KINGDOM OF THAILAND
MINISTRY OF AGRICULTURE AND COOPERATIVES
ROYAL IRRIGATION DEPARTMENT

PRE-FEASIBILITY STUDY ON THE SAKAE KRANG RIVER BASIN IRRIGATION PROJECT

MAIN REPORT

MARCH 1985

JAPAN INTERNATIONAL COOPERATION AGENCY

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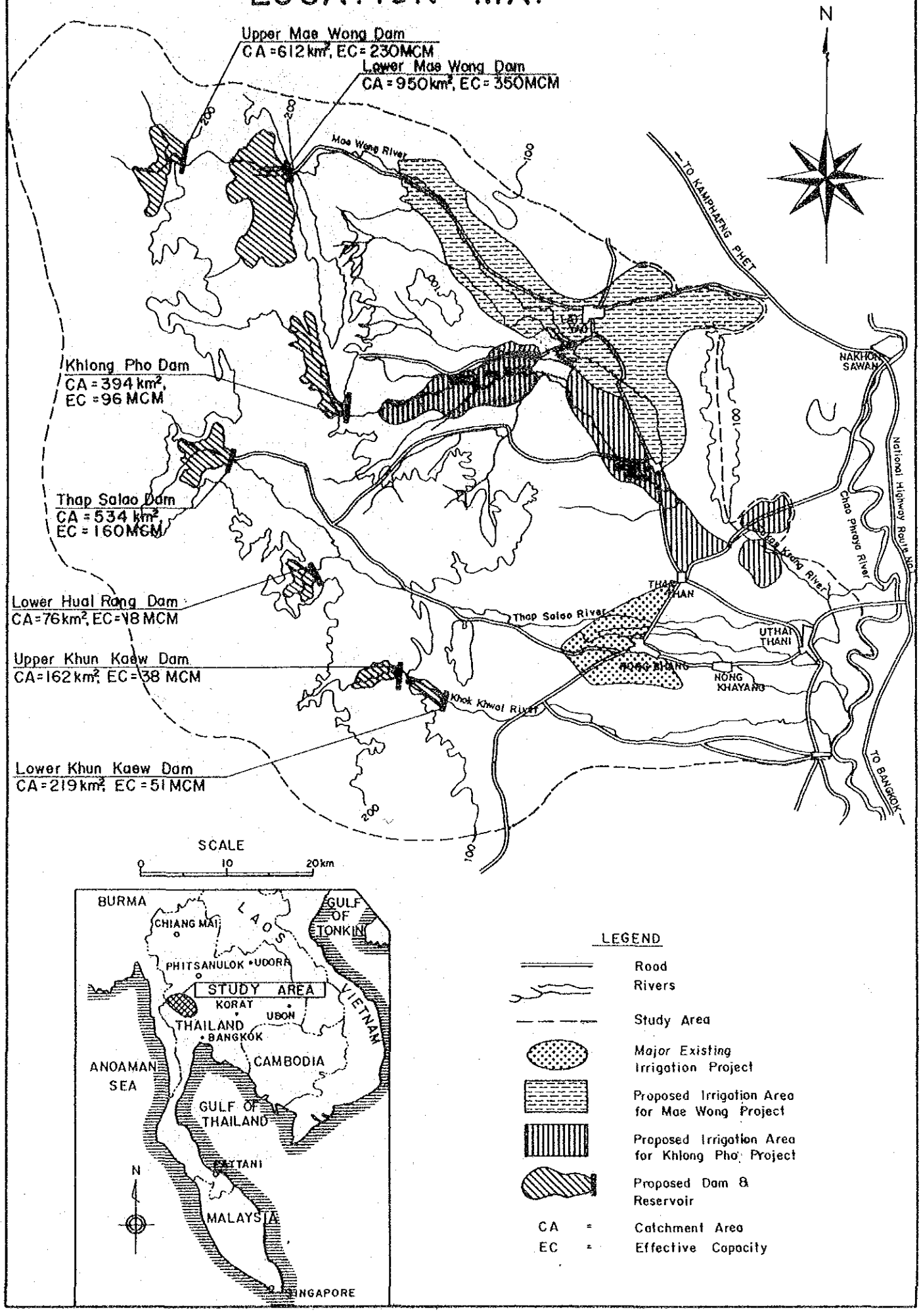
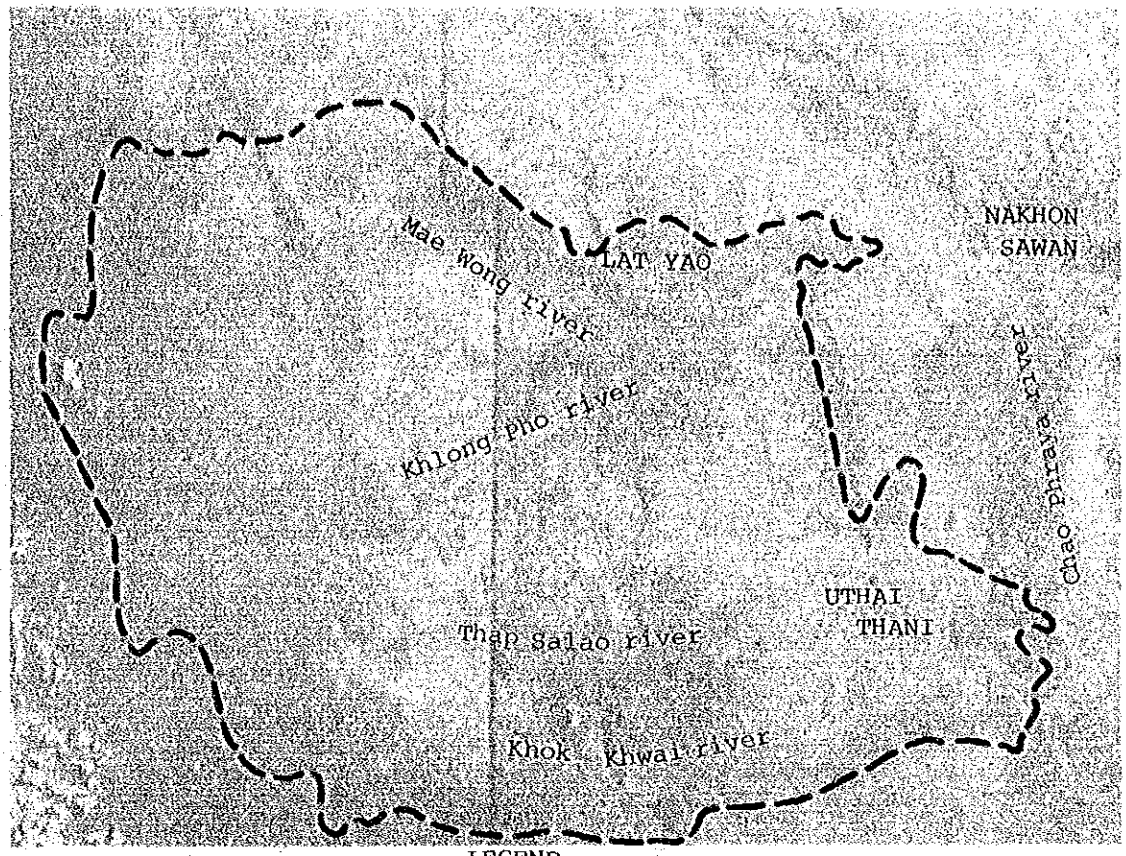
LOCATION MAP



SAKAE KRANG RIVER BASIN

(LANDSAT IMAGES)



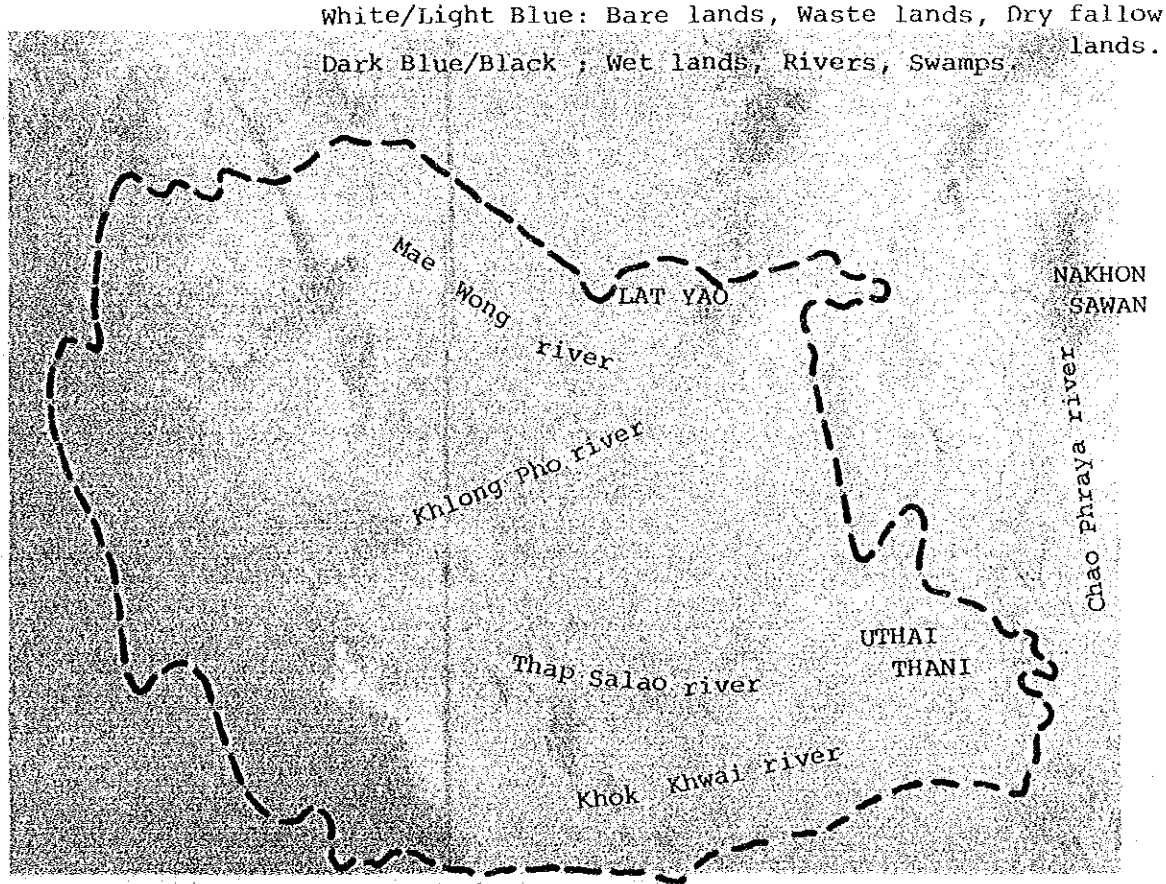
July 6, 1983 (Rainy Season)

LEGEND

Red/Orange : Forest, Shrubs, Orchard, Farm lands.

