recent years. The trend of consumer price indexes has been kept on a steady level until 1988 as follows.

However, the general price level continues to rise rather steeply, caused by expansion of aggregate demand and higher production costs of goods accompanied with a raise in salary and the upward adjustment of minimum wages.

Consumer Price Index

at 1976 = 100

Year	CPI	Growth rate
1983	187.9	%
1984	189.5	0.9
1985	194.1	2.4
1986	197.7	1.9
1987	202.6	2.5
1988	210.4	3.8
1989		5.4
1990	(1st four months)	6.3

Note : Growth rate in 1989 and 1st four months 1990 are based on the news paper "Bangkok Post".

TABLE 2-1. EXPORTS, IMPORTS AND BALANCE OF TRADE

Unit : million bahts, %

Year	Exports	Growth Rate	Agricultural Export	Non-Agricultural Export	Import	Growth Rate	Balance
1983	146,472		95,627 (65.2)	50,845 (34.8)	236,609		-90,137
1984	175,237	19.3	113,397 (64.7)	61,840 (35.3)	245,155	3.6	-69,918
1985	193,365	10.3	115,974 (60.0)	77,391 (40.0)	251,169	2.5	-57,803
1986	233,383	20.7	134,416 (57.6)	98,967 (42.4)	241,358	-4.0	-7,975
1987	299,853	28.5	153,991 (51.4)	145,862 (48.6)	334,340	38.5	-34,487
1988	403,570	34.6	194,195 (48.1)	209,375 (51.9)	513,114	53.5	-109,544

Source : Department of Customs

TABLE 2-2. TREND OF ORDER ON EXPORT VALUE OF GOODS

Unit : Billion Baht

Order	1978		1987 (Target)	
	Goods	Billion Baht	Goods	Billion Baht
1	Tapioka	10.9	Textile Pro.	23.2
2	Rice	10.4	Rice	20.0
3	Rubber	8.0	Tapioka	17.0
4	Tin	7.2	I.C	16.8
5	Textile Pro.	6.8	Rubber	15.0
6	Maize	4.3	Jule	14.5
7	Sugar	4.0	Cloth & Yarn	12.4
8	I.C	2.2	Fish Preserved	11.9

Source : Ministry of Commerce

Debt Service Ratio

The debt service ratio, estimated as the percentage of repayment amount of an external debt to export value, was reduced from 21.9% in 1985 to 17.0% in 1987.

Falling tendency of the ratio would explain the satisfactory development of the national economy in recent years.

Foreign Trade

The negative balance of foreign trade had been reduced from 90 million bahts in 1983 to 34 million bahts in 1987. This satisfactory trading states had been caused by the high growth of exports in contrast with the low growth of imports. The expansion of the import value in 1988, however, resulted in a deterioration of balance.

The remarkable features on high growth of exports are represented by the quick expansion of traded value and the conversion of trading structure from the agricultural exports to non-agricultural exports. The share of agricultural export value had been falling from 65.2% in 1983 to 48.1% in 1988. This recession is due to the falling of international prices of agricultural products and the comparatively low international competitive capability.

The expansion of non-agricultural export value is represented by high growth of light industry production. The exported goods highly ranked in 1978 and 1987 indicate significant difference in order.

National Development Plan

It has passed 25 years from the beginning of the First Five Year Development Plan (1961 to 1966) to the end of the Fifth Plan (1981 to 1986).

During this period, the national economic development achieved the average growth rate of GDP of about 7%.

Per capita income also increased from 2,150 baht in 1981 to 20,420 baht in 1986.

Although the overall national economic and social development has been quite successful, such serious problems as the falling of growth rate of the national economy by only 4.6% during the Fifth Plan, fiscal and trade deficits, poverty, unemployment and accumulated national debt etc. were brought out.

In view of success and problems mentioned above, the Six Plan (1987-1991) was established. The Six Plan defines two major objectives, that is economic and social objectives.

The economic objective is to maintain an average rate of growth on a level not lower than 5% in order to absorb 3.9 million persons at a minimum to enter the labor market. The social objective is to make a progress of social development continuously that is, development of basic needs in the nationwide area and dissolution of the different quality of life in both rural and urban areas.

