No. 2

KINGDOM OF THAILAND
ROYAL IRRIGATION DEPARTMENT
MINISTRY OF AGRICULTURE AND COOPERATIVES

THE FEASIBILITY STUDY ON THE AGRICULTURAL WATER DEVELOPMENT PROJECT OF CHANTHABURI RIVER BASIN

Main Report

JUNE 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

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ROYAL IRRIGATION DEPARTMENT
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PREFACE

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

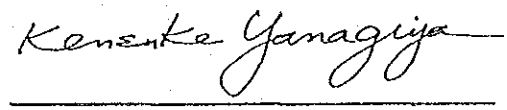
JICA sent to the Kingdom of Thailand a study team headed by Mr. Satoshi Kadowaki, Sanyu Consultants Inc., three times from April, 1988 to March, 1989.

The team held discussions with the officials concerned of the Government of the Kingdom of Thailand and conducted a field survey in Chanthaburi River 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 deep appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the team.

June, 1989



Kensuke Yanagiya

President

Japan International Cooperation Agency

June, 1989

Mr. Kensuke Yanagiya
President
Japan International Cooperation Agency
Tokyo

Dear Sir,

LETTER OF TRANSMITTAL

It is our pleasure to submit herewith the Final Report of the Feasibility Study on the Agricultural Water Development Project of Chanthaburi River Basin.

The field survey and study have been conducted in two stages during the period from April 1988 through March 1989.

This Report consists of two separate volumes: Volume-1 - Main Report of the study which describes the results of survey and analysis; and Volume-2 - Appendix to the main report which provides the supplemental information on both the technical and socio-economic aspects. In addition to these reports, the pre-feasibility study report, which deals with the overall water resources development schemes and selection of the priority sub-project covering the entire Chanthaburi River basin, has already been submitted in September 1988 as the Interim Report of the Study.

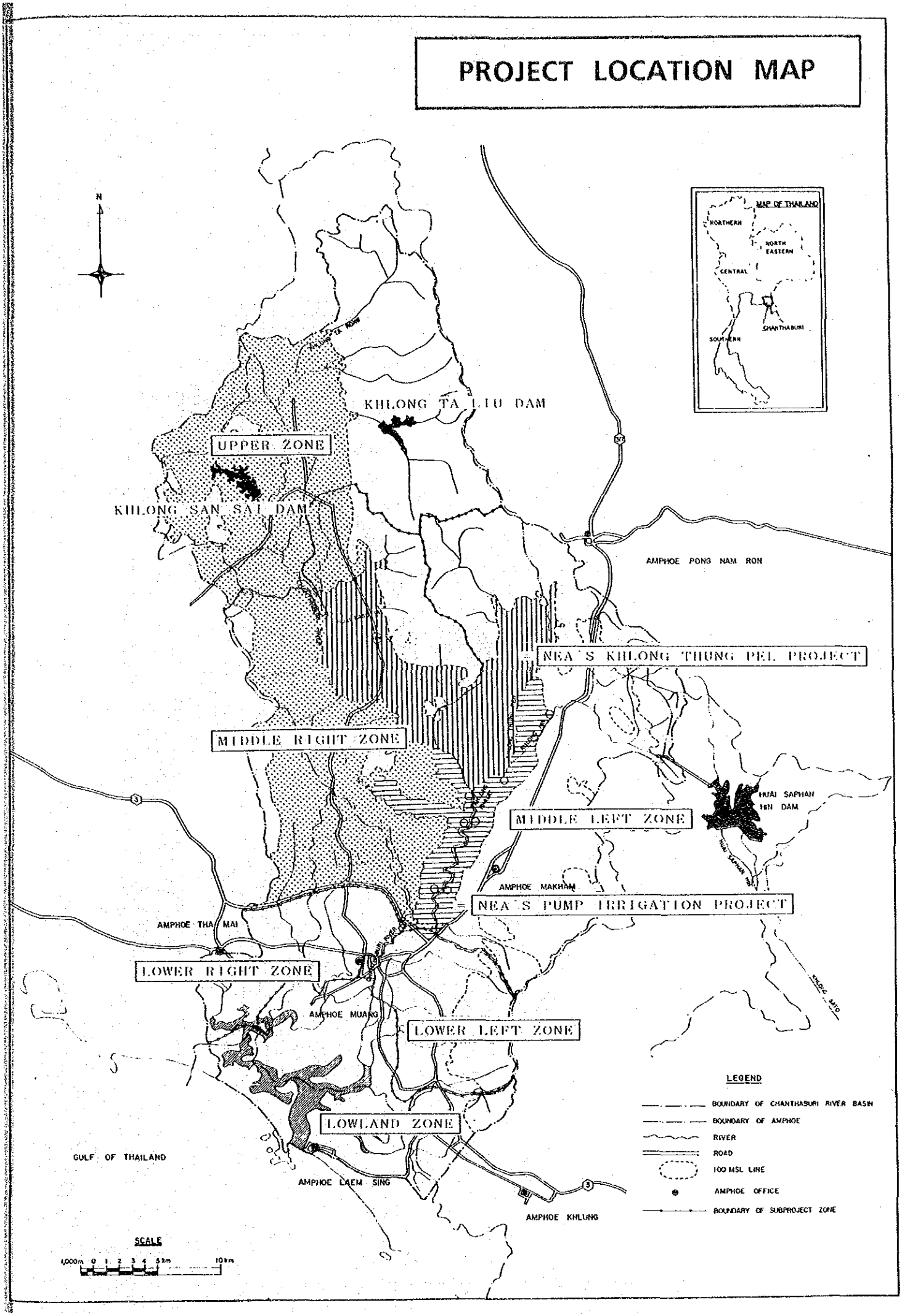
We hope that implementation of the proposed Project would greatly contribute to the regional economy especially through promotion of tropical fruit production. Finally, we would like to take this opportunity to express our sincere gratitude to Japan International Cooperation Agency, Ministry of Foreign Affairs, Ministry of Agriculture, Forestry and Fisheries of the Government of Japan, the Embassy of Japan in Thailand, Advisory Committee and the officials concerned of the Government of Thailand for their utmost cooperation and useful advices given to the study team during the periods of field survey and home office work.

Very truly yours,

S. Kadowaki

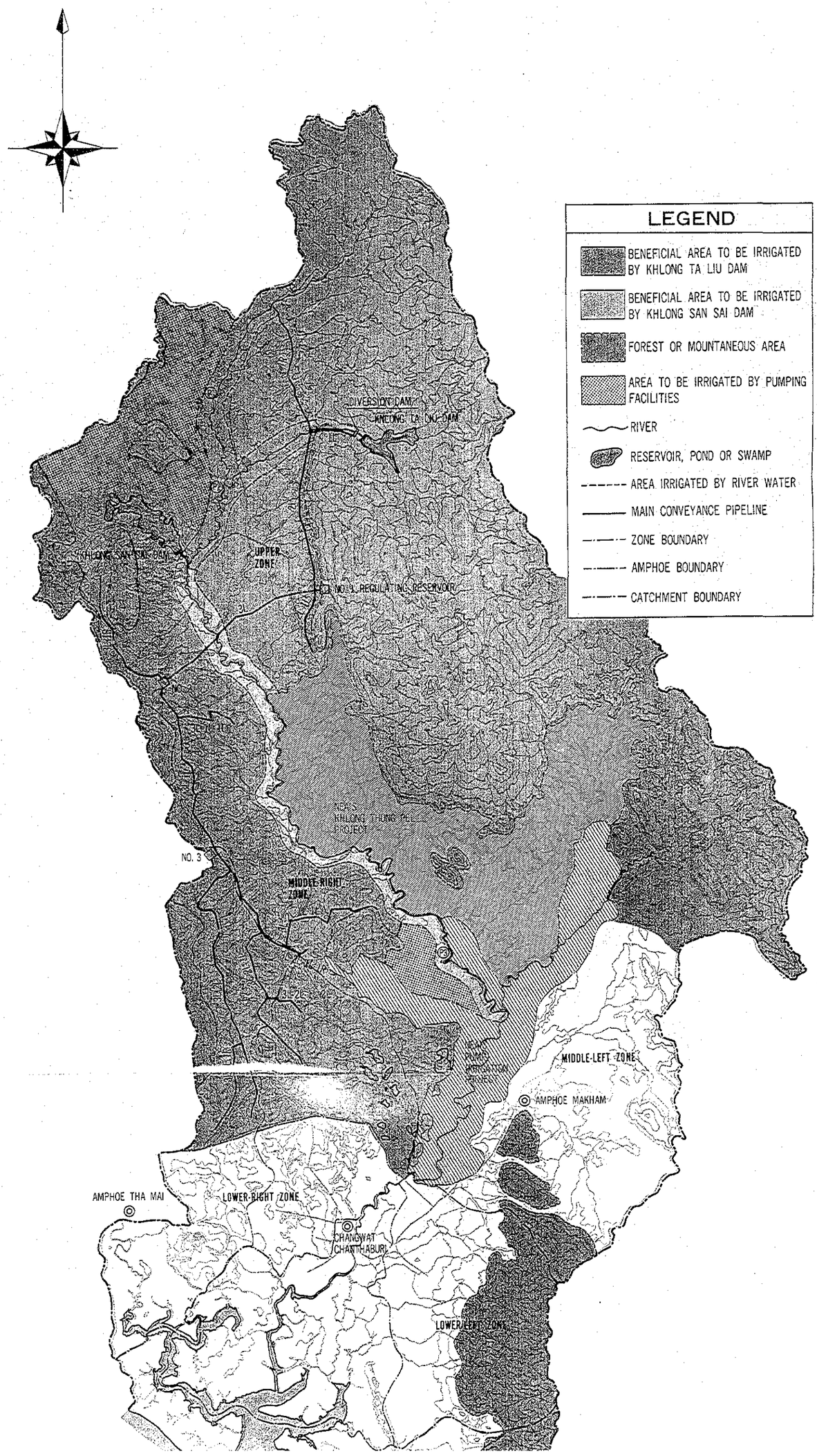
Satoshi Kadowaki
Team Leader
Agricultural Water Development
Project of Chanthaburi River

