KINGDOM OF THAILAND
MINISTRY OF INTERIOR
PUBLIC WORKS DEPARTMENT

FEASIBILITY STUDY ON THE NONG KHO–LAEM CHABANG WATER PIPELINE PROJECT

MAIN REPORT

MARCH 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

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LIST OF REPORTS

MAIN REPORT

SUPPORTING REPORT

I	TOPOGRAPHIC SURVEY
II	HYDROLOGY
III	GEOLOGY AND SOIL MECHANICS
IV	WATER DEMAND PROJECTION
V	ENGINEERING DATA AND PRICED BILL OF QUANTITY

P R E F A C E

In response to the request of the Government of the Kingdom of Thailand, the Japanese Government decided to conduct a study on the Nong Kho-Laem Chabang Water Pipeline Project and entrusted the study to the Japan International Cooperation Agency (JICA).

The JICA sent to Thailand a survey team headed by Mr. K. Endo, comprising experts of Nippon Koei Co., Ltd. and Nippon Kensetsu Consultant company, from August 24 to November 30, 1983.

The team had discussions with the officials concerned of the Government of the Kingdom of Thailand over the Project and conducted a field survey in the East Coast area. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the team.

March, 1984

Keisuke Arita
President
Japan International Cooperation Agency

March, 1984

Mr. Keisuke Arita
President
Japan International Cooperation Agency
Tokyo

Dear Sir,

LETTER OF TRANSMITTAL

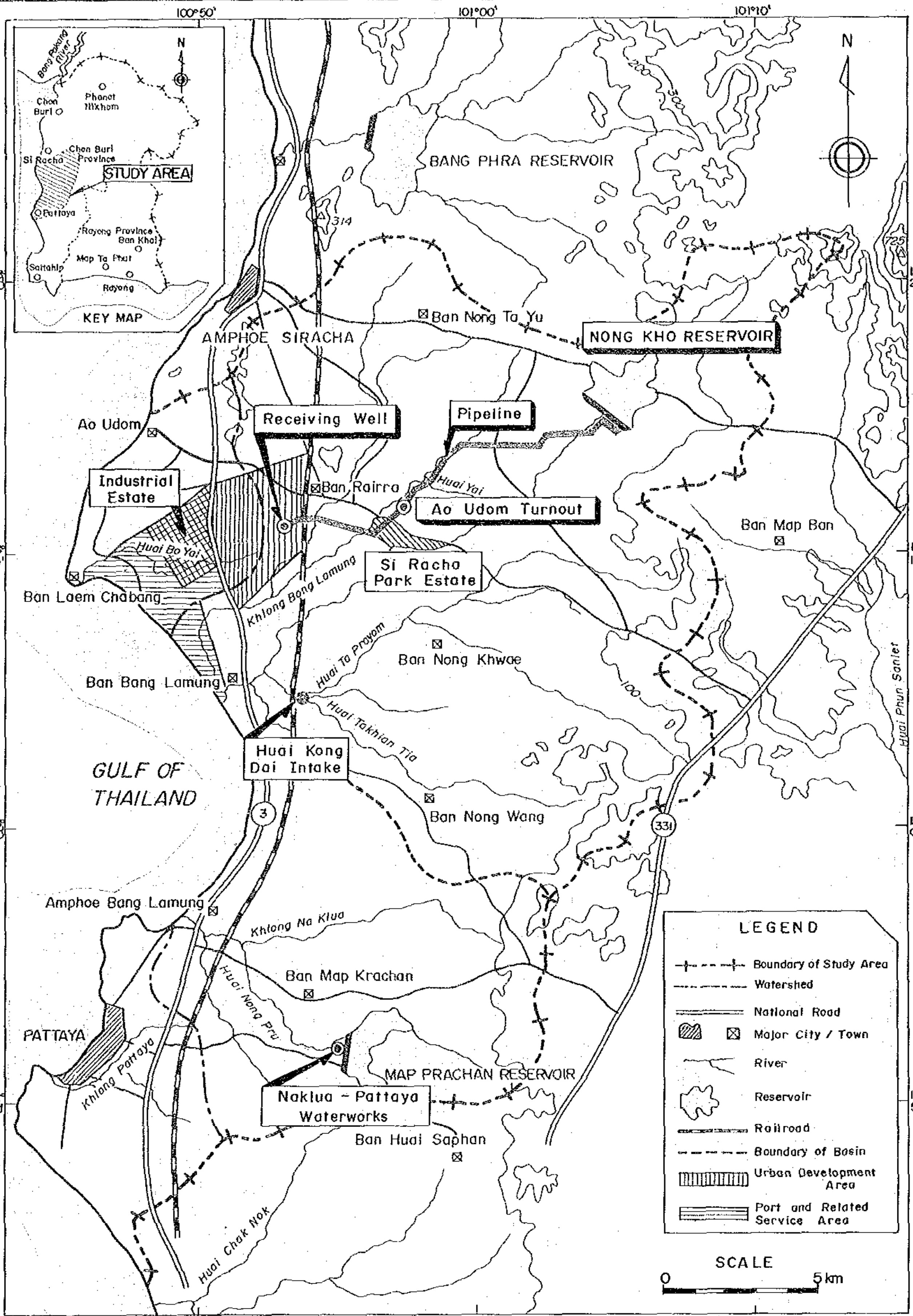
We are pleased to submit to you the Final Report of the Nong Kho-Laem Chabang Water Pipeline Project in the Kingdom of Thailand.

The feasibility study of the project was carried out during the period from August, 1983 to March, 1984, including the field survey and investigation during a 3-month period from August to November, 1983 in Thailand. The project is requisite for successful performance of Laem Chabang Complex development. Its technical feasibility and financial viability are amply justified by the study. We hope that the Government takes an immediate action for implementation of the project in line with the principles set forth in the report to promote the Laem Chabang Complex development.

All members of Study Team wish to express their grateful acknowledgement to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs and Embassy to Thailand as well as officials of the Government of the Kingdom of Thailand for their assistance and cooperation extended to the Study Team.

Very truly yours,

Kazushige Endo
Team Leader



Location Map

KINGDOM OF THAILAND
NONG KHO - LAEM CHABANG
WATER PIPELINE PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

PRINCIPAL FEATURES OF PROJECT

		First Stage		Second Stage	
		Nong Kho-Turnout	Turnout-Receiving Well	Nong Kho-Turnout	Turnout-Receiving Well
1. Raw Water Pipeline					
Design Discharge	m^3/s	0.82	0.74	0.82	0.82
Type of flow		Gravity	Gravity	Gravity	Gravity
Diameter of pipe	ø, mm	1,000	900	1,000	900
Length of pipe	km	10.95	3.49	10.95	3.49
Butterfly valve	loc.	4	5	4	5
Air valve	loc.	6	1	6	1
Blow-off	loc.	2	2	2	2
Flow meter					
Type		Ultra-sonic	Ultra-sonic	Ultra-sonic	Ultra-sonic
Number	nos.	1	1	1	1
Expected completion year		1988	1988	1994	1994
Water level in Nong Kho dam					
H.W.L.	El. m	65.0	-	65.0	-
L.W.L.	El. m	58.9	-	58.9	-
2. Turnout					
Design discharge	m^3/s	0.08	-	-	-
Delivery pipe	ø, mm	250	-	-	-
Sluice valve	nos.	2	-	-	-
Flow meter					
Type		Ultra-sonic	-	-	-
Number	nos.	1	-	-	-
3. Aqueduct					
Type		-	Pipe-beam	-	Pipe-beam
Net span	m	-	27.5	-	27.5
Diameter of pipe	ø, mm	-	900	-	900
4. Receiving Well					
Shape		-	Rectan-gular	-	Rectan-gular
Dimension (WxHxL)	m	-	6.3x4.4 x16.4	-	6.3x4.4 x16.4
Water level	El. m	-	36.7	-	36.7
Regulating valve					
Type		-	Sleeve	-	Sleeve
Number	nos.	-	1	-	1
Butterfly valve,					
ø900	nos.	-	4	-	3
ø700	nos.	-	-	-	2

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

1. The feasibility study of the Nong Kho-Laem Chabang Water Pipeline Project was executed by Japan International Cooperation Agency (JICA) during the period from August, 1983 to March, 1984, in response to the request made by the Government of the Kingdom of Thailand (the Government). The project aims at transmitting the raw water from the Nong Kho dam to the Laem Chabang Complex for the industrial and domestic use.

2. The objectives of the feasibility study were to formulate a plan for the pipeline system from the Nong Kho dam to the Laem Chabang and to verify the feasibility of the project. In order to perform the Study, the JICA appointed the Study Team, which was formed by Nippon Koei Co., Ltd., associated with Nikken Consultant Inc.

3. The Study Team carried out the field investigation and survey such as data collection, topographic survey, soil and geological investigation, hydrological investigation, water demand projection, etc. during the period from August to November, 1983 in Thailand with counterpart services provided by Public Works Department (PWD), an executing agency of the project appointed by the Government.

4. The Government has been placing a great emphasis on successful and smooth implementation of the Eastern Seaboard Development Programme (ESDP) to attain the policy objectives and economic targets set forth in the Fifth National Economic Development Plan, which covers a 5-year period from 1982 to 1986. The ESDP has been established laying a top priority on development of natural gas related industries in Map Ta Phut, Rayong Province and pollution free-light labor intensive industries in Laem Chabang, Chon Buri Province and on creating jobs and facilities to encourage urban development away from Bangkok Metropolis. It is being expected that the ESDP would result in creating a new job opportunity for

approximately 300,000 people and saving approximately ฿40 x 10^9 of foreign exchange annually upon its accomplishment. The other target areas are Pattaya for commercial and tourism and Sattahip for transportation.

5. The major development components of the Laem Chabang Complex are the industrial estate covering 450 ha of land, deep seaport with 5 berths and one pier, and urban area. Such types of industries as resources-based, export processing, downstream manufacturing and ship repairing are being supposed to be induced into the Laem Chabang Complex. The first element of the deep seaport has been scheduled to be committed in service between 1987 and 1990.

6. Pattaya is internationally famous for ocean resort. The number of tourists was 9,200 per day in 1982 and is expected to grow to 12,600 per day in 1986, 18,100 per day in 1991, 24,800 per day in 1996 and 30,900 per day in 2001. This would impose a stress on the water supply situation in Pattaya in future.

7. The development scale of the project evidently depends on the water demand and supply balance in and around the Laem Chabang Complex. The long-term water demand and supply balance over the Eastern Seaboard has already been studied by the "East Coast Water Resources Development Project (Phase II), Main Report, Feasibility Study on Khlong Yai Dam Scheme, August 1983, JICA". It concludes that the Laem Chabang-Pattaya corridor would suffer seriously from water deficit in near future and that the inter-basin water diversion system, Nong Pla Lai dam-Nong Kho dam-Pattaya, is the most advantageous measure to keep the Laem Chabang-Pattaya corridor fully supplied of the required water. The objective area of the feasibility study (the Study Area) is therefore demarcated embracing the Laem Chabang-Pattaya corridor.

8. The Study Area covers an area measuring 488 km^2 and is composed of the Khlong Bang Lamung river basin (Laem Chabang Basin) with an area of 333 km^2 and the Huai Nong Pru river basin (Pattaya Basin) with an area of 155 km^2. Population in the Study Area is expected to increase largely and rapidly as presented below, due to the implementation of the ESDP.

(Unit: 10^3)

Basins	1982	1986	1992	1996	2001
Laem Chabang	62.9	72.6	93.7	122.1	166.2
Pattaya	54.0	69.5	87.9	105.9	121.0
Total	116.9	142.1	181.6	228.0	287.2

It is anticipated that approximately 80% of population of the both basins would concentrate in development area, which consists of the proposed industrial estate and urban area.

9. Under the present public pipe-water supply administration, the Study Area is divided into the Ao Udom and Bang Lamung Sanitary Districts and Pattaya City. The Ao Udom Sanitary District operates its own waterworks, with a daily production capacity of 1,200 m^3. Its service area mainly covers the Ao Udom Town and Si Racha Park Estate and serves about 7% of the district's population (64,400) in 1982. The water consumption per capita is 180 liter per day. The waterworks was forced to stop its operation during a two-month period from April to May, 1982, since its water source, the Huai Lek river run dry. The present water tariff varies between ฿3.00/m^3 and ฿5.00/m^3. The Bang Lamung Sanitary District is not provided with the public pipe-water supply facilities at present.

The Pattaya City is fed by the Naklua-Pattaya waterworks with a daily production capacity of 25,920 m^3. It is located at the Map Prachan damsite and sustains the tourism related bulk water consumption in Pattaya. The annual water supply amounted to approximately 3,000 x 10^3 m^3 in 1982. The Naklua-Pattaya waterworks is operated under the full responsibility of the Provincial Water Works Authority (PWWA). The PWWA was established in 1979 as autonomous government agency and manages the large scale water supply programme over 88 municipalities and 135 sanitary districts throughout the country in 1982. The PWWA applies a progressive tariff which ranges from ฿2.00/m^3 to ฿5.50/m^3.

10. In the Study Area, 8 private enterprises and 3 government institutions run their own water supply facilities. The annual water consumption of these water users are estimated to be about 2,882 x 10^3 m^3 in 1982, of which 2,699 x 10^3 m^3 accrue from the private enterprises. The annual water consumption of the private enterprises is anticipated to grow to 3,409 x 10^3 m^3 in 1985, 4,269 x 10^3 m^3 in 1986, and 6,460 x 10^3 m^3 in 1987. Out of the annual water consumption of the private enterprises in 1987, 1,500 x 10^3 m^3 will rely on sea water and 2,000 x 10^3 m^3 will be diverted from the Bang Phra dam.

11. The water demand and supply balance in the Study Area was elaborated at intervals of 5 years; 1986, 1991, 1996 and 2001, in order to clarify the future water supply plan over the Study Area and to formulate the definitive plan of the project. The future water demand in the Study Area accrues from the industry, domestic, port and tourism sectors and was projected based on such parameters as anticipated types of industries, projected number of employees and tourists, projected population, estimated port cargo handling volume, water consumption per capita/employee, assumed potable water supply ratio, etc. The projection was made separately for the Laem Chabang Basin and the Pattaya Basin for the convenience of the water balance study. The future water demand in terms of source water demand are as summarized below.