In order to attain the principal economic and social objectives, three development guidelines and ten main programmes are defined.

Three guidelines consist of enhancing the efficiency of national development, improving the production system and distributing income prosperity into provincial regions and rural areas.

Annual Growth Rate

Sector	Fourth Plan	Fifth Plan	Six Plan
(1) GDP	7.1%	4.6%	5.1%
(2) Agriculture	3.5	2.9	2.9
(3) Non-agriculture	8.5	5.5	5.7
(4) Manufacture	8.7	5.6	6.6
(5) Mining	10.1	6.5	6.4
(6) Electricity	11.7	8.0	6.1
(7) Construction	9.5	3.6	5.1
(8) Services	8.2	5.6	5.3

Note : Fourth and Fifth Plans show actual figures.
Six Plan shows target figures.

2-3. Thai Agriculture

Commercial Production

In the decade of 1950 about 90% of total cropped areas were occupied by rice. Afterwards, commercial crops production had been developed through an expansion of commodity economy. These commercial crops were represented by cassava sugarcane, maize and rubber. In the decade of 1980 new commercial crops such as mungbean, soybean and onion were extended.

Trend of Cropped Areas of Main Crops

Unit : 1,000 rai

Crop	1950 - '54	1974 - '76	1980 - '84	1985 - '89
Rice	38,047	53,028	60,357	62,178
Maize	279	8,029	9,860	11,668
Cassava	89	4,359	8,050	9,163
Sugarcane	337	2,394	3,353	3,603
Coconut	611	2,040	2,395	2,527
Kenaf	57	1,857	1,270	1,128
Rubber	2,302	8,890-	9,840	10,373
Mungbean	-	-	2,909	3,148
Soybean	-	-	810	1,869
Onion	-	-	-	12,627

Note : Areas of onion in 1982/83 to 1988/89 were averaged
Source : Data for 1950 to '54 and 1974 to 76 were quoted from Thailand Agriculture, AICAF, Japan, 1979, prepared based on Agricultural Statistics of Thailand.
Data for 1980 to '84 and 1985 to '89 were based on Agricultural Statistics of Thailand, 1988/89/MOAC.

The cropped areas of crops mentioned above have been extended through a reclamation of forest land and wild plain. Consequently the forest land has been reduced rapidly.

In recent years, rice, tapioca and maize are under production control influenced by world market condition.

Agricultural Sector in National Economy

The share of GDP in agricultural sector fell down from 24% in 1979 to 14.5% in 1988 as shown in the following table:

GDP in Agriculture Sector

Unit : Billion baht

Year	Total GDP	Agriculture	%
1979	558.9	134.1	24.0
1980	658.5	152.9	23.2
1981	760.2	163.0	21.4
1982	820.0	156.8	19.1
1983	910.1	185.6	20.4
1984	1,148.6	175.2	15.3
1985	1,184.3	169.9	14.3
1986	1,275.5	180.8	14.2
1987	1,432.3	198.3	13.8
1988	1,713.5	247.7	14.5

Source: 1. Agricultural Statistics of Thailand 1988/89, MOAC
2. NESDB

Although the status of agricultural sector in the natural economy has fallen since 1984, livestock and simple agricultural processing sub-sectors play an important role in the sector.

Share of GDV in Agricultural Sector

Unit : %

Year	Crops	Livestock	Fisheries	Forestry	Agri. Services	Agri. Processing	Total
1979	63.8	12.1	5.5	4.9	3.6	10.1	100.0
1984	65.9	12.1	5.4	3.0	3.1	10.5	100.0
1985	65.7	11.9	5.2	2.7	3.1	11.4	100.0
1986	62.6	13.9	5.7	2.9	2.9	12.0	100.0
1987	60.9	15.0	5.6	2.8	2.9	12.8	100.0
1988	63.1	14.6	5.1	2.5	2.8	11.9	100.0

Agricultural Policy

During the Sixth Plan period, the government will execute the restructuring of the system of agricultural production in order to reduce the risks attendant on fluctuating and unstable productions and market conditions.

