MINISTRY OF INTERIOR
PROVINCIAL WATERWORKS AUTHORITY

DEVELOPMENT PLAN AND FEASIBILITY STUDY ON PROVINCIAL WATER SUPPLY PROJECTS IN THE KINGDOM OF THAILAND

FINAL REPORT FOR PHUKET

MARCH 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of Thailand, the Japanese Government decided to conduct a Feasibility Study on the Improvement of the Sewerage System in the Southern Part of Lima and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Thailand a survey team headed by Mr. Ikuo Miwa, Nippon Jogesuido Sekkei Co., Ltd., from July to October, 1988, from January to March, 1989, and from October to November, 1989.

The team held discussions with concerned officials of the Government of Thailand, and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

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

March, 1990

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

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EXECUTIVE SUMMARY

Part I - GENERAL

THE STUDY AREA

Phuket is the only island province in Thailand. It is in the Indian Ocean about 867 km from Bangkok and stretches 49 km from north to south and 19 km from east to west.

Phuket is quite mountainous and has many small streams and mining pits. It also has beautiful beaches along the western and southern side of the island that have become major tourist attractions.

Tin ore is the major mining resource in Phuket. Among its agricultural resources are coconut, rubber and fisheries. The promotion of the island as a tourist destination has generated new job opportunities. The average income per person in Phuket is considerably higher than the national average.

Phuket can be reached by land, air or sea. Recently, a Deep Sea Port in Tambon Wichit was constructed, the only one in the west coast of Thailand. Phuket Municipality is the hub of urbanization in the province where expansion is moving beyond its present administrative boundary.

Future land development trends points to the western coast for tourism oriented establishments and industrial complexes because of the Deep Sea Port. Development of an industrial estate is being planned near the airport at Tambon Mai Khao.

The development of Phuket is not without problems. These are unemployment, environmental deterioration, lack of roads, water shortages, high cost of living and land use controversies.

WATER SOURCE

Although Phuket is blessed with an annual average rainfall of 2,500 mm, this is carried away by small streams. Ground water potential is low due to shallow bed rock.

Water supply thus comes from waterfalls, abandoned mining pits and the Bangwad reservoir. Rainwater is used as an alternative to shallow wells.

Phuket Municipal Water Supply sources, for example, are from five mining pits that produce high quality water.

About 3,000 shallow wells, are all over the island and are mostly seen on the western coast or in the northeastern villages. These wells are often contaminated by waste water or seawater. Deepwells are also in use for private water supply.

New water sources are being eyed for development such as dams, other mining pits and the tapping of streams. The potential yield of ground water is still limited.

EXISTING WATER SUPPLY SYSTEM

There are five independent water supply systems in Phuket island. It is the PWA Phuket Waterworks that could supply the entire island while the Phuket Municipal Waterworks supplies the municipality of Phuket. The rest are small community waterworks.

The PWA's waterworks now covers the areas which are Patong Beach, Kathu, and the area along the distribution pipeline stretched to the Deep Sea Port from the Bangwad Water Treatment Plant. The waterworks has also started in 1989 to supply treated water to the Phuket Municipality to help the water shortage in the municipality.

It is the PWA Regional Offices (IV) that directly supervise the urban and rural waterworks. The Phuket Waterworks, which has 666 connections, itself functions with three sections - water production, service and administration.

Water production and sales of the Phuket waterworks in 1987 are 805,878, and 394,314 cu m/day, respectively.

POPULATION AND WATER DEMAND

The study area is the main island of Phuket Province consisting of Ampoes Thalang, Kathu and Muang Phuket and Phuket Municipality with a total of 17 tambons.

The population of the study area was 153,600 in 1987 with a growth rate of 2.3 percent.

The future served population was calculated by tambon in the service area density, i.e., high density, medium, low as shown in the following table:

Year	Population Prediction				Average Service Ratio
	Municipality	Tourism Spot	Other Area	Total	
1991	34,428	3,254	0	37,682	33.24
	(60,400)	(21,684)	(31,292)	(113,376)	
1996	42,055	7,053	5,095	54,203	44.37
	(64,700)	(23,507)	(33,960)	(122,167)	
2001	50,589	9,998	9,029	69,616	53.38
	(69,300)	(24,993)	(36,115)	(130,408)	
2006	60,926	14,477	15,216	90,619	65.35
	(74,300)	(26,319)	(38,040)	(138,659)	
2011	71,550	19,167	19,797	110,514	75.45
	(79,500)	(27,380)	(39,588)	(146,468)	

As Phuket has a large number of the tourists, the tourist population is taken into consideration when plotting future water consumption aside from domestic, institutional, commercial and industrial consumption.

The number of tourist was predicted referring to "the Study on Potential Tourism Area Development for Southern Region in Thailand" for the Tourism

Authority of Thailand (TAT). The latest status of the hotel development plan in the Phuket municipality was also considered. The predicted number of tourist is tabulated in the table below:

Prediction of the Number of Tourist

Area	1991	1996	2001	2006	2011
Inside Municipality	3,780	3,780	3,780	3,780	3,780
Outside Municipality	13,698	17,466	19,895	19,895	19,895
Northern Area					
High Class	2,244	4,830	6,067	6,067	6,067
Low Class	12	275	324	324	324
Sub-total	2,256	5,105	6,391	6,391	6,391
Southern Area					
High Class	7,312	7,978	8,677	8,677	8,677
Low Class	4,130	4,383	4,827	4,827	4,827
Sub-total	11,442	12,361	13,503	13,503	13,503