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

Basin	1986	1991	1996	2001
Laem Chabang	9.8	19.7	28.6	39.1
Industrial use	6.8	14.6	20.1	25.2
Domestic use	3.0	4.9	8.1	13.3
Port use	0	0.2	0.4	0.6
Pattaya	10.7	14.5	18.8	23.0
Industrial use	1.0	1.0	1.0	1.0
Domestic use	7.3	10.1	13.1	16.2
Tourism use	2.4	3.4	4.7	5.8
Overall Water Demand for Study Area	20.5	34.2	47.4	62.1

12. A concept of river maintenance flow is introduced. It is defined as minimum discharge to preserve riparian land and people's amenity, to conserve groundwater, and to maintain water quality, channel stability, aqua-eco system. The rate of the river maintenance flow was determined conservatively to be 0.04 m^3/s at the Nong Kho damsite and 0.03 m^3/s at the Map Prachan damsite for a standard drought year.

13. The availability of the water resources in the Study Area was carefully reviewed to perform the water balance study. The groundwater development potential has been ascertained to be quite low due to geohydrological reason. As to the surface water resources, the Nong Kho and Map Prachan dams have been constructed in the Laem Chabang Basin and Pattaya Basin respectively by the Royal Irrigation Department for multiple-purpose such as water supply, irrigation and flood control. Further large scale surface water resources development is inferred impracticable because of socio-economic reasons in the basin area.

The development of the surface water resources of the Huai Kong Dai river is proposed by means of construction of headwork at the confluence of the Huai Kong Dai and Huai Takhian Tia rivers.

The simulation study of the reservoir operation was carefully analyzed in order to inquire into the water supply capacity of the Nong Kho and Map Prachan dams. The study was based on the estimated run-offs during a 15-year period from 1968 to 1982, which was derived from the simulated run-offs at the Bang Phra damsite. As the result the annual water supply capacities of the Nong Kho and Map Prachan dams were estimated to be 13.9 x 10^6 m^3 and 9.8 x 10^6 m^3 respectively, for the standard drought year, which is the driest year among the 15-year's hydrological data. The available run-off at the Huai Kong Dai headwork is assessed to be 5.0 x 10^6 m^3 per year, corresponding to a 75% dependable run-off.

14. The water balance was calculated basin by basin. The balance point was selected at the Nong Kho damsite for the Laem Chabang Basin and at the Map Prachan damsite for the Pattaya Basin, in due consideration of the present water utilization situation in each river basin. The water withdrawal was initially obtained by deducting the available local water resources from the water demand. It therefore means the quantity of water to be supplied by dams. The water balance of the respective basin is as summarized below.

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

Description	1986	1991	1996	2001
Laem Chabang Basin				
Water withdrawal	8.3	16.9	25.8	36.3
Supply by Nong Kho dam	13.9	13.9	13.9	13.9
Balance	+5.6	-3.0	-11.9	-22.4
Pattaya Basin				
Water withdrawal	11.5	10.3	14.6	18.8
Supply by Map Prachan dam	9.8	9.8	9.8	9.8
Balance	-1.7	-0.5	-4.8	-9.0

The Study Area will suffer seriously from shortage of water supply in future. It is suggested to realize the inter-basin water diversion system between the Nong Pla Lai dam and the Nong Kho dam by 1989. The amount of the water diversion will be 3.5 x 10^6 m^3 per year in 1991, 16.7 x 10^6 m^3 per year in 1996 and 31.4 x 10^6 m^3 per year in 2001.

15. The raw water distribution plan was carefully worked out in order to determine the annual raw water transmission quantity by the project facilities, in due consideration of the existing water supply plan and water supply situation. It is planned to install one turnout in the course of the pipeline to feed the Ao Udom waterworks and Sri Racha Sugar Factory, both of which have been facing a shortage of water resources. The annual water transmission quantity was calculated as follows.

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

Pipeline Reach	1986	1991	1996	2001
Nong Kho dam - Ao Udom Turnout	6.8	15.7	28.7	43.1
Ao Udom Turnout - Laem Chabang Complex	5.7	13.7	26.7	41.1

16. A study was made as to the site of the filtration plant. It is concluded that the Laem Chabang site is superior to the Nong Kho damsite in investment and O&M costs, water management, bacteria and sanitary controls. The route of the pipeline was determined through a comparative study of three alternatives and in consultation with the government agencies and departments concerned.

17. A project optimization study was elaborated in order to establish an optimum development plan of the project and was accomplished in two steps. In the initial steps, ten development alternatives were formulated by a combination of three factors; location and water level of receiving well, development sequence and hydraulic condition and their costs were compared to select the best

configulation of the three factors. The selected configuration was further refined by the second step, which aims at justifying the commissioning year of the second stage development. As the result of the study, the optimum development plan of the project was determined as summarized below.

(a) The receiving well will be located at the so-called Site "A", being about 1.8 km east of the proposed industrial estate, and its water level will be set at El 36.7 m.

(b) The project will be implemented in two stages. The first stage development will be formulated to meet the water requirement of 21.6 x 10^6 m^3 per year in the Laem Chabang Complex in 1995. The second stage development with the annual transmission quantity of 21.5 x 10^6 m^3 will be put into operation in 1994.

(c) Pipeline system will be designed under the condition of gravity flow. The inside diameter of the pipeline will be ø1,000 mm in a reach between the Nong Kho dam and Ao Udom turnout and ø900 mm in a reach between the Ao Udom turnout and the receiving well.

18. Preliminary design of the project facilities was carried out. The major project components are the pipeline system, turnout, aqueduct and receiving well. The principal features of the project are presented in the attached table. The configulations of the first stage and second stage developments are quite the same each other.

Innovation of the existing outlet in the Nong Kho dam is done to connect the pipeline with the existing outlet pipe. The pipeline is equipped with two units of flow meters; one at the head of the pipeline and the other at the downstream end. The design discharge of the pipeline are 0.82 m^3/s for the upstream reach of the turnout and 0.74 m^3/s for the downstream reach. The length of the pipeline is 14.44 km, being composed of 10.95 km with ø1,000 mm in the upstream reach of the turnout and 3.49 km with ø900 mm in the downstream reach. Wall thickness of the steel pipe is 9.5 mm for ø1,000 mm pipe and 7.9 mm for ø900 mm pipe.

The turnout is located at about 1.5 km west of the Ao Udom waterworks and is mainly composed of delivery pipe with ø250 mm, flow meter and sluice valve with ø250 mm. The design discharge is 0.08 m^3/s.

The aqueduct is situated at a-13.1 km point from the Nong Kho dam and is designed as a pipe beam type. It has a net span of 27.5 m and set with sufficient allowance for track clearance. A thickness of pipe beam is 19.1 mm.

The receiving well is designed with a retention time of 4 minutes and in a rectangular shape with 16.4 m in length, 6.3 m in width and 4.4 m in depth. Its high water level is fixed at El 36.7 m. A sleeve valve is installed at inlet of the receiving well to regulate the discharge.

19. Construction plan was worked out taking into account topographic, climatological, geological and other conditions prevailing over the area. Implementation programme of the project consists of detailed design, tender, contract and construction. The implementation period is estimated at 4 years from 1985 to 1988 for the first stage development and 3 years from 1992 to 1994 for the second stage development. The construction period is 20 months including 7 months of rainy period for the both first and second stage developments.

20. Investment cost was estimated based on the end-1983 price level as shown below.

(Unit: ₱10^6)

Stages	Foreign Currency	Local Currency	Total
First Stage	212.3	163.2	375.5
Second Stage	180.7	121.6	302.3
Total	393.0	284.8	677.8

The estimated investment cost includes the physical and price contingencies and tax to be levied on the construction work. The physical contingency is assumed to be 20% of the base cost. The price contingency is estimated at assumed escalation rates; 8% per annum for the local currency portion and 6% per annum for the foreign currency portion. The tax is computed to be 3.4% of the construction cost including physical contingency, in accordance with the current government regulation.

21. The disbursement schedule of the investment cost is prepared as shown below in accordance with the established project implementation schedule.

(Unit: ₱10^6)

First Stage				Second Stage			
Fiscal Year	Foreign Currency	Local Currency	Total	Fiscal Year	Foreign Currency	Local Currency	Total
1985	22.9	36.3	59.2	1992	10.8	3.4	14.2
1986	5.8	2.1	7.9	1993	104.3	72.1	176.4
1987	97.4	65.4	162.8	1994	65.6	46.1	111.7
1988	86.2	59.4	145.6				
Total	212.3	163.2	375.5	Total	180.7	121.6	302.3

22. Economic evaluation was conducted by computing economic internal rate of return (EIRR) based on economic cost and benefit with an economic life of 40 years. EIRR is calculated at 11.6% indicating high economic feasibility of the project. Sensitivity analysis revealed that the project maintain its economic soundness even with unfavorable changes in economic conditions.

23. Financial viability of the project was evaluated by financial internal rate of return (FIRR). FIRR was calculated at 9.6% showing sound financial viability of the project. Further, repayability of the assumed foreign loan was assessed by preparing cash flow statement. It was clarified that the project is capable of generating revenue to a sufficient extent to repay the assumed foreign loan.

24. It is deemed appropriate that the PWD will be responsible for implementation of the project and operation and maintenance will be undertaken by the Industrial Estate Authority of Thailand (IEAT). It is recommended that in the both stages, a close coordination with other development activities in the Laem Chabang Complex will be pursued by both agencies to ensure smooth and consistent proceeding of the project.

25. It is strongly recommended that the Government takes a prompt step to implement the water filtration plant and distribution system in compliance with an overall development programme of the Laem Chabang Complex.

TABLE OF CONTENTS

Page

Page

LIST OF TABLES

Page

LIST OF FIGURES

LIST OF DRAWINGS

ABBREVIATION 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
		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 = ¥ 230)
		US$	=	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

Alk.	=	alkalinity
mmho	=	micromho = conductance
ppm	=	parts per million
ppb	=	parts per billion
%	=	per cent
PS	=	0.736 kW
pH	=	scale for acidity
RSC	=	residual sodium carbonate
SAR	=	sodium adsorption ratio
SSP	=	soluble sodium percentage
TH.	=	total hardness
o	=	degree
'	=	minute
"	=	second
^{o}C	=	degree centigrade

(9) Derived Measures Based on the Same Symbols

m^3/s	=	cubic metre per second
t/ha	=	ton per hectare
MCM/yr	=	million cubic metre per year
lcd	=	litre per capita per day

B. OTHER ABBREVIATIONS

ASTM	=	American Society for Testing and Material
GDP	=	gross domestic product
GRP	=	gross regional product

El.	=	elevation
H.W.L.	=	high water level
L.W.L.	=	low water level
SD	=	sanitary district
DA	=	development area
NDA	=	non-development area
FOB	=	free on board
CIF	=	cost, insurance and freight

C. ABBREVIATION OF ORGANIZATIONS

DCD	Department of Community Development
DH	Department of Health
DOLA	Department of Local Administration
EGAT	Electricity Generation Authority of Thailand
IEAT	Industrial Estate Authority of Thailand
JICA	Japan International Cooperation Agency
LDD	Land Development Department
MD	Meteorology Department
MOI	Ministry of Industry
MWWA	Metropolitan Water Works Authority
NEB	National Environment Board
NESDB	National Economic and Social Development Board
NHA	National Housing Authority
NSO	National Statistical Office
OARD	Office of Accerelated Rural Development
OECF	Overseas Economic Cooperation Fund (Japan)
PAT	Port Authority of Thailand
PEA	Provincial Electricity Authority
PWD	Public Works Department
PWWA	Provincial Water Works Authority

RID	Royal Irrigation Department
SRT	State Railway of Thailand
TAT	Tourism Authority of Thailand
TCPD	Town and City Planning Department
WHO	World Health Organization

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 the Nong Kho-Laem Chabang Water Pipeline Project (the Study) was carried out in accordance with Scope of Work for the Feasibility Study on the Water Pipeline Construction from Nong Kho to Laem Chabang, which was concluded on 15 July, 1983 between Japan International Cooperation Agency (JICA), an official agency responsible for the implementation of technical cooperation programmes of the Government of Japan, and Public Works Department (PWD), Ministry of Interior, an executing agency of the Government of the Kingdom of Thailand (the Government).

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

The Study Team carried out the field survey and investigation during a 3-month period from August to November,1983, with the counterpart support provided by the Government. This final report was prepared by duly incorporating the Government's comments on the draft final report, which was submitted to the Government in February, 1984.

1.2 Historical Background

The Government requested the Government of Japan to provide technical cooperation for the Study. The project aims at transmitting the raw water from Nong Kho reservoir to Laem Chabang Complex through pipeline for domestic and industrial uses. The Laem Chabang Complex is one of target areas to be developed under Eastern Seaboard Development Programme (ESDP), which plays a role of spearhead in accomplishing the industrialization of Thailand. The ESDP is directed by the Eastern Seaboard Committee which is chaired by the Prime Minister.

The Laem Chabang Complex has three major development activities, involving the development of deep seaport, industrial estate and urbanization. The industrial estate covers the area of 450 ha and the first element of the deep seaport has been planned to come into operation between 1987 and 1990. The Nong Kho reservoir was created in 1983 by constructing a dam on the Khlong Nong Kho river by Royal Irrigation Department (RID), with a primary purpose to supply water to the Laem Chabang Complex. The Nong Kho dam is located at approximately 15 km east of the proposed Laem Chabang Complex. The reservoir has a gross storage capacity of 26×10^6 m^3.

In response to the request of the Government, the Government of Japan decided to conduct the Study within the general framework of technical cooperation between Japan and Thailand, which is set forth in the Agreement of Technical Cooperation between the Government of Japan and the Government of the Kingdom of Thailand signed on 5 November, 1981. The Government of Japan dispatched a mission, through JICA, to Thailand in July, 1983 to confirm the Scope of Work of the Study.

Apart from the above, in compliance with the requests of the Government, JICA has completed the feasibility study of the East Coast Water Resources Development Project in two phases during the period from 1981 to 1983, in a close coordination with RID. The Phase I Study was performed during the period from 1981 to 1982 and formulated the feasibility study of the Ban Bung and Nong Pla Lai Dam Projects. The Phase II Study elaborated the long-term water supply plan over the entire Eastern Seaboard and the feasibility study of the Khlong Luang, Khlong Yai and Khlong Thap Ma Dam Schemes. The Khlong Yai Dam Scheme includes an inter-basin water diversion system between the Nong Pla Lai dam and the Nong Kho dam as a part of the scheme. The inter-basin water diversion system has been planned with the aim to alleviate the Laem Chabang-Pattaya corridor from water deficit.

1.3 Objectives of Study

The objectives of the Study are;

(1) to formulate a plan for the pipeline system from the Nong Kho dam to Laem Chabang, and

(2) to verify the feasibility of the pipeline system for the industrial and domestic water in the Laem Chabang Complex.

In order to accomplish satisfactorily the above objectives, the scope of work has been set forth as outlined below.