It is aimed to adjust an transform to the production system by diversifying agriculture and to introduce diversification of services. Consequently, more rural income and employment will be generated and foreign exchange earning will be brought.

A change of structure in an international trade influenced exports and production of such traditional crops in negative as rice, tapioca, sugarcane, tobacco, rubber and maize. These crops occupy 70% of agricultural export value and 50% of agricultural production. Annual growth rate of these six crops were 7.1% in the Third Plan, 4.7% in the Fourth Plan and 1.3% in the Fifth Plan. It is forecasted at only 0.5% during the Sixth Plan. Especially, during the Fifth Plan 7.7% of the export prices of the six crops fell down.

Hence, in order to make export prices raise the government executes the development policy of agricultural products.

Main items are diversification of crop production to meet demand of export, improvement of qualities of exported products, reduction of crop production cost, tax, credit etc.

Agricultural Structure

Land utilization by region is shown as follows. Farm holding land extended from about 11.2 million rai in 1975 to about 148 million rai in 1988, while forest land reduced about 131 million rai to about 90 million rai.

Land Utilization by Region

Unit : million rai, %

Region	Total	Forest	Farm holding	Unclassified
North-Eastern	105.5	14.8 (14.0)	60.8 (57.6)	29.9 (28.4)
Northern	106.0	50.3 (47.4)	34.0 (32.1)	21.7 (20.5)
Central Plain	64.9	15.7 (24.1)	34.0 (52.3)	15.3 (23.6)
Southern	44.2	9.1 (20.7)	19.0 (43.0)	16.1 (36.3)
Whole Kingdom	320.6	89.9 (28.0)	147.8 (46.1)	83.0 (25.9)

Source : Agricultural Statistics of Thailand, 1988/89 MOAC,

Utilization of farm holding land in 1988 is composed of the following land types.

Utilization of Farm Holding

Unit : million rai, %

Type of Land	Whole Kingdom	North East	Northern	Central Plain	Southern
1. Paddy Land	50.2	63.4	49.8	42.3	22.6
2. Under Field Crops	24.2	22.1	34.6	30.3	1.2
3. Under Fruit Trees and tree crops	13.2	3.2	4.7	12.5	62.4
4. Under Vegetable and Flowers	0.6	0.3	1.0	0.6	0.4
5. Livestock Farm Area	3.2	1.5	3.3	7.5	0.8
6. Idle Land	5.2	6.7	3.0	2.7	9.0
7. Housing Area	2.3	1.9	2.8	2.3	2.3
8. Other Land	1.2	0.9	0.9	1.8	1.4
Total	100.0	100.0	100.0	100.0	100.0

About 82% of farm holding land or 147.8 million rai are occupied by land owner. However, ratio of land owned by region is different, that is, 90% in North-Eastern , 70% in Northern and Central Plain and 91% in southern.

Average farm size is estimated at 28.2 rai in the Whole Kingdom and those in North -Eastern, Northern, Central Plain and Southern are 28.2, 24.8, 34.0 and 26.5 rai respectively.

Number of farm household increased from 4,120 thousand in 1975 to 5,245 thousand in 1988.

Farm Economy

Farm cash income and farm cash expense per farm indicates the following main points.

- Net farm cash income is in shortage to cover a household net cash expense.
- Consequently farmer has to earn non-farm cash income of about 1.5 times of net farm cash income.
- Cash farm income per farm ranges from 36,063 baht in Central Plain to 11,020 baht in North-Eastern.
- Net household cash expense per farm ranges from 30,628 baht in Central Plain to 14,129 baht in North -Eastern in the same order as those of cash farm income.
- Cash farm income per farm in whole Kingdom consists of incomes from crop of 78.2%, livestock and poultry of 20.4% and other of 1.4%. Main income sources are food crops of 65%, fruit trees & tree crops of 17% and vegetable crops of 6%.

2-4. Rural Development Policies

The rural development was accorded an extremely high priority in the Fifth Plan and given even high priority in the Sixth Plan.

The policy on the rural development has to contribute to the overall national development by expansion of economy, development of society, improvement of the life quality of the people and distribution of wealth and prosperity to the rural areas.