White/Light Blue: Bare lands, Waste lands, Dry fallow lands.

Dark Blue/Black : Wet lands, Rivers, Swamps.



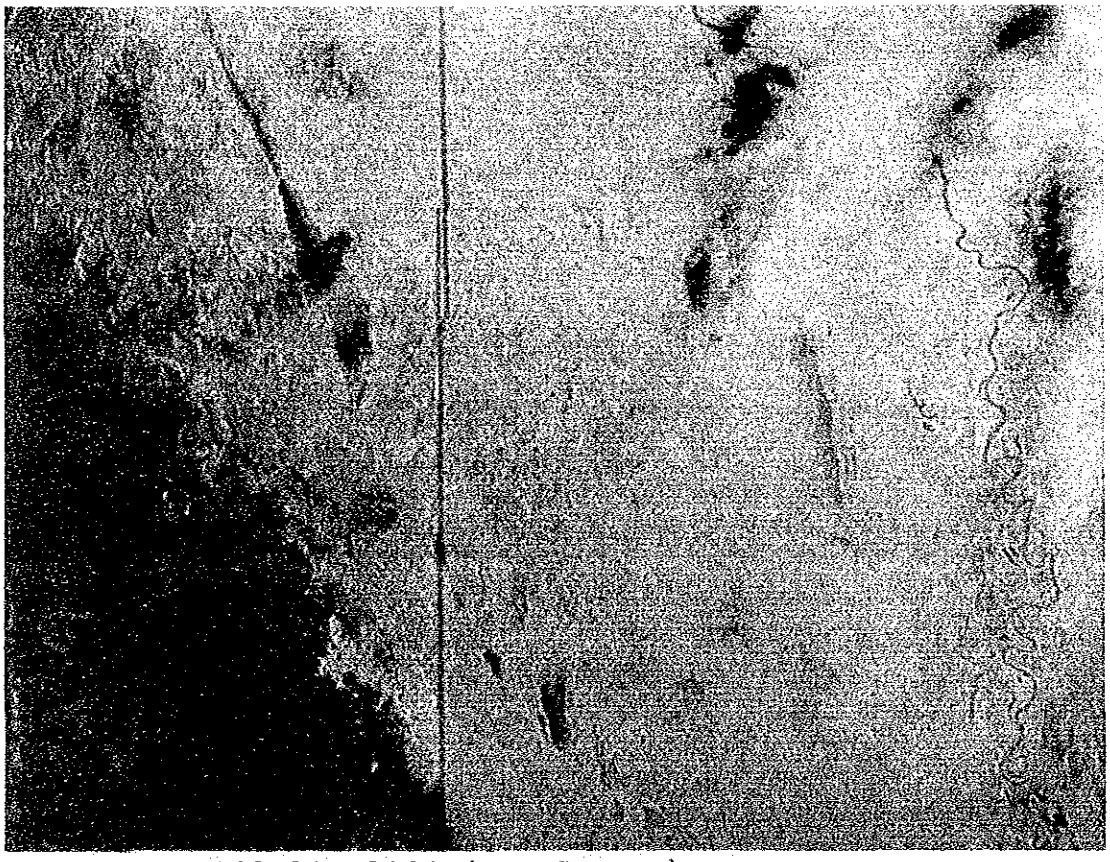
April 19, 1984 (Dry Season)

Source: REMOTE SENSING DIVISION
NATIONAL RESEARCH COUNCIL
OF THAILAND

SAKAE KRANG RIVER BASIN

(LANDSAT IMAGES)

July 6, 1983 (Rainy Season)



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SUMMARY

INTRODUCTION

01. This report presents the results of field investigation and pre-feasibility study made during the period from October, 1984 to March, 1985, and deals mainly with the finding on the present conditions in and around the Sakae Krang river basin, development concept and overall river basin development, and pre-feasibility on the selected high priority projects, including selection of the first priority project.

02. 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 six (6) 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 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.

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 sturucture. 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 proverty and accelerate rural development in the backward area, and

- to uplift rural living standard as well as 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 should be one of the most potential basins for water resources exploitation in the northern region of Thailand.

SAKAE KRANG RIVER BASIN

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 consist 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 part of four (4) provinces of Kamphaeng Phet, Nakhon Sawan, Uthai Thani and Chainat.

06. Four 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 drainage area and endowed mean annual runoff of respective tributaries are estimated at each proposed dam site as given below:

Rivers	Drainage Area (km^2)	Annual Runoff (MCM)
Mae Wong		
- Upper site	612	193
- Lower site	930	294
Khlong Pho	394	85
Thap Salo		
- Thap Salao site	534	125
- Upper Huai Rang site	41	10
- Lower Huai Rang site	76	18
Khok Khwai		
- Upper Khun Kaew site	162	38
- Lower Khun Kaew site	219	51

07. 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. Annual mean temerature 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 in April (260 mm) and the minimum in September (128 mm).

08. The Sakae Krang 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 dam sites are 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 rivers between the diluvial terraces and extend over the downstreams areas in the east.

09. About 1.43 million rai (2,300 km^2) of arable land resources are endowed in the Sakae Krang river basin. Out of these potential arable land, about 1.16 million rai (1,860 km^2) have been developed for agricultural production, both for paddy and upland crop cultivations. The remaining land resources are expoitable only for upland crop cultivation in view of shallow soil depth, coarse sandy soil texture, undulating topography and difficulty in irrigation water supply.

10. Of total basin area of 6,300 km^2, the existing agricultural land is about 1,860 km^2 (29.5%). The rest of 4,440 km^2 (70.5%) includes mountains, steep slopes, forest reserve, river and swamps, roads and urban areas. The existing agricultural land comprises 1,390 km^2 of paddy field, 360 km^2 of upland crop field and 110 km^2 of orchard and others.

11. 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. The planted area of wet season paddy widely fluctuates year by year, depending on the available rainfall and river flow. The paddy yield also fluctuates, being directly affected by the total depth of annual rainfall. It ranges from 160 kg/rai (1.0 ton/ha) to 320 kg/rai (2.0 tons/ha).

12. There are 56 existing irrigation projects in the basin, covering about 534,000 rai (85,500 ha) of the paddy field in total. These include one (1) large scale irrigation project covering 88,000 rai (14,000 ha) in Thap Salao and five (5) medium scale irrigation projects with a total service area of 190,000 rai (30,500 ha) and 50 small scale irrigation projects scattered along the major river courses having a toal area of 256,000 rai (41,000 ha). Present water balance study indicates that these existing irrigation areas are not always actually

irrigated due to insufficient water availability and only about 58% of the existing irrigation area is actually served with water supplies and others are laid under rainfed cultivation under normal rainfall condition with 80% probability.

13. The existing paddy field of 869,000 rai (139,000 ha) is classified on the basis of the adopted ropping intensity which is largely affected by the degree of irrigation:

Paddy Field	Cropping Intensity (%)	Area rai	Area ha	Percentage (%)
Paddy Field with Irrigation Facilities				
(1) irrigated (double cropping)	120	146,000	23,400	16.8
(2) irrigated (single cropping)	100	162,000	25,900	18.6
(3) mainly rainfed (single cropping)	75	226,000	36,200	26.0
Sub-Total		534,000	85,500	61.5
Rainfed Paddy Field	75	335,000	53,500	38.5
Total	-	869,000	139,000	100.0

14. Total population in the Sakae Krang river basin is estimated at about 320,000 in total. It has been increasing at the rate of 2.1% per annum. Total number of household is about 61,400, out of which farm household accounts for 43,800 or 71% of the total. About 98% of the farmers own their farmland with an average holding size of 27 rai (4.3ha).

15. The present farming practices is still of conventional; local varieties are still predominant, use of fertilizers is limited, agrochemicals 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.

AGRICULTURAL CONSTRAINTS AND BASIC STRATEGIES FOR DEVELOPMENT

16. 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 activites. Agriculture contributes to about 45% of gross regional product, while it accounting for only about 25% 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.

17. 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 Bahts, corresponding to roughly two-third of national average (5,610 Bahts). The area suffers also from the instability in annual income which fluctuates largely year by year. Such poor economic situtation of the area is mainly derived from low productivity of agriculture.

18. 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.

