KINGDOM OF THAILAND
MINISTRY OF AGRICULTURE AND COOPERATIVES
ROYAL IRRIGATION DEPARTMENT

FEASIBILITY STUDY ON THE SAKAE KRANG RIVER BASIN IRRIGATION PROJECT

MAIN TEXT

MARCH 1986

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to the request of the Government of the Kingdom of Thailand, the Japanese Government decided to conduct a feasibility study on the Sakae Krang River Basin Irrigation Project and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA dispatched to Thailand a survey team headed by Mr. Tadashi SAKAMOTO from July to September 1985. The team exchanged views on the Project with the officials concerned of the Government of the Thailand and conducted a survey in the Sakae Krang river basin. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will be useful as a basic reference for development of the region.

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 our team.

March 1986

Keisuke ARITA

President

Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Mr. Keisuke ARITA
President
Japan International Cooperation Agency,
Tokyo, Japan

Dear Sir,

We have pleasure in submitting herewith one hundred and thirty (130) copies of Feasibility Study Report on the Sakae Krang River Basin Irrigation Project in the Kingdom of Thailand in accordance with the terms of reference issued by JICA. The report consists of three separate volumes: Main Text summarizes the results of the study and presents the conclusion and recommendations; Annex provides more detailed technical informations and procedures; Drawings give the general plan of the project area and the layouts of dam, canals, and related structures.

This study has been made to formulate the optimum development plan which aims to improve farmer's living standards in the project area by increasing paddy production through provision of a storage reservoir and irrigation and drainage facilities.

It is verified throughout the study that the project is technically sound and economically and financially viable. In view of the pressing needs and the economic contribution of the project, we would recommend that the project would be soon implemented.

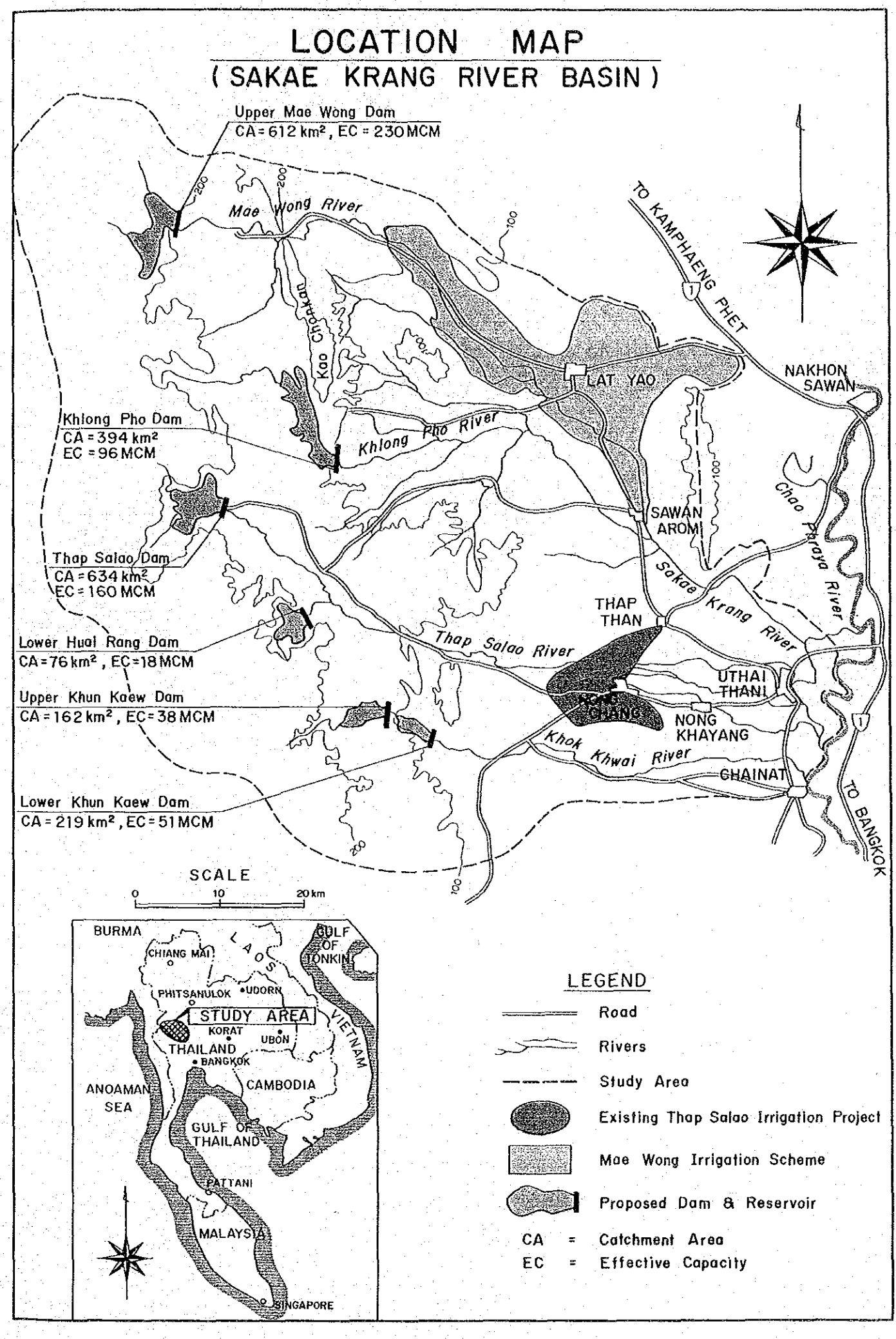
In submitting this report, we wish to express our sincere appreciation and gratitude to the personnel concerned of JICA, the Embassy of Japan in Thailand and the Authorities concerned of the Government of Thailand for the courtesies and cooperation extended us during our field surveys and studies.

Very truly yours,

T. Sakamoto

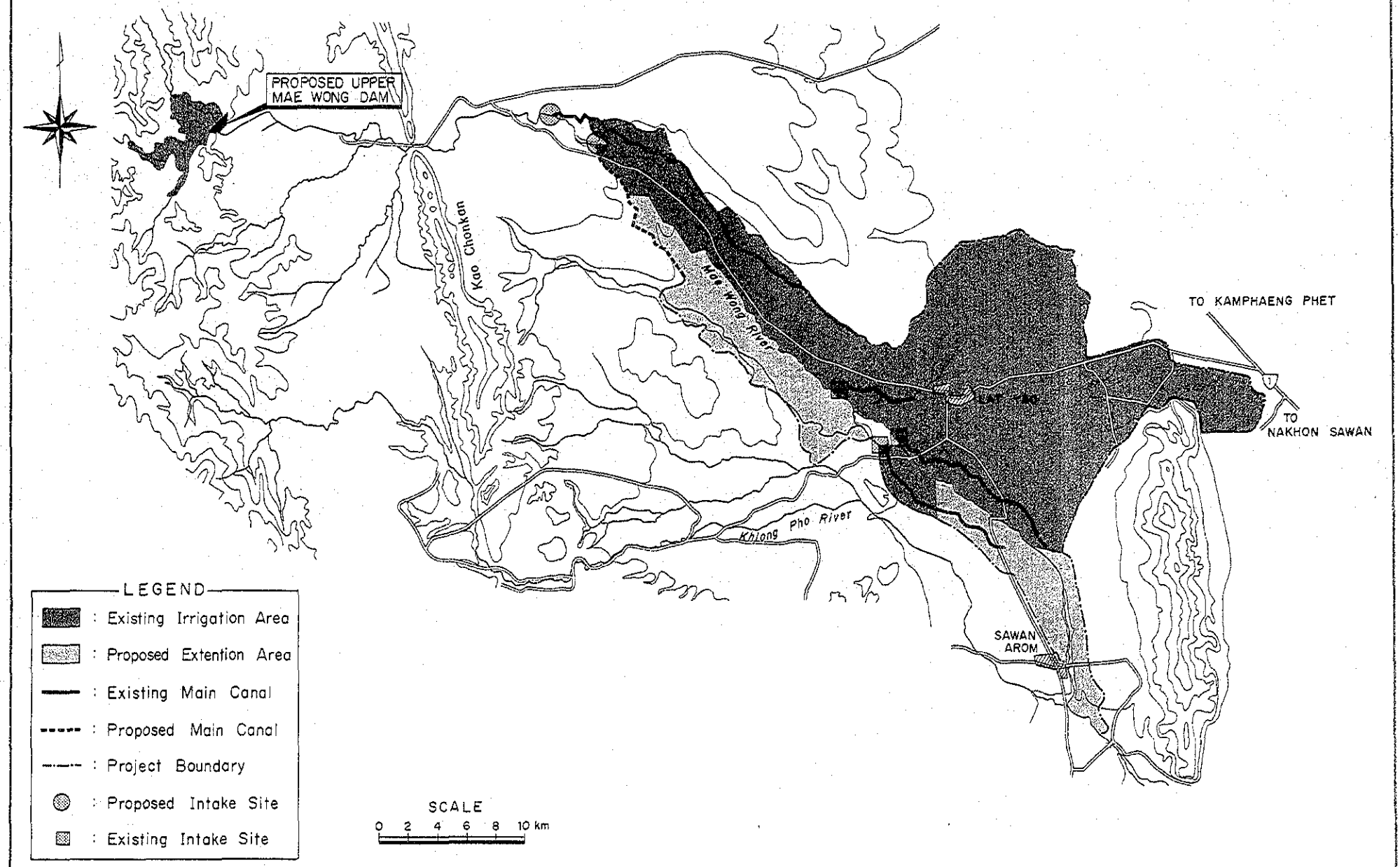
Tadashi SAKAMOTO
Leader of The Study Team
for The Sakae Krang River Basin
Irrigation Project

LOCATION MAP
(SAKAE KRANG RIVER BASIN)



LOCATION MAP

(MAE WONG IRRIGATION SCHEME)



PRINCIPAL FEATURES OF MAE WONG IRRIGATION SCHEME

1. Dam and Reservoir

(1) Dam

a.	Type	Rockfill dam
b.	Height	57 m
c.	Crest length	794 m
d.	Embankment volume	2.5 million m^3

(2) Reservoir

a.	Catchment area	615 km
b.	Total storage volume	250 MCM
c.	Effective storage volume	230 MCM
d.	Reservoir area	17.6 km^2

2. Irrigation Development

(1) Irrigation area

a.	Upgrading	230,000 rai (36,800 ha)
b.	New development	61,900 rai (9,900 ha)
	Total	291,900 rai (46,700 ha)

(2) Irrigation facilities

		Upgrading	New construction	Total
a.	Intake weir	-	2 nos.	2 nos.
b.	Irrigation canals			
	Main canal	64.7 km	12.0 km	76.7 km
	Lateral and Sub-lateral	171.4 km	113.8 km	285.2 km
c.	Drainage canals	96.1 km	108.1 km	204.2 km
d.	Inspection road	236.1 km	125.8 km	361.9 km

(3) Cropping pattern

a.	Crops	Paddy & Mung Beans
b.	Cropping intensity	105%

3. Financial Cost (Million Baht)

F.C.	L.C.	Total
1,946.2	948.9	2,895.1

4. Economic Evaluation

(1)	IRR	13.0%
(2)	NPV (at discount rate 10%)	475 MB

5. Other Aspects of Development

(1) Hydropower

a.	Installed capacity	6,500 KW
b.	Annual production	15.2 GHH

(2) Inland Fishery

a.	Type	- Aqua-culture in reservoir
b.	Annual Production in reservoir	170 tons

(3) Resettlement

a.	Nos. of household	101
b.	Resettlement area	Ban Wan San Forestry Village (4,000 rai)

(4) Forestry in reservoir

a.	Timber volume	136,000 m^3
b.	Net value	33 MB

SUMMARY

INTRODUCTION

01. Agricultural development in the Sakae Krang river basin has long been desired among the local inhabitants. The Royal Irrigation Department (RID) has recently picked up several dam construction projects in the Sakae Krang river basin and made a request to the Government of Japan to extend a technical cooperation. The agreed "Scope of Work" for the feasibility study contains three major programs as follows:

Part A : Study on overall Sakae Krang river basin water resources development and identification of possible project(s),

Part B : Pre-feasibility study on high priority project(s) to be selected in Part A, and

Part C : Feasibility study on first priority project to be selected in Part B.

02. This report presents the results of the feasibility study on the Mae Wong Irrigation Scheme (Part C) which has been selected with the highest priority in the Sakae Krang river basin through the past studies made in Part A and B.

BACKGROUND

03. The Kingdom of Thailand sustained about 8% of the economic growth rate during the recent decade of 1970's. Such rapid stride of the economic growth in Thailand causes drastic changes in financial and economic structure. These situations consequently bring about serious and complex problems of economic disparities in various sectors and also social tensions particularly in rural areas due to widening gap in amount of income. In order to overcome such problems and tensions, the Fifth Economic and Social Development Plan (1982 - 1986) has been set out containing long-term strategies and new approaches. Major objectives given in the Development Plan are:

- to restructure the key productive sectors like agriculture so as to improve the current economic and financial situations,
- to reduce absolute poverty and accelerate rural development in the backward area, and
- to uplift rural living standard as well as to strive more equitable distribution of income.

04. In order to achieve the agricultural development (4.5% per annum) stipulated in the Development Plan, the Government has put more emphasis on raising agricultural productivity through the irrigation development coupled with exploitation of new water resources. It is generally recognized nowaday that there remains a few river systems much suitable for creating reservoir in Thailand. The Sakae Krang river system, particularly the Mae Wong river, should be one of the most potential basins for water resources exploitation in the northern region of Thailand.

SAKAE KRANG RIVER BASIN AND DEVELOPMENT STRATEGIES

05. The Sakae Krang river basin extends over the northwestern part of the Central Chao Phraya Plain with a total area of about 6,300 km^2. The Sakae Krang river system consists of four (4) rivers; i.e., from north to south, the Mae Wong, Khlong Pho, Thap Salao, and Khok Khwai rivers. The river basin compasses parts of four (4) provinces of Kamphaeng Phet, Nakhon Sawan, Uthai Thani and Chainat.

06. About 0.32 million people lived in the Sakae Krang river basin primarily rely on agriculture. Farm household accounts for about 70% of the total household. Others are mostly engaged in trading, transportation, and public administration which support the agricultural activities. Agriculture contributes to about 45% of gross regional product, while it accounting for only about 24% of GDP in national economy. Agriculture has been and will continue to be the most important key determinant in regional economy of the basin area.

07. Two provinces of Nakhon Sawan and Uthai Thani where most of the Sakae Krang river basin area included, have about 2.6% of the Kingdom's population. The share of the provinces in GDP is however only less than 1.3%. The relatively poor position of the area is also indicated by its lag in per capita income; the average in past five years amounts to about 3,670 Baht, corresponding to roughly two-thirds of national average (5,610 Baht). The area suffers also from the instability in annual income which fluctuates largely year by year. Such poor economic situation of the area is mainly derived from low productivity of agriculture.