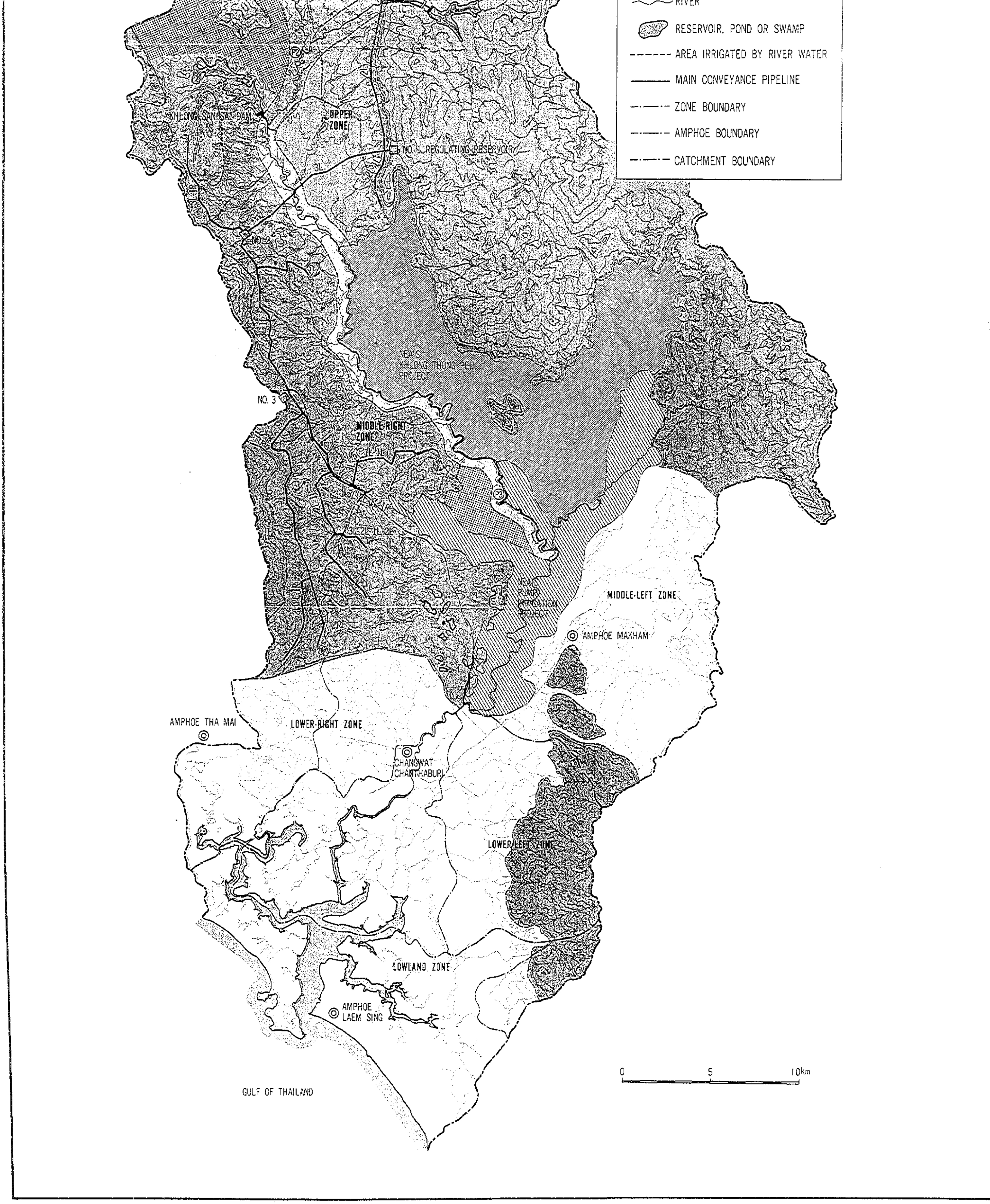
PROJECT LOCATION MAP



GENERAL PLAN

THE AGRICULTURAL WATER
DEVELOPMENT PROJECT
OF CHANTHABURI RIVER BASIN




RIVER
RESERVOIR, POND OR SWAMP
AREA IRRIGATED BY RIVER WATER
MAIN CONVEYANCE PIPELINE
ZONE BOUNDARY
AMPHOE BOUNDARY
CATCHMENT BOUNDARY
KHLONG SIN SAI DAM
UPPER ZONE
NO. 1 REGULATING RESERVOIR
NO. 3
MIDDLE-RIGHT ZONE
MIDDLE-LEFT ZONE
AMPHOE MAKHAM
AMPHOE THA MAI
LOWER-RIGHT ZONE
CHANGWAT CHANTHABURI
LOWER-LEFT ZONE
LOWLAND ZONE
AMPHOE LAEM SING
GULF OF THAILAND
0
5
10km

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CURRENCY EQUIVALENTS

- at 1988 OCTOBER term -

US$ 1.00 = Baht 25.50

Baht 1.00 = US$ 0.04

UNITS OF MEASUREMENT

1 rai = 0.16 ha = 1,600 sq.m

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

THAI FISCAL YEAR

October 1 to September 30, next year

ABBREVIATIONS AND ACRONYMS USED

THAI GOVERNMENT

BAAC	:	Bank for Agriculture and Agricultural Cooperatives
CDD	:	Community Development Department, MOI
CPD	:	Cooperatives Promotion Department, MOAC
DOA	:	Department of Agriculture, MOAC
DLD	:	Department of Land Development, MOAC
DOAE	:	Department of Agricultural Extension, MOAC
DOF	:	Department of Fisheries, MOAC
DOLA	:	Department of Local Administration, MOI
MD	:	Meteorological Department, MOC
MOAC	:	Ministry of Agriculture and Cooperative
MOF	:	Marketing Organization for Farmers, MOAC
MOI	:	Ministry of Interior
NEA	:	National Energy Administration, Ministry of Science, Technology, and Energy

NEB	:	National Environment Board, Ministry of Science, Technology and Energy
NESDB	:	National Economic and Social Development Board, Office of the Prime Minister
NSO	:	National Statistical Office, Office of the Prime Minister
ORRAF	:	Office of Rubber Replanting Aid Fund, MOAC
PEA	:	Provincial Electricity Authority, MOI
PWWA	:	Public Water Works Authority
RFD	:	Royal Irrigation Department, MOAC
RID	:	Royal Irrigation Department, MOAC

GENERAL

฿	:	Baht
EL	:	Elevation above Mean Sea Level
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
JICA	:	Japan International Cooperation Agency
M.	:	Million
NPV	:	Net Production Value
WL	:	Water Level
cu.m	:	Cubic meters
MCM	:	Million cubic meters
kw	:	Kilowatt
kwH	:	Kilowatt hour
l	:	Liter
ha	:	Hectare
m	:	Meter
mm	:	Millimeter
kg	:	Kilogram
km	:	Kilometer
sq.km	:	Square kilometers
sq.m	:	Square meters
ton	:	Metric ton
p.a.	:	per annum
yr	:	Year
hr	:	Hour

min	:	Minute
sec	:	Second
°C	:	Degree centigrade
mS/cm	:	Milli siemens per centimeter (same as m.mho/cm)
HP	:	Horsepower
ppt	:	part per thousand

GLOSSARY

Changwat	:	Province
Amphoe	:	District
Tambon	:	Sub-District
Muban	:	Village
Khlong	:	A tributary of the large river

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SUMMARY

SUMMARY

1. Introduction

1.1 In response to the request of the Kingdom of Thailand, the Government of Japan through the Japan International Cooperation Agency (JICA) dispatched the Preliminary Study Team to Thailand and concluded the Scope of Work for the Technical Cooperation (S/W) between the Royal Irrigation Department (RID) and JICA for the Feasibility Study on the Agricultural Water Development Project of Chanthaburi River Basin dated on March 13, 1987.

In accordance with the S/W, JICA dispatched the Study Team composed of 10 members to Thailand for two times of the field survey during the period from 1988 to 1989.

1.2 This Final Report consists of Main Report and Appendix which were prepared based upon the findings and observations of the field survey. The Final Report mainly concentrates upon the priority area (Upper and Middle Right Zones of the Chanthaburi River Basin) to which priority was given through a series of discussions and analyses as mentioned in the Interim Report (Pre-Feasibility Study Report on September, 1988) and as summarized in the Chapter 2 of this report.

2. Summery of the Pre-Feasibility Study

2.1 Chapter 2 of this report summarizes the Pre-Feasibility Study which covers the entire Chanthaburi River Basin. The major components required for the subject basin development as concerns agricultural development and irrigation and other water conveyance systems' consolidation are summerized as follows ;

Agricultural Development

- Increase of crop yield by means of improvement of farming technique and of providing stable source of irrigation water.
- Rubber of local variety to orchard conversion.
- Upland crops, mainly cassava, to orchard conversion.
- Establishment of orchard farming systems of high quality variety and improvement of collection and forwarding systems of agricultural products.
- Establishment of pilot farm and strengthening of research facility.

Irrigation Systems Consolidation

- Construction and rehabilitation of storage dams, intake facilities, barrages, regulating reservoirs and other structures required for water resources development.
- Installation of irrigation water conveyance and distribution systems.
- Consolidation of on-farm irrigation facility in newly developed area.
- Introduction of water management systems.

Other Water Conveyance Systems Consolidation

- Establishment of water resources development plan based on long term prospect of domestic water supply, covering not only existing service area but also rural area.
- Establishment of water resources development plan for brackish water fishery, in response to the current movement in the lowland area.