During the Sixth Plan period, the following objectives and strategies are established and executed.

1) Objectives

The objectives of rural development policies are to improve the life quality for rural people, to promote self-reliance and to increase adaptability to economic and environmental conditions.

2) Strategies

In order to achieve the objectives mentioned above, the rural development policies will be carried out in line with the following four strategies.

i) The policy for approaching the target will be executed to solve the socio-economic and securing problems of each area according to the actual conditions and the people's needs.

ii) The government will concentrate its efforts and financial resources on developing the backward and the intermediate areas. Improvement of the living standard in progressive area will be encouraged by the private sector.

iii) The coordination of the efforts of government agencies, and of the public and private sectors will be emphasized.

iv) The role of people's organizations and the general public people in deciding how to solve their own problems and problems of their communities will be encouraged by the government. Thus self-reliance will increase.

OVERALL BASIN STUDY

CHAPTER 3. THE BANG PAKONG RIVER BASIN

CHAPTER 3. THE BANG PAKONG RIVER BASIN

3-1. Natural Features

3-1-1. Location

Being situated in the east-central part of Thailand, the Bang Pakong River Basin has a catchment of 17,660 sq. km which covers about 3.4 percent of the total national land area. The western boundary of the basin is located at a distance about 60 km to the east of Bangkok, whilst the basin extends about 200 km to the east to the national boundary with Cambodia. The two primary tributaries of the Bang Pakong river are the Nakhon Nayok and Prachin rivers which join near the western boundary of the basin. The Prachin river originates near Kabinburi where the Hanuman and Phra Prong rivers join. Approximately 57 percent of the Bang Pakong basin area drains into the Prachin river, 11 percent into the Nakhon Nayok river and the remainder of the basin drains into the Bang Pakong river downstream of the two major tributaries. The basin occupies major portions of the Changwats Chonburi, Chachoengsao, Prachinburi and Nakhong Nayok.

3-1-2. Physiography, Geology and Seismicity

1) Physiography

Four major physiographic features are distributed in the basin. They are the northern mountain range on the south flank of the Khorat Plateau, the deeply dissected hills and low mountains in the south, the flood and terracial terrain among tributaries, and the extensive alluvial plain in the west.

2) Geology

The northern mountains along the northern basin divide which attains more than 900 meters in elevation is mainly underlain by sequence of thick sandstones with interbedded siltstone of Khorat Group ranging in the age from Jurrasic to Tertiary. This mountain is characterized by the prevalence of flat ridge trending northwest to southeast. The mountain is remnants of sandstone lying along the crest of the ridge due to different durabilities of solid sandstone and friable siltstone.

The southern hills and low mountains with generally small streams follow the general structural trend of north-northwest to south-southeast direction of the remaining upland remnants. This area is mainly underlain by

sandstone and limestone of the Ratburi Group, sandstone and schist of the Thung Song and Tanaosi Group, and several igneous rocks. The former three groups range in the age from the Pre-Cambrian to Permian, and igneous rocks range from the Carboniferous to Triassic. The sedimentary rocks were subjected to weather and disintegrate at the surface.

The flood and terracial terrain in the tributaries present a rather undulating surface and underlie a relatively shallow body of unconsolidated deposits which range in the age from the Pleistocene to Recent. The flood plain along the Prachin river, one of major tributaries of the Bang Pakong river, is distributed between the northern mountains and southern hills and low mountains with more than 5 km width trending west-northwest to east-southeast and attained a maximum of 61 meters at the divide of Cambodia. A tectonic boundary, which divides two distinctive physiographic units supposedly underlies in this flood plain, because extraordinarily different characteristic of topographic and lithologic features are presented among the respective units.

The extensive alluvial plain of the Bang Pakong river basin forms a salient of the Chao Phraya Plain on the east. This flood plain is underlain by thick alluvial deposits of clay, sand, and sand and gravel where saline water is occasionally intruded into the deposits.

The stratigraphy of the project area is shown in Table C-1, Appendix C.