19. 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 condition,
- to maximize the planted area of wet season paddy with a full use of the limited exploitable water resources,
- to give a special attention to groundwater development for further development of rainfed areas, and
- to consider the dry season cropping with secondary importance.

Water Resources

- to seek the possibility of construction of storage dams on major rivers so as to regulate and contorl the significant fluctuation of stream flows,
- to exploit the maximum potential of possible dams and reservoirs, and
- to continue the observations and study on groundwater balance for future development, particularly on the affects 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,
- to utilize the natural streams for drainage to a maximum extent, and to provide the collector drains in each irrigation scheme.

20. 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

21. 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 dam site geology, as follows:

River/Dam Site	Effective Storage	Dead Storage	Total Storage
	MCM	MCM	MCM
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

22. 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	19.5	68.0	32.0	2.2	2.2	7.3
Foundation		Hard Rock	Weathered Rock	Alluvial Deposit	Alluvial Deposit	Hard Roack	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	3.40	0.38	0.74	0.83	1.32	2.06

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

Item		Mae Wong Upper	Mae Wong Lower	Khlong Pho	Huai Rang	Khun Kaew Upper	Khun Kaew 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	40.4
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	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

* 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 projects were selected as high priority projects.

24. 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 (ha)
1. Mae Wong	Upper Mae Wong Dam or Lower Mae Wong Dam	47,800
2. Khlong Pho	Khlong Pho Dam	17,900
3. Thap Salao	Thap Salao Dam	17,600
4. Khok Khwai	Upper Khun Kaew Dam	13,000
5. Sakae Krang	Groundwater	35,000
Total		131,300 ha

After full development of the endowed water resources, a total of about 131,000 ha (821,000 rai) will be irrigated. This potential irrigable area corresponds to about 96% of the total existing paddy fields in the Sakae Krang river basin.

PROSPECTIVE DEVELOPMENT PLAN FOR HIGH PRIORITY PROJECT

25. The following three (3) alternative plans are studied for selection of the optimum scale of the proposed dams and reservoirs:

Alternative

D-1 Dam and reservoir sufficiently large enough for assuring the supplemental irrigation water supply to the existing irrigation areas for wet season paddy only.

D-2 Dam and reservoir sufficiently large enough for assuring the supplemental irrigation water supply to the potential maximum irrigable areas for wet season paddy only.

D-3 Potential maximum scale of dam and reservoir.

The irrigable areas under the above conditions are estimated through water balance study. They are summarized below:

Dam	Alternative	Effective Storave	Irrigable Areas			Crop Intensity
			Existing	New	Total	
		(MCM)	(ha)	(ha)	(ha)	(%)
Upper Mae Wong	D-1	115	36,800	-	36,800	100
	D-2	205	36,800	11,000	47,800	100
	D-3	230	36,800	11,000	47,800*	105**
Lower Mae Wong	D-1	115	36,800	-	36,800	100
	D-2	235	36,800	11,000	47,800	100
	D-3	350	36,800	11,000	47,800*	115**
Khlong Pho	D-1	25	10,600	-	10,600	100
	D-2	45	10,600	7,300	17,900	100
	D-3	96	10,600	7,300	17,900*	140**

* : Potential maximum irrigable area

** : Mung beans are considered as dry season crop if water is still available after supplemental irrigation for wet season paddy is assured to a maximum extent up to the potential maximum areas.

26. The project costs, benefits and IRR for the above alternatives are:

Project	Alternative	Construction Cost (10^6฿)	Annual Net Benefit (10^6฿)	IRR (%)
Upper Mae Wong	D-1	1,794.3	308.0	11.8
	D-2	2,385.0	445.7	12.9
	D-3	2,453.4	461.3	13.0
Lower Mae Wong	D-1	1,521.1	308.0	13.0
	D-2	1,984.6	445.7	14.4
	D-3	1,989.0	492.4	15.2
Khlong Pho	D-1	863.7	79.2	6.5
	D-2	1,247.7	170.6	9.5
	D-3	1,271.4	217.2	11.5

The above economic comparison indicates that the larger dam scale makes the economic viability higher. Considering the above result and the basic concept for development that the endowed water resources should be fully exploited, the alternative D-3 was selected.

27. For optimization of irrigation area, two (2) alternatives are considered under the condition that dam and reservoir are maximized:

Alternative	Description
I-1	Supplemental irrigation water supply to the existing irrigation areas with maximum cropping intensity
I-2	Supplemental irrigation water supply to the potential maximum irrigable area with minimum cropping intensity

The irrigable areas and cropping intensity under the above alternatives are:

Project	Alternative I-1		Alternative I-2	
	Irrigation area (ha)	Cropping intensity (%)	Irrigation area (ha)	Cropping intensity (%)
Upper Mae Wong	36,800	130	47,800	105
Lower Mae Wong	36,800	140	47,800	115
Khlong Pho	10,600	190	17,900	140

28. The results of economic comparison between the above alternatives are:

Project	Alternative	Construction Cost (10^6฿)	Annual Net Benefit (10^6฿)	IRR (%)
Upper Mae Wong	I-1	2,025.4	380.0	13.0
	I-2	2,453.7	461.3	13.0
Lower Mae Wong	I-1	1,565.7	403.9	15.4
	I-2	1,989.0	492.4	15.2
Khlong Pho	I-1	963.6	141.4	10.3
	I-2	1,271.4	217.2	11.5

No significant difference is recognized, particularly for the cases of Upper and Lower Mae Wong dams, between alternative I-1 and I-2. In such case, the basic concept for development that the endowed land and water resources should

be fully utilized with a particular emphasis on improvement of present income disparity, should be again considered for selection of better alternatives. With this in view, the alternative I-2 was selected.

29. The proposed development plan for the high priority projects would be, in conclusion, the potential maximum scale of dam and reservoir coupled with the potential maximum irrigation development in area.

30. Paddy and mung beans are selected as main crops in the priority projects areas. 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 cropping intensity will be 105% for the upper Mae Wong Project, 115% for the Lower Mae Wong Project and 140% for the Khlong Pho project.

31. Crop yield will be substantially increased after completion of the projects with introduction of improved farming practices under assured irrigation system. The target crop yield will be:

Paddy		
- high yielding varieties	:	820 kg/rai
- local varieties	:	640 kg/rai
Mung beans	:	190 kg/rai

32. The net incremental benefit of the project, which is defind as the difference between the respective net production values under "with project" and "without project" conditions, and is estimated as summarized below:

Projects	Without Project (฿ Million)	With Project (฿ Million)	Increment (฿ Million)
1. Upper Mae Wong	299.5	760.8	461.3
2. Lower Mae Wong	299.5	791.9	492.4
3. Khlong Pho	108.5	325.7	217.2

33. Irrigation water requirements were estimated on the proposed cropping pattern. The unit design irrigation requirement was determined at 1.0 ℓ/sec/ha.
The estimated total unit irrigation water requirements in depth are 700 mm for the wet season and 785 mm for the dry season.

34. The design drainage requirements are estimated for 3-day consecutive rainfall with a 5-year return period, using the rainfall data at Thap Than. The unit drainage requirements are estimated at 3.7 ℓ/sec/ha.

35. The proposed storage dams, especially for the Upper Mae Wong dam, provide a possibility of hydropower development. According to the preliminary study results, about 13,700 MWH of annual energy output will be produced with an installed capacity of 5,000 kW at the Upper Mae Wong dam. The hydropower development potential for the Lower Mae Wong and Khlong Pho dams is rather small compared with the Upper Mae Wong dam. The annual energy outputs estimated for these dams are about 5,300 MWH for Lower Mae Wong dam and 600 MWH for Khlong Pho dam.

PROPOSED WORKS FOR HIGH PRIORITY PROJECTS

36. The Upper Mae Wong dam site is located at about 17 km upstream of the Lower Mae Wong dam where the Mae Wong river emerges on the flood plain from the mountain ranges of Mt. Khao Mokochun. The foundation of dam is formed by massive hard rocks bearable for construction of all types of high dam. Rockfill type with center core was proposed for the Upper Mae Wong dam on the basis of availability of embankment materials, suitability of foundation for high dam and economical construction. The upstream and downstream slopes of embankment were designed at 1:1.7 and 1:16 respectively so as to stabilize the dam body. Cement grouting was proposed for the foundation treatment to decrease the seepage flow through dam foundation. The service spillway of ungated side channel type was proposed at the right.
Intake structures consist of drop inlet structure and intake tunnel which will be initially construction for the river diversion during embankment construction period.
The hydraulic energy of impounded reservoir can be utilized at the outlet of intake tunnel for the possible hydropower generation.

37. The Lower Mae Wong dam site is located at about 3 km upstream of the RID gauging station CT-5A, where the Mae Wong River runs through the narrow valley of the Khao Chonkan mountains. Weathering of foundation rocks seems remarkable. A structural fault is indicated at about 400 m upstream of the proposed dam axis on the geological map of the Royal Thai Survey Department. Center core zone earthfill type was applied for the Lower Mae Wong dam based on the availability of embankment material. The dam body with upstream slope of 1:2.0 and downstream of 1:2.5 was designed through the stabilization analysis. Cement grouting was proposed for the foundation treatment. Considering the topographic condition and utility of excavated materials for embankment, the location of the service spillway was selected at the right side abutment. A diversion tunnels was proposed at both river banks. Intake structure of drop inlet type was designed to be connected with the left bank diversion tunnel.

38. The Khlong Pho dam site is located at the southern end of the Khao Chonkan Mountain ranges, where the Khong Pho river runs through the high terrace of the plain.
The dam foundation is composed of diluvial sand layers. Rock Mateirals are not obtainable around the dam site.

