KINGDOM OF THAILAND
MINISTRY OF AGRICULTURE AND COOPERATIVES
ROYAL IRRIGATION DEPARTMENT

MASTER PLAN STUDY
ON
THE WATER MANAGEMENT SYSTEM AND MONITORING PROGRAM
IN
THE CHAO PHRAYA RIVER BASIN

MAIN REPORT

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ANNEX-2 WATER MANAGEMENT PLANNING
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JUNE 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

THE KINGDOM OF THAILAND

ROYAL IRRIGATION DEPARTMENT

MASTER PLAN STUDY
ON
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FINAL REPORT

MAIN REPORT

JUNE, 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

P R E F A C E

In response to a request from the Government of the Kingdom of Thailand, the Japanese Government decided to conduct a Master Plan Study on the Water Management System and Monitoring Program in the Chao Phraya River Basin and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA sent to Thailand a Study Team headed by Mr. Shigekatsu Watanabe, Sanyu Consultants Inc., from January 1987 to March 1989.

The Study Team held discussions with concerned officials of the Government of the Kingdom of Thailand and conducted field surveys in the Basin. 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 development of the project and to the promotion of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the Study Team.

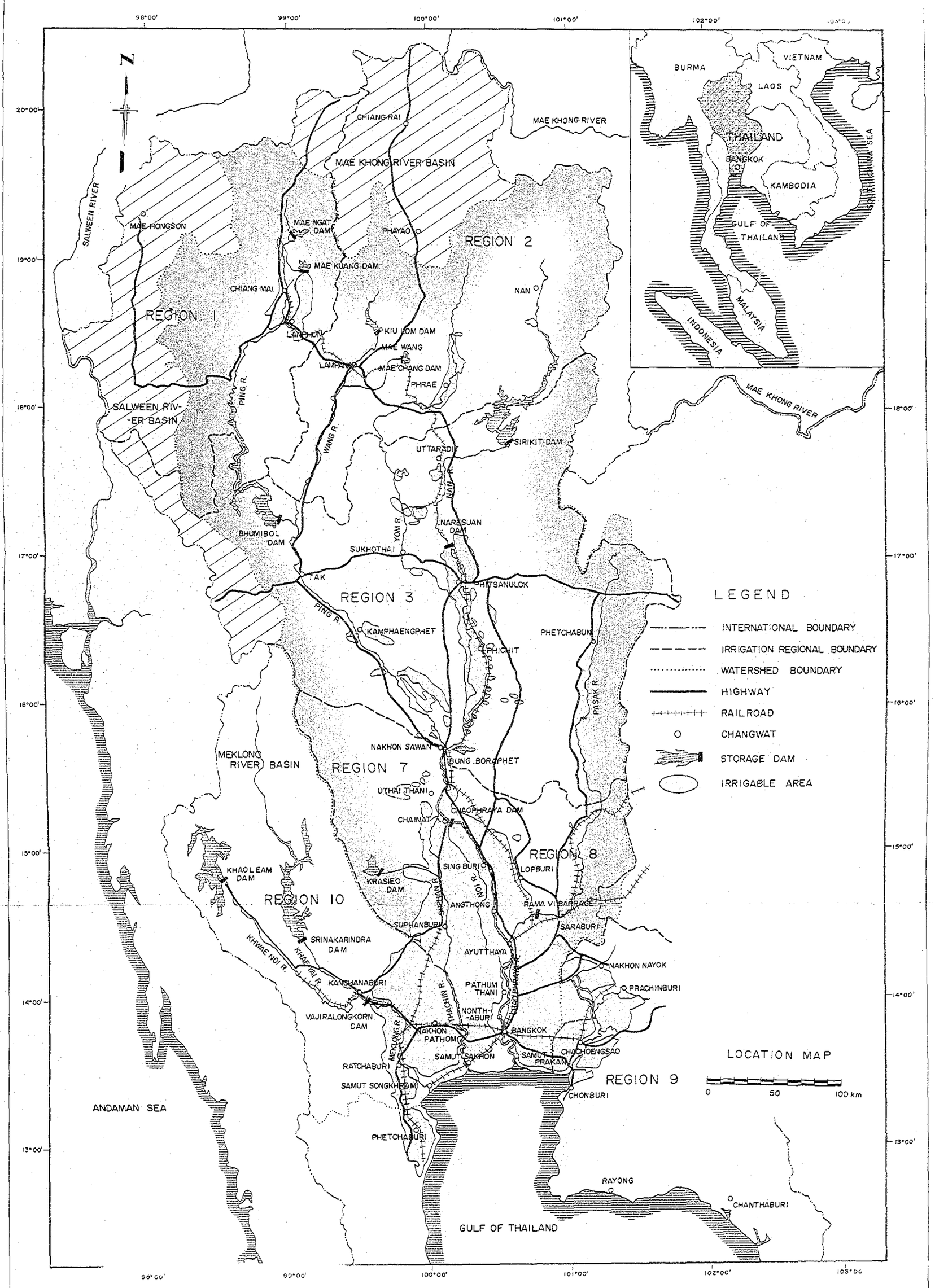
June, 1989

Kensuke Yanagiya

Kensuke Yanagiya

President

Japan International Cooperation Agency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PHAYAO
REGION 2
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WANG R.
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KHAE KAI R.
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NAKHON NAYOK
KANCHANABURI
PATHUM THANI
PRACHINBURI
THACHIN R.
NONTH-ABURI
VAJIRALONGKORN DAM
MEKLONG R.
NAKHON PATHOM
BANGKOK
SAMUT SAKHON
SAMUT PRAKAN
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RATCHABURI
SAMUT SONGKHRAM
REGION 9
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ANDAMAN SEA
PHETCHABURI
RAYONG
CHANTHABURI
GULF OF THAILAND
BURMA
VIETNAM
LAOS
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SOUTH CHINA SEA
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INDONESIA
MAE KHONG RIVER
LEGEND
INTERNATIONAL BOUNDARY
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HIGHWAY
RAILROAD
CHANGWAT
STORAGE DAM
IRRIGABLE AREA
LOCATION MAP
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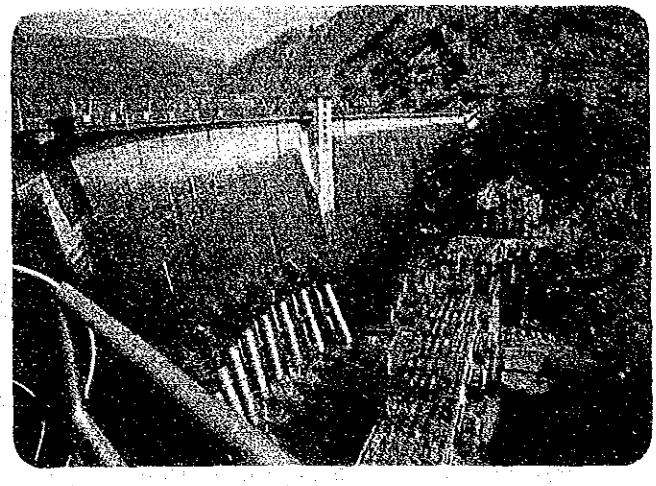
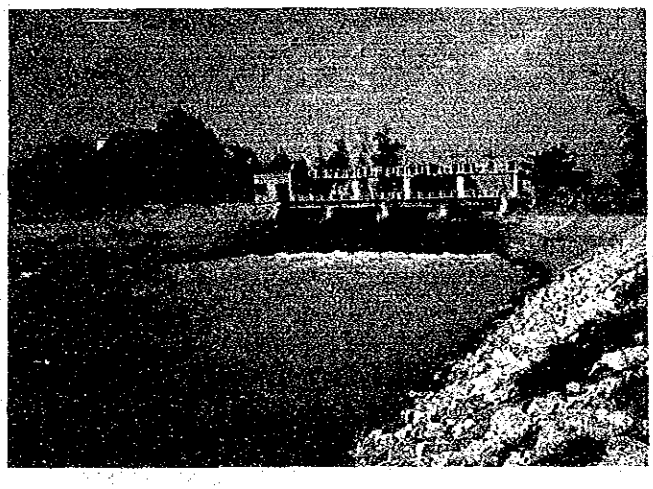
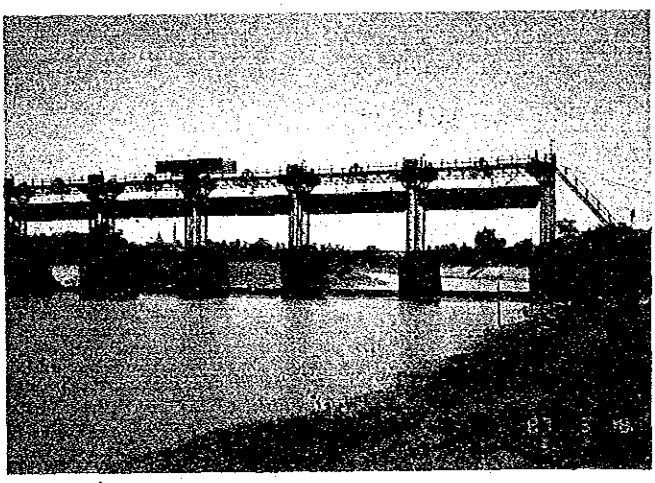


1. BHUMIBOL DAM

2. SIRIKIT DAM



3. BOROMATHAT MAIN REGULATOR



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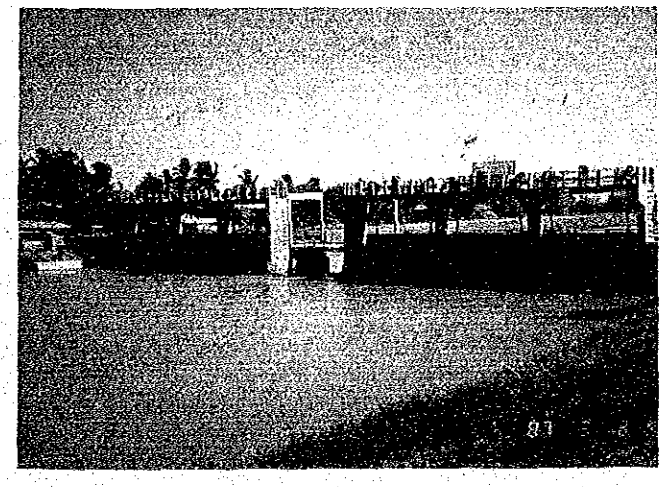
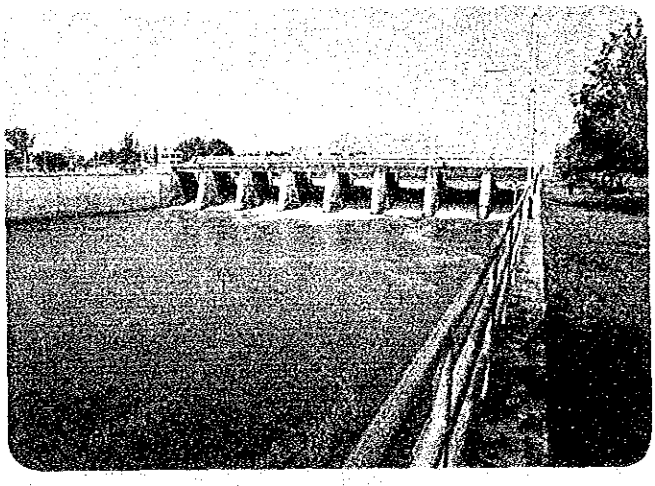


5. REGULATOR ON RAPHIPHATANA MAIN CANAL



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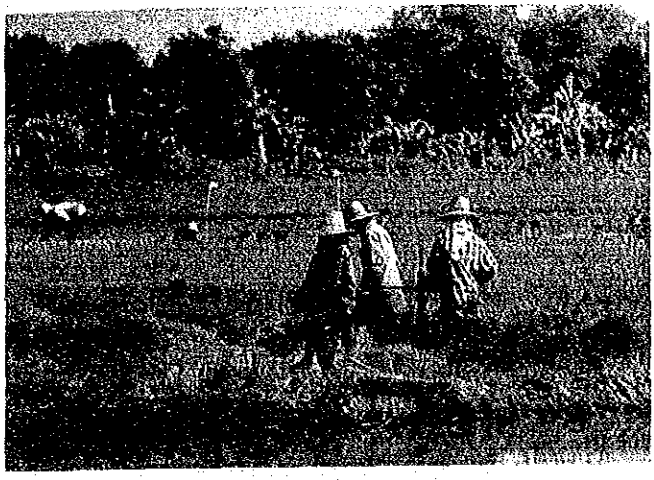

