KINGDOM OF THAILAND

MINISTRY OF AGRICULTURE AND COOPERATIVES

ROYAL IRRIGATION DEPARTMENT

THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT (PHASE II)

VOLUME 2

MAIN REPORT

FEASIBILITY STUDY ON

KHLONG LUANG DAM SCHEME

AUGUST 1983

JAPAN INTERNATIONAL COOPERATION AGENCY

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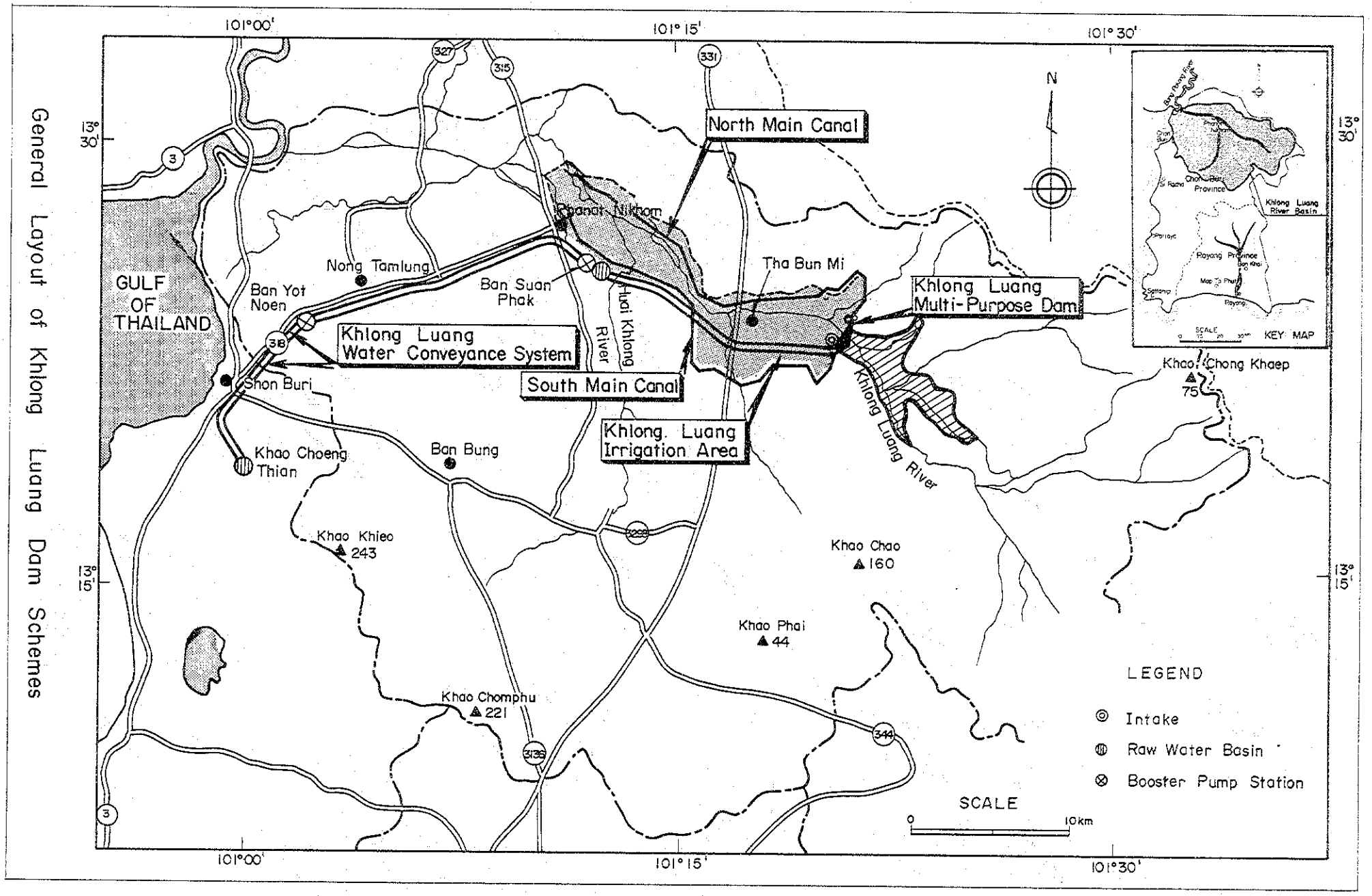
General Layout of Khlong Luang Dam Schemes
101°00'
101°15'
101°30'
13° 30'
13° 15'
N
North Main Canal
Khlong Luang Multi-Purpose Dam
Khlong Luang Water Conveyance System
South Main Canal
Khlong. Luang Irrigation Area
Khlong Luang River
Huai Khlong River
GULF OF THAILAND
Phanat Nikhom
Nong Tamlung
Ban Yot Noen
Ban Suan Phak
Tha Bun Mi
Khao Chong Khaep
▲75
Chon Buri
Khao Choeng Thian
Ban Bung
Khao Khieo
▲243
Khao Chao
▲160
Khao Phai
▲44
Khao Chomphu
▲221
LEGEND
Intake
Raw Water Basin
Booster Pump Station
SCALE
0
10km
KEY MAP
Khlong Luang River Basin
Chon Buri Province
Rayong Province
Sattahip
Phanat Nikhom
Mae Ta Phut
Rayong
SCALE
0
20
30km

SUMMARY OF CONCLUSION AND RECOMMENDATION

1. The Government of Kingdom of Thailand issued the Fifth National Economic and Social Development Plan (the Fifth National Plan), which covers a 5-year period from 1982 to 1986. The Fifth National Plan focuses to restore the nation's economic and financial stability, to improve the economic efficiency and to alleviate the poverty through the development of industry and increase of agricultural production.

2. The Eastern Seaboard Development is the spearhead of the nation's industrial development plan and aims at developing the basic industry based on natural gas. The development area extends over Chachoengsao, Chon Buri and Rayong Provinces. The majority of the development area are located along the coastal area in Chon Buri and Rayong Provinces.

3. The agricultural development is regarded to be promoted in the backward area of the industrial development area in order to create the balanced socio-economic situation throughout region and to increase the exportable quantity.

4. The East Coast Water Resources Development Project, Phase II (the Study) was launched by the Government to treat of increasing importance of land and water resources development for the industrial development and agricultural production.

   The objective area of the Study (the Study Area) covers Chon Buri and Rayong Provinces, except the Prasae river basin, and embraces the majority of the Eastern Seaboard Development Area.

5. The Study contains two subjects; (a) study for the long-term water demand and supply balance in the Study Area and (b) feasibility study for Khlong Luang, Khlong Yai and Khlong Thap Ma Dams.

6. The long-term water supply plan over the Study Area has been elaborated already and has pointed out clearly the significance of development of Khlong Luang Dam Scheme (the Scheme). The Scheme is distinguished as multiple-purpose areal-development project, since it is designed as an element in regional plan.

7. The Scheme is located in the Khlong Luang river basin, which has a drainage area of 1,930 km^2. The population in the basin is 291,100 in 1981, of which about 88% resides in the rural area.

8. The lands and water resources of the basin remain almost untapped. The flat alluvial plains, occupying about 40% of the basin area, are used extensively for agriculture.

   The irrigation and drainage system, however, is provided only 7,800 ha of lands, which is served by the water diverted from the Bang Pakong river basin.

   The main crops are rice, cassava and sugarcane. The crop productivity is low due to lack of irrigation supply and agricultural input and inundation.

9. The pipe-water service is provided mainly for the urban areas. The existing six water works serve about 20 x 10^3 people, being only 7% of the total population in the basin.

   The remaining people depend on groundwater or water-vender for their domestic use.

10. The alluvial plains are prone to inundation to a large extent, owing to flat topography and flooding of the Khlong Luang river. It is estimated that about 58,300 ha of lands were inundated in 1974.

11. The domestic and industrial water dependent on the Khlong Luang reservoir is estimated as the sum of the quantity of inter-zone water diversion and the demand within the basin. It is 1.9 x 10^6 m^3 per year in 1986, 4.1 x 10^6 m^3 per year 1991, 10.9 x 10^6 m^3 per year in 1996 and 17.8 x 10^6 m^3 per year in 2001.

12. The plan formulation study was conducted to ascertain the optimum development plan of the Scheme. It was performed in two steps each of which treats of various alternatives. The first step is directed to formulate the optimum land and water resources development plan, including the water supply. The second step is led to formulate the optimum flood mitigation measure in the basin. As the results, the optimum development plan of the Scheme is determined.

13. The flood mitigation plan evolved the most favourable basic flood control plan for standard project flood with a 50-year recurrence interval. The basic plan is made up of combination of dam and river improvement works. Both dam and river improvement works generate high economic return by the reduction of flood damages. It is expected that the river improvement works will be proceeded in stage-wise manner after the completion of the Khlong Luang Dam.

14. The water conveyance system will be implemented in two phases taking into account the growth of the domestic and industrial water demand. The first phase with 5.5 x 10^6 m^3 per year of system capacity must be realized at latest in 1991 in order to release Chon Buri-Pattaya area from the water shortage. The system capacity will be expanded to 11.0 x 10^6 m^3 per year with completion of the second phase in 1996.

15. The proposed irrigation development area of 6,600 ha extends along the both banks of the Khlong Luang river in the immediate downstream from the dam. The area is divided into the North Area (3,100 ha) and the South Area (3,500 ha).

The recommended crops are rice, mungbeans, groundnuts and vegetables. The rice will be cultivated in the whole irrigation area during the wet season while the crops will be grown during the dry season. Cropping intensity is 1.4, an increase of 0.4 from the present. The crop production will increase largely as shown below, resulting from the introduction of advanced farming practices and proper water management.

Crops	Without Project (t)	With Project (t)	Increase (t)
Rice			
- Local variety	7,150	5,280	-1,870
- High Yielding Variety	6,100	23,760	17,660
Mungbeans	-	630	630
Groundnuts	100	4,030	3,930
Cassava	6,400	-	-6,400
Sugarcane	16,770	-	-16,770
Vegetables	-	6,100	6,100

16. Preliminary designs were performed for the dam, raw water conveyance system and irrigation and drainage system, respectively.

Dam comprises a main dam and a saddle dam. The main dam is of homogeneous earth-fill type with the maximum height of 17.1 m above the river bed and the crest length of 3,820 m. The upstream and downstream slopes are 1:2.6 and 1:2.4 respectively. The total embankment volume is 3,271 x 10^3 m^3. The spillway is designed as a side-channel spillway with open channel chuteway based on inflow design flood with a peak discharge of 1,460 m^3/s (500-year recurrence interval). Its crest elevation and length are El. 39.5 m and 70.0 m, respectively.

The water conveyance system is has a total length of 56 km. The pipeline is designed by coating steel pipe having an inside

diameter of 600 mm and is installed in two rows. The intake is located in outlet of irrigation outlet of South Main Canal and is equipped with 3 units of volute pumk. The row water basins are selected at Khao Choeng Thian near Chon Buri. Two booster pump stations are installed on the pipeline; the one equipped with 3 units of volute pump is located at Ban Suan Phak and the other with 3 units of volute pump is installed at Ban Yot Noen.

Two irrigation intakes are constructed in the reservoir and are connected to the North and the South Main Canals respectively. The intake comprises an intake tower with 10.4 m in height and equipped with regulating gate (2.0 m x 2.0 m), conduit pipe with inside diameter of 2.0 m and outlet associated with discharge measurement device. The North and the South Main Canals are designed with concrete lining and stretch for 31 km and 22 km, respectively. Fifteen lateral canals are aligned within the irrigation area and their total length is approximately 34 km.

17. Environmental aspects of the scheme is preliminarily evaluated according to the standard established by National Environmental Board. The standard comprises four categories namely, physical resources, ecological resources, human use values and quality of life values. It is clarified that the scheme will induce positive impact on human use value and quality of life values greatly through the water resources development. Impact on such items as water quality and fauna and flora will be minimized or avoided by guaranteeing the river maintenance flow to the downstream of the river. It is recommended that detailed survey on environmental impacts of the Scheme will be conducted by the executive agency before the implementation of the Scheme.

18. The scheme will be implemented in two stages. The first stage includes the construction of multiple-purpose dam and the first phase of water conveyance system and the development of irrigation and drainage system. The second stage is the construction of the second phase of the water conveyance system.

The first stage will extend over 8 years from 1985 to 1991. The construction period will be 5 years from 1985 to 1990 for the dam, 4 years from 1987 to 1991 for the first phase of the water conveyance system and 5 years for the irrigation and drainage system.

The second stage will be implemented in a 4-year period from 1991 to 1995.

19. The total investment cost is estimated to be ฿ 4,566 x 10^6 comprising ฿ 2,664 x 10^6 of local currency component and ฿ 1,902 x 10^6 of foreign currency component as shown below:

(Unit: ฿ 10^6)

Project Components	Local Currency Component (B10^6)	Foreign Currency Component (B10^6)	Total (B10^6)
Multiple-purpose dam	752.8	1,716.8	2,469.6
Irrigation and Drainage System	277.6	629.6	907.2
Water Conveyance System, 1st Phase	388.3	170.6	558.9
Water Conveyance System, 2nd Phase	483.2	146.8	630.0
Total	1,901.9	2,663.8	4,565.7

20. The benefit accrues from the water supply, irrigation and drainage development and flood control and is estimated as follows for the full development stage:

(Unit: ฿ 10^6)

Benefits	Annual Benefit (฿ 10^6)
Water Supply	423.3
Irrigation and Drainage	180.7
Flood Control	49.8
Total	653.8

The water supply benefit is measured by justifiable expenditure.

21. Economic feasibility of the Scheme is evaluated by economic internal rate of return (EIRR). EIRR is computed at 16.1 %, indicating the high economic soundness of the Scheme.

22. Investment cost is allocated to the components by "Separable costs - remaining benefit method" and summarized as follows.

(Unit: ฿ 10^6)

Components	Foreign Currency	Local Currency	Total
D&I Water Supply	1,112.3	866.8	1,979.1
Irrigation	684.1	1,556.7	2,240.8
Flood Control	105.5	240.3	345.8
Total	1,910.9	2,663.8	4,565.7

23. Financial aspect of the Scheme is evaluated by respective component paying particular attention to the repayability of the Scheme to the international loan. International lona is assumed to be financed with an interest rate of 3.5 % per annum and term of 30 years including 10 years of grace period. Repayability is examined based on the project cost allocated to each project component and revenue expected to be collected through water supply is assumed to be ฿ 4.0/m^3. Water tariff on irrigation water is broadly estimated at ฿ 670/ha to recover annual O&M cost. International loan is expected to be repayed in due schedule, with Government subsidy given at the appropriate time.

24. RID will be responsible for implementation, operation and maintenance of dam and irrigation components. An appropriate agency would be appointed for the implementation, operation and maintenance of the raw water conveyance system. The Center for

the Integrated Plan of Operation (CIPO) established within National Economic and Social Development Board (NESDB) will coordinate all the activities of the agencies with the activities related to the Eastern Seaboard Development.