Inclined core earthfill type was selected for the Khlong Pho Dam. The dam body with upstream slope of 1:2.0 and downstream of 1:2.0 to 2.5 was designed through the stabilization analysis. Cement grouting was proposed for foundation treatment. The service spillway was proposed at the right abutment. The proposed intake structure at the right bank can be used for the river diversion works.

39. The Principal features of each dam are summarized as follows:

Item		Upper Mae Wong	Lower Mae Wong	Khlong Pho
1. Reservoir				
Catchment area	km^2	612	930	394
Effective Storage	MCM	230	350	96
Dead Storage	MCM	20	30	14
Total Storage	MCM	250	380	110
Water level				
Full Storage	Elm	216	136	100
High water	Elm	219	140	102
Dead Storage	Elm	189	124	95
Reservoir area				
Full Storage	km^2	17.0	54.0	30.0
High water	km^2	19.5	68.0	36.0
2. Dam				
Type		RF	ZEF	EF
Height	m	62.0	38.1	20.9
Crest level	Elm	222	143.1	104.9
Foundation level	Elm	160	105	84
Crest length	m	775	225	1,555
Embankment	MCM	3.40	0.38	0.74
3. Spillway				
Design flood	m^3/S	1,770	2,600	1,190
Crest length	m	165	155	200
Total length	m	525	465	850
4. Diversion tunnel				
Design discharge	m^3/S	700	1,240	10
Tunnel diameter	m	9.0	8.5	1.8
Tunnel length	m	190	831	300
5. Intake structure				
Type		DI	DI	DI
Intake discharge	m^3/S	35.0	36.0	10

RF: Rockfill type
ZEF: Zone type earthfill
EF: Earthfill type
DI: Drop Inlet type

*: Right side tunnel 565 m
Left side tunnel 266 m

40. Since no existing topographic maps were available for making the proper layout planning of irrigation and drainage systems in all the Mae Wong and Khlong Pho river basins, a model area of 46,000 rai (7,360 ha) covered by the topographic maps on a scale of 1/10,000 was selected for preliminary design of irrigation and drainage facilities and consequently construction cost estimate.

The facilities required for the model area consist of the intake facilities, irrigation and drainage canals and their related structures. The intake weir of ogee type was proposed to divert the irrigation water to the model area. The intake structure was proposed at the right bank.

The major irrigation canal system for the model area consist of a main canal and four laterals with concrete linning. All the existing irrigation canal systems in the model area would be rehabilitated or improved for incorporating into the project as many as possible. A large number of such related structures as turnout with check, syphon, culvert, side spillway, etc. are required for full function of the canal system.

The existing rivers and streams in the model area were proposed to be used as the main and lateral drains with minor rehabilitation and improvement works. To collect and drain the excess water by irrigation and rainfall, collector drain was newly proposed.

The main inspection road with an effective width of 5 m was proposed for inspection, operation and maintenance of main canal. The road would be laterite-paved. The lateral inspection roads were also proposed alongside the lateral canal. All these roads have a width of 4 m. The main features of the model area are shown as follows:

1. Head Works

1.1 Intake Weir

Type of weir	Ogee type
Weir height	4.5 m
Weir length	28.6 m

1.2 Scouring Sluice

Gate type	Slide gate
Size of gate (B x H x No.)	2.0m x 2.0m x 2nos.

1.3 Intake Structure

Intake discharge	7.36 m^3/sec
Gate type	Slide gate
Size of gate (B x H x No.)	2.0m x 1.8m x 3nos.

2. Irrigation System

Irrigation service area	7,360 ha
Main canal (concrete linning)	12.7 km
Lateral (concrete linning)	52.7 km
Sub-lateral	44.8 km
Related structures	
Turnout with check	48 nos.
Syphon	7 nos.
Culvert	24 nos.
Side spillway	2 nos.

3. Drainage system

Lateral drain	4 km

CONSTRUCTION PLAN AND COST ESTIMATE

41. Rock zone for embankment of the Upper Mae Wong dam would be obtained from the quarry site proposed on the left bank. Hard rocks excavated by dynamite blasting would be used for rock zone embankment. Core materials would be obtained from the borrow area proposed on the right bank. Materials for transition would be mainly obtained from service spillway excavation, river diversion channel excavation and quarry site. Filter zone materials would be obtained from river sand excavation. All construction works for the Upper Mae Wong dam would be executed using mainly the heavy machinery.

42. Most of excavated materials from the service spillway would be utilized for embankment of the Lower Mae Wong dam. Core materials would be obtained from the borrow area located at downstream of dam. Filter material will be produced from the river sand. All materials for embankment from the spillway excavation should be once stockpiled to adjust the embankment speeds of different zone. All construction works for the Lower Mae Wong dam would be mainly carried out by the heavy machinery.

43. Available materials near the Khlong Pho dam site would be applicable for only randam zone of embankment. Core materials would be borrowed in far distance about 5 km from the dam site. The river sand would be used as filter materials. Most of construction works for the Khlong Pho dam would be executed by the heavy construction machinery.

44. Stripping and surface excavation of the main canals would be mainly executed by bull-dozer, and sub-surface and deep excavation by back hoe shovel depending on the soil condition at working site. Man power would be contribute to the lateral canals construction, face smoothing, compacting of canal invert,

etc. The excavated materials excessive of filling requirement would be transportated to a spoil area. In case of lacking of materials for filling, the materials would be supplemented from borrow area selected near the working site. Earth works for the structures related to the canals would be done by man power. The concrete would be mixed by portable mixer and placed by man power.

45. The construction period of all high priority projects is estimated at 5 years. Prior to the construction works, the detailed design would be carried out for two years including loan arrangement. The preparatory works such as construction of office, quarters, access road, etc. and land acquisition for the dam and canal system would be executed for one year prior to the major construction works. The construction works for dam would be commenced from the 3rd year and completed within 5 years. The construction works for irrigation facilities will be started from the 4th year and finished within 4 years. Total implementation period would become 7 years.

46. The total project cost including physical and price contingencies for each high priority project is estimated as follows:

(Unit: 10^6฿)

High Priority Project	Foreign Currency	Local Currency	Total
Upper Mae Wong	1,812.4	2,100.2	3,912.6
Lower Mae Wong	1,085.8	2,009.0	3,094.8
Khlong Pho	727.4	1,267.4	1,994.8

PRELIMINARY PROJECT EVALUATION

47. The economic viability was evaluated in terms of the internal rate of return. The calculated results are shown below:

	Mae Wong		
	Upper	Lower	Khlong Pho
IRR %	13.0	15.2	11.5

48. The sensitivity analysis is made for uncertain number of household in the reservoir areas. Number of household in each prospective reservoir area may range as follows:

	Mae Wong		
	Upper	Lower	Khlong Pho
Minimum	40	520	360
Maximum	80	2,500	2,000

The analysis result shows that if number of household in the reservoir area of the Lower Mae Wong is more than 1,600, the IRR value of the Lower Mae Wong project will become lower than that of Upper Mae Wong project.

49. 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:

(1) possibility of hydropower generation

(2) Increase of potential fish production

(3) foreign exchange earning

(4) increase of employment opportunity

(5) improvement local transportation

(6) mitigation of flood damages

ENVIRONMENTAL CONSIDERATIONS

50. The implementation of project facilities, particularly dam and reservoir, and irrigated agricultural development after the project would bring about various ecological and environmental changes to the area. Although these environmental impacts will have to be carefully studied during the course of the feasibility study, the major impacts will include:

(1) Impacts of dam construction

- inundation of farmlands and houses in the reservoir areas,
- increase in irrigation area,
- creation of new hydropower development potential,
- mitigation of flood damages, and

(2) Impacts of irrigated agricultural development

- increase in crop production,
- improvement of local transportation,
- increase in employment opportunity, and
- improvement of rural water supplies.

RECOMMENDATIONS

51. It is recommended that the Upper Mae Wong project should be selected as the first priority project on the following reasons:

(1) The Khlong Pho project is rather small in development scale, having smaller irrigation area, smaller number of project-benefited farmers and minor hydropower potential, and its economic viability of is also low, as indicated by comparatively low IRR of 11.5%. The project 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 project has the economic and social difficulties which will be induced by the resettlement of and compensation to a large number of villagers in this 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 Project 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 project could not be neglected and might seriously affect the project costs and construction schedule.

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

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

52. The feasibility study on the first priority project is scheduled to be commenced from June, 1985. RID has been requested to complete additional surveys required for feasibility study by the beginning of June, 1985.