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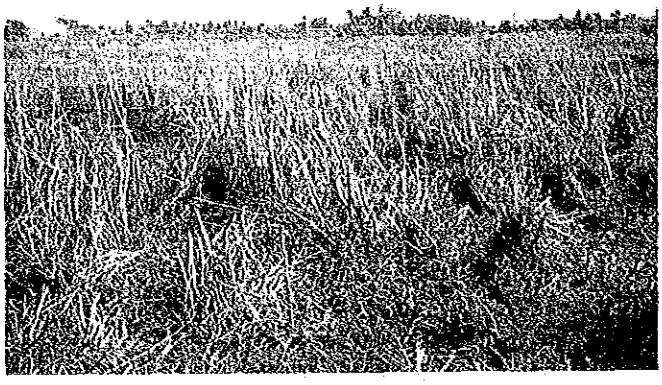

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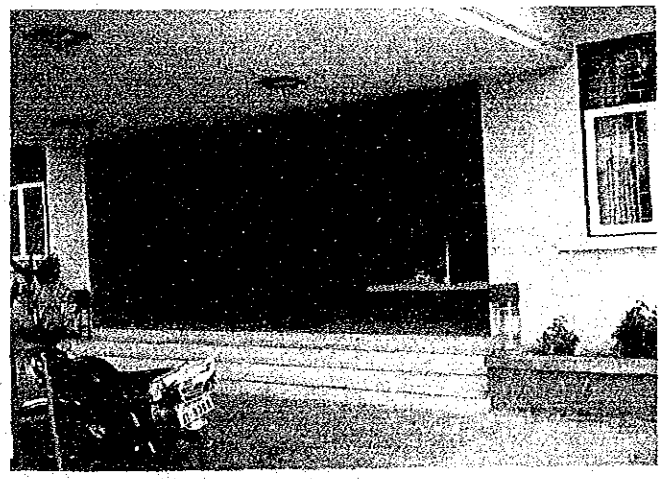

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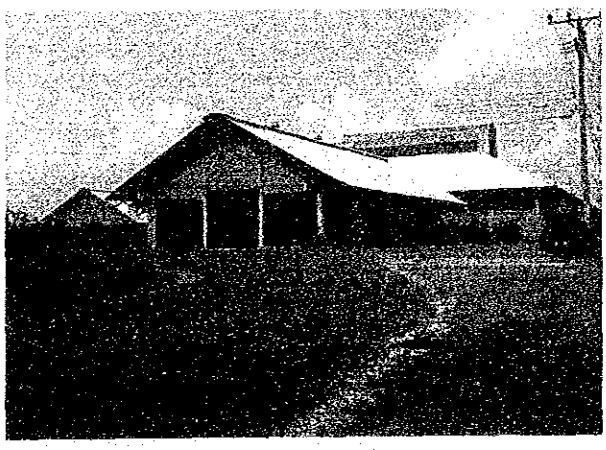

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13. PUMPING IRRIGATION (1)

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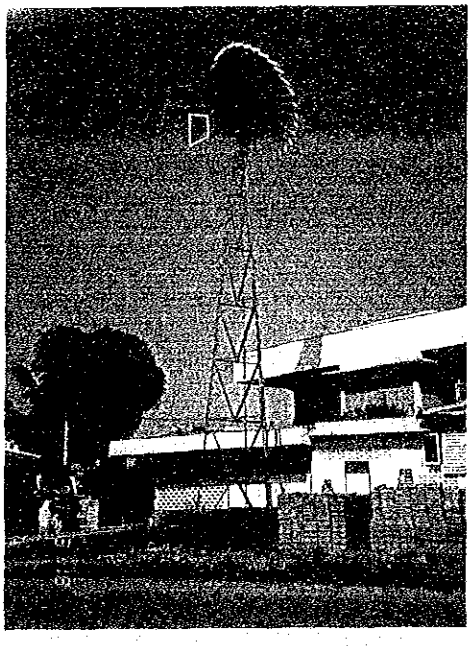

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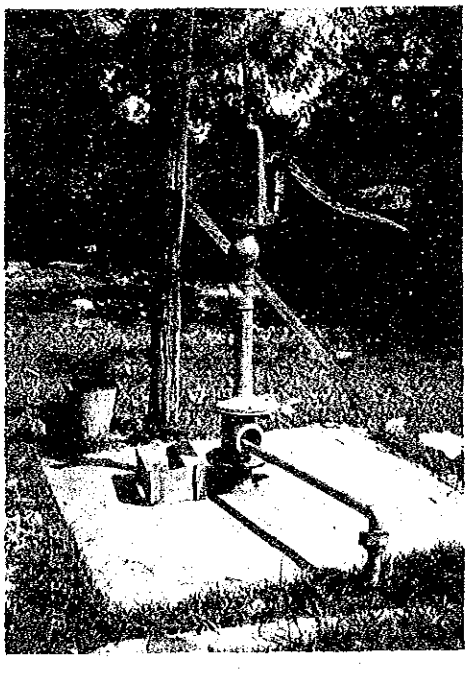

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Abbreviation and Glossary

Abbreviations

ADB	Asian Development Bank
AIT	Asian Institute of Technology
ALRO	Agricultural Land Reform Office
ARD	Office of Accelerated Rural Development
BAAC	Bank for Agriculture and Agricultural Cooperatives
BMA	Bangkok Metropolitan Administration
CAT	Communication Authority of Thailand
CIF	Cost Insurance and Freight
°C	Degree Centigrade
DCP	Department of Cooperative Promotion
DOAE	Department of Agricultural Extension
DOF	Department of Fishery
DOH	Department of Health
DOLA	Department of Local Administration
DTEC	Department of Technical and Economic Cooperation
EGAT	Electricity Generating Authority of Thailand
EL	Elevation
FAO	Food and Agriculture Organization
FC	Foreign Currency
FOB	Free on Board
F/S	Feasibility Study
FY	Fiscal Year
GDP	Gross Domestic Product
GNP	Gross National Product
GWH	Giga Watt Hour
HF/SSB	High Frequency/Single Side Band
HP	Horsepower
HWL	High Water Level
HYV	High Yielding Variety (of Paddy)
IBRD	International Bank for Reconstruction and Development
IEC	Irrigation Engineering Center
IRR	Internal Rate of Return
JICA	Japan International Cooperation Agency
KV	Kilo Volt
KW	Kilo Watt
KWH	Kilo Watt Hour
LC	Local Currency
LV	Local Variety
LWL	Low Water Level
MD	Meteorological Department
MOAC	Ministry of Agriculture and Cooperatives
MOF	Marketing Organization for Farmers
MOI	Ministry of Interior
MOIN	Ministry of Industry
MSL	Mean Sea Level
MWL	Mean Water Level
MW	Mega Watt
NEA	National Energy Administration

NESDB	National Economic and Social Development Board
NSO	National Statistics Office
OAE	Office of Agricultural Economy
O & M	Operation and Maintenance
PH	Potential of Hydrogen
PPM	Parts Per Million
PTD	Post and Telegraph Department
PWD	Public Works Department
PWO	Public Warehouse Organization
RID	Royal Irrigation Department
RTA	Royal Thai Army
SSIP	Small Scale Irrigation Project
TOT	Telecommunication Organization of Thailand
VHF/FM	Very High Frequency/Frequency Modulation
WOC	Water Operation Center

Measures

Length

mm	millimeter(s)
cm	centimeter(s)
m	meter(s)
km	kilometer(s)

Area

rai	0.16 ha
sq.cm	square centimeter(s)
sq.m	square meter(s)
sq.km	square kilometer(s)
ha	hectare = 6.25 rai

Capacity

lit.	liter
cu.m	cubic meter
MCM	Million Cubic Meter

Weight

g	gram(s)
kg	kilogram(s)
ton	metric ton

Others

cm/sec	centimeter per second
m/sec	meter per second
km/sec	kilometer per second
cu.m/sec	cubic meter per second

Glossary

Amphoe	District
Baht	Unit of Local Currency (about 5 Japanese Yen)
Changwat	Province
Muang	Capital of Province
Muban	Village
Tambon	Sub-District

Conversion

Rai	0.16 ha
Baht	US$1.00 = ฿25 = ¥125
	฿1.00 = US¢4.00 = ¥5.00

Fiscal Year

From 1st October to 30th September

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSIONS

1. GENERAL OUTLINE

1.1 Chao Phraya River Basin has, all through the history of Thailand, been prosperous as the center of national politics, economy, society and culture. Thanks to the rich water resources of the Mae Nam (mother-river) Chao Phraya, paddy farming has been practiced since the early history, forming the water-societies from the local water-cultures.

1.2 Agricultural development in Thailand has, for a long time, been achieved mainly by expanding farm land. In the Chao Phraya Basin, deforestation by logging and shifting cultivation for the expansion of farm land in the upper and middle basins and expanded paddy farming by providing irrigation facilities in the lower basin have progressed over the years.

1.3 From the viewpoint of basin water management, the former has contributed to the deterioration of basin water retention capacity, while the latter to the increased dry season cropping and its popularity. They have accelerated the economic development of the country on the one hand, and shortage problem of available water resources on the other hand. It is now feared that, in a long run, basin deterioration will decrease agricultural productivity.

1.4 The Government of Thailand, awaring of the above mentioned dangers, has announced the following policies regarding agriculture and water resources development in the "Sixth National Economic and Social Development 5-year Plan":

- Promotion of multi-lateral and diversified crop production in conformity with export demands

- Continuous, disciplinary and economical use of water resources

- Establishment of a regime of standard operation and management for natural resources and environment conservation

1.5 Measures to cope with problems of water management can be compiled into:

- Internal measure

  (1) Formulation of water resources utilization plan
  (2) Up-grading of water operation technologies

- External measure

  (1) Improvement of productivity of water resources
  (2) Appropriate management of basin environment and social capital

2. BACKGROUND OF WATER MANAGEMENT

2.1 Large-scale development for irrigated agriculture in the Chao Phraya Delta, the largest granary of Thailand, was commenced at the beginning of the 20th century and has been continued by RID for almost a century. As such, the irrigation and drainage systems in the delta vary from 30 - 90 years old. they were constructed in the lower left bank in 1930s, in the lower right bank in 1950s and in the upper delta in 1960s. Furthermore, Chao Phraya Dam (diversion dam), Bhumibol Dam (storage dam) and Sirikit Dam (storage dam) were completed in 1957, 1964 and 1972 respectively.

2.2 Both storage dams were constructed to secure supplementary irrigation water supply in wet season and hydro-power generation, at the time. Today, water supply from the dams does not meet the increasing demands due to increased dry season paddy cropping, industrial development, increased population by urbanization, etc.

2.3 RID, in solving the shortage problems, has not only promoted new water resources development but also made various efforts for the effective use of water resources since mid-1970s. However, water itself is now becoming one of the key constraints to social and economic growth in the Chao Phraya Basin, and this Study is based on such background and requirements.

3. EMERGENCE OF WATER PROBLEMS

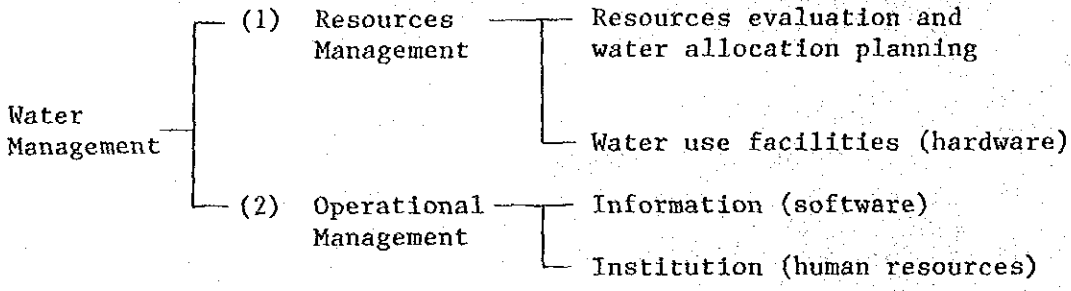
3.1 The emergence of water shortage problems in the Basin has been caused by the change of water from a free to an economic property during the course of economic development in the Basin. This is basically due to the scarcity of water resources. What is needed, in this context, under the current situation, is a new order of water which will provide the contemporary needs, and re-structuring of methodological frame works. The problems of basin water management can be summarized as follows:

(1) Shortage of water resources
(2) Flood and drainage problems
(3) Environmental and ecological deterioration
(4) Problems in O&M of existing water use facilities
(5) Difficulties in new water resources development
(6) Increasing fragility of basin water conservation functions
(7) Unestablished legal structure of water management

In order to solve the above problems in a comprehensive way, various studies/examinations have been carried out under the procedures as depicted in Figure 5-5.

4. BASIN WATER MANAGEMENT CONCEPT

4.1 In order to deal with the problems of a vast river basin, this study is based on a unified basic concept and the methods of water management have been classified as below:



4.2 The water resources development plan is composed of (1) water use plan, (2) construction plan and (3) project evaluation. And, the management activities after construction can be classified into (1) operation and (2) maintenance. The objective of water management is defined in this study as "to deliver the required volume of water equitably at the right time and places". Therefore, what are needed, in this connection, are the maintenance of hardware functions and smooth transmission of information as will as particularly institutional reinforcement and activation. (See Figure 5-1)

5. EVALUATION OF BASIN WATER RESOURCES

5.1 In order to quantify and evaluate the use of water resources in the basin under the present conditions of water use facilities and information, organization and technological systems, a macro-scale mathematical simulation model for the basin was constructed.