2.2 To realize above-mentioned project components, the Project aims to foster the farmers of complex farming with highly improved agricultural incomes, by means of introducing double cropping on the existing paddy field, converting part of existing cassava field into orchard, accelerating replantation of high yield variety for rubber and converting a part of rubber field into orchard. Such modified land use plan (crop conversion plan) is summarized as follows:

	Projected Land Use Plan				
Existing Land Use	Orchard	Rubber	Upland	Paddy	Total
Orchard	25,160				25,160
Rubber	2,964	14,653			17,617
Upland	2,284		6,803		9,087
Paddy	53			7,753	7,806
Total	30,461	14,653	6,803	7,753	59,670

2.3 In the irrigation development, the higher priority is given to construct four storage dams with total live storage capacity of 114.24 MCM, which cover approx. 25,200 ha of existing orchard area, 5,300 ha of converted orchard area, and 2,900 ha of double cropped area on paddy.

2.4 The total investment cost required for the implementation of full stages of the Chanthaburi River Basin development is estimated at 8,384 million Baht, which comprises sector-wise investment costs of 6,879 million Baht for irrigation, 69 million Baht for water supply and 1,436 million Baht for fishery.

2.5 Technical and economic feasibility, requirement of beneficiaries, financial availability and regional development impact were combined to arrange implementation schedule of sub-project schemes, especially for irrigation components included. As a result of such consideration of pre-feasibility level, the combination of the Middle-Right and Upper Zones was selected as the highest priority sub-project.

3. Summery of the Feasibility Study

3.1 The project area of 67,730 ha includes 3 Amphoes, 8 Tambons and 50 Mubans. The 1988 population of the area is estimated at 26,000 with the number of household at 5,700 of which 90% are being engaged in farming activities. Mushrooming population growth rate of 4.7% is observed in the area, which is mainly attributable to the social population increase by the immigrants.

3.2 Within 28,300 ha of farm land, 11,400 ha corresponding to 40% of the total is classified as orchard, followed by 8,400 ha of Para rubber, 7,900 ha of upland crops and 600 ha of paddy. The orchard represented by rambutan, durian and mangosteen yields about 140 thousand tons of annual production, however, due to severe and unexpected drought, its production shows big annual fluctuation.

3.3 At present orchard irrigation is practised during dry season from November to April with waters mainly pumped up from rivers and/or from farmponds. The project proposes to provide two storage dams, namely; Khlong Ta Liu dam and Khlong San Sai dam, in order to supply adequate irrigation water to some 14,930 ha of area composed of 14,870 ha of orchard and 60 ha of double cropped area on paddy.

3.4 The project also involves the integrated agricultural development plans which envisage to accelerate land and labor productivity through strengthening of institutional aspects and converting the existing land into valuable orchard. The orchard area is planned to be enlarged by approx. 3,500 ha with 97,000 ton of production increase, with 20% of Para rubber and paddy and 30-40% of cassava fields to be replaced to orchard.

3.5 The Khlong Ta Liu dam with a live storage capacity of 34.65 MCM is of a rockfill type, while the Khlong San Sai dam with a live storage capacity of 9.80 MCM is designed to be an earthfill type. The recommended water conveyance system from the Khlong Ta Liu dam is mainly the gravity pipelines with the total length of 111,620 m. Waters stored in the Khlong

San Sai dam is to be discharged directly to the Chanthaburi River, in order that the waters are easily pumped up to irrigate orchards along the river channels.

3.6 Irrigation water is to be diverted from gates or valves installed along the main or lateral pipeline and is distributed through sub-lateral pipeline of common use to the farmpond and newly developed area.

3.7 The total investment cost, including the cost for price escalation but excluding the interest during the construction period, is estimated at 3,063 million Baht (equivalent to US$123 million), of which about 1,992 million Baht will be foreign currency while 1,071 million Baht will be local currency. The construction costs of the proposed Khlong Ta Liu dam and Khlong San Sai Sub-project are estimated at 2,860 and 203 million Baht respectively. The period of project implementation inclusive of detail design and construction supervision is estimated at five years.

3.8 As a general policy for agricultural development in Thailand, the Government has taken a policy that the total Project cost is invested by the Government until the time when the beneficial farmers are stable and they can repay the investment. On the other hand, post-project O&M services for major facilities are commonly undertaken by RID and the farmers have responsibility for O&M works at on-farm level.

3.9 The beneficial farmers in the Project area, however, have managed a relatively large-scale orchard plantation, and they have obtained a considerable amount of net production incomes as compared with other crop growers, such as para rubber, cassava and paddy rice. According to the financial farm budget analysis of the concerned farmer, solvency of beneficial farmers to share a part of the project investment cost would be high. The amount of their solvency, after reducing the cost of living allowances from annual net production cost, ranges around B70,000 to B137,000.

3.10 It is judged that the investment cost to be shared or the line of demarcation for construcion works to be drawn between the national Government and beneficial farmers should be determined on the basis of appropriate policy in order to support the original Government's policy. As the result of the study, the Government is recommendable to be responsible for the construction and O&M works for main irrigation facilities upto the 200 ha command area and beneficial farmers should manage those works from the distribution point of about 200 ha command area up to the terminal end irrigation facilities called on-farm facilities.

3.11 Through the implementation of the Project, considerable increase of family cash income, as compared with present condition, ranging from 47% to 110% can be expected and consequently, disposable income is also expected to have enough capacity for cost recovery of the project investment. The beneficiaries can contribute to the charge for the project cost at 10-40% of beneficiaries affordability, therefore, the Project is concluded to be financially viable.

3.12 Beneficiaries' charges to the Project recommended through the analysis amount to 374.42 million Baht for Khlong Ta Liu sub-project and 16.92 million Baht for Khlong San Sai sub-project, which correspond to approx. 20% and 16% of the initial project costs, respectively. Since the Government has not obliged the beneficiaries for cost recovery of the project so far, approx. 20% charge from the beneficiaries is favorably justifiable even though this charge is lower than the WB's touchstone of 30%.

3.13 The Project EIRR is computed at 14.62% which is about 1.6% higher than the rate for opportunity cost of capital of 13% in Thailand. Sensitivity analysis also denotes that the Project has sufficient elasticity against the various kinds of the project risks, thus, economical feasibility of the Project is also ensured.

CHAPTER 1. INTRODUCTION

CHAPTER 1. INTRODUCTION

1.1. Authorization

In response to the request of the Government of the Kingdom of Thailand, the Government of Japan decided to implement the Feasibility Study on the Agricultural Water Development Project of Chanthaburi River Basin (hereinafter referred to as "the Study"), within the general framework of technical cooperation between Japan and Thailand, which is set forth in the Agreement on Technical Cooperation between the Government of Japan and the Government of the Kingdom of Thailand signed on November 5, 1981.

Subsequently, the Government of Japan dispatched the Preliminary Survey Team for the Study during the period of 4 to 14 March 1987 through the Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of the technical cooperation programs of the Government of Japan.

The Preliminary Survey Team headed by Mr. Kazuo HARADA, Senior Irrigation Engineer, Overseas Technical Cooperation Office, Construction Department, Agricultural Improvement Bureau, MAFF, and the Thai officials concerned headed by Mr. Chari TULAYANOND, Deputy Director General for Construction, Royal Irrigation Department, Ministry of Agriculture and Cooperatives (hereinafter referred to as "RID") had a series of discussions and exchanged their views in the field as well as in the head office in Bangkok on the Scope of Work for the Study. As a result, both sides have agreed upon the Scope of Work for the Study on 13 March 1987.

On the basis of the agreed Scope of Work for the study, JICA dispatched the Japanese Study Team (hereinafter referred to as "the Study Team") headed by Mr. Satoshi KADOWAKI for commencement of the

field work on April 3, 1988, in accordance with the relevant laws and regulations set forth in Japan and in close cooperation with the Government authorities of Thailand. It is stated in the Scope of Work for the Study that RID shall act as counterpart agency to the Study Team and also as coordinating body in relation with other relevant organizations for the smooth implementation of the Study.

This Final Feasibility study Report (75 copies) has been prepared in accordance with the Scope of Work for the Study, summarizing all of the work and study after completion of all the services required as well as all of the findings and recommendation of the Study Team including the detailed implementing arrangement, formulation and preparation of the proposed project.

1.2. Objective of the Study

The objective of the Study is to review the existing agricultural studies/projects and other water related project(s) in the Chanthaburi river basin in due consideration of better water utilization on natural water resources, and to establish an agricultural water development plan in the basin so as to sustain the substantial national agricultural area.

1.3. Outline of the Study

1.3.1. The Study Area

The study area covers the Chanthaburi river basin with about 1,664 sq.km which is located in Chanthaburi province in the south east region of Thailand.

1.3.2. Scope of the Study

The activities to be undertaken by the Study Team is divided into two stages as follows:

Phase I (Pre-feasibility) Study

a. To conduct the preliminary study on the agricultural water development plan, and to diagnosis the basin-wide water utilization systems in the Chanthaburi river basin.

b. To identify the possible agricultural project(s) grouping by project scale with priorities, and to recommend the stage of basin development.

Phase II (Feasibility) Study

To conduct the feasibility study on the project with the highest priority as identified and ranked in Phase I Study.

(1) The Phase I Study

The Phase I Study covers the following items:

1) To collect and review the relevant existing data and information including topography, meteorology, hydrology, geology and hydrogeology, irrigation and drainage, soil, agriculture, agro and regional economy and institution, and others.

2) To survey in the study area including topographical survey, meteorological survey, hydrological survey, groundwater survey, irrigation and drainage survey, agricultural survey, flood discharge survey, construction material and cost survey, and other survey.