MAIN FEATURES OF HIGH PRIORITY PROJECTS

Item	Unit	Upper Mae Wong	Lower Mae Wong	Khlong Pho
1. Dam & Reservoir				
a. Effective Storage	MCM	230	350	96
b. Reservoir Area	Km^2	19.5	68.0	32.0
c. Dam Height	m	62.0	38.1	20.9
d. Crest Length	m	775	225	1,555
e. Embankment	MCM	3.40	0.38	0.74
2. Irrigation				
a. Without Project				
- irrigated	ha	23,600	23,600	8,900
- semi-irrigated	ha	13,200	13,200	1,700
- rainfed	ha	11,000	11,000	7,300
(Total)	ha	(47,800)	(47,800)	(17,900)
b. With project				
- irrigated	ha	47,800	47,800	17,900
- cropping intensity	%	105	115	140
3. Reservoir Performance				
a. Eff. Storage/ Irri. Area	m^3/ha	4,812	7,322	5,363
b. Embk. Vol./ Eff. Storage	m^3/MCM	14,800	1,100	7,700
c. Irri. Area/ Eff. Storage	ha/MCM	208	137	186
4. Economic Project Cost				
a. Dam	M฿	1,123.5	628.1	579.1
b. Irrigation	M฿	944.9	944.9	424.1
c. Resettlement	M฿	19.7	144.8	92.2
d. Others	M฿	365.6	271.2	176.0
(Total)	M฿	(2,453.4)	(1,989.0)	(1,271.4)
e. Unit Cost	฿/ha	51,300	41,600	71,000
5. Annual Benefit				
a. Total	M฿	461.3	492.4	217.2
b. Unit	฿/ha	9,600	10,300	12,100
6. Internal Rate of Return (IRR)	%	13.0	15.2	11.5
7. Resettlement & Compensation				
a. House	No.	40 - (80)	520 - (2,500)	365 - (2,000)
b. Land	Km^2	19.5	68.0	32.0
c. Cost	M฿	19.7 - (27.7)	144.8 - (540.8)	92.2 - (419.2)
d. Sensitivity to IRR	%	13.0 - (12.9)	15.2 - (12.3)	11.5 - (9.2)
8. Hydropower Potential				
a. Intake Level	EL.m	207.9	131.2	98.3
b. Tail Water Level	EL.m	162.5	116.8	91.0
c. Gross Head	m	45.4	14.4	7.3
d. Rate Net Head	m	43.1	12.4	6.1
e. Max. Discharge	m^3/sec	14.2	17.6	3.9
f. Installed Capacity	KW	5,000	1,500	170
g. Energy Production	MWH	13,718	5,289	571
h. Construction Cost	M฿	173	109	60

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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 = 1,000 kg
qwt	=	quintal = 100 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

(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

C. ABBREVIATION OF ORGANIZATIONS

MOAC	Ministry of Agriculture and Cooperatives
RID	Royal Irrigation Department
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

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.

This report presents the results of pre-feasibility study and mainly deals with the findings on the present conditions, development concept and identification of possible projects, overall development plan and selection of the high priority projects, and pre-feasibility study on the selected high priority projects.

1.2 PROJECT HISTORY

The water resource and agricultural development in Sakae Krang river basin has been strongly requested for a long time by the rural people in the basin. In response to the request, RID commenced the survey and studies on irrigation and agricultural development in the the Thap Salao and Khlong Pho river sub-basins in 1970's. Subsequently, the Thap Salao Irrigation project with a net area of 88,000 rai (14,080 ha) was implemented and completed in 1982. The river-flow in the Thap Salao basin, however, is not so dependable as to irrigate the project area of 88,000 rai. Exploitation of supplemental water resources is, therefore, essential for the said irrigation project as well as the Sakae Krang river basin as a whole.

In recent years, RID has envisaged construction of storage dams to eliminate the constraints of shortage of irrigation water all over the Sakae Krang river basin. Six dam site have been reconnoitered by the RID. In conformity with the major objectives stipulated in the Current National Development Plan, RID intends to urgently promote the water resources development in the Sakae Krang river basin.

On the basis of the conditions above stated, the Government of Thailand 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.

The JICA dispatched a preliminary Survey Team headed by Dr. H. Nakamichi, Chief Engineer, the Bureau of Agriculture 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 for the Feasibility Study on the Sakae Krang River Basin Irrigation Project was, after full and fruitful discussions, concluded between the RID and Survey Team on behalf of JICA, on the date of July 6, 1984.

Based on the above "Scope of Work", the pre-feasibility study was commenced on October 1, 1984. The field investigation and study lasted until the end of December, 1984. The Study Team submitted the Progress Report to RID at the end of the field work in Thailand. As the major outcome of the field work, the high priority projects, i.e., Upper Mae Wong, Lower Mae Wong and Khlong Pho projects, were selected through a series of discussions with RID. The pre-feasibility study on the selected high priority projects was made in Japan during the period from January to March, 1985.

1.3 OUTLINE OF THE "SCOPE OF WORK"

As specified in the Scope of Work (ATTACHMENT-1), the feasibility study contains the following three (3) programs:

Part-A: To review the overall Sakae Krang river basin water resources development plan and to indentify the possible project(s).

Part-B: To conduct the pre-feasibility study on the high priority project(s).

Part-C: To conduct the feasibility study on the first priority project.

The work plan for the feasibility study comprises the field work in Thailand and home office work in Japan. The Scope of Work for feasibility study is outlined as follows:

(1) Study area :

The study area covers the Sakae Krang river basin with a gross area of 7,000 km^2 which is composed of the Mae Wong, the Khlong Pho, the Thap Salao and the Khok Khwai sub-basins.

(2) Scope of Part-A (Field Work):

- review of all the existing and proposed irrigation project 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,

- study on overall implementation schedule for possible projects;

- selection of high priority project(s),

- preliminary environmental study; and

- preliminary study on hydropower development potential.

(3) Scope of 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.

(4) Scope of 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,

- 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 reconnaisance 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.

Informal discussions were frequently made between the personnel concerned to coordinate the field activities and to smoothly execute the field work.

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 projects; namely, Upper Mae Wong, Lower Mae Wong and Khlong Pho projects 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 project and the pre-feasibility report was hereby presented in mid.-March, 1985.

The RID official concerned, members of the Supervisory Committee and study team are shown in ATTACHMENT-2.

CHAPTER II NATIONAL ECONOMIC BACKGROUND

2.1 GENERAL ECONOMIC SITUATIONS AND NATIONAL DEVELOPMENT PLAN

Since the First National Economic and Social Development Plan launched in 1961, the Government of Thailand has drawn up four consecutive National Development Plan in order to develop and rehabilitate infrastructual facilities needed for the expansion of production and trade, and for the well-being for the people. All these 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 846 billion Bahts as of 1982 coresponding to the per capita GDP of 17,450 Bahts. This growth was made possible through the combination of a favorable external economic environment, high level of private investment and public sector expenditure, but the key was a steady increase in agricultural production.
Such growth, however particularly in more recent years, has created and accumulated many problems detrimental to the stability of the nation's economic and financial position such as deficits in balance of payment, increase in economic and income gap, deterioration of basic natural resource, etc.

The Government of Thailand has established the Fifth Social and Economic Development Plan (1982-86) as a "policy plan" which give clear policy directions 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) Improvement of economic and financial position,

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

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

(4) Poverty alleviation in backward areas, and

(5) Coodination of economic development activities with national security management, and adjustment of economic structure.

2.2 AGRICULTURE IN THAILAND

Past national development efforts have been concentrated in the agricultural sector since agriculture is the highest single source of income, accounting for about 25% of Thailand's GDP, employs about three-fourth of the labor force, and is the source of about 60% of total exports. Therefore, the performance of the agricultural sector, although the 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. However, expansion over the past decade has been slower compared to the 1960's. Agricultural GDP increased at annual rate of 5.5% in 1960-1970, 5.1% in 1970-75, and 3.5% in 1975-80.

The key factor in the past growth of agriculture has come from an expansion of the area under cultivation (about 4% per annum), along with a movement into high valued crops. Although paddy is planted on more than 60% of cultivated area, the area planted to maize, cassava and sugarcane is now just over 22 million rai and has doubled in the last decade. Yields of the major crops, however, have remained stagnant and the cropping intensity has also remain at a low level. Moreover, as rapidly accessible arable land reserves are exhausted, continued high growth of this sector will be more difficult to maintain.

In addition, there are significant disparities in farm income between 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 North and Northest Region is the low yield of crop 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.

2.3 GOVERNMENT POLICY FOR AGRICULTURAL DEVELOPMENT

In spite of the relatively poor performance of agriculture in the late 1970's, the Fifth National Development Plan set a target for agricultural GDP to increase at 4.5% per annum (country's economic target 6.6%).

The plan details agricultural sector strategies that aim to expand the value added in agriculture by 4.5%. These are;

(1) to increase agricultural production,

(2) to alleviate rural poverty and redress inter-regional income desparities,

(3) to expand agricultural exports rapidly to help the balance of payments, and

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

CHAPTER III SAKAE KRANG RIVER BASIN AND BASIC DEVELOPMENT STRATEGIES

3.1 LOCATION

The Sakae Krang river basin extends over the north-western 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 rivers; i.e., from north to south, the Mae Wong, Khlong Pho, Thap Salao and Khok Khwai rivers. The area is bounded by the mountain ridges on the west, the Chao Phraya river on the east, the northern ridge of the Mae Wong river on the north and southern ridge of the Khok Khwai river on the south. The longest distance in north-south direction is about 90 km, and in west-east direction about 80 km. The highest mountain peak in the basin is Mt. Khao Mikochun with altitude of 1,960 m above sea level. The river basin is administratively located within the jurisdictions of four provinces (changwat); i.e., Kampheng Phet, Nakhon Sawan, Uthai Thani and Chainat (see Fig. 3.1.1). Major towns within the river basin are Lat Yao in the north, Sawang Arom and Thap Than in the middle, and Uthai Thani in the south. Changwat Nakhon Sawan, capital of the province, is located at about 250 km north from Bangkok and in the vicinity of the river basin, about 35 km east from Lat Yao, the northern central of the river basin. The Nakhon Sawan municipality is directly connected with Bangkok and other major towns by the National Highway Route No. 1.