08. Paddy cultivation is a mainstay in the Sakae Krang river basin. It is surely suited to the area in economic-social-historical-cultural-physical context. The area is endowed with good soils and climate (except rainfall) suitable for paddy cultivation and the farmers are accustomed to paddy cultivation. Farmers heavily rely on paddy production economically. It however gives them only unstable results of yield due to irregular water availability.

09. The most important single constraint to be increased agricultural production in the basin is the lack of assured irrigation facilities coupled with the shortage of available water. Other constraints such as yield limitations of local variety, low input use and inadequate crop management should become secondary in importance when considered against regular crop damages caused by present irregularity in water supply.

10. The basic concepts for overall basin development in the fields of agriculture, water resources and irrigation are:

Agriculture

- to stabilize wet season paddy cultivation with regular water supplies,
- to increase unit yield of wet season paddy through improvement of farming practices under supplemental irrigation,
- to maximize the planted area of wet season paddy with a full use of the limited exploitable water resources, and
- to consider the dry season cropping with secondary importance.

Water Resources

- to stabilize significant fluctuation of streamflow through construction of dam and reservoir,
- to exploit the maximum potential of possible dam and reservoir within economically reasonable range,
- to implement dam and reservoir as early as possible, since the forest cover of watershed has been encroached rapidly by farmers and number of inhabitants in the reservoir area has been increasing every year, and
- to continue the observations and study on groundwater balance for future development, particularly on the effects of reservoir exploitation at upstream and irrigation development at downstream in future.

Irrigation

- to give a first priority to the supplemental irrigation for wet season paddy in the existing irrigation area,
- to expand the irrigation area with optimum use of available water resources,
- to incorporate existing irrigation systems into the proposed projects so as to minimize the project cost,
- to consider proper water management system at farm level as well as overall O/M system for irrigation facilities, and

- to utilize the natural streams for drainage to a maximum extent, and to provide the collector drains in each irrigation area.

11. The development planning for the Sakae Krang river basin would require, in addition to the above, further studies on other aspects of development potential, problems and measures. These include flood mitigation, hydropower development, inland fishery in the proposed reservoir and the resettlement problems involved in dam construction.

RIVER BASIN DEVELOPMENT PLAN AND SELECTION OF FIRST PRIORITY PROJECT

12. Eight (8) potential dam sites are identified in the Sakae Krang river basin. Potential reservoir capacity of these dams is estimated, on the basis of river runoff, topography and damsite geology, as follows:

(Unit: MCM)

River/Dam Site	Effective Storage	Dead Storage	Total Storage
Mae Wong river			
- Upper Mae Wong dam	230	20	250
- Lower Mae Wong dam	350	30	380
Khlong Pho river			
- Khlong Pho dam	96	14	110
Thap Salao river			
- Thap Salao dam	160	8	168
- Upper Huai Rang dam	10	2	12
- Lower Huai Rang dam	18	3	21
Khok Khwai river			
- Upper Khun Kaew dam	38	6	44
- Lower Khun Kaew dam	51	8	59

13. The Thap Salao dam is already taken up by the Government and will soon be put under construction. The Upper Huai Rang dam is not significant in storage capacity compared with the lower site. Out of eight (8) potential dams, the following six (6) potential dams, excluding the above two (2) dams, were further studied. The dam construction at these potential sites is technically feasible. The major dimensions of these possible dams are as follows:

Item		Mae Wong		Khlong	Haui	Khun Kaew	
		Upper	Lower	Pho	Rang	Upper	Lower
Effective Storage	MCM	230	350	96	18	38	81
Reservoir Area	km^2	19.5	68.0	32.0	2.2	2.2	7.3
Foundation		Hard Rock	Weathered Rock	Alluvial Deposit	Alluvial Deposit	Hard Rock	Alluvial Deposit
Height	m	62.0	38.1	20.9	30.5	49.5	32.0
Crest Length	m	775	225	1,555	1,470	570	2,500
Embankment	MCM	3.50	0.38	0.74	0.83	1.32	2.06

14. The overall water balance study for all the major tributaries including the Thap Salao, was made and the potential areas for irrigation development in each sub-basin were identified:

River Basin	Water Resources	Irrigable Area (rai)	Irrigable Area (ha)
1. Mae Wong	Upper Mae Wong Dam or Lower Mae Wong Dam	291,900	46,700
2. Khlong Pho	Khlong Pho Dam	111,900	17,900
3. Thap Salao	Thap Salao Dam	110,000	17,600
4. Khok Khwai	Upper Khun Kaew Dam	81,300	13,000
5. Sakae Krang	Groundwater	218,800	35,000
Total		813,900	130,200

After full development of the endowed water resources, a total of about 813,900 rai (130,200 ha) will be irrigated. This potential irrigable area corresponds to about 95% of the total existing paddy fields in the Sakae Krang river basin.

15. For selection of high priority projects, preliminary evaluation was made over the proposed six (6) projects using the parameters of reservoir performance, incremental irrigation area, construction cost and cost for compensation and resettlement:

Item			Mae Wong		Khlong Pho	Huai Rang	Khun Kaew	
			Upper	Lower			Upper	Lower
1. Reservoir Performance								
Irr. Area/Eff. Storage		ha/MCM	213	153	260	111	342	292
Embk, Vol/Eff. Storage		10^3m^3/MCM	14.8	1.1	7.7	46.1	34.7	40.9
2. Irrigation								
Irrigation Area*		10^3 ha	49.0	53.5	25.0	2.0	13.0	14.9
Incremental Irr. Area		10^3 ha	25.4	29.9	18.0	-	4.7	6.6
Irr. Area/Eff. Storage		ha/MCM	110	85	187	-	124	129
3. Dam Construction Cost								
Direct Const. Cost		M฿	1,148	620	567	195	403	545
Cost/Eff. Storage		M฿/MCM	4.9	1.8	5.9	10.8	10.6	10.7
Cost/Embk. Vol.		฿/m^3	326	1,140	497	235	305	265
Construction Period		Yr	5	5	5	4.5	5	5
4. Resettlement								
House		No	40	520	365	218	30	105
Land		km^2	19.5	68.0	32.0	2.2	2.2	7.3
Compensation	@0.2	M฿/house						
	@0.6	M฿/km^2						
		M฿	19.7	144.8	92.2	44.9	7.3	25.4

Note: *: for wet season paddy only

Based on the evaluation on these four components, the Upper Mae Wong, the Lower Mae Wong and the Khlong Pho dams were selected as high priority projects. The selected projects are all large scale projects which will give a large impact to the basin. Other projects are also considered worthwhile for future development. Particularly a special attention should be paid to the Upper Khun Kaew project and groundwater development in the downstream area.

16. Following the Part A program, the pre-feasibility study on the high priority projects (Part B) was made mainly for selection of the first priority project. The pre-feasibility study comprises (1) determination of optimum scale of development, (2) formulation of development plan based on the selected development scale, (3) preliminary design of project facilities and cost estimate, and (4) preliminary economic evaluations for comparison. As for optimum scale of development, the pre-feasibility study concludes through various alternative studies that the irrigation development of potential maximum area with potential maximum scale of dam and reservoir is the best alternative plan. Based on this optimization study, preliminary design was made and thereby project costs were estimated on a preliminary basis. The preliminary cost estimates and economic internal rate of return for each of the high priority projects are as follows:

Item	Unit	Upper Mae Wong	Lower Mae Wong	Khlong Pho
1. Economic Project Cost				
a. Dam	M฿	1,123.5	628.1	578.1
b. Irrigation	M฿	944.9	944.9	423.1
c. Others	M฿	385.3	416.0	268.2
(Total)	M฿	(2,453.4)	(1,989.0)	(1,271.4)
d. Unit Cost	฿/rai	8,210	6,660	11,400
2. Annual Benefit				
a. Total	M฿	461.3	492.4	217.2
b. Unit	฿/rai	1,540	1,650	1,940
3. Internal Rate of Return (IRR)	%	13.0	15.2	11.5

17. The results of the pre-feasibility study on the high priority projects are summarized as follows:

(1) All the high priority projects are technically sound and economically feasible.

(2) Irrigation development in the Mae Wong river basin is more beneficial than that in the Khlong Pho river basin, having larger irrigation area, larger number of project-benefited farmers and higher hydropower potential. Its economic viability is also high.

(3) Comparison between two projects for irrigation development in the Mae Wong river basin indicates that the Lower Mae Wong project seems to be more attractive in both technical and economic aspects, showing higher IRR of 15.2% against that of 13.0% for the Upper Mae Wong project. However, the Lower Mae Wong project has the following economic and social difficulties which will be induced by the resettlement of and compensation to a large number of villagers in its reservoir area:

a. Uncertainty is involved in the estimate of the project cost due to lack of reliable data on resettlement and compensation costs as well as uncertain number of household in the reservoir area, and if the number of household in the reservoir area is more than 1,600, its economic viability will become lower than that of the Upper Mae Wong project. Such case could be foreseen with rather high probability.

b. Large land area will be required for resettlement program. The land requirement will range from 850 ha to 4,000 ha, depending on the number of household. The potential agricultural land resources are already almost fully utilized in the Sakae Krang river basin and therefore new land development for resettlement program will be difficult.

c. It may take several years to completely settle the problems of resettlement and compensation. The case of the Thap Salao dam project gives an idea how the problems should be settled. Peaceful settlement of the problems will require untiring efforts over several years. It may affect the construction schedule adversely and the completion of the project may be delayed.

d. The problem of social tensions which may be induced by resettlement of a large number of household, is also foreseen, and can not be neglected.

e. The reservoir area is largest among those of other projects. There exist large farmlands and forest reserve. If the project is realized, large negative benefits for these will surely arise.

(4) The Upper Mae Wong Project should be selected as the first priority project on the following reasons:

a. The Upper Mae Wong project is economically feasible and technically sound, with the same development scale as the Lower Mae Wong.

b. The socio-economic difficulties of the Lower Mae Wong project could not be neglected and might seriously affect the project costs and construction schedule.

c. The Upper Mae Wong project has no such socio-economic difficulties and will possibly be realized in a shortest time.

d. The Upper Mae Wong project has higher hydropower development potential.

MAE WONG IRRIGATION SCHEME AREA

18. The Mae Wong river is the largest tributary of the Sakae Krang river, forming the largest sub-basin with a total area of 2,170 km^2 or 34% of the Sakae Krang river basin. The Mae Wong river originates from the western mountain ranges. The stream gradient in the upper reaches is steep and the valley sections are more or less pronounced. The topography becomes flatter as the river emerges onto the alluvial plain after cutting through the mountain ridges of Kao Chonkan located about 14 km downstream of the damsite. The river passes through the broad agricultural lands, extending on the altitude from 60 m to 100 m, until it eventually meets and becomes the Sakae Krang river.

19. The Mae Wong river basin is characterized by two distinct seasons; i.e., dry season from November to April and wet season during the rest of the year. The mean annual rainfall is about 1,070 mm, of which about 85% is concentrated in the wet season. Total depth of annual rainfall fluctuates largely year by year within a range from the lowest, about 660 mm to the highest, about 1,890 mm. Annual mean temperature is about 28.5°C with maximum monthly mean of 31.9°C in April and minimum mean of 25.2°C in December. Annual mean pan evaporation is 2,089 mm, in which maximum evaporation occurs is April (260 mm) and the minimum in September (128 mm).

20. The Mae Wong river basin is broadly divided into two geological zones; i.e., western Paleozoic zone and eastern Mesozoic zone. The western zone has a distinct N-S geological structure affected by the Burmese - Malaya geosynclinal movement of meridional trend. The proposed damsite is located along the eastern edges of this Paleozoic zone. In the eastern Mesozoic zone, a vast diluvial terrace is developed. Semi-recent alluvial flats run slenderly from west to east along the river between the diluvial terraces and extend over the downstream areas in the east.

21. Average runoff rate and annual outflow for the watershed of the Mae Wong river at the streamflow gaging station CT-5A located about 13 km downstream from the damsite, are summarized as follows:

Gaging Station	Drainage Area (km^2)	Average Rainfall (mm/yr)	Average Annual Runoff (MCM/km^2)	Average Runoff Rate (%)
CT-5A	936	1,339	0.360	26.9

The river runoff is characterized by long low flow period from December to July. Reliable amount of water resources supplied by the Mae Wong river is limited only during four (4) months from August to November. About 80% of total annual runoff occurs during this period as shown below:

(Unit: 1,000 m^3/km^2)

Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
2.3	8.5	15.4	18.6	37.6	85.1	125.0	45.0	12.0	6.3	3.8	2.8

Annual fluctuation of streamflow is remarkably large. The annual runoff ranges from 0.09 MCM/km^2 in 1977 to 0.88 MCM/km^2 in 1983 with an average of 0.36 MCM/km^2 for the past 30 years.

22. About 0.46 million rai (731 km^2) of arable land resources are endowed in the Mae Wong river basin. Out of these potential arable land, about 0.44 million rai (710 km^2) or 97% of the total area, have been developed for agricultural production, both for paddy and upland crops cultivations. The potential arable lands are almost fully developed. The rest of 0.91 million rai (1,440 km^2) includes mountains, steep slopes, forest reserve, river and swamps, road and urban areas. The existing agricultural land comprises 0.33 million rai (520 km^2) of paddy field and 0.11 million rai (190 km^2) of upland fields.

23. Paddy rice is by far the most important crop, grown on about 73% of the total agricultural land. Paddy cultivation is concentrated in the rainy season and extremely limited in the dry season, because the dependable water resources are almost completely exhaused during the dry season. The planted area of wet season paddy widely fluctuates year by year, depending on the available rainfall and riverflow. Paddy yield also fluctuates, being directly affected by the amount of water available. It ranges from 200 kg/rai (1.2 ton/ha) in the rainfed area to 450 kg/rai (2.8 tons/ha) in the irrigated area.

24. There are 10 existing irrigation projects in the Mae Wong river basin, covering a total area of 230,000 rai (36,800 ha). These include three (3) medium scale irrigation projects (MSIP) and seven (7) small irrigation projects (SSIP), as shown below:

Existing Projects	Irrigation Area (rai)	Irrigation Area (ha)
MSIP		
1. Wang Kun Pao	105,000	16,800
2. Kun Lard Boriban	55,000	8,800
3. Khlong Nam Hom	10,000	1,600
Sub-total	170,000	27,200
SSIP		
1. Ban Wang Nam Kao	3,000	400
2. Khlong Saingu	10,000	1,600
3. Huai Hin Lab	3,000	480
4. Wang Ma	26,000	4,160
5. Lan Bai Dieo	4,000	640
6. Nong Yao	4,000	640
7. Wang Hin Phoeng	10,000	1,600
Sub-total	60,000	9,600
Total	230,000	36,800

25. The existing irrigation areas of 230,000 rai (36,800 ha) are not always actually irrigated due to insufficient availability of irrigation water. The water balance study on the existing condition indicates that only about 60% of the paddy field in the existing irrigation areas are actually irrigated in the rainy season under normal condition with 80% probability rainfall. Field observations confirm that this estimate reflects well the actual irrigated condition in the areas.