3) To collate the Study Report of existing/proposed irrigation and drainage projects, prevailing water utilization systems, and to evaluate the agricultural water development in the Chanthaburi river basin.

4) To identify and prepare the possible agricultural water development project(s) with priorities.

5) To estimate the general project cost of selected possible agricultural water development project(s) and other water-related project(s) as occasion demand.

6) To conduct a preliminary design of the major structure(s) as required in the above mentioned project(s).

(2) The Phase II Study

The Phase II Study covers the following items:

1) To conduct additional survey and data collection including soil and land classification survey, geological survey, groundwater survey, irrigation and drainage survey, socio-economic survey, regional economic and agro-institutional survey, and others.

2) To determine the basic items for the project including land use and cropping pattern, water requirement, irrigation and drainage canal networks and facilities, estimation of yields, agro-institutional plan, social-institutional services, and others.

3) To formulate the agricultural water development plan for the project.

4) To conduct the preliminary design of the major facilities of the project.

5) To prepare the implementation schedule.

6) To estimate the project cost and benefits.

7) To conduct the project evaluation.

8) To prepare the operation and maintenance plan.

9) To prepare the recommendation.

(3) Reports

During the course of the Study, the Study Team prepared and submitted the following reports in English to the Government:

1) Inception Report (50 copies), at the commencement of the field work in the Phase I Study (3 April 1988).

2) Progress Report I (20 copies), at the end of the field work in the Phase I Study (16 June 1988).

3) Interim (Pre-feasibility) Report (100 copies), at the commencement of the field work in the Phase II study after completion of the home office work for the Phase I Study (17 October 1988).

4) Progress Report II (20 copies), at the end of the field work in the Phase II Study (14 January 1989).

5) Draft Final Feasibility Study Report (50 copies), after completion of the home office work in the Phase II Study (15 March 1989).

1.4. Organization of the Study

(1) The JICA-Advisory Committee

The Advisory Committee is responsible for direction, supervision and evaluation of activities and studies of the Study Team, being composed of four members as follows:

1)	Chief	:	Mr. Sota IWAMOTO Chief Engineer Agricultural Structure Improvement Bureau MAFF
2)	Irrigation and Drainage	:	Mr. Fumio NAKAHORI Deputy Director Agricultural Structure Improvement Bureau MAFF
3)	Agriculture	:	Mr. Yasuki ARAKI Deputy Director Seed and Nursery Division Agricultural Production Bureau MAFF
4)	Economic Evaluation	:	Mr. Ikuro SATO Deputy Director Technical Appraisal Coordination and Planning Division, Economic Research and Technical Appraisal Department OECF

(2) The Study Team

The Study Team is composed of ten experts with names and titles as listed follows:

1)	Team Leader/Regional Planning	:	Mr. Satoshi KADOWAKI
2)	Irrigation & Drainage/Co-Team Leader	:	Mr. Yoshiaki KIMURA
3)	Hydrology	:	Mr. Atsushi KIKUOKI
4)	Soil & Land Use	:	Mr. Michiaki HOSONO
5)	Agriculture	:	Mr. Hirokazu KOURIKI
6)	Agro-economy	:	Mr. Takato FUKUSHIMA
7)	Water Resources	:	Mr. Munehisa MURAYAMA
8)	Geology	:	Mr. Shigeru SUGIYAMA
9)	Facility Design & Cost Estimate	:	Mr. Yasumi KINOSHITA
10)	Project Evaluation	:	Mr. Masashi TAKANO

(3) The RID Working Group

The counterpart personnel of the government of Thailand are engineers of RID who are specially organized into a Working Group.

1)	Chief Engineer	:	Dr. Boonyok VADHANAPHUTI (Senior Expert for Water Resources Planning and Development)
2)	Secretary	:	Dr. Siripong HUNGSPREUG (Project Planning Division)
3)	Project Planner	:	Mr. Lertoviroj KOWATTANA (-do-)
4)	Planning Engineer	:	Mr. Kusol UT-SA HAWATTANASUK (-do-)
5)	Planning Engineer	:	Mr. Anan PHOONTHAWEE (-do-)
6)	Planning Engineer	:	Mr. Wanlop MEKPRUKSAVONG (-do-)
7)	Facility Engineer	:	Mr. Thanar SUWATTANA (-do-)
8)	Facility Engineer	:	Mr. Prasert LAKSHANASOMYA (-do-)
9)	Facility Engineer	:	Mr. Sakul HOVANOTAYAN (-do-)
10)	Survey Engineer	:	Mr. Sompoj PIMOLPUN (Topographical Survey Division)
11)	Survey Engineer	:	Mr. Preecha CHOTESANGASA (-do-)
12)	Hydrologist	:	Mr. Prasert MILINTANGUL (Hydrology Division)
13)	Hydrologist	:	Mr. Phonchai KLINGHACHORN (-do-)
14)	Agronomist	:	Mr. Osot CHARNNEJ (O & M Division)
15)	Agronomist	:	Mr. Apichai WATHANAYOMNAPORN (-do-)
16)	O & M Expert	:	Mr. Prasert KANOKSINGHA (-do-)

17)	Agro-Economist	:	Miss. Supha SINGHAINTRA (Project Planning Division)
18)	Agro-Economist	:	Miss. Kuakul THUMMAPHUT (-do-)
19)	Agro-Economist	:	Miss. Naiyana HARIVANGSKUL (-do-)
20)	Agro-Economist	:	Miss. Tanya REJTAVEEPORNDEJ (-do-)
21)	Agro-Economist	:	Mr. Boonsong PHUTOYA (-do-)
22)	Agro-Economist	:	Mr. Manolo TONTAYAPILUO (-do-)
23)	Soil Scientist	:	Mr. Danai TRIYADHEN (Geo-Technical Division)
24)	Soil Scientist	:	Mr. Somsak LERTWONGTRAKUL (-do-)
25)	Soil Scientist	:	Miss. Premrudee SAELEE (-do-)
26)	Geologist	:	Mr. Suphol JIYAPHUN (-do-)
27)	Geologist	:	Mr. Wichit SRIWISEAD (-do-)
28)	Geologist	:	Mr. Nirud KANANURAK (Region IX)
29)	Dam Engineer	:	Mr. Nopadol RAMANUT (Design Division)
30)	Coordination	:	Mr. Somchart KHIEWCHAOON (RID Laem Sing Irrigation Project)

1.5. Circumstantial Background of Project Implementation

1.5.1. Coordination on Project Implementation

(1) Projects Initiated by the King

On July 28, 1988 at Yan Sangwon temple in Amphoe Bang Lamung, Changwat Chonburi, the King asked RID for studying, planning and considering implementation of Chanthaburi project to provide irrigation water to the orchard area in any amphoes of Changwat Chanthaburi, where lack of water occurs always in dry season. Additional comments were also given by the King about this problem on August 16, 1988 at Chai Pattana building, Chitrada palace, and accordingly RID had studied and prepared a preliminary report and submitted to the King on October 9, 1988.

The contents of the said Preliminary Study Report was explained by the Office of Special Affairs, RID, on a coordination meeting which was held on November 8, 1988 jointly attended by representatives from RID, Royal Forest Department (RFD), Department of Fishery (DOF), Provincial Waterworks Authority (PWWA) and the Study Team, stating that there were several projects, in the Chanthaburi river basin, initiated by the King which had been focussing on the development of left bank of the Chanthaburi river by providing three dams and a weir nearby the existing Huai Saphan Hin dam. On the right bank of the river basin, a list of projects for water resources development was also prepared, however, their components were confirmed to coincide mostly with those planned by the subject pre-feasibility study.

It was explained by the representatives of National Energy Authority (NEA) on the occasion of presentation of the Progress Report II of the Study on January 11, 1989 that an additional water resources development project, for which detailed design work would be commenced in 1989, were to be studied and implemented by NEA. The project covers about 9,000 ha of farmland, of which about 4,300 ha are laid overlapping with the beneficial area proposed by the Study, stretching along the left bank of the Chanthaburi river, in Amphoe Makham. Of two dams projected by NEA, the Ban Pluang dam corresponds to the Thung Pen dam which is initiated by the King for producing hydro-electric power.

Under the circumstances and background mentioned above as well as in consideration of the earliest opportunity for project implementation, the overlapping area was concluded to be involved in the NEA project and accordingly excluded from the Study.

(2) NEA's Pump Irrigation Project

Series of discussions were made with representatives of NEA regarding necessary coordination for project implementation between

RID and NEA. Along the main course of the Chanthaburi river, in total seven pumping stations have already been completed by NEA, of which three stations with farmland of about 1,565 ha are overlapped with the service area proposed by the Study. As concerns the exact boundary of the NEA's Pump Irrigation Project for the project implementation stage, latest information was provided on a 1/5,000 scale map from Construction Division of NEA, and it was concluded mutually between RID and NEA that based on the latest project boundary the NEA area would be separated and excluded from the subject Feasibility Study.

(3) Reserved Area Development

The existing laws and regulations would require for the implementing agency utilizing the reserved forest area to get permission from RFD for the implementation of the proposed water resources development. In this concern there is an on-going activity in watershed classification in various basins in Thailand, however, for Chanthaburi river basin this activity has not been made yet.

1.5.2. Recommendation of Priority Project

The Interim Report (Pre-Feasibility Report) of the Study recommended the "Middle Right Zone" of Chanthaburi river basin as the highest priority sub-project for implementing the Feasibility Study. Regarding the final conclusion of selection of the priority sub-project, an official order from RID was issued on November 30, 1988 stating that "it is considered that for the best possible benefit to the rural people living in the Chanthaburi river basin, the RID would like the JICA study team to include the Upper zone of the Chanthaburi river basin into the Feasibility Study". Accordingly the Study covers the "Middle Right" and "Upper" zones of the Chanthaburi river basin. It should be noted here that the studies were based on 1/10,000 scale topo-maps for the Middle Right zone, while 1/50,000 scale maps were used to cover the Upper zone.