(1) Topographic survey
(2) Geological investigation, including laboratory test of soils
(3) Review of hydrological data
(4) Review of water balance study
(5) Plan formulation
(6) Preliminary design and cost estimate
(7) Economic and financial evaluation

1.4 Study Team and Advisory Committee

The JICA appointed a Study Team to carry out the Study with the counterpart support provided by the PWD. An Advisory Committee was established by the JICA to review the findings by the Study Team.

The members of the Advisory Committee and Study Team are listed in Table 1.

1.5 Acknowledgement

The Study Team wishes to record its appreciation to Mr. Tongchul Singhakul, Director General of the PWD, and Mr. Pojana Kantamala, Deputy Director General of the PWD, for their kind assistance throughout the study period. A heartfelt thank is made to Mr. Niyom Niyamanusorn, Director of Provincial Water Supply Division, PWD, for his constant advice and cooperation.

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2. BACKGROUND

2.1 Characteristics of Thailand

Thailand with a territorial area of 513,000 km^2 is situated in the Indo-Chinese Peninsula. It lies between 5^o and 21^o in the north latitude and between 97^o and 106^o in the east longitude.

The population in Thailand was approximately 46.5×10^6 in 1980, of which about 4.7×10^6 people are concentrated in Bangkok Metropolis, a capital of the Thailand. The population growth was 2.5% per annum during a 10-year period from 1970 to 1980.

Thailand is primarily an agricultural country; approximately 63% of the total working people are engaged in agriculture. The GDP reached ฿315×10^9 in 1981 at 1972 constant price, being composed of ฿151×10^9 deriving from the service sector, ฿88×10^9 from the manufacturing sector and ฿76×10^9 from the agricultural sector. The amounts of imports and exports in 1981 were ฿217×10^9 and ฿153×10^9, respectively. The most dominant export commodity is rice with amount of ฿26×10^9, while petroleum and lubricant are the major import commodities with amount of ฿65×10^9.

2.2 National Development Plans

The economy of Thailand has achieved a continuous expansion, through its Five-Year National Development Plans, which cover the periods of 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. The GDP marked a high growth rate of 8.5% per annum, through the Third and Fourth national plans.

The Government issued, in October 1981, the Fifth National Economic and Social Development Plan (Fifth National Plan), covering a 5-year period from 1982 to 1986. The Fifth National Plan was enacted reflecting the performance in the previous four national plans. The policy objectives of the Fifth National Plan are (i) to restore the nation's economic and financial stability, (ii) to adjust the economic structure and to improve the economic efficiency, (iii) to develop the social structure and to improve the social services, (iv) to alleviate poverty and (v) to coordinate consistently the economic development activities with the national security management. With regard to economic growth, the Fifth National Plan aims at attaining the overall growth rate of 6.6% per annum in terms of GDP, consisting of 4.5% per annum in agriculture, 7.6% per annum in manufacturing and 16.4% per annum in mining.

2.3 Eastern Seaboard Development Programme

The Government lays a great emphasis on successful implementation of the Eastern Seaboard Development Programme in order to accomplish the policy objectives and economic targets set forth in the Fifth National Plan. The Eastern Seaboard extends over Chachoengsao, Chon Buri and Rayong Provinces as shown in Fig. 1, and development period of the ESDP covers the Fifth and Sixth National Plans, 1982 to 2001. The ESDP has been established with a high priority to;

(1) development of the natural gas related industries in Map Ta Phut in Rayong Province and pollution free and light labor intensive industries in Laem Chabang in Chon Buri Province, and

(2) creating jobs and facilities to encourage urban development away from Bangkok Metropolis.

The ESDP contemplates to develop two other target areas; Pattaya for commercial and tourism industry and Sattahip for transportation.

It is being expected that the ESDP will create a new job opportunity for approximately 300,000 people and will save approximately ฿ 40×10^9 in foreign exchange. Thailand is expected to be a semi-industrialized country by the end of the Fifth National Plan and an industrialized country by the end of the Sixth National Plan.

The major industries to be introduced into Map Ta Phut Complex are gas separation plant, fertilizer complex, petrochemical complex and soda ash plant. As to the industrial development of the Laem Chabang Complex, although definite plan has not been formulated yet, a general framework has been issued as aforementioned. Recently "Eastern Seaboard, Industrial Opportunities Identification Study" (IOS) was completed by Coopers and Lybrand associate under contract with the NESDB. The IOS envisages to introduce five categories of industry into the Laem Chabang Complex; (i) resources based industry, (ii) export processing industry, (iii) downstream manufacturing industry, (iv) ship repairing and services and (v) other light industry. Specific types of industry for each category are presented in Table 2, together with the proposed number of plants to be operated by 1991.

The Government has been endeavouring to provide and improve various infrastructural facilities such as railroads, roads, water and power supplies, communication system, transportation facilities etc. for smooth and successful implementation of the ESDP. According to the "Eastern Seaboard Development Programme, January 1983, NESDB", the amount of investment for infrastructural facilities is estimated to be ฿ 13,353 x 10^6.

2.4 Pipe-water Supply Services

The public pipe-water supply service in Thailand is divided into two categories, namely, large scale water supply programme and rural water supply programme. The objective areas of the former cover the municipalities/sanitary districts with more than 5,000 population, while that of the latter is composed of the sanitary districts/rural communities with 1,500-5,000 population.

A number of the government agencies and departments are concerned with the public pipe-water supply services. The Metropolitan Water Works Authority (MWWA), which was established in 1967 as a state organization, is wholly responsible for Bangkok Metropolis. The Provincial Water Works Authority (PWWA), which was established in 1979 under jurisdiction of the Provincial Water Works Act B.E. 2522, manages the large scale water supply programme over 88 municipalities and 135 sanitary districts in 1982. PWD, DH, DCD, DOLA, OARD and sanitary district authority are related to the implementation and operation of the rural water supply programme. There are a number of the so called concession water works, for which PWD is responsible for all engineering and management activities.

According to "The Fifth Five Year Economic and Social Development Plan (B.E. 2525-2529)" prepared by PWWA, the 1981 pipe-water supply situation over Thailand excluding Bangkok Metropolis is as summarized below.

Water Supply Programme	Nos. of System (nos.)	Plant 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

The present pipe-water service ratio is estimated to be 15% for the whole Thailand excluding Bangkok Metropolis. The average water consumption per capita is 180 liter per day, according to the record of water consumption by 14 waterworks in Region 1 covering the Chachoengsao, Chon Buri, Rayong, Trad and Chantaburi Provinces. The record is presented in Table 3.

The water tariff of PWWA is uniform throughout the administrative area and is as tabulated below.

Monthly Water Use (m^3)	Tariff (฿/m^3)
below 10	2.00
11 - 20	2.50
21 - 50	3.00
51 - 80	4.00
81 - 100	4.50
101 - 300	5.00
above 301	5.50

The water tariff system of the rural water supply programme is different from that of PWWA and is established individually by sanitary district authority. The present rate ranges from ฿1.00/m^3 to ฿5.00/m^3.

3. THE STUDY AREA

3.1 Delineation of The Study Area

In the Scope of Work, the Study Area has been defined as follows.

(1) Water Source : Nong Kho dam

(2) Service Area : Laem Chabang vicinity

(3) Pipeline Route : Nong Kho Dam to Laem Chabang Complex

The project, however, must be formulated in due consideration of the long-term water demand and availability of water resources in and around the Laem Chabang Complex.

According to the "East Coast Water Resources Development Project (Phase II), Main Report, Feasibility Study on Khlong Yai Dam Scheme, August 1983, JICA", a city of Pattaya would suffer from shortage of water supply in near future and it is most advantageous to install water conveyance system between the Pattaya and the Laem Chabang Complex.

With the above background and in order to formulate a definite plan of the project, the Study Area is delineated encircling the Laem Chabang-Pattaya corridor as shown in Fig. 2. It is composed of the Khlong Bang Lamung river basin (hereinafter called Laem Chabang Basin) and Huai Nong Pru river basin (herein after called Pattaya Basin). The Laem Chabang Basin covers the area of 333 km^2, including the Huai Bo Yai river having a drainage area of 32.4 km^2. The Pattaya Basin with a gross area of 154.7 km^2 embraces also two sub-river basins; the Khlong Pattaya river basin with a drainage area of 20.3 km^2 and the Map Phawa river basin with 31.4 km^2.

3.2 Administrative Division and Population

Administratively the Study Area covers the majority of Si Racha and Bang Lamung Districts and the entire Pattaya City in Chon Buri Province.

According to the statistic data of DOLA, population in the Study Area is approximately 116.9×10^3 in 1982. It is anticipated to grow rapidly and largely due to the ESDP. The future population in the Study Area has been projected by the "Eastern Seaboard Study, September 1982, Coopers and Lybrand Associates" (ESS), as shown below.

(Unit: 10^3 people)

District	1982	1986	1991	1996	2001
Si Racha	59.7	68.9	89.6	117.9	162.6
Bang Lamung	18.8	21.7	24.1	24.3	21.7
Pattaya	38.4	51.4	67.9	85.8	103.0
Total	116.9	142.0	181.6	228.0	287.3

Pattaya is well-known as a seaside resort place. The number of tourist in 1982 amounted to 599×10^3 in terms of arrival.

3.3 Topography

The Study Area is characterized by undulating hilly topography. The land elevation rises from the sea level to El. 542 m at Khao Nam Cho in the northeastern tip of the Study Area. The majority of the Study Area are below El. 100 m.

The proposed deep seaport area is facing the Gulf of Thailand and the most of the area lie below El. 5 m. The area of the industrial estate is located adjacent to the proposed deep seaport area in the west of Route 3 as shown in Fig. 2. Its altitude ranges from El. 5 m to El. 30 m. The urban development area is likely to be selected to the opposite side of the industrial estate. The elevations of the area varies from El. 20 m to El. 60 m.

3.4 Climate

The climate over the Study Area is tropical and monsoonal. There are two distinct seasons in a year. Dry season with the northeast monsoon lasts from November to April, while wet season with the southwest monsoon extends from May to October.

Air temperature is 27.9°C on the average. Its diurnal and annual variations are about 2°C and 9°C respectively. Mean relative humidity ranges from 66% in December to 80% in September. Diurnal variation of relative humidity is 30-35% for the dry season and 25-31% for the wet season. The average annual rainfall is about 1,300 mm, of which more than 80% occurs during the wet season. The amount of evaporation is slightly less than annual rainfall, being 1,100 mm per year. The climatological features of the Study Area are summarized in Table 4.

3.5 Hydrology

Major rivers in the Study Area are the Khlong Bang Lamung and Huai Nong Pru rivers. Their drainage areas are, at estuary, 301 km^2 and 103 km^2 respectively. The water resources of the both river basins have been developed to some extent; the Nong Kho dam has just been built on the Khlong Nong Kho river, a tributary of the Khlong Bang Lamung river by the RID in 1983, and the Map Prachan dam has also been constructed astride the Map Prachan and Map Tao Kiat rivers, tributaries of the Huai Nong Pru river, by the RID in 1979. Both dams have a multiple-purpose nature for water supply, irrigation and flood control.

In spite of such water resources development activity, the observed hydrological records are hardly available for the both river basins and even for the similar river basins in the eastern seaboard. The annual water supply capacities of the Nong Kho and Map Prachan reservoirs, therefore, have never been analyzed yet quantitatively in detail, though they are the most significant factors in water supply planning.

In the hydrological investigation, therefore, the work programme was laid to analyze the run-offs at the Nong Kho and Map Prachan damsites in order to estimate the water supply capacity of the reservoir. At first, the run-offs of the Bang Phra damsite/1 were analyzed based on a reservoir water balance calculation by using the reservoir operation record, evaporation and rainfall. The simulated run-offs were further refined by comparing them with the recorded run-offs at the Dok Krai damsite/2. The run-offs at the Nong Kho and Map Prachan damsite were finally derived from the simulated run-offs of the Bang Phra damsite in proportion of their drainage areas. The detailed procedures of the run-off analysis are reported in Supporting Report II, Hydrology.

The estimated monthly run-offs of the two damsites are presented is Tables 5 and 6. The average, maximum and minimum annual run-offs during a 15-year period from 1968 to 1982 are as summarized below.

Damsite	Annual Run-off ($10^6 m^3$/yr)		
	Average	Max.	Min.
Nong Kho	21.8	41.6	6.0
Map Prachan	13.9	26.2	3.8

In order to determine the rate of river maintenance flow and to verify the availability of water resources in the Huai Kong Dai river, flow duration curve of the Khlong Bang Lamung river at the Nong Kho damsite is prepared based on the estimated run-offs during a 15-year period from 1986 to 1982 as presented in Fig. 3.

/1 : Located in the Huai Sukhrip river basin with a drainage are of 123 km^2, adjacent to the Khlong Bang Lamung river basin.

/2 : Having a drainage area of 291 km^2 and located in the Rayong river basin.

3.6 Water Quality

Water samplings and quality tests were conducted periodically throughout the field investigation period in collaboration with the PWD's laboratory. The purpose is to test the quality of water in the Nong Kho reservoir and Huai Kong Dai river as industrial and domestic water source. The results of the laboratory tests are presented in Table 7.

According to the results, no defects were found to use it as source of industrial and domestic water. Both the Nong Kho reservoir and Huai Kong Dai river are judged to Class 2 in the light of NEB's water quality criteria of fresh surface water. This class is defined as good quality water source and can be used for consumption and supply after general treatment, conservation of aquatic life with regard to fishery, agriculture, recreation, etc.

At present, there are not any particular pollutant sources in the watersheds of the Nong Kho dam and Huai Kong Dai river. Probable source of pollution in future is deemed to be poultry farms and human waste. Sewage from these sources are being disposed by pit latrines. It is foreseeable that amount of sewage would increase largely in future due to expansion of economic activities and growth of population. It is advisable to monitor the water quality carefully and to establish appropriate measure for watershed management for conservation of the water resources and quality.

3.7 Geology and Soil Mechanics

The geological and soil mechanical investigations were performed during the period from October to November 1983, during which both field investigation and laboratory test were carried out. The field investigations were made for both the south and middle routes of the pipeline, with more stress on the middle route. The middle route was investigated by means of core drilling, hand auger boring and test pitting. The spots of the investigations are shown in Fig. 4. Details of the geological and soil mechanical investigations are reported in Supporting Report III, Geology and Soil Mechanics.

The proposed pipeline route (middle route) is laid out on a flat plain with a little undulation, descending with very mild gradient from the Nong Kho dam at El. 60 m up to the Huai Lek river crossing at El. 15 m and then ascending more sharply up to the receiving well at El. 37 m. The distance is approximately 12.7 km from the Nong Kho dam to the Huai Lek river and 1.8 km from the Huai Lek river to the receiving well. The terrain in the surroundings consists of cultivated land. Vegetation is mainly composed of cassava and palm in the higher parts than El. 25 m and on the mild slopes. Low flat land is utilized for cultivation of paddy and sugarcane.