26. In the Mae Wong river basin, the irrigated paddy field is mostly located along the upstream of the river and the existing canals, and the rainfed paddy fields extend over the downstream areas. There is clear difference in crop yield and therefore in farm income between the actually irrigated area and rainfed area. It is reported that serious disputes for irrigation water often occur between farmers in upstream areas and those in the downstream areas. This causes some social tensions in the basin area.

27. Total population in the Mae Wong river basin is estimated at about 75,000 in total. It has been increasing at the rate of 2.4% per annum. Total number of household is about 13,500, out of which farm household accounts for 10,200 or 76% of the total. About 85% of the farmers own their farmland with an average holding size of 28.7 rai (4.6 ha).

28. The present farming practices is still conventional; local varieties are still predominant, use of fertilizers is limited, agro-chemicals for plant protection are not used, use of certified extension seeds is very rare, etc. These are derived from present unreliable water availability, because most of the improved farming practices are possibly introduced only under the condition that irrigation water is assured.

PROSPECTIVE DEVELOPMENT PLAN

29. The Mae Wong Irrigation Scheme (hereinafter referred to as "the Project") will greatly contribute to the realization of the basic requirement for rural development in the Sakae Krang river basin, which basically aims at:

(1) improvement of present poor economic position of the area through full utilization of the endowed water resources for increase of paddy production, and

(2) uplifting of rural living standard and improvement of present income disparity in the area.

These basic principles are exactly conformed to the government policy given in the Fifth National Development Plan, and with this in view, the Government has accorded the high priority to the water resources development of the Sakae Krang river system in the said Plan.

30. The Project will have various aspects of development which include:

(1) exploitation of new water resources by construction of the Upper Mae Wong dam,

(2) up-grading of existing farmer's irrigation system

(3) expansion of irrigated paddy fields (irrigation to existing rainfed paddy fields), and

(4) other aspects of development including:

a. hydropower development at the Upper Mae Wong dam,

b. inland aquaculture development at the Upper Mae Wong reservoir,

c. flood mitigation by dam construction,

d. resettlement of the farmers who are living in the reservoir area, and

e. lumbering in the reservoir area.

31. Based on the results of water balance study, the optimum scale of the Project is determined as given below:

Reservoir Capacity	Irrigation Area	Cropping Intensity
250 MCM	291,900 rai (46,700 ha)	105%

32. The present land use in the Project area will be changed as follows:

(Unit: ha)

Land Use Categories	Without Project	With Project
Paddy field		
- irrigated	22,000	46,700
- semi-irrigated	14,800	-
- rainfed	7,800	-
Sub-total	44,600	46,700
Upland (rainfed)	2,100	-
Total	46,700	46,700

33. Paddy and mung beans are selected as main crops in future framework of cropping patterns. Paddy will be cultivated in the wet season and mung beans will be grown after harvest of wet season paddy in the dry season. The crop intensity of 105% is proposed in view of irrigation water balance, i.e. 100% of wet season paddy comprising 80% of high yielding varieties and 20% of improved local varieties, and 5% of dry season mung beans.

34. With introduction of improved farming practices and proper water management, the crop yields are substantially increased. The anticipated crop yields are set up as given below:

Paddy	
- high yielding varieties	720 kg/rai (4.5 tons/ha)
- local improved varieties	640 kg/rai (4.0 tons/ha)
Mung beans	190 kg/rai (1.2 tons/ha)

35. The crop production will gradually increase during the build-up period of 5 years after completion of the Project. The incremental crop production at the full development stage is estimated:

(Unit: tons)

Crops	Without Project	With Project	Increment
Paddy	98,400	205,500	107,100
Mung beans	2,400	2,800	400
Maize	4,600	-	-

36. The net incremental benefit of the Project, which is defined as the difference between the respective net production values under future "with" and "without" project conditions, is estimated as follows:

(Unit: 10^6 ฿)

Crops	Without Project	With Project	Increment
Paddy	237.7	604.1	366.4
Mung beans	7.3	10.7	3.4
Maize	5.8	-	-5.8
Total	250.8	614.8	364.0

37. Irrigation water requirements are calculated based on the potential evapotranspiration estimated by the modified Penman method. The unit design water duty for canals and related structures is determined at 1.25 ℓ/sec/ha (0.20 ℓ/sec/rai).

38. The drainage modulus is estimated based on the 3-day consecutive rainfall with 5-year return period, using the rainfall data observed at Lat Yao. The drainage modulie are 3.67 ℓ/sec/ha for the paddy field and 4.84 ℓ/sec/ha for the high terraces and hills.

39. The preliminary layout planning of irrigation and drainage canals is made on the topographic maps on a scale of 1/10,000 prepared by RID. In the planning, the existing farmer's irrigation systems are incorporated into the Project as far as possible.

For the upgrading plan of existing farmer's irrigation systems, the following concepts are considered:

- Existing intake weirs and regulator (gate) would be integrated under the Project to simplify the water management on the Mae Wong river,
- Existing intake weirs and regulator other than the proposed or integrated ones under the Project would be removed and all cutting of the Mae Wong river bank by farmers would be reclosed to assure the stable intake of irrigation water released from the Upper Mae Wong dam to each irrigation area,
- Measuring devices would at least be provided at the head of main canal for proper water management, and
- There exist no inspection roads along the existing canals. Inspection roads would be provided for proper operation and maintenance of irrigation facilities.

40. The hydropower generation plan is made to fully utilize the irrigation water to be released from the Upper Mae Wong dam. The optimum hydropower development plan is determined as given below:

Maximum high water level	:	207.5 m
Normal high water level	:	204.5 m MSL
Rated water level (in case of maximum output)	:	197.0 m MSL
Minimum water level	:	180 m MSL
Tail water level	:	152.3 m MSL
Gross head	:	44.7 m
Rated effective head	:	42.5 m
Maximum discharge	:	18.5 m^3/sec
Maximum output	:	6,500 kW
Annual energy production	:	15,238 MWh

41. According to the results of water balance study, the return flow to the other basins is estimated at about 53.0 MCM in the wet season and 2.1 MCM in the dry season in the drought year with 5-year return period. Such return flow can be used as irrigation water and/or domestic water for the people living in the other basins.

42. Incidental but considerable reduction of flood scale and frequency will be attained from the implementation of the Upper Mae Wong dam. Based on the results of flood routing analysis, the reductions of peak and flood volume are estimated as follows:

Flood Probability (year)	Without Reservoir Peak (m^3/sec)	Without Reservoir Volume (MCM)	With Reservoir Peak (m3/sec)	With Reservoir Volume (MCM)	Reduction Peak (%)	Reduction Volume (%)
10	860	91	650	70	24.4	23.1
50	1,200	127	990	103	17.5	18.9
100	1,340	141	1,130	116	15.7	17.7

43. The project will provide a large possibility of inland fishery development in the area, by creating a reservoir and irrigation canals. In the reservoir, an annual fish production of about 170 tons is expected under natural condition without fish releasing and feeding. It is approximately valued at 8 million Baht. The possibility of aquaculture is also large in the reservoir. High production of high-valued fishes is expected; in the case of cage culture or heedless culture, an average of 1.6 tons per rai will possibly be realized under proper management.

44. The resettlement program is recognized as an important step to the project implementation with the intention of mitigating the impacts on the quality of life values. There is presumably little or no specific problem as to the relocation of inhabitants in the reservoir area, if they are provided appropriate compensation and resettlement site. The potential site for such resettlement is conceived in the forestry village project area which is managed by RFD and located close to Ban Wang San in Amphoe Lat Yao.

45. Since the forests which are commercially valuable are found in some parts of the reservoir area, it is possible to gain some incomes by selling merchantable timber trees in advance of the inundation. The calculated total net profit is about 33.2 million Baht. It is highly recommended from this result that the forests in the reservoir area should be cleared before impounding the water.

PROPOSED PROJECT WORKS

46. Topography of damsite is rather complicated, valley shape is wide and river course is winding. Left side abutment is relatively thin and deep topographic depression is located at right side abutment. Saddle shape topography is located at about 1.5 km north of damsite, where the ground elevation is almost same as proposed dam crest elevation and deep valley develops at downstream of saddle shape.

47. The dam foundation consists of hard rocks of Quartzite, Calc-silicate and Schist and there will be no leakage through the abutments or the foundation of dam. However, curtain grouting will be necessary to seal all fractures, joints and shear series near the rock surface. Consolidation grouting to supplement curtain grouting would be required. Reservoir area is generally formed by granite rocks. Dissolvable limestone groups are not expected in the reservoir geology. A fault is in evidence crossing the reservoir from northeast to southwest at about 1.5 km upstream of dam. This fault is old and small in scale. There will be no problem of leakage and no treatment will be required to prevent such losses from the reservoir.

48. Through the comparison study, the rockfill type dam was selected for the Upper Mae Wong dam in all aspects such as material availability, suitability for high dam and economic construction. The most economical dam axis was selected through the comparison based on the preliminary designs and cost estimates for three alternative dam axes.

49. The height of the dam would be 57 m above the dam foundation. The crest of the dam would be designed at elevation 211 m with a maximum freeboard of 3.5 m. The dam crest would have 10 m in width, and 794 m in length. The slope of the upstream and downstream faces would be 1:1.75 and 1:1.6, respectively. The total embankment volume of the dam would be about 2,500,000 m^3.

50. The dam foundation and abutments will be treated by curtain grout to seal all fractures, shears, joints and all cracks made during explosive excavation of cut-off trench. The maximum depth of curtain grout was designed at 20 m at abutments and 6 m under the cut-off trench.

51. The Upper Mae Wong dam will have a service spillway of ungated side-channel type at rightside abutment and an emergency spillway of ungated chute type at about 1.5 km north of damsite. Design flood of 1,770 m^3/sec is allocated with 1,200 m^3/sec at 50-year return period for service spillway and with 570 m^3/sec for emergency spillway. Flood overflow depth was designed at 3.0 m at service spillway and 1.5 m at emergency spillway.

52. A diversion tunnel alignment was selected at left abutment from the topographic conditions. Diversion of the river will be accomplished through a concrete lined tunnel, 7.6 m in diameter and 230 m in length, which will pass the design flood of 480 m^3/sec with a water surface elevation of 173.0 m at upstream.

53. For the purpose of furnishing irrigation water, the design discharge of 43 m^3/sec will be released with the water surface elevation of 180 m in the reservoir. The intake structure was designed to be located at the inlet portion of diversion tunnel with a drop-inlet type. The outlet pipeline of 3.4 m in diameter will be located through diversion tunnel. The flow water through the pipe will be controlled by high pressure gate of 1.5 m in diameter.

54. The principal features of the Upper Mae Wong dam and reservoir are summarized as follows:

1. Reservoir		
Catchment area		612 km2
Total storage volume		250 MCM
Effective storage volume		230 MCM
Dead storage volume		20 MCM
Water level		
Total storage level		EL. 204.5 m
Flood surcharge level		EL. 207.5 m
Dead storage level		EL. 180.0 m
Reservoir area		
Total storage area		17.6 km^2
Flood surcharge area		19.8 km2
Dead storage area		3.0 km^2
2. Dam		
Type		Center-cored rockfill type
Height		57 m
Crest elevation		EL. 211 m
Crest length		794 m
Crest width		10 m
Slopes	Upstream	1:1.75
	Downstream	1:1.6
Embankment volume		2,500,000 m^3
3. Spillway		
Service spillway		Ungated side channel type
Design discharge		1,200 m^3/sec
Crest length		110 m
Emergency spillway		Ungated chute type
Design discharge		570 m^3/sec
Crest length		210 m
4. River diversion		
Approach canal		220 m
Diversion tunnel		230 m
Diameter	2R Horse shoe	7.6 m
Diversion canal		790 m
Diversion dam		90,000 m^3
5. Intake and outlet works		
Intake design discharge		43 m3/sec
Intake structure		Drop inlet
Outlet pipe diameter		3.4 m

55. The optimum hydropower development plan was examined changing the maximum discharge released from the Upper Mae Wong dam. The salient features of the hydropower development plan are as follows:

1.	Penstock	:	embedded type, 3 m of inner diameter
2.	Powerhouse	:	semi-underground type, 19 m of width x 19 m of length
3.	Power generation facilities	:	horizontal Francis type, 6,500 kW of unit capacity, 42.5 m of normal effective head, discharge capacity of 18.5 m^3/sec
4.	Transmission system	:	30 km

56. Two (2) intake weirs are proposed to divert the irrigation water to the Ban Tha Ta Yu irrigation area of 105,000 rai (16,800 ha) and the Khlong Saingu irrigation area of 51,000 rai (8,160 ha). The intake weir of Ban Tha Ta Yu irrigation area would be 2.7 m high and 30 m long including the scouring sluice portion. The intake weir of Khlong Saingu irrigation area would be 1.3 m high and 28 m long.

57. The proposed irrigation/drainage facilities comprise main and lateral irrigation canals and their related structures, drainage canals and their related structures, and farm roads. The main irrigation canal would be trapezoidal and lined with 10 cm thick plain concrete.

The lateral irrigation canal would be also trapezoidal and unlined. The related structures, such as turnout, check, drop, syphon, culvert, bridge, spillway, cross drain, and water measuring devices, would be of reinforced concrete. The newly proposed collector drain is trapezoidal and unlined. Its related structures, such as cross drain and culvert, would be also of reinforced concrete. All the inspection roads would be so designed as to have an effective width of 5 m and to be laterite-paved. The lateral inspection roads would be provided with an effective width of 4 m.

58. The principal features of irrigation facilities are given below:

1.	Source of irrigation water	Mae Wong river	
2.	Net irrigation area	46,700 ha	
		Upgrading	New construction
3.	Intake weir		2 nos.
4.	Main canal		
	Canal length	64.7 km	12.0 km
	Number of related structures		140 nos.
5.	Lateral and sub-lateral canal		
	Canal length	171.4 km	113.8 km
	Number of related structures		632 nos.

		Upgrading	New construction
6.	Drainage canal		
	Canal length	96.1 km	108.1 km
	Number of related structures		46 nos.
7.	Inspection road		
	Main road		76.7 km
	Lateral road		285.2 km
8.	Land reclamation		1,100 ha

CONSTRUCTION PLAN AND COST ESTIMATE

59. After the preparatory works such as access roads, office yards, motor pools, etc., the dam construction works will be commenced from the beginning of the dry season. The excavation works of dam foundation, river diversion canal and diversion tunnel can be progressed almost in parallel. Foundation treatment should start from riverbed in order to enable earlier dam embankment works and remaining both sides treatment works might be gradually carried out prior to the dam embankment. Excavation of spillway would be executed in parallel to the dam embankment, because the useful excavated materials are planned to haul directly to the dam, and concrete works would be carried out after completion of the excavation. Construction of intake facilities could be carried out on a proper occasion without relation to the dam construction. After completion of those major works, plug works of diversion tunnel would be executed.

60. The construction works of intake weir would be mainly executed during the dry season in due consideration of flood in the river. Concrete would be produced by several numbers of portable concrete mixers and placed using backet hanged by truck-crane. Stripping and surface excavation of the main canals and laterals would be mainly made by bulldozer, and sub-surface and deep excavation, by back-hoe shovel depending on the soil condition at the working site. Spreading of filling materials would be mainly made by bulldozer and supplementally by manpower. After completion of earth works, concrete lining works would be executed by manpower using portable concrete mixer. Construction works of the related structures would also be executed by manpower using portable concrete mixer.