3.2 PHYSICAL FEATURES

3.2.1 River system

Small streams starting from the western mountain ranges form four major sub-basins of the Sakae Krang river as indicated on Fig. 3.2.1, namely from the north, the Mae Wong, the Khlong Pho, the Thap Salao and the Khok Khwai. Stream gradients in the upper reaches of these rivers are steep and the valley sections are more or less pronounced. They become flatter upon emerging on the Central Chao Phraya Plain as the rivers pass through broad agricultural regions until they eventually meet and become the Sakae Krang river near the town of Uthai Thani. The drainage area of the Sakae Krang river at the confluence with the Chao Phraya river is approximately 6,300 km^2. Among sub-basins of the Sakae Krang river, the Mae Wong river is the largest, having river length of about 200 km and gradient of about 1/250 at upstream and 1/1,500 at downstream. The drainage areas of major rivers in the basin are as follows:

River	Drainage Area (km^2)
Mae Wong	2,171
Khlong Pho	1,211
Thap Salao	1,253
Khok Khwai	1,108
Sakae Krang	557
Total	6,300

3.2.2 Climate

The Sakae Krang river basin is characterized by two pronounced season, one dry from November to April, the other wet during the rest of the year. Aerial rainfall distribution in the basin affected by the topography is relatively small. Average annual rainfall is about 1,230 mm, ranging from 1,350 mm in the western watershed to 1,150 mm in the eastern plain of the basin, of which about 90% is concentrated during wet season. September is generally the month of haviest precipitation during the prevailing southwest monsoon season.

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 Communications is located at Nakhon Sawan. Among hydrological gaging stations under the RID within the basin, the stations at CT-5A, CT-7 and CT-9 furnish meteorological data of temperature, evaporation and wind speed. These data are summarized in Table 3.2.1 and Table 3.2.2.

3.2.3 Streamflow

There are seven gaging stations within the basin. The locations of these stations are shown in Fig. 3.2.2. The station CT-5A on the Mae Wong river is equipped recently with

the automatic water level recorder which is being operated by RID. Other stations are equipped with the staff gages and operated by RID. All these stations are rated by current matter measurements, where river stage versus discharges are plotted to establish rating curves every year. These rating curves are used to convert daily gage height readings to daily discharges. The runoff data at stations of CT-5A, CT-7 and CT-9 are, among other stations, considered fairly accurate since they show relatively constant runoff rate in the double mass curves over the observation period. Records of monthly runoff at CT-5A, CT-7 and CT-9 are summarized in Table 3.2.3.

Streamflow in the Sakae Krang basin is characterized by large fluctuation of runoff between dry and wet seasons and by small runoff rates throughout the year. Runoff record of CT-7 gaging station at downstream of the proposed Khlong Pho dam shows often zero runoff in April. In an extremely dry year of 1977, the CT-7 recorded zero runoff for successive 3 months from February until April.

The average annual runoff rates were estimated, by using the actual runoff records and generated streamflow by tank models for 29 years from 1954 to 1982, as follows:

River	Gauging Station	Average Rainfall (mm)	Average Annual Discharge (MCM/km^2)	Average Runoff Rate (%)
Mae Wong	CT-5A	1,293.0	0.316	24.4
Khlong Pho	CT-7	1,283.5	0.217	16.9
Thap Salao	CT-9	1,346.5	0.231	17.2
Khok Khwai*	CT-9	1,346.5	0.231	17.2

* In the absence of actual or reliable runoff records, the tank model renoff analysis results obtained from the case of the Thap Salao river were applied.

The vegetation cover and geological condition of watershed considerably affect to the average runoff rate of these rivers. Watershed of the Mae Wong river is covered by comparatively thick forest and sandy alluvial or diluvial deposit is not remarkable within the drainage area of CT-5A. On the contrary, in the watersheds of CT-7 and CT-9, the forest cover is rough and thin and alluvial or diluvial sand layers are widely formed within the drainage area.

The drainage area and endowed mean annual runoff of these rivers are estimated at each potential dam site as given below:

Rivers	Drainage Area	Annual Runoff
	(km^2)	(MCM)
Mae Wong		
- Upper site	612	193
- Lower site	930	294
Khlong Pho	394	80
Thap Salao		
- Thap Salao site	534	125
- Upper Huai Rang site	41	10
- Lower Huai Rang site	76	18
Khok Khwai		
- Upper site	162	38
- Lower site	219	51

Monthly river runoff simulated by runoff models for the period from 1954 to 1982 are summarized as follows:

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

River	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Mae Wong	2.4	9.6	18.7	18.0	31.8	73.3	103.2	36.2	11.2	5.8	3.5	2.7
Khlong Pho	0.6	3.0	12.7	16.1	19.4	51.3	70.7	29.9	5.9	3.4	2.3	1.6
Thap Salao	1.9	4.4	11.5	12.7	16.1	48.7	90.4	29.5	5.9	4.3	3.3	2.6
Khok Khwai	1.9	4.4	11.5	12.7	16.1	48.7	90.4	29.5	5.9	4.3	3.3	2.6

The river runoff 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.

3.2.4 Groundwater

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 preliminary study on grounwater potential was conducted by RID during the period from 1973 to 1978.

The groundwater potential in the basin is described by RID, on each of the potential zones classified on the potential zones classified on the basis of geological formation and results of test wells. The classified potential zones are indicated on Fig. 3.2.3. The potential of each zone is summarized as follows:

Zone I	Unconsolidated aguifer in active flood plain located along right side of the Chao Phraya river and consists of sand and gravel. Groundwater yield tests show the yield of more than 2.3 cum/min.
Zone II	Low terrace of the Sakae Krang basin and unconslidated aguifer, located adjacent to the Zone I.
Zone III	High terrace of the basin consists of sand lens interbedded with silty clay. Yield is about 0.1 - 0.2 cum/min. It is located along the right side of the Sakae Krang river.
Zone IV	Semi-consolidated rocky pediment consists of lateritic soil and clay. No groundwater potential.

The downstream area of the basin is a part of vast flood alluvial plain of the Chao Phraya river. 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 esitmated flow directions of grounwater are illustrated on Fig. 3.2.3.

The potential productivity of the groundwater is roughly estimated for each zone assuming the effective void ratio of aquifer at 0.2 and average thickness from the data on test wells and experimental bore holes.

Zone	Average Thickness	Unit Productivity
	(m)	(MCM/sq. km)
I	37	7.4
II	20	4.0
III	14	2.8

3.2.5 Water quality

(1) Surface water

The irrigation water quality is classified into four grades with respect to the sodium hazard (S1-S4) in terms of sodium-absorption ratio (SAR) and the salinity hazard (C1-C4) in terms of electric conductivity (EC). Results of water quality analysis on the samples taken from each of the dam sites are summarized in Table 3.2.4. All samples are classified into C1-S1 class except the sample from the Khlong Pho dam site which is classified into C2-S1. Based on this quality analysis, the river waters are all within the tolerable limit and suitable for irrigation. In fact, no adverse effects have been reported by using the river water for irrigation during past years.

Among other items of quality analysis, high PH values for all rivers and high Ca contents for the Khlong Pho river are noted. It will be necessary to investigate the existence of line stone at drainage areas of proposed dam sites.

(2) Groundwater

Chemical analysis of the water samples obtained from the bore holes were conducted in the said RID study. It should be noted that 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 grounwater quality to clarify the potential productivity for irrigation.

3.2.6 Geology

The Sakae Krang river basin is boradly divided into two geological zones by Tertiary volcanic belt running along latitude of about E-99-30; the western Paleozoic zone and the eastern Mesozoic zone. The western zone has a district N-S geological structure affected by the Burmese-Malaya geosynclinal movement of mericional trend. The proposed dams are located along the eastern edge of this Paleozoic zone. The eastern Mesozoic zone, in which a vast diluvial plateau is developed, has more gentle and flat topography and geostructure and is suitable for agricultural purposes.

These geostructural modes have been formed as a result of the crustal movements during the Mosozoic and Tertiary periods. Chronology of this area is summarized in Table 3.2.5. The geological map is shown in Fig. 3.2.4.

3.2.7 Soils

The land of the Sakae Krang river basin is classified into the following six (6) land form categories:

1. Flood Plain
2. Semi-recent Fan and Alluvium
3. Low Terraces
4. High terraces
5. Dissected Erosion Surface
6. Mountains

These land-forms are identified on the basis of the detailed reconnaissance soil maps scaled 1 to 100,000 prepared by the Department of Land Development and have been confirmed through the present field observations. The land-form map is given in Fig. 3.2.5. The areas of each land-form category in each of sub-basins, are given as follows:

(Unit: km^2)

Sub-basin	Land-form Categories						
	Flood Plain	Semi-recent Alluvium	Low Terraces	High Terraces	Erosion Surfaces	Mountains	Total
Mae Wong	-	544	187	546	256	638	2,171
Khlong Pho	-	348	25	158	479	201	1,211
Thap Salao	70	353	32	32	265	501	1,253
Khok Khwai	30	199	146	154	253	326	1,108
Sakae Krang	95	255	17	17	84	89	557
Total	195	1,699	407	907	1,337	1,755	6,300
(%)	(3.1)	(27.0)	(6.5)	(14.4)	(21.2)	(27.8)	(100.0)

The major soils of the Sakae Krang river basin are those on semi-recent alluvium and low terrace of diluvial deposits. These occupy about 36% of the total area. The soils developed on other land form categories are not irrigable due to their steep topography and feature of sandy or gravelly shallow soil depth.