5.2 After dividing the Chao Phraya Basin into 14 sub-basins, monthly water balance analyses have been made for the past 10 years. Steps for the analyses are (1) rainfall-runoff conversion, (2) irrigation water demand calculation, (3) reservoir operation simulation and (4) verification of the results with observed data. Water level gauges and the display panel which were introduced by the Study Team has fully been used for the above verification. The simulated results showed good agreement with the observed data which were used to prove the reliability of the analysis. From the analyses, the followings have been clarified.

(1) Water operation has been conducted with a high standard by making full use of the existing facilities under the present regime and constraints.

(2) After implementation of the proposed "Water Management Model Project" and "Monitoring/Communication System Improvement Project" up to the main canal system level, following benefit is expected.

Estimated cost	947 Mill. Baht
Newly available water resource	1,000 MCM
Increased dry season cropping	80,000 ha

To realize the above, Bhumibol and Sirikit Reservoirs should be operated in accordance with the water release plan formulated based on the annual cropping plan.

(3) Re-use of the return flow is closely related to groundwater and water quality. Therefore, it is more practical to manage it empirically on local basis, rather than to rely on theoretical and analytic ways.

6. LEVELS OF MANAGEMENT

6.1 To formulate an orderly study system, and consequently to facilitate the overall planning of water management, the Study subjects have been classified into a form of matrix consisting of structural components and management levels. The structural components of basin water management are classified as follows by structural facilities. (See Figure 5-2)

(1) Reservoir release control
(2) Diversion control
(3) Main canal system distribution control
(4) Lateral canal system distribution control
(5) On-farm soil moisture control
(6) Creek water pumping control
(7) Drainage pumping station control
(8) Water quality control

6.2 A "management level" concept has also been introduced to clarify the status/position of component facilities, information and organizations (see Table 5-3). This arrangement facilitates the adoption of alternative countermeasures upon changes of conditions.

Management Level	Control Area	Structural System	Information System	Institutional System
Level-1	up to 172,000 km	River/Basin		RID.HQ & Reg.Off.
Level-2	150,000-100,000 ha	Main Canal System		Proj. O&M Off.
Level-3	10,000-15,000 ha	Lateral Canal System		Water Master & Zoneman Off.
Level-4	50-100 ha	On-farm System		Farmers' Org.

7. OUTLINES OF THE IMPROVED WATER MANAGEMENT SYSTEM

7.1 In the Study, the present water management regime and component systems of RID were taken as a single large system and were reviewed to locate problems which need improvement or solution. Within the basic frame work mentioned above, plans for each of the problems identified have been formulated. Projects and plans as explained in the Table below are proposed in a systematic manner in order to achieve the overall improvement of the water management system. (See Figures 5-1 and 5-6)

PROJECT & STUDIES IN THE IMPROVED WATER MANAGEMENT SYSTEM

Project / Study	Manage. Level	Imple. Term
(1) Water Management Model Project	until Level-4	short-term
(2) Monitoring/Communication System Improve. Project	until Level-2	short-term
	until Level-3	medium-term
	until Level-4	long-term
(3) Data Management System Improvement Plan	(to be formulated during/after imple. of the Model Project)	
(4) Irrigation and Drainage System Improve. Project	until Level-2	medium-term
	after Level-2	long-term
(5) Study on Comprehensive River Basin Development Plan		short-term
(6) Study on Crop Diversification Promotion Center		short-term

N.B. Short-term implies 5-7 years, while medium-term 8-15 years and long-term over 15 years.

7.2 Water Management Model Project

(short-term project; 3,930 mill. Yen or 786 mill. Baht)

7.2.1 Implementation of all the projects identified under the improved water management system requires huge resources of labor, fund and time. It is, therefore, proposed to implement the "Water Management Model Project" as the first step and through actual implementation to examine and establish concrete methodologies and detail procedures.

7.2.2 In order to materialize the outcome of the Study, the Model Project aims to build a prototype system in sample area with typical local natures. The major roles thereof are the preparation of criteria, demonstration and dissemination among the water management specialists concerned, technology development and staff training for the improved water management system.

7.2.3 In addition, some preparatory works for the proposed "Crop Diversification Promotion Center" should be conducted as soon as possible. They are (1) upland crop irrigation technologies, (2) crop-water relation study, (3) marketing/price information study, (4) land use and zoning, etc.

7.3 Monitoring/Communication System Improvement Project

(until Level-2 : short-term project ; 947 mill. Baht)
(until Level-3 : medium-term project ; 1,258 -do-)
(until Level-4 : long-term project ; 1,980 -do-)

7.3.1 Information management system for water management is composed of systems designed for the various purposes such as (1) monitoring system for comprehension of current situations through information sensing and collection, (2) communication system for correct and smooth information transmission and (3) data management system for storage, filing and processing of collected information.

7.3.2 (1) and (2) of 7.3.1 are the bottle-necks of the present water operation, and the proposed improvement project aims to improve them. Implementation of the project until Level-2 (river and main canal system) is proposed as a short-term project.

7.3.3 Improvement of operational technologies are also required along with the project implementation and staff training is

programmed in the Model Project. By combining improved equipment and technologies (i.e. combining hardwares and softwares), benefits such as those given in the Section 5.2 (2) could be expected.

7.4 Data Management System Improvement Plan

7.4.1 Data management may be classified into (1) that for RID's organizational activities and (2) that for operation of water management system. The present activities of the O&M Division play an interfacing role between the two.

7.4.2 Implementation of the improved Data Management system is recommended as a medium-term project, after formulation of its basic plan through the implementation the Model Project.

7.5 Irrigation and Drainage System Improvement Project
(until Level-2 : medium-term project ; 1,050 mill. Baht)
(after Level-2 : long-term project ; 14,944 -do-)

7.5.1 In order to recover and improve the functions and capacities of the existing irrigation and drainage facilities in the Chao Phraya River Basin, the captioned improvement project has been formulated. Improvement of those facilities considered necessary by responsible personnel in the field O&M offices of RID were looked into, and the results were compiled and standardized by applying some criteria employed by the Study Team. The findings have then been formulated into the captioned improvement plan.

7.5.2 Preparation of feasibility study reports and project implementation plans regarding the captioned plan will be conducted in the course of implementation of the Model Project.

7.6 Study on Comprehensive River Basin Development Plan
(short-term study ; 500 mill. Yen or 100 mill. Baht)

7.6.1 Along with development of social and economic activities in the Chao Phraya River Basin, finiteness of basin water resources has been emerged. Availability of water resources is now becoming a constraint for social and economic development in the basin, and re-evaluation of the development methodology is therefore necessary. That is, development plans formulated individually need to be re-evaluated from the viewpoint of basin water resources utilization.

7.6.2 Measures for optimum allocation of production resources (including water resources), conservation of environment, improvement of productivity, etc. should thereby be formulated.

7.7 Study on Crop Diversification Promotion Center
(short-term study ; 2,900 mill. Yen or 580 mill. Baht for the Center including 135 mill. Yen for the Study)

7.7.1 Some of the activities of the captioned Center will go beyond RID's roles in some aspects, and the Center forms a twin concept to the Model Project and has natures to give a direction of the agriculture in the Basin.

7.7.2 To complete the improved water management system, further development are needed for improved agricultural production and farm income, harmonized combined functions of (1) diversified cropping, (2) market information and (3) planning.

7.7.3 As afore-mentioned, those activities in the fields closely related to the Model Project are expected to start with (1) upland crop irrigation practices, (2) crop-water relation study, (3) marketing/price information study and (4) land use and zoning.

8. PROPOSED WATER MANAGEMENT MODEL PROJECT

8.1 In order to materialize the outcome of the Study, implementation of the captioned project is herein proposed.

(1) Objectives:

1) Project implementation through experimental procedure for a project prototype.

2) Setting-up of water management methods and standards to fit the localities.

3) Demonstration and dissemination to/among the people concerned.

4) Staff training and development of knowhow on water management system/project.

5) Preparation of feasibility study reports for the subsequent project implementation and proposals on the implementation system, following the proposed water management model project.

(2) Function:

1) Improvement of an overall water management system including technology transfer and farmers organizing by setting targets in cropping and farming achievements in each selected project area/site.

2) The Project functions as a central station on one hand to widely monitor water phase in the Basin, and at the same time on the other hand as a local station to intensively control water facilities in some specific areas. Harmonized and organic uses of the functions are performed.

3) Diversified functions of center are played at RID Head Office and these at a number of local station of project O&M offices. They are gradually expanded and intensified along with accumulation of experiences through practices.

4) During the course of implementation of the Model Project, effective use of the IEC's available

facilities will much facilitate the Project activities.

5) For efficient implementation of the Project, Technical Cooperation has room to be considered.

(3) Project Site:

Function	Project Site	Features of Site
Center Sta.	1) RID Head Office	° Center of overall control ° Centralized control of present WOC and IEC
Local Sta.	2) Reg. 7 Office/Chao Phraya Dam Off.	° Main river diversion control
	3) Reg. 8 Office/Koke Kathiem Prj.	° Diversion control of large-long canal ° Gravity irrigation
	4) Rangsit Tai Prj.	° Urban agriculture ° Water conservation irr. & on-farm water manage. ° Fruit plantation
	5) Phasi Charoen	° Urbanized area ° Water conserv. irrigation ° Fish ponds & horticulture ° Water pollution
	6) Bang Ban Prj.	° Pumps operation control ° Pumping irrigation

(4) Project Activities:

1) Management of water resources
2) Water distribution planning
3) Hydrological observation
4) Set-up of data management methodology
5) Development of softwares for water management
6) Training, dissemination and education
7) Public information service

(5) Estimated Project Cost:

Phase I : 230 Mill. Baht Total 786 Mill.Baht
Phase II : 266
Phase III : 290

(N.B. Project term: 5 years proposed)

RECOMMENDATION

For prompt materialization of the afore-mentioned improved water management system as an integrated body of the outcome of the Master Plan Study on the Water Management System and Monitoring Program in the Chao Phraya River Basin, the following short-term projects and studies are here in recommended (The following order is based on their priority).

1. Implementation of "Water Management Model Project"

2. Implementation of "Monitoring/Communication System Improvement Project (until Level-2)"
   (Staff training for the improved system is undertaken by the Model Project)

3. Commencement of a study on "Comprehensive River Basin Development Plan"

4. Others
   Plan/formulation of the crop diversification promotion center, etc. will be required.

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

1.1.1 Outline of the Study Area

The Chao Phraya River, flowing southerly through the central part of Thailand and into the Gulf of Thai, is most important in the country.

In addition to the agricultural use, the water resources in the basin have been utilized multi-purposely such as power generation, navigation, domestic/municipal/industrial uses, fishery, salinity control, etc., playing important roles in the national economy.

The Chao Phraya Plain, sometimes called the Chao Phraya Delta, developed in the downstream reaches of the Chao Phraya River has prospered for a long time as a central region of politics, economy and social activities in the country. The biggest granary over the plain has been formed as historical resultants of the paddy cultivation supported by abundance of irrigation water.

The Chao Phraya River with 980 km in river length and 162,600 sq.km in basin area shares about 32 percent of the national territory of Thailand. There is a 5.8 million ha of arable land in the basin, of which an irrigated area in the wet season amounts to 1.82 million ha and in the dry season 0.92 million ha. There has a population of 19.2 million capita in the basin identical with 37 percent of the national population.

Meanwhile, in accordance with progress of various development projects in the basin, several problems have been revealed such as (1) tighter relation between demand and supply for water resources, caused by increase of water demand not only for irrigation use

especially during dry season but also for other uses, (2) increase of inundation damages due to transform of basin conditions. Furthermore, such environmental problems as water contamination, salt intrusion, land subsidence and so forth, have been also pointed out in recent years.

In order to solve the said problems, it is considered as one of option to promote a new large-scale water resource development project, but the option is presently facing with various social and economic constraints.

1.1.2 Circumstances of the Study

To meet the needs of new water management system under the said social and economic situations, RID had developed a modernized water management system and initiated its operation in 1982.

Meanwhile, an investigation study under IEC (Irrigation Engineering Center) Project has been implemented since 1985 to provide technical guidance and advice on overall irrigation engineering aspect to Thai counterpart personnel with cooperation by the Government of Japan.

However, it was found in the circumstances that it might be difficult to cope with such conglomerated problems currently existing in the basin under the present frameworks of IEC Project.

RID requested a technical cooperation to the Government of Japan for the Study in August 1985 under such background. In response, the Government of Japan conducted the contact survey in March 1986 through JICA. JICA subsequently dispatched a preliminary survey mission and concluded the scope of work for the Study with RID.

The Study has been and will be undertaken from January 1987 to May 1989 based on the Scope of Work and the Inception Report submitted. This Report compiles study results obtained through the Study.