3) Seismicity

According to the Thailand statistics of seismic activities compiled by the Network Head Quarters Studies and Research Division of the Meteorological Department during 76 years from 1912 to the present, earthquake activities in Thailand occur mainly in the northern district and have not been observed in the southeastern district including the study area.

Seismicity map (cf. Appendix H.1.4) shows the distribution of earthquake epicenters of Thailand. The majority of earthquakes occur in neighbouring countries, and the epicenters are mostly distributed in the following places:

- Myanmar from the south to the north
- Along the border between Laos and Thailand
- Andaman Sea

Probability of earthquake activities in Thailand is indicated in a seismic probability map (cf. Appendix H.1.5), each zone showing the approximate destructive intensity of earthquake. The Project area is situated in the Zone 0 which means "No Damage". However, the dam shall be designed

in consideration of probable seismic occurrence for safety purpose against hazard of earthquakes judging from the importance of a dam.

In the Study, the horizontal seismic force is taken as kh = 0.05 for the design of fill dam.

3-1-3. Climate

Two distinct climatic areas occupy the Bang Pakong basin. The northern mountain range, primarily the southern extension of the Phechaburi Range, is one of the highest rainfall areas in Thailand, while the southwestern part of the basin, namely lower Bang Pakong area receives considerably less rainfall. There are two weather regimes that affect the basin and provide seasonal differences. The southern monsoon during May through October carries tropical air over the basin from the Gulf of Thailand and the Andaman Sea. The northwest monsoon, during November through March, generally brings dry air and high temperature. Short transition periods precede each monsoon, but basically the regime has two seasons; wet and dry. Both the seasonal dominance of monsoon and the geographical conditions of the basin conforms the climatic features of the area. Mean annual rainfall ranges between 900 and 2,400 mm in recent 20 years. It increases in proportion to the latitude from Chonburi to the northern area of the basin in Prachinburi and Nakhon Nayok. Monthly temperature is between 26 to 30°C and its areal difference is not seen in the whole basin.

3-2. Regional Socio-Economic Condition

3-2-1. Population and Social Setting

Four main provinces (Changwat) involved in the Bang Pakong basin are Chonburi, Chachoengsao, Prachinburi and Nakhon Nayok. Changwats Chonburi and Chachoengsao are included in the Eastern Seaboard Industrial Development Plan. Together with Nakhon Nayok, they are situated adjacent to the Bangkok Metropolitan Circle and are designated as one of the Second Project Areas to be promoted, according to the Criteria for Tax and Duty Privileges for Promoted Projects revised by BOI in 1988 which aims at dispersion of the investment concentrating into Bangkok Metropolitan Circle to local areas, and in turn the dissolution of earning differentials between the Metropolitan Circle and the local areas. Prachinburi, on the other hand, is located close by the border of Cambodia and is an important base of the national defense, and is a trading center for commodity exchanges.

The number of Amphoe (District) in the four provinces are 9, 9, 13 and 4 of which numbers related to the Study area are 6, 8, 10 and 4 respectively.

The rurality is predominant over the socio-economic environments in the area. As concerns social setting, the area may be classified into two zones. One is the area where the socio-economic environment is influenced to some extent by the progress of the Eastern Seaboard Development. This pattern is seen in Changwats Chonburi, Chachoengsao and a part of Prachinburi. The other is such the area that a rural life is being enjoyed and will still be enjoyable even in future. This pattern is dominant in Changwat Nakhon Nayok.

The trend of population during the recent decade would indicate an index for social setting. Annual growth rate of population has been increasing in the area, while that for the whole country decreases. Particularly high rates of population growth have been recorded in the Cities of Chonburi and Chachoengsao, both of which are appointed as the Regional Urban Growth Center in the Sixth National and Social Development Plan (1987-1991), showing 3.15 % and 2.50 % respectively. The highest rate of 3.80 % recorded in Prachinburi is inevitably caused by the rates of 10.7 % and 6.2 % respectively in Amphoes Aranyaprathet and Wang Nam Yen, both situated along the national boundary with Cambodia.