Geological condition along the proposed pipeline route is as shown in Fig. 5. Bed rock is granite in the entire project area, and is classified into (i) completely weathered zone, (ii) highly weathered zone and (iii) slightly weathered zone. The completely weathered zone is approximately 3 m in thickness, including top soil, and is composed mainly of sand or sandy soil. The highly weathered zone, underlying the completely weathered zone, tends to be thick in relatively high land and thin in relatively low land, consisting dominantly of sandy soil with high clay content. The slightly weathered zone, the lowermost of the three zones, still retains texture of granite, and is often sampled as rock fragments with clayey material.

It has been revealed through the sub-surface exploration that a fairly homogeneous condition can be expected for the completely weathered and highly weathered granite zones, where the pipeline will be laid. Therefore, the foundation has only to be compacted sufficiently and homogeneously. It is deemed that the highly weathered granite zone encountered at about 3 m of depth provides a competent sub-base for the structures, upon which the structures can be placed directly.

As shown in Table 8, the soil is for the most parts sandy up to the depth of 3 m and falls under the classification of "SM". These soils are observed to be good for embankment or backfill material. The value of pH of the soil falls under the range of weak acidity from 5 to 6 for the most part and is 4.5 in the minimum. Acidic corrosion of steel is strong when pH is less than 4.0, and measured value is barely out of limit for that. So far as the pH is concerned, effect of corrosion seems to be not intensive. In-site corrosion test, however, is recommended to be carried out at detailed design stage.

3.8 Infrastructure

Various infrastructural development activities are being energetically promoted by the Government in relation to implementation of the ESDP. Major infrastructures are described hereunder.

A single track railroad linking Chachoengsao and Sattahip is under construction by SRT and runs in parallel with Route 3 as shown in Fig. 6. A branch track leading to Laem Chabang deep seaport is planned to be laid down along the existing rural road in future.

A national highway, Route 3 passes through the Study Area in a north-south direction and Route 331 also running in the north-south direction goes through almost in parallel along the eastern boundary of the Study Area. Within the Study Area, the provincial highways and rural roads are well developed and they connect Route 3 with Route 331.

The Study Area is served by the well networked electricity supply system. EGAT is now constructing double circuit-230 kV transmission line in addition to the existing single circuit-115 kV transmission line.

There exist two public waterworks in the Study Area; one is Ao Udom waterworks and the other is Naklua-Pattaya waterworks. The water supply status in the Study Area is discussed in Chapter 4.

Gas pipeline, which takes its origin in the Map Ta Phut Complex, will be aligned across the Study Area to reach a Marine Terminal Station located in the vicinity of Laem Chabang.

Particularly in Pattaya, further development of infrastructures such as road network, drainage, sewerage collection system and sewage treatment plant is at present underway to promote tourism.

4. WATER SUPPLY SITUATION IN THE STUDY AREA

4.1 Public Pipe-water Supply Systems

The public pipe-water supply comprises residential, commercial and manufacturing water use. There is no separate water supply system for manufacturing in public utility system in the Study Area.

Under the prsent public pipe-water supply administration,the Study Area is divided into three sub-areas, namely, Ao Udom Sanitary District, Bang Lamung Sanitary District and Pattaya City. The division of the sanitary districts is as shown in Fig. 7.

The Ao Udom Sanitary District extends over 379 km^2, of which approximately 70 % falls in the Study Area. Out of the district population of 64,350, 51,450 people reside within a territorial area of the Study Area. A part of the district is served by the pipe-water from the Ao Udom waterworks, which is sorted as rural water supply system and is managed by the Ao Udom Sanitary District Office.

The Bang Lamung Sanitary District covers the area of 22.4 km^2 with a population of 8,190. The district, however, is not provided with the public pipe-water supply system.

The Pattaya City with about 53,000 population is served by Naklua - Pattaya waterworks, operating under full responsibility of PWWA.

The locations and approximate service areas of two existing waterworks are shown in Fig. 7. The characteristics of the existing waterworks are briefly described below.

(1) Ao Udom Waterworks

It is located in the vicinity of Ban Bo Yang and was developed by the Ao Udom Sanitary District Office in 1970. The treatment plant capacity is 1,200 m^3 per day. The service area is confined to Ao Udom Town and area along Route 3241. The water source is dependent on the Huai Yai river, where the Nong Kho dam is situated at approximately 10 km upstream from the waterworks. The water supply quantity varies largely from month to month in correlation with fluctuation of stream flow of the Huai Yai river. During a two-month period from April to May 1980, the water supply service is completely stopped, since the Huai Yai river ran dry owing to extreme drought. A radical measures are urgently required to preserve health and welfare of inhabitants. The water tariff system of the Ao Udom Sanitary District is different from that of the PWWA. The present water tariff is as tabulated below.

Monthly Water Use (m^3)	Tariff (฿/m^3)
below 50	3.00
50 - 150	4.00
above 151	5.00

(2) Naklua - Pattaya Waterworks

The waterworks are located adjacent to the Map Prachan dam and have a daily production capacity of 25,920 m^3 per day. The production capacity was augmented to the present level in 1981, by adding a new treatment plant with a daily production capacity of 24,000 m^3. It is now feeding a number of hotels in Pattaya City, which had been dependent mostly on a very confined groundwater resources for their bulk water use before completion of the additional facilities installation of the Naklua - Pattaya waterworks and completion of the Map Prachan dam.

Table 9 summarizes the historical water supply and use, number of consumers and other relevant data concerned with the Ao Udom and Naklua - Pattaya waterworks.

Except for Pattaya City, the Study Area is scarcely favoured with the pipe-water supply. In the Ao Udom Sanitary District, pipe-water served population is no more than 7 % of the entire population in 1982. Residents in the outside of the pipe-water service area depend on rain-water and groundwater for their domestic use. Almost all homesteads are provided with rain barrels or cisterns to store rainwater running off roofs or shallow dug-well. The water onsumption per capita is 180 liter per day at present, according to the historical water supply record of the Ao Udom waterworks.

4.2 Private Water Supply Facilities

Apart from the public pipe-water supply system, there are a number of water supply facilities owned by private enterprises and government institutions in the Study Area. They derive their water from pondage, stream and groundwater to meet their water requirement.

An extensive inventory survey was conducted over the Study Area to identify such private water supply facilities. The survey was rather crucial, since no statistics are available. The locations and water sources of the private water supply facilities are shown in Fig. 8. The characteristics of these facilities are shown in Table 10 and are summarized below.

Category of Private Water Supply Facilities	Present Water Supply (10^3 m^3/yr)			
	Surface water	Sea water	Groundwater	Total
1. Government Institutions	146	0	37	183
2. Private Enterprises				
Oil refinery	860	790	0	1,650
Sri Racha Park estate	0	0	249	249
Agro-processing	800	0	0	800
Total	1,806	790	286	2,882

There are two oil refinery plants consisting of Thai Oil Refinery and ESS Oil Refinery. The former will increase the water withdrawal from the Bang Phra reservoir to 2.0×10^6 m^3 per year in 1987 and the latter will augment its water consumption to 1.5×10^6 m^3 per year in 1985.

Sri Racha Park Estate is located at approximately 7 km east of Ao Udom Town and is at present, accommodating 6 firms of light industry in its 58 ha of land. Out of 6 firms, 5 firms are using tube-wells for their water supply. The estate will be expanded to 160 ha in 1987, resulting in the increased water demand of 1.3×10^6 m^3 per year. The organization of the estate is keen to secure new source of the stable bulk water. The availability of the water resources in the surrounding area appears short of the requirement.

The agro-processing industry comprises of Sri Rach Sugar Factory and Kho Chang Cassava Industry. Sri Racha Sugar Factory has been confronted with serious water shortage. In 1980, the firm was unexpectedly obliged to stop its operation, since the stream flow of the Huai Lek river ran dry. Kho Chang Cassave Industry has obtained concession from the RID for water withdrawal from the Map Prachan reservoir. According to the firm, its annual water consumption will amount to 860×10^3 m^3 in 1986.

4.3 PWWA's Five-Year Plan

The PWWA has drawn up its own five-year plan in the light of objectives of the Fifth National Plan. Basic policies of the plan are as follows.

(1) The PWWA will develop and strengthen the utility services in the urban area in conformity with the government's urban development planning and land utilization programmes.

(2) The PWWA will assist the local authorities financially and technically to promote the pipe-water supply services in the rural area in order to reduce a gap in living standard between the urban area and the rural area.

In line with the above policies, the targets have been set forth as follows.

(1) The large scale water supply programme will include;

- improvement of plant and expansion of distribution area for 125 locations,
- construction of new plants in 50 locations,
- expansion of plant capacity and distribution area for 81 locations,
- master planning for waterworks development for 10 locations

The above activities will result in producing potable water up to $1,414 \times 10^3$ m^3 per day by 1986, and serve approximately 4.4 million people.

(2) The rural water supply programme will be composed of;

- development and expansion of water works in 150 locations, consisting of 100 sanitary districts and 50 villages,
- provision of a new supply system for 250 locations, consisting of 200 sanitary districts and 50 large communities

By the end of the five-year plan, there will be 900 waterworks, covering 2,000 communities, in the rural area.

As far as the Study Area is concerned, the PWWA's plan includes two projects within the large scale water supply programme. One is to strengthen the water supply services in the Ao Udom Sanitary District in order to meet the rapidly increasing water demand due to development of the Laem Chabang Complex. According to the plan, a new waterworks with daily production capacity of 4,000 m^3 will be constructed by 1983 and the water will be supplied from the Bang Phra reservoir through Si Racha waterworks. The other is to provide the pipe-water service system in the Bang Lamung Sanitary District. The water supply will be made by means of extension of the Naklua - Pattaya water supply system and its quantity will be 1,000 m^3 per day. Its completion has been set out in 1984.

So far PWWA has not taken up any direct action with respect to the implementation of the above programmes. Meantime, the Nong Kho - Laem Chabang Water Pipeline Project has been launched by the Government, aiming at supplying the industrial and domestic water to the Laem Chabang Complex from the Nong Kho reservoir. In the light of the latest circumstances, the PWWA's plan is evidently subject to modification to some extent. It is advisable to establish the well-organized water supply system over the Laem Chabang area so that water resources management can be executed efficiently and effectively and water supply administration can also be attained rationally and systematically.

5. WATER DEMAND AND SUPPLY BALANCE

5.1 Approach to Study

The scale of the project is eventually dependent on magnitude of water demand and availability of water resources in and around the Study Area. It has been predicted in "The East Coast Water Resources Development Project (Phase II), Main Report on Feasibility Study on Khlong Yai Dam Scheme, August 1983, JICA" that the Study Area will face an accute shortage of water supply and that an inter-basin water diversion between the Nong Pla Lai dam and the Nong Kho dam is the most promising plan to keep the Study Area wholly supplied of the required water. A study on water demand and supply balance is therefore significant to formulate an optimum development plan of the project and to clarify the timing and quantity of the inter-basin water diversion. The water balance of the Study Area was reviewed based on the updated water demand projection and hydrological analysis. Several important factors related to the water balance study are expressed below.

(1) Target Year

A final target year has been set forth in 2001, by which the first stage development of the Laem Chabang Complex is being programmed to be completed. The water demand projection and balance study are, however, worked out at intervals of 5 years; 1986, 1991, 1996 and 2001. This is requisite to formulate the optimum development plan of the project and timing of the introduction of the inter-basin water diversion system.

(2) Division of Study Area

The water resources management is, in principle, controlled on the basis of river basins. The Study Area is divided into the Laem Chabang Basin and Pattaya Basin. Referring to the ESS, each basin is further sub-divided into development area

(DA) and non-development area (NDA) as shown in Fig. 7. The development area is composed of the proposed industrial and urban development areas and the surrounding area where the socio-economic activity is foreseen to be generated spontaneously in consequence of the various development activities by the government in the proposed development area. The non-development area covers the rest of the Study Area.

(3) Water Demand

The water demand is broadly classified into domestic use, industrial use, port use and tourism use. In addition, river maintenance flow is taken into account. The river maintenance flow is the minimum discharge, which is able to preserve riparian land and people's amenity, to conserve groundwater and to maintain water quality, channel stability, aqua-eco system, etc.

(4) Standard Year

The water supply project is generally designed based on hydrological condition of a standard drought year, which has a recurrence interval of once in 10 years. In the present case, it is conservatively determined that the project will be formulated based on hydrological condition of the driest year during a 15-year period from April, 1968 to March, 1983. This concept is introduced under apprehension that the 15-year hydrological data are not sufficient enough to deal with unforeseen risks, which may occur in a long-range hydrological cycle.

5.2 Water Demand Projection

5.2.1 Industrial Water Demand

The industrial water demand accrues from three sources, namely, existing industry, induced industry and multiplied industry. The present and future water demands of the existing industry are explained in detail in Chapter 4 based on the inventory survey. The multiplied industry is defined by industries that would be generated in the surrounding areas of the proposed industrial estate as a result of multiplier effect of the induced industrial development. The water demand of the multiplied industry is assumed to be included in domestic water, since it is difficult to identify specific types of industries and its amount of water consumption would not be as big as to be treated independently. The industrial water demand projection, therefore, focuses on the induced industry. Details of the water demand projection are compiled in Supporting Report IV, Water Demand Projection.

The water demand of the induced industry was estimated on the basis of number of employees and unit water consumption per employee by type of industry. The industrial water demand is therefore projected for each type of industries at intervals of 5 years by the following equations.

$$DI = En \times UC \times (1 - Rn) \times 365/(1 - UW) \quad \text{.................} \quad (1)$$

$$DI(i) = DI \times En(i) \times [1 - Rn(i)]/[En \times (1 - Rn)] \quad \text{..........} \quad (2)$$

where,

DI; water demand in 2001, m^3/year

En; number of employee in 2001

UC; water consumption per employee, m^3/employee/day

Rn; rate of recycled water

UW; rate of unaccounted for water

Suffix (i) indicates the intermediate years

The prospected types of industries to be introduced into the Laem Chabang Complex have been studied by the IOS as presented in Table 2. The number of employees to be generated by the induced industries has also been projected by the ESS as presented below.