In parallel with the Study on water management system, another Study on flood forecasting system for the Chao Phraya River Basin had been undertaken under the technical assistance of JICA. Since there are many aspects relating to the Study, both teams conducted their study by contacting and collaborating each other.

1.1.3 Objectives of the Study

The Study aims to formulate a master plan for efficient and proper management of water resources through evaluation of potential water resources and dependable water availability for agricultural development, wherein rationalization of water uses among existing projects in the same basin with consideration in the scope of future agriculture of the region is also aimed at. Following investigations are undertaken for the purpose.

(1) Review of present water management system for irrigation and drainage.

(2) Execution of intensive observation and data collection at selected hydrological key stations.

(3) Formulation of monitoring system improvement plan for water management.

(4) Improvement of data management system in considering the future function of Irrigation Engineering Center.

(5) Identification of necessary projects for appropriate water management.

(6) Formulation of improved water management system for irrigation and drainage.

(7) Formulation of stage-wise implementation program of the above.

In addition, transfer of technology to the Thai counterparts is carried out through the execution of the Study.

1.1.4 Study Area

The whole Chao Phraya Basin is subject to the Study, wherein the middle and lower reaches of the basins are focussed.

1.1.5 Basic Guideline of the Study

The following basic guideline has been employed for execution of the Study in cooperation and coordination with RID.

(1) To lay stress on the site survey during the course of study

- In case of the water management project, since hydraulic facilities have been already provided, more attention be concentrated to the site survey on the existing facilities.
- Interview or discussion with the persons in charge of water management also be emphasized.

(2) To keep harmony with the existing hydraulic facilities

- Existing water use facilities and methods for their practices be esteemed to make full use of their function.
- Upon formulation of improvement plans, due attention also be paid to implementation priority and target level of improvement.

(3) To establish practical, effective and realistic project plans

- To establish practical and evident project plans aiming to quick-return benefit during an early stage of the study course.

(4) To maintain close cooperation/coordination with agencies concerned

- It is an absolute requirement to maintain close cooperation and coordination with the agencies concerned for smooth undertaking of the Study.

(5) To highlight technology transfer to counterparts personnels

- For mutual understandings of the Study concept which is a unique and new type of technical cooperation, some seminars/symposiums for transfer of knowledge be programmed. It is expected to foster water management staff in future.

1.2 Formative of Study Report

A formative of the Study Report is as follows:

(1) MAIN REPORT (English, Japanese)

(2) ANNEX (Technical Report for the Main Report, English)

ANNEX-1 METEOROLOGY/HYDROLOGY

ANNEX-2 WATER MANAGEMENT PLANNING

ANNEX-3 WATER MANAGEMENT MODEL PROJECT

ANNEX-4 MONITORING/COMMUNICATION/DATA MANAGEMENT SYSTEM

ANNEX-5 IRRIGATION AND DRAINAGE FACILITY

ANNEX-6 LAND USE/AGRICULTURE

ANNEX-7 SOCIAL SYSTEM/ECONOMY

1.3 Related Projects

1.3.1 Irrigation Engineering Center

(1) Background

Irrigation Engineering Center (IEC) refers a Project Type Technical Cooperation being operated for a period of five years from April 1st, 1985 under Record of Discussion (R/D) agreed on March 8th, 1985, between RID and Japanese Government.

(2) Objectives

Objectives of the Japanese Technical Cooperation is to give the technical guidance and advice to the Thai counterpart personnel in the following fields:

(i) Examination of Criteria
- Examination of planning and design criteria;
- System design for planning and design criteria;

(ii) Hydraulic Model Analysis
- Case study of hydraulic model tests and simulation analysis for design

(iii) Construction Material Tests and Analysis
- Case study of soil and construction material tests and analysis for design and construction management

(iv) System Development
- Case study of system development for technical calculation

(v) Training
- Guidance and advice for technical training

(3) Japanese Experts

- Team Leader
- Coordinator/Liaison Officer

- Examination of Criteria
- Hydraulic Model Analysis
- Construction Material Tests and Analysis
- System Development

1.3.2 Flood Forecasting System Study

The Study on "Flood Forecasting System in the Chao Phraya River Basin" had been conducted by JICA from February 1987 to May 1988 as outlined below:

The Study Plan was divided into two steps as follows.

Step-1: Flood forecasting system utilizing existing facilities with introduction of supplemental equipment. Implementation time is 36 months in total or 12 months for system installation and 24 months for software development with training of staff. Estimated cost is about 360 million yen or US$2,786,000.

Step-2: Flood forecasting system with updated facilities having high reliability of flood prediction results. Implementation time inclusive of proposed integrated study period is 11 years. Estimated cost is about 7,300 million yen or US$55,947,500.

1.4 Personnel Concerned

(1) Royal Irrigation Department

Name	Position
Executive	
Mr. Chari Tulayanond	Director General
Mr. Suha Thanomsingha	Director General (Former)
Mr. Leck Jindasanguan	Deputy Director General

Name	Position
Mr. Chamroon Chindasanguan	Senior Expert for O & M Div.
Dr. Boonyok Vadhanaphuti	Senior Expert for Water Resources Planning and Development
Mr. Kitcha Polparsi	Chief Civil Engineer
Mr. Vira Poomvises	Chief Civil Engineer (Former)
Mr. Chareuk Nonthathum	Chief Civil Engineer (Former)

Operation and Maintenance Division

Mr. Nukool Thongtawee	Director
Mr. Thanom Klaikayai	Chief of Water Management Br.
Mr. Vasan Boonkird	Chief of Engineering Sect.
Mr. Virat Khao-Uppatum	Hydraulic Engineer
Mr. Lek Prapasajehavet	Irrigation Engineer
Mr. Piphat Sathianpantarit	Irrigation Engineer
Mr. Somnuk Siewsakal	Irrigation Engineer
Mr. Wichai Supanode	Irrigation Engineer
Mr. Prasert Kanoksing	Chief of Irrigation Agriculture Br.
Mr. Anek Vichayakul	Chief of On-Farm Development Br.

Project Planning Division

Mr. Maitri Poolsup	Director
Mr. Suthi Songvoravit	Chief
Mr. Kitla Thepalaglekha	Acting Director
Mr. Vudhichai Chullakesa	Chief of Project Planning Br. III
Dr. Siripong Hungspreug	Chief
Mr. Chaiyuth Sukhsri	Engineer
Mr. Theerawat Tangpanich	Engineer

Hydrology Division

Mr. Prasert Milintangul	Director
Mr. Taweechai Mackaman	Director (Former)
Mr. Prasong Jitseri	Hydrologist

Name	Position
Communication Division	
Mr. Sinserm Ketudat	Director
Mr. Putchai Nitakorn	Telecommunication Engineer
Data Processing Division	
Mr. Sompote Sukhumparnich	Director
Mr. Chairat Gua-Arun	Data Processing Div.
Research and Laboratory Division	
Mr. Jumsak Tejasen	Director (Former)
Mr. Thonglaw Charoenrat	Engineer

(2) Colombo Plan Experts

Name	Assignment
Mr. Kazushige MATSUO	Planning
Mr. Fumio ARAKI	Operation & Maintenance
Mr. Hiroshi KUDO	Geology

(3) Experts for Irrigation Engineering Center

Name	Assignment
Mr. Akinori MASUDA	Team Leader
Mr. Yohji EBIHARA	Coordinator/Liaison Officer
Mr. Akira HASHIMOTO	Examination of Criteria
Mr. Takashi MITOMO	Hydraulic Model Analysis
Mr. Hitoshi SUNAZAWA	Construction Material Tests and Analysis
Mr. Hideaki SEKIOKA	System Development

(4) Study Team

Mr. Shigekatu WATANABE	Leader/General Management*
Mr. Koki MITSUNOBU	Water Management Planning*
Mr. Masahiro YAMADA	Hydraulic Model Planning

Name	Assignment
Mr, Hiroshi OHKUBO	Hydraulic Model Analysis
Mr. Takanori TAKATSUKA	Monitoring/Data Processing*
Mr. Masaru MIZUKAMI	System Design (I)
Mr. Shinobu MAEDA	System Design (II)
Mr. Takayoshi NAKABAYASHI	Data Communication
Mr. Kiyoshi OGAWA	Irrigation & Drainage System*
Mr. Satoshi SHOJI	Irrigation & Drainage Facilities
Mr. Ryosuke SAKANASHI	Hydrology/Meteorology
Mr. Yoshitomo MIYANISHI	Economy/Project Evaluation*
Mr. Kensuke IRIYA	Agronomy/Social System
Dr. Kazuo ABE	Soil Science/Land Use

Note: * denotes member engaging in the whole study period.

Further details on assignment period, reference is made to "Manning Schedule" attached to the last page of this report.

CHAPTER 2

BACKGROUND

CHAPTER 2 BACKGROUND

2.1 Sixth National Economic and Social Development Plan

2.1.1 Special Feature of the Plan

The national economic and social development plan has started since 1961, and the Sixth National Economic and Social Development Plan (6th NESDP) covers five years from October 1986 to September 1991.

In order to solve various problems which have been accumulated by implementation of the former five NESDPs, the current plan is characterized as an adjustment one, and it stresses strongly to change the development pattern from expansion in quantity to enrichment in quality. For the purpose of successfully implementing the 6th NESDP, the following basic policy is taken into consideration;

- To give higher priority to improvement of financial balance with foreign countries through careful management of entire economy during the first half of the plan period,
- To seek a growth pattern depending on expanding employment opportunity,
- To diversify production pattern, attaching more importance to marketing than expanding production of traditional primary commodity,
- To carry out industrialization by utilizing resources close to one such as plentiful labor force and agricultural products,
- To utilize vitality in private sector,
- To give priority to not a large scale project but small and medium scale projects.

2.1.2 Composition of the 6th NESDP

In view of the problems and limitations on the one hand and the development opportunities falling within Thailand's province in the near future on the other, the 6th NESDP defines its two major objectives as follows:

ECONOMIC

Maintain an average rate of growth at a level of 5% in order to absorb the minimum of 3.9 million persons who will be entering the labour market. Growth should be accomplished in such a way that economic stability is strengthened and the economic problems that arose during the 5th NESDP period are solved.

SOCIAL

Develop the quality of the population so that social development can progress, peace and justice be attained and development of the country as a whole supported. The national identity, culture and system of values will be maintained and the quality of life of the Thai people will be raised in both rural and urban areas.

Table 2-1 indicates macro economic targets of the 6th NESDP.

Based on the said two objectives for development, the 6th NESDP specifies 10 programmes divided into three major categories as the operating framework for the government and private sector, as follows:

Improving the efficiency of development

(1) Overall Economic Development

(2) Population, Social and Cultural Development

(3) Development of Natural Resources and the Environment

(4) Development of Science and Technology

(5) Improving the Administration and Reviewing the Role of the Government in National Development

(6) Development of State Enterprises

Restructuring production and improving quality of infrastructure services

(7) Development of the Production System, Marketing and Employment

(8) Development of Infrastructure Services

Distributing prosperity and creating justice

(9) Development of Urban and Specific Areas

(10) Rural Development

2.2 Major Objectives of Agricultural Policy

The sector of agriculture, forestry and fishery had kept the leading position in the gross domestic product (GDP) for long time, but the weight of the sector dropped down the third position in 1984, occupying 17 percent of GDP in 1985, because of rapid expansion in the sectors of manufacture and commerce.

The phenomena does not indicate the decrease in growth of the agricultural sector, but the stagnation in development of rural economy, which absorbs about 70 percent of the national population.

While products of agriculture, forestry and fishery including their related ones, occupied about 60 percent of total export earnings in 1985, and have supported Thai economy by gaining foreign exchange, the share or weight has been decreasing in these three years. The reason is that export earnings by the other sector have

been increasing and an international market for primary commodities, especially agricultural, forestry and fishery products have stagnated.

Thai government has devoted to expand production of main agricultural products, such as rice, maize, cassava, sugarcane, etc., as well as to maintain paddy price received by farmers, in her agricultural policy. However, stagnation in farmers' receiving prices of main agricultural products have become more serious, because the relation between supply and demand for the main agricultural products is presently under slack situation in the world market. Therefore, Thai government started to control paddy production since 1984, and also is forced to control cassava production, because of EEC's import restriction on a tapioca.

Under such circumstances, Thai government plans to raise the farmers' receiving prices of agricultural products through primarily promoting export of them, for which the following important objectives are taken into consideration;

- Crop diversification coping with exportable demand
- Quality improvement for strengthening export competitiveness
- Reduction of production cost
- Mitigation of obstacles for export promotion such as export tax, export premium, etc.
- Provision of credit to farmers, rice millers, exporters with low interest rate.

In the 6th NESDP, the following development objectives are adopted;

(1) Agricultural Development

1) Rural development for poverty alleviation

2) Development in area which has much rainfall

3) Development in advanced area where farmers own average management size ranging 20 to 25 rai.

- Expanding cultivation of vegetables, fruits, and plants having shorter gestation period, for both domestic and international market.
- Improving cultivation of main crops such as rice, maize, cassava, etc.