61. First two years will be necessary time for preparatory works including tendering, survey and mapping, detailed design works, construction of offices and quarters and so on. The actual construction works will be commenced from the third year. Dam construction including relevant facilities will need five years in total. In parallel with the above dam construction schedule, irrigation facilities will also be executed and finished before completion of the dam construction, so as to enable to use stored water as early as possible.

62. The project costs are estimated based on the mid-1985 prices.

(Unit: 10^6 ฿)

Item	Total	Foreign Currency	Local Currency
1. Construction Cost (including Overhead, Profit and Tax)			
1.1 Dam Construction	1,051.0	807.3	243.7
1.2 Irrigation Facilities	638.8	367.8	271.0
1.3 Office & Quarters	24.2	-	24.2
Sub-total	1,714.0	1,175.1	538.9
2. Land Acquisition, Resettlement & Compensation	28.0	-	28.0
3. O & M Equipment	44.6	40.5	4.1
4. Administration	42.9	-	42.9
5. Physical Contingency	183.0	121.6	61.4
6. Engineering Services	235.3	194.9	40.4
Sub-total	533.8	357.0	176.8
Total	2,247.8	1,532.1	715.7
7. Price Contingency	647.3	414.1	233.2
Grand Total	2,895.1	1,946.2	948.9

(Exchange Rate: US$1.0 = ฿27 = ¥240)

ORGANIZATION AND MANAGEMENT

63. RID will be the main implementation body for the Project. The Construction Office will consist of a main office and four branch offices. The main office has four sections such as administrative, engineering, construction and tertiary development sections.

64. After completion of construction works, the Construction Office will be re-organized into the O & M Office under the Regional Office VII, RID. The Office will consist of a main office and four branch offices. The main office will consist of two divisions, administrative division and technical division, and the technical division will have three sections, namely engineering, operation and maintenance and mechanical sections.

65. The water management for the Project will broadly be divided into the water management for the Mae Wong river including the operation of the Upper Mae Wong dam and the water management for the irrigation service area.

In the full operation stage of the Project, the Mae Wong river will play an important role to feed the released water from the Upper Mae Wong dam to each irrigation service area. In order to assure the stable intake of irrigation water to the field at diversion points on the Mae Wong river, the river should properly be managed and maintained by RID (O & M Office).

Efficient operation of the irrigation systems in the irrigation area should ensure that the right amount of irrigation water is supplied to the crop at the right time. The water management of main systems such as intake facilities, main and lateral canals will be full responsibility of the O & M Office. The water management of on-farm facilities will be the responsibility of the farmers. For the proper water management at farm level, the establishment of water User's Association by farmers themselves is indispensable.

PROJECT EVALUATION

66. The project evaluations are made in order to ascertain the feasibility of the Project in view of economic, financial and socio-economic aspects. The economic feasibility of the Project is evaluated in terms of the internal rate of return (IRR) and the net present value (NPV) at the discount rate of 10%. The calculated result is as follows:

IRR : 13.0%
NPV : 475 Million ₿

67. In order to evaluate the soundness of the Project against the possible changes in future economic conditions, sensitivity analyses are made for the following cases:

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

Case-2: 10% project benefit decrease due to unexpected decrease in forecasted price of farm products and in crop yields

Case-3: Two years overrun of build-up period due to unexpected insufficiency in O & M management and agricultural extension services

Case-4: Two years overrun of construction period due to unexpected and unforeseen reasons

The effects of these changes on IRR and NPV (discounted at 10%) are summarized as shown below:

Case	IRR (%)	NPV (Million ฿) 10%
Case-1	11.9	331
Case-2	11.8	284
Case-3	12.5	406
Case-4	11.8	285

68. The result of economic evaluation indicates that the Project has a high economic viability and is rather insensitive to the possible changes in basic assumptions for economic evaluation.

69. The financial evaluation of the Project is made through the farm budget analyses on different size of farmers. The payment capacity is recognized as the ability of the project-benefited farmers to bear the expenses required for operation and maintenance of the project facilities as well as for repayment of capital cost. The payment capacity is measured by the difference of net disposable reserves under future with and without project conditions, which the farmers can actually earn from the Project after all the farm expenses and living costs are deducted from the gross farm income. The payment capacity under the Project at the full development stage is estimated:

(Unit: ฿/farm/year)

Farm Size	Average Farm Size rai	Average Farm Size ha	Existing Irrigation Area (36,800 ha)	Rainfed Area (9,900 ha)	Weighted Average
(1) Small Size Farm (less than 20 rai)	7.5	1.2	6,800	10,100	7,500
(2) Medium Size Farm (21 - 50 rai)	28.1	4.5	24,600	27,700	27,400
(3) Large Size Farm (more than 51 rai)	75.0	12.0	66,100	103,000	33,900

The increased net disposable reserve would offer the incentives for farm reinvestment and further development to the farmers, and the substantial payment capacity would enable the farmers, if necessary, to make some payment for irrigation water

70. It is assumed that the capital required for the project implementation will be arranged under the following conditions:

(1) For foreign currency portion, the capital is financed by bilateral or international organizations with an interest rate of 3.5% per annum for a repayment period of 30 years including 10 year grace period.

(2) For local currency protion, the capital is arranged by the government budget allocation without repayment.

During the repayment period of 30 years for foreign loan, the average amount of the government budget allocation required for covering the loan repayment, loan interest and O & M costs is about B125 million.

71. In Thailand, the participating farmers are not requested to pay any water charges, but contribute indirectly to the government revenue by selling their rice surplus at low price which enable the exporters to contrive the export tax and premium. These indirect incremental revenue would amount to about 46.1 million Baht per annum in total under present regulations. This would correspond to about 37% of the required government budget allocation for the Project.

72. In addition to the direct benefits stipulated in the economic evaluation, the following secondary direct benefits and favourable intangible socio-economic impacts are expected from the implementation of the Project:

Secondary direct benefit

(1) Possibility of hydropower generation

a.	Installed capacity	6,500 KW
b.	Annual energy production	15.2 MWh

(2) Increase of potential fish production

a.	Type	- Aqua-culture in reservoir - Pond-culture in irrigation area
b.	Annual production in reservoir	170 tons

(3) Effective use of return flow

Total volume of return flow	53 MCM in the wet season 2 MCM in the dry season

(4) Revenue from forestry resources in the reservoir area

a.	Timber volume	136,000 m^3
b.	Net value	33 MB

(5) Mitigation of flood damage

a.	Reservoir's regulate ratio	78%
b.	Regulating of peak flood (10-year flood)	24%

Favolable socio-economic impact

(1) Foreign exchange earning

(2) Increase of employment opportunity

(3) Improvement of local transportation

(4) Improvement of the water supplies for domestic uses in the irrigation area

ENVIRONMENTAL CONSIDERATIONS

73. The implementation of project facilities, particularly dam and reservoir, and irrigated agricultural development would bring about various environmental changes to the area.

The results of the environmental study in accordance with NEB guideline are summarized as followa:

(1) Impacts of dam construction

The construction of the dam and reservoir yields huge amount of water, and the regular supply pf water to the downstream area from the reservoir will contribute to increase of irrigation area and groundwater potential, mitigation of flood damages, creation of hydropower development potential and improvement of rural water supplies.

The river water quality will not turn worse, and the change of sediment transportation mechanism will not seriously affect on the environmental resources.

A new opportunity of fish production will be created in the reservoir. The unfavourable impacts on forests and wild-life habitat will be little, and the considerable income will be gained from selling the timber which is felled and logged in the area.

It is recommended that a resettlement program should be prepared for the people who will lose farm lands and houses by creation of the reservoir. Before preparation of the resettlement program, the detailed field survey should be carried out for both the reservoir area and resettlement area.

(2) Impacts of irrigated agricultural development

Major crops production will be increased through the irrigation development. Increase of agricultural productivity and up-grading of farmers' skill will steadily increase the demand for manufacturing and service industries and create new employment opportunity in industrial sector. The well networked irrigation system will encourage the farmers to develop the fish culture in the project area.

The inspection road network will provide for the people in the project area much transportation services.

RECOMMENDATIONS

74. Agricultural development in the Sakae Krang river basin should be primarily geared to the irrigation development coupled with new water resources exploitation. The feasibility study on the Sakae Krang River Basin Irrigation Project identified the following irrigation development projects:

(1) irrigation of 291,000 rai (46,700 ha) by Upper Mae Wong dam (Mae Wong Irrigation Scheme),

(2) irrigation of 111,900 rai (17,900 ha) by Khlong Pho dam,

(3) irrigation of 81,300 rai (13,000 ha) by Upper Khun Kaew dam, and

(4) groundwater irrigation development of 218,800 rai (35,000 ha) in the downstream areas.

It is recommended that these projects be realized gradually in several stages. The first stage of the irrigation development in the Sakae Krang basin should be the Mae Wong Irrigation Scheme (the Project) which will cover the largest irrigation area and give the largest economic impacts to the area. If the Project is realized, together with the irrigation area of 110,000 rai (17,600 ha) by the Thap Salao dam, about 401,900 rai (64,300 ha) or about 50% of the existing paddy fields will be put under irrigation in the Sakae Krang river basin. These significant changes of irrigated condition will increase the total volume of return flow and give favourable impacts to the small scale irrigation projects and groundwater flow in the downstream areas.

75. The Project is technically sound and economically feasible. About 74,500 people in the Project-benefited area have long desired its early implementation. Irrigation development in the Sakae Krang river basin was started in the Thap Salao area in the Uthai Thani province and the Mae Wong area which belong to the Nakhon Sawan province, has been left behind. This situation causes some social tensions. If project implementation is delayed, the watershed area will be encroached by illegal immigrants and the forests will be cleared for farming. These will result in more serious problems of water shortage and floods in the downstream area. The implementation of the Project will also become difficult, if construction is delayed, because of the increasing number of illegal immigrants in the reservoir area.

With such background, it is highly recommended that the Project be implemented as early as possible.

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ABBREVIATIONS AND LOCAL TERMS

A. ABBREVIATION OF MEASURES

(1) Length

mm	=	millimetre
cm	=	centimetre
m	=	metre
km	=	kilometre

(2) Area

m^2	=	square metre
ha	=	hectare = 10^4 m^2
km^2	=	square kilometre = 10^6 m^2
rai	=	0.16 ha

(3) Volume

lit, l	=	litre = 1,000 cm^3
kl	=	kilolitre - 1 m^3
m^3	=	cubic metres
MCM	=	million cubic metres
	=	1,000,000 m^3

(4) Weight

mg	=	milligramme
g	=	gramme
kg	=	kilogramme
t, ton	=	ton = 1,000 kg

(5) Time

s, sec.	=	second
min	=	minute
h	=	hour
d	=	day
yr	=	year

(6) Money

฿	=	Baht (unit of Thai currency US$ 1 = ฿ 27.0)
$	=	US dollar
¥	=	Japanese Yen (US$ 1 = ¥ 240)

(7) Electric Measures

kv	=	kilovolt
kw	=	kilowatt
MW	=	megawatt = 1,000 kW
kWh	=	kilowatt hour
kVA	=	kilovolt Ampere
GWh	=	gigawatt hour

(8) Other Measures

mmho	=	micromho
ppm	=	parts per million
ppb	=	parts per billion
%	=	per cent
PS	=	0.736 kW
pH	=	scale for acidity
°	=	degree
'	=	minute
"	=	second
°C	=	degree centigrade
10^3	=	thousand
10^6	=	million
10^9	=	billion

(9) Derived Measures Based on the Same Symbols

m^3/s	=	cubic metre per second
ton/ha	=	ton per hectare
10^6 m^3/yr	=	million cubic meter per year

B. OTHER ABBREVIATIONS

GDP	=	gross domestic product
El.	=	elevation
HWS	=	high water surface
FOB	=	free on board
CIF	=	cost, insurance and freight
O & M	=	Operation and Maintenance
HYV	=	High Yielding Varieties

C. ABBREVIATION OF ORGANIZATIONS

RID	Royal Irrigation Department
MOAC	Ministry of Agriculture and Cooperatives
DOF	Department of Fisheries
LDD	Land Development Department
NESDB	National Economic and Social Development Board
NEB	National Environment Board
NSO	National Statistical Office
MOI	Ministry of Interior
DMR	Department of Mineral Resources
DIW	Department of Industrial Works
MOC	Ministry of Communications
DHW	Department of Highways
DOH	Department of Health
PWWA	Public Water Works Authority
MD	Meteorology Department
DOLA	Department of Local Administration
JICA	Japanese International Cooperation Agency
IBRD	International Bank for Reconstruction and Development

FAO	Food and Agriculture Organization
DOA	Department of Agriculture
DAE	Department of Agricultural Extension
MOF	Marketing Organization of Farmers
BAAC	Bank for Agriculture and Agricultural Cooperatives
EGAT	Electricity Generating Authority of Thailand
PEA	Provincial Electricity Authority
MEA	Metropolitan Electricity Authority

D. LOCAL TERMS

Changwat	:	Privince
Amphoe	:	District (Township)
Tambon	:	Sub-district
Muban	:	Village
Muang	:	Administrative Center of Province
Mae Nam	:	River
Khwae	:	Main tributary of river
Huai	:	Stream, creek or small tributary
Khlong	:	Canal
Khao	:	Mountain

CHAPTER I INTRODUCTION

1.1 Authority

This report is compiled in accordance with Article V-3 of the "Scope of Work for the Feasibility Study on the Sakae Krang River Basin Irrigation Project" agreed upon between the Royal Irrigation Department (RID) of Thailand and the Japan International Cooperation Agency (JICA) on July 6, 1984. The agreed "Scope of Work" contains three (3) major programmes:

Part A: study on overall Sakae Krang river basin water resources development and indentification of possible project(s),

Part B: pre-feasibility study on high priority project(s) to be selected in Part A, and

Part C: feasibility study on the first priority project to be selected in Part B.

This report presents the results of the feasibility study on the Mae Wong Irrigation Scheme (hereinafter referred to as "the Project" unless otherwise specified) which has been selected with the highest priority through the past studies made in Part A and B.

1.2 Project History

The water resources development in the Sakae Krang river basin has been strongly requested by the rural people. RID commenced the survey and studies on irrigation and agricultural development in 1970's, and the Thap Salao irrigation project with a net area of 88,000 rai (14,080 ha) was implemented in 1982. The river-flow in the Thap Salao is, however, not so dependable as to irrigate the project area of 88,000 rai. It has been also recognized that the stream-flow of other tributaries fluctuates largely and causes repeated crop damages by drought and flood.

In recent years, RID has envisaged construction of storage dams to eliminate the constraints of shortage of irrigation water in the Sakae Krang river basin. Six dam sites have been reconnoitered by RID. In conformity with the major objectives stipulated in the current Fifth National Development Plan, the Government of Thailand intends to urgently promote the water resources development in the Sakae Krang river basin, and requested to the Government of Japan to extend technical cooperation for the feasibility study on the Sakae Krang river basin water resources development in July 1983. In response to the request, the Government of Japan decided to execute the technical cooperation and entrusted thereof to JICA, the official agency responsible for the Government of Japan.