Categories of Industry	Number of Employee 1986	1991	1996	2001
Downstream	250	1,250	2,500	4,000
Light	250	1,400	3,550	7,800
Export processing	0	2,000	5,000	11,000
Agro-processing	250	250	250	250
Total	750	4,900	11,300	23,050

The types of the industries presented in Table 2 are adjusted so as to correspond to the classification of number of employees in order to obtain the number of employee of each industry. The industries of the both resources based and other light industry categories are integrated into the light industry. The number of employee of each plant is assumed to be proportional to the number of plant and is calculated as shown in Table 11.

The water consumption per employee by industry is quoted from the statistical data in Japan and is as presented in Table 11.

The cyclical use of water is foreseen to be practiced widely in future with the progress of water saving technology and for the purpose of cost saving. Rate of water recycling is different industry by industry. Relatively high portion of water would be recycled in industries producing such basic materials as steel and chemical products and other industries related with processing and assembling of machines etc. On the contrary, the rate would be low in such industries as food and apparel production. It is assumed that the rate of recycling would be pervaded with the following progress.

Categories of Industry	Average Water Recycling Rate (%)			
	1986	1991	1996	2001
Downstream	0	11	22	34
Light	0	17	34	50
Export processing	0	23	46	68
Agro-processing	0	3	6	10
Total	0	14	31	50

The water demand of the induced industry was calculated initially for the target year 2001 by the above equation (1) as shown in Table 11, while that of the intermediate year was obtained by the equation (2) as summarized below.

Categories of Induced Industry	Industrial Water Demand ($10^6 m^3/yr$)			
	1986	1991	1996	2001
Downstream	0.6	2.8	5.0	6.8
Light	0.3	1.4	2.8	4.7
Export processing	0	1.9	3.3	4.3
Agro-processing	1.7	1.6	1.6	1.5
Total	2.6	7.7	12.7	17.3

The above water demand will be generated in the Laem Chabang industrial estate. The annual gross industrial water demand in the Study Area will be 2.9×10^6 m^3 in 1982, 7.1×10^6 m^3 in 1986, 14.2×10^6 m^3 in 1991, 19.2×10^6 m^3 in 1996 and 23.8×10^6 m^3 in 2001, including the water demand of the existing industry.

5.2.2 Domestic Water Demand

The domestic water demand comprises residential, commercial, institutional and minor manufacturing water uses. It is forecasted also for every 5-year period for the development and non-development areas of the Laem Chabang and Pattaya Basins as well as the Bang Lamung Sanitary District, for which provision of the pipe-water supply is being planned as explained in the preceding Section 4.3. The projection of the domestic water demand is given by the following equation;

$$Dd = Pn \times CPC \times SF \times 365/(1 - UW) \quad \ldots\ldots\ldots \quad (3)$$

where,

Dd; domestic water demand, m^3/yr

Pn; population

CPC; consumption per capita, m^3/capita/day

SF; service factor

UW; rate of unaccounted for water

Historical and future population in the Study Area are presented in Table 12. The future population is derived from the population projection by the ESS.

Rate of consumption per capita is determined based on the currently prevailing rate in Thailand and assumed growth rate in future. For the Laem Chabang development area and Bang Lamung Sanitary District, the consumption per capita in 1982 is assumed to be 180 liter per day, which is corresponding to the average of 6 waterworks with served population of more than 10,00 in Region 1 as shown in Table 3. For the Pattaya development area, the consumption per capita is presumed to be the same with the standard rate of Bangkok Metropolis, 250 liter per day, because of the existence of many tourism related services industries. In the non-development area, commercial, minor manufacturing and institutional uses are deemed to be far less than that of the development area. Accordingly, the present rate of consumption per capita is assumed to be 140 liters per day.

In future, the rate of the consumption per capita is foreseen to grow steadily consistent with expansion of economic development activities and upgrading of living standard. The annual growth rate is broadly assumed to be one per cent. The future consumption per capita thus calculated is presented in Table 12.

The service factor is the ratio between the pipe-water served population and the total population in the service area. It is assumed that the development areas and Bang Lamung Sanitary District will completely be provided with the pipe-water supply network. Prevalence rate of the pipe-water supply service will be slower in the non-development area; 10 per cent in 1986, 15 per cent in 1991, 20 per cent in 1996 and 30 per cent in 2001.

The unaccounted for water is taken at 15 per cent as same as the industrial water demand. The projection of the domestic water demand is shown in detail in Table 12.

The annual domestic water demand will be 9.3×10^6 m^3 in 1986, 13.7×10^6 m^3 in 1992, 19.2×10^6 m^3 in 1996 and 26.9×10^6 m^3 in 2001.

5.2.3 Port Water Demand

The port water demand comprises two categories; one is related to port services such as loading, unloading and port administration and the other is water use by ship. The port water demand is, therefore, given by the following equation:

$$Dp = [(W \times UCw) \times 365 + (Cv \times UCc)]/(1 - UW) \quad (4)$$

where,

- Dp; port water demand, m^3/yr
- W ; number of workers at port
- UCw; water consumption per worker, m^3/worker/day
- Cv; cargo handling volume, ton/year
- UCc; water consumption per cargo volume, $m^3/t/year$
- UW; rate of unaccounted for water

The port water demand was initially projected for 1991. For 1996 and 2001, it is estimated in proportion to cargo handling volumes, since no appropriate data are available concerning the number of workers beyond 1991.

The number of workers has been projected to be 2,800 in 1991 by the National Housing Authority. The water consumption per worker and per cargo handling volume are set down at 150 liters per day and 4.1 liters per year respectively, according to the "Draft Final Report for The Development Project of The Industrial Port on The Eastern Seaboard in The Kingdom of Thailand (Phase II), September 1983, JICA".

The cargo handling volume is determined basically depending on the "Feasibility Study of The Development of Laem Chabang Port, December 1982, Louis Berger International Inc.". The report predicts the total cargo volume of the Bangkok and Laem Chabang ports. By subtracting the cargo handling capacity of the Bangkok port (6.5×10^6 ton/yr in 1985)/1 from the total cargo volume, the annual cargo handling volume of the Laem Chabang port is forecasted to be 3.1×10^6 tons in 1991, 6.3×10^6 tons in 1996 and 9.0×10^6 tons in 2001.

Annual port water demand is projected to be 0.2×10^6 m^3 in 1991, 0.4×10^6 m^3 in 1996 and 0.5×10^6 m^3 in 2001.

/1 : According to the Port Authority of Thailand

5.2.4 Tourism Water Demand

The tourism water demand is obtainable by the following equation:

$$Dt = T \times UCt \times 365/(1 - UW) \quad \text{.......................... (5)}$$

Where,

Dt; tourism water demand, m^3/yr

T ; number of tourist

UCt; water consumption per tourist, m^3/tourist/day

UW; rate of unaccounted for water

The number of tourists to Pattaya has been projected by the ESS as shown below. The water consumption per tourist is assumed to be 400 liters per day, which corresponds to the average rate prevailing in Japan. The figure includes various water uses in hotels by customers and hotel's facilities such as pool, restaurant etc.

The potable water will be served for the whole tourists. The rate of the unaccounted for water is the same as those of development areas.

The projection of the tourism water demand are as given below.

Description	Unit	1982	1986	1991	1996	2001
Number of tourist	10^3p/d	9.2	12.6	18.1	24.8	30.9
Consumption rate	lcd	400	400	400	400	400
Service factor	%	100	100	100	100	100
Unaccounted for water	%	15	15	15	15	15
Annual water demand	10^6m^3	1.6	2.2	3.1	4.3	5.3

5.2.5 Overall Water Demand

The overall water demand is the sum of the industrial, domestic, port and tourism water demands and is calculated at every 5-year period as presented in Table 13. The domestic water demand of the Bang Lamung Sanitary District is, however, comprised in the Pattaya Basin, based on the premise that the district will be fed by the Naklua-Pattaya waterworks, which is located in the Pattaya Basin. The overall water demand by the river basin is as summarized below.

Basin	Overall Water Demand ($10^6 m^3/yr$)				
	1982	1986	1991	1996	2001
Laem Chabang	3.3	8.9	18.0	26.0	35.5
Pattaya	3.3	9.7	13.2	17.1	21.0
Study Area	6.6	18.6	31.2	43.1	56.5

The projected water demand is indicated in terms of consumer demand, which is defined as the amount of water to be produced in the waterworks.

5.3 River Maintenance Flow

The river maintenance flow treats of various aspects as aforementioned. The rate of the river maintenance flow should be determined for each river, based on the conditions particular to the river. If it is set considerably high, it may impair the amount of water to be used for conservation purposes such as water supply and irrigation or may require a costly development of water source facilities. On the other hand, the rate should not be the same with the recorded minimum flow, which is too small to sustain the existing uses and environmental quality properly.

There is no established criteria with respect to the river maintenance flow in Thailand. In actual operation of the Bang Phra and Map Prachan reservoirs, no water is being released to the downstream constantly throughout the year. The water is released sporadically only at request of water users in the downstream reach. It appears that the same practice as the Bang Phra and Map Prachan reservoirs would be adapted to the Nong Kho reservoir in future.

The water supply plan of the project is formulated based on the hydrological conditions of the driest period during the recent 15-year period. Under such severe drought condition, the river maintenance flow may be reduced to the extent of subsistence of water use. Since there are no appropriate data and information concerning water use in the downstream reach of the Map Prachan and Nong Kho dams, the rate of the river maintenance flow is assumed to be equivalent to the 90 % dependable run-off during a 15-year period at the damsite. The run-off duration curves at the Nong Kho damsite is presented in Fig. 3.

The river maintenance flows at the Nong Kho and Map Prachan damsites are thus determined at 0.04 m^3/s and 0.03 m^3/s respectively. The figure of the Map Prachan damsites is derived from that of the Nong Kho damsite in proportion of drainage areas. The rate of the maintenance flow is, of course, able to be augmented in normal years because of much favourable hydrological conditions.

5.4 Water Resources

5.4.1 Potential Water Resources

The assessment of availability of water resources is the crucial matter to formulate the water supply plan over the Study Area. An overall water resources investigation over the Eastern Seaboard has been carried out by the East Coast Water Resouces Development Project (Phase II) under the JICA in 1982-1983.

According to the results of the investigation, it is concluded that groundwater resources development potential appears to be quite low due to salt water intrusion into the alluvial plain and poor hydraulic characteristics of terrace deposits which widely cover the major part of the Study Area. The surface water resources of the Study Area have been developed to some extent. The Nong Kho and Map Prachan dams have been constructed by the RID in the Laem Chabang Basin and Pattaya Basin respectively. Although three other potential damsites (Huai Bung, Huai Takhian Tia and Khlong Naklua) have been identified by RID in the Study Area, their realizations have been inferred impracticable because of socio-economic reasons. The construction of intake has been proposed on the Huai Kong Dai river, a tributary of the Khlong Bang Lamung river.

Accordingly the Nong Kho and Map Prachan dams and Huai Kong Dai intake are sorted as conceivable water source facilities in the Study Area. Water supply capacities of these water source facilities are analyzed in detail in the succeeding sub-sections 5.4.2 and 5.4.3.

5.4.2 Nong Kho and Map Prachan Dams

Both the Nong Kho and Map Prachan dams have a multiple-purpose nature. Their salient features are as presented in Table 14.

The Nong Kho dam is situated in the Huai Nong Kho river in the Laem Chabang Basin at approximately 15 km east of the Laem Chabang industrial estate as shown in Fig. 2. It was completed in September 1983, primarily for water supply to the Laem Chabang Complex and secondarily for agriculture. The active storage capacity of the reservoir is 18.0×10^6 m^3.

The Map Prachan dam was completed in 1979 and is located in the Huai Nong Pru river in the Pattaya Basin at about 8 km east of Pattaya. It is now catering for the bulk water consumption for tourism related services in Pattaya City. The active storage capacity of the reservoir is 14.0×10^6 m^3.

Although the Map Prachan dam has been put into services and Nong Kho dam is also expected to commence its services soon, their water supply capacities have not been analyzed yet quantitatively owing to the absence of hydrological data. It is one of principal objectives of the present study to clarify exactly the water supply capacities of both dams, which are prerequisite to formulate the water supply plan over the Study Area. The analysis was accomplished based on the estimated run-offs at the damsite and other climatological data such as rainfall and evaporation.

The rate of withdrawal of water from reservoir is called the net draft rate, in other words the water supply capacity. There are uncontrollable withdrawals, such as those caused by evaporation and seepage. They should be added to the net draft rate to produce the gross draft rate. The draft rate varies with active storage capacity of reservoir. In the present case, the active storage capacity of reservoir has been given as aforementioned.

The net draft rate is obtainable by means of mass-curve analysis or mathematical solution of reservoir water balance. The water balance of reservoir is expressed by the following equation;

$$\frac{dV}{dt} = I + R - O - E \quad \text{..................................} \quad (6)$$

where,

dV; reservoir storage at time "dt"

dt; time interval

I; inflow into reservoir

R; rainfall fallen directly on reservoir

O; net draft

E; evaporation from reservoir

In the present study, the net draft consists of domestic and industrial water and the river maintenance flow and is kept constant throughout the year.

The net draft was obtained by means of simulation of reservoir operation by the above mathematical equation. As indicated in Figs. 9 and 10, both the Nong Kho and Map Prachan reservoirs had experienced a long spell of drought during the period from 1976 to 1983. The net draft rate during the period was simulated to be 0.44 m^3/s, equivalent to 13.9 x 10^6 m^3 per year for the Nong Kho reservoir and to be 0.31 m^3/s, equivalent to 9.8 x 10^6 m^3 per year for the Map Prachan reservoir.

By deducting the maintenance flow from the net draft rate, the domestic and industrial water supply rate is obtained at 0.40 m^3/s or 12.6 x 10^6 m^3 per year for the Nong Kho reservoir and 0.28 m^3/s or 8.9 x 10^6 m^3 per year for the Map Prachan reservoir.

5.4.3 Huai Kong Dai Intake

A large portion of the surface water resources in the Laem Chabang Basin remains untapped. The Huai Kong Dai Intake aims at exploiting the surface run-offs of the Huai Kong Dai and Huai Takhian Tia rivers. It is located at immediately downstream of the confluence of both rivers as shown in Fig. 7. The catchment area at the intake is 117 km^2.

In accordance with a design criteria of water supply project, stream flow with 75 per cent dependability is adopted as exploitable water. The dependable flow is estimated to be 0.16 m^3/s or 5.0 x 10^6 m^3 per year, based on the flow duration curves at the Nong Kho damsites which are shown in Fig. 3.

5.5 Water Balance Study

5.5.1 Water Withdrawal

The water demand and supply balance was calculated basin by basin at intervals of 5 years in order to reveal the timing of implementation and quantity of the inter-basin water diversion from the Nong Pla Lai dam to the Nong Kho dam and the timing of water supply to the Pattaya Basin and of implementation of the Huai Kong Dai intake.