Population and Growth Rate

Year	Thailand	Chonburi	Chachoengsao	Prachinburi	Nakhon Nayok
1978	44,455,000	696,800	474,300	601,800	197,800
1983	49,734,000	769,600	503,200	709,000	205,800
1988	53,605,000	897,200	569,400	854,200	223,200
78 to 83	2.30%	2.00%	1.20%	3.35%	0.85%
83 to 88	1.85%	3.15%	2.50%	3.80%	1.75%
78 to 88	2.10%	2.55%	1.85%	3.55%	1.20%

Note : 1987 figures were used for 1988 Thailand.
Source: Population Statistics

According to "Population Projections for Thailand 1980-2015" issued by NESDB, the population in the whole country in 2000 is estimated to be 64,389,000 persons, and the increasing rate is calculated at 1.62 % on the basis of 1980 statistics.

On the other hand, in the eastern region of the Kingdom, the increasing rate is 1.66% higher than that for the whole country, and then the population will be 3,895,000 persons including the population to move into this area from the other areas.

Shown above may have a close correlation with a rapid growth of manufacturing industries newly registered in the region and employees. Although the number of factories has increased in recent years, the region still remains as a rural area when agricultural statistics are taken into consideration. The farm household ratio is given in the following table showing that the Changwat Chonburi is the most urbanized. This is, however, mainly owing to the low values of 23% in Muang Chonburi, 16% in Sattahip and 46 % in Siracha. If they are excluded, even Chonburi still remains with a high farm household ratio of about 72 %.

Farm Household Ratio by Changwat (1987)

Number of Household	Chonburi	Chachoengsao	Prachinburi	Nakhon Nayok	Total
Total Household (1)	106,239	76,689	109,309	32,732	324,969
Farm Household (2)	52,901	53,544	83,309	22,432	212,186
Ratio (2) / (1)	49.8%	69.8%	76.2%	68.5%	65.3%

Source: NSO Village Survey, 1987

3-2-2. Regional Economy and Industry

The economy in the Kingdom of Thailand has attained sudden growth upon the background of the development of an international trading in these several years. The substantial growing rate was high resulting in 11 % in 1988 and still 9 % in 1989, and the national income per capita rose above 1,000 dollars U.S. at present. In the Seventh Five Year Development Plan under establishment by NESDB, the growing rate of 7 to 8 % will be estimated.

The GPP (Gross Provincial Products) in 1987 in the four provinces are shown in Table 3-1; Chonburi has the highest amount of 60,368 Bahts per capita which is ranked as the third of the whole provinces (Samut Prakan as the first, and Bangkok Metropolis as the second), Chachoengsao has the amount of 23,021 Bahts, even higher than the average of the whole provinces. Nakhon Nayok has the amount of 12,997 Bahts and Prachinburi has that of 10,953 Bahts, both of which are lower than the average amount of the whole provinces. The Northeastern region of Thailand, however, has the amount much lower than the above two provinces. Chonburi and Chachoengsao owe such a high GPP to an industrial development as seen in the Eastern Seaboard Development Plan and other formulation plans of industrial complex, resulting in enlarging the earning differentials against the rural zone in the Study area.

The rate of agricultural product to gross domestic product in both Nakhon Nayok and Prachinburi is still high, whilst the lowest is recorded in Chonburi at 7.4%. This would indicate that Chonburi is the most advanced province in the region, Chachoengsao is a developing, and that Nakhon Nayok