1.5.3. Circumstantial Background

Under the aforementioned circumstances, the subject Feasibility Study covers the Upper and Middle Right zones of the Chanthaburi river basin, excluding the areas commanded by the Pump Irrigation Project and the Khlong Thung Pen Project, already implemented or to be implemented by the National Energy Administration of the Ministry of Science, Technology and Energy. Accordingly, incidental and substantial revision of the Pre-Feasibility Study Report (Interim Report) was caused as summarized in Chapter 2.

CHAPTER 2. SUMMARY OF AGRICULTURAL WATER DEVELOPMENT PROJECT OF CHANTABURI RIVER BASIN (PRE-FEASIBILITY STUDY)

CHAPTER 2. SUMMARY OF AGRICULTURAL WATER DEVELOPMENT PROJECT OF CHANTHABURI RIVER BASIN (PRE-FEASIBILITY STUDY)

2.1. Present Condition of the River Basin

2.1.1. Physical Feature

The Chanthaburi river basin with the catchment of 1,664 sq.km is situated in the central part of Changwat Chanthaburi, occupying about a fourth part of the Changwat, on the coast of the Gulf of Thailand in the eastern region at a distance about 250 km from Bangkok. The river basin covers portions of 6 Amphoes, viz. Muang Chanthaburi, Makham, Laem Sing, Tha Mai, Khlong and Pong Nam Rong, with the total population of about 200,000, of which about 65,000 are concentrated in the municipal area.

The Chanthaburi river rises in the mountain ridges of Changwat Chanthaburi with elevations ranging from 400 to 600 m above mean sea level, situated at a distance about 70 km to the north from the estuary. The river traverses meanderingly southward and flows into the Gulf of Thailand after joining a number of tributaries. The river has relatively steep slope of about 1/500 in the upper and middle reaches where alluvial plains are formed along the river course. In the middle reaches, the river slope is moderate at about 1/1,000 with a width which becomes gradually wide. In the lower reaches the river has very gentle slope and wide flow. Plentiful alluvial plains with elevations less than 10 m formed by floods and inundations are spread around the estuary, extending over the range of about 50 km and 20 km respectively from north to south and east to west.

The climate of the river basin is monsoonal. Three major seasons recognized are: 1) cool season from November to February, 2) hot season from March to May and 3) wet season from May through

October. Annual rainfalls vary widely from 1,600 mm to 2,500 mm with an average of 2,100 mm, of which some 90% concentrates during wet season. Annual runoffs from the Chanthaburi river basin are estimated at 2,200 MCM or 1,336 mm or 1.34 MCM per sq.km for the period of 17 years from 1970 to 1986. Favoured by such an abundant rainfall, tropical fruit trees represented by durian, rambutan and mangosteen are cultivated elsewhere in the area.

2.1.2. Socio-Economic Condition

The total output of Changwat Chanthaburi, which belongs to the Eastern Region of Thailand, ranks in the middle among seven regions. Per capita output ranks second to the Bangkok capital sphere and is considerably higher than other regions. The gross national product as of 1988 was about 1,100 billion bahts.

Agriculture and commerce are the main productive sectors in Changwat Chanthaburi accounting for 69% of total output, while the industrial sector has an output value of only 8%. Share of agriculture and commerce in gross provincial product (GPP) exceeds widely that of the eastern region of Thailand, whereas the share of mining, manufacturing and construction is much inferior, as shown below:

(unit: %)

Item of Industry	Chanthaburi Province	Eastern Region	Whole Thailand
Agriculture	35.8	19.3	16.7
Industries	7.9	41.5	27.8
Public Utilities	8.2	8.7	11.8
Commerce	33.1	18.4	27.9
Public Administration	5.1	3.1	4.5
Services	10.0	9.0	11.3
Total	100.0	100.0	100.0

The demographic information of Changwat as of 1987 indicates the population of 408,500, the households of 37,944, farmland of 165,580 ha with an average land holding of 4.4 ha per farm household, which is 13% larger than the national average of 3.9 ha.

2.1.3. Agriculture and Land Use

Aside from fruit crops represented by durian, rambutan and mangosteen, three main crops, such as rubber, cassava and paddy, are also intensively planted in the area. Of the 64,800 ha currently utilized as farmland, 29,900 ha or 46% are planted to fruit crops, 18,700 ha or 29% to rubber, 9,100 ha or 14% to upland crops represented by cassava and 7,900 ha or 12% to paddy.

Current status of land use in the area has a wide variation, depending upon topography, soil, availability of irrigation water, type of settlement form and grade of public infrastructure consolidated. Farming pattern subsequently shows a regional change from north to south. The following 6 types of farming prevail in the area:

Farming Type

Main Crops	Area
Orchard	Middle reaches of Chanthaburi river and mountain ridges in lower reaches
Orchard + Cassava	Upper reaches
Orchard + Paddy	Part of middle reaches
Orchard + Rubber	Upper and middle reaches
Paddy	Lower reaches
Paddy + Fishery	-do-

In accordance with such a regional variation in farming pattern, the entire river basin was divided into 6 sub-project zones with the present land uses as given below:

Zone-Wise Existing Land Use

(unit: %, ha and ha/H.H)

Zone	Major Crops	Paddy	Upland	Orchard	Rubber	Total	House -hold
		(2)	(55)	(24)	(19)	(100)	
Upper	Cassava	309	7,712	3,350	2,689	14,060	2,088
		0.15	3.69	1.60	1.29	6.73	
		(2)	(1)	(64)	(33)	(100)	
Middle Right	Orchard	387	162	12,746	6,724	20,019	3,051
	Rubber	0.13	0.05	4.18	2.20	6.56	
		(22)	(1)	(42)	(35)	(100)	
Middle Left	Orchard	2,160	150	4,250	3,480	10,040	2,240
	Paddy	0.96	0.07	1.90	1.55	4.48	
		(6)	(6)	(47)	(41)	(100)	
Lower Right	Orchard	360	360	2,770	2,410	5,900	1,570
	Rubber	0.23	0.26	1.77	1.54	3.77	
		(7)	(-)	(53)	(40)	(100)	
Lower Left	Orchard	480	10	3,530	2,700	6,720	2,410
		0.20	-	1.47	1.22	2.79	
		(48)	(8)	(37)	(7)	(100)	
Lowland	Paddy	4,160	710	3,210	660	8,740	3,440
		1.21	0.21	0.93	0.19	2.54	
		(12.0)	(13.9)	(45.6)	(28.5)	(100)	
Entire Basin		7,856	9,104	29,856	18,663	65,479	14,799
		0.53	0.62	2.02	1.26	4.42	

Note: Unit = % (upper row), ha (middle row) and ha/household (lower row)

Main fruits are delivered simultaneously from orchard to the local market within extremely limited period, which is 3 months or shorter. Problems are not only quantitative but also qualitative as the extremely short life of fruits make hasten to sell them in the market at the soonest possible. The taste of durian, the most predominant fruits in the market, is delicious in 2 or 3 days just after maturity and turns stale gradually within a week. Local market prices in 1987 are as follows:

Local Market Prices of Representative Fruit Crops

(unit: Bahts/kg)

Fruit Crops		May	June	July
Durian	: Mawn Towng	22.55	25.18	38.50
	: Cha Nee	11.59	10.93	16.98
Rambutan	: Rohny Rian	11.19	7.98	7.88
	: See Chompoo	8.91	4.34	2.96
Mangosteen		14.30	10.17	11.00

Exportation of fresh fruits and their products from Thailand has increased year by year as shown below:

Fruit	Unit	1984	1985	1986
Durian	1,000 Bahts	67,685	171,851	173,480
	ton	3,470	9,784	6,964
Rambutan	1,000 Bahts	3,951	11,382	13,973
	ton	431	1,169	1,865

2.1.4. Water Consumption

(1) Irrigation

Irrigation practice in the river basin is categorized into two types in accordance with source of water.

Area Irrigated by River Water

Countless numbers of small pumping facility are installed along the main course and tributaries of Chanthaburi river and are diverting water for irrigating orchard. Every possible efforts are being made during dry season by farmers individually or in group to ensure the required amount of water to be diverted, by constructing temporary weirs across the river and/or excavating upstream river bed in order to maintain water levels and to keep storage capacity. Due to the fact, however, that the

upstream area has a priority in diverting river water and also absolutely small river runoff is only available in dry season, there are no surface flow in the middle, or sometimes in the upper-middle, courses of the river especially during the second half of dry season.

Area Irrigated by Farmpond Water

Due to limitation of small capacity of pumping facility and water distribution systems, areas irrigated by river water are situated at both river banks within a distance less than 500 m. Irrigation by pond water is predominant in the remote area. Shallow wells are used mainly for domestic purposes and supplementarily for irrigation of small area. Normally one to three farmponds constructed by a back-hoe at the lowest location in or nearby the orchard have such a structure that, with a standard depth of 5 to 6 meters, expects groundwater supply. Waters are pumped up from pond or well and then distributed to orchard through pipes. Majority of farmers have experienced shortage of water and also purchase of water by tank.

Irrigation water application experienced in the field, as summarized from the results of field survey, is as follows:

(unit: liter/tree/day)

Water Source	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total in mm
River	70	110	140	180	180	180	180	314.5
Pond	110	100	110	120	120	130	110	242.0
Average	90	105	125	150	150	155	145	278.3

(2) Domestic Water Supply

Urbanized area receiving domestic water supply from water filtration plants, to which raw water is conveyed from the Chanthaburi river by lifting pump systems, are the Chanthaburi municipal area, and Nong Bua and Tha Mai sanitary districts. Present service population and water demand as of April 1988 are summarized as follows:

- Total Population : 62,586
- Service Ratio : 60%
- Service Population : 37,550
- Average Daily Water Demand : 480 (cu.m/hr)
- Gross Average Water Demand per Capita: 307 (liter/capita/day)
- Ditto at House Connection : 245 (liter/capita/day)

Currently, the majority of inhabitant living in the rural area have their own wells for the purpose of domestic use, or sometimes dual purposes for irrigation and potable water supply. Rain water are also stored in a clay pot and used for domestic purposes.