The Great Soil Groups identified on the semi-recent alluvium and low terraces are (1) Non-calcic Brown Soils, (2) Low Humic Gley Soils and (3) Gray Podzolic Soils. These are further sub-divided into nine (9) Soil Series as follows:

Land Form	Soil Group	Soil Series	Area km^2	Area %
Semi-recent alluvium	Non-calcic Brown Soil	(1) Phechaburi	633	30.1
		(2) Nakhon Pathom	308	14.6
		(3) Mae Sai	77	3.7
		(4) Kamphaeng Saen	681	32.3
Sub-total			1,699	80.7
Low Terraces	Low Humic Gley Soil	(5) Deum Bang	132	6.3
		(6) Pak Tho	67	3.1
		(7) Roi Et	97	4.6
	Gray Podzelic Soil	(8) Ubon	35	1.7
		(9) San Pa Tong	76	3.6
Sub-total			407	19.3
Total			2,106	100.0

Three (3) Soil Series of non-calcic brown soils, i.e., Phechaburi, Nakhon Pathom and Kamphaeng Saen, are predominant in the basin. The generalized characteristics of these soil series are given below:

- The Phechaburi series are formed from semi-recent alluvium, and occur on the lower parts of the semi-recent levees. Relief is flat to nearly flat. Slopes are 2% or less. The effective soil depth is very deep. The texture of A horizon is sandy loam and that of B horizon is clay loam. Soil reaction is medium acid to neutral. The soils are somewhat poorly drained. Permeability is moderate and surface runoff is slow. The soils of this group are classified as

Utic Haplustalfs (USDA) or Non Calcic Brown Soils (National). Phechaburi series are predominantly used for transplanted rice cultivation.

- The Nakhon Pathom series are developed on semi-recent alluvium and occur on low terraces. Relief is flat or nearly flat. Slopes are 1% or less. The effective soil depth is very deep and the soil is clay loamy to clayey textured. Soil reaction is slightly acid to moderately alkaline. The soils are somewhat poorly drained. Permeability and surface runoff are slow. The soils are classified as Non Calcic Brown Soils (National) or Utic Haplustalfs (USDA). Nakhon Pathom series are mainly used for transplanted rice cultivation. In some places, sesame, beans and groundnuts are grown, together with sugar cane in the dry season.

- The Kamphaeng Saen series are formed from semi-recent alluvium and occur on old levees and breach deposits of semi-recent terraces. Relief is flat to nearly flat, with a slightly undulating micro-relief. The effective soil depth is very deep. The soil texture is loam or clay loam. The soils are generally well drained, permeability is moderate and surface runoff is slow. Soil reaction is slightly acid to mildly alkaline. The soils are classified as Non Calcic Brown Soils (National) or Utic Haplustalfs (USDA). Kamphaeng Saen series are mainly used for transplanted rice cultivation. In some places, they are put under upland crops cultivation such as maize, cotton and sugar cane.

The distribution of soil groups identified in the Sakae Krang river basin is shown on Fig. 3.2.6. The relationship between present land use and land form categories combined with soil types, is roughly studied as shown in Fig. 3.2.7. The present land use is generally conformed to the land and soil characteristics.

3.2.8 Land capability

According to the classification system developed by RID in the Greater Mae Khlong multi-purpose project in 1968, total areas in the Sakae Krang river basin are classified into 8 land classes as follows:

Land Class Group	Land Class	Area km²	Area %
R1	U3sd/R1	308	4.9
R2	U3s/R2s	730	11.6
U2/R2	U2sd/R2s	199	3.2
	U2s/R2s	272	4.3
U1	U1/R2s	76	1.2
U2	U2s/R3s	716	11.4
U3/R3	U3st/R3st	2,244	35.6
6	6	1,755	27.8
Total		6,300	100.0

(Detailed explanation on land classification is given in ANNEX-III.)

The RID land classification system has been formulated through the past experience of the observations and studies on soil, drainage and topographic characteristics and their effects on crop productivity. The standard specification for land classification is shown in Table 3.2.6. The framework of the system is basically three (3) classes rating for rice and upland crops. Limitations on suitability of land due to soil, drainage and topography are indicated by the symbols "s", "d" and "t", either individually and collectively.

The land classification data are primarily derived from the land suitability maps scaled 1 to 100,000 prepared by the Department of Land Development. The results of land classification study indicate that about 37% of the total land area, or about 2,301 km^2, are suitable for agricultural production, of which about 1,038 km^2 are suitable for paddy cultivation, 792 km^2 for upland crops cultivation and the remaining 471 km^2 are suitable both for paddy and upland crops as summarized below (for details, see table 3.2.7):

(Unit: km^2)

Sub-basin	R1 & R2		U1 & U2		U2/R2	
	Area	%	Area	%	Area	%
Mae Wong	366	43.4	247	31.2	118	17.7
Khlong Pho	173	20.5	161	20.3	39	5.9
Thap Salao	202	15.7	151	19.1	102	25.8
Khok Khwai	54	2.8	221	27.9	100	19.5
Sakae Krang	243	17.6	12	1.5	112	31.1
Total	1,038	100.0	792	100.0	471	100.0

The preliminary land classification map is shown in Fig. 3.2.8.

3.3 CURRENT SITUATIONS

3.3.1 Population

The past census results indicate that the total population of the Study Area is about 240,000 persons in 1970 and about 295,000 persons in 1980, and has been increasing at the rate of 2.1% per annum. The present population as of 1984 is estimated at about 320,000 in total. The population density is about 50.9 persons per km^2. Total number of household is about 61,300, out of which farm household accounts for 43,800 or 71% of the total. Average size of farm household is 4.8 persons. Farm labour force ranges 2-3 persons per farm household on an average. The demographic data are given in Table 3.3.1.

3.3.2 Infrastructure

(1) Transporation

The major transport network in the basin area consists of the provincial asphalt-paved roads and the provincial laterite-paved roads. One provincial asphalt-paved road runs south to north along the eastern boundary of the study area connecting Chainat, Uthai Thani, Thap Than and Lat Yao. The other provincial asphalt pavement road runs west to east along the northern boundary of the study area connecting the lower Mae Wong dam site and Lat Yao. This road further extends from Lat Yao eastward and is connected with the national highway route No. 1.

One provincial laterite-paved road stretchs out from Nong Chang and runs westward. Many rural roads are branched off from the provincial road and are networked in and around the study area. Most of these roads are laterite-paved, but these roads are considerably deteriorated due to insufficient maintenance works. After heavy rainfall, some of them are not jeepable.

(2) Water supply

Each village in and around the study area mainly depends its potable and domestic water resources on groundwater, ephemeral rivulets thereabout and rainfall. During the dry season, the village people get their drinking water from shallow well, since no rainfall water is expected and all rivulets are completely depleted. The urban areas of Nakon Sawan, Uthai Thani, Chainat have installed modernized municipal water supply systems.

(3) Power supply

Except for western mountaineous ranges, electric power is supplied. Even no supply area of electric power, people use their own small generators.

(4) Communication

Except for urban areas of Nakon Sawan, Uthai Thani and Chainat, the telephone services are not available in the study area. Recently, the television sets have come into wide extension.

(5) Education

In many villages, there exists at least one elementary school and most of the children can reach a school within short walking distance. Major districts in the study area have secondary schools.

(6) Health

The hospital faciliites are limited within the urban areas of Nakhon Sawan, Uthai Thani and Chainat. All districts and major villages have simple health care facilities.

3.3.3 Present condition of agriculture

(1) Land tenure and land holding

The agricultural census in 1978 reveals that about 98% of farm household own their farm land with an average holding size of 27 rai (4.3 ha). Distribution of farm household by different size of holding is as follows:

Land Holding size (rai)	Percentage of farm household (%)
Less than 6	5.9
6 to 15	11.9
15 to 25	18.8
25 to 40	29.1
40 to 60	19.8
60 to 100	11.1
More than 100	3.4

(2) Present land use

Of the total area of 3.94 million rai (6,300 km^2) the Sakae Krang river basin, permanent agricultural holdings account for 1.16 million rai (1,860 km^2). The rest of 2.78 million rai (4,440 km^2) are mountains, steep slopes, forest reserve, rivers and swamps, roads and public facilities compounds. The major types of agricultural land use are paddy, upland crops, orchard, forest and pasture. The distribution of these major land use types are shown in Fig. 3.3.1. The pattern of land utilization closely relates with the land-form patterns and soil-type distribution. Paddy field is mostly confined to semi-recent alluvial plain of the Sakae Krang river and the low terraces. Upland crops field mainly extends on middle and high terraces, while orchard and pasture are observed sporadically within upland crop areas.

Present agricultural land use is summarized as follows:

(Unit: km^2)

River Basin	Agricultural Land Use			Non-agric Land	Total
	Paddy	Upland Crops	Orchard & others		
Mae Wong	520	170	20	1,461	2,171
Khlong Pho	158	52	41	960	1,211
Thap Salao	298	23	8	924	1,253
Khok Khwai	166	98	11	833	1,108
Sakae Krang	248	17	30	262	557
Total	1,390	360	110	4,440	6,300

Paddy rice is by far the most important crop, grown on about 75% of the total agricultural land. Upland crops occupy virtually most of the remaining agricultural land. Major crops grown on the upland field are maize, sorghum, mung beans, cassava and sugar cane.

Interpretation of Landsat imagery made between 1978 and 1982 by Forestry Department indicates serious destruction of forest area in two provinces of Nakhon Sawan and Uthai Thani which cover most of the study area. For the 1978-1982 period, a reduction of 228 km^2, or 6.9% of previously forest area, is observed. The deforested land has partly been brought under upland crop cultivation and partly laid bare or covered only with shrub mainly due to poor soil conditions.

(3) Present cropping pattern

Irrigation facilities are well developed in this area. About 534,000 rai (85,500 ha) or 61% of the existing paddy fields, are more or less presently provided with irrigation facilities, while all of the upland crop fields are rainfed. In this area, existence of irrigation facilities does not mean continuous year-round irrigation, but supplemental water supplies for rainy season paddy cultivation. Even though irrigation facilities are provided, all these paddy fields are not alway actually irrigated due to limited availability of water. In general, paddy fields extending along upstreams of major rivers, are rather sufficiently irrigated, while the ones along the downstreams are less irrigated or not actually irrigated and are likely subject to annual drought damages.