TABLE 3-1 GROSS PROVINCIAL PRODUCTS IN 1987

Unit : 1,000 Baht

Province	Whole Kingdom	Bangkok Metropolis	Eastern Region	Chon Buri Province	Chachoengsao Province	Nakhon Nayok Province	Prachin Buri Province
Agriculture	198,283,996	8,513,540	17,738,444	3,531,830	3,445,686	727,174	2,868,402
– Crops	121,097,999	495,685	11,469,821	2,135,071	2,154,272	566,640	2,034,910
– Livestocks	22,595,005	733,908	1,658,974	513,357	451,393	66,707	356,764
– Fisheries	14,304,001	146,416	1,946,380	320,203	314,082	8,229	12,659
– Forestry	9,036,994	0	451,585	9,151	221,118	653	45,935
– Agricultural Services	7,198,996	37,188	872,509	241,041	146,108	36,682	206,991
– Processing Products	24,051,001	7,100,343	1,339,175	318,007	158,713	48,263	211,143
Mining and Quarrying	38,203,000	0	7,747,257	314,921	5,686,155	54	10,258
Manufacturing	295,511,939	174,738,541	23,343,701	18,607,550	894,253	46,267	669,524
Construction	62,995,003	24,511,625	2,850,765	1,246,399	282,095	130,730	455,107
Elect. and Water Supply	31,858,000	10,734,414	2,579,276	878,663	637,569	68,506	175,408
Trans. and Comm.	92,946,991	49,761,670	5,441,053	1,846,035	755,160	227,442	594,791
Trade	192,381,000	80,625,312	16,983,744	8,199,128	2,168,120	295,105	1,110,341
Banking	48,670,999	29,448,899	2,181,479	875,203	296,008	95,892	222,137
Ownership of Dwelling	48,802,000	12,854,449	3,171,106	783,140	503,368	192,755	703,833
Public Admin. and Defence	52,711,910	14,518,648	3,339,819	1,258,849	363,156	240,746	688,281
Services	171,665,202	83,636,403	15,120,638	10,145,365	1,065,656	614,082	966,766
Total : Gross Product	1,234,030,090	489,343,501	100,497,282	47,687,083	16,097,226	2,638,753	8,464,848
Per capita GP (Bahts)	23,021	81,940	31,094	60,368	31,501	12,999	10,951
Population (1,000 pers)	53,605	5,972	3,232	790	511	203	773

Source : NESDB

and Prachinburi are underdeveloped provinces. It is noted here that the values of agricultural product per active population are remarkably high in Chonburi and Chachoengsao, despite the fact that the rate of agricultural product to the gross product is low. (cf. Appendix G-1)

The growth rates of GDP founded on the value in 1981, were 8.8% in Chonburi, 14.6% in Chachoengsao, 5.8% in Nakhon Nayok and 7.6% in Prachinburi, generally on a high level. Especially, the sudden growth in Chachoengsao was remarkable, owing to the growth of a manufacturing sector. On the contrary, in the agricultural sector, it is characterized that the rates of growth on agricultural product during the same period were as low as 1.4%, 2.0%, 0.6% and 4.0%, respectively. (cf. Appendix G-2)

In the Study area, the agro-industry processing agricultural products as raw materials is thriving. Industrial sector in the region is divided into two groups in accordance with type of factory. The first group comprises traditional agro-industries such as rice mill, cassava pellets and tapioca flour factory, sugar factory, pineapple canning factory, etc. Six sugar industries in Chonburi share 11.2% of products in the whole Kingdom. The 87, 15 and 18 cassava pellet factories established respectively in Chonburi, Chachoengsao and Prachinburi occupy 37% of the national total products. The 78 tapioca flour factories (76 in Chonburi and one each in Chachoengsao and Prachinburi) also share 37% of products in the entire country. In Bang Pakong Port area, a large number of silos and godowns are established of for export. The facilities including port warehouses with storage capacities of about 700,000 ton in total (a share of 41% of whole country) are functionable as a distributing center of local cassava products.

Rice mills are scattered widely in paddy production areas, enumerating 33 units in Chachoengsao, 12 in Nakhon Nayok and 29 in Prachinburi, when mills of relatively large size with capacities exceeding 20 tons per day are extracted. According to the annual report of Provincial Commercial Offices, the number of factories in various fields are as below.

Number of Factory, Worker and Investment

Province	Factory (Unit)	Worker (Person)	Investment/Value per One Unit (Baht)
Prachinburi	838	5,647	869,187
Nakhon Nayok	85	498	995,932
Chachoengsao	416	13,736	12,421,460
(Note 1)	(213)	(1,312)	(4,646,917)
Chonburi	1,496	30,006	30,791,679
(Note 2)	(894)	(10,453)	(3,216,988)

Note 1: Amphoes Bang Pakong, Bang Khla and Muang Chachoengsao are excluded.
Note 2: Figure denotes agro-industry sector only.