(3) Brackish Water Fishery

Since the earnest development of aquaculture in the area, especially for shrimp raising, was commenced in 1986, expansion of the aquaculture area has been remarkable showing a rapid rate of growth. Developed and developing shrimp ponds are found in many places along the river course in the low-lying flood plain, located in the south of the Chanthaburi city. Such developments include not only large scale exploitation by private sectors being implemented in the existing paddy area but also illegal development of small scale in the reserved mangrove forest area whose reclamation is regulated by Royal Forest Department. The scale of the existing aquaculture is roughly estimated at 16,150 rai (2,584 ha).

2.2. Development Concept and Project Component

2.2.1. Development Concept

Basic concepts and approaches to be considered are; 1) to utilize existing farmland most effectively, 2) to ensure stable source of water for irrigation and other purposes and 3) to grade up farming practices and to add values of agricultural products. As the result expected from such countermeasures, land and labour productivity can be expanded extremely with unit area production increase. Realistic plan to increase agricultural products are to introduce gradually high profitable crops with providing stable irrigation water.

About 40% of the Chanthaburi river basin are intensively used for agricultural purposes. Non-product area shares 60% of which 46% are composed of forest, road, urban area, water-way and others, and 14% are reserved mangrove forest and idle land comprising nipa, grass and shrub area.

Since such unused area is hardly expected to be converted into farmland even when complete improvement for drainage and environmental preservation are excluded, the most recommendable manner to maximize the benefit from the potential farmland is to convert existing upland and rubber fields into orchard and to introduce as much double cropping as possible during dry season in paddy area. In order to realize above target, dependable supply of irrigation water and consolidation of terminal facilities on farmland are inevitably needed.

At present, only 2% of annual runoff of Chanthaburi river are being utilized for irrigation, since about 90% of annual runoff of 2,200 MCM are concentrated during wet season when consumptive uses of crop are usually covered by effective rains. An appropriate manner to utilize most efficiently the huge amount of water

available in wet season is to store water in the reservoir and to release water to the consumers during dry period. Optimum plan of water resources development should be prepared taking into account the proper water demand projection, water allocation between respective water users with the possible plan of project implementation and more technical and economical feasibility.

2.2.2. Project Component

The project components required for the subject feasibility study as concerns agricultural development and irrigation systems consolidation are summarized as follows:

Agricultural Development

- Increase of crop yield by means of improvement of farming technique and of providing stable source of irrigation water
- Rubber of local variety to orchard conversion
- Upland crops, mainly cassava, to orchard conversion
- Introduction of double cropping in existing paddy area
- Establishment of orchard farming systems of high quality variety and improvement of collection and shipping systems of agricultural products
- Establishment of pilot farm and strengthening of research facility

Irrigation Systems Consolidation

- Construction and rehabilitation of storage dams, intake facilities, barrages, regulating reservoirs and other structures required for water resources development
- Installation of irrigation water conveyance and distribution systems
- Consolidation of on-farm irrigation facility in newly developed area
- Introduction of water management systems

Other Water Conveyance Systems Consolidation

- Establishment of water resources development plan based on long term prospection of domestic water supply, covering not only existing service area but also rural area

- Establishment of water resources development plan for brackish water fishery, in response to the current movement in the lowland area

2.3. Agricultural Development

2.3.1. Land Use Plan

Revised land use plans (crop conversion plan) by sub-project zone are summarized as follows:

Revised Crop Conversion Plan

(unit: ha)

Land Use	Sub-Project Zone						
		Middle		Lower			
	Upper	Right	Left	Right	Left	Lowland	Total
1. Paddy							
(1) Existing	309	387	2,160	360	480	4,160	7,856
(2) Double Crops	50	-	1,660	260	-	510	2,480
(3) Double Vegetable	12	-	-	-	365	35	412
(4) into Orchard	-	53	-	-	-	-	53
(5) Wet Rice Only	247	334	500	100	115	3,615	4,911
2. Upland Crops							
(6) Existing	7,712	162	150	360	10	710	9,104
(7) into Orchard	2,243	41	-	-	-	-	2,284
(8) remain Upland	5,469	121	150	360	10	710	6,820
3. Rubber							
(9) Existing	2,689	6,724	3,480	2,410	2,700	660	18,663
(10) into Orchard	239	900	705	480	530	110	2,964
(11) remain Rubber	2,450	5,824	2,775	1,930	2,170	550	15,699
4. Orchard							
(12) Existing	3,350	12,746	4,250	2,770	3,530	3,210	29,856
(13) from Paddy =(4)	-	53	-	-	-	-	53
(14) from Upland=(7)	2,243	41	-	-	-	-	2,284
(15) from Rubber=(10)	239	900	705	480	530	110	2,964
(16) Sub-Total	5,832	13,740	4,955	3,250	4,060	3,320	35,157
5. Total	14,060	20,019	10,040	5,900	6,720	8,740	65,479

As is clear in the above table, on the premise of stable supply of irrigation water, the Project envisages to foster the farmers of complex farming with highly improved agricultural incomes, by means of introducing double cropping on the existing paddy field, converting part of existing cassava field into orchard, accelerating replantation of high yield variety for rubber and converting a part of rubber field into orchard. Such modified land use plan (crop conversion plan) is summarized as under:

Land Use Plan

Existing Land Use	Projected Land Use Plan				
	Orchard	Rubber	Upland	Paddy	Total
Orchard	25,160				25,160
Rubber	2,964	14,653			17,617
Upland	2,284		6,803		9,087
Paddy	53			7,753	7,806
Total	30,461	14,653	6,803	7,753	59,670

Area for irrigation is then totaled as follows:

Orchard	30,461 ha
Double Crops in Paddy	2,892 ha
Total	33,353 ha

2.3.2. Crop Production Plan

Data available from agricultural statistics, target yield provided from agricultural extension offices, results of farm survey and advice from the Chanthaburi Horticulture Research Center were combined to set up the target yields of respective crops.

Target Yield of the Project

Corps	ton/ha	kg/rai
(Fruit Tree)		
Durian	12.0 - 14.3	1,900 - 2,300
Rambutan	15.3 - 17.0	2,400 - 2,700
Mangosteen	16.2 - 18.0	2,600 - 2,900
(Upland Crop)		
Soybeans	1.9	304
Groundnuts	1.9	304

2.4. Water Demand Projection and Water Resources Development

2.4.1. Runoff Analysis

Hydrological analyses were dealt with as a time series for the recent 20 years from 1967 to 1986 using a daily or 10-daily time unit. Runoff discharges obtained from Ban Puk station on the main course of Chanthaburi river and other available river records of relatively short period were used to develop a simple runoff model called "single tank model with finite height and distribution factors for surface runoff". The daily data of rainfall for the 15 stations collected from Meteorological Department, RID and NEA within and around the vicinity of the river basin were used to estimate runoffs expected from drainage basins of the proposed reservoirs as well as of irrigation blocks.

2.4.2. Water Demand Projection

(1) Irrigation

Theoretical method of estimation of crop consumptive uses, such as the Modified Penman Method, Blaney Criddle Method and Pan-Evaporation Method, are compared to know crop water requirement throughout a year. An areal conversion rate of 2.200 derived from the result of field test was used to adjust differences observed between theoretical values and amount of irrigation water actually applied by farmers in the area. Most irrigation systems in the area use dual sprinklers mounted with a distance of about one meter, for irrigating a fruit tree of more than 10 years age. Water distribution from individual sprinkler forms a circular path with a diameter of 7.0 m. The extent of irrigation water distribution thus observed in the field was evaluated at 45.5 sq.m. A typical pattern of fruit tree planting is investigated with 10 m interval, hence the ratio of areas planted to actually irrigated is calculated as 10 x 10/45.5 = 2.200. Values estimated by the Modified Penman Method, after adjusted with areal conversion rate of 2.200, were used in the study.

Taking an overall irrigation efficiency at 0.70 for orchard irrigation and 0.60 for upland crop irrigation, unit irrigation water demands are estimated as follows:

Irrigation Water Demand

Month	Orchard		Upland Crop	
	Field Requirement (1) (mm/day)	Irrigation Demand (2) (m^3/ha/day)	Field Requirement (3) (mm/mon)	Irrigation Demand (4) (m^3/ha/day)
Apr.	3.91	25.390	-	-
May	3.38	21.948	-	-
Jun.	2.96	19.221	-	-
Jul.	2.93	19.026	-	-
Aug.	2.79	18.117	-	-
Sep.	2.74	17.792	-	-
Oct.	3.24	21.039	-	-
Nov.	3.83	24.870	8	4.444
Dec.	3.89	25.260	77	42.778
Jan.	3.98	25.844	127	70.556
Feb.	3.87	25.130	100	55.556
Mar.	3.88	25.195	11	6.111

Notes: 1. (2) = (1)/2.200/0.7x10
2. 2.200 = area planted/actually irrigated
3. (4) = (3)/0.6x10

(2) Domestic Water Supply

In accordance with the projection made by the Provincial Water Work Authority, the domestic water supply demand for the municipal area as of the target year 2000 was estimated at 12.86 MCM/yr. As for water supply demand for rural area, annual requirement of 7.02 MCM/yr was estimated with prospective population of 178,000, average gross water demand of 180 liter per day per capita and a service ratio of 60%. Monthly variation of water supply is as follows:

Monthly Demand of Water Supply in Target Year 2000

Month	Recommended Monthly Rate	Water Demand	
		Domestic (MCM/day)	Rural (MCM/day)
Apr.	1.15	0.0405	0.0221
May	1.10	0.0388	0.0211
Jun.	0.95	0.0335	0.0183
Jul.	0.95	0.0335	0.0183
Aug.	0.95	0.0335	0.0183
Sep.	0.90	0.0317	0.0173
Oct.	1.00	0.0352	0.0192
Nov.	1.00	0.0352	0.0192
Dec.	0.85	0.0299	0.0163
Jan.	1.00	0.0352	0.0192
Feb.	1.05	0.0370	0.0202
Mar.	1.10	0.0388	0.0211
Total	1.00	12.86 MCM	7.02 MCM

(3) Fresh Water Demand for brackish Water Fishery

The 30 ppt of the target salinity content in fishponds and the proposed area of shrimp farming of 16,150 rai or 2,584 ha was used to estimate the fresh water demand for brackish water fishery in the lowland area, as tabulated below:

Month	Water Requirement (MCM/day)
Jan.	0.1211
Feb.	0.2421
Mar.	0.2623
Apr.	0.1412
Total	22.9 MCM

(4) River Maintenance Water

A specific drought runoff of 100 lit./sec/100 sq.km was considered as a guideline to determine the magnitude of river maintenance water. At the site of NEA's rubber dam having a watershed of about 1,500 sq.km, maintenance water so estimated is at a level of 1.5 cu.m/sec.