(2) Annual growth rate in the agricultural sector: 2.9%

(3) To place stress on from an expansion in quantity to an improvement in quality.

2.3 Development Policy on Water Resources

Among the 10 programmes set forth in the 6th NESDP as mentioned in paragraph 2.1.2 of Chapter 2, "(3) Development of National Resources and the Environment" deals with the development policy on water resources as follows;

Unsystematic use of natural resources in the past has resulted in severe deterioration. Occasionally there have been serious conflicts between the use of resources and environmental concerns. Therefore, in order to make the most efficient use of the country's depleted natural resources in a way that corresponds to environmental conditions while at the same time looking for as yet untapped natural resources for use in national development in the future, the following key operational guidelines are defined:

- Improve the use of natural resources in generating employment. In particular the private sector will be encouraged to use land for growing trees for economic purposes, resources in Thai territorial waters will be conserved to ensure continued and consistent economic use and water resources will be used with increased efficiency.

- Establish various and appropriate types of land ownership. This will be implemented within the period of the 6th NESDP. In addition, it is necessary to improve the system of agricultural production according to the productivity of the land and to solve problems which arise from soil depletion and other types of soil problem.

- Locate and continuously develop additional natural resources. In particular an aerial geophysical survey of the entire country and exploratory drilling will be undertaken at various points where data indicate the existence of energy resources and economically valuable minerals. For water resources, support will be given to efforts to use underground water sources wherever feasible; elsewhere support will be given to the construction of small water resources for household consumption and agricultural use.

- Provide instruments in the form of master plans and maps. These will be used in natural resources and environmental planning; for example, standardized land maps will be made for use by various government units; master plans will be formulated for the country's national parks and wild-life sanctuaries and for developing the economic potential of natural resources in coastal areas; and studies will be undertaken to solve the problems of toxic substances.

- Complete and standardize the system of management of natural resources and the environment. Local organizations will be encouraged to set up near the location of natural resources in order to participate more in the administration and management of these resources and the environment.

2.4 National Economy

2.4.1 Overview

Four noteworthy features of the Thai economy in 1987 were: first, led by the export industry, economic recovery gained strength

and was widely spread among manufacturing and other major sectors such as trade, construction, and banking. Manufacturing achieved a very high rate of growth of 8.5%, and with strong growth in almost all non-agricultural sub-sectors, gross domestic product rose by an impressive 6.6%.

Second, faced with two successive droughts, a decline in agricultural production resulted, particularly for rice and maize. However, crop prices have trended up, thus contributing to higher incomes for farmers than in the previous year.

Third, during the course of economic recovery, pressure on prices and the balance of trade was inevitable. However, the country was never on the verge of any severe problems. The consumer price index in 1987 increased by 2.5%. The balance of trade was limited to a deficit of ฿46,000 million as imports grew substantially in the wake of economic recovery, while exports also rose vigorously by 25%. In addition, income from tourism and investment coupled with other capital inflows also surged, resulting in a balance of payments surplus of ฿18,000 million. International reserves amounted to US$5,200 million, reflecting a stable financial position.

The fourth feature is that the liquidity in the financial system sustained throughout the year contributed to low loan rates which in turn assisted in stimulating the economy.

Policy-wise, the authorities implemented measures on various fronts to support economic recovery. Export promotion, investment promotion, monetary and exchange rate policies were used to help the private sector adjust to the changing economic environment. As a result, the Thai economy in general performed relatively satisfactorily.

2.4.2 Individual Performance

At the end of 1987, the population of Thailand totalled 54 million, an increase of 2% from the previous year. Of this total, the labour force (over 11 years of age) numbered 28.9 million. Amongst them, about 27 million were employed, with 17.4 million in the agricultural sector, 2.5 million in the manufacturing sector and 7 million in other activities. The minimum wage rates were adjusted upward by 3.7% on average, effective as from April 1987, showing their regional differences.

Nominal income in 1987 increased by 11%, substantially higher than the 6% growth of the previous year. In real terms, national income rose by approximately 8%, higher than the 4% rate in 1986. In the agricultural sector, income of most farmers improved despite lower production of major crops resulting from droughts that occurred in two successive years while prices of several crops rose in line with buoyant export prices. Those crops that showed an increase in earnings were rubber, soybean, tapioca, rice, coconuts and sugarcane. On a regional basis, farmer incomes rose in all regions, but most notably in the South and the Northeast.

During 1987, prices remained stable. with the consumer price index increased by 2.5% compared with 1.9% last year. On the other hand, the producer price index rose by a substantial 6.0% in 1987 after declining continuously over the past three years. Prices of agricultural goods, especially paddy, cash crops, fresh vegetables and fruits, showed marked increases, resulting in rises in the prices of food and animal feed. The export price index showed a notable increase as demand for exports remain high while supplies of major agricultural products, both domestic and abroad, fell.

Despite being negatively affected by protectionist measures of various countries, Thai exports maintained a remarkable performance during 1987. This was achieved through considerable efforts on the

part of the exporters, support given by the government in seeking new markets as well as in improving product form and quality, and improved export competitiveness which reflected international exchange rate developments. The total value of exports reached ฿291,000 million in 1987, or an increase by 26% from last year. Export volume increased by 15%, a marked increase for the second consecutive year. On the other hand, imports value also increased--by 37%--owing to the sharp growth in investment and the rapid economic recovery. As a result, trade balance registered a large deficit of around ฿46,000 million in 1987 compared with the ฿14,369 million deficit recorded in 1986. However, this trade deficit was largely offset by the surplus in services and transfers account, which rose markedly in 1987 and a net surplus registered in the capital account, showing the overall balance of payment position of Thailand had a large surplus of approximately ฿18,000 million.

International reserves amounted to US$5,200 million, equivalent to 4.7 months of imports. Meanwhile, with major reduction in the private sector external debt, the total debt service ratio fell to 17% of export earnings, compared with 20.1% in 1986.

2.5 Agricultural Production and Marketing System

Figure 2-1 shows the past trend of cropped area and production of major crops. In Thailand, an agricultural production has been carried out by expanding cultivable land through mainly converting forest land. For the past 10 years, around 5 million hectares of forest land was converted to other uses including farm land, and its ratio against the national land has lowered below 30%, which is so-called as dangerous level in monsoon countries, causing various adverse effects from both viewpoints of environment and water management.

Although the weight of agricultural products has gradually dropped in the total export earnings due to the recent stagnation of the world market prices, they still occupy around 60% of the earnings, on which the Thai economy could depend. Especially, rice export from Thailand occupies about 40% of the world trade amount, establishing the stable foundation in the sector. It is, of course, forecasted that the both international and domestic prices of paddy/rice would fluctuate due to the world market situation and climatic condition. However, due attention should be paid for continuous effort to increase productivity of paddy, because the rice would keep its important position as a source of the Thai export earnings.

In the past, the government intervened the marketing of agricultural products through such official agencies as MOF (Marketing Organization for Farmers) and PWO (Public Warehouse Organization) as well as price policies including premium for rice export. However, the degree of intervene has been decreasing due to deterioration in financial position with stagnation of international prices of primary agricultural products, and the marketing activity is presently maintained mainly by the private sector.

In relation to required marketing information for effective operation of the system, primary information sources are limited, and the information is for the specific and diverse purposes of each agency. Consequently, there is no uniformity in the type, standard or data-collection period of the information. As a result, the existing information cannot be used as an effective mechanism for integrating production and marketing plans.

2.6 General Condition of Social System

2.6.1 Administrative System

(1) Central Level

Thai central administrative organization is composed of the Prime Minister Office and 13 ministries, under which there are about 80 departments. NESDB, Budget Bureau, DTEC and 16 other divisions and departments are in charge of preparing a national development program and budget allocation and the related activities, under the Prime Minister Office.

(2) Local Level

The local administrative system is basically classified into, from top to down, changwat, amphoe, tambon and muban. In the whole Thailand there are 73 changwats as of 1986, and out of which 38 changwats including Bangkok Metropolis are included in the Study Area, with 278 amphoes, 342 sanitary districts and 53 municipalities.

2.6.2 Land Holding System

According to the land reform law of Thailand, the government purchases and compensates for the portion exceeding 50 rai (8 ha) per farm in case of ordinary farm land and 100 rai (16 ha) per farm in case of dairy farm land as land ownership. However, there exist many exceptional measures in the definition of land holding system.

2.6.3 Education System

Educational system in Thailand is basically divided into three stages, namely a primary one for 7 years, a middle one for 5 years, and an advanced one for 4 years, and the first one is categorized as compulsory system.

The primary education system is further divided into two, a lower school for four years and an upper one for three years. Similarly, the middle education system is done two, a lower school for three years and an upper school for two years in case of a general course, and three years each for both schools in case of a vocational courses. In the advanced education system, there are colleges for two years and a university for four years.

2.6.4 Taxation System

Taxation system is composed of both direct and indirect taxes, and around 80% of tax revenues depend on the latter. Main taxes are an income tax for an individual and an enterprize, business tax, consumption tax, and custom duties on import and export. In addition, there are a stamp duty, an amusement tax, an advertisement tax, a regional development tax, and a local tax, etc., of which tax rates are rather low.

Table 2-1 OVERALL ECONOMIC TARGETS IN THE SIXTH PLAN

Category	Fifth Plan Targets (1982-1986)	Sixth Plan Targets (1987-1991)
1. Trade Deficit (current prices)		
1.1. Average value per year (million baht)	55,600	35,900
1.2. Trade deficit/GDP (%)	5.8	2.7
2. Current Account Deficit (current prices)		
2.1. Average value per year (million baht)	36,000	11,800
2.2. Current account deficit/GDP (%)	3.8	0.9
3. Export of Goods and Services		
3.1. Value growth rate (%)	9.8	9.9
3.2. Volume growth rate (%)	8.4	7.4
4. Export of Goods		
4.1. Value growth rate (%)	8.4	10.7
4.2. Volume growth rate (%)	8.3	8.1
4.3. Average value per year (million baht)	177,500	290,700
5. Income from Tourism (current prices)		
5.1. Value growth rate (%)	12.2	7.4
6. Import of Goods and Services		
6.1. Value growth rate (%)	3.7	9.3
6.2. Volume growth rate (%)	2.0	4.5
7. Import of Goods		
7.1. Value growth rate (%)	2.9	9.5
7.2. Volume growth rate (%)	2.9	4.6
7.3. Average value per year (million baht)	233,100	326,700
8. Economic Growth (%/yr a constant prices)		
8.1. Agriculture	2.1	2.9
8.2. Manufacturing	5.1	6.6
8.3. Mining	6.1	6.4
8.4. GDP	4.4	5.0
9. Government Revenue/GDP (%)	14.8	15.8
10. Population Growth Rate (%)	1.7*1	1.3*2
10.1. Municipal districts	(2.7)	(2.5)
10.2. Sanitary districts	(2.1)	(2.4)
10.3. Villages	(1.4)	(0.8)
11. Inflation Rate (%)	2.9	2.3
12. Per Capita Income (baht)	21,395*1	27,783*2