JICA dispatched a preliminary survey team headed by Dr. H. Nakamichi, Chief Engineer, the Bureau of Agricultural Structure Improvement, Ministry of Agriculture, Forestry and Fisheries, from 25th June to 7th July in order to investigate the project site and to talk about Scope of Work for the feasibility study. The Scope of Work was, after full and fruitful discussions, concluded between the RID and the survey team on behalf of JICA, on the date of July 6, 1984.

Based on the above "Scope of Work", the overall basin study and pre-feasibility study on high priority projects (Part A and B) were commenced on October 1, 1984. The field investigation and study lasted until the end of December, 1984. As the major outcome of the field work, six (6) possible dams were identified and among others, the high priority dams, i.e., the Upper Mae Wong, Lower Mae Wong and Khlong Pho, were selected through a series of discussions with RID. The pre-feasibility study on the selected high priority dams was made in Japan during the period from January to March, 1985, and the pre-feasibility report was presented in mid-March, 1985. In the report, it was recommended that first priority be given to the irrigation development by the Upper Mae Wong dam.

Following the pre-feasibility study, JICA dispatched a study team to the project site again on July 1, 1985 to implement the feasibility study on the Mae Wong Irrigation Scheme. The study team completed the field survey by the end of September 1985 and submitted the Interim Report to RID. Home office work for part C was made during the period from October to December, 1985. The Draft Final Report was prepared by the study team and submitted to RID in early January, 1986.

A discussion meeting on the Draft Final Report was held on January 9, 1986. Based on the comments at the meeting, the Draft Final Report was finalized hereby by the Team in March, 1986.

1.3 Outline of the "Scope of Work"

The "Scope of Work for the Feasibility Study on the Sakae Krang River Basin Irrigation Project" is outlined as follows (for detail, see ATTACHMENT 1):

(1) Part-A (Field work)

- review of all the existing and proposed irrigation projects in the basin,
- assessment of land and water resources,
- identification of possible projects for new water resources development,
- study on agricultural development concept and formulation of possible irrigation projects,
- selection of high priority project(s),
- preliminary environmental study, and
- preliminary study on hydropower development potential.

(2) Part-B

(Field work)

- supplemental collection and review of the relevant data and information,

- field survey in the selected high priority project(s) area concerning with topography, meteorology, hydrology, agriculture, socio-economy, floods, construction materials, etc.,

(Home office work)

- formulation of development plans for high priority project(s),

- priority ranking of the project(s) and selection of the first priority project, and

- preparation of pre-feasibility report.

(3) Part-C

(Field work)

- additional field survey and data collection for the first priority project, concerning with soil and land classification, geology, groundwater and others,

- study and determination of basic frame-work for project planning, including development scale, land use and cropping pattern, water requirement, dam planning and design, and project works and benefits,

- formulation of integrated development plan for the first priority project, and

- preparation of interim report and discussion with RID.

(Home office work)

- review of interim report,

- definite plan of water resources, agricultural and irrigation development,

- preliminary design of project facilities,

- economic and financial evaluation,

- O/M planning, and

- preparation of recommendations to the Government of Thailand.

1.4 Activities of Study Team

The JICA pre-feasibility study team arrived in Thailand on October 1, 1984. Prior to the substantial investigation and study, the study team undertook the field reconnaissance in the study area and prepared a report on "plan of operation for the study".

After submitted the said report to RID, the discussion was held at the RID headquarters on October 8, between the authorities concerned and the study team. The approach to the project and the plan of operation proposed in the report were basically accepted by the authorities concerned.

Since then, actual field investigation and study were carried out with cooperation of RID both in Bangkok and study area. These include:

(1) overall review of existing development plans,

(2) data collection in the fields of hydrology, meteorology, geology, soils, land use, existing irrigation systems and agricultural economy,

(3) computerized analysis of meteorological and hydrological data,

(4) study on present agricultural conditions,

(5) field investigation and study on existing irrigation system,

(6) study on development strategies,

(7) assessment of endowed water resources and water balance study, and

(8) preliminary design of dam and related structures.

In the course of the study, the Supervisory Committee headed by Dr. H. Nakamichi, Chief Engineer, the Bureau of Agricultural Structure Improvement, Ministry of Agriculture, Forest and Fisheries, also visited Thailand to inspect the field investigation and study undertaken by the study team. A series of discussions were made between the Committee and the study team during the period of the Committee's stay in Thailand from December 9 to December 16, 1984. The interim results of the study were basically approved by the Committee with some technical comments.

The study team then prepared a draft progress report, compiling the interim results of field investigation and study and submitted it to RID on December 13, 1984. The meeting was held on December 19, 1984 between the Thailand authorities and the study team, together with the Committee, to discuss the interim study results. In the meeting, the high priority dams; namely, Upper Mae Wong, Lower Mae Wong and Khlong Pho dams were officially selected. The result of discussion was confirmed again in the technical meetings which were held individually with various divisions of RID during the period from December 20 to December 25, 1984. The progress report was finalized, following the comments and suggestions made by the Committee and RID officials, and was submitted to RID on December 28, 1984.

The study team made, in Japan, the pre-feasibility study on the selected high priority dam and irrigation schemes and the pre-feasibility report was presented in mid-March, 1985. A discussion meeting on the pre-feasibility report was held at RID on March 18, 1985 and the results of the pre-feasibility were accepted; particularly the high priority of the Upper Mae Wong dam was confirmed between RID and the study team. Thus, the studies for both Part-A and Part-B were completed in March, 1985.

The JICA study team for the feasibility study on the first priority project was dispatched on July 1, 1985. The team prepared the Plan of Operation for Part-C study and held a meeting with RID on July 9, 1985. The team made various activities for the feasibility study after the Plan of Operation was accepted, of which major activities include:

(1) data collection in the fields of topographic survey, geological boring, soil mechanical tests, land classification survey and socio-economic survey which have been carried out by RID,

(2) inventory survey for irrigation facilities in the existing irrigation areas,

(3) geological investigation on the proposed damsite and reservoir area,

(4) study on present agricultural condition and formulation of future cropping pattern under the Project,

(5) study on irrigation water requirement,

(6) computerized analysis of meteorological and hydrological data and assessment of endowed water resources,

(7) computerized water balance study and optimization of development scale,

(8) preliminary design of project facilities,

(9) preliminary cost estimate and construction planning,

(10) preliminary study on project institutions concerning water management and agricultural support services, and

(11) preliminary environmental survey and assessment of environmental impacts.

The present report has been prepared on the basis of all these activities mentioned above.

The RID official concerned, members of the Supervisory Committee and study team are shown in ATTACHMENT-2. The minutes of meetings held, between RID and the Study Team, on all past reports, are also given in ATTACHMENT-3.

CHAPTER II BACKGROUND

2.1 General Economic Situation

Since the First National Economic and Social Development Plan launched in 1961, the Government of Thailand has drawn up four consecutive National Development Plans in order to develop and rehabilitate infrastructural facilities needed for the expansion of production and trade, and for the well-being of the people.

Unlike the first two plan periods (1961 - 1971), where the economy achieved high growth rates with modest inflation and an impressive accumulation of foreign reserves, the economy during the combined Third and Fourth Plan periods (1972 - 1981) was severely affected by the instability of the international monetary system, high interest rates abroad and the rising prices of oil, because of the increased openness of Thailand's economy, and in particular because of its heavy dependence on imported oil.

Considering as a whole, however, all these four consecutive development plans have led to great achievement in economic growth and development over the past two decades. Real GDP has quadrupled and GDP per capita has more than doubled, namely the amount of GDP reached 929 billion Baht as of 1983 corresponding to the per capita GDP of about 19,000 Baht. This growth was made possible through the combination of a favorable external economic environment except the first and second oil crisis periods, high level of private investment and public sector expenditures, but the key was a steady increase in an agricultural production, though the manufacturing sector also grew rapidly in response to an expanding domestic market. Such growth, however, also led to accelerating inflation, a quickly deteriorating external balance, a rapidly growing saving-investment gap increasing in income gap in the public sector, and increased reliance on foreign borrowing.

2.2 Agriculture in Thailand

Thailand is divided into four major regions: North, Northeast, Central Plain and South, based on climate, geography and administrative units. Furthermore, the Ministry of Agriculture and Cooperatives through the Office of Agricultural Economics has divided Thailand into 19 agro-economic zones which are based on soil-type, rainfall, temperature, crops grown, production efficiency and type of farm and income from agriculture.

The total land area of Thailand consists of approximately 321 million rai (51.4 million ha), 37.8% of which is classified as farm holding land. Of the farm holding land, paddy land accounts for 74 million rai (60.6%), field crops for 27 million rai (22.6%), fruit and tree crops for 11 million rai (9.4%). The remainder, 9 million rai (7.2%) includes idle land, grass land, vegetable land, housing area, etc.

Of the total planted area (101 million rai) in 1983, paddy accounts for more than 60%, maize for 10.3%, rubber for 10.0%, cassava for 8.7%, and in turn sugarcane (3.6%), mung beans (3.0%), kenaf (1.3%), soy beans (1.0%), etc.

Thailand's 4.5 million farm families occupy about 121.3 million rai, throughout the 4 regions and 72 provinces. The average farm size is approximately 27 rai. Nearly 90% of the 4.5 million farm families are self employed and 85% of the holdings are farmed by owner-operated rather than tenants and land tenure problem only exists in a few provinces in the Central Plain. The farm size distribution in 1983 is estimated as follows:

Size of Farm (ha)	% of Farms	% of Area
Less than 1.0	15.9	2.3
1.0 - 2.4	27.4	11.4
2.5 - 4.9	30.0	25.7
5.0 - 7.9	17.3	27.1
8.0 - 12.5	6.2	15.0
More than 12.6	4.1	18.5

Land classified as "irrigated" is calculated about 22 million rai in 1983. However, it should be noted that irrigation is primarily supplemental during the rainy season, and irrigation water cannot always be supplied enough to the irrigated area. It is estimated that less than one fifth of the irrigated area represents land with adequate water control to permit double croppings.

Thailand's economically active population (15 - 64 years of age) amounts to 28.7 million, of which 18.0 million (62.8%) are in agricultural sector and 10.7 (37.1%) are in non-agricultural sector, of which 1.5 million in the industry sector.

Agricultural exports in Thailand contribute roughly 60% of the total exports for earning of foreign exchange, though the share has dropped from 72% in 1972. As to the contribution to GDP, the agricultural sector also has decreased its share in Thailand's GDP, but accounted for 23.6% in 1983 and still being the largest one in the economy.

In addition to the above-mentioned facts, it can be pointed out that, in comparison with other Asian countries, Thailand's agriculture is characterized by its rapid increase in production and diversification based on a very fast expansion of land, pervasion of tractors, with low levels of fertilizer application, stagnancy of yields and a high variability of agricultural production from year to year.

2.3 National Development Plan

The Government of Thailand has published its Fifth National Development Plan (1983 - 1986) in October 1981 as a policy plan which gives clear policy direction to be translated into actual operational plans, in order to overcome the problems mentioned above and promote economic progress while preserving a national harmony.

Major objectives of this plan include:

(1) Coordination of economic development activities with national security management, and adjustment of economic structure,

(2) Improvement of economic and financial position,

(3) Restructuring of the key productive sectors to raise economic efficiency,

(4) Provision of social services, especially to backward rural areas, and

(5) Poverty alleviation in backward areas.

The plan accorded greater emphasis on structural adjustment of Thai economy and was accompanied by a number of policy actions designed to initiate this reform on a broad front. In support of these efforts, Thailand received its first structural adjustment loan from the IBRD in 1982, and a second one in 1983. Main areas in which the Government is aiming for structural reform are agriculture, industry, energy, fiscal policy, and public administration, especially in management of public resources.

Generally restrictive fiscal and monetary policies will be followed with a view to reducing budgetary and current account deficits. Accordingly, some of these adjustments has necessarily involved a reduction in its economic growth rate. In the Fifth Development Plan, GDP in real terms is planned to grow at 6.5% per year, somewhat lower than historical rates.

The growth in agricultural production is planned to be an annual average rate of 4.5% over the 1982 - 1986 period, with agriculture's share in GDP declining to 22.6% by 1986 and roughly matching the manufacturing sector's share of 22%.

2.4 Government Policy for Agricultural Development

2.4.1 The role of agriculture within the Thailand's economy and its problems

Past national development efforts have been concentrated in the agricultural sector since agriculture is the highest single source of income, accounting for about 24% of Thailand's GDP, employs about three-fourths of the labor force, and is the source of about 60% of total exports. Therefore, the performance of the agricultural sector, though its share in the GDP had gradually dropped year by year, has been and will continue to be the key determinant of the country's social and economic progress.

During the past 20 years of agricultural development, agricultural output has expanded at a rather high rate of 5% per annum and has been the mainsprings of overall economic growth. Such development has been mainly achieved though the diversification of crops (although paddy is planted on more than 60% of cultivated area, the area planted to maize, cassava and

sugarcane is now just over 23 million rai and has doubled in the last decade), the expansion of the government's infrastructural services such as the development of water resources and expansion of the irrigation systems as well as the expansion of road networks between production and marketing locations, and especially through the expansion of the cultivated area.

The growth of agricultural GDP, however, has shown a tendency of declining in recent years, at 5.1% in 1970 - 1975 and 3.5% in 1975 - 1980 respectively, as compared with 5.5% in 1960 - 1970. The cause of such diminution would be mainly based on the following points:

- Cultivated area has been expanding at an annual rate of approximately 4% to reach 110 million rai at present, but land frontier is now nearly ended since suitable land for agriculture is almost running out,

- Yield of major crops have remained stagnant and the cropping intensity has also remained at a low level (96%).

In addition, there are significant disparities in farm income among the four major regions and/or the agro-economic zones, mainly due to unequal resources endowment, with the highest incomes being realized in areas of irrigated agriculture in the Central Region and the lowest in the North and Northeast. The main cause of poverty in the North and Northeast Region is the low yield of crops under rainfed condition and low cropping intensity, particularly in years of low rainfall. Development of the rainfed areas, therefore, has a special bearing on efforts to redistribute farm income.

2.4.2 Government policy for agricultural development

The Fifth Nation Development Plan states that "if there are no effective measures to improve the efficiency in the utilization of land and water resources, agricultural expansion is likely to be decline further to below 3.5% per annum during the firth plan period. Thus, it will be necessary to improve the production process and efficiency in the utilization of land and water resources in order to maintain the strategic importance of the agriculture sector during the next 5 - 10 years".

Based on the recognition that future agricultural development must come from intensification rather than from openning up new lands, the plan set a target for agricultural GDP to increase 4.5% per annum (country's economic target 6.5%), in spite of the relatively poor performance of agriculture in the late 1970's.