PRINCIPAL FEATURES OF KHLONG LUANG DAM SCHEME

1. MULTIPLE-PURPOSE DAM

1.1 Hydrology

(a)	Catchment area	526 km^2
(b)	Annual average inflow	3.97 m^3/s
(c)	Design flood for spillway (500-year flood)	1,460 m^3/s
(d)	Extra-ordinary flood (Probable maximum)	2,520 m^3/s

1.2 Reservoir

(a)	High water level	El. 39.5 m
(b)	Low water level	El. 33.8 m
(c)	Flood water level	El. 40.5 m
(d)	Extra-ordinary flood water level	El. 40.9 m
(e)	Gross storage	169.1x10^6 m^3
(f)	Surcharge	34.3x10^6 m^3
(g)	Active storage	119.0x10^6 m^3
(h)	Dead storage	15.8x10^6 m^3
(i)	Reservoir area at HWL	32.2 km^2

1.3 Main Dam

(a)	Type	Homogeneous earthfill
(b)	Crest elevation	El. 42.5 m
(c)	Dam height above riverbed	14.5 m
(d)	Crest length	3,820 m
(e)	Crest width	8.0 m
(f)	Slope, upstream	1 : 2.6
	downstream	1 : 2.4
(g)	Embankment volume;	
	Earthfill, including blanket	2,605,000 m^3
	Filter	213,000 m^3
	Rock riprap	154,000 m^3

1.4 Saddle Dam

(a)	Type	Homogeneous earthfill
(b)	Crest elevation	El. 42.5 m
(c)	Dam height above original ground surface	7.5 m
(d)	Crest length	2,250 m
(e)	Crest width	8.0 m
(f)	Slope, upstream	1 : 2.6
	downstream	1 : 2.4
(g)	Embankment volume;	
	Earthfill	215,000 m^3
	Filter	53,000 m^3
	Rock riprap	31,000 m^3

1.5 Spillway

(a)	Type	Non-gated side channel weir
(b)	Overflow weir crest elevation	El. 39.5 m
(c)	Overflow weir width	70.0 m
(d)	Length of chuteway, including stilling basin	90.0 m

2. WATER CONVEYANCE SYSTEM

		First Phase	Second Phase
2.1	Intake		
(a)	Location	Khlong Luang Dam	
(b)	Design discharge	15.3 m^3/min	15.3 m^3/min
(c)	Type of pump	Horizontal double suction volute pump	
(d)	Pump capacity	110 kW/unit	110 kW/unit
(e)	Number of unit	2	1
(f)	Floor area of pump station	15.3 m^2	
2.2	Pipeline		
(a)	Type of pipe	Coating steel pipe	
(b)	Inside diameter of pipe	ø600 mm	ø600 mm
(c)	Number of row	1	1
(d)	Length of pipeline	56 km	56 km

	First Phase	Second Phase
2.3 Booster Pump Station No.1		
(a) Location	Ban Suan Phak	
(b) Design discharge	14.5 m^3/min	14.5 m^3/min
(c) Type of pump	Horizontal double suction volute pump	
(d) Pump capacity	190 kW/unit	190 kW/unit
(e) Number of unit	2	1
(f) Floor area pump station	162.5 m^2	
2.4 Booster Pump Station No.2		
(a) Location	Ban Yat Noen	
(b) Design discharge	13.6 m^3/min	13.6 m^3/min
(c) Type of pump	Horizontal double suction volute pump	
(d) Pump capacity	160 kW/unit	160 kW/unit
(e) Number of unit	2	1
(f) Floor area of pump station	162.5 m^2	
2.5 Raw Water Basin No.1		
(a) Location	Ban Yat Noen	
(b) Storage capacity	180 m^3	
2.6 Raw Water Basin No.2		
(a) Location	Khao Choeng Thian	
(b) Storage capacity	4,200 m^3	

3. IRRIGATION AND DRAINAGE SYSTEM

	North Area	South Area
3.1 Net Irrigation Area	3,100 ha	3,500 ha
3.2 Intake		
(a) Location	Khlong Luang Reservoir	
(b) Design discharge	4.81 m^3/s	5.94 m^3/s
(c) Diameter of outlet conduit	ø2,000 mm	ø2,000 mm
(d) Length of outlet conduit	54.0 m	300.0 m
(e) Intake gate (BxH)	2.0m x 2.0m	2.0m x 2.0m

		North Area	South Area
3.3	Main Canals		
	(a) Type of canal	Trapezoidal, lined with concrete	
	(b) Side slope	1 : 1.5	
	(c) Effective width of inspection road	5.0 m	
	(d) Length	31.1 km	21.8 km
3.4	Lateral and Sub-Lateral Canals		
	(a) Type of canal	Trapezoidal, unlined	
	(b) Side slope	1 : 1.5	
	(c) Effective width of inspection road	3.0 m	
	(d) Total length	15.0 km	19.0 km
3.5	Canal Structures	158 nos.	241 nos.
3.6	Drainage		
	(a) New drains	27 km	
	(b) Improved drains	10 km	
	(c) Structures	45 nos.	

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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 = second
- min = minute
- h = hour
- d = day
- yr = year

(6) Money
- ฿ = Baht (unit of Thai currency US$ 1 = ฿ 23.0)
- $ = US dollar
- ¥ = Japanese Yen

(7) Electric Measures
- kV = kilovolt
- kW = kilowatt
- MW = megawatt = 1,000 kW
- kWh = kilowatt hour
- kVA = kilovolt Ampere

(8) Other Measures
- mmho = micromho = conductance
- ppm = parts per million
- ppb = parts per billion
- % = per cent
- LCD = litre per capita per day
- PS = 0.736 kW
- pH = scale for acidity
- ° = degree
- ' = minute
- " = second
- °C = degree centigrade
- 10^3 = thousand
- 10^6 = million
- 10^9 = billion (milliard)

(9) Derived Measures Based on the Same Symbols
- m^3/s = cubic metre per second
- ton/ha = ton per hectare
- $10^6 m^3/yr$, MCM/yr = million cubic meter per year

B. OTHER ABBREVIATIONS

- GDP = gross domestic product
- GRP = gross regional product
- El. = elevation
- HWS = high water surface
- SD = sanitary district
- DA = development area
- ESS = Eastern Seaboard Study
- FOB = free on board
- CIF = cost, insurance and freight
- WHO = World Health Organization

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 Industry
DMR	Department of Mineral Resources
DIW	Department of Industrial Works
MOC	Ministry of Communications
HD	Harbor Deparment
DHW	Department of Highways
DOH	Department of Health
RTN	Royal Thai Navy
PWWA	Public Water Works Authority
MD	Meteorology Department
DOLA	Department of Local Administration
TAT	Tourism Authority of Thailand

D. LOCAL TERMS

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

1. INTRODUCTION

1.1 Authority

The Feasibility Study on East Coast Water Resources Development Project, Phase II (the Study) was carried out in accordance with Implementation Arrangement, Technical Cooperation for Feasibility Study on East Coast Water Resources Development Project (Phase II), Khlong Luang, Khlong Yai and Khlong Thap Ma Dam (the Implementation Arrangement), which was concluded in the date of February 22, 1982 between Japan International Cooperation Agency (JICA), an executive agency of the Government of Japan and Royal Irrigation Department (RID), Ministry of Agriculture and Cooperatives, an executive agency of the Government of Kingdom of Thailand. The objective area of the Study (the Study Area) extends over Chon Buri and Rayong Provinces, excluding the Prasae river basin.

The JICA entrusted the Study to Nippon Koei Co., Ltd., associated with Nikken Consultant Inc. (the Study Team).

The Study Team conducted the field investigation and study during the period from July, 1982 to July, 1983 with the counterpart support provided by the Government of Kingdom of Thailand (the Government). This report is one of draft final report and presents the findings and recommendations on the Khlong Luang Dam Scheme.

1.2 Historical Background

Thailand is embarking in a new era of industrialization with enforcement of the Fifth National Economic and Social Development Plan (the Fifth National Plan), which covers a 5-year period from 1982 to 1986. The Fifth National Plan places a great emphasis on Eastern Seaboard Development as the keystone of industrialization. It involves not only industrial development but also urban development and associated infrastructural development. The agricultural development is also given high priority in the Fifth National Plan. So far as the Study Area is concerned, the agricultural development deserves particular attention.

It must be promoted positively in the backward area of the industrial development areas so as to create the balanced socio-economic situation throughout the Study Area.

In order to cope with the rapidly increasing water demand due to the above-mentioned development activities, the Government launched the East Coast Water Resources Development Project (the Phase I Study), objective of which was to conduct the feasibility study of Nong Pla Lai and Ban Bung Dams. The Phase I Study was carried out by JICA in compliance with request made by the Government during the period from February, 1981 to March, 1982.

The NESDB conducted Eastern Seaboard Study (the ESS) and issued an Interim Report in July, 1982. The report contains a comprehensive study relevant to Eastern Seaboard Development, including economic, infrastructural, social and urban development programme, implementation, finance and impact of development.

The Government further requested the Government of Japan to extend the technical cooperation on the Study in September, 1981. The Government of Japan decided to provide the necessary technical cooperation and entrusted its execution to JICA. The JICA dispatched a Preliminary Survey Team to Thailand during the period from February 9 to 23, 1982 to finalize the technical cooperation and concluded the Implementation Arrangement with RID as aforementioned.

1.3 Scope of Study

The Study is to conduct the feasibility study on the water resources development of the Khlong Luang river and Rayong river, especially centering the construction of dams, namely Khlong Luang, Khlong Yai and Khlong Thap Ma dams. The Scope of Work contains two studying subjects as follows;

Part A: Study for the long-term water demand and supply balance in the Study Area.

Part B: Feasibility study for Khlong Luang, Khlong Yai and Khlong Thap Ma Dams.

For the purpose of the Study, target years have been set forth; 1991 as intermediate target year and 2001 as final target year.

The study for the long-term water demand and supply balance has been completed already during the field investigation period and "Study Report on Long-Term Water Supply Plan" was issued in January, 1983. The report points out clearly the significance of development of Khlong Luang Dam Scheme (the Scheme). The Scheme is distinguished as multiple-purpose areal-development project, since it is designed as an element in regional plan. The feasibility study of the Scheme deals with;

(1) Khlong Luang multiple-purpose dam development,

(2) Irrigation and agricultural development,

(3) Raw water conveyance system development, and

(4) Flood mitigation plan

2. BACKGROUND

2.1 Socio-Economy of Thailand

2.1.1 Land and Population

The territory of Thailand is approximately 514 x 10^3 km^2, being located between 5°20' and 20°40' north in latitude and between 97°20' and 105°40' east in longitude. Administratively the country is divided into 72 provinces. Each province is further divided into more or less 10 districts. Each district is further subsegmented into several townships which are composed of a number of villages. Map of Thailand is shown in Fig. 1.

Thailand lies in tropical monsoon zone and is blessed with fairly rich land and water resources. Approximately 177 x 10^3 km^2, corresponding to 34 % of the nation's land, are used for agricultural purpose, of which about 118 km^2 are paddy fields.

The national population was 44.3 x 10^6 in 1980, of which 4.7 x 10^6 people reside in Bangkok Metoropolis. The population density in 1980 was 86.3 persons per km^2 on the average, ranging from 52.7 in North Region to 137.5 in Central Region. The population growth was 2.6 % per annum during a 10-year period from 1970 to 1980.

2.1.2 Economic Performance

The economy of Thailand has achieved a continuous expansion, through its five-year national development plans, of which the period is 1962 - 1966 for the first plan, 1967 - 1971 for the second plan, 1972 - 1976 for the third plan and 1977 - 1981 for the fourth plan, respectively. The GDP increased from ฿ 140 x 10^9 in 1971 to ฿ 315 x 10^9 in 1981 at 1972 constant price, or from ฿ 3,602 per capita to ฿ 6,636 per capita. The average growth rate was 9.5 % per annum in 1971 - 1976 and 7.4 % per annum in 1977 - 1981.

The 1981 GDP is composed of ฿ 151 x 10^9 in service sector, ฿ 88 x 10^9 in manufacturing sector and ฿ 76 x 10^9 in agricultural sector. The share of the manufacturing sector increased from 16 % in 1971 to 21 % in 1981, while that of the agricultural sector declined from 28 % to 24 %.

The export of goods and services increased sharply from ฿ 17 x 10^9 in 1971 to ฿ 153 x 10^9 in 1981, while the import of goods and services also increased from ฿ 27 x 10^9 in 1971 to ฿ 217 x 10^9 in 1981. The most dominant export and import commodities are rice and petroleum, respectively. Rice export was 3,036 x 10^3 tons in 1981 and earned ฿ 26 x 10^9, corresponding to 17 % of the total export value. The import of petroleum and lubricant amounted to ฿ 65 x 10^9 in 1981, which nearly coincides with the deficit in the foreign trade.

The socio-economy of Thailand is reported in more detail in Sectoral Report I, Socio-Economy.

2.2 The Fifth National Plan

The Government issued in October, 1981, the Fifth National Plan, which was established reflecting the performance in the preceding national plans during the last two decades. The Fifth National Plan contemplates to accomplish the following national policy objectives;

(1) To restore the nation's economic and financial stability by mobilizing more saving and building up the national and economic discipline in both the public and private sectors.

(2) To adjust the economic structure and to improve the economic efficiency in order to magnify the economic activities in the rural area, to earn more foreign exchange with expansion of export and to be consistent with the world's economic changes.

(3) To develop the social structure and to improve the social services such as education, health, justice and other basic needs in the rural area.

(4) To alleviate poverty in backward area.

(5) To coordinate consistently economic development activities with the national security management.

The economic target of the Fifth National Plan is presented in Table 1 in comparison with that of the Fourth National Plan.

More detailed explanation on the Fifth National Plan is presented in Sectoral Report I, Socio-Economy.

2.3 Eastern Seaboard Development

The Fifth National Plan sets forth the following policy measures with respect to industrial activity:

(1) To switch from import substitution to exports.
(2) To decentralize the industrial activities to the provincial areas.
(3) To develop the basic industry, practically based on natural gas.
(4) To develop labour intensive industry and technology in export industry.

The Fifth National Plan sets forth the following targets for industrial activities:

	Description	Average Growth Rate (%/yr)
(1)	Manufacturing output	7.6
	Export industry	15.0
	Domestic consumption	5 - 6
(2)	Employment increase	7.6
(3)	Consumption of petroleum product (max. level)	4.0

The Eastern Seaboard Development will make a great contribution to the national policy objectives. Firstly, it will spearhead to change the industrial structure from import substitution to exports, based on local resources, particularly on a natural gas. Secondly it will become a major employment generator in North and East Regions. Thirdly, in the long term, it will serve decentralization of economic and industrial activities from Central Region.

The ESS proposes seven strategic development areas in the eastern seaboard; Chon Buri, Si Racha-Laem Chabang, Pattaya, Sattahip, Map Ta Phut-Rayong, Chachoengsao and Ban Phe. Out of these, Chachoengsao and Ban Phe are located outside the Study Area. Fig. 2 shows the map of the Study Area, including the development areas.

Six industrial development zones have been designated by the ESS as tabulated hereunder together with development area and plan.

Proposed Zone	Area (ha)	Proposed Industrial Development
Chon Buri	160	Urban service industries
Laem Chabang	480	Export processing and light industry
Sattahip	40	Ship repairs and services and transhipment
Map Ta Phut	800	Heavy industry, polluting industry and construction materials
Rayong	80	Agro-industry
Chachoengsao	80	Agro-industry

The development of infrastructures is an integral part of industrialization. The infrastructure development plan has also been worked out by the ESS as presented in Table 2.