Water withdrawal was computed firstly as the water demand deducted by the available local water resources. The water withdrawal should be met by water release from the reservoir, if there is no more prospective water resources in the basin. The following existing source facilities are treated as the local water resources:

(1) Groundwater facilities	:	Si Racha Park Estate Djittabhawan College
(2) Surface water facilities	:	Bang Lamung Police Resort Center Bang Lamung Home for Aged Thai Oil Refinery
(3) Sea water facilities	:	ESSO Oil Refinery

In addition to the above, the Huai Kong Dai intake is counted as the local water resources for the convenience of the water balance study and assumed to be realized between 1986 and 1991.

The calculation of the water withdrawal is presented in Table 15 in detail.

5.5.2 Water Deficit

A balance point is designated in the main stream of the respective basin for the purpose of water balance calculation. For the Pattaya Basin, the balance point is set at the Map Prachan damsite, in the Huai Nong Pru river, since there are no permanent intake facilities in the downstream reach of the dam. In the Laem Chabang Basin, the Huai Yai river is the main river and there exists the Ao Udom waterworks at about 10 km downstream from the Nong Kho damsite. The balance point is, however, selected at the Nong Kho damsite, based on the premise that the Ao Udom waterworks will receive raw water directly from the Nong Kho-Laem Chabang raw water pipeline as explained in Chapter 6.

All water demand can be met and all water use can be sustained if water supply capacity of the reservoir is more than water withdrawal, otherwise water deficit occurs. The water balance of the respective basin is calculated as tabulated below.

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

Description	1986	1991	1996	2001
Laem Chabang Basin				
Water withdrawal	8.3	16.9	25.8	36.3
Supply by Nong Kho reservoir	13.9	13.9	13.9	13.9
Balance	+ 5.6	- 3.0	-11.9	-22.4
Pattaya Basin				
Water withdrawal	11.5	10.3	14.6	18.8
Supply by Map Prachan reservoir	9.8	9.8	9.8	9.8
Balance	- 1.7	- 0.5	- 4.8	- 9.0

5.5.3 Proposed Water Balance

As clarified through the water balance study, the Study Area would be encountered with serious shortage of the water supply within several years, even if the water resources of the Huai Kong Dai river is developed. Since further water resources development in the Study Area is extremely difficult, the water supply plan is established taking into account the inter-basin water diversion between the Nong Pla Lai dam and the Nong Kho dam and is elaborated for two cases as described below.

(1) Case 1, With Pattaya Basin

This case envisages the whole Study Area. The water deficit of the Study Area is wholly met solely by the inter-basin water diversion as shown in Fig. 11. The annual inter-basin water diversion is therefore 3.5×10^6 m^3 in 1991, 16.7×10^6 m^3 in 1996 and 31.4×10^6 m^3 in 2001. Assuming that the Huai Kong Dai intake should be completed in 1988, first element of the inter-basin water diversion system must be put into operation in 1989. The water supply system to the Pattaya Basin should also be realized in 1989.

(2) Case 2, Without Pattaya Basin

This case is exclusively for the Laem Chabang Basin. The Pattaya Basin is excluded from the objective area of the inter-basin diversion system. The annual inter-basin diversion is, therefore, reduced to 3.0×10^6 m^3 in 1991, 11.9×10^6 m^3 in 1996 and 22.4×10^6 m^3 in 2001. However, alternative water sources, to replace the Nong Pla Lai-Nong Kho inter-basin diversion system, should be ascertained to cover the water deficit in the Pattaya Basin. The proposed water balance is shown in Fig. 12.

As described elsewhere in this report, further water resources development is hardly conceivable in and around the Study Area. It is explicit that the Pattaya Basin eventually depends on the inter-basin water diversion from the Nong Pla Lai dam for its supply. Thus, it is just matter whether the water diversion will be made through the Nong Kho-Laem Chabang water pipeline or other alternative measure.

The inter-basin water diversion plan between the Nong Pla Lai dam and the Nong Kho dam has been studied at feasibility level under the East Coast Water Resources Project (Phase II) by JICA in 1982-1983. A part of the final report of the project, entitled "Feasibility Study on Khlong Yai Dam Scheme", describes the comparative studies of various inter-basin diversion alternatives. It finally concludes that water diversion through the Nong Kho-Laem Chabang water pipeline is technically and economically the most promising plan. The proposed layout is shown in Fig. 13 for reference. The principal features of the Nong Pla Lai dam are as shown in Table 14.

With the above background, it is suggested that the Nong Kho-Laem Chabang Water Pipeline Project is formulated based on the proposed water balance for Case 1 "With Pattaya Basin". Even if the function of water transmission to the Pattaya Basin is deleted in future, it would not cause the project excessive investment. In that event, the Nong Kho-Laem Chabang water pipeline affords to supply the required water properly to the Laem Chabang Complex beyond the target year of 2001.

6. FORMULATION OF DEVELOPMENT PLAN

6.1 Water Supply Plan

6.1.1 Raw Water Distribution Plan

Planning of raw water distribution is important element for determination of nature and scale of the project and management of water resources. The raw water distribution plan was carefully evolved paying particular attention to the existing water supply plans, growth of water demand, characteristics of the existing water supply facilities and future operation and maintenance of the project facilities. The configuration of the plan is set forth as described hereunder.

(1) Laem Chabang Basin

There are two water demand centers in the basin. One is called here "Laem Chabang Complex", of which water demand consists of the port and industrial uses and domestic use in the development area. The pipe-water supply system of the existing Ao Udom waterworks is proposed to be integrated into that of the Laem Chabang Complex in future so that consistent and rational water supply system can be established within the development area.

The other demand center is called here "Ao Udom" and is composed of two major water consumers. One is the Si Racha Park Estate and the other is the Sri Racha Sugar Factory. These water consumers have encountered serious water shortage in the past and are located within one km distance from the proposed route of the raw water pipeline. It is, therefore, planned to feed the Ao Udom center directly from the Nong Kho reservoir through the abovesaid pipeline. This measure is considered superior in efficiency of water use to supply of water through the natural channel.

For the Sri Racha Sugar Factory, raw water will be supplied at the rate of 800 x 10^3 m^3 per year. The water supply to the Si Racha Park Estate will be done through the Ao Udom waterworks, since the estate requires purified water. It is anticipated that, in future, the Ao Udom waterworks will devote itself mainly to supply of industrial water to the Si Racha Park Estate rather than domestic water supply, because its service area will be integrated into the Laem Chabang Complex as aforesaid. The production capacity of the Ao Udom waterworks will be expanded to meet the increased water demand of the Si Racha Park Estate.

(2) Pattaya Basin

There are also two water demand centers in the Pattaya Basin. One is the Kho Chang Cassava Industry, which draws the water directly from the Map Prachan reservoir by its own facilities.

The other demand center is called here "Naklua-Pattaya" and embraces the Bang Lamung Sanitary District and Pattaya City. The Bang Lamung Sanitary District will be served with pipe-water through the Naklua-Pattaya waterworks as planned by PWWA.

Based on the above basic configuration, raw water distribution plan is elaborated at intervals of 5 years as shown in Fig. 14. The water transmission quantity of the Nong Kho-Laem Chabang raw water pipeline is calculated as shown in Table 16 and is summarized below.

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

Reach of Pipeline	1986	1991	1996	2001
Nong Kho dam - Ao Udom	6.8	15.7	28.7	43.1
Ao Udom - Laem Chabang Complex	5.7	13.7	26.7	41.1

6.1.2 Water Supply Plan in the Laem Chabang Complex

As aforementioned, natures of industries in the Laem Chabang Industrial Estate are labor intensive and pollution free light industries of small scale. From the viewpoints of nature, category and scale of the induced industries as well as extent of the industrial estate, it is being regarded that water supply will be executed in a state of purified water to all consumers, as the case of many other similar industrial estates.

Port and urban development areas are located close to the industrial estate. For these, as a matter of course, potable water will be served.

Such being the case, it is highly recommended to form a comprehensive water supply system over the whole development area in the Laem Chabang Basin. A large scale treatment plant with sufficient capacity to meet the industrial, domestic and port water uses will be installed at an appropriate location and distribution network would be aligned systematically over the development area.

The above measure will certainly lead to reduce the capital investment and operation and maintenance cost in treatment plant and distribution system. In addition, a consistent operation and maintenance can be achieved from the water source facilities down to the distribution networks, bringing about effective and efficient use of the precious water resources and resulting in achievement of rational and systematic water supply administration.

6.2 Alignment of Raw Water Pipeline

6.2.1 Location of Filtration Plant

The location of the filtration plant is the dominant factor in formulation of water supply system over the Study Area. Broadly speaking, it would be possible to locate the filtration plant either at the Nong Kho damsite or Laem Chabang Complex. In the former case, distribution basin should be constructed in the vicinity of the Laem Chabang Complex and it would be connected with the filtration plant by distribution main. The scope of works of the Study has been based on the later case; raw water pipeline will be laid down between the Nong Kho dam and the Laem Chabang Complex and filtration plant will be constructed at the terminal of the raw water pipeline.

It appears that there are no fundamental differences in economic and technical aspects between the two cases. The configurations of the distribution main and raw water pipeline are presumed to be almost the same as each other. However, the later case has been chosen in preference to the former case in due consideration of the following views.

(1) Water supply for domestic and municipal purposes should satisfy the physical, chemical, and bacteria criteria, which indicate the safety of water for ingestion, culinary, and sanitary purposes. The water treatment and distribution system should be constructed safely against possible pollution, paying particular attentions to the structural layout, construction materials, construction supervision etc. It may be probable that the distribution main with a long distance may incur the risk of certain pollution in future, owing to superannuation of pipes, which progresses as time goes by.

(2) In the later case the raw water pipeline can be jointed directly and simply to the existing ø600 mm outlet pipe in the Nong Kho dam. The raw water can accordingly be conveyed to the filtration plant in the Laem Chabang Complex by gravity flow. Pumping facilities would be installed only in the filtration plant to pump the purified water into the distribution basin, which would be located higher than the filtration plant to distribute the water by gravity flow. The distribution basin can be constructed close to the treatment plant.

(3) Land around the existing outlet in the Nong Kho dam is characterized by very flat topography with El. 58 m, while the design intake water level has been set out at El. 58.9 m. If the filtration plant is intended to be constructed at the damsite, it must be located higher than the design intake level to acquire the water head required for water filtration processing. The pumping facilities, therefore, should be installed at the damsite. In addition, another pumping facilities shall be provided at the end of the distribution main to lead the purified water to the distribution basin. The investment cost and operation and maintenance cost would certainly exceed that of the later case.

(4) From the water management viewpoint, the later case is deemed superior to the former case. In the later case, water management could favorably be controlled completely at the filtration plant consistently from the Nong Kho dam down to the distribution system, whereas that of the former case water management would be dispersed into the filtration plant and distribution basin.

(5) Various construction activities of the Laem Chabang Complex is expected to be commenced within a couple of years. The water should be made available timely and sufficiently to carry out the construction activities smoothly. The raw water pipeline is able to meet such need as it can be realized in a short period.

6.2.2 Identification of Pipeline Routes

The route selection of the raw water pipeline was done based on field reconnaissance survey and available topographic data such as 1/50,000 and 1/2,000 topo-maps. Three alternative routes were selected for comparisons as shown in Fig. 15.

The North Route runs along Routes 3241 and 3, which pass through rolling hilly lands with the maximum elevation of El. 87 m as shown in Fig. 16. Since the design intake water level is fixed at El. 58.9 m, pumping facilities shall be installed at the intake to flow out water. Its total length is approximately 18.7 km.

The Middle Route is aligned mostly along the existing laterite roads with a width of 6-8 m wide and has a total length of 14.5 km. Topographic relief is very gentle and is, as a whole, gradually descending towards the possible receiving well site as shown in Fig. 16. The raw water can be transmitted by gravity flow. The route crosses over the Huai Lek river and railway. There have not been found out any particular obstruction in the route.

The South Route has almost the same topographic nature as the Middle Route as shown in Fig. 16 but is approximately one km longer than the Middle Route. The pipeline passes through Ban Dan Si and Bang Nong Pru villages and crosses over the Huai Yai and Huai Lek rivers and railway.

The above three routes were carefully examined from the technical and economical viewpoints and views have been exchanged for determination of the pipeline route among the Study Team and the government's agencies and departments concerned. As the result, the Middle Route is concluded superior to the other two routes for the following reasons.

(1) The Middle and South Routes possess a great advantage over the North route that they can be realized by gravity flow and in shorter pipeline length.

(2) The Middle Route is approximately one km shorter than the South Route in pipeline length and its number of appurtenant and protective works is lesser than that of the Middle Route. The construction cost and operation and maintenance cost of the Middle Route will evidently be the minimum among the three.

(3) The Middle Route is scarcely crowded with houses and traffics compared with the others. A smooth execution of construction work is expected without causing any serious traffic disturbance and dispute and argument with inhabitants.

Thus topographic survey and geological survey were concentrated mainly on the Middle Route. The formulation of development plan and preliminary design has been accordinly devoted to the Middle Route.

6.3 Formulation of Development Plan

6.3.1 Development Alternatives

The raw water pipeline system has been determined to be developed with an enough capacity to carry the required water volume in 2001 and has been planned to be installed between the Nong Kho dam and the receiving well, which will be constructed in the proximity of the Laem Chabang Complex. The project could possibly be divided into two stages in accordance with growth of water requirement. The configuration of the raw water pipeline system largely varies with the hydraulic condition, which is consequently dependent on location of the receiving well. Furthermore, the location of the receiving well widely influences the annual cost of the pumping facilities, which would be provided in the filtration plant to pump the purified water up into distribution basin.

As explained in the succeeding sub-section 6.3.2, the project optimization study was elaborated in two steps to ascertain technically and economically the most sound development sequence of the project. The first step is directed to clarify the appropriateness of the stage development and the configuration of the pipeline in relation to the location of the receiving well. Key parameters relevant to the optimization study are (i) the location of the receiving well, (ii) the development sequence, and (iii) hydraulic condition. For each parameter, a set of alternatives was conceived as described below.

(1) Receiving Well

The receiving well will be located within the area of the filtration plant, which will be constructed in the vicinity of the Laem Chabang Complex as described in the preceding sub-section 6.2.2. Two possible filtration plant sites, namely Sites "A" and "B", have been identified through the field investigation and discussion with the Government's departments and agencies concerned. The location of the sites are shown in Fig. 15.

Site "A" is situated within the prospected urban development area and its ground elevation ranges from El. 35 m to El. 45 m. Site "B" is located within the proposed industrial estate, which has been expropriated already by IEAT, and its ground elevation is El. 28 m at the highest point. Fig. 17 indicates a conceptual layout of water supply system from the water source facilities down to the water distribution for both sites.