2.4.3. Water Resources Development Plan

(1) Irrigation Scheme and Miscellaneous Water Demand

Fruit crops represented by durian, rambutan and mangosteen, inclusive of pepper, and double crops such as groundnuts, soybeans and vegetables planted on the existing paddy are planned to be irrigated by the subject Project.

After considering crop conversion plans from existing paddy, rubber and upland represented by cassava into orchard, areas subject to irrigation are summarized as follows:

Area for Irrigation

(unit: ha)

Sub-Project Zone	Orchard to be Converted from					Double Crop on Paddy	Total
	Existing	Upland	Rubber	Paddy	Sub-Total		
Upper	3,294	2,243	239	-	5,776	62	5,838
Middle Right	8,106	41	900	53	9,100	-	9,100
Middle Left	4,250	-	705	-	4,955	1,660	6,615
Lower Right	2,770	-	480	-	3,250	260	3,510
Lower Left	3,530	-	530	-	4,060	365	4,425
Lowland	3,210	-	110	-	3,320	545	3,865
Total	25,160	2,284	2,964	53	30,461	2,892	33,353

Water demands for various beneficiaries are summarized as follows:

1) Irrigation

Irrigation requirements during dry period from November upto April were accumulated as 4,550 and 5,880 cu.m/ha respectively for fruit crops and double crops on existing paddy field.

Crop	Irrigation Area (ha)	Demand (MCM/year)
Fruit Crops	30,461	138
Double Crops on Paddy	2,892	17
Total	33,353	155

2) Water Supply

Water Supply for Urban Area	12.86 MCM/year
-do- for Rural Area	7.02
Total	19.88 MCM/year

Requirements in dry season, November to April, are estimated at 51.25% of annual demand. Thus, 19.88 x 0.5125 = 10.2 MCM.

3) Fishery

Requirement during dry season from January to April is estimated at 22.9 MCM.

4) River Maintenance Water

Requirement for four dry months is roughly estimated at 15 MCM.

(2) Water Balance and Required Storage Capacity

Computations for water balance between the proposed storage reservoir and beneficial areas were made with 10-daily time step for the recent 20 years from 1967 to 1986. Among the basic conditions given in such water balance simulation, available total capacity of farmponds in the area was taken as 850 cu.m./ha for conservative purpose to evaluate available water resources in the entire Chanthaburi river basin, despite that 920 cu.m/ha was obtained for the selected sub-project zones, Upper and Middle Right, during the course of the second phase field survey.

Annual maximum required capacities of the proposed reservoirs so computed were then put into statistical analyses to evaluate those required for the standard drought years, which would occur once in 5, 7 and 10 years.

Required Capacity of Proposed Reservoirs

	Probability of Drought (MCM)		
	1/5	1/7	1/10
Capacity	95.3	101.9	109.0

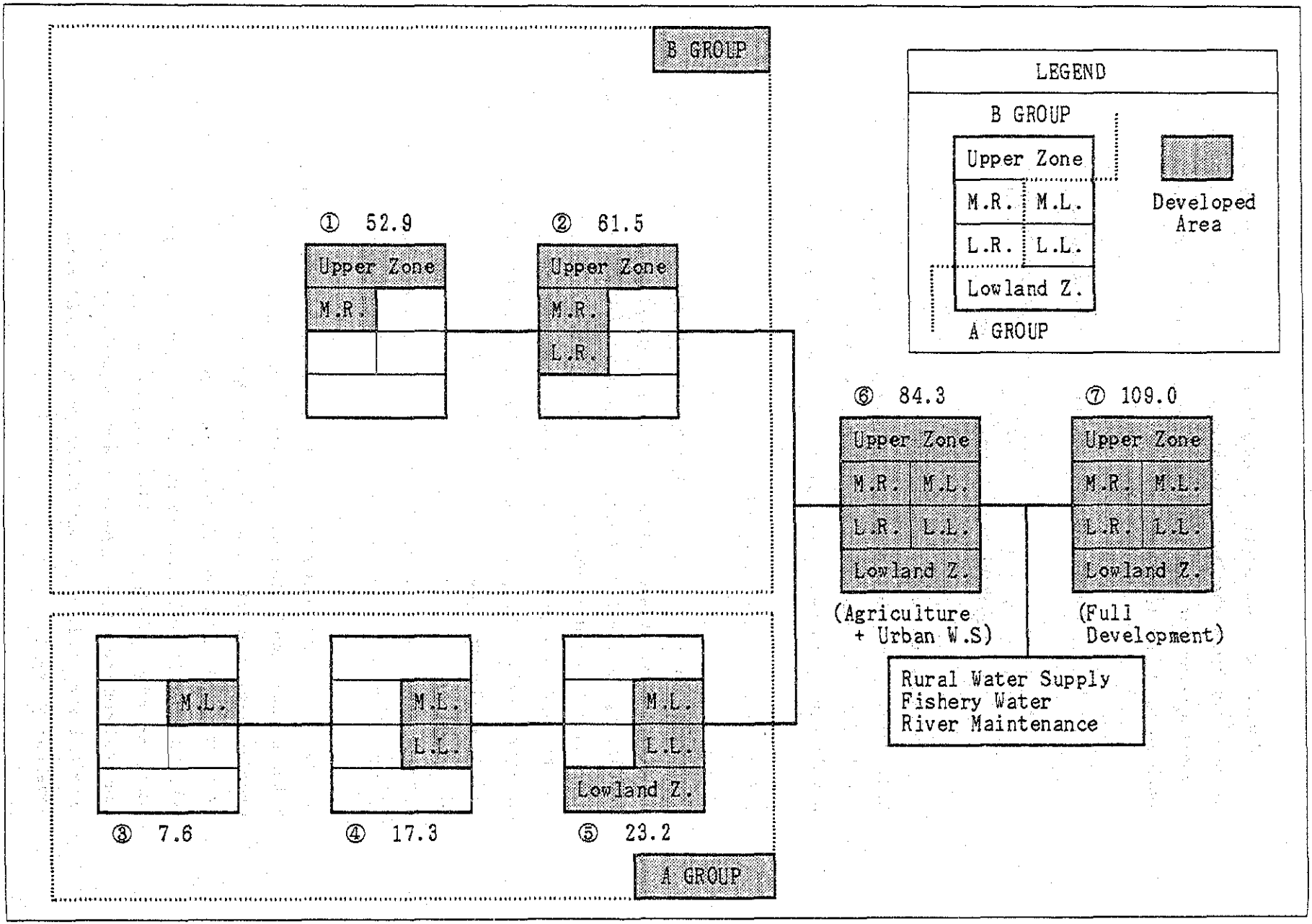
In order to evaluate available water resources required for implementing possible plans of phased development, water balance simulations for six cases of alternative combination of zoned development plan were progressed as shown in Figure 2-1.

2.4.4. Preliminary Facility Plan

Major irrigation facilities to be proposed are storage dam, diversion dam, main conveyance pipeline, pumping station and regulating reservoir. Existing natural rivers and tributaries are also used as main conveyance facilities. The available river runoffs and existing farmpond storages are used most effectively to irrigate orchard, supplemented by the water to be released from the proposed storage dams. Waters released from the proposed dams are either diverted at the intake facility (diversion dam) and conveyed through pipeline by gravity, or lifted up at the pumping station to be installed along the main course of the Chanthaburi river.

Project facilities are classified into two categories; i.e. main facility and terminal facility. Main facility comprises storage dam, diversion dam, main conveyance pipeline up to about 200 ha of commandable area, barrage for river water level control, main pumping station and regulating reservoir, whilst terminal facility involves other pumping facility, lateral and sub-lateral pipeline, connection pipeline to link orchard grower's farmpond, and terminal-end irrigation facilities to be consolidated in the developing area.

FIGURE 2-1 REQUIRED RESERVOIR CAPACITY FOR PHASED DEVELOPMENT



(1) Site Selection of Storage Dam

Among 19 damsites which were preliminary selected in the first phase field survey, the following four damsites are proposed for implementation.