Note: *1 ... In 1986, *2 ... In 1991

Source: National Economic and Social Development Board

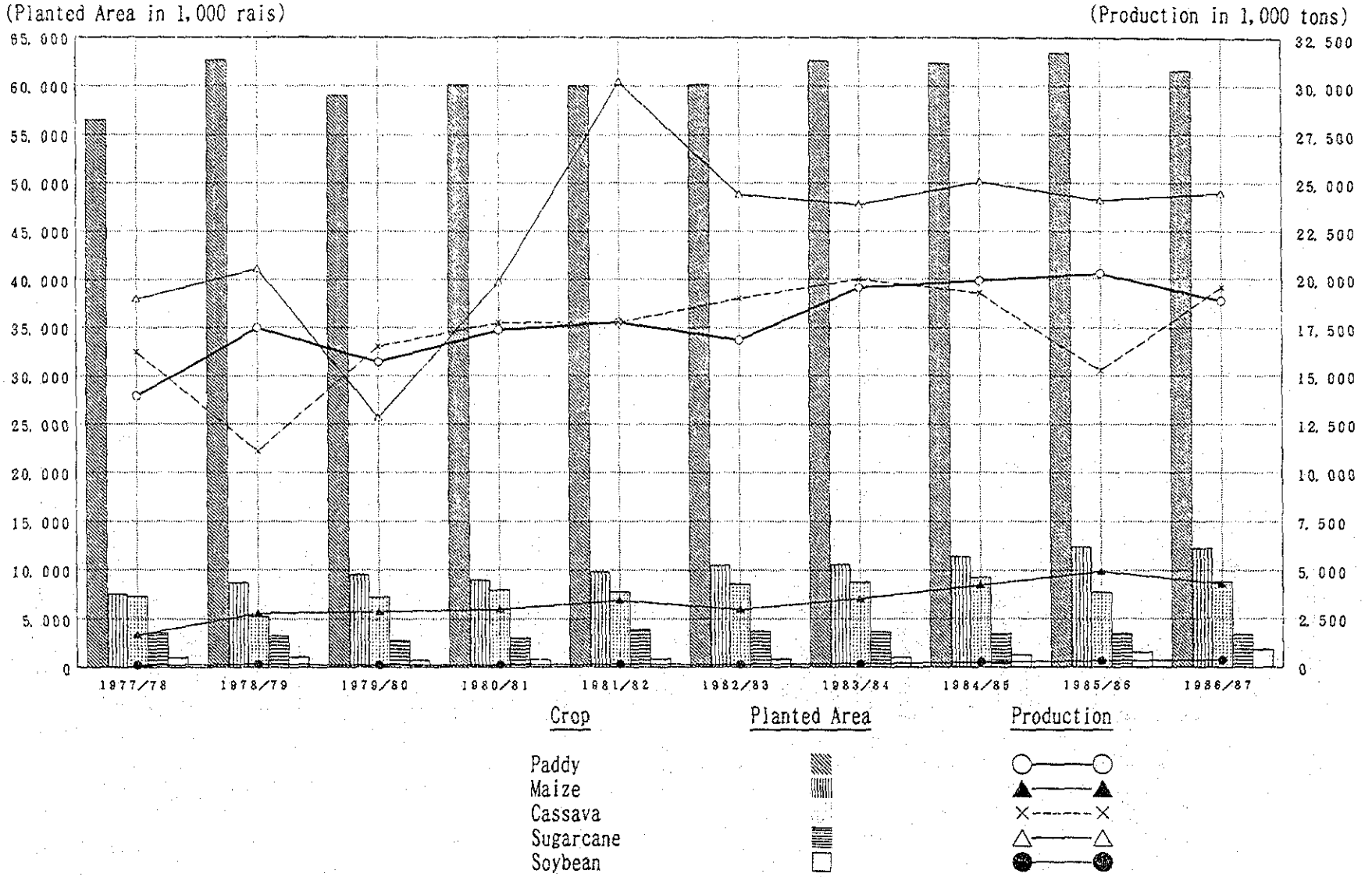


Figure 2-1 PRODUCTION TREND OF MAJOR CROPS IN THAILAND

CHAPTER 3

THE STUDY AREA

CHAPTER 3 THE STUDY AREA

3.1 Natural Features

3.1.1 Geography

Chao Phraya River Basin is located in between 14-20°N and 98-101°E shaped long slip in N-S direction. To the national territory of 514,000 sq.km, the basin occupies 162,600 sq.km as large as the one-third, and is surrounded by Mekong Basin in the North and East, Salween and Meklong Basins in the West and the Gulf of Thailand in the South. The basin may be divided into three; the upper basin of Northern highland, the middle basin of the middle flood plain and surrounding watersheds and the lower basin of the Chao Phraya Delta and its surrounding watersheds.

The upper basin is composed of watersheds of Bhumibol and Sirikit Reservoirs, Wang basin and upper part of Yom basin and is as large as 56,700 sq.km. Its alluvial fans and rolling terraces are good for farming and have almost already been developed. Highlands and forest areas to serve for water source, however by shifting agriculture by hill tribes and current excessive exploitation of forest resources some negative effects are now feared.

The middle basin is composed of flood plains upper than Nakhon Sawan along Ping, Yom and Nan Rivers and their surrounding watersheds and the upper part of Pasak River basin as large as 64,000 sq.km. The said 3 tributaries meet in Nakhon Sawan to form Chao Phraya River, where had sometimes been suffered floods from the tributaries before construction of the aforesaid two reservoirs.

The lower basin is composed of Chao Phraya Delta and its surrounding watersheds lower than Nakhon Sawan as large as 41,900 sq.km. Chao Phraya River branches off Suphan River, Noi River and

Lopburi River and joins with Noi River and Lopburi River again and Pasak River near Ayutthaya. Ground elevation in the delta is about 16 m MSL in the upper part then come slowly down to Ayutthaya as high as about 2 m MSL where is almost at the middle of the main water course in the delta. Ground slope lower than Ayutthaya then becomes almost horizontal as little as 1:50,000.

3.1.2 Meteorology and Hydrology

Climate in Thailand belongs to hot and humid tropical monsoon consisted of two seasons; wet season in May-October and dry season in November-April. Annual rainfall in the Study area varies 1,100 - 1,500 mm while in the largest granary of Thailand, Chao Phraya Delta, it rains as little as 1,100 - 1,200 mm in the Northern and West bank areas. Rainfall during wet season is distributed uneven and it varies considerably year by year. Therefore, even in wet season, paddy cultivation requires supplementary irrigation under the climate.

Chao Phraya River basin is as much as 110,000 sq.km, 32% of the national territory, and its annual runoff coefficient varies 0.13 - 0.47 in each tributary basin such as 0.22 in the upper basin of Bhumibol Dam and 0.47 in the upper basin of Sirikit Dam, while annual runoff and rainfall in the Chao Phraya River basin at Nakhon Sawan is 33,000 MCM and 1,220 mm, respectively, to show annual runoff coefficient 0.25 in average.

Floods to some extent emerge occasionally in the hill areas when local downpour happens, while those of wide extent is limited only in the middle and lower Delta. Flood in 1983 is the largest one in the recent decades, and the maximum instantaneous flow of 4,100 cms was recorded at Chao Phraya Dam in Chainat. Meanwhile in Bangkok Metropolis, some small floods sometimes occur due to deteriorated drainage capacity by land subsidence when downpour coincides with high tide.

Natures of water behavior in the upper and lower Delta differ much. In the upper Delta, water acts as flow under the control to distribute, make use of and drain out water by well-developed canal network and regulating structures. While in the lower Delta, water acts as conserved stock under the control water tables so as to store and reuse irrigation and drained water from the upper areas and rain water in efficient ways.

In order to promptly and precisely monitor the water behavior and to feed-back the information for water control operation in the Delta, a large number of observation sites are keeping monitoring. However, the records are not always effectively utilized due probably to complexity and tediousness in information communication and poor reliability of monitored water information, especially calibrated flows. Therefore, some improved reliable, efficient and practical information communication system and further efforts to examine reliability of water information such as overall revision of H-Q calibration charts/tables/formulae are strongly wanted.

Problems in water quality is limited only in the lower Delta. Salt intrusion in Chao Phraya River and Tachin River is controlled by water release for the purpose from the upper dam/regulator whenever salt concentration exceeds the allowable limit. Salt intrusion along the sea coast is periodically monitored and tidal gates are operated when the salt concentration exceeds the limit. Meanwhile in Bangkok Metropolis, water quality is much deteriorated in recent years due seemingly to increased sewerage from factories an residencial area caused by concentration of industries and population in the Metropolis. No damage in the adjacent irrigated land has been reported for the time being, however damages have already been reported in the adjacent fish/shrimp culture that the water pollution has become a severe problem.

Groundwater as one of water resources is abundant as a whole. Water potentiality in the alluvial aquifers in the middle basin is

immense. Zones of 20 km width along Ping, Yom and Nan Rivers may be developed not only by deep wells but also by shallow ones. In the Delta, areas upper than Sing Buri are similar to the middle basin, while areas lower than there is formed with 8 aquifers confined by about 20 m deep clay layer atop. Water extraction in a large extent in the city areas has caused severe land subsidence in the Metropolis that water extraction in the metropolis and adjacent 5 provinces are now under regal control.

3.1.3 Soil

In the upper basin, high terraces and fans are formed in all major alluvial basins. Soils in moderately drained areas are loamy-textured Gray Podzolic Soils, while in the slope areas they are gravel-textured Red Yellow Podzolic Soils and are use for upland crop farming. In the middle basin along low terraces, high terraces and fans are widely formed with soils of well-drained loamy till gravel-textured Grey Podzolic soils and are covered by forests.

Soils in hilly areas in the middle and upper basins are of products from granite, shale and its metamophic equivalents and marl as well-drained Red Yellow Podzolic Soils or Reddish Brawn Lateritic Soils.

In the lower basin, soil natures differ place to place. Along the coastal area, soils are poorly drained grey-colored clayey textured Saline Hydromorphic Alluvial Soils, while in the areas around Bangkok where is the center of tidal flats they are poorly-drained gray-colored Hydromorphic Alluvial Soils with very fine textures. And in areas between Bangkok and Ayutthaya, marine or older brakish water deposits are extended the soils are poorly-drained very fine-textured Hydromorphic Alluvial Soils of Acid Sulfate Soils, which are characterized by yellow jarosite mottles and extreme acidity in the profile.

In flood plains of recent alluvium developed along Chao Phraya River from Ayutthaya till Phitsanulok and Kamphaen Phet, soils on the higher plain are moderately-drained Loamy Alluvial Soils, while those in the low lying parts are fine loamy to clayey-textured Low Humid Gley Soils and are used for paddy farming.

3.1.4 Hydraulics in Chao Phraya Delta

Comparison of hydraulic characteristics in the Chao Phraya Delta is the first needs for planning of improved operation and control of irrigation and drainage water. In order to reinforce the present network of hydrological and hydraulic observation in the delta and to cross-examine reliability of the observed data, the Study team, in cooperation with RID, installed the hydrological observation equipment brought into Thailand for the Study, and then operated, observed and examined the following hydraulic characteristics.

(1) Analysis on fluctuation of water levels and discharges at major regulators in the delta:

Available existing data of water levels have been examined with records of automatic water level gauge installed for the Study and employed for statistical analysis after verification of their reliability. The analysis has been made at Chao Phraya Dam, Rama VI Barrage, regulators in Noi River, Suphan River, Chainat-Pasak Canal and the other major regulators in the delta. (Refer to the Chapter 4 of ANNEX-1)

(2) Examination of flow capacity of major irrigation canals

The Study Team conducted surveys on profile, cross-section and levels and flow measurements by use of equipment brought for the Study along Chainat-Pasak Canal and Raphiphathana Canal, which are the most important in the left bank area, for examination of flow

capacity. Water levels recorded by automatic gauges installed for the Study were employed for the examination.

In addition, surveys and examinations of canal cross-sections, regulator sill elevations and flow capacities in Chainat-Ayutthaya Canal, Noi River, Suphan River and a few other canals have been made. (Refer to ANNEX-1)

(3) Survey and analysis on water quality in salinity-affected area

In order to comprehend salinity intrusion in the area along the coast, Chao Phraya River, Thachin River and Ban Pakong River, the Study Team, in combination with RID, conducted water quality survey and tests by use of equipment brought for the Study. The results of the survey and tests are presented in the Chapter 5 of ANNEX-1.

(4) Flow measurement in Chao Phraya River at Pathum Thani

The Study Team, in combination with RID, conducted direct flow measurement at Pathum Thani in Chao Phraya River by use of flow measurement equipment brought for the Study. Water level records of an automatic gauge installed for the Study at the place and those at two other places were employed to yield water level-flow calibration-equations. It resulted that highly correlated formula (corr.= 0.8 - 0.9) were derived therefrom. (Refer to the Section 4.5 of ANNEX-1)

3.2 Water Use Facilities

3.2.1 Present Water Use Facilities and Their Background

Major water use facilities in Thailand are mostly constructed by the government, and their majority are irrigation and drainage facilities which are, together with the relevant facilities, under control of RID. Since establishment of the Canal Department, which

was the former body of RID, in 1902 RID has been continuing their construction and O&M up to date and developed 3.45 mill. ha of irrigable are in Thailand through large- and medium-scale projects. While in the Chao Phraya Basin, 1.81 mill. ha equivalent to 52% of the total is irrigated by the 192 projects.

Development of Chao Phraya Delta, as one of the largest granaries in Thailand, had been started since the establishment of the former body of RID to complete construction of the lower left bank in 1930's, of the lower left bank in 1950's, and of the upper Delta in 1960's sequentially. Meanwhile in the 1970's and 1980's the neighboring Meklong Phase I Project and Phase II Project had respectively been completed. In addition, Phitsanulok Phase I Project in the middle basin of the Study Area was completed in 1985.

Irrigation and drainage facilities in the Delta are accordingly as old as 30-50 years or more. And design concepts of them were based not on the modern water utilities but only on development of supplementary irrigation of wet season paddy by assuming no on-farm ditches through plot-to-plot irrigation/inundation. Such design of the original system has given a lot of difficulties in application to current dry season irrigation and diversified intensive water utilities.

3.2.2 Water Source Facilities

A number of the most important water source facilities in the basin are the two huge Bhumibol and Sirikit Reservoirs with gross storage capacities of respective 13,463 and 9,000 MCM, the largest three diversion dams of Chao Phraya Dam across Chao Phraya River, Rama VI Barrage across Pasak River and Naresuan Dam across Nan River. Rural storage capacity of the two reservoirs is as much as 95% of the basin total while service area of the three diversion dams is as much as 2/3 of the basin total of irrigable area.

The Bhumibol and Sirikit Dams were constructed in 1964 and 1972 respectively and are serving for hydropower, flood control and irrigation as multi-purpose dams and functions as supplementary source of water for wet season crops and major source for dry season crops in the Chao Phraya Delta. The two reservoirs are so important for the Delta that the present irrigation therein would not be imagined without them.