For Site "A", water level of the receiving well could be selected within a range of El. 35 m and El. 45 m, so that the pipeline can possibly be designed in gravity flow. It however cannot be lowered below El. 35 m owing to occurrence of negative pressure in the pipeline.

The water level of the receiving well can be varied within a given range and, for comparison purpose, it was set out at three different levels; namely El. 35 m, El. 40 m and El. 45 m. In Site "B", the water level is limited to El. 30 m, owing to the topographic and hydraulic conditions.

(2) Development Sequence

Two alternative development sequence were envisaged.

Sequence "I" is to construct the project facilities at a time with a full capacity against the water transmission requirement in 2001, 43.1 x 10^6 m^3 per year.

Sequence "II" is to implement the project in two stages. The first stage development nearly corresponds to the water transmission requirement of the Laem Chabang Complex in 1995, 21.6 x 10^6 m^3 per year. The second stage development bears the increased water transmission requirement after 1995, 21.5 x 10^6 m^3 per year, and was planned to be put into commission in 1994 to hold a certain reserve against the water requirement.

(3) Hydraulic Design

The water pipeline can be designed either for gravity flow or pump flow.

Condition "1" means the gravity flow system through all the stages. In case of Sequence "I", the pipeline will therefore be installed in each stage.

Condition "2" is the combination of gravity flow and pump flow and is therefore adaptable to Sequence "II". In the initial stage, the pipeline system is installed for gravity flow. In the second stage, pumping facilities will be installed at the intake to augment the velocity in the pipe so that the discharge capacity can be increased to the required level. This alternative is applicable to only such case that the pipe installed in the initial stage can safely respond to the increased water pressure in the second stage.

The above alternatives were carefully sorted out and combined to each other to produce the development alternatives. Ten development alternatives were identified as tabulated in Table 17 together with their configuration and principal features. Out of 10 development alternatives, 8 alternatives are concerned with the receiving well Site "A". The principal features were based on the preliminary hydraulic design.

6.3.2 Project Optimization Study

A justification of the optimum development plan is based on the least-cost solution. Related costs are the initial investment, replacement cost and annual O&M cost, including running cost of pumping facilities at the intake. In addition, the annual running cost of pumping facilities, which would be installed in the filtration plant to lead the purified water to the distribution basin, is also important factor in this case study. It varies largely with water level of the receiving well and therefore must be taken into consideration in order to evaluate all the development alternatives at equitable level.

The initial investment and replacement cost were estimated based on the preliminary hydraulic design. The annual O&M cost, excepting the running cost of pumping facilities, was assumed to be 0.5% and 2.5% of the investment cost for the gravity flow system and pump flow system respectively. The annual running cost of the pumping facilities is practically electricity charge, which was based on the PEA's tariff. The estimated investment cost is shown in Table 18. Outlay of the initial investment, replacement cost and O&M cost was prepared for each development alternative as shown in Table 19, based on the development sequence and project implementation schedule.

The project optimization study was accomplished in two steps. The first step emphasizes on the aspect to ascertain the optimum configuration of the project among 10 development alternatives. As shown in Table 19, all the costs were converted into the present worth in 1984 at assumed discount rate of 12% per annum. The total present worth of the respective alternative is then correlated to the corresponding water level of the receiving well as shown in Fig. 18.

As is evident in Fig. 18, the Development Alternative "A-3" can be justified to be optimum plan among 10 alternatives. The configuration of Development Alternative "A-3" is constituted by the followings:

Location of receiving well	:	Site "A"
Designated WL of receiving well	:	El. 35 m
Development sequence	:	Sequence "II"
Hydraulic condition	:	Condition "1"

The second step of the project optimization study is to examine in more detail the configuration of the Development Plan "A-3", particularly in view of a timing of implementation of the second stage development. Three different commissioning years of the second stage development were established as shown in Fig. 19.

The same procedures as the first step are adopted. The preliminary hydraulic design was initiated and related costs were estimated. Tables 20, 21 and 22 present the principal features, estimated cost and annual expenditure schedule respectively. The total present worth of the respective case is correlated to the corresponding commissioning year as shown in Fig. 18.

As shown in Fig. 18, Case "2" is justifiable as an optimum plan among three cases. Therefore the second stage development is proposed to be put into service in 1994.

6.3.3 Optimum Development Plan

Through the project optimization study in sub-section 6.3.2, the optimum development plan was determined as summarized hereunder.

(1) The receiving well will be constructed within the area of the filtration plant, which will be located at Site "A". The water level of the receiving well should be set at around El. 35 m.

(2) The project implementation will be divided into two stages. The second stage development will be put into operation in 1994. System capacity of the first stage development will be designed solely for the water requirement in the Laem Chabang Complex in 1995, being 21.6 x 10^6 m^3 per year.

(3) The raw water pipeline will be designed under the gravity flow condition throughout all stages. Thus the pipeline will be laid down in two rows along the proposed Middle Route. The inside diameter of the pipeline is ø1,000 mm in the reach between the Nong Kho dam and the Ao Udom turnout and ø900 mm in the reach between the Ao Udom turnout and the receiving well.

The water filtration plant and distribution system are requisite for smooth and successful implementation of the development of the Laem Chabang Complex. It is suggested that the government puts forward an immediate action programme to materialize the implementation of the water filtration plant and distribution system.

Aiming at performing the rational and consistent water management from the water source facilities down to the distribution system, a control center and living quarters for O&M staffs would be located in the filtration plant site. Such facilities, however, are more concerned with the water filtration plant and distribution system rather than the raw water pipeline. Accordingly, the control center and living quarters are recommended to be constructed as an integral part of the filtration plant.

7. PRELIMINARY DESIGN

7.1 Design Criteria

The preliminary design was conducted for the following structures:

(1) Pipeline System
(2) Turnout
(3) Aqueduct
(4) Receiving Well
(5) Protective Structures

For the hydraulic design of pipeline, Hazen Williams formula was applied. In case of circular pipe, the equation is as follows:

$$V = 0.35464 \times C \times D^{0.63} \times I^{0.54} \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

where V : mean velocity (m/s)
C : velocity coefficient
D : diameter of pipe (m)
I : hydraulic gradient

The other design criteria and design condition related to the hydraulic and structural design of pipeline are as follows:

(1) The design discharge is assumed to be 1.2 times of the source water demand taking into account the seasonal fluctuation in water use.

(2) The pipe diameter is determined from the Hazen Williams formula so as to transmit the design discharge by gravity flow under the condition of the lowest hydraulic gradient.

(3) The lowest hydraulic gradient is derived from the hydraulic gradient between L.W.L. of the reservoir and H.W.L. of the receiving well.

(4) The ark welded steel pipe of AWWA C200 or equivalent is adopted for the pipeline system.

(5) The velocity coefficient of Hazen Williams formula, "C" is assumed to be 110 taking into account all head losses.

(6) Allowable mean velocity is within the range between 0.3 m/s and 5.0 m/s.

(7) Longitudinal profile of the pipeline is set under the hydraulic gradient in normal operation condition.

(8) The valve operation at the receiving well is made automatically by electric motor in an emergency to avoid high pressure by water hammer.

(9) Wall thickness is determined taking into consideration of static pressure of 28.3 m, water hammer of 19.2 m, earth pressure of 2 m embankment and loading of T-20.

7.2 Preliminary Design

Raw water conveyance system is composed of the reservoir, intake, pipeline system and receiving well. Out of them the Nong Kho reservoir and intake have already been constructed by RID in 1983. The pipeline system and receiving well will be implemented in two stages to meet the water requirement in the target year 2001 as determined through the project optimization study. A row of pipeline will be laid down in each stage.

7.2.1 Nong Kho Reservoir

H.W.L. of the Nong Kho reservoir is El. 65 m and L.W.L. is El. 58.9 m. The L.W.L. was derived from the following equation:

$$L.W.L. = El.\ 58.2\ m + 1.5 \times \frac{V^2}{2g} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

where the first term of right hand side is elevation of top of inlet and second term is velocity head of outlet pipe added 50 % of itself. The L.W.L. was determined so as to prevent air entrainment and to keep the stability of flow in pipeline.

The salient feature of the Nong Kho dam and reservoir is as shown in Table 14.

7.2.2 Intake

Intake of the raw water conveyance system is located at the Nong Kho dam as shown on DWG. No. 1. Three outlet pipes with 600 mm in diameter and 75 m in length have been also installed underneath the dam by the RID for domestic and industrial water supply and irrigation water supply.

Out of three outlet pipes, two outlet pipes are planned to be connected to raw water pipeline system one by one. The existing outlet canal will be renovated for the construction of the pipeline system and irrigation water supply to downstream as shown on DWG. No. 15.

7.2.3 Pipeline System

Pipeline route was selected at the Middle Route as stated in Chapter 6. Plan and profile of the pipeline system are shown on DWG. No. 2 thru DWG. No. 14. The pipe diameter was determined from Hazen Williams formula for two reaches under the condition of gravity flow. One is between the intake and the turnout and its length is 10.95 km. The other is between the turnout and the receiving well with a legnth of 3.49 km. The wall thickness was derived from the standard of AWWA for the safety side as a result of structural design.

The pipeline system is determined to be implemented in two stages under the following conditions.

Development Stage \ Reach	Nong Kho dam to Ao Udom Turnout				Ao Udom Turnout to Receiving Well			
	ø	t	Q	V	ø	t	Q	V
1st Stage	1,000	9.5	0.82	1.04	900	7.9	0.74	1.16
2nd Stage	1,000	9.5	0.82	1.04	900	7.9	0.82	1.29

Note: ø: diameter (mm), t: wall thickness (mm),
Q: discharge (m^3/s), V: velocity (m/s)

The hydraulic gradient of the pipeline system is presented in Fig. 20.

The ground elevation of pipeline system ranges from El. 60 m at the intake site to El. 15 m at the Huai Lek river, which is located at a-12.6 km point from the intake. The pipeline is laid down mainly within the completely weathered granite zone. The foundation will be compacted sufficiently and homogeneous for pipe installation. The typical sections of pipe installation are shown on DWG. No. 14. The minimum coverage is determined at 1.5 m in order to protect the pipe from floatation and to disperse the external force as much as possible. Thrust blocks are not used since the arc welded joint is strong enough to bear the tension at a joint portion.

A flow meter of ultra-sonic type is installed at the Nong Kho damsite and receiving well to grasp and regulate the amount of water supply.

The butterfly valve is installed at 2 km intervals in principle and such locations as the downstream of blow off and on both sides of aqueduct. The air valve is installed at a convex part to release the entrained air and to prevent the cavitation by negative pressure. The type and dimensions of valve chambers are shown on DWG. No. 19.

7.2.4 Ao Udom Turnout

Ao Udom turnout is to distribute raw water of 0.08 m^3/s to Ao Udom Waterworks and is located at a-10.9 km point from the intake, near the Si Racha Park Estate. Its design is shown in DWG. No. 16.

The diameter of branch pipe is determined at 250 mm based on the result of hydraulic calculation. One flow meter of ultra-sonic type and two sluice valves are also installed as shown on DWG. No. 16. The branch pipe will also be installed for stand-by in the second stage.

7.2.5 Aqueduct

Aqueduct is constructed to cross over the railway which is under construction for transportation along Chachoengsao, Sattahip and Map Ta Phut. It is located at a-13.1 km point from the Nong Kho dam.

It is designed as a pipe beam aqueduct with 900 mm in diameter and 27.5 m in span length from the technical and economic point of view. The axis of aqueduct is set at El. 32.4 m in due consideration of track clearance as shown on DWG. No. 17. The wall thickness of aqueduct was determined at 19.1 mm from the nomogram for simple support type pipe beam aqueduct. The aqueduct is supported by concrete abutments on both sides. An air valve is set at the middle of aqueduct.

7.2.6 Receiving Well

The receiving well is constructed at the area about 1.8 km east of Route 3 in the vicinity of Ban Nong Kapok.

The receiving well is designed for a retention time of 4 minutes and its H.W.L. is determined at El. 36.7 m from the result of hydraulic calculation of the pipeline system. The receiving well is designed in rectangular shape and is divided into 3 chambers i.e. inlet chamber, calming chamber and outlet chamber in order to stabilize its water surface level. DWG. No. 18, shows the design of the receiving well overflow weir is equipped for the purpose of discharge measurement at the end of calming chamber. Crest elevation of the weir is determined at El. 36.4 m from the formula for discharge over the weir. Overflow pipe is installed in the calming chamber. The elevation of the top of overflow pipe is determined at El. 36.7 m to spill out excess water. The water depth is 3 m. By-pass pipe is provided for the sake of maintenance of the receiving well.

A sleeve valve is installed at an inlet of receiving well for the regulation of discharge. It shows superior behaviour to reduce the cavitation or extreme high pressure by water hammer.

A preliminary layout plan of water treatment plant and distribution basin is prepared for reference as shown in Fig. 21.

7.3 Construction Plan

7.3.1 Implementation Schedule

The implementation of the project is expected as follows:

Procedures	1st Stage	2nd Stage
Financial arrangement	By Jul., 1984	By Jul., 1991
Tender design	Jan. - Dec., 1985	Jan. - Apr., 1992
Tendering and contract award	Jan. - Oct., 1986	Jan. - Oct., 1992
Construction	Nov. 1986 - Jun. 1988	Nov. 1992 - Jun. 1994

The construction planning was performed based on the required work quantities and climatological conditions. The main components of the project are the raw water pipeline with a total length of 14.5 km, turnout, aqueduct and receiving well. The quantities of the major work items are summarized in Table 23. The project implementation schedule is illustrated as shown in Fig. 22.

7.3.2 Construction Plan

(1) Preparatory works

The preparatory work will consist of the improvement of existing roads and bridges, construction of temporary buildings for construction uses, etc.

Major temporary buildings are as estimated below and they will be located in the receiving well site.

Buildings	Estimated Area (m^2)	
	Land	Building
Government office	1,000	200
Contractor's office	1,500	300
Contractor's quarter	4,000	1,500
Warehouse	1,400	120

The electric power required by the offices and quarters will be supplied from the existing distribution line of the PEA, while that for welding of steel pipes will be supplied by portable diesel engine generators. The total electric power requirement is estimated at approximately 250 kW for the building uses. If steel pipe production plant is provided at the receiving well site, electric power requirement will increase greatly.

The water supply for the offices and quarters will be made from the distribution system of the Ao Udom waterworks. A daily consumption is roughly estimated at 10 m^3. Water for construction use would be obtained from local sources.