Dam No.	Live Storage Capacity (MCM)	Dam Volume (cu.m)	Storage Efficiency
No.1	29.74	6,600,000	4.5
No.4	41.70	5,020,000	8.3
No.5	13.85	650,000	21.3
No.9	28.95	910,000	31.8
Total	114.24		

(2) Design Discharge

In consideration of project economy as well as of hydraulic function required for other water users such as water supply and fishery, flow capacity of the proposed conveyance facility was determined in principle to be a 24-hour discharge. Accordingly, the unit design discharges for irrigation are as follows:

Irrigation	Design Discharge
Orchard	0.30 lit./sec/ha
Double Cropping on Paddy	0.79 lit./sec/ha

2.5. Project Implementation and Priority Project

2.5.1. Implementation Agencies

Major consumers of the developed water resources in the Chanthaburi river basin are irrigation, domestic water supply and fishery. Governmental agencies as concerns these water utilization are as follows:

- Irrigation : Royal Irrigation Department (RID) and National Energy Administration (NEA)
- Water Supply : Provincial Water Work Authority (PWWA) and Office of Accelerated Rural Development (ARD)
- Fishery : Department of Fishery (DOF)

2.5.2. Phased Project Implementation

Criteria for priority project selection and project phasing are basically set up taking into account; 1) promotion of fruit production, 2) crop diversification to meet areal cultivation plan, 3) stable source of irrigation water to meet these requirement, 4) appropriate extent of beneficial area to be continuously utilized as farmland, 5) appropriate stretch of beneficial area suitable for formulating of sub-project, and 6) project impact to be caused by improvement of crop production and market structure.

Middle-Right and Upper sub-project zones were selected as the first priority project for implementation. Following to this, Middle-Left zone is the most recommendable. Effectiveness of the project investment, trend of urbanization being observed in the surrounding area and other aspects related to the development including environmental assessment should be carefully considered to promote development of the remaining zones, such as Lower-Right, Lower-left and Lowland zones.

In this connection, evaluation of lowland development scheme as revised in Appendix-K indicates the benefit-cost ratio of 0.34, Despite that some indirect benefits may be expected, additional costs for compensation works, including salt water distribution systems for shrimp farming and their operation and maintenance cost, and environmental impacts against the regional economy would be considerable. Moreover, development of the reserved mangrove forest

area is strongly restricted by the existing law. No reasonable merit in developing the lowland zone has been investigated from both economic and environmental points of view. Consequently, immediate development is not recommendable.

Two schemes of domestic water supply, urban and rural, are involved in the subject project. The former is being implemented based on the long-term development plan provided by PWWA. The latter however has no complete development plan and necessity for the implementation of the scheme has not become realized yet for the time being.

Project implementation for the fresh water supply to brackish water fishery is considered to be not required immediately for the time being, since until the time of completion of the full scale development of the river basin when the project distributes irrigation water to meet the requirement of the whole basin, fresh water supply required by shrimp farming may be achieved by river runoffs even during dry period.

2.5.3. Project Investment

The total investment cost required for the implementation of full stages of the Chanthaburi river basin development is estimated at 8,384 million baht, which comprises sector-wise investment costs of 6,879 million baht for irrigation, 69 million baht for water supply and 1,436 million baht for fishery.

2.5.4. *Recommendation for Priority Project*

Technical and economic feasibility, requirement of beneficiaries, financial availability and regional development impact were combined to arrange implementation schedule of sub-project schemes, especially for irrigation components included. As a result of such consideration of pre-feasibility study level, the combination of the Middle-Right and Upper zones was selected as the highest priority sub-project.

CHAPTER 3. THE STUDY AREA

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3.1. Project Boundary and Area

The entire Chanthaburi river basin, which covers the drainage area of 1,664 sq.km, stretches along 80 km from north to south and expands over 20 to 25 km from east to west. The Upper and Middle-Right zones of the basin were selected for the implementation of the subject Feasibility Study. After coordination made with National Energy Administration (NEA) of Ministry of Science and Technology, irrigable area commanded by the Pump Irrigation Project under the stage of implementation by NEA and the area to be irrigated by the Khlong Thung Pen Project, initiated by the King and studied and to be implemented by NEA, were excluded from the subject study. Accordingly, the study covers 67,730 ha of drainage area, of which about 28,270 ha are used as farmland.

Project Area by Amphoe (ha)

Amphoe	Farmland	Other Land	Total
Makham	21,772.7	33,057.3	54,830
Muang	2,561.2	2,438.8	5,000
Tha Mai	3,935.5	3,964.5	7,900
Total	28,269.4	39,460.6	67,730
Rate(%)	(41.7)	(58.3)	(100)

3.2. Characteristics of the Project Area

3.2.1. Household and Farm Characteristics

(1) Household Characteristics

The project area of 67,730 ha includes 3 Amphoes, 8 Tambons and totally involves 50 Mubans. The 1988 population of the Project area is estimated at 26,000 and the number of households at 5,700 of

which 90% are engaged in farming activities. The average family size of 4.54 persons per households is smaller than the provincial average of 5.44 persons. The areal annual average population growth rate (compound rate) between 1985 - 1987 is estimated at 4.7% which is 3.6% higher than provincial average of 1.1%; the above growth rate suggest the mushroom immigration from other place. Assumable immigrants might be from nearby provinces such as Rayong and Chon Buri where the farmers are enjoying a boom in land prices affected by Eastern Seaboard Development Programme. The economic labor force (age groups 15 to 64 years) is about 17,400 persons which correspond to 67% of total population.

(2) Farm Characteristics

The land holding area per farm was averaged at 34.4 rai which is larger than the provincial average of 25.6 rai by 8.8 rai, which is attributable to the cassava production farms with 38.4 rai of average farm size in the upper part of the Project area. It is considered that about 40% of farms belong to small farm (less than 20 rai of land holding area), 30% of farms belong to medium farm (21 - 40 rai) an 20% of farms belong to large farm (40 rai over).

Most of farms have their own land and some farms rent it additionally from others. Illegal occupancy of land is regrettably observed in some area of upper district. The land rent is particularly common among paddy cultivators; they rent the land from land owners on the sharing arrangement at 70 - 80 kg/rai of paddy or one-third of total production.

The shortage of irrigation water during dry season is the serious problem for the orchard farmer. Especially in drought year, the farmers have to pay much money for irrigation water intending rather to protect the tree lives from death than to increase their production. Nevertheless, the strong intention of converting to orchard from other crops can be observed especially among the cassava production farms in upper area.

Rambutan and durian are major orchard in the area and mangosteen comes up next. Farmers apply much farm inputs (e.g. fertilizer, pesticide, hormone, hired labor, fuel and so on) to produce valuable fruits and the bulk of fruits are marketed for cash. Para rubber and cassava are also major production in the area, however the marketability is further low comparing to orchard. Producing these commodities require a lot of hired labors especially in harvest season, as is normally supplied by seasonal workers from North-East region at ฿45 - 50/day of wage rate.

3.2.2. Topography, Geology and Seismicity

(1) Topography

The Chanthaburi river has a relatively steep longitudinal slope of about 1/500 in the upper and middle reaches, and forms alluvial plains along the river course. Hilly regions with an elevation 40 to 80 m are developed distant from the river course where several suitable damsites are found out. In the middle reaches, the river slope is moderate at about 1/1,000 and the river width becomes gradually wide. Plentiful alluvial plains are also formed and are utilized as an orchard. The mountain ranges with elevations ranging from 800 to 1,500 m lie extending from north to south on the east side of the Study area and form the catchment boundary, showing a steep V-shape valley along the stream. The mountainside forms partly and elevated peneplain having gentle slope and erosions are observed to begin again. On the west side, isolated elliptical shaped mountains with elevations 300 to 600 m are distributed from north to south.

(2) Geology

General geology of the Project area consists of Triassic granite and graywacke, Permain to Carboniferous chert, Carboniferous shale and Quaternary basalt as shown on geological stratigraphy

(refer to table below). The bedrock of the area is mainly Triassic granite. Triassic graywacke distributes partly on the south side of Khao Phra Bat as well as east side along the national highway No.317 in the middle reaches of the basin. Basalt, chert and shale on the limited narrow range near Amphoe Tha Mai. Quaternary alluvial deposit which covers widely over the bedrock of the area is composed of gravel, sand, silt and clay. In the upper reaches quaternary alluvial terraces composed of gravel, sand, silt, clay and laterite are well developed around the foothills of the mountain range and cover bedrock of granite. The property of granite possess developed joints, medium to coarse grained and porphyritic, and include hornblende and biotite. Most of the mountains are composed of granite. All outcrops of granite observed from mountainside to the top of mountain have become sand by remarkable weathering. A hard granite outcrops is observed only on the river bed except the both abutments. The joint of outcrops are well developed regularly.

Geological Stratigraphy

AGE		GROUP	FORMATION	ROCKS
Quaternary	Recent Pleistocene			Alluvial deposits (Al) Diluvial deposits (Td) Basalt (Ba)
Triassic			Pong Nam Ron	Graywacke (Gw) Granite (Gr)
Permain – Carboniferous				Chert (Ch)
Carboniferous				Shale (Sh)

Many tectonic lines may exist because mountains usually have a complicate topography. The weathered granite is suitable for the impervious material of fill dam because of inclusion of fine materials. The graywacke is fine to medium grained and massive, and has slightly joints. General geological map is presented in Figure B.3.1 of APPENDIX-B.

(3) Seismicity

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

Seismicity map (Figure H.4 of APPENDIX-H) shows the distribution of earthquake epicentres of Thailand. The Majority of earthquakes occur in neighbouring countries, and the epicentres are mostly distributed in the following places:

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

Probability of earthquake activities in Thailand is indicated in a seismic probability map of Figure H.5, APPENDIX-H, each zone showing the approximate destructive intensity of earthquake. The Project area is situated in the Zone 0 which means "No Damage". However, the dam shall be designed in consideration of probable seismic occurrence for safety purpose against hazard of earthquakes judging from the importance of a dam.

In the Study, the horizontal seismic force is taken as kh = 0.05 for the design of fill dam in accordance with the "U.S Corps. of Engineers".