The Eastern Seaboard Development will certainly create additional employments and induce migrants from the outside of the Eastern Seaboard. The additional employments and induced population have been projected to be 130,200 and 201,550, respectively, by the ESS for a 20-year period from 1981 to 2001. The ESS predicts that approximately 71 % of the additional employment occurs in three development areas, Si Racha-Laem Chabang, Pattaya and Rayong-Map Ta Phut.

2.4 Agricultural Development

The agriculture still plays an important role in the economy of Thailand. It sustains the self-sufficiency of staple food and the employment absorption. It also makes a great contribution to foreign trade; share of agricultural products accounts for 52 % of the total export value in 1980. Major crops are rice, rubber, maize and cassava.

The agricultural development during the last two decades was characterized by diversification of crops and expansion of cultivation area. During a 10-year period from 1972 to 1981, planted areas were expanded year after year with a considerably high rate; 15.3 % per annum for upland crops, 40.0 % per annum for oil crops, 16.2 % per annum for perennial crops and 3.4 % per annum for paddy. The increase in production was mainly resulted from such rapid expansion of planted areas. However, an increase in crop yield remained as low as 2.0 % per annum on an overall average during the Fourth National Plan.

The Fifth National Plan puts forward the following targets and supporting policy measures, in order to achieve the short-run objectives of a rapid economic recovery and a greater degree of economic stability:

(1) To attain the target of about 7 % increase in GDP, the value in agricultural sector is projected as,

(a) overall target: annual increase by 4.5%
(b) crop production: annual increase by 4.7%
(c) livestock production: annual increase by 4.2%
(d) fisheries production: annual increase by 5.4%
(e) forestry production : annual increase by 0.3%.

(2) More emphasis will be placed on the conservation of forest and watershed. The forests and national park, totalling about 10.4×10^6 ha, should carefully be conserved by proper rehabilitation works and the reafforestation should be implemented at a rate of about 48,000 ha per annum. Hence, expansion of farmland will be limited over the 5-year period. In this context, the strategy of agricultural development has to emphasize structural improvement within the sector.

(3) In order to raise productivity of agriculture, the priority is given to development of irrigation system and expansion of on-farm facilities as well as water resources development. An emphasis will be placed on soil improvement and strengthening the agricultural support services.

Sectoral Report I, Socio-Economy presents in more detail the issues and policy measures of agricultural development in Thailand.

2.5 Pipe-Water Supply Services

The pipe-water supply services are mainly administerd by MWWA and PWWA. The MWWA is responsible solely for Bangkok Metropolis and the PWWA assumes a direct responsibility for 117 townships, 707 sanitary districts and 2,000 villages throughout the country.

The PWWA has been endeavouring to expand the pipe-water supply services along its two basic programmes; large scale water supply programme and rural water supply programme. The former focuses on the municipalities and sanitary districts with more than 5,000 population and is executed under full responsibility of PWWA. The latter is promoted for sanitary districts and rural communities with 1,500 - 5,000 population and is mainly implemented by the local administrative authorities under financial and technical assistance from PWWA, OARD and DMR.

According to the information obtained from PWWA, the pipe-water supply situation in 1982 are as follows.

Water Supply Programme	Nos. of Supply System (nos)	Water Supply Capacity (10^3 m^3/day)	Served Population (10^6)
Large Scale	169	849	3.7
Rural	663	378	2.1
Total	832	1,227	5.8

As is clear from the above table, the pipe-water served population is only 13 % of the national population. The water supply per capita is 210 l/day on the average.

In line with the policy measures set forth in the Fifth National Plan, the PWWA established its Five-Year Plan. It stipulates the following basic objectives;

(1) The water supply capacity in the urban area will be augmented from 849 x 10^3 m^3 per day in 1981 to 1,414 x 10^3 m^3 per day in 1986. Pipe-water supply population will be 4.4 x 10^6 m^3 in 1986.

(2) The rural water supply programme will also be emphasized in order to alleviate a gap in standard of living between the urban area and the rural area. The objective is to develop and expand the water supply system for 150 communities and to construct the new water supply system for 250 communities. These will bring about an additional water supply capacity of 35 x 10^6 m^3 per annum.

According to the Five-Year Plan of PWWA, the total investment cost is estimated at ฿ 7,665 x 10^6, comprising ฿ 1,577 x 10^6 for the rural water supply programme and ฿ 6,088 x 10^6 for the large scale water supply programme.

2.6 Long-Term Water Supply Plan

2.6.1 General

In order to meet the rapidly increasing water demand due to industrial and urban development and agricultural development, long-term water supply plan has been worked out for the Study Area as one of the objectives of the present study. The proposed development plan is reported in Study Report on Long-Term Water Supply Plan. Herein contained are the outline of the plan.

The long-term water supply plan is, in principle, formulated aiming at satisfying all the water demands in the Study Area in Target Year 2001. The Target Year is determined in due consideration of periods of the national five-year development plans and development period of Eastern Seaboard Development.

Pursuant to principle of water resources management, the Study Area is basically divided into 10 zones as shown in Fig. 2. Each zone consists of a single river basin or a couple of river basins. The water supply plan over the Study Area is formulated primarily based on the result of water demand and supply balance of the respective zone.

It should, however, be kept in mind that the water supply plan presented in this report is a little different from that originally proposed in the Study Report on Long-Term Water Supply or other relevant sectoral reports. The water diversion from New Ban Bung dam, which was an integral part of the original plan, has been cancelled in due consideration of the RID's policy amendment. In the revised plan, corresponding amount of water is supplied from the Bang Phra dam by means of reduction of a rate of river maintenance flow. The reduction of the river maintenance flow is judged allowable for the following reasons.

(1) The Bang Phra dam is located only at 2.5 km distance to estuary. There is neither intake nor water user inbetween the dam and the river mouth.

(2) The Bang Phra dam has never been releasing regularly the water to the downstream for unspecified use, according to its operation record. The unspecified release is rarely possible, since the Bang Phra reservoir is 2.4 times bigger than the average annual inflow.

(3) Under the present reservoir operation practices, any particular adverse effect on aquatic ecology has not been identified.

(4) The river maintenance flow is still sustained at a rate of 1.1×10^6 m^3 per year. The aquatic ecology and riparian lands would, therefore, be preserved at the same status as the present.

The water demand and supply balance and alignment of raw water conveyance systems have been adjusted accordingly in this report.

2.6.2 Water Demand

The water demand comprises the domestic use, industrial use and irrigation use. In addition, a concept of river maintenance flow is introduced. The projection of the water demand is discussed in detail in Sectoral Report IV, Domestic and Industrial Water Demand, and III, Irrigation Development Plan.

(1) Domestic Water Demand

In compliance with the pipe-water supply programme set forth in the Five-Year Plan of PWWA, each zone is classified into urban area and rural area. The urban area is defined as municipality/ sanitary district with more than 5,000 population by Target Year 2001 and is further classified into development area and non-development area in accordance with Eastern Seaboard Development Plan.

The domestic water demand is projected based on the projected population, water consumption per capita and service factor for every 5-year period, namely, 1986, 1991, 1996 and 2001. The projected population and domestic water demand are shown in Table 3.

(2) Industrial Water Demand

The industrial water demand has been projected by ESS in line with the industrial development plan described in the preceding Section 2.3. The industrial water demand projected by ESS accrues only from the development areas.

Presently several enterprises are extracting groundwater or water from reservoirs by their own facilities. For enterprises located outside the development area, the same quantity of water as being consumed needs to be guaranteed. This water supply was carefully investigated and is added to the industrial water demand

projected by ESS to produce the real industrial water demand. The estimated industrial water demand is presented in Table 4.

(3) Irrigation Water Demand

In the Study Area, there are two major irrigation areas at present. They are Bang Phra irrigation area with a net irrigation area of 1,120 ha in Zone 2 and Ban Khai irrigation area with 4,800 ha in Zone 10.

In addition, three irrigation development schemes are envisaged to be newly realized in association with development plan of Khlong Luang, Khlong Yai and Khlong Thap Ma dams. The irrigation area of the respective scheme is tentatively determined based on the preliminary water balance study. The development programme was set up in conjunction with water resources development requirement for the domestic and industrial water supply.

The irrigation water requirement is estimated based on the provisional cropping pattern with 150 % of cropping intensity and approximated irrigation area. The irrigation area and water requirement applied for water balance study are given below,

Irrigation Scheme	Irrigation Area (ha)	Irrigation Water Requirement (10^6 m^3/yr)			
		1986	1991	1996	2001
Khlong Luang	4,700	0	60.1	60.1	60.1
Bang Phra	1,120	15.4	15.4	15.4	15.4
Ban Khai	4,800	65.8	65.8	65.8	65.8
Ban Khai Extension	5,400	75.1	75.1	75.1	75.1
Thap Ma	2,200	0	0	30.6	30.6
Total	18,220	156.3	216.4	247.0	247.0

It should be noted that the above agricultural development plan is provisional. They will finally be determined through optimization study of the agricultural land and water resources development of the respective development shceme.

(4) River Maintenance Flow

The reduction of river flow due to intensified water use will result in adverse effect to various water users, if it exceeds a certain amount. It is therefore proposed to introduce the concept of the river maintenance flow. The river maintenance flow is the minimum discharge which is able to maintain water depth, flow velocity, water quality, channel stability, aquatic ecosystem and scenery to the extent necessary for navigation, fish catch, operation and maintenance of intakes, maintenance of river facilities, sea water repulsion, prevention of estuary clogging, conservation of groundwater, preservation of riparian land and people's amenity.

In the Study, in principle, the rate of the river maintenance flow is tentatively assessed to be equal to 90 % dependable monthly run-off at balance point. The river maintenance flow thus assessed is shown in Table 5.

(5) Overall Water Demand

The overall water demand of the respective zone is presented in Tables 6 through 9. The followings are the overall water demand expressed in terms of source water demand for the whole Study Area.

(Unit: 10^6 m^3/yr)

Water Demand	1986	1991	1996	2001
Domestic	33.1	45.4	66.7	91.5
Industrial	56.6	71.2	77.4	88.5
Irrigation	156.3	216.4	247.0	247.0
River maintenance flow	21.0	21.0	31.5	31.5
Total	267.0	354.0	422.6	458.5

2.6.3 Water Resources Development Potentials

As varified in the succeeding sub-section 2.6.4, under the present water resources development conditions, water shortage of about 57 x 10^6 m^3 is foreseen to occur in Target Year 2001. A new water resources development plan is indispensable to satisfy the whole water demand for the successful implementation of Eastern Seaboard Development and agricultural development.

The water resources development potentials in the Study Area are studied primarily based on the data and information so far collected by RID as reported in detail in Sectoral Report XI, Water Resources Engineering.

As listed hereunder, there are 8 dams either existing or under construction or under planning as shown in Fig. 2 and Table 10.

Out of dams in operation, both the Phluta Luang and Khlong Bang Phai dams are used exclusively for Sattahip Naval Base. Thus they are not taken into consideration in the formulation of the long-term water supply plan.

Six dams, Bang Phra, Map Prachan, Dok Krai, Nong Kho, New Ban Bung and Nong Pla Lai dams have the active storage capacity of 339.7 x 10^6 m^3 in total and produce the net regulated outflow of 227.5 x 10^6 m^3 per year in such drought year as 1979.

There have been identified 9 potential damsites, including Khlong Luang, Khlong Thap Ma and Khlong Yai damsites, in the Study Area. Out of these, five damsites are located in small rivers in the coastal area as shown in Fig. 2. It is foreseeable that the anticipated water shortage will be met by development of several dams among the potential damsites.

Water supply capacity of the respective potential damsite is obtained based on storage-draft relationships of Khlong Luang, Dok Krai, Nong Pla Lai and Khlong Yai damsites, where streamflow observation records are available for a 14-year period from April, 1968 to March, 1982. The said storage-draft relationships are shown in Fig. 3. A relationship between storage ratio and unit development cost of water is then developed for the respective potential damsite as shown in Fig. 4.

The relationships shown in Fig. 4 expresses two elements. Firstly, Khlong Luang, Khlong Yai and Khlong Thap Ma damsites are incomparably superior to the other potential damsites in terms of unit development cost of water. Secondly development scale is the most economical within a range of 80 - 100 % in terms of storage ratio. For the purpose of water balance study, development scale is tentatively determined to be 100 % in terms of the storage ratio for Khlong Luang, Khlong Yai and Khlong Thap Ma damsites and 80 % for the remaining 6 pontential damsites. Table 11 shows the salient features and water supply capacity of the respective potential dams at the pre-determined development scale.

2.6.4 Water Balance

The water balance study was performed in order to determine the water resources development requirement as reported in detail in Sectoral Report X, Water Balance Study.

The representative river is selected in each zone, in which a balance point is located for the water balance study. The balance point is, in principle, set up at the lowest intake site. The representative river and balance point of the respective zone are as shown in Table 5.

The water demand and supply balance was calculated zone by zone at intervals of 10-day period during a 12-month period from May, 1979 to April, 1980, which is the driest year among a 14-year period from 1968 to 1981.

At first water withdrawal was computed as the water demand deducted by the available local water resources. The water withdrawal means the net reduction in river flow which is required to meet the water demand. The water deficit is then calculated as the water withdrawal less the natural run-off at the balance point under the following presumptions.

(a) The Dok Krai Pipeline Project fully supplies the water withdrawals in Zones 7 through 9.

(b) As to Zone 2, natural run-off of the representative river is negligibly small compared to the domestic and industrial water demand. Therefore the whole domestic and industrial water demand is determined to be met by inter-zone water diversion.

The water demand and supply balance was initially calculated under the present water resources development condition. The Nong Kho and Nong Pla Lai dams are treated as existing one. The result is given hereunder.

(Unit: 10^6 m^3/yr)

Year	Water Demand	Water Withdrawal	Water Deficit	Supply by Dams	Balance
1986	267.0	264.9	214.0	218.0	-4.0
1991	354.0	351.9	283.1	218.0	+65.1
1996	422.6	420.5	335.3	218.0	+117.3
2001	458.5	456.4	367.5	218.0	+149.5

As shown in the above, the water supply as a whole is short of the demand. The water demand and supply balance situation varies largely from zone to zone, depending on the magnitude of water demand and the availability of water resources. The integrated development of water resources and inter-zone water diversion system is ascertained to be most appropriate measure to overcome the shortage of water supply.

A set of four water supply alternatives were drawn up for Target Year 2001 to ascertain the most optimal plan. The water demand and supply balance was further computed for the respective water supply alternative. The water demand and supply balance under the proposed water supply plan is given in Tables 6 to 9 and is summarized below.

(Unit: 10^6 m^3/yr)

Year	Water Demand	Water Withdrawal	Water Deficit	Supply by Dams	Balance
1986	267.0	264.9	214.0	227.5	-13.5
1991	354.0	351.9	306.2	369.7	-63.5
1996	422.6	420.5	371.5	411.0	-39.5
2001	458.5	456.4	404.0	411.0	-7.0

The water balances for the intermediate years are calculated referring to the development sequence of the proposed water supply plan.