In order to achieve the said target, the plan laid down the various policy directions and measures. Corresponding to these facts, the main objectives of the Government's agricultural policy has been focused on the following points;

(1) To increase agricultural productions,

(2) To expand agricultural exports rapidly to help the balance of payments,

(3) To improve the agricultural marketing and pricing systems,

(4) To alleviate rural poverty and redress inter-regional income desparities, and

(5) To better utilize the available land suitable for agriculture, and protect against deforestation and conserve natural resources.

CHAPTER III SAKAE KRANG RIVER BASIN AND DEVELOPMENT CONCEPT

3.1 Current Situation of Sakae Krang River Basin

The Sakae Krang river basin extends over the northwestern part of the Central Chao Phraya river with a total area of about 3.94 million rai (6,300 km^2). It occupies about 3.6% of the entire Chao Phraya river basin. The Sakae Krang river system consists of four (4) major tributaries; i.e., from north to south, the Mae Wong, Khlong Pho, Thap Salao and Khok Khwai rivers. The river basin is located at about 250 km north from the Bangkok and compasses part of four (4) provinces of Khamphaeng Phet, Nakhon Sawan, Uthai Thani and Chainat.

Four (4) tributaries of the Sakae Krang river originate in the western mountain ranges and drift down from west to southeast to confluence with the mainstream of the Sakae Krang, and finally with the Chao Phraya river. The annual average discharges of these tributaries are estimated, from the runoff analysis for 30 years, at about 0.36 MCM/km^2 for the Mae Wong river, 0.20 MCM/km^2 for the Khlong Pho river and 0.23 MCM/km^2 for the Thap Salao and Khok Khwai rivers.

The river discharge in the basin reaches maximum in October and become minimum in March. The river runoff pattern is characterized by long low flow period from December to July. Reliable water resources supplied by the rivers are limited only during four (4) months from August to November. About 80% of total annual runoff occurs during these months. The river runoff also largely fluctuates year by year, ranging from 90 to 880 MCM/km^2 for the Mae Wong river, from 9 to 540 MCM/km^2 for the Khlong Pho river and from 30 to 530 MCM/km^2 for the Thap Salao and Khok Khwai rivers.

The Sakae Krang river basin is characterized by two distinct seasons; i.e., dry season from November to April and wet season during the rest of the year. The mean annual rainfall is about 1,230 mm, of which about 90% is concentrated in the wet season. Total depth of annual rainfall fluctuates largely year by year within a range from the lowest, about 720 mm to the highest, about 2,530 mm.

Of total basin area of 6,300 km^2, the agricultural land is about 1,860 km^2. The rests of 4,440 km^2 are non-agricultural lands like mountains, steep slopes, forest reserve, rivers and swamps, roads and urban areas. The agricultural land consists of 1,390 km^2 of paddy field, 360 km^2 of upland crop field and 110 km^2 of orchard and others.

Paddy rice is by far the most important crop, grown on about 75% of the total agricultural land. Paddy cultivation is concentrated in the rainy season and extremely limited in the dry season, because the dependable water resources are completely exhausted during the dry season. The planted area of paddy, even in the rainy season, widely fluctuates year by year depending on the endowed rainfall and river flow. The paddy yield is directly affected by total depth of annual rainfall. It ranges from 160 kg/rai (1.0 tons/ha) to 450 kg/rai (2.8 tons/ha).

About 61% of the existing paddy fields, or 534,000 rai (85,500 ha) in area, are presently covered with the existing irrigation projects of 56 in number; one large scale (Thap Salao), five medium scale and 50 small scale irrigation projects. However, most of the paddy fields still remain under rainfed condition. The dependable water resources is not sufficient for supplying the irrigation water throughout the growth period of rainy season paddy, to a whole irrigation area. Only about 58% of the existing irrigation area is actually served with water supplies and the rest laid under rainfed condition under normal rainfall condition with 80% probability.

Most of the irrigation canals aligned in the existing paddy fields are constructed by the farmers themselves. These canals are generally deteriorated due to improper maintenance. The density of the existing canal network is very low. This makes equitable distribution of irrigation water difficult. No technical drainage system has been provided so far in the existing irrigation area. Most of the existing canal have dual function of irrigation and drainage. This substantially contributes to repeated use of the limited water resources.

The present farming practices is still conventional; local varieties are still predominant, use of fertilizers is limited, agro-chemicals for plant protection are not used, use of certified extension seeds is very rare, etc. These apparent limitations for agricultural production increase come from present unreliable water availability, because most of the improved farming practices are possibly introduced only under the condition that irrigation water is assured.

About 0.32 million people lived in the Sakae Krang river basin primarily rely on agriculture. Farm household accounts for about 70% of the total household. Others are mostly engaged in trading, transportation, and public administration which support the agricultural activities. Agriculture contributes to about 45% of gross regional product, while it accounting for only about 24% of GDP in national economy. Agriculture has been and will continue to be the most important key determinant in regional economy of the basin area.

3.2 Agricultural Constraints

The Sakae Krang river basin is endowed with vast land resources suitable for agricultural production. Nevertheless, land productivity is still very low, due to various problems and constraints involved in the current agriculture. The major problems and constraints are:

(1) annual shortage and uneven distribution of rainfall,

(2) occasional floods,

(3) unreliable water sources for irrigation,

(4) inadequate canal networks and insufficient density of canals which make equitable water distribution difficult,

(5) improper water management and lack of water user's associations,

(6) insufficient farm road network,

(7) scattered type of land holding pattern and small size of field plots, and

(8) conventional farming practices.

The problems are manifold; however, the most important single constraint to agricultural development in the basin is the lack of assured irrigation facilities coupled with the shortage of available water. The rainy season paddy crop often suffers from moisture stress at critical periods of growth, resulting in total of partial crop damages. There is a great concern among the farmers in the basin for such almost regular drought conditions than crop damages from any other causes. Other constraints such as yield limitations of local variety, low input use and inadequate crop management should become secondary in importance when considered against regular crop damages caused by present irregularity in water supply.

3.3 Basic Strategies for Development

The Kingdom of Thailand sustained about 8% of the economic growth rate during the recent decade of 1970's. Such rapid stride of the economic growth in the country caused serious and complex economic problems and social tensions (for detail, see Chapter II). In order to overcome such problems and tensions, the Fifth Economic and Social Development Plan (1982 - 1986) has been set out containing long-term strategies and new approaches. Major objectives given in the Development Plan are:

(1) to restructure the key productive sectors like agriculture so as to improve the current economic and financial situations,

(2) to reduce absolute poverty and accelerate rural development in backward areas, and

(3) to uplift rural living standard as well as to strive more equitable distribution of income.

Two provinces of Nakhon Sawan and Uthai Thani where most of the Sakae Krang river basin are included, have about 2.6% of the Kingdom's population. The share of the provinces in GDP is however only less than 1.3%. The relatively poor position of the area is also indicated by its lag in per capita income; the average in the past five years amounts to about 3,670 Baht, corresponding to roughly two-thirds of national average (5,610 Baht). The area suffers also from the instability in annual income which fluctuates largely year by year. Such poor economic situation of the area is mainly derived from low productivity of agriculture which is definitely ascribed to lack of assured irrigation system coupled with the shortage of available water.

Paddy cultivation is a mainstay in the Sakae Krang river basin. It is surely suited to the area in economic-social-historical-cultural-physical context. The area is endowed with good soils and climate (except rainfall) suitable for paddy cultivation and the farmers are accustomed to paddy cultivation. Farmers heavily rely on paddy production economically. It however gives them only instable results of yield due to irregular water availability. The most important sole constraint to rural development in this area is again shortage of available water.

The Government of Thailand has emphasized the importance of paddy production increase in the Fifth National Development Plan. It is generally recognized among the government officials that for increase of paddy production, more attention will be given to the improvement of unit yield per rai because expansion of paddy field has become rather difficult in the country, and the priority is given to the improvement of unit yield in the existing paddy fields of the Central and Northern Regions where exploitable water resources still remain. The Sakae Krang river basin is one of the areas endowed with such exploitable water resources.

The irrigated paddy field in the Sakae Krang river basin is limited to only 36% of the total existing paddy fields; others are presently put under rainfed condition. The irrigated paddy field is mostly located along the upstream of each river, and the rainfed paddy fields extend over the downstream areas. There is clear difference in crop yield and therefore in farm income between irrigated areas and rainfed areas. It is reported that serious disputes for river water are often occurred between farmers in upstream areas and those in the downstream areas. This causes some social tensions in the area.

The Sakae Krang river basin is a considerably matured area for agricultural production, where numerous irrigation systems have been implemented and the presently available water is fully utilized with almost fixed cropping system. There is no water available for vast rainfed fields. Under these conditions, significant changes in agricultural production will not be expected unless new water resources are exploited.

Considering all these, basic strategies for development in the Sakae Krang river basin are considered as follows:

(1) The area is endowed with large potential for rice production and therefore the current poor economic position should be improved through full utilization of the endowed resources for increase of paddy production.

(2) The present rural living standard should be uplifted with particular emphasis on improvement of present income disparity in the area.

These basic principles are exactly conformed to the government policy given in the Fifth National Development Plan. With these in mind, the basic development concept for the Sakae Krang river basin is conceived as in the following. Major items of the basic concept are:

(1) exploitation of new water resources by means of dam construction,

(2) full utilization of existing irrigation systems and improvement of existing facilities, and

(3) expansion of irrigated paddy field.

These measures will significantly contribute to the realization of the above basic requirement for rural development in the Sakae Krang river basin. In order to realize these measures and attain the prospective goals, more precise guidelines for formulation of development plans will be required. The proposed guidelines for development planning in the fields of agriculture, water resources development and irrigation/drainage are given in the following sub-sections.

3.3.1 Agricultural development

The agricultural development plan should be formulated on the basis of the following basic concepts:

(1) Cultivation of wet season paddy should be stabilized through optimum utilization of newly exploited water resources.

(2) Unit yield of wet season paddy should be maximized through proper supplemental irrigation and improved farming practices.

(3) Supplemental irrigation area for wet season paddy should be maximized with full use of the limited exploitable water resources; however, first priority should be given to the existing irrigation areas. If water would still remain after supplying sufficient water to the existing irrigation area, the rainfed areas should be benefited within economically reasonable range.

(4) Special attention should be paid to the rainfed areas, in connection with further studies on possibility of groundwater exploitation.

(5) Dry season cropping should be considered as secondary importance; if water is still available during the dry season, irrigation for dry season cropping should be considered to a possible maximum extent. In order to save the water consumption and to use the limited water resources more effectively, some upland crops other than paddy should be considered as second crop in the dry season.

3.3.2 Water resources development

The water resources development will be the key component in the rural and economic development of the Sakae Krang river basin. The development plan in this field should be formulated on the basis of the following concept:

(1) Significant annual and seasonal fluctuation of streamflow should be stabilized through the construction of dam and reservoir.

(2) The exploitation of dam and reservoir should be at their maximum extent of storage within economically reasonable ranges.

(3) The implementation of dam and reservoir should be commenced as early as possible, since the forest cover of the watershed has been encroached by farmers and the number of inhabitants in the reservoir area has been increasing every year.

(4) As for the groundwater exploitation, the potential productivity is large in the downstream area along the Chao Phraya river. Small scale groundwater development should be accelerated under the technical assistance of RID and financial support of BAAC. The observation and study on the groundwater balance and quality analysis should be required prior to the exploitation of large scale groundwater development.

3.3.3 Irrigation and drainage development

In order to realize the concepts for agricultural development, the following basic concepts for irrigation and drainage development are envisaged in conformity with the concepts for water resources development:

(1) First priority for irrigation development would be given to the supplemental irrigation for wet season paddy cultivation in the existing irrigation areas.

(2) Possible further extension of irrigable area would be examined taking the topographic and soil conditions into consideration. If the exploited water resources are available, either the supplemental irrigation for the wet season paddy cultivation in the above extension area or the irrigation for the dry season upland crop cultivation in the existing irrigation areas would be considered.

(3) In principle, the irrigation facilities in the existing irrigation areas would be incorporated into the project as far as possible to minimize the project cost. From viewpoints of water management, the extent of rehabilitation and improvement or integrated plan of the existing facilities would be considered.

(4) Basin-wise water management organization and method would be recommended to timely and fairly to distribute the exploited water to each irrigation block. Establishment of water user's organization would also be recommended for proper water management at farm level.

(5) The natural streams in the basin would be used for drainage as many as possible. The collector drains would be provided for proper drainage in each block.

3.3.4 Basic concept for other aspects of development

(1) Hydropower

Water resources development will be primarily considered for irrigation development. The dam plans will be worked out with the aim of ensuring a good supply of irrigation water. The water supplies to the irrigation areas will not be constant, being different from one season to another. It will be impossible under such condition to obtain the firm power constantly all the year round. However, substantial energy development will become possible if dam projects are realized. It will greatly contribute to the effective utilization of the endowed water resources and also to the increasing power demand in the area.

(2) Inland fishery

In the present state fishery activities in Thailand are divided into marine and inland fisheries. Production of marine fishery has had the overwhelming majority of the total production (more than 95% of total production of 2 million tons, 1982). Although production of inland fishery is not so large, its activity has played an important role for providing the rich protain food to people, especially those who live in the depressed rural areas. Furthermore, the development of aquaculture has drown the attention from the viewpoint of effective utilization of water resources.

The latest Fifth National Development Plan states that "speed up the production of fresh-water fishes and release them to multiply in natural water reservoirs and various irrigation project in order to provide a source of protain". The water resources development in the Sakae Krang river basin will provide the rural people with a good chance to develop the aquaculture in the reservoirs.

(3) Flood control

Flood control would not be considered to be a primary purpose under the envisaged projects, since the major agricultural constraints in the river basin are shortage and irregularity in water supply but flood damage is a minor component. Incidental but considerable reduction of flood scale and frequency could be attained from the operation of reservoir usually in the early part of wet season. The reservoir capacity between the designed flood water level and full storage level would also work as a flood storage pool. The peak flood would be reduced by this storage capacity.

(4) Environmental consideration

The implementation of project facilities, particularly dam and reservoir and irrigation and drainage canal systems would bring about various ecological and environmental impacts to the area.

Although these impacts would be clarified through the studies, the major impacts, other than the subsequent creation of development potentials for hydropower, flood mitigation and inland fishery, would include:

- physical and ecological resources changes in reservoirs and watershed areas such as stagnancy of streamflow, inundation of forests, etc.
- effect on human use values and life values, such as increase of agricultural production, resettlement problems, etc.