Chao Phraya Dam, completed in 1957 at Chainat, is located at the northern end of the Delta to dam-up water level of Chao Phraya River to divert the flow into the distribution network and at the same time to release required flow for river maintenance and downstream water needs. The dam is equipped with electric-drive 16 sets of 12.5 m wide and 7.5 m high radial gate and a navigation lock.

Rama VI Barrage, completed in 1924 located across Pasak River in Saraburi, dams up flow of the main channel and that from Chao Phraya River through Chainat Pasak Canal to divert water to the distribution network for the lower left bank area. The barrage is equipped with manual-drive 6 sets of 12.5 m wide and 10.4 m high steel-made slide gates and a navigation lock. The barrage was constructed about 60 years ago and is still maintaining its structural shape and functions as it was built without any restructuring.

Naresuan Dam, completed in 1985 across Nan River at Phitsanulok, dams up the flow to divert water to the whole areas of the Phitsanulok Phase I Project, and is equipped with electric drive 5 sets of 12.5 m wide 7.3 m high steel-made radial gates and a navigation lock. To the dam, flow of the Nan is released from the Sirikit Dam good enough to cover requirements for the areas as well as for the Chao Phraya Delta.

3.2.3 Water Conveyance and Regulating Facilities

Water conveyance and regulating facilities, which are the major concerns for field water management, had been constructed since the old days. Among them, the most key ones may be said the followings.

Whole canals are, in principle, unlined earth canals and under management of RID until at farm turn-outs along main, lateral and sub-lateral canals. The 25 project areas in the Chao Phraya Delta which receive water of Chao Phraya River may be divided into two categories of areas by irrigation manners as gravity irrigation and water conservation irrigation areas; the former covers 17 projects in the northern parts of the delta and the later in the southern 8 project areas and their major component facilities are quantified as in the following table.

3.2.4 On-farm Facilities

Farm turn-outs, which serve 30-60 ha each, are the terminal level of irrigation water control by RID, and the beneficial farmers control the system after them. Farm ditches were limited to only short lengths from FTOs when originally constructed to serve in plot-to-plot irrigation without any ditch network. Therefore the on-farm system was an inconvenient one to practice efficient rotation irrigation.

RID therefore commenced the so-called Ditch and Dike Project to provide the system with farm-ditch network of 25 m/ha in 1961, and up to date one mill. ha have been provided in the Central Plain including Mekong Delta. Furthermore, the Land Consolidation Act was enacted and such projects started since 1974. To date about 90,000 ha have been consolidated by the projects in the gravity irrigated areas of the Delta. There are two typical ways of land consolidation; with or without land leveling. The latter has recently been popular due mainly to financial and economic reasons.

Densities of ditches, farm-roads and drain ditches are 35-45 m/ha, and capacity of irrigation ditches is 1.3 l/ha, which is more than that of laterals by 50%, so as to perform rotational irrigation right after the consolidation.

3.2.5 Other Facilities

(1) Pumping Facilities

A large number of small pumping stations are found along Nan River and Chao Phraya River in the upstream of Chainat. In the Delta, Bang Ban Project area is totally irrigated systematically by 12 pumping stations. A large number of private-owned portable pumps are popularly used to irrigate small pieces of elevated land in the gravity areas and to pump-up water in canal network conserved for dry season use in the water conservation area.

Pumping stations for drainage are only in/around the Metropolis. They are those recently constructed along Chao Phraya River and the Gulf Coast to improve drainage being deteriorated by land subsidence therein. Among them, the largest one is Phrakanon Pumping Station equipped with 35 sets of 1.00 m bore and total capacity of 100 cms.

(2) Flood Protection Dike

Since the largest flood in 1983 in current years, construction of flood protection dikes has continuously been planned and implemented all over the Delta. Those around the Metropolis have already been completed, and in the Delta the construction is continued along not only Chao Phraya River but also Noi River, Suphan River, Bang Pakong River and canals of project area boundaries.

(3) Hydrological Observation Facilities

Details of existing facilities for hydrological observation in the basin and those brought in and installed by the Study Team are presented in ANNEX-1, Chapter 2 and 3 for reference.

3.3 Present Agriculture

3.3.1 Crop Production

Table 3-3 clearly shows that the Chao Phraya River Basin has played a quite important role for crop production in the whole Kingdom, occupying 51% of total paddy production, 83% of dry season paddy, and around 90% of mungbean, sorghum and soybean, while the basin occupies only 33% of the farm land.

3.3.2 Land Use

Paddy cropping is predominantly practised in RID Regions 7 and 8, in which better irrigation condition is available. In RID Regions 1 and 2 of the upper basin, rate of dry season cropping is smaller than in the other Regions, however various kind of fruits and upland crops are cultivated. In addition that RID Region 3 of the middle basin produces rather big amount of wet season paddy, field crops such as maize, cassava, sugarcane, mungbean and soybean are intensively grown, especially producing 64% of mungbean in the whole Kingdom.

Forest land has hastily converted to the other purpose mainly farm land, especially in the upper and middle basins.

3.3.3 Irrigated Agriculture

The ratio of irrigable area against cultivated land is highest in RID Region 9, followed by Regions 7, 1 and 8, but only about 3.3%

of Region 9 area is included in the Study area, and the cultivated area occupies quite small portion in Region 1 which develops along the Chiang Mai valley. Therefore, it can be said that an irrigated agriculture is predominantly carried out in RID Region 7 and 8 in the basin, and Region 7 produces about 60% of dry season paddy in the whole Kingdom.

3.3.4 Farm Mechanization

A farm machinery used most popularly in the basin is a 2-wheel hand tractor, and its diffusing rate is one unit per six farms on an average, ranging one for four farms in Regions 3 and 8, one for five in Region 7, one for sixteen in Region 1, and one for fourteen in Region 2. This indicates that farm mechanization is more advanced in paddy cropping area. A threshing machine is also mainly used in the delta area, on the contrary, threshing works are done by hand in the upper basin.

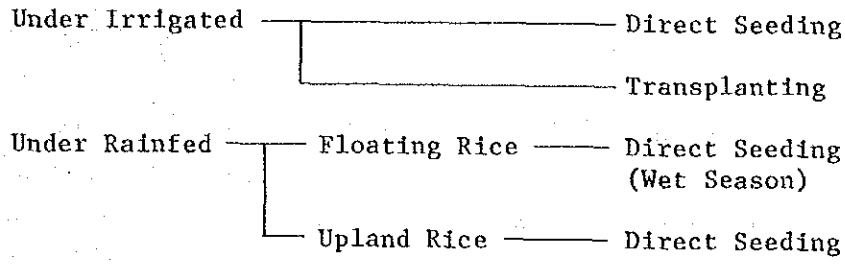
The diffusion rate of a small pump for irrigation is highest in Region 7, one unit for three farms, followed by Region 8 and then 3.

3.3.5 Land Holding

An average management size per farm in the entire basin is 3.9 ha which is a little bit smaller than that of national average, 4.3 ha. Proportions of owner farmers and tenant farmers are, averagely, 70% and 30%, and the rate of owner farmer tends to decrease in Changwats of Nonthaburi and Samut Prakan.

3.3.6 Pattern of Paddy Cropping

Pattern of paddy cropping differs from one area to another, being reflecting various conditions such as climate, topography, soil, hydrology, socio-economy and so on, as summarized below;



In these patterns, the floating rice is grown in inundation areas with water depth ranging two to four meters during wet season, of which total cropping area in 1986/87 reached to 228,300 ha. The inundation areas extend in the middle part of the delta centering around Ayutthaya and in the eastern suburbs of Bangkok Metropolis.

Recently, areas under the direct seeding method tend to increase in the delta, in order to reduce a production cost by saving farm labour cost for transplanting seedlings of paddy. Since the direct seeding method requires more irrigation water than transplanting method, it causes big problems and conflicts for water use especially during dry season.

While proportions of direct seeding method and transplanting one in the entire basin is 68% and 32%, the latter is mostly practised in the RID Regions 1 and 2 of the upper basin.

3.3.7 Cropping Pattern

Most of all cropping patterns prevailing in the Study Area are based on paddy cropping, with some variation reflecting local characteristics, of which typical patterns are summarized in the following;

Basin	Dry Season	Wet Season	Remarks
Upper	Garlic	Rice	
(Region 1, 2)	Tobacco	Rice	
	Vegetables	Rice	
	Groundnut	Rice	
	Soybean	Rice	Most popular type
Middle	Rice	Rice	With good irrigation
(Region 3)	Soybean	Rice	
	Rice	Maize	Phetchabun, Nakhon Sawan
	Maize	Maize	Nakhon Sawan
Lower	Rice	Rice	
(Region 7, 8, 9)	Vegetables	Vegetables	Bangkok suburbs
	Fruit	(Fruit)	Rangsit area

3.3.8 Agricultural Supporting Services

(1) Agricultural extension office

Agricultural extension services in Thailand is mainly conducted by Department of Agricultural Extension which has 10 divisions, six Regional Extension Offices, 73 Provincial Extension Offices, and 720 District Extension Offices as a terminal extension organization.

(2) Certified seeds production

Seed Division under the Department of Agricultural Extension takes charge of certified seeds production and distribution. There are 20 seed centers in the whole Thailand as of May 1986, which produces about 30,000 to 40,000 tons of seeds (1,500 - 2,000 tons/center), amounting to 20 to 30 percent of the total seed requirement. There are nine seed centers in the Study Area.

(3) Agricultural credit

Banking agencies for farmers are Bank for Agriculture and Agricultural Cooperatives (BAAC) and commercial banks. BAAC finances to farmers and agricultural cooperatives and agricultural groups as main clients. There are three kinds of credits such as short-term, medium-term and long-term, and financed amount is the highest in short-term credit.

Following four credits are prepared for agricultural cooperatives.

- Finance for the members loan
- Finance for purchasing agricultural materials
- Finance for purchasing agricultural products from member
- Finance for the fund for long-termed investments

(4) Agricultural research institutes

Experiments and researches on agriculture are carried out by each department under the Ministry of Agriculture and Cooperatives; in details, experiments on crops by Department of Agriculture, livestock and forage crop by Department of Livestock, irrigation and drainage by RID and land improvement by Department of Land Development, respectively.

The central experimental station belonging to the Department of Agriculture is located at Bang Kaen neighbouring to Bangkok and branch stations are distributed throughout the country in order to research paddy, field crops, horticulture, sericulture and rubber. Training Division of the Rice Research Institute is in charge of technical transfer on experiments and farming of paddy to the technologist of the Department of Agriculture and Department of Agricultural Extension.

In addition, there are four Regional Agricultural Development Centers in Thailand, two of which are located at Chiang Mai and Chainat in the Study Area, researching agricultural problems facing by farmers from technical and economic viewpoints.

3.3.9 Farmer's Organization

(1) Cooperatives

There are six kinds of cooperatives in Thailand. The rate of participating members in the agricultural cooperatives is 18 percent for the whole Thailand and 21 percent in the Study Area. The most serious problem in managing cooperatives is a low participation rate.

(2) Agricultural groups

By regulation, the agricultural group is in a position to be transferred to the agricultural cooperative in the future and the group's activity is similar to that of the agricultural cooperatives. As of 1985, number of members of agricultural groups is only 12 percent of the total farm household in the Study Area.

3.4 Socio-Economic Condition

3.4.1 Social Infrastructure

(1) Road networks

As shown in Figure 3-1, the main road networks connecting major municipalities with each other are well consolidated for more convenient and speedy communication than other communication systems. Particularly the national highway No. 1 (823 km) connecting Bangkok with Chiang Rai via Saraburi is completely paved and is the main road for transportation in the Study Area.

(2) Railway

The railway is less consolidated than the road networks, and operation length of the State Railway of Thailand (SRT) as of 1982 is 3,735 km and new line has not been constructed since 1970.

The railway networks of SRT are laid radially from Bangkok, as northern line, northeastern line, eastern line, and south line (Refer to Figure 3-1). As for Mae Klong line, running western part of Bangkok with 67 km length, is not connected with the aforesaid four main lines and cut off at Khwae Noi River.

In the Study Area, northern line runs between Bangkok and Chiang Mai and the railway networks are provided to connect major municipalities. The northern line, main railway in the Study Area, is double lined between Bangkok and Ban Phachi for 90 km, but others are single-lines and electrification of the lines has not been realized yet.

(3) Airlines

In the Study Area, there are eight airports for regular flights, out of which Bangkok and Chiang Mai Airports are the international airports. Demand for the domestic transportation by airplanes has been also increased and become indispensable as communication system because of the more speedy transportation than any other means of transportation.

(4) Inland water transportation

The total length of canal in Thailand reaches about 3,000 km and particularly, the canal networks of the Chao Phraya River Basin are the largest in the Country. Those canal networks have been used for the transportation of gravels, cement, paddy, maize, and so on; however, the problems on water-borne transportation is that the year

round navigation is impossible due to fluctuation in water depth and high cost canal dredging.