Difficulties are involved in estimating the extent of well irrigated paddy field, because the area well-irrigated largely fluctuates year by year depending upon seasonal water availability. The 1978 Agricultural Census indicates that some double cropping was carried out on about 146,000 rai of the paddy fields (23,400 ha) in 1978/79. This suggests that these double cropping areas are sufficiently irrigated, and that other paddy fields with irrigation facilities are supplementarily irrigated only for rainy season paddy cultivation or partly put under rainfed cultivation due to lack of water. Water balance study on existing condition indicates that about 58% of the total paddy fields with irrigation facilities, or about 308,000 rai (49,300 ha) of the paddy fields are irrigated in the rainy season under normal condition with 80% probability rainfall. Field observations confirm these preliminary study results; i.e., the existing paddy field is classified:

Paddy Field	Area		Percentage (%)
	rai	ha	
Paddy Field with Irrigation Facilities	534,000	85,500	61.5
(1) irrigated (double cropping)	146,000	23,400	16.8
(2) irrigated (single cropping)	162,000	25,900	18.6
Sub-total	308,000	49,300	35.5
(3) mainly rainfed (single cropping)	226,000	36,200	26.0
Rainfed Paddy Field	335,000	53,500	38.5
Total	869,000	130,000	100.0

As seen from the above, only 36% of the paddy field is actually irrigated. The representative cropping pattersn on these categoriezed paddy fields are shown on Fig. 3.3.2.

The irrigated paddy field where some double cropping is carried out, mainly extends along the upstream of the Mae Wong river. In these areas, paddy is planted from mid-June and harvested in November-December. Local varieties of paddy like Luang Pra Tarn and Kao Dawk Mali are planted on about 60% of the area; the rest is planted with high yielding varieties (H.Y.V.) like RD 7 and RD 21. Dry season cropping usually starts immediately after harvesting of rainy season paddy. The extent of dry season cropping is around 20% of the area. Major crops in the dry season are mung beans (15%) and paddy (5%).

The paddy field where irrigated single paddy cropping is almost guaranteed with adequate supply of irrigation water, is observed on the upstream areas of each existing irrigation block. In these area, only rainly season paddy is cultivated on almost 100% of the paddy field. Local varieties are predominantly used for about 75% of the area. Paddy is usually planted from early July and harvested in December-January.

Rainfed paddy field has two categories as previously mentioned; i.e., (1) paddy field with irrigation facilities however not actually irrigated due to lack of water supplies, and (2) ordinary rainfed paddy field

without irrigation facilities. These paddy fields extend over the downstream areas. Only rainy season paddy cropping is practiced in these areas. Planted area, however, largely fluctuates year by year; only about 50% of the area is planted in drought years and almost 100% in rainy years (however, harvested area is usually smaller than the planted area due to drought damages in drought years and flood damages in rainy years). Average planted/harvested area is estimated at about 75% of the paddy field.

Upland crop area extends mainly on middle and high terraces and mountain slopes. In the rainy season, maize is the major crop. In Nakhon Sawan province, sorghum is also planted, together with maize, in the rainy season. In Uthai Thani province, upland crop area is subject to annual flood damages; therefore, rainy season maize is planted in mid-April and harvested in August in order to avoid the major flood season in September/October. Dry season cropping is common. About 40% of the upland crop field are utilized for dry season cropping. Major crop is mung beans.

(4) Farming practices

The farming practices in the Sakae Krang river basin are still of conventional.

Land preparation: A combination of tractor power (8 ps class two wheel hand tractor) and animal draft are used; in interview with extension workers, it appeared that about 70% of paddy field are cultivated by hand tractors and 30% by buffaloes. This greater dependence on tractor power may be attirubted to the large farm size and the fact that only short period is generally available for land preparation due to uncertain water supplies in the rainy season. Before land preparation, previous season's paddy stubble is burned in the dry months of March-April, and the field is ploughed using light showers of rain, or taking the irrigation water into the field where water is available, to moisten the soil, in May-June.
A second harrowing is common. According to the information obtained from agricultural extension office in each Amphoe concerned, about 20% of farmers own their tractors lend them to the neighbours at the cost of 150-200 Bahts per rai. Second harrowing is usually carried out with standing water in the field, mainly in June.

Nursery/Transplanting: Nursery establishment is made in June-July and transplanting of 3-4 week old seedlings is in July-August. In the Sakae Krang river basin, the transplanted rice is predominant. Boardcasted rice is confined to only the flooded areas. Most of the rice grown in the area is non-glutinous.

Crop management: This comprises weed control, fertilizer application, control of plant pests and diseases and distribution of irrigation water. Weed control is generally made by hand. Investment for weeding is however, generally low and present condition of weed control is unsatisfactory. Use of fertilizers is generally limited. The local varieties do not receive any fertilizers, but HYVs do receive an application of some fertilizers. Chemical control of pest and diseases is not common. There is no farmer's institutions responsible for collective irrigation water distribution. Farmers take water at discretion from rivers/canals as they require if water is available. No rotational irrigation schedule is applied. Two wheel small tractors are fully used as power source for pumping water from river/canal and tube wells.

Harvesting: The rainy season paddy is harvested in the dry months of November/December. Harvesting is carried out manually with sickle knives; the sheaves are left in the field for a period of drying and thereafter boundled and removed to the threshing floor. Threshing is usually made by tractor or under the feet of buffaloes. Winnowing is effected manually. Threshing/Winnowing is rather leisurely operation carried out over a 2-3 month period. The rice is thereafter bagged and transported, either for storage or for sale.

(5) Crop yield and production

Paddy yield largely fluctuates year by year. Reasons are manifold. Decisive factor is, however, unstable water supply resulting from uneven seasonal distribution of rainfall as well as irregular total depth of annual rainfall which causes drought and flood repeatedly. Fig. 3.3.3 shows annual paddy yield and production in past 10 years in Nakhon Sawan and Uthai Thani. Relationship between paddy yield and annual rainfall is shown in Fig. 3.3.4.

Crop production in the Sakae Krang river basin is roughly estimated, by multiplying the estimated crop areas and unit yield data given in the agricultural production statistics (1973/74 - 1982/83), as follows:

Crop	Crop Area (1,000 Rai)	Crop Production (1,000 ton)		
		Highest	Lowest	Average
Major Rice	869	283	137	234
Second Rice	7	5	4	4
Mung Beans	99	18	6	13
Maize	132	53	21	36
Sorghum	64	14	8	11
Cassava	13	40	27	33
Sugar Cane	12	114	54	102
Cotton	4	-	-	-

(6) Livestock

Various kinds of livestock; i.e., buffaloes, cattle, swine, goat, chicken and duck, are raised individually in the Sakae Krang river basin. Buffaloes still play an important role in land preparation. Others are not economically significant in present farm economy.

(7) Crop marketing and processing

Paddy rice is both the subsistence crop and the only significant cash crop in the basin. In visits to the agricultural extension offices at each changwat concerned, it was learned that about 50% of paddy production was intended for sale. In addition, part of the produce stored for consumption will also be sold, when the following harvest is secured. The value of paddy depends in past on its grain guality which is in turn chiefly a matter of variety and cultivation method. Grading of paddy is normally undertaken by hand milling of a few sample grains and quality is judged by eye. The marketing of paddy remains largely a private sector activity. The farmer usually negotiates a sale at his home, to either a middle man, or directly with an agent of the rice miller.

There are about 800 rice mills in the provincial areas of Nakhon Sawan and Uthai Thani. Paddy is not necessarily milled in the area where it is grown. Provincial middlemen may transport it to other centres inside or outside the province, seeking the best price. The miller may sell some of the rice locally, but much of the rice will go to the Bangkok wholesale market, and prices there largely influence what the miller can offer for paddy to the farmer. In an overall sense, the

private marketing system appears to operate efficiently within the Basin area. There are inevitably disputes between farmers and merchants on the grading of the paddy; however, each farmer has an opportunity to compare offers from several merchants and/or agents of the rice mills.

The farm gate price of paddy fluctuates seasonally. Present average farm gate price of paddy is 2,800-2,900 Bahts per ton.

(8) Agricultural institutions

A number of governmental and non-governmental organizations play a major role for improvement of rural life and increase of agricultural production. Among the organizations, the Ministry of Agriculture and Cooperatives is systematically leading the agricultural supporting services for the farmers.

Agricultural extension: The Sakae Krang river basin area is covered by the early phase of the National Agricultural Extension Project, financed by the World Bank in 1977. According to the provincial extension offices in the Basin area, the Project components are already finalized and in operation. The full staff complement of extension workers is also in place with transport. Package of practices has been determined and pre-season training and visiting schedules are established. In each tambon at least one extension worker is assigned. Extension work is concentrated on rice and maize.

Farmer organization: There are several agricultural cooperatives in the Basin area. Apart from the informal exchange and hire of farm labour and equipment, there is little evidence of cooperative movements in farming and marketing. There is no water user's association in the existing irrigation areas.

Agricultural research: The Basin area is well served by the Chainat Rice Experiment Station which is part of the Rice Division of the Department of Agriculture. All important aspects of rice research are covered by this station, including seed multiplication, crop rotation and plant protection in rice crops. Field extension workers are trained in rice production technique by the staff of this station.

The Chainat Field Crop Research Institute is one of the branch stations under the Department of Agriculture. In this station, emphasis is laid on testing dry season upland crops rotations with rainy season paddy.