3.4 Overall River Basin Development Plan

3.4.1 Identification of possible dams

Eight (8) potential damsites are identified in the Sakae Krang river basin. Potential reservoir capacity of these dams is estimated, on the basis of river runoff, topography and damsite geology, as follows:

(Unit: MCM)

River/Damsite	Effective Storage	Dead Storage	Total Storage
Mae Wong river			
- Upper Mae Wong dam	230	20	250
- Lower Mae Wong dam	350	30	380
Khlong Pho river			
- Khlong Pho dam	96	14	110
Thap Salao river			
- Thap Salao dam	160	8	168
- Upper Huai Rang dam	10	2	12
- Lower Huai Rang dam	18	3	21
Khok Khwai river			
- Upper Khun Kaew dam	38	6	44
- Lower Khun Kaew dam	51	8	59

The Thap Salao dam is already taken up by the Government and will soon be put under construction. The Upper Huai Rang dam is not significant in storage capacity compared with the lower site. Out of eight (8) potential dams, the following six (6) potential dams, excluding the above two (2) dams, were further studied. The dam construction at these potential sites is technically feasible. The major dimensions of these possible dams are as follows:

Item		Mae Wong		Khlong	Huai	Khun Kaew	
		Upper	Lower	Pho	Rang	Upper	Lower
Effective Storage	MCM	230	350	96	18	38	51
Reservoir Area	km^2	17.6	68.0	32.0	2.2	2.2	7.3
Foundation		Hard Rock	Weathered Rock	Alluvial Deposit	Alluvial Deposit	Hard Rock	Alluvial Deposit
Height	m	57.0	38.1	20.9	30.5	49.5	32.0
Crest Length	m	794	225	1,555	1,470	570	2,500
Embankment	MCM	2.50	0.38	0.74	0.83	1.32	2.06

3.4.2 Potential irrigation areas in the Sakae Krang river basin

The overall water balance study for all the major tributaries including the Thap Salao, was made and the potential areas for irrigation development in each sub-basin were identified (see Fig. 3.4.1):

River Basin	Water Resources	Irrigable Area (rai)	Irrigable Area (ha)
1. Mae Wong	Upper Mae Wong Dam or Lower Mae Wong Dam	291,900	46,700
2. Khlong Pho	Khlong Pho Dam	111,900	17,900
3. Thap Salao	Thap Salao Dam	110,000	17,600
4. Khok Khwai	Upper Khun Kaew Dam	81,300	13,000
5. Sakae Krang	Groundwater	218,800	35,000
	Total	813,900	130,200 ha

After full development of the endowed water resources, a total of about 814,000 rai (130,200 ha) will be irrigated. This potential irrigable area corresponds to about 95% of the existing paddy fields in the Sakae Krang river basin.

3.4.3 Selection of high priority dams

For selection of high priority dams, preliminary evaluation was made over the identified six (6) dams, using the parameters of reservoir performance, incremental irrigation area, construction cost and cost for compensation and resettlement:

Item		Mae Wong		Khlong Pho	Huai Rang	Khun Kaew	
		Upper	Lower			Upper	Lower
1. Reservoir Performance							
Irr. Area/ Eff. Storage	ha/MCM	213	153	260	111	342	292
Embk, Vol./ Eff. Storage	10^3m^3/MCM	10.9	1.1	7.7	46.1	34.7	40.4
2. Irrigation							
Irrigation Area*	10^3 ha	49.0	53.5	25.0	2.0	13.0	14.9
Incremental Irr. Area	10^3 ha	25.4	29.9	18.0	-	4.7	6.6
Irr. Area/ Eff. Storage	ha/MCM	110	85	187	-	124	129
3. Dam Construction Cost							
Direct Const. Cost	M฿	1,148	620	567	195	403	545
Cost/Eff. Storage	M฿/MCM	4.9	1.8	5.9	10.8	10.6	10.7
Cost/Embk. Vol.	฿/m^3	459	1,140	497	235	305	265
Construction Period	Yr	5	5	5	4.5	5	5
4. Resettlement							
House	No	101	4,337	365	218	30	105
Land	km^2	19.8	68.0	32.0	2.2	2.2	7.3
Compensation	@0.2 M฿/House, @0.6 M฿/km^2 M฿	32.1	908.2	92.2	44.9	7.3	25.4

Note: *: For wet season paddy only

Based on the evaluation on these four (4) components, the Upper Mae Wong, the Lower Mae Wong and the Khlong Pho dams were selected as high priority schemes.

3.4.4 Consideration on other possible schemes

(1) Upper Khun Kaew dam

The priority has not given to this dam in the preliminary economic comparison. However, this dam has the following merits:

- small investment cost compared with other identified possible dams,
- less resettlement problem, and
- suitable geological foundation for dam construction.

Considering the above merits, it is recommended that the further investigation on the hydrological, topographical and geological aspects should be carried out by RID for future development of the Upper Khun Kaew dam.

(2) Groundwater development

Flat and low-lying area at downstream of the basin is formed by the alluvial deposits consisting of loose to unconsolidated layers of sand, gravel, silt and clay. Average thickness of the alluvial deposits is approximately 50 m above foundation rocks. Of these, sand and gravel layers are potential aquifer of groundwater. The groundwater flows from north to south along the Chao Phraya river, supplemented by the flow from the western watershed. The groundwater flow is partly blocked by massive rocks of quartz feldspathic tuff rising in the plain. The potential productivity of the groundwater is roughly estimated at 2.8 - 7.4 MCM/km^2.

For development of this substantial groundwater potential, it is recommended that RID support the following activities:

- The present small scale groundwater development should be accelerated under technical assistance of RID and financial support of BAAC,

- The exploitation of large scale groundwater resource should be concentrated to the downstream areas in the Sakae Krang river basin, where the surface water resources development could not be expected,

- Prior to the exploitation of large scale groundwater resources, the investigation and study on the groundwater balance and quality analysis should be required, and

- The present observation of groundwater should be continued for future development, particularly on the effects of reservoir exploitation at upstream and irrigation development at downstream in future.

3.5 Selection of Mae Wong Irrigation Scheme

After pre-feasibility study on the high priority dams, i.e., Upper Mae Wong, Lower Mae Wong and Khlong Pho dams, the JICA study team reached the conclusion that the Upper Mae Wong dam should be selected as the first priority scheme on the following reasons:

(1) The Khlong Pho scheme is rather small in development scale, having smaller irrigation area, smaller number of project-benefited farmers and minor hydropower potential, and its economic viability is also low. The scheme also involved the problems of resettlement and compensation because a large number of villagers are living in the reservoir area.

(2) The Lower Mae Wong scheme has the economic and social difficulties which will be induced by the resettlement and compensation to a large number of villagers in the reservoir area. The major difficulties are:

- uncertain number of household and thereby uncertain costs required for resettlement and compensation,

- difficulty of land acquisition for resettlement program,

- possibility of delayed construction period,

- problems of social tensions, and

- large negative benefits for farmlands and forest reserve.

(3) The Upper Mae Wong scheme is economically feasible and technically sound, with same development scale as the Lower Mae Wong.

(4) The socio-economic difficulties of the Lower Mae Wong scheme could not be neglected and might seriously affect the construction costs and construction schedule.

(5) The Upper Mae Wong scheme has no such socio-economic difficulties because a small number of villagers are living in the reservoir area and will possibly be realized in a shortest time.

(6) The Upper Mae Wong dam has the highest hydropower development potential.

CHAPTER IV MAE WONG IRRIGATION SCHEME AREA

4.1 Location

The Mae Wong river basin extends over the northern part of the Sakae Krang river basin with a total area of 2,170 km^2, about 1/3 of the Sakae Krang river basin. The area is bounded by the mountain ridges on the west and the Chao Phraya river on the east. The location map is shown in Fig. 4.1.1. The longest distance in north-south direction is about 30 km and in west-east direction about 90 km.

The river basin is administratively located within the jurisdictions of three provinces (Changwat); i.e., Kampheng Phet, Nakhon Sawan and Uthai Thani. (see Fig. 4.1.2) Major towns within the river basin are Lat Yao in the middle of irrigation area and Sawang Arom in the south east of the basin. Changwat Nakhon Sawan, capital of the province, is located in the eastern vicinity of the river basin, about 35 km east from Lat Yao and about 250 km north from Bangkok. The Nakhon Sawan municipality is directly connected with Bangkok by the National Highway Route No. 1.

4.2 Topography

The Mae Wong river basin has generally the topographical gradient from west to east and from north to south.

The highest mountain peak in the basin is Mt. Khao Mokochu with altitude of 1,960 m above sea level. In the upper reach of the Mae Wong river, the stream gradient is steep about 1/250, the valley sections are more or less pronounced and the watershed is covered by thick forest, having about 600 km^2 of drainage area. The proposed damsite is located at downstream edge of the watershed, where the altitude of riverbed is about 160 m above sea level.

In and around the reservoir area, the topography is generally moderate. Steep slopes and hills are developed at the proposed damsite and middle part of reservoir. Land-slides or large scaled talus deposite is not formed in the proposed reservoir area.

The topography becomes flatter as the river emerges on to the Central Chao Phraya Plain after cutting through the thin mountain ridges of Khao Chonkan located about 14 km downstream of damsite. The river passes through broad agricultural regions, having altitude of about 60 m to 100 m above sea level, until the river eventually meets and becomes the Sakae Krang river. The average river gradient at downstream reach is about 1/1,500 and total river length is about 200 km.

4.3 Climate

The Mae Wong river basin is characterized by two pronounced seasons, one dry from November to April, the other wet during the rest of the year. The temperature differentials within the basin are relatively small. Based on the data at Nakhon Sawan, mean temperature is about 28.5°C. The coolest month is December with the mean monthly temperature of 25.2°C while the hottest one is April with 31.9°C.

The prevailing wind direction over the basin is south and relatively constant during the months of February through October. The average relative humidity varies from 61% to 82% and average annual value is 70% at Nakhon Sawan. Mean annual pan evaporation is 2,089 mm with monthly variations of 260 mm in April and 128 mm in September.

Meteorological station under the Ministry of Communication is located at Nakhon Sawan. Among hydrological gaging stations under RID within the basin, the station CT-5A furnish meteorological data of temperature, evaporation and wind speed. The meteorological data at Nakhon Sawan are summarized in Table 4.3.1.

4.4 Hydrology

4.4.1 Rainfall

Rainfall data were collected from 50 gaging stations located in and around the Sakae Krang river basin. Among these stations, 4 gaging stations are located within the Mae Wong river basin. Correlation and probability analyses for rainfall data are shown in ANNEX-I.

Average monthly rainfall distribution for the above 4 stations is as follows:

(Unit: mm/month)

Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
73	163	128	138	179	262	150	40	6	10	12	25

Note: Code numbers of 4 stations are 12081, 26072, 26270, 69062

Average annual rainfall of the Mae Wong river basin is 1,180 mm of which about 85% is concentrated during wet season. September is generally the month of heaviest rainfall and December is the driest month. Aerial distribution of rainfall affected by the topography is not remarkable. Average annual rainfall is calculated at about 1,320 mm in the western watershed and about 1,120 mm in the eastern plain of the basin.

4.4.2 Streamflow

(1) Streamflow record

There are two streamflow gaging stations under RID located along the Mae Wong river. The station CT-5A is located at downstream edge of watershed area or about 14 km downstream from the proposed Upper Mae Wong damsite. The station CT-4 is located at the middle reach of the river or about the center of irrigation area. Observations were started from 1969 at CT-5A and 1975 at CT-4. The station CT-5A is equipped recently with the automatic water level recorder. Staff gage is used at CT-4.

The runoff data at station CT-5A are considered fairly accurate since they show highly constant runoff rate in the double mass curve analysis over the observation period. The effects of irrigation water intake are noticeable at CT-4. Applying tank model method, the streamflow was generated at CT-5A from 1954 to 1968. Monthly river runoff for 30 years from 1954 to 1983 is derived from the tank model simulation and observation record at CT-5A and summarized in Table 4.4.1.

(2) Streamflow characteristics

Average runoff rate and annual outflow from the basin watershed, represented by 30 years streamflow at CT-5A, are summarized as follows:

Gaging Station	Drainage Area (km^2)	Average Rainfall (mm/yr)	Average Annual Runoff (MCM/km^2)	Average Runoff Rate (%)
CT-5A	936	1,339	0.360	26.9

Average Monthly Runoff

(Unit: 1,000 m^3/km^2)

Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
2.3	8.5	15.4	18.6	37.6	85.1	125.1	45.0	12.0	6.3	3.8	2.8

The river runoff from the basin watershed is characterized by long low flow period from December to July. Reliable amount of water resource supplied by the river is limited only during four months from August to November. About 80% of total annual runoff occurs during these months.

Yearly fluctuation of streamflow is noticeably large. The annual runoff amount is recorded at 0.09 MCM/km^2 in extremely dry year of 1977 and 0.88 MCM/km^2 in 1983 while the average runoff amount is 0.36 MCM/km^2 for 30 years.

Vegetation covers and geological condition of watershed affects to the average runoff rate of river. Watershed of the Mae Wong river is covered by comparatively thick forest and sandy alluvial or dilluvial deposit is not remarkable within the drainage area of CT-5A. The average annual runoff rate of the Mae Wong river shows the highest value among other tributaries of the Sakae Krang river basin.

4.4.3 Water quality

Samples for water quality analysis were taken at 21 points along the Mae Wong river including the proposed damsite and irrigation canals. According to the "United State Department of Agriculture", the irrigation water quality is classified into four grades with respect to the sodium hazard (S1 - S4) depending on the sodium absorption ratio (SAR) and the salinity hazard (C1 - C4) depending on the electric conductivity (EC). Nineteen (19) samples are classified into C1 - S1 class and two (2) samples are C2 - S1 class. Based on this water quality analysis, the river water is all within the tolerable limit and suitable for irrigation.

As for the groundwater quality, the preliminary study was conducted by RID from 1973 to 1978 for the downstream area of the Sakae Krang river basin including a part of the Mae Wong river basin. In this study, most of the water samples obtained from the bore holes are found suitable for irrigation. However, 18 samples out of 53 were found unsuitable because of very high electric conductivity and sodium absorption ratio. Certain correlations or tendency on the depth or locations among these samples of unsuitable quality is not determinable as the number of samples are not sufficient. It is necessary to continue the observation on the seasonal variation of groundwater quality to clarify the potential productivity for irrigation.

4.4.4 Sedimentation

Sediment load of the river is one of the major factors to be considered in the reservoir design and intake structure design. Sediment inflow is usually calculated from bed load and suspended load. Samples on the gradation analysis on the riverbed materials were taken at the Upper Mae Wong damsite and 49 samples for suspended load analysis were collected at the river gaging station CT-5A.

Applying Sato, Kikkawa and Ashida formulae, the total sediment inflow was estimated at about 183 m^3 per year per km^2 of catchment area. This scale of sediment inflow is considered moderate and will not cause serious effects on the operation of dam and intake structures in the downstream of the river. Appropriate safety measurement should be considered in application of the above result of analysis to the design of dam and other structures.

4.4.5 Flood

Since the observation of river discharge was started in 1969 at CT-5A in the Mae Wong river, the recorded peak discharges of major floods are as follows:

Date	Peak Discharge (m^3/sec)	Total Rainfall (mm)	Specific Discharge (m^3/sec/km^2)
Nov. 8, 1981	703	178	0.75
Oct. 1, 1978	592	120	0.63
Oct. 13, 1983	514	183	0.55

In case of 1981 flood, inundated farming area in Lat Yao district was reported at 54,500 rai (8,700 ha) and it was 18,000 rai (2,900 ha) in case of 1983. In other words, about 16% of cultivated area before flood was inundated by 1981 flood and about 5% by 1983 flood. Based on the flood analysis presented in ANNEX-I, the above floods are of moderate scale compared with the river catchment area. The flat topography and no river treatment are considered to be the main causes to accelerate the flood damage and to prolong the inundation period. Flood mitigation may not be indispensable compared with the serious problem of irrigation water shortage but will be one of the important factors expected for the development of the basin.