(2) Raw water pipeline

The construction of raw water pipeline is a key factor of the project and is scheduled to extend over a 20-month period, including an import of steel material, manufacturing and transportation of steel pipes. The steel materials and valves of all kinds will be imported within a 4-month period after contract award and will be followed by the manufacturing of the steel pipes over a 12-month period.

Owing to the climatological conditions, installation of the steel pipes will be suspended during the wet season. In the first dry season, the pipe installation will be limited to approximately two km around the Nong Kho damsite. The rest will be completed in the second dry season. A typical pipe installation is shown in Fig. 23; a distance between two pipes will be 4 m and pipes will be embedded at a depth of 3 m. During the first stage construction, for temporary deposit of excavated soils, a 6-meter wide land will be required along the route for which compensation would be made.

Trench excavation will be executed mainly by back hoe and its bottom will be compacted sufficiently and homogeneously by hand rammer. Around the Nong Kho dam and Si Racha Park Estate, trench excavation will be supported by wooden sheet piling.

Welding of steel pipes will be made by use of arc welders and automatic welders.

(3) Aqueduct

It is designed as a pipe beam type. The pipe beam will be manufactured during the wet season and will be installed in the second dry season upon completion of civil works. Concrete work of abutments will be executed by portable concrete mixer.

(4) Receiving well

The construction of the receiving well will be executed over a 7-month period in the first dry season. A sleeve valve will be installed upon completion of concrete work of valve chamber. Electic power supply for the sleeve valve will be made from the PEA's distribution line. The construction of valve control station will be executed in parallel with installation of the sleeve valve.

7.3.3 Required Major Construction Equipment and Plants

The major plants and equipment for the construction of the project are as listed in Table 24.

7.3.4 Required Manpower

The monthly requirement of the manpower for the construction of the project was estimated as shown in Table 25 based on the established construction plan and time schedule.

7.3.5 Estimated Land Expropriation

The extent of land expropriation was provisionally estimated to be 32.5 ha, consisting of 23.5 ha for pipeline and 9.0 ha for filtration plant based on pipe installation method shown in Fig. 23. Compensation for temporary use would be made. Its extent was roughly estimated at 8.5 ha.

7.4 Cost Estimate

7.4.1 Investment Cost

The investment cost consists of the construction cost, engineering services, land acquisition and compensation, government administration, physical contingency, price contingency and tax on construction work as shown in Table 26. All the cost reflect the end-1983 price level.

The construction cost was estimated based on the work quantities and unit price of each item related to the construction. The unit prices were established under the following conditions;

(1) The construction work of the project will be executed by a contractor selected through the international competitive bid.

(2) Division of foreign and local currency portions will be as follows.

Foreign Currency Portion

- Depreciation cost of constructional and manufacturing plant and equipment
- Fuel, lubricant, oil
- Steel and coating materials and welding rods
- Valves and flow meters
- Freight and insurance of imported materials and goods.

Local Currency Portion

- Labor wages
- Timber, cement, concrete aggregate, and other local materials
- Import duties, inland transportation.

(3) Import duties are assumed to be induced at a rate of 35% of CIF for semi-finished materials.

(4) Tax on construction works is assumed to be 3.4% of the estimated construction cost in accordance with the prevailing government regulation.

(5) The currency exchange rate is;

US$ 1 = Baht 23 = Japanese Yen 230.

Priced Bill of Quantities is compiled in the Supporting Report.

Engineering services were estimated from the sum up of the costs for required man-months and others necessary for the detailed design and construction supervision stages in both the first and second stage developments.

Government administration cost was assumed to be 4% of the base cost.

Land acquisition and compensation cost is estimated based on the land prices and estimated area of land expropriation for pipeline and filtration plant. The land prices have been surveyed by the PWD's task force as compiled in Supporting Report I, "Topographic Survey".

Physical contingency was assumed to be 20% of the base cost. Price contingency was estimated with assumed price escalation rates; 6% per year for the foreign currency portion and 8% per year for the local currency portion.

Tax to be levied on the construction work is estimated to be 3.4% of the estimated construction cost including 20% of physical contingency, in accordance with the prevailing government regulation.

Yearly disbursement schedule of investment cost is prepared in accordance with the project implementation programme as shown in Table 27.

7.4.2 Operation and Maintenance Cost

Annual operation and maintenance costs of the Project were assumed to be 0.5% of base cost including physical contingency for the pipeline and other appurtenant structures. It is estimated at ₱1.0 x 10^6 for the first stage and ₱2.0 x 10^6 upon completion of the second stage.

8. ECONOMIC AND FINANCIAL EVALUATION

8.1 Economic Evaluation

8.1.1 General

Economic feasibility of the project is evaluated by means of economic internal rate of return (EIRR). Sensitivity analysis is further conducted to assess degree of impact of possible changes in economic conditions on the economic soundness of the project.

Following assumptions are established for the evaluation.

(1) Only direct benefit is counted and indirect and intangible benefit are not taken into account.

(2) Price is expressed in terms of 1983 constant price.

(3) Economic useful life of the project is assumed to be 40 years.

8.1.2 Economic Cost

Financial cost obtained in the previous sub-section 7.4.1 is adjusted to economic cost which reflects true economic value of goods and services. Economic cost is obtained under the following assumptions.

(1) Land acquisition and compensation cost is not included in the economic cost, since it is a transfer payment. Production foregone by the project is considered to be negligibly small and not taken into account.

(2) Economic cost of construction cost is obtained by deducting import duty to be induced on imported construction materials from financial cost.

(3) Administration cost and local currency portion of engineering service are converted to economic value by applying standard conversion factor of 0.8. This figure is derived from "Staff Working Paper No. 299, 1978 World Bank".

(4) Contract tax for construction work is excluded in economic cost as a transfer payment.

Disbursement schedule of economic cost is presented in Table 28 and summarized as follows.

(Unit: $\not{B}10^6$)

Stage	F.C	L.C	Total
1st	176.9	64.5	241.3
2nd	158.2	61.4	219.6

8.1.3 Benefit

Benefit generated by the project is estimated by multiplying net water demand and unit water supply benefit.

Net water demand is the prospected amount of water which will be actually consumed by water users. Therefore it excludes unaccounted for water and water loss between intake and waterworks which are assumed to be 15% and 10% of water produced at waterworks respectively.

Net water demand includes water to be supplied to Pattaya basin as well.

Unit water supply benefit is estimated from the rate of water charge to be induced on water users considering that it reflects the willingness to pay of the users. Although benefit of water resources development or water supply project is generally obtained from the cost of alternative facilities with the second best priority, the present study does not apply this method since it is practically impossible to establish a reasonable alternative plan.

Rates of water charge is obtained by estimating appropriate rates for purified water first and then converting them into rates for raw water. The rates are assumed to be ฿1.5/m^3 and ฿2.5/m^3 for domestic and industrial water respectively.

Rates for purified water is broadly estimated to be ฿3.0/m^3 and ฿5/m^3 for domestic and industrial water respectively. These are actual rates at which local inhabitants and industries in Si Racha Park Estate are paying to Ao Udom Water Works for supplied water. Willingness to pay of water users are considered probably higher than these rates when instances of other areas are taken into account. At Sattahip where water supply system is basically for exclusive use of the Thai Navy, purified water is being sold to local inhabitants by vendors at a rate of ฿53/m^3. In Bangkok Metropolitan area, water is supplied to industries consuming more than 300 m^3/day of water at a rate of ฿8/m^3. In the present study, therefore, rates of ฿3/m^3 and ฿5/m^3 are applied as indicating minimum level of the willingness to pay of inhabitants and industries in the Study Area.

Since benefit is created by the construction of raw water pipeline as well as a filtration plant and distribution system, water charge of purified water should be divided into the portion of raw water conveyance and the one of purification and distribution. In the present study, ฿3/m^3 and ฿5/m^3 of purified water for domestic and industrial use are converted to ฿1.5/m^3 and ฿2.5/m^3 as the portion of raw water with reference to the data of Dok Krai-Map Ta Phut water pipeline. Construction cost of the Dok Krai-Map Ta Phut water pipeline shares nearly half of the total construction cost of the water supply system including Dok

Krai-Map Ta Phut water pipeline and filtration plant and distribution system planned to be located at Map Ta Phut.

According to the procedure explained above, water supply benefit created by the project is estimated as shown in Table 29. Annual water supply benefit is estimated at ฿14.4 x 10^6 and ฿60.0 x 10^6 for domestic and industrial water supply respectively in 2001 and thereafter. Cost-benefit flow is presented in Table 30.

8.1.4 Economic Internal Rate of Return

Based on the economic cost and benefit estimated in the previous sub-sections, EIRR is calculated at 11.5% showing high economic soundness of the project. Further, sensitivity analysis is conducted to evaluate the viability of the project against possible changes in the economic conditions. The results are presented in Fig. 24 and summarized below.

Condition		EIRR (%)
(1)	Standard Condition	11.6
(2)	Cost increase of 10%	10.6
(3)	Benefit Decrease of 10%	10.5
(4)	(2) + (3)	9.6

It is clarified through the analysis that the project still maintains high economic feasibility even with unfavorable changes in economic conditions.

For reference sensitivity of the Project was further assessed paying attention to the delay in construction for two cases. One is the delay for 2 years in the completion of the inter-basin water diversion from Nong Pla Lai reservoir to Nong Kho reservoir and the other 2 years extension of construction period of the 1st stage of the present project. EIRR is computated at 8.6% and 8.9% for the two cases ascertaining the economic soundness of the Project.

8.2 Financial Evaluation

8.2.1 General

Financial viability of the Project is evaluated by calculating financial internal rate of return (FIRR) as well as preparing cash flow statement to see the repayability of foreign loan.

8.2.2 Financial Internal Rate of Return

FIRR is calculated based on financial cost estimated in the previous chapter and revenue from water users. Cost is expressed in terms of constant price in 1983. Revenue is obtained by net water supply to consumers and unit water charge of ₱1.5/m^3 and ₱2.5/m^3 for domestic and industrial water as explained in the previous section. Sensitivity analysis is conducted to assess the financial viability of the Project against possible increase and decrease of cost and benefit. The result is presented in Fig. 24 and summarized below.

Condition		FIRR (%)
(1)	Standard Condition	9.6
(2)	Cost increase of 10%	8.7
(3)	Benefit decrease of 10%	8.6
(4)	(2) + (3)	7.8

It is conceived from this result that the project bears sound financial viability, considering that loan by international agencies for water supply projects is provided generally at an interest rate of around 8% or below. Even under unfavorable circumstance, the project is considered to generate enough benefit. Financial cash flow is presented in Table 31.

Financial viability of the project was also ascertained for the two cases of construction delay. FIRR was calculated at 10.4% for the delay in construction of Nong Pla Lai inter-basin water diversion system and 10.7% for the delay of Nong Kho-Laem Chabang water pipeline.

8.2.3 Loan Repayability

Repayability of foreign loan is assessed by preparing cash flow statement as presented in Table 32. Foreign loan is primarily assumed to be provided with an interest rate of 3% and repayment schedule of 30 years including a grace period of 10 years. For reference, cash flow statement under the loan condition of an interest rate of 8% and repayment schedule of 20 years including a grace period of 5 years is also prepared.

The statements indicate that under either conditions the Project is capable of bringing about revenue to a sufficient extent to repay principal and pay interest of foreign loan. It is also clarified that reinvestment on a project with the same scale is possible by applying surplus revenue of the Project after the economic life of the Project is over.

8.2.4 Water Cost

Water cost is indicated as annual equivalent cost of investment cost and OM cost divided by average annual water supply amount. It is calculated at ฿1.8/m^3 with discount rate of 12% and project life of 40 years.

8.3 Socio-economic Impact

The Laem Chabang Complex is expected to play a major role in promoting industrialization of Thailand as well as Map Ta Phut in Rayong Province in the Fifth National Plan. For the implementation of the development programme, development of infrastructural and utility facilities is a minimum requisite. In this respect development of the water supply system is expected to contribute indirectly to the development of regional as well as national socio-economy. Its impacts are anticipated to be induced on such aspects as increase of job opportunities, upgrading of living standard, improvement of trade balance, and mitigation of congestion in Bangkok. Through the development of industrial estate, urban area and port by the government, surrounding area is also expected to achieve socio-economic development as a result of multiplier effect.

In rural part of the Study Area, which has been scarcely provided with pipe-water supply except Ao Udom sanitary district, implementation of the project is also expected to contribute to the improvement of life of inhabitants, especially in such aspects as decrease of water borne desease and reduction of fire damages.

9. ORGANIZATION

9.1 Executive Agency for Construction

Construction of water pipeline system will be proceeded under the responsibility of Public Works Department (PWD). PWD, which belongs to Ministry of Interior, is in charge of development of infrastructure such as road and bridge and utility facilities for water supply, and electrification. With regard to water supply, PWD takes responsibility mainly in surveying, designing and construction of some of waterworks which belong to municipalities and sanitary districts and construction of tube-wells with large diameter and water distribution system. Organization Chart of PWD is shown in Fig. 25.

9.2 Executive Agency for Operation and Maintenance

Operation and maintenance of the water pipeline system, is recommended to be undertaken under the condition in which raw water pipeline, filtration plant and distribution system are operated in an unified system. Under such system, effective and consistent operation of the systems will be made possible coping with probable fluctuation in water consumption pattern in the Laem Chabang Complex. In this context, it is deemed appropriate that Industrial Estate Authority of Thailand (IEAT) which is now promoting development activities of the Laem Chabang Complex will take responsibility for operation and maintenance.

IEAT is an autonomous government agency established in 1972. It is responsible for the development of industrial estates and export processing zone throughout Thailand especially focusing on undertaking of feasibility study, acquisition and development of land, investment in the development of infrastructure, sale and lease of land and provision of support services and facilities to industrialists within industrial estate. It participates in promotion of industrialization of Thailand in cooperation with other government agencies concerned such as Board of Investment (BOI), Small Industries Finance Office (SIFO) and Industrial Finance Corporation of Thailand (IFCT). Organization chart of IEAT is shown in Fig. 26.

Institutional relationship among agencies concerned for operation and maintenance is as shown in Fig. 27. Discussion will need to be held between IEAT and Royal Irrigation Department (RID) regarding allocation of water resources at Nong Kho reservoir. Rate of water charge to be induced on water users in the Laem Chabang Complex will be adjusted in consideration of currently prevailing rate of Provincial Water Works Authority (PWWA) as well as the rate being induced by Ao Udom waterworks. Coordination among these agencies will also be pursued at the level of local offices. An optimum institutional system for operation and maintenance will be established at a later stage when whole development programme of the Laem Chabang Complex is materialized.