2.6.5 Proposed Long-Term Water Supply Plan

All the water supply alternatives were examined in detail from the viewpoint of investment requirement, technical soundness and social problems. As the results, the water supply plan shown in Figs. 5 to 8 is determined to be most promissing plan. The fundamentals of the proposed water supply plan for Target Year 2001 are as follows;

(1) Development of water resources facilities
Khlong Luang, New Ban Bung, Khlong Thap Ma and Khlong Yai dams

(2) Development of water conveyance systems
Khlong Luang, Ban Bung, Nongkho, Nong Pla Lai, Bang Lamung, Huai Yai, Dok Krai and Ban Khai systems

(3) Water diversion from the inland area to the coastal area
Khlong Luang river basin to Chon Buri Pattaya area: 11.0 x $10^6 m^3/yr$
Rayong river basin to Chon Buri-Pattaya area: 31.3 x $10^6 m^3/yr$
Rayong river basin to Sattahip-Map Ta Phut area: 54.8 x $10^6 m^3/yr$.

Water demand and supply balance until the target year 2001 is shown in Fig. 9.

Investment requirement for the proposed water supply plan is roughly estimated to be ฿ 8,827 x 10^6, consisting of ฿ 3,602 x 10^6 for water resources development, ฿ 4,205 x 10^6 for water conveyance system and ฿ 1,020 x 10^6 for irrigation development.

3. KHLONG LUANG RIVER BASIN

3.1 Natural Conditions

3.1.1 Location and Topography

The Khlong Luang river basin is located in the northern part of the Study Area and extends over approximately 1,930 km^2. It is bounded on the north with the Bang Pakong river basin, on the south with the Rayong river basin and on the east with the Prasae river basin. The basin map is shown in Fig. 10.

The Khlong Luang river is a tributary of the Bang Pakong river, which pours itself into the Gulf of Thailand immediately downstream from the confluence with the Khlong Luang river. It originates in Mt. Khao Ang Kraden (El. 338 m) and has a total length of about 90 km.

The Khlong Luang river basin embraces vast and flat alluvial plains, which occupy approximately 40 % of the basin area. The alluvial plains have a slope of more or less one per cent and have been used for agriculture extensively. Owing to its excessively gentle land slope, the alluvial plains are subject to poor drainability and are prone to inundation annually to a great extent. The ground height is for the most parts lower than El. 100 m.

3.1.2 Climate

Details of climate over the Study Area are reported in Sectoral Report VII, Meteorology and Hydrology.

The climate over the Khlong Luang river basin is tropical and monsoonal. There are two distinct seasons in a year. Dry season with the northeast monsoon lasts from November to April, while the wet season with the southwest monsoon extends from May to October. The climatological data at Chon Buri, Sattahip and Ban Nong Mapring stations are presented in Table 12.

Air temperature varies only slightly from the annual average of 29°C. The average annual basin rainfall is approximately 1,300 mm, of which more than 80 % occurs during the wet season. The relative humidity is almost constant throughout the year, 93 % on the average.

3.1.3 Hydrology

The stream flow of the Khlong Luang river has been recorded at Ban Mai stream gauge, which is located at 500 m downstream from the proposed Khlong Luang damsite. There is no other stream gauge in the basin. The drainage area of the Khlong Luang river is 484 km^2 at the stream gauge. The catchment area of the proposed damsite is 525 km^2, including the Huai Sung river basin.

The run-offs at the proposed damsite were estimated at 10-day intervals for a 14-year period from April, 1968 to March, 1982. Table 13 shows the monthly mean run-offs at the damsite. The average annual run-off is 3.98 m^3/s, ranging from 1.04 m^3/s in 1979 to 8.30 m^3/s in 1974.

The flood analysis was made by means of unit hydrograph method. The synthesized probable floods at the damsite are as follows:

Return Period (year)	Peak Discharge (m^3/s)
10	860
50	1,100
100	1,220
500	1,460
Probable Max.	2,520

The sediment yield from the basin area is evaluated to be 300 $m^3/km^2/year$.

The run-off and flood analyses and sediment transport are discussed in detail in Sectoral Report VII, Meteorology and Hydrology.

3.1.4 Groundwater

The reconnaissance survey on groundwater resources was carried out as explained in Sectoral Report IX, Groundwater Resources.

Local phreatic aquifers are found in flood plains, which consists of silty sand, sandy clay and rare gravelly sand layers. The aquifers are recharged by rivers and paddy fields. Remarkable descent of groundwater level in the aquifers takes place during the dry season. The aquifers are encountered with salt water intrusion; chloride content in groundwater amounting to 600 ppm in and around Phanat Nikhom.

Regional confined or unconfined aquifers are ascertained to be existent to a very small extent, due to high clay content and resultant low permeability and also low storage capacity in the terrace deposits. The groundwater in the terrace deposits appears to be recharged by vertical infiltration of rainfalls.

According to the inventory and sampling surveys, approximately 80 % of rural population are dependent on shallow dug-wells for their domestic water. The annual groundwater abstraction through the shallow dug-wells are roughly estimated at 6.8×10^6 m^3, all of which is presumed to be domestic use. There are two tube-wells in the basin at present. They produce 0.3×10^6 m^3 of groundwater annually, of which 90 % are exclusive use for manufacturing.

The groundwater development potential is concluded to be quite low owing to the salt water intrusion deep into the alluvial plains and poor hydraulic characteristics of the terrace deposits.

3.1.5 Geology

In the Khlong Luang river basin basement rock is pre-Cambrian metamorphic rocks, comprising gneiss, gneissose granites, quartz-micaschists, phyllites, shales and quartzites. The basement rock is intruded with granite of Carboniferous to Triassic periods.

The metamorphic rocks are developed in the eastern part of the basin and exposed around the uppermost reaches of the river and the eastern watershed. The intrusive granites are located in the western part and crop out in the southern watershed.

Quarternary deposits of terrace and fan, as well as lateritic residual soil, cover the bedrock extensively in the upper half of the basin, while alluvial flood deposits and coastal sand are wide-spread in the lower half of the basin.

The Sectoral Report VIII, Geology discribes in more detail the geological condition of the basin and proposed damsites.

3.1.6 Soils

Soils and land capability explained herein are for the potential irrigable area, among which the irrigation service area of Khlong Luang dam will eventually be selected. Figs. 11 and 12 show detail soil map and land capability map respectively.

The soils in the potential irrigable area are classified into two soil groups; soils of recent alluvium and soils of semi-recent alluvium. They are divided into a number of soil series by LDD. Table 14 presents distribution of soils by soil series. The most predominant one is Chon Buri series which occupies 55 % of the whole potential irrigable area. Klaeng series covers 28 % of the area. The generalized brief descriptions on these soil series are as summarized below.

Chon Buri Series (Cb): The soils are derived from terrace sediments and mainly extend over the low marine terrace. They have, in general, very deep effective soil depth, loamy to sandy texture and mottled profile. pH value varies from 4 to neutral. Drainage condition is somewhat poor and permeability is moderate. The series are correlated with Low Humic Gley Soils (National) or Typic Paleaqualfs in USDA taxonomy.

Klaeng Series (Kl): They are derived from alluvium underlain by marine deposits and occupy the level terrain of the lower portion on the low terraces which mainly extend over the northwestern part of the potential irrigable area. The soils are deep in effective soil depth, fine to medium in texture and mottled throughout the profile and are strongly acid. Drainage conditions are externally and internally poor. The series are classified into Low Humic Gley soils (National) or Oxic Plinthaqualfs (USDA).

The land capability of the potential irrigable area is referred to Land Capability Map published by LDD and is presented in Fig. 12. According to the LDD's classification, land capability is broadly divided into two categories, namely, "Suitable" and "Not Suitable". A category of "Suitable" is further sub-divided into (1) Class I, highly suitable, (2) Class II, moderately suitable, (3) Class III, suitable and (4) Class IV, marginally suitable. Nearly 80 % of the potential irrigable area is ascertained to be Classes II and III.

3.2 Administrative Division and Population

The Khlong Luang river basin falls in with Chon Buri Province and includes 51 townships. Major town/city is Phanat Nikhom, Tha Bun Mi, Nong Tamlung and Ban Bung. The administrative divisions are shown in Fig. 10.

The total population in the basin is 291,100 in 1981, of which 88 % resides in rural area. The urban population is 32,200 in 1981; 13,500 in Phanat Nikhm, 4,900 in Tha Bun Mi, 9,800 in Nong Tamlung and 6,000 in Ban Bung.

3.3 Infrastructure

3.3.1 Transportation

The Khlong Luang river basin is served with well-developed road network systems. One primary, one inter-regional and 4 secondary national highways and 2 provincial highways run through the basin as shown in Fig. 10.

Phanat Nikom is connected with Chon Buri (capital city of Chon Buri Province) through Route 315 with a distance of about 30 km and then with Bangkok Metropolis through Route 3 or Route 34 with a distance of 80 km. The Route 3 links Chon Buri with the port city of Sattahip through the international tourism resort, Pattaya with a distance of 100 km. Route 331 passes through the center of the basin and interconnects with Route 344 and Route 3138. The former with a length of about 105 km runs between Chon Buri and Klaeng through Ban Bung and the latter connects Ban Bung with Rayong (capital city of Rayong Province) with a distance of about 90 km. The national and provincial highways are paved with asphalt.

Rural roads are spread over the basin area. Most of the rural roads are laterite-paved with two lanes.

3.3.2 Pipe-Water Supply

There are 2 large scale water works and 4 rural water works in the Khlong Luang river basin as listed below.

Types	Water Works	Plant Capacity (m^3/day)
Large Scale	Ban Bung	480
	Phanat Nikhom	2,160
Rural	Nong Kakha	240
	Phan Thong	720
	Tha Bun Mi	720
	Ban Soet	480
	Total	4,800

The pipe-water served population is roughly estimated at 19.5×10^3 in 1981, comprising 10.3×10^3 under large scale water works and 9.2×10^3 under rural water works. The pipe-water service factor is, therefore, approximately 7 %. Majority of people rely on groundwater and water vender for their domestic use. Per capita water supply is estimated to be about 120 l/day for 1981.

The Sectoral Report XII, Water Conveyance Engineering compiles more information and data on the pipe-water supply.

3.3.3 Irrigation and Drainage

The RID has been endeavoring to develop the irrigation systems and to improve the drainage condition. The following irrigation and drainage projects have been realized by RID in the basin, up to date.

(1) Bang Pakong Left Bank Flood Protection and Conservation Project

The project area is located along the left bank of the Bang Pakong river and extends over 10,400 ha, of which about 2,700 ha falls in with the Khlong Luang river basin. The purpose of the project is to protect the land from flood damages and to prevent the

salt water intrusion into the lands. The paddy cultivation is predominant in the project area at present under the rainfed condition.

(2) Tha Lat Irrigation Project

The project area extends over both the Bang Pakong and Khlong Luang basins with net irrigation area of 20,700 ha. The stream flow of the Tha Lat river is diverted at about 34 km upstream from the confluence with the Bang Pakong river to irrigate about 20,700 ha of land. Approximately 7,800 ha of the service area is located in the Khlong Luang river basin.

(3) Phan Thong Project and Phan Thong Extension Drainage and Conservation Project.

The project areas are located in the most downstream portion of the Khlong Luang river basin. The projects were implemented in order to improve the drainage condition in about 6,500 ha of lands and to prevent the saline water intrusion. Drainage channels have been constructed between the Khlong Soet river, Khlong Phan Thong river and the Bang Pakong river with a total length of 10.6 km. Tidal gates are installest at the downstream end.

The locations of the above-mentioned projects are shown in Fig. 13. The Sectoral Report III, Irrigation Development Plan displays more detailed descriptions.

3.3.4 Dams and Barrages

The surface water resources of the Khlong Luang river basin remains almost untapped. There has been developed only one dam, Ban Bung, in a small tributary of the Khlong Luang river. Its salient features are presented in Table 10. The Ban Bung dam is capable of producing the net regulating flow of 2.2×10^6 m^3/year with active storage capacity of 0.4×10^6 m^3. It devotes itself mainly to supplying water to manufacturing sector.

3.4 Regional Agriculture

3.4.1 Farm Population and Households

Agriculture over the proposed irrigation area of 6,600 ha is described herein. The Sectoral Report II, Agricultural Development Plan describes the regional agriculture over the Khlong Luang river basin.

The population and number of household in the proposed irrigation area are 13,368 and 2,140, respectively, according to the statistic data obtained from Agricultural Extension Office in Phanat Nikhom. The average family size is 6.2 persons.

The number of the farm household is estimated at 1,917 and the farm population at 7,800. Potential farm labor force is presumed to be 2 to 3 persons per farm household.

3.4.2 Land Holding and Land Tenure

The average land holding size is 4.1 ha, which is 0.8 ha smaller than that of the entire Chon Buri Province. According to the Agricultural Census Report, 1978, the households with land holding size of less than 1.0 ha account for 15 % of the total in Chon Buri Province. The households of 1.0 to 4.0 ha are most predominant, occupying about 43 % of the total.

Approximately 74 % of farms are owner operator and 13 % tenant in Chon Buri Province, according to the Agricultural Census Report, 1978. Approximately 75 % of the entire farm holding lands is occupied by the owner operators.

3.4.3 Land Use

The land use in the proposed irrigation area was ascertained by land use map in a scale of 1 to 250,000 and field survey. The land use map is shown in Fig. 14.

Although the proposed irrigation area is not provided with irrigation, rice is grown in 87 % of the area under rainfed condition. Approximately 1,000 ha of the area is used for cultivation of upland crops such as cassava, sugarcane, groundnuts, etc. Tree crops such as mangoo and banana are grown in about 630 ha of the area.

3.4.4 Cropping Pattern

The cropping pattern prevailing over the proposed irrigation area is shown in Fig. 15.

Rice is planted from the beginning of July to the middle of August and is harvested from the beginning of November to the middle of December. It is not cultivated during the dry season owing to lack of irrigation water supply.

Cassava is cultivated in rather limited area during the dry season. Planting extends over two and half months from the middle of October to the end of December and harvesting lasts also two and half months from the middle of August to the end of October.

The cropping intensity is 1.0 under the present condition.

Sugarcane is cultivated widely in the area. Planting of plant cane takes place during the period from the middle of December to the end of April. It is harvested during the period from the middle of December to the end of April.

3.4.5 Farming Practices

Various varieties of rice are cultivated in the proposed irrigation area, all of which are of non-glutinous type. The high yielding varieties have been spread over about 40 % of paddy cultivation area. Applications of fertilizers and agro-chemicals are rarely practiced. Transplanting and harvesting are done still manually. Harvested paddy is threshed mainly by means of trampling of buffaloes.

Cassava is mainly grown for industrial use. Native variety designated as "Rayong" is predominantly cultivated in the proposed irrigation area. Fertilizing is generally not carried out. Planting is made manually at a rate of one set per square meter; 10,000 sets per ha.

Sugarcane is planted with a spacing of 1.3 m by 0.3 m, 25,600 sets per ha. Earthing is done two times during the growing period; the first is one to one and a half month after planting and the second two to three months after planting. Ratooning is commonly practiced after harvesting with cutting the stubbles of harvested cane. Fertilizers are applied at a rate of 310 kg per ha of compound fertilizer (N:15 - P:15 - K:15).

3.4.6 Crop Yield and Production

Yields of crops remain low because of lack of irrigation water supply and less supply of agricultural requisite: Productions of crops vary from year to year, characterized by climatological conditions. Crop yield and production for 1981 are given below.