4.4.6 Groundwater

The downstream outside of the basin, i.e., after joining the Khlong Pho river, is a part of vast alluvial flood plain of the Chao Phraya river. High potential productivity of the groundwater is expected in this area. However, within the Mae Wong irrigation area, it is expected from the geological formation that the unconsolidated aquifer development will be limited relatively narrow along the river course.

In the area extending downstream of the Upper Mae Wong dam, alluvial and diluvial sand layers are developed. Groundwater flow from the Mae Wong watershed through these layers are confined by the Khao Chonkan mountain located about 13 km downstream from the dam. The depth of the aquifer will be about 10 to 30 m. Fine sand portion is relatively dominant and permeability will be about 5×10^{-3} cm/sec. Topographically and geologically, the area will receive the stable supply of groundwater flow.

4.5 Geology

4.5.1 General geology

Geologically, the Mae Wong river basin is divided roughly into two parts; the western Paleozoic zone and the eastern Mesozoic part by a Tertiary volcanic belt running along latitude of about E-99°-30', or along the Khao Chonkan mountain ranges.

The proposed Upper Mae Wong damsite and reservoir are located within the western Paleozoic zone which has a distinct N-S geological structure, suffuring from the Burmese - Malaya geo-synclinal movement of meridional trend. These geostructural modes are thought to have been formed as a result of the crustral movements during the Mesozoic and Tertiary periods.

The irrigation area is located within the eastern Masozoic part, in which a vast Khorat Platean develops, having a more gentle, almost flat geostructure. The area is widely covered by Pleistocen old flood deposits of gravel, sand, silt and laterite. In the downstream of the area, alluvial deposits develop along river course and form unconfined aquifer. Significant outcrops of rock materials are not found in the area. Geological chronology of the river basin is summarized in Table 4.5.1.

4.5.2 Reservoir and damsite geology

(1) Reservoir geology

The reservoir area of the proposed Upper Mae Wong dam is geologically formed by granite groups of granite, diorite and gabbro. Predominant rocks are granite gneiss along the Mae Wong river in the reservoir, feldspathic granite at downstream of damsite, schistose granite at damsite and quartzose granite at upstream left bank.

The direction of schistosity of these granite groups is about N 20°E. The Mae Wong river course is largely winding because the river runs against the geological schistosity. Dissolvable limestone groups are not expected in the reservoir geology.

The reservoir geology shows a final state of geologic history and forms a gentle and stable topography. Land-slide or active movement of topography would not be expected.

A geologic fault was found along the lineament crossing the reservoir from northeast to southwest about 1.5 km upstream of damsite. The fault would be expected small in scale and old.

(2) Damsite geology

The geology of the proposed damsite is predominated by green rocks which belong to the Precambrian Uthai Thani complexes. These green rocks are composed of Quartzite, Calc-silicate rocks and Schist. Boundary of these rocks are transitional and partly alternated. General characteristics of rocks are summarized as follows:

	Quartzite	Calc-silicate	Schist
1. Color		- Greenish grey -	
2. Schistosity	Massive	Massive	Weak
3. Hardness	Very hard	Hard	Hard to Medium
4. Rock surface	Cracky	Sound	Slightly to Medium Weathered
5. Component	Silica	Siliceous Calcareous	Siliceous Calcareous Micaceous

4.6 Soils

The land of the Mae Wong river basin is classified into the following five (5) land-form categories:

1. Semi-recent Fan and Alluvium
2. Low Terrace
3. High Terrace
4. Dissected Erosion Surface
5. Mountains

In the prospective gross irrigation area of about 309,400 rai (49,500 ha), the first three (3) land-form categories are identified. The areas of each land categories are as follows:

Land Form Categories	Mae Wong Sub-basin			Prospective Irrigation Area		
	(rai)	(km^2)	(%)	(rai)	(km^2)	(%)
1. Semi-recent fan and alluvium	340,000	544	25.1	169,400	271	54.7
2. Low terrace	116,900	187	8.6	115,600	185	34.7
3. High terrace	341,300	546	25.1	24,400	39	7.9
4. Dissected erosion surface	160,000	256	11.8	-	-	-
5. Mountains	398,700	638	29.4	-	-	-
Total	1,356,900	2,171	100.0	309,400	495	100.0

The major soils of the prospective irrigation area are those developed on the semi-recent fan and alluvium and low terrace of diluvial deposits. These occupy about 92% of the area. The area includes small area of high terrace which is marginal for irrigation development. The soils on other land form categories are not irrigable due to their general features of steep topography, sand and/or gravelly texture and shallow soil depth.

The soils of the prospective irrigation area are classified into five (5) great soil groups and are further sub-divided into 12 soil series.

Land-Form	Great Soil Group	Soil Series (Field Symbol)	Area (rai)	Area (ha)	%
Semi-recent Fan and Alluvium	Non Calcid Brown Soils	Kamphaeng Phet (Kp)	3,100	500	0.9
		Nakhon Pathom (Np)	56,900	9,100	18.4
		Phetchaburi (Pb)	35,000	5,600	11.4
		Kamphaeng Saen (Ks)	15,000	2,400	4.9
		Mae Sai (Ms)	59,300	9,500	19.1
	Sub-total		169,300	27,100	
Low Terrace	Low Humic Gley Soils	Deum Bang (Db)	36,200	5,800	11.9
		Pak Tho (Pth)	64,400	10,300	20.8
		Roi Et (Re)	13,800	2,200	4.5
	Gray Podzolic Soils	Ubon (Ub)	1,300	200	0.4
	Sub-total		115,700	18,500	
High Terraces	Regosols	Korat (Kt)	3,100	500	1.1
	Reddish Brown Lateritic Soils	Nam Phong (Np)	1,300	200	0.4
		Chiang Khan (Ch)	20,000	3,200	6.4
	Sub-total		24,400	3,900	
	Total		309,400	49,500	100.0

The major characteristics of each soil series are summarized in Table VII-1 of ANNEX-VII. Details of soil description and results of physico-chemical laboratory analysis are also given in ANNEX-VII.

The soils of the prospective irrigation area are mostly developed on the semi-recent alluvium and low terraces with flat to slightly undulating topography. The soils are generally deep and medium to fine textured. The soil reaction is slightly acid. The soils are free from salinity problem. The soil fertility is generally low, having low contents of plant nutrients. The drainability is low due to flat topography and fine texture of soil. The soils are graded at R1 to R3, according to the RID specification for land capability classification, which are suitable for irrigated rice cultivation.

4.7 Infrastructure

4.7.1 Transportation

The major transport network in the Mae Wong river basin consists of the provincial asphalt-paved roads and the provincial laterite-paved roads. An asphalt-paved road traverses the irrigation area from west to east connecting the Lower Mae Wong area and Lat Yao which is the capital of Amphoe Lat Yao. This road further extends from Lat Yao eastward and is connected with the national highway (Route No. 1). An asphalt-paved road stretches out from Lat Yao and runs southward. This road runs through Sawan Arom and Thap Than and is connected with Uthai Thani, capital of the Uthai Thani province. Many rural roads are branched off from the provincial roads and are networked in and around the project area. Most of these roads are laterite-paved, but they are considerably deteriorated due to insufficient maintenance works. After heavy rainfall, some of them are not jeepable.

4.7.2 Water supply

The municipal areas being adjacent to the Mae Wong river basin have modernized municipal water supply system. The villages in and around the Mae Wong Irrigation area, however, mainly depend the domestic water resources on rainfall in the wet season and shallow wells in the dry season. The majority of villagers do not have their own wells but have access to village wells (or wells of neighbours). On the other hand, almost all villagers have two or three ungalzed big jars for collecting rainfall and storing water from wells nereby for their drinking and domestic use.

4.7.3 Power supply

Power supply in the Mae Wong river basin is made through 22 kV transmission line from Nakhon Sawan Substation via Amphoe Lat Yao to Ban Rai.

Nakhon Sawan Substation is interconnected with the National Grid from where electricity and power are supplied and then distributed to consumers in the irrigation area.

The energy consumption record from 1983 through 1984 at Nakhon Sawan Substation shows that the maximum demand has increased by 10% over the previous year and has reached at 29,900 kW, whereas the energy consumption has increased by 10.8%, being 136,500 MWh. The energy consumption at Nakhon Sawan Substation accounted for about 30% of the total energy consumption in Northern Region 3.

According to the data compiled by PEA, the electrification ratio in Nakhon Sawan Province is around 39% in 1984.

4.7.4 Health

The Government intends to install at least one hospital in each district (Amphoe) and one health center in each sub-district (Tambon). In Nakhon Sawan province, this target has been almost achieved, having 134 health centers per 115 sub-districts. Since this province covers a large area, some sub-districts have two health centers.

In the Mae Wong irrigation area, there is one hospital with 30 beds, served by 4 medical doctors and 30 nurses at Lat Yao town. There also exist 20 health centers and 3 private clinics in the area. As for the drugstore, about 60 stores are available. The villagers living in the project area are well served by these medical facilities.

In addition to the above, there is a general hospital with 500 beds at Nakhon Sawan located 35 km away from Lat Yao, which is also ready to serve the people of the project area.

4.7.5 Education

The public education is composed of primary school and secondary school. Primary schools are controlled by the Provincial Administration of the Ministry of Interior, while secondary schools are under the supervision of the Ministry of Education. Primary school with 6 year term is compulsory. The children enter school at the age of six. Primary education is followed by non-compulsory secondary education.

According to the Provincial Administration, there are 138 primary schools with 1,008 teachers against 137 villages in Lat Yao district. It means that there exists one primary school in each village. Secondary school, in general, exists in each district center. In the Mae Wong irrigation area, there are 2 secondary schools, which have a total of 80 teachers. The average distance to the secondary school is less than 15 km. The main transport means used by the students is local buses, pick-ups or bicycles.

4.7.6 Communication

The inter-provincial communication service by post, telegraph and telephone is available on a 24-hour basis but such communication except post is only limited among provincial capital. The communication between Nakhon Sawan and Lat Yao is made by radio communication, but this is for official use only.

4.8 Existing Irrigation and Drainage System

4.8.1 Irrigation system

More than 20 years ago, irrigation development in the Mae Wong river basin has voluntarily been commenced by the local people. About 70% of the existing paddy field or 230,000 rai (36,800 ha) in the basin,

are presently covered with the existing farmer's irrigation systems. Thereafter, serious disputes for river water use often occurred between farmers in the downstream areas and those in the upstream areas. Since mid-1970's, RID provided the regulators at the heads of farmer's irrigation systems to control the intake of irrigation water and also constructed the intake weirs to assure the stable intake of irrigation water under the medium and small irrigation projects in response to the local people's request.

(1) Medium scale irrigation project

There exist three (3) medium scale irrigation projects in the Mae Wong river basin. The total irrigation area is 170,000 rai (27,200 ha) as shown below:

Name of Project	Irrigation Area	Main Intake Facility
Wang Kun Pao	105,000 rai (16,800 ha)	Regulator
Khun Lard Boriban	55,000 rai (8,800 ha)	Regulator
Khlong Nam Hom	10,000 rai (1,600 ha)	Weir

At the end of July, 1985, the Huai Sadao Sai weir was constructed on the Mae Wong river, just downstream of diversion place to the Khlong Nam Hom irrigation area, under the small scale irrigation project. The main function of the Huai Sadao Sai weir is to assure the irrigation water to the Khlong Nam Hom area. After construction of the weir, the old bank opening to the Khlong Nam Hom area was closed.

(2) Small scale irrigation project

There exist seven (7) small scale irrigation projects in the Mae Wong river basin. The total irrigation area covered with all these projects is 60,000 rai (9,600 ha) as shown below:

Name of Project	Irrigation Area	Main Intake Facility
Ban Wang Nam Kao	3,000 rai (480 ha)	Regulator
Khlong Saingu	10,000 rai (1,600 ha)	Regulator
Huai Hin Lab	3,000 rai (480 ha)	Regulator
Wang Ma	26,000 rai (4,160 ha)	Weir
Lan Bai Dieo	4,000 rai (640 ha)	Weir
Nong Yao	4,000 rai (640 ha)	Weir
Wang Hin Phoeng	10,000 rai (1,600 ha)	Weir

(3) Pump irrigation services by RID

RID Regional Office VII provides pump irrigation services with free charge for the farmers who have rainfed paddy field along the rivers and streams in the basin. The regulations of the services are as follows:

- Operation hours of pump unit are 22 hr/day.
- Irrigation service period is 120 days.
- The regulations limit farmers receiving the services for only one crop season, wet season or dry season.

The records of pump irrigation services by RID for recent five (5) years are summarized as follows:

Year	Irrigation Service Area (rai)			
	Dry Season		Wet Season	
	Paddy	Upland	Paddy	Upland
1981	600	100	800	-
1982	300	100	8,800	-
1983	300	100	7,870	-
1984	2,630	-	9,942	-
1985	800	-	12,020	-

The pump irrigation services increase year by year, average annual increasing rate of 11%.

4.8.2 Drainage system

Most of the existing canals constructed by farmers have dual purposes for irrigation and drainage. Besides the above farmer's irrigation systems, many natural streams traverse the existing irrigation areas. These streams are also used for drainage purpose.

4.8.3 Present condition of existing irrigation system

In order to incorporate the existing farmer's irrigation systems into the project as far as possible, an inventory survey was conducted to grasp such their present conditions as dimension, degree of deterioration, etc.

The followings are found through the inventory survey:

- All the canals are unlined canals.
- Most of canals have dual purposes of irrigation and drainage.

- Existing canals were constructed by farmers, irrespective of topography.

- The water management is far from the proper water delivery, because of few control structures.

- No operation records of intake facilities are available, even in case of the intake facilities constructed by RID.

- Irrigation water is taken by farmers, irrespective of irrigation area size. It means that the upstream area is more advantageous than the downstream.

- Most of existing irrigation areas have the problem on the difficulty of gravity irrigation, because of improper canal route alignment. Under such situations, the farmers are using the small tractor's engine to pump the irrigation water up from the canals to their fields.

- Based on the results of inventory survey, it seems that approximate half of the existing irrigation area faces the difficulty of gravity irrigation.

4.8.4 Water management in the Mae Wong river basin

As already stated, the existing irrigation systems in the basin were voluntarily constructed by farmers. At present, the water management for the systems is carried out by the voluntary farmer's group. There exist no established water management procedures for the systems. As a result, no operation records on the systems are available and the dispute on water use of the Mae Wong river often occurs between the upstream farmers and those of the downstream.

4.9 Present Condition of Agriculture

4.9.1 Demography

The total pupulation of the project area is estimated at about 74,500 as of 1985. The average annual growth rate is about 2.4%. Total number of household is estimated at about 13,500, out of which farm households account for 10,200 or 76% of the total.

	Population	Household	Farm Household
Mae Wong irrigation area	74,500	13,500	10,200

Source: The National Statistical Office