(5) Power generation

In 1983, the total generating capacity in Thailand was 4,976 MW and the total generated power was 19,066 GWH. In the power generation, 21 percent is by hydropower and the remainder is by thermal power.

Out of 14 hydropower plants managed by Electricity Generating Authority of Thailand (EGAT), almost of the existing hydropower plants including Bhumibol Dam with 535 MW capacity and Sirikit Dam with 375 MW capacity are located in northern and central plain regions.

(6) Water supply

"Population and Housing Census of 1980" shows that the housing rate equipped with water supply is 16 percent for whole Thailand and 70 percent in the Bangkok Metropolis. In the rural area, public and private wells are popularly used. In the Bangkok Metropolis, land subsidence caused from over-pumping of groundwater has become a social problem.

3.4.2 Regional Economy

According to geographical division of Thailand, the Study Area covers the entire area of North Region and most of Central Plain Region, relating to six (6) RID Regional Offices of No. 1, 2, 3, 7, 8 and 9, and 33 changwats. On the basis of 1980 census, total number of households and total population in the Study Area are estimated at 3,709 thousand households and 18,466 thousand capita, among which agricultural households and population are 1,687 thousand households and 8,605 thousand capita, respectively.

According to gross regional and provincial product in 1986, the Study Area produced about 678.3 billion bahts in current prices, occupying 63 percent of Gross Domestic Product, 1,098.4 billion bahts. Out of the gross regional product in the Study Area, 678.3 billion bahts, manufacturing sector produced 174.0 billion bahts occupying top position, and their commercial sector 118.5 billion bahts, service sector 79.6 billion baths, and agricultural sector accounts for 62.5 billion baths at 6th position, following banking and transportation sectors.

3.4.3 Human Resources

As of 1985, population in Thailand is 51,795,650 and annual growth rate since 1980 is accounted at 2.0 percent. According to the projection by NESDB, population is estimated to be 55,458,000 in 1989. Presently 82 percent of population is living in rural areas.

Population in the Study Area is about 21,281 thousand in 1985, corresponding to 41 percent of the total population in Thailand. Bangkok Metropolis has 5,363,000 population which corresponds to 25 percent of the Study Area, causing over-centralization phenomenon.

Workable population above 11 years of age in the Study Area is estimated at about 9.4 million (45%) and out of them 6.8 million people (72%) are engaged in agriculture.

Table 3-1 KEY WATER CONVEYANCE AND REGULATING FACILITIES

Facilities	Dimensions	Remarks
(Regulating Facilities)	No W H	
Phonlathep Regulator	4-6.50 x 7.30	at the head of the Suphan
Borommathat Reg.	4-6.00 x 6.30	at the head of the Noi
Manorom Regulator	6-6.00 x 3.80	at the head of Chainat-Pasak C.
Phra Narai Reg.	8-4.20 + 5-3.00	at the head of Raphiphatana C.
(Conveyance Facilities)		
Suphan River	(natural river)	for irr. drain. and navig.
Noi River	(-do-)	-do-
Chainat-Pasak Canal	130 km	130-240 cm in upper E-bank
Raphiphatana Canal	33 km	80-100 cm in lower E-bank

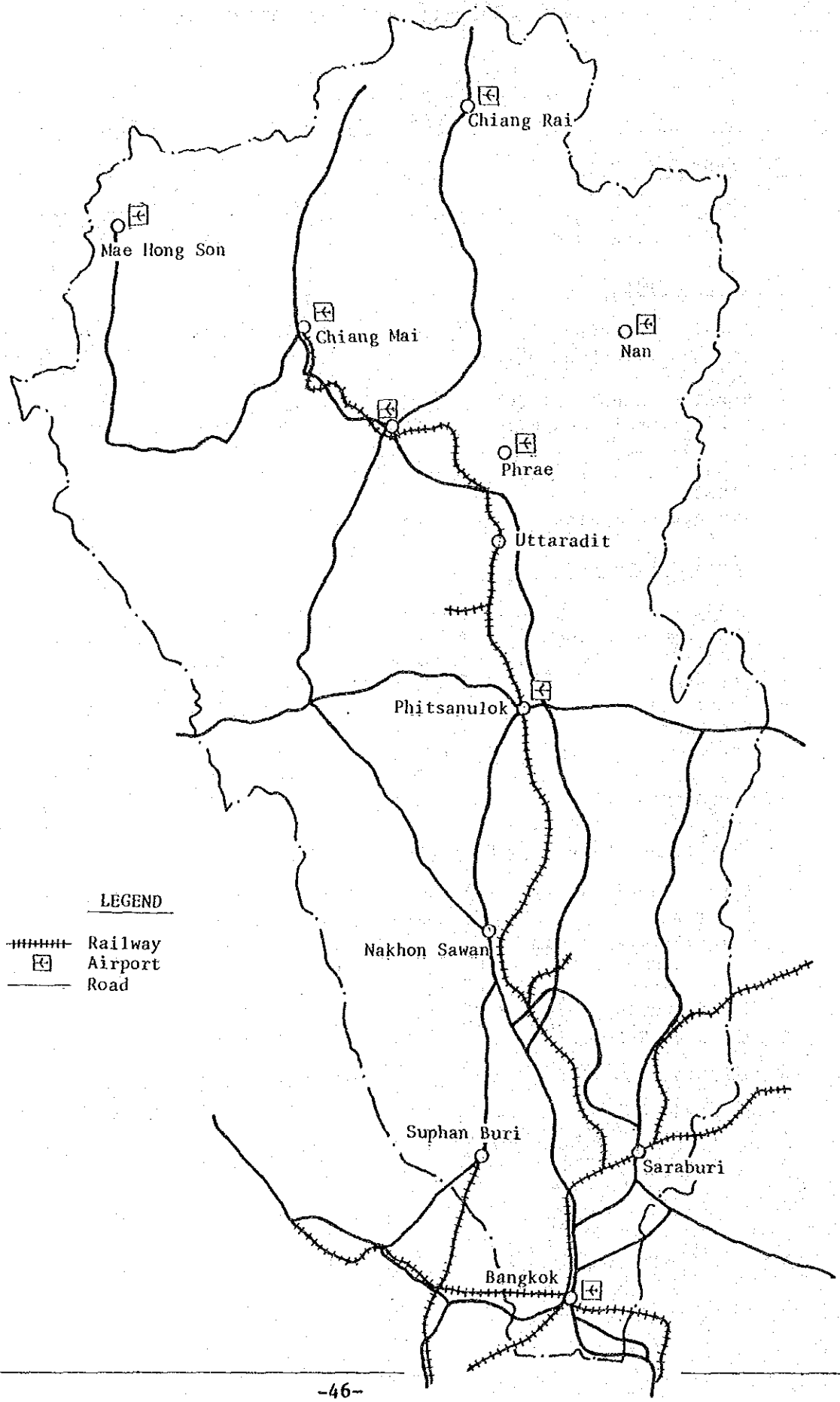
Table 3-2 MAJOR COMPONENTS OF WATER CONVEYANCE AND REGULATING FACILITIES OF 25 PROJECT AREAS IN THE DELTA

Facilities	Gravi.Irri. Area (km)	Wat. Consv. Area (km)	Total (km)
(Irri. Canal)			
0 - 1 cms	1,606.8	0	1,606.8
1 - 10	1,361.5	422	1,783.5
10 - 30	227.9	35	262.9
30 - 100	126.8	52	178.8
100 -	166.9	0	166.9
Sub-total	3,489.9	509	3,998.9
Drainage Canal	2,387	216	2,603
Major Navi. Canal	0	780	780
Other Canal	0	3,914	3,914
Canal Total	5,876.9	5,419	11,295.9
(Regulator)			
Width 5 m or less	96 plcs	148 plcs	244 plcs
5 - 15 m	45	120	165
15 m or more	26	11	37
Sub-total	167	279	446
Pipe-culvert	1,028 plcs	98 plcs	1,126 plcs
Farm Turn-out	6,138 plcs	227 plcs	6,365 plcs
(Irrigable Area)	4.8 mill.rai	3.5 mill.rai	8.3 mill.rai

Table 3-3 MAGNITUDE OF THE STUDY AREA

Item	Unit	Whole Thailand	Study Area
1. Land Use			
- Total Land	1,000 ha	51,312 (100%)	19,060 (37.1%)
- Farm Holding Land	1,000 ha	20,050 (100%)	6,611 (33.0%)
2. Demography			
- Total Population (1985)	1,000	51,796 (100%)	21,281 (41.1%)
- Agricultural Population (1980)	1,000	25,903 (100%)	8,605 (33.2%)
- Total Household (1980)	1,000	8,460 (100%)	3,710 (43.9%)
- Agricultural Household (1985)	1,000	4,676 (100%)	1,687 (36.1%)
- Population Density (1985)	per km^2	100	112
- Average Farm Size	ha	4.3	3.9
3. Agricultural Production (1986/87)			
- Paddy	1,000 t	18,868 (100%)	9,555 (50.6%)
(Dry Season Paddy)	1,000 t	(2,042 (100%))	(1,686 (82.6%))
- Maize	1,000 t	4,309 (100%)	2,745 (63.7%)
- Cassava	1,000 t	19,554 (100%)	1,692 (8.7%)
- Sugarcane	1,000 t	24,450 (100%)	9,343 (38.2%)
- Mungbean	1,000 t	301 (100%)	275 (91.4%)
- Sorghum	1,000 t	211 (100%)	193 (91.5%)
- Soybean	1,000 t	350 (100%)	308 (86.5%)
- Groundnuts	1,000 t	169 (100%)	102 (60.4%)
4. Gross Domestic/Regional Products (1986)			
- Agricultural Sector	10^6 Bahts	183,037 (100%)	62,533 (34.2%)
° Crop	10^6 Bahts	124,906 (100%)	46,884 (37.5%)
° Livestock	10^6 Bahts	26,669 (100%)	9,768 (36.6%)
° Fishery	10^6 Bahts	17,564 (100%)	4,236 (24.1%)
° Forestry	10^6 Bahts	13,898 (100%)	1,645 (11.8%)
- Manufacturing Sector	10^6 Bahts	226,572 (100%)	174,011 (76.8%)
- Other Sectors	10^6 Bahts	688,757 (100%)	441,725 (64.1%)
- Total	10^6 Bahts	1,098,366 (100%)	678,269 (61.8%)

Figure 3-1 TRAFFIC NETWORK IN THE STUDY AREA



CHAPTER 4

FINDINGS AND CONSTRAINTS IN CURRENT WATER MANAGEMENT

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4.1 Achievements of Irrigated Agriculture and Future Prospects

Irrigated agriculture in Thailand has achieved a remarkable development since the beginning of this century to date by implementation of a large number of large scale irrigation projects with helps of favorable climate and fertile vast lowland delta. Irrigated agriculture practiced widely in the delta has mostly been subject to wet season paddy cropping. And the products are of low price and high quality with high competitiveness in the world market and exported a large quantity to contribute as one of major exports to earn foreign exchange.

Low price and high quality of Thai rice are due not only to good variety of paddy but also to the rather low cost of production in the Asia caused by very extensive farm management, under which little investment for farm inputs such as agro-chemicals are made even cropping is advantaged by natural flooding and/or artificial water supply. Increasing demands of paddy for domestic consumption and exports had been met by expansion of cropping area in the whole country, and to date further increase of the area may not be expected.

In parallel with the demand increase, efforts for improvement of productivity has been continued such as improvement, construction and management of irrigation and drainage systems and development of water resources. In addition to wet paddy, new and various water utilities have thereby become available such as irrigation of dry season paddy, upland crops fruit trees, fish ponds etc. And thus availed water has accordingly been managed. However, in the current years the supply cannot meet with the increasing demands and therefore restrictions on crops and cropping area are imposed in dry season.

In combination with industrialization, development of agricultural production is one of key long-term policies for national development. However to date, availability of land and water resources themselves has come to constraints of the development. For future development of irrigated agriculture, dissemination and achievement of the following 4 activities will necessarily be required.

(1) Precise, equitable, timely and stable water supply
(2) Decreased water demand by replacement by field crops
(3) Intensive farming of high-return crops
(4) Education of farmers and promotion of their cooperative activities

Precise, equitable, timely and stable water supply is a promise for stable farm management, and by achievement of this farmers can safely invest on fertilizers and pesticides and they do not selfishly and wastefully take water to give no stresses onto the neighboring farms and they can consequently enjoy intensive farming equally without water losses. Achievement of such water supply will require well-equipped water use facilities and high level know-hows for efficient operation and management.

Water consumption by field crops is usually less than half of that of paddy, which implies that more than double of farmland can grow them by replacing paddy. In the delta at present irrigation for dry season paddy is still performed in a part, and the area totally relies on water from the upstreams reservoir storages. By replacing by field crops water saving will, therefore, be considerable. Meanwhile in the current world market, rice is used to be oversupply and the price fluctuates much and is becoming one of non-high-return crops as it was. Replacement of paddy by other high-return crops has therefore come to more feasible than before.