Crops	Average yield (kg/ha)	Production (tons)
Rice, local varieties	1.8	7,150
Rice, high yielding varieties	2.3	6,100
Cassava	16.0	6,400
Sugarcane	43.0	16,770
Groundnuts	1.3	100

3.5 Flood Problems

3.5.1 Flood Characteristics

The Khlong Luang river flows through broad alluvial plains subject to frequent overflow, in a reach between the proposed damsite and the estuary. The reach is characterized by flat bed slopes, meandering channels of very small flow capacity, and low banks. The reach is marked by the formation of numerous secondary channels. The average full of the reach is 0.4 m per kilometer.

Systematic stream gauging has been conducted only at Ban Main Stream gauge station located at 500 m down stream from the proposed damsite since 1967. According to the stream gauging records, the Khlong Luang river basin has been experiencing numerous floods over the years. The recent devastating floods were observed in 1974 and 1981.

The floods generally occur during the months of September and October, although it rarely happens in the months of August and November.

3.5.2 Channel Capacity

Critical channel capacities were analyzed for all river reaches pertinent to flood control study. Critical flows or bankful flows were computed by means of non-uniform flow formula based on the longitudinal profile and cross-sectional survey data along the main stem of the Khlong Luang river. Fig. 16 shows the critical channel capacities along the river stretch.

The average bankfull flow is 63 m^3/s for the lowest reach, 23 m^3/s for the middle reach and 60 m^3/s for the upper reach. The magnitude of the floods exceed far beyond the critical channel capacity, causing flood damage along the whole stretch.

3.5.3 Flood Magnitude and Frequency

In the basin, flood records are available for a short period at Ban Mai stream gauge. Thus flood run-off analysis was performed by means of flood run-off simulation model in order to reveal the magnitude of flood and establish a relationship among frequency, magnitude of flood and flood damage. The simulation model consists of three basic elements, i.e., (i) flood run-off calculation by sub-basin, (ii) channel routing calculation, and (iii) flood regulation by dam.

For the analysis, the Khlong Luang river basin is divided into 8 sub-basins as shown in Fig. 17. The main stem of the river is divided into 5 reaches. The simulation model is then formed as presented in Fig. 18.

The flood run-off of the respective sub-zone is synthesized by means of unit hydrograph method. The basin rainfall of the sub-zone is obtained based on a relationship between the point rainfall and the areal rainfall. A rate of direct flood run-off is estimated to be 55% based on the past flood run-off records.

The routing through river channel is computed by applying the storage function method.

The flood run-off at the upstream end of the respective reach was simulated by a combination of the flood run-off calculation and channel routing calculation. Flood frequency curve thus obtained is shown in Fig. 19.

The flood run-off analysis is discussed in Sectoral Report VII. Meteorology and Hydrology.

3.5.4 Flood Prone Area

Because of insufficient channel capacity, the lower Khlong Luang river basin has been sufferred from floodings. The flooding pose a severe hazard to the population and exert a negative effect on economic growth of the area.

In order to grasp the extent of flooding and the character of flood losses, the flood damage survey was carried out during the period from August to October, 1982 in collaboration with RID. The survey was dependent on a interview survey, which was conducted at 31 spots in the basin.

As the results, flood inundation area has been revealed for the 1974 and 1981 floods as shown in Figs. 20 and 21. The inundation area is estimated to be 58,300 ha for the 1974 flood and 44,400 ha for the 1981 flood. The 1974 and 1981 floods have recurrence intervals of 18.0 year and 3.6 year, respectively, according to the flood frequency curve at Ban Mai stream gauge.

The inundation areas are classified into four land use categories as shown below, according to the topographic map and land use map.

Land Use	Inundated Area (ha)	
	1974-flood	1981-flood
Paddy field	40,100	40,400
Uplands	2,100	1,700
Village area	1,700	1,500
Other lands	14,400	10,800
Total	58,300	44,400

The number of houses subject to flood damage is estimated at 17,360 for the 1974 flood and 15,350 for the 1981 flood.

3.5.5 Flood Damages

The flood damages in the basin have been broadly grouped into four categories, namely, (i) rice, (ii) upland crops, (iii) house and household effects and (iv) livestock. Other tangible losses such as impairment of public facilities and utilities and buiseness and financial losses are assumed to be 20 % of the damages of the above categories. Intangible losses are not taken into account.

The damage rate was determined for each damage category depending on the seasonal occurence and frequency of flooding and the characteristics of flooding such as depth and period. The damageable value is also determined for each category. The damageable values of rice and crop are based on their yields and prices prospected to 1990 and are estimated to be ฿ 13,760 per ha and ฿ 7,130 per ha respectively. The damageable values of house and household effects and livestock are estimated to be ฿ 39,600 per household and ฿ 7,390 per household respectively.

The flood damage was calculated based on the damageable value and damage rate for each damage category and flood damage curve is prepared for each river reach as shown in Fig. 22. The flood damages of the 1974 and 1981 are estimated for the whole river basin as shown below.

(Unit: ฿ 10^6)

Damage Categories	1974-flood	1981-flood
Rice	173.5	95.8
Upland crops	3.4	1.8
House and household effects	25.6	18.6
Livestock	109.5	75.1
Other tangible	62.4	38.3
Total	374.4	229.6

The average annual flood damage in the basin is estimated to be ฿ 123.4 x 10^6 based on the flood damage curves.

Thorough study on flood damage is compiled in the Sectoral Report XIII, Flood Mitigation Engineering.

4. LAND AND WATER RESOURCES DEVELOPMENT PLAN

4.1 Plan Formulation

4.1.1 Methodology

As is displayed in Section 2.6. The Khlong Luang Dam Scheme has a nature of multiple-purpose areal-development project and is the key-stone of the proposed water supply plan over the Study Area. It is designed to serve the domestic and industrial water supply for both the inside and outside of the Khlong Luang river basin, irrigation and flood control. Among the purposes, water supply and irrigation have priority over flood control. Therefore, plan formulation was initially directed to the land and water resources development.

The domestic and industrial water supply forms an integral part of the land and water resources development. The quantity of the domestic and industrial water supply are the same as estimated in Section 4.3. Therefore the optimum land and water resources development plan will be formulated dealing with three variables; extent of irrigation area, cropping intensity and development scale of dam.

In order to establish a relationship among the irrigation area, cropping intensity and reservoir active storage, a number of reservoir operation studies were conducted with the aid of a digital computer. Based on the relationship, various development alternatives were arbitrarily selected and their cost and benefit were estimated for economic comparative study. A development plan generating the maximum annual net benefit is selected as the optimum development plan.

The plan formulation on the land and water resources development is elaborated in Sectoral Report XI, Water Resources Engineering.

4.1.2 Reservoir Operation Study

The reservoir operation was simulated at intervals of 10-day period during a 14-year period from April, 1968 to March 1982. The release from reservoir comprises the domestic and industrial water supply, irrigation water supply and maintenance flow. The reservoir operation study follows the basic conditions set forth as below.

(1) In order to avoid a conflict between the water uses, the Khlong Luang dam assures completely all the water withdrawals dependent on it during the aforementioned 14-year period.

(2) The river maintenance flow is sustained throughout the year at a rate of 0.06 m^3/s as adopted in the formulation of the long-term water supply plan.

(3) The quantity of the domestic and water supply is 17.8 x 10^6 m^3 per year in Target Year 2001. It will be supplied at a constant rate of 0.56 m^3/s throughout the year.

The simulation of reservoir operation is presented in Fig. 23 for the optimum development plan. Based on the results of the reservoir operation study, the relationship between the irrigation area, cropping intensity and reservoir active storage capacity is developed as shown in Fig. 24. The cropping patterns and corresponding irrigation water requirements are compiled in Sectoral Report II, Agricultural Development Plan and Sectoral Report III, Irrigation Development Plan, respectively.

4.1.3 Development Alternatives

The relationship in Fig. 24 is carefully examined from the viewpoint of the land and water resources development and twelve development alternatives are arbitrarily established to sound their economic feasibility. The twelve alternatives are as under-listed.

Development Alternatives	D&I Water Supply (10^6 m^3/yr)	Cropping Intensity (%)	Net Irrigation Area (ha)	Reservoir Active Storage (10 m)
1-1	17.8	130	5,900	89
1-2	17.8	130	6,700	103
1-3	17.8	130	7,200	119
1-4	17.8	130	7,400	135
2-1	17.8	140	5,300	89
2-2	17.8	140	6,100	103
2-3	17.8	140	6,600	119
2-4	17.8	140	6,800	135
3-1	17.8	150	4,500	89
3-2	17.8	150	5,300	103
3-3	17.8	150	5,800	119
3-4	17.8	150	6,000	135

4.1.4 Economic Comparison

The project cost and benefit were calculated for the respective development alternatives as described hereunder.

(1) Project Cost

The construction costs of dam and irrigation facilities and water conveyance system were estimated based on the basic layout design and at the price level of 1982.

The project cost was converted into annual equivalent cost at a discount rate of 8 % per annum with economic life of 50 years. The annual O & M cost and replacement cost were also estimated.

(2) Project Benefit

The project benefit is derived from the domestic and industrial water supply and from the land development. Project benefit derived from every component is discussed in Chapter 8.

The domestic and industrial water supply benefit is estimated at ฿ 166.0 x 10^6 per annum.

The annual agriculture benefit is estimated to be ฿ 25,224/ha for cropping intensity 130 %, ฿ 27,358/ha for 140 % and ฿ 30,577/ha for 150 %.

The annual equivalent cost and benefit and OM & R costs are summarized in Table 15. The annual net benefit is defined as the annual benefit less the annual equivalent cost and OM & R cost. It is calculated for the respective development alternative as shown in Table 15 and is illustrated in Fig. 25.

As is evident in Table 15 and Fig. 25, the development alternative 2-3 generates the highest annual net benefit among the twelve alternatives compared. Therefore, the alternative 2-3 is recommended as an optimam plan for the land and water resources development.

4.2 Optimum Development Plan of Khlong Luang Dam Scheme

The plan formulation on the land and water resources development plan has clarified the optimum reservoir active storage, cropping intensity and irrigation area. Also the plan formulation on the flood mitigation plan has revealed the storage capacity requirement in the Khlong Luang reservoir for flood control. The development scale of Khlong Luang Dam Scheme is finally determined integrating the above study results as shown below.

(1) Multiple-Purpose Dam

Purpose	:	Domestic and industrial water supply, irrigation water supply and flood control
Reservoir	:	
Storage capacity		
Gross	:	169.1 x $10^6 m^3$
Surcharge	:	34.3 x $10^6 m^3$
Active	:	119.0 x $10^6 m^3$
Dead	:	15.8 x $10^6 m^3$
Flood water level	:	El. 40.5 m
High water level	:	El. 39.5 m
Low water level	:	El. 33.8 m
Dam		
Crest elevation	:	El. 42.5 m
Dam height	:	17.1 m above the river bed

(2) Land Development

Irrigation area	:	6,600 ha
Proposed crops	:	Paddy, Groundnuts, Mungbeans, Vegetables
Cropping intensity	:	140 %

(3) Domestic and Industrial Water Supply

Supply quantity	:	17.8 x 10^6 m^3 per year

4.3 Domestic and Industrial Water Supply Plan

4.3.1 Water Demand Centers

The water demand centers are defined as urban area with more than 5,000 population and development areas in the Eastern Seaboard Development. The urban area will be provided with pipe-water service in accordance with the large scale water supply programme of PWWA.

There is no development area in the Khlong Luang river basin.

According to the population projection in Sectoral Report I, Socio-Economy, there will be four urban areas by Target Year 2001 in the basin. They are Ban Bung, Phanat Nikhom, Tha Bun Mi and Nong Tamlung, all of which are presently served with pipe-water by either large scale water supply programme or rural water supply programme. The Ban Bung and Phanat Nikhom areas are facing an acute shortage of water. The Five-Year Plan (1982 - 1986) of PWWA includes the improvement of existing plant and expansion of distribution area for Ban Bung and Phanat Nikhom. It should, however, be noted that Ban Bung area is not included in the objective area of Khlong Luang Dam Scheme. According to the long-term water supply plan, Ban Bung area will be served by New Ban Bung dam.

The service areas of the rural water supply programme have not been identified yet by PWWA. However the water resources development will be formulated taking into account the domestic water demand of rural area in future.

4.3.2 Projected Water Demand

The domestic water demand in the Khlong Luang river basin has been projected in line with the same method as described in the preceding sub-section 2.6.2. The projected population and water demand by 5-year period are shown in Table 16. Projected annual domestic water demand is 3.0 x $10^6 m^3$, 4.8 x $10^6 m^3$, 6.5 x $10^6 m^3$ and 7.9 x $10^6 m^3$ for the year 1986, 1991, 1996 and 2001 respectively.

As explained in the preceding sub-section 3.3.2, there are 6 water works in the Khlong Luang river basin, excepting Ban Bung water works. These water works have their water sources in small streams or irrigation channel running nearby. The water supply capacity of 6 water works is estimated to be 1.1 x 10^6 m^3 per year, which is presumed to be continuously available even in future. Therefore the actual domestic water demand is defined as the total water demand deducted by local water resources.

There is no particular industrial water demand dependent on Khlong Luang Dam Scheme. The Bang Pakong Power Station, which is located to the north of the Khlong Luang river basin and requiring 6.6 x 10^6 m^3 per year of water in Target Year 2001, is taking the required water off from Bang Phra reservoir.

4.3.3 Inter-Zone Water Diversion

The Khlong Luang Dam Scheme bears the water supply to the coastal area. According to the water demand and supply balance, Chon Buri-Pattaya area will encounter with a huge quantity of water shortage; 5.3 x 10^6 m^3 in 1991, 19.7 x 10^6 m^3 in 1996 and 42.3 x 10^6 m^3 in 2001. The long-term water supply plan endorsed the inter-zone water diversion plan. The water shortage will be solved by water diversion both from the Khlong Luang and Rayong river basins, in proportion to their run-off coefficients and availabilities of water. Water diversion from the Khlong Luang dam is computed by the following equation;

$$Qd = WD \times [k(1) \times AD(1)]/[k(1) \times AD(1) + k(2) \times AD(2)]$$

$$AD(1) = ND(1) - DI(1) - MF(1)$$

$$AD(2) = ND(2) - DI(2) - MF(2)$$

where,

Qd: annual water diversion from the Khlong Luang dam
WD: annual water shortage in Chon Buri-Pattaya area
k : run-off coefficient of river
ND: annual regulated outflows from the reservoirs
DI: domestic and industrial water demand in the basin
MF: river maintenance flow
Suffixes (1) and (2) mean the Khlong Luang river basin and the Rayong river basin respectively.

The Khlong Luang Dam Scheme diverts the domestic and industrial water into Chon Buri-Pattaya area at a rate of 0.4 x 10^6 m^3 in 1991, 5.5 x 10^6 m^3 in 1996 and 11.0 x 10^6 m^3 in 2001.

The total domestic and industrial water demand dependent on the Khlong Luang Dam Scheme is summarized as follows;

(Unit: 10^6 m^3/yr)

Description	1986	1991	1996	2001
Basin use, urban area	0.5	1.0	1.2	1.4
Basin use, rural area	1.4	2.7	4.2	5.4
Inter-zone diversion	0	0.4	5.5	11.0
Total	1.9	4.1	10.9	17.8

The water demand in 1986 is mostly attributed to the domestic use in rural area, which would continue to depend on local water resources or groundwater for the present. The Khlong Luang Dam Scheme should, however, come into operation in 1991 at the latest in order to ensure the water demand in both the inside and outsie of the basin.

4.4 Agricultural Development Plan

4.4.1 Proposed Irrigation Area

The plan formulation manifested that the optimum land development is to irrigate 6,600 ha of lands with the proposed cropping pattern having 140 % of cropping intensity.

The irrigation development area is carefully selected within the potential irrigable area, paying attentions to the present land use, soils, land capability, economic return and so on. The selected irrigation area is almost coincided with that delineated by RID. As shown in DWG No. 3-1 it is located immediately downstream from the proposed Khlong Luang damsite and is divided into two areas, namely, North Area with 3,100 ha and South Area with 3,500 ha in a net irrigation area.

4.4.2 Proposed Cropping Pattern

The proposed cropping pattern with 140 % of cropping intensity is shown in Fig. 15.

Rice will be cultivated predominantly as nation's principal food and export commodity. The Government has been emphasizing in its Fifth National Plan an increase of rice production to cope with future population increase and to improve the international trade balance. The high yielding varieties will be predominant among rice varieties in future and will be planted for 80 % of the proposed irrigation area during the wet season. The traditional varieties will also be grown in the remaining 20 % of the area during the wet season for the sake of distribution of risk and choise in taste.

Groundnuts and mungbeans will be cultivated during the dry season. They are selected from the viewpoints of soil conservation and farmer's cash income.

Vegitables will also be cultivated during the dry season in relatively large area. Consumption of vegitables are predicted to be increased with a leap in the coastal area resulting from the induced population.

The future land use in the proposed irrigation area will be as follows.

(Unit: ha)

Crops	Wet Season	Dry Season	Total
Rice			
Local varieties	1,320	-	1,320
High yielding varieties	5,280	-	5,280
Groundnuts	-	1,610	1,610
Mungbeans	-	420	420
Vegetables	-	610	610
Total	6,600	2,640	9,240

4.4.3 Proposed Farming Practices

In line with development of advanced irrigation and drainage system, the improved farming practices will naturally be introduced into the area to attain and maintain the high crop productivity. The proposed farming practices by major crop are described hereunder.

(1) Rice

The distribution of seeds of the high quality is essential to increase the crop yield as expected. The RD varieties such as RD-7, RD-9 and RD-25 are recommended as high yielding varieties.

The fertilization is also significant to increase the yield. The fertilizer application rates are proposed as follows:

Varieties of Rice	Application Rate (kg/ha)	
	Nitrogen	Phosphate
High Yield	80 - 100	30 - 50
Local	30 - 40	20 - 30

For plant protection, intensive application of agro-chemicals will be adopted to control insects (stemborers and plant hoppers) and disease (blast). It is recommended to carry out the spraying systematically through the farmer's group.

The proper water management is indispensable for cultivation of rice, particularly the high yielding varieties. Water will be supplied deep in depth during the rooting period of seedlings and critical period for the punicle development and fertilization stage of rice plants.

(2) Groundnuts and Mung Beans

To maintain the expected yields of groundnuts and mungbeans, good land preparation, careful pulverizing, optimum application of fertilizers and partinent spraying of agro-chemicals should always be sustained. The recommended fertilizer applications are as follows.

Fertilizer	Application Rate (kg/ha)
Nitrogen	7 to 13
Phosphate	7 to 13
Potassium	10 to 20

4.4.4 Farm Input

(1) Labour Requirement

The labour force requirements are estimated for "without project" and "with project" conditions respectively, as tabulated below.

(Unit: 10^3 man-day)

Month	Labour Requirement		Available family labour	Month	Labour Requirement		Available family labour
	Without project	With project			Without project	With project	
Jan.	26.3	31.4	124.6	Jul.	84.2	60.8	119.8
Feb.	5.0	19.1	110.2	Aug.	75.3	111.6	115.0
Mar.	4.6	15.2	124.6	Sep.	12.7	21.8	95.9
Apr.	4.8	12.6	119.8	Oct.	17.1	34.3	105.4
May	5.1	3.2	110.2	Nov.	42.0	95.3	124.6
Jun.	9.7	13.7	119.8	Dec.	46.6	43.7	124.6
				Total	333.4	462.7	1,394.5

The family labour fully satisfies the labour force requirement.

(2) Material Requirements

The requirements of farming materials such as seed, fertilizers and agro-chemicals will increase substantially due to introduction of advanced farming practices. The annual material requirements are estimated as follows for the full development stage.

Farming Materials	Unit	Quantity
Seed		
Rice, local varieties	t	40
high yielding varieties	t	158
Groundnuts	t	48
Mungbeans	t	13
Vegitables	t	18
Fertilizer		
Compound (N:16, P:20, K:0)	t	1,680
(N:15, P:15, K:15)	t	490
(N:13, P:13, K:21)	t	220
Urea	t	430
Agro-chemicals		
Insecticides, Fungicides	kg	14,245
Herbicides	l	16,150
Rodenticides	kg	29,700

4.4.5 Anticipated Yield and Production

The target yields are projected referring to the results of experiments in the Agricultural Experimental Stations and the other information from the Agricultural Extension Office in Chon Buri. The target crop yields and productions are shown below.

Crops	Target Yield (t/ha)	Production (t)
Rice		
Local varieties	4.0	5,280
High yield varieties	4.5	23,760
Groundnuts	2.5	4,030
Mungbeans	1.5	630
Vegitables	10.0	6,100

A five-year period will be required to reach the target yields because of the need for strengthening of agricultural support service systems.

4.5 Irrigation Development Plan

4.5.1 Irrigation Requirement

The irrigation requirement was calculated at intervals of 10-day to perform the plan formulation and to determine the design discharge for the irrigation facilities. The calculation method is briefly described below.

Reference crop evapotranspiration was calculated based on the Modified Penman Method for the respective crop. The climatological records at Chon Buri station was applied for the calculation.

Effective rainfall was derived from a rainfall - effective rainfall relationship, which was developed by RID. The rainfall records observed at Ban Mai rain gauge were adopted.

Irrigation efficiency is determined as shown below.

	Canal Conveyance Efficiency	Canal Operation Efficiency	Combined Efficiency
Field canal duty	90	95	86
Lateral canal duty	95	95	77
Main canal duty	95	95	70

The diversion requirement was calculated at 1.55 l/s/ha at the maximum. This figure will be employed as design discharge for preliminary design of irrigation facilities.

4.5.2 Drainage Requirement

The drainage improvement will be planned so as to remove within 72 hours excess water resulting from the maximum 3-day continuous rainfall expected to occur at a frequency of 10 years. Three-day ten-year frequency rainfall is 166 mm according to the rainfall records observed at Ban Mai rain gauge. Drain design discharge is calculated at 4.9 l/s/ha.

4.5.3 Irrigation and Drainage Systems

The irrigation service will be directly attained by the Khlong Luang dam through two main canal systems as shown in DWG No. 3-1.

The North Main Canal with a total length of 31.1 km will run along the right bank of the Khlong Luang river and commands 3,100 ha. Its conveyance capacity will be 4.81 m^3/s at its head.

The South Main Canal will be aligned along the left bank of the Huai Sung and commands 3,500 ha. Its total length will be 21.8 km and has a conveyance capacity of 5.94 m^3/s at its head.

The irrigation area will be divided into adequate numbers of lateral and/or sub-lateral units, each of which will be further sub-divided into a number of tertiary units. The maximum command areas of the lateral and tertiary units will be limited to 500 ha and 40 ha respectively. Fifteen lateral canals are aligned within the irrigation area. The total length of lateral canals is 15 km and 19 km for the north area and the south area respectively.

Systematic drainage system will be provided over the irrigation area. Excess water will be evacuated from the irrigated land principally by natural channels but many of the channels will need improvement. Artificial drains would also be constructed in some areas. The total length of drains is roughly estimated at 37 km, comprising 10 km of the natural channel improvement and 27 km of the artificial drain construction.

5. FLOOD MITIGATION PLAN

5.1. Formulation of Basic Flood Control Plan

5.1.1 Basic Principles

As explained in Section 3.5, flooding have incurred damages on agricultural product, house and housing property etc. It could be expected that flood hazards to life and health will increase as population expands, and intensified use and occupancy of flood plain lands will result in increased property damage from future floods.

An appropriate flood protection measure will be essential for enforcement and prosperity of economic activity, conservation of land, increase of agricultural productivity and assurance of human life and health. Such protective measure, however, should be in view of long-term perspective.

A basic flood control plan is elaborated as a guide in establishment of flood mitigation measure and plan of flood protection works. The basic plan is based on a standard project flood, which has a recurrence interval of 50 years.

It is being anticipated that New Ban Bung dam will be taken place in 1984. As well, Khlong Luang dam will also be implemented within a couple of years to meet the increased water demand. These dams will evidently contribute to flood damage reduction. Therefore the basic flood control plan is established depending on a combination of New Ban Bung and Khlong Luang dams and river improvement work.

The flood mitigation plan is thoroughly explained in Sectoral Report XIII, Flood Mitigation Engineering.

5.1.2 Flood Control Alternatives

The magnitude of the river improvement works is dominated by flood regulation effect by reservoir, which varies with surcharge volume in the reservoir. The surcharge volume is dependent on discharge capacity of spillway. Thus the flood control alternatives were set up by appling the spillway width of Khlong Luang dam as a parameter. Three alternatives are arbitrarily set up as shown below.

Structures	Unit	Alternatives		
		1	2	3
New Ban Bung Dam				
High water level	El.m	82.1	82.1	82.1
Flood water level	EL.m	84.3	84.3	84.3
Surcharge volume	10^6m^3	7.8	7.8	7.8
Spillway width	m	20.0	20.0	20.0
Dam crest	El.m	86.3	86.3	86.3
Khlong Luang Dam				
High water level	El.m	39.5	39.5	39.5
Flood water level	El.m	40.6	40.5	40.4
Surcharge volume	10^6m^3	39.2	34.3	31.4
Spillway width	m	50.0	70.0	90.0
Dam crest	El.m	42.6	42.5	42.4
River Improvement Work				
Length	km	47.0	47.0	47.0
Earthwork	10^3m^3	5,712	5,718	5,725

The features of New Ban Bung Dam are quoted from "Main Report, The East Coast Water Resources Development Project".

As for Khlong Luang dam, the high water level has been determined at El. 39.5 m through the land and water resources development plan. The spillway is designed as a side-channel spillway without gate and its crest elevation is the same with the high water level. The surcharge volume and flood water level are decided by routing the 500-year inflow flood.

The requirement of the river improvement work was worked out subsequent to flood routing by reservoir and according to the flood run-off simulation model presented in Section 3.5. Preliminary design of channel improvement work is carried out based on the criteria recommended by Ministry of Construction, Japan. The quantity of earth work, practically dike embankment indicates only slight difference among the alternatives, since flood run-offs from the sub-basins in downstream from the dam is so large compared to critical channel capacities.

The construction cost of each structure is estimated for cost comparison among the alternatives. Since New Ban Bung Dam is expected to be completed before implementation of Khlong Luang dam, its construction cost is excluded. The construction cost of Khlong Luang dam attributable to flood control is presumed to correspond to dam embankment cost above the high water level and spillway cost. The estimated costs are as follows.

(Unit: ฿/10^6)

Structures	Alternatives		
	1	2	3
Khlong Luang Dam (incremental only)	307.7	302.9	303.9
River improvement work	1,086.6	1,087.4	1,088.2
Total	1,394.3	1,390.3	1,392.1

5.1.3 Proposed Basic Flood Control Plan

The construction costs of three alternatives are almost even. The alternative 2, however, indicates the minimum cost and its total dam construction cost is also the lowest among the three. Therefore the alternative 2 is proposed as the basic flood control plan.

The Khlong Luang dam retains the surcharge volume of 34.3 x $10^6 m^3$ between FWL 40.5 m and HWL 39.5 m. The spillway width is determined at 70 m and its crest is set at El. 39.5 m.

The discharge distribution is prepared as shown in Fig. 26. The existing river channel will be improved as smooth as possible and flood run-off will be confined between the dikes. Plan and profile of the proposed river improvement work are shown in Fig. 26 respectively.

5.2. Flood Control Effects by Dams

5.2.1 Flood Regulation by Reservoir

Both the New Ban Bung and Khlong Luang dams will withhold a large portion of flood peak run-off for a while and thus reduce damages in the downstream reaches. The flood regulation by reservoir is worked out for various probable floods and then flood frequency curves of the respective channel reach was modified taking into account the effect of reservoir flood regulation. The modified flood frequency curves are shown in Fig. 19.

5.2.2 Flood Control Benefit by Dams

The flood control benefits were measured as the difference between the annual damages under unregulated conditions of flooding and those with the reservoir in operation. The flood control benefits of Ban Bung and Khlong Luang reservoirs are estimated as follows.

(Unit: ฿ 10^6)

Conditions	Residual damage	Benefit
Unregulated	240.9	-
New Ban Bung	230.3	10.6
New Ban Bung + Khlong Luang	180.5	49.8

The annual flood control benefit of Khlong Luang dam is assessed to be ฿49.8 x 10^6, which is consequently adopted in economic evaluation of Khlong Luang Dam Scheme.

5.3. Economic Comparison of River Improvement Works

The river improvement plan involved in the basic flood control plan is established for a long-range objective and will be realized as a mean of final flood control resort, since existing channel capacity is exessively small compared to magnitude of flood. It, however, would be planned to be executed in a stage-wise in due consideration of flood damage severities.

Economic viability of river improvement work was examined for three different risk levels, namely, 10-year, 30-year and 50-year in terms of recurrence interval of flood. The construction cost was estimated based on the preliminary layout design and converted into annual equivalent cost at an assumed discount rate of 8 % per annum. The operation and maintenance cost was also estimated for each measure. The annual benefit was estimated from the flood damage curves after New Ban Bung and Khlong Luang dams. The estimated annual cost and benefit are as shown below.

(Unit: ₱ 10⁶)

River Improvement Works	Annual Cost	Annual Benefit	Annual Net Benefit
Risk Level : 10-year	102.3	158.5	56.2
Risk Level : 30-year	108.9	172.7	63.8
Risk Level : 50-year	114.1	175.7	61.6

As shown above, the river improvement works generate high economic return by reducing flood damages. Among the three cases, the river improvement work at the risk level of 30 years is most atractive from the economic point of view, creating the annual net benefit of ₱ 63.8 x 10⁶.

It is expected, therefore, that river improvement work will be firstly proceeded aiming at protecting the flood with the recurrence interval of 30 years. It is recommended to conduct systematic flood damage statistical survey so that economic and financial losses in the basin will be realistically clarified.

6. PRELIMINARY DESIGN

6.1 Dam and Reservoir

6.1.1 Reservoir

According to the plan formulation studies, the gross storage capacity of the reservoir is determined at 169.1 x 10^6 m^3, consisting of 15.8 x 10^6 m^3 of dead storage, 119.0 x 10^6 m^3 of active storage and 34.3 x 10^6 m^3 of surcharge. The dead storage is decided taking into account sediment deposit over 100 years. The flood water level, high water level and low water level are El. 40.5 m, El. 39.5 m and El. 33.8 m, respectively. The flood water level is determined against a 500-year probable flood. The reservoir water level rises to El. 40.9 m, when probable maximum flood should occur.

DWG No. 1-1 shows the map of reservoir area. Fig. 27 shows the area-storage curve of the reservoir.

6.1.2 Dam

Khlong Luang multiple-purpose dam consists of a main dam and a saddle dam as shown in DWG No. 1-2. The saddle dam is located behind the left abutment of the main dam. The main dam sits astride two streams; the Khlong Luang river and the Huai Sung rivers.

(1) Dam Crest Elevation

Crest elevation of dam is set at El. 42.5 m allowing 2.0 m of freeboard above the flood water surface. Dam height is 17.1 m above the river bed and crest length is 3,820 m.

(2) Geological and Geotechnical Evaluation

In order to supplement the existing data, additional geological investigation was carried out. The results of the investigation are compiled in Sectoral Report VIII, Geology.

The proposed axis of the main dam is identical with that selected by the previous study. As shown in Fig. 28, dam and reservoir are situated in the geological province of pre-Cambrian Schist. A prominent hill, named Khao Nong Nam, forms the left abutment of the main dam and is composed of the pre-Cambrian shales and schists. The right abutment is the undulating uplands, which are wholly underlain by the terrace deposits of sands and gravelly clay. The river valley is approximately 4,000 m in width and is covered by thick flood plain deposits. The geological map of the damsite is shown in Fig. 29 and geological profile along the proposed dam axis is presented in Fig. 30.

Permeability, measured in the recently drilled two bore holes BL1 and BL2, shows low value in the order of 10^{-5} cm/s for the flood plain and terrace deposits under the Khlong Luang valley. The bore hole BL1 revealed that the underlying weathered shale and schist are more pervious, with 1.3 to 7.2 x 10^{-4} cm/s of permeability coefficient, from 7 m to 20 m of depth, and they are virtually impervious below 20 m. This intermediate zone of permeability in the order of 10^{-4} cm/s will provide main leakage path on impounding the reservoir. Though the rate of leakage per unit width of a vertical slice of foundation is not very much, the total leakage quantity would be a noticeable amount since the dam is very long. However, it is deemed not reasonable to sink an impervious earth cut-off up to 20 m of depth, while the height of dam is only 14 m above the river bed. If the unconsolidated overburden with low permeability is continuously developed in the upstream, it may be regarded to function as natural blanket to suppress the possible leakage within a reasonable amount. In view of local irregular variation of permeability, however, the continuity of the natural blanket is very dubious.

Under such circumstances, it seems that the most appropriate measure for leakage control is to spread an artificial earth blanket upstream from the earth embankment of the dam. This will be constructed as an extension of the earth blanket on the left

bank which has been recommended to control the high leakage area by Sverdrup & Parcel International, Inc. (1973), and cover the right abutment as well, where the interface of the weathered bedrock to the overlying terrace deposit does not rise more than El. 25 m.

(3) Type of Dam

Geological and topographic conditions allow to build only a fill type dam at the proposed damsite. A homogeneous earth fill type dam is selected from the viewpoint of the availability of embankment materials such as earth, rock, sand and gravel.

According to the material survey, earth borrow area is selected on the left abutment of the main dam. The soils are composed of terrace and colluvium deposits. Riprap and sand and gravel will be produced in Khao Bo Kwang Thong quarry site, which is located at about 15 km south of the proposed damsite. The Sectoral Report VIII. Geology contains the material survey.

(4) Zoning

Typical dam section is shown in DWG No. 1-2. Dam body is embanked with homogeneous earth material. A chimney drain with a thickness of 2.5 m is arranged in dam body for drainage. The dam foundation is excavated to 3-5 m in depth in the terrace deposits and the flood plains and to about 3 m on the left abutment. The upstream slope is surfaced with a rock riprap and downstream slope with sodding.

(5) Stability Analysis

Based on the stability analysis, the upstream and downstream slopes of dam are determined at 1:2.6 and 1:2.4 respectively. The minimum allowable safety factor is set at 1.2. The design values of materials, results of the stability analysis and the sliding circles are shown in Fig. 31.

The preliminary design of dam and its appurtenant structure is attained as a part of water resources engineering as presented in Sectoral Report XI.

(6) Seepage Analysis

In compliance with the recommendation in the above (2), an earth blanket is spread over in the upstream from the main dam for leakage control. Its length is 60.0 m at the maximum and its thickness is 2.0 m.

The analysis of seepage through dam body and foundation was attained by applying the Finite Element Method. Detailed analysis data such as mesh of input, potential flow line, flow function, uplift pressure head and vector of flow velocity are compiled in Sectoral Report XI, Water Resources Engineering.

The blanket is designed so as to reduce the quantity of seepage water less than one per cent of the average annual inflow, namely 40 l/s.

6.1.3 Spillway

The spillway is located on the left abutment of the main dam as shown in DWG No. 1-3.

In accordance with the design criteria of RID a 500-year probable flood, of which peak discharge is 1,460 m^3/s is adopted as design inflow flood. The design of spillway is made taking into account the retardation effect of the reservoir.

A side-channel spillway is selected as most suitable type to the proposed damsite. Its crest length is determined at 70 m from the viewpoint of flood mitigation plan as explained in Chapter 5. The crest elevation is set at El. 39.5 m, the same elevation as the high water level. The maximum outflow from the spillway is 147.0 m^3/s at flood water level El. 40.5 m. The flood regulation by the reservoir is shown in Fig. 32.

In case of occurrence of the probable maximum flood with a peak discharge of 2,520 m^3/s, the reservoir water level rises to El. 40.9m and the spillway discharges 245.0 m^3/s at the maximum.

The side-channel spillway is connected to chuteway with a total length of 40.0 m. A stilling basin is provided at the downstream end of chuteway to dissipate the excess energy of flow.

6.2. Water Conveyance System

6.2.1 Pipeline

The water conveyance system is planned to be implemented in two phases so that system capacity can be adjusted to possible increase or decrease in water demand. The design of the water conveyance system is thoroughly described in Sectoral Report XII, Water Conveyance Engineering.

The intake is located at the head of the South Main Irrigation Canal and raw water basin is provided at the end of the pipeline in Khao Choeng Thian. The pipeline is aligned along provincial highway and national highway as shown in DWG No. 2-1. The pipeline is designed in pressure flow and has a total length of 56 km in two raws.

Design discharge is determined as shown below, taking into account the plant factor of 1.3 and water diversion to the rural area within the basin.

Reach	Length (km)	Discharge (m^3/s)		Pipe Dia. (mm)	
		1st Phase	2nd Phase	1st Phase	2nd Phase
Intake-5 km point	5.0	0.26	0.26	600	600
5 km point-Ban Suan Phak	14.0	0.25	0.25	600	600
Ban Suan Phak-31.8 km point	12.8	0.24	0.24	600	600
31.8 km point-Raw water basin	23.7	0.23	0.23	600	600

The most economical combination of pump capacity and pipe size is selected through comparative study of several alternatives.

The pipes are of coating steel pipe having an allowable stress of 10 kg/cm^2. In hydraulic design, static head is confined at 80 m at the maximum for the sake of water hammer. The hydraulic design of the system is shown in Fig. 33.

6.2.2 Intake

The intake is located at the left bank of the South Main Irrigation Canal. It is composed of diversion pipe, receiving well, pump well and pumping and electric stations as shwon in DWG No. 2-2.

Pump well has a capacity of 108 m^3 between HWL 34.4 m and LWL 31.4 m. Three double suction volute pumps with ø 200 mm are installed, of which one unit is the standby. Each pump has a discharge capacity of 15.3 m^3 per minute and pumping height of 30 m in gross.

6.2.3 Booster Pump Station

The booster pump station is installed at two locations, namely, Ban Suan Phak and Ban Yot Noen. The Ban Suan Phak station is equipped with 3 units of double suction volute pump with ø 200 mm, including a standby, each of which has a discharge capacity of 14.5 m^3 per minute with total head of 55 m. The associated pump well has a capacity of 878 m^3 between HWL 21.8 m and LWL 18.8 m.

The Ban Yot Noen station is situated at about 42 km point from the intake and is equipped with 3 units of double suction volute pump with ø 200 mm, including a standby. The discharge capacity and total head of each unit are 13.6 m^3 per minute and 50 m respectively. The pump well has a capacity of 878 m^3 between HWL 36.8 m and LWL 33.8 m.

The preliminary design of the booster pump stations is shown in DWG No. 2-3.

6.2.4 Raw Water Basin

Two raw water basins are provided. The one is located at the same site as Ban Suan Phak booster pump station for convenience of delivery of water to Phanat Nikhom. It has a storage capacity of 180 m^3, sufficient for 4 hours retention.

The other raw water basin is installed at the end of the pipeline, Khao Choeng Thian. Its storage capacity is 4,200 m^3 between HWL 62.0 m and LWL 59.0 m and is determined taking into account 4 hours retention time. DWG No. 2-4 shows the preliminary design of the raw water basins and DWG No. 2-5 the appurtenant facilities.

6.3 Irrigation and Drainage System

6.3.1 Intakes

The preliminaray design of the irrigation and drainage system is contained in Sectoral Report III, Irrigation Development Plan. The summary is explained herein.

Two intakes will be located in the reservoir as shown in DWG No. 3-2. Both intakes comprise intake tower, conduit, outlet with energy dissipator and discharge measuring device, and operation bridge.

The intake tower is equipped with a regulating gate of 2 m in height and 2 m in width. The sill elevation is set at El. 31.8 m. The conduit with a steel liner of 2 m in diameter is embedded deep into foundation to prevent possible piping. Its length is 54. 0 m for the North Intake and 300 m for the South Intake.

6.3.2 Irrigation Canal and Canal Structures

The alignment of the irrigation canals is shown in DWG No. 3-1. Longitudinal profiles of the main canals are shown in DWG No. 3-3.

For design of canal, the maximum and minimum velocities are set at 1.2 m/s and 0.6 m/s respectively for concrete-lined canal and at 0.7 m/s and 0.4 m/s respectively for earth canal. The main canals are lined with 7 cm thick plain concrete for their entire reach and have a trapezoidal cross-section with side slope of 1:1.5.

The irrigation system is associated with various canal structures such as culvert, inverted siphon, drop structure, check gate, turnout, spillway, cross-drain, aqueduct and bridge.

6.3.3 Drainage Canal and Related Structures

The drainage network in the irrigation development area is shown in DWG No. 3-1. The natural streams and existing local drains are incorporated into the drainage system as much as possible.

6.3.4 Inspection Road

The inspection road is classified into main inspection road and lateral inspection road. The main inspection roads run along the main canals and have an effective width of 5 m paved with laterite. The lateral inspection roads are aligned almost along with the lateral canals and is 3 m in width.

6.4 Environmental Aspects

6.4.1 NEB Standard

Impacts of the Scheme on environmental conditions are preliminarily evaluated in the present study. The standard established by National Environmental Board (NEB standard) is applied to the evaluation.

The NEB is the responsible agency for preservation of the nation's environment and making recommendations to the Government on environmental impacts of projects. NEB standard was prepared in 1979 and includes evaluation standard for dam and reservoir.

6.4.2 Environmental Impact Evaluation

Four categories are presented as to be evaluated for water resources development project, as listed below.

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

Each category includes more specific items to be examined.

The following table presents the result of the evaluation focused on the items considered to be related to the Khlong Luang Dam Scheme.

Environmental Resources	Item	Grade	
		Dam and Reservoir	Irrigation System
Physical Resources	Water Quality	2 and (1)	(1)
	Soils	-	(2)
Ecological Resources	Fisheries	2 and (1)	1
	Fauna & Flora	(1)	2
	Forests	(1)	-
	Fertilizer & Agro Chemical	-	(1)
Human Use Value	Water Supply	3	3
	Flood Control	3	-
Quality of Life Values	Socio-economy	3	3
	Public Health	2	1
	Recreation	3	1

Grade is expressed by figures 3, 2, 1 indicating the beneficial impact of major, intermediate and minor, while figures with parentheses indicate adverse effect; (3), (2) and (1) mean major, intermediate and minor adverse effect.

According to the result, the Khlong Luang dam induces positive effect on the most items in human use value and quality of life values. The Scheme contributes to the improvement of sanitary condition, economic situation and recreational opportunities of the local population either directly or indirectly through water resources development and resultant industrialization and agricultural development of the area.

Although the Scheme poses to induce a little adverse effect on several items of physical resources and ecological resources, it is expected that they will be limited to the minimum level by guaranteeing the river maintenance flow to the downstream of the river. As already explained in sub-section 2.6.2, the concept of river maintenance flow is introduced in the present study in order to minimize or avoid the adverse effect of the water resources development on such items as water quality, fauna and flora and fishery.

6.4.3 Recommendations

Environmental impacts of the Scheme is evaluated preliminarily in the present study. It is proposed that detailed study will be conducted according to the NEB standard at the implementation stage of the Scheme.

Following actions are recommended to be taken by the executive agency before the implementation of the Scheme.

(1) Detailed survey on the environmental conditions in the Scheme area.
(2) Establishment of specific counter measures against possible adverse effect
(3) Establishment of regular monitoring system on water quality, fauna and flora etc.

7. COST ESTIMATE

7.1 Investment Cost

7.1.1 Basic Conditions

The Scheme comprises three components; multiple-purpose dam, raw water conveyance system and irrigation and drainage system. The investment cost of the respective component consist of the direct cost, compensation and relocation cost, administration cost of executive agencies, engineering service, physical contingency and price contingency. It was estimated based on the 1982 price level. The followings are the basic conditions for the direct cost estimate.

(1) The currency exchange rates were assumed;
US$ 1 = Baht 23 = Japanese Yen 240

(2) All the construction works will be executed by contractors selected through international competitive bidding.

(3) Unit price of each work item included direct cost such as personnel and labour expenses, material costs and operation and depreciation costs of construction equipment. The unit price is divided into foreign currency portion and local currency portion in accordance with the following classification.

Foreign Currency Portion

- Depreciation cost of construction plant and equipment,
- Large gate and valve,
- Electrical equipment,
- Hydro-mechanical equipment,
- Steel pipe and valve,

Local Currency Portion

- Labour wages,
- Sand, gravel, timber, board,
- Fuel, oil, lubricant,
- Cement,
- Small gate, reinforcement steel bars,
- Inland transportation cost.

(4) The contractor's overhead and profit was estimated in accordance with the Government's guideline issued in July 30, 1982.

(5) Income taxes to be levied by the Government is also included in accordance with the above guideline.

(6) Import tax and duty on the equipment, plants and materials imported by contractors were not taken into account.

The compensation and relocation cost is referred to the result of the compensation survey, which was directly conducted by RID in 1982.

The administration cost of the executive ageancies was assumed to be 2 %, 4 % and 5 % of the direct cost for dam, water conveyance and irrigation component respectively.

The costs of engineering services was assumed to be 10 % of the direct cost for the dam components, 8 % for the water conveyance component and 13 % for the irrigation component respectively.

The physical contingency is assumed to be 15 % of the sum of the direct cost, compensation and relocation cost, administration cost of the executive agencies and cost of engineering services.

The price contingency was estimated assuming broadly a price escalation of 10 % per annum for the local currency portion and of 8 % per annum for the foreign currency portion.

7.1.2 Investment Cost

The investment cost estimate is presented in Table 17 and is summarized as follows:

(Unit: ฿ 106)

Component	Foreign Currency Portion	Local Currency Portion	Total
First Stage			
Multiple-purpose Dam	752.8	1,716.8	2,469.6
Irrigation and Drainage System	277.6	629.6	907.2
Water Conveyance System	388.3	170.6	558.9
Sub-total	1,418.7	2,517.0	3,935.7
Second Stage			
Water Conveyance System	483.2	146.8	630.0
Sub-total	483.2	146.8	630.0
Total	1,901.9	2,663.8	4,565.7

The detailed construction cost estimate of the dam, water conveyance and irrigation components are compiled in the Bill of Quantities attached to the report.

The above investment cost is estimated on the international competitive bid basis, based on which economic evaluation of the project is conducted. However, apart from the above, the investment costs on the basis of force account construction are estimated for dam and irrigation components, respectively for the purpose of reference. They are compiled in Sectoral Report XI, Water Resources Engineering, and Sectoral Report III, Irrigation Development Plan, respectively.

7.2 Operation and Maintenance Cost

The operation and maintenance cost of the respective project component is assumed to be 0.5 %, 1.0 % and 0.5 % of construction cost for dam, water conveyance system and irrigation and drainage systems respectively. For the water conveyance system, electrical charge is added at the rate of ฿ 1.19 per kWh.

The annual operation and maintenance cost is estimated to be ฿ 5.1 x 10^6 for the dam, ฿ 15.2 x 10^6 for the water conveyance system and ฿ 1.8 x 10^6 for the irrigation and drainage system.

7.3 Replacement Cost

Some facilities and equipment need to be replaced periodically. Economic life and replacement cost are estimated as follows:

Facilities and Equipment	Economic Life (year)	Replacement Cost (฿ 10^6)	
		First Stage	Second Stage
Water Conveyance System			
Hydro-mechanical equipment	16	10.2	4.7
Electrical equipment	16	27.9	6.0
Pipeline	40	184.8	184.6
Irrigation and Drainage System			
Gate	25	22.5	-
O&M equipment	10	21.8	-

7.4 Implementation Schedule

The implementation schedule of the Scheme is shown in Fig. 34. The implementation of the Scheme is divided into two stages, since the water conveyance system is completed in two phases in accordance with the growth of water demand.

The first stage includes the construction works of the multiple-purpose dam, irrigation and drainage system, the first phase of the water conveyance system and the procurement of O&M equipment for irrigation services. The commencement of the first stage is assumed to be the beginning of fiscal year 1985. The construction period by the project component is scheduled as follows:

Multiple purpose dam	:	1985 to 1990
Irrigation and drainage system	:	1986 to 1991
Water conveyance system, 1st phase	:	1987 to 1991

The second stage is the implementation of the second phase of the water conveyance system. It will take place in 1991. The construction period will extend over two and half years from 1993 to 1996.

Disbursement schedule of investment cost is presented in Table 18.

7.5 Major Construction Equipment

The major construction plant and equipment required by the project component are listed as shown in Table 19.

8. BENEFIT

8.1 Domestic and Industrial Water Supply Benefit

8.1.1 Unit Water Supply Benefit

Domestic and industrial water supply benefit is derived from the cost of alternative facilities with the single purpose of supplying domestic and industrial water. Alternative facilities include the dam, which is assumed to be located at the same location as the proposed Khlong Luang dam and the water conveyance system which is proposed in the present study. The benefit is estimated at the terminal point of the water conveyance system which is the raw water basin proposed to be located at Khao Choeng Thian.

Unit D&I water supply benefit is obtained by the following formula.

$$\sum_{n=1}^{n} \frac{C_{1(n)} + C_{2(n)}}{(1+i)^n} = \sum_{n=1}^{n} \frac{\alpha \cdot Sn}{(1+i)^n}$$

where, $C_{1(n)}$; Construction cost of alternative facilities (฿10^6)

$C_{2(n)}$; OM & R cost of alternative facilities (฿10^6)

α ; Unit D&I water supply benefit (฿/m^3)

Sn ; Water supply volume (10^6 m^3/year)

i ; Discount rate, which is the same rate as the internal rate of return (IRR)

Construction Cost of Alternative Facilities (฿10^6)

Dam	764.5
Water Conveyance System	542.3
Total	1,306.8

OM Cost of Alternative Facilities (฿10^6)

	1991	1996	2001
Dam	2.9	2.9	2.9
Water Conveyance System	4.0	10.5	14.8
Total	6.9	13.4	17.7
Water Supply Volume (10^6 m^3)	4.1	10.9	17.8

Replacement cost is as shown in section 7.3. Unit D&I water supply benefit by different discount rate is as shown below.

Discount Rate (%)	Unit Benefit (฿/m3)
10.0	12.69
12.0	15.88
14.0	19.51
16.0	23.57
18.0	28.07

Unit D&I water supply benefit is estimated at B 23.78/m^3 at the discount rate of 16.1% which corresponds to internal rate of return of the Scheme.

8.1.2 Water Supply Benefit

Total D&I water supply benefit is obtained by multiplying the unit water supply benefit by annual water supply for domestic and industrial use. It is estimated at ฿ 97.5 x 10^6, in 1991, ฿ 259.2 x 10^6, and ฿ 423.3 x 10^6 in 2001. Domestic and industrial water supply benefit will reach the maximum level at around year 2001 and thereafter will be kept constant.

8.2 Agriculture Benefit

8.2.1 Agricultural Production

In the Khlong Luang Scheme area, such new crops as mungbeans and groundnuts will be introduced as second crop after rice. Agricultural production of each crop under "without project" and "with project" conditions is summarized as follows.

(Unit: t/year)

Crop	Without Project	With Project	Increment
Rice (Local)	7,150	5,280	-1,870
Rice (High Yielding)	6,100	23,760	17,660
Mungbeans	0	630	630
Groundnuts	100	4,030	3,930
Sugarcane	16,770	0	-16,770
Vegetable	0	6,100	6,100
Cassava	6,400	0	-6,400

Figures in the above table are the annual production at the full development stage. Build-up period is assumed to be four years.

8.2.2 Price Prospect

Economic prices of major agricultural commodities and products are estimated in terms of the international market price prospected for the year 1990 in the 1982 constant price. Prices after 1991 is assumed to be constant. International market price, which is CIF and FOB prices at Bangkok or CIF price at other international port, is adjusted to farm gate price by taking into account costs for inland transportation, handling charge and processing etc.

Financial price of agricultural input and output is obtained from available data at government agencies and local offices and based on the farm survey conducted by the Study Team. Both economic and financial prices are presented in Table 20.

8.2.3. Benefit

Benefit created by agricultural development is indicated by the net incremental benefit. It is the difference in net production value between with project condition and without project condition. Net production value of each case is obtained by subtracting production cost from gross production value. Total incremental benefit of the Scheme is estimated at ฿ 180.7 x 10^6 per annum as shown in Table 21.

8.3. Flood Control Benefit

Annual flood control benefit by the Khlong Luang dam is estimated in sub-section 5.2.2. It is ฿ 49.8 x 10^6 per annum.

9. PROJECT EVALUATION

9.1 Economic Evaluation

9.1.1 Basic Assumptions

The economic feasibility of the Scheme is evaluated by economic internal rate of return (EIRR). Further, sensitivity analysis is conducted to assess the impact of possible changes in economic conditions on the economic soundness of the Scheme.

The following assumptions are established in the evaluation.

(1) The implementation period is 11 years from 1985 to 1996.

(2) Only direct benefit is counted in the evaluation and any indirect or intangible benefit is not taken into account.

(3) Economic price is expressed in terms of the 1982 constant price.

(4) Economic useful life of the project is assumed to be 50 years.

9.1.2 Economic Cost

Economic cost is derived by subtracting transfer payment from financial cost. Transfer payment includes tax, compensation and relocation cost and price escalation. In addition, 15 % of local currency portion is deducted as transfer payment.

Land cost of the reservoir area is estimated by the opportunity cost of land which is the annual agricultural production foregone. Production foregone is estimated to be ₿ 38.5 x 10^6 per annum based on the net production value of crops under without project condition. It is extracted from the net incremental benefit.

Economic investment costs of dam, raw water conveyance system and irrigation facilities are presented below.

(Unit: ฿ 10⁶)

Component	Foreign Currency Portion	Local Currency Portion	Total
FIRST STAGE			
Multiple-purpose Dam	508.9	653.9	1,162.8
Water Conveyance System (First Phase)	240.7	62.3	303.0
Irrigation	173.8	283.7	457.5
Sub-total	923.4	999.5	1,923.2
SECOND STAGE			
Raw Water Conveyance System (Second Phase)	201.7	37.6	239.3
Sub-total	201.7	37.6	239.3
Total	1,125.1	1,037.5	2,162.5

Irrigation facilities include the intake on the left bank which is the joint facility for domestic and industrial water supply and irrigation water supply.

Disbursement schedule of economic investment cost is presented in Table 22.

9.1.3 Benefit-Cost Stream

Based on the implementation plan and estimated annual benefit, benefit-cost stream of the Khlong Luang Dam Scheme is established as shown in Table 23.

9.1.4 Economic Internal Rate of Return

Economic Internal Rate of Return (EIRR) is computed based on the benefit-cost stream for several cases and presented as below.

(Unit : %)

Condition		EIRR
(1)	Standard	16.1
(2)	10 % of Cost Increase	13.5
(3)	10 % of Benefit Decrease	13.3
(4)	(2) + (3)	11.2
(5)	Delay in Construction for 2 years	11.0

EIRR is found to be 16.1 % for the standard condition indicating the high economic soundness of the Scheme.

9.2 Financial Evaluation

9.2.1 Cost Allocation

Investment cost and O&M cost of joint facilities are allocated to the domestic and industrial water supply component, irrigation water supply component and flood control component respectively, in order to clarify the size of investment cost to be borne by each related agency. Joint facilities include the dam and the intake at the left bank of the dam.

Investment cost is allocated by "Separable Cost - Remainig Benefit Method". The investment cost by project component is summarized as follows.

(Unit: ₱ 10^6)

Component	Foreign Currency	Local Currency	Total
D&I Water Supply	1,112.3	866.8	1,979.1
Irrigation	684.1	1,556.7	2,240.8
Flood Control	105.5	240.3	345.8
Total	1,901.9	2,663.8	4,565.7

Allocated cost for flood control component will be borne by the government subsidy.

9.2.2 Financial Evaluation of Domestic and Industrial Water Supply

Investment cost for domestic and industrial water supply is financed based on the following assumptions.

a. Foreign currency portion of the investment cost is financed through international loan with an annual interest rate of 3.5 % and a term of 30 years including grace period of 10 years.

b. Local currency portion is borne by the Government.

Disbursement schedule of allocated investment cost for domestic and industrial water supply is presented in Table 24.

Allocated operation and maintenance cost is estimated to be ₱ 16.8 x 10^6 annualy. Replacement cost is directly derived from the replacement cost of raw water conveyance system as presented in Section 7.3

Recovery of the foreign currency portion of investment cost, O&M cost and replacement cost is planned under the condition that O&M cost and 10 % of the total investment cost and replacement cost is recovered by water tariff collected from water users.

Most of the investment cost is borne by the government, since the dam and water conveyance system for domestic and industrial water supply is one of the most essential infrastructure for the industrial development of the area. Under the above conditions, the water tariff is assumed to be ฿ 4/m^3 including ฿ 2.5 for management cost of PWWA including O&M cost of purification and distribution system and ฿ 1.5 for O&M cost of raw water conveyance and 10 % of investment cost and replacement cost.

Cash flow statement of domestic and industrial water supply is presented in Table 25.

9.2.3 Financial Evaluation of Irrigation System Development

Investment cost for irrigation system development is financed based on the following assumptions.

a. Foreign currency portion of the investment cost is financed through international loan with an annual interest rate of 3.5 % and a term of 30 years including 10 years of grace period.

b. Local currency portion is borne by the Government.

Disbursement schedule of allocated investment cost is presented in Table 24.

Allocated OM & R cost is estimated to be ฿ 4.4 x 10^6 annualy. Replacement cost is same as those presented in section 7.3.

Recovery of investment cost, O&M cost and replacement cost is planned under the following conditions.

a. O&M cost is recovered by water tariff collected from beneficiaries..

b. Investment cost and replacement cost is borne by the Government.

Cash flow statement is presented in Table 26.

9.2.4 Farm Budget Analysis

Farm budget analysis is conducted to assess the impact of the Scheme on the economy of farm household. Farm households which own gross land area of 2.0 ha and 4.5 ha are taken up as typical farms.

Annual income and outgo under the "with project" and "without project" condition is estimated as below.

(Unit: ฿/year)

Size of Household	Without Project			With Project			Increment of Reserve
	Income	Outgo	Reserve	Income	Outgo	Reserve	
1.8 ha	21,230	21,230	0	38,860	33,990	4,870	4,870
4.5 ha	33,130	30,280	2,850	96,540	53,670	42,820	40,020

With the implementation of the Scheme, farmer's income is expected to grow remarkably. It is considerd that the farmers will have enough capacity to pay for the water tariff induced on irrigation water use. Annual water tariff is broadly estimated to be ฿ 670 per ha which is equivalent to the annual O&M cost.

10. ORGANIZATION AND MANAGEMENT

10.1 Related Organizations

The water administration in Thailand is directed by the Water Resources Committee although several ministries, government agencies and autonomous institutions have responsibilities and interest in water resources development and conservation.

The RID is engaged in water resources development relevant to agricultural land development. The organization chart of RID is shown in Fig. 35. The RID has 11 Regional Offices. Each regional office assumes a responsibility for construction, operation and maintenance of water resources, irrigation and drainage facilities in its administrative area. The Khlong Luang river basin is within a territorial area of Regional Office No. IX.

The PWWA is an autonomous agency and is responsible for the pipe-water supply in the area outside of Bangkok Metoropolis.

The PWD of the Ministry of Interior has a responsibility mainly for infrastructure development in rural area, such as electrification, road, minor pipe-water supply, etc. The PWWA was formerly a division within PWD. The organization chart of PWD is presented in Fig. 36.

The proposed development activities are deeply concerned with the Eastern Seaboard Development. The Eastern Seaboard Development Committee (the Committee) is chaired by the Prime Minister and is empowered to rule on behalf of the Cabinet. Fig. 37 shows the organization chart of the Committee. The function of the Committee is the overall control of the development programme related to policy issues.

The NESDB is a part of the Office of the Prime Minister responsible for advising on the economic and social development of Thailand. The Center for the Integrated Plan of Operation (CIPO) is a

technical division within NESDB and is the Secretariat Office of the Committee. CIPO assumes responsibility for preparing the details of the development operation as well as coordinating and monitoring the implementation programmes of all government agencies concerned.

10.2 Executive Agencies

Two executive agencies will directly be involved in the implementation of the Khlong Luang Dam Scheme.

The RID will be responsible for the implementation as well as operation and maintenance of the dam and irrigation components. The project manager will be appointed by RID and he will take the whole responsibility to the RID for the proper implementation of the dam and irrigation components.

An appropriate government agency will be appointed for the proper implementation, operation and maintenance of water conveyance system.

CIPO will coordinate all the activities of the agencies with other activities related to Eastern Seaboard Development.