The predicted total water demand is summarized as shown below:

Water Demand Prediction

(Unit : cu.m/d)

Item	1991	1996	2001	2006	2011
Domestic	13,889	17,054	20,516	25,139	29,993
Inside Mun.	13,564	15,900	18,544	21,772	25,138
Outside Mun.	325	1,154	1,972	3,367	4,855
Governmental	2,251	2,409	2,556	2,701	2,838
Inside Mun.	1,392	1,453	1,518	1,589	1,663
Outside Mun.	859	956	1,038	1,112	1,175
Tourism	12,387	14,727	16,212	16,212	16,212
Inside Mun.	4,200	4,200	4,200	4,200	4,200
Outside Mun.	8,187	10,527	12,012	12,012	12,012
Commercial	3,707	4,690	5,371	5,533	5,701
Inside Mun.	678	795	927	1,089	1,257
Outside Mun.	3,029	3,895	4,444	4,444	4,444
Industrial	1,684	1,684	1,684	1,684	1,684
Inside Mun.	684	684	684	684	684
Outside Mun.	1,000	1,000	1,000	1,000	1,000
Sub-Total	33,918	40,564	46,339	51,269	56,428
Inside Mun.	20,518	23,032	25,873	29,334	32,942
Outside Mun.	13,400	17,532	20,466	21,935	23,486
Municipality & New Service Area					
Water Demand	23,753	33,406	38,393	43,043	47,882
Unaccounted-for Water Ratio (%)	20	20	20	20	20
Unaccounted-for Water	5,938	8,352	9,598	10,761	11,971
PWA Existing Service Area (Kathu & Patong)					
Water Demand	6,465	7,155	7,945	8,225	8,546
Unaccounted-for Water Ratio (%)	37	33	28	24	20
Unaccounted-for Water	3,797	3,524	3,090	2,597	2,137
Daily average	39,953	52,437	59,026	64,626	70,536
Peak Factor	1.30	1.30	1.30	1.30	1.30
Daily Maximum	51,939	68,168	76,734	84,014	91,697

DESIGN CRITERIA

The design criteria for the treatment system and pipeline was established on the various design standards employed in Thailand and other countries, taking into consideration the project site and the raw water quality.

The design criteria is summarized as follows:

1. Water loss - a total of intake and treatment loss is 5 %

2. Pipeline - velocity is a maximum of 3.0 m/s and a minimum of 0.3 m/s. Pipe material is steel for 400 mm diameter pipes or larger and A/C for 300 mm or smaller.

3. Treatment Plant - a) receiving well: treatment time is 1.5 min.; b) mixing tank: mechanical flush mixer; c) filter: rapid sand filtration; d) clear water reservoir: 8.0 hour retention time.

4. Distribution facilities - Minimum service pressure is planned at 1.0 kg/cm2 for hourly maximum flow.

BASIS OF COST ESTIMATE

The construction of the facilities to be built is calculated based on 1989 prices.

a) Pipelines - by linear meter for transmission and distribution pipes

b) Water treatment plant - PWA's data for the unit cost is used for the civil structures of the treatment plant. For the mechanical works, major items are counted individually. The cost of the electrical works are calculated by the percentage to the mechanical works.

c) Land acquisition - land cost was calculated on the basis of the unit land costs as follows:

Flat area in the island	:	Baht 2,000,000 per rai (1,600 sq m)
Hill side area near the beach	:	Baht 5,000,000 per rai
Rubber plantation are at the hill side	:	Baht 500,000 per rai
Hill side area in and outside the island	:	Baht 300,000 per rai

The cost estimates are separated into foreign and local cost portions as shown here:

Item	Foreign Currency	Local Currency
Pipeline	(%)	(%)
A/C pipes	30	70
Steel pipes	80	20
Structural/Architectural	30	70
Mechanical Works	80	20
Electrical Works	80	20
Land Acquisition	0	100

Operation and maintenance costs, based on 1989 prices, consist of energy, chemical, manning, replacement and repair costs. Costs of the PWA's head office and the regional office allocated for this waterworks are also calculated and added in the financial study.

Part 2 - DEVELOPMENT PLAN

DEFINITION AND EVALUATION OF ALTERNATIVES

In proposing the alternative solutions to the water problem in Phuket, the following factors were taken into consideration:

a) the water supply expansion should cope with present and future development of resorts in the island;

b) a balanced layout of facilities should be made as the service area is scattered into 11 blocks;

c) land acquisition should be seriously considered as land is becoming expensive due to increased private sector investments.

Five dams are proposed to be constructed with a maximum intake capacity of 58,400 cu.m./d. The characteristics of each dam is shown as follows:

Dam	Reservoir Volume	Supply Capacity
Bang Tho Sung	4,300,000 cu m	9,600 cu m/day
Khlong Katha	5,000,000	10,900
Bang Nieo Dam	3,100,000	8,900
Khao Che Tra	3,000,000	7,600
Khlong Lo Yung	11,500,000	21,400

While the dams are being constructed, temporary water sources should be made available. The tapping of Khlong Bang Yai Stream is proposed to supplement the intake capacity of the Bangwat Reservoir. Two mining pits at Khao Na Bon and Ban Tan Muang can be utilized as well.

For establishing the water supply system, the total service area is divided in 11 zones as shown in Figure S-1. As the water sources and service areas are scattered, the layout of the water supply system is limited by the geographical condition.

It is recommended that a total service area is divided into five systems and that several treatment plants are constructed close to the proposed dam sites as shown in Figure S-2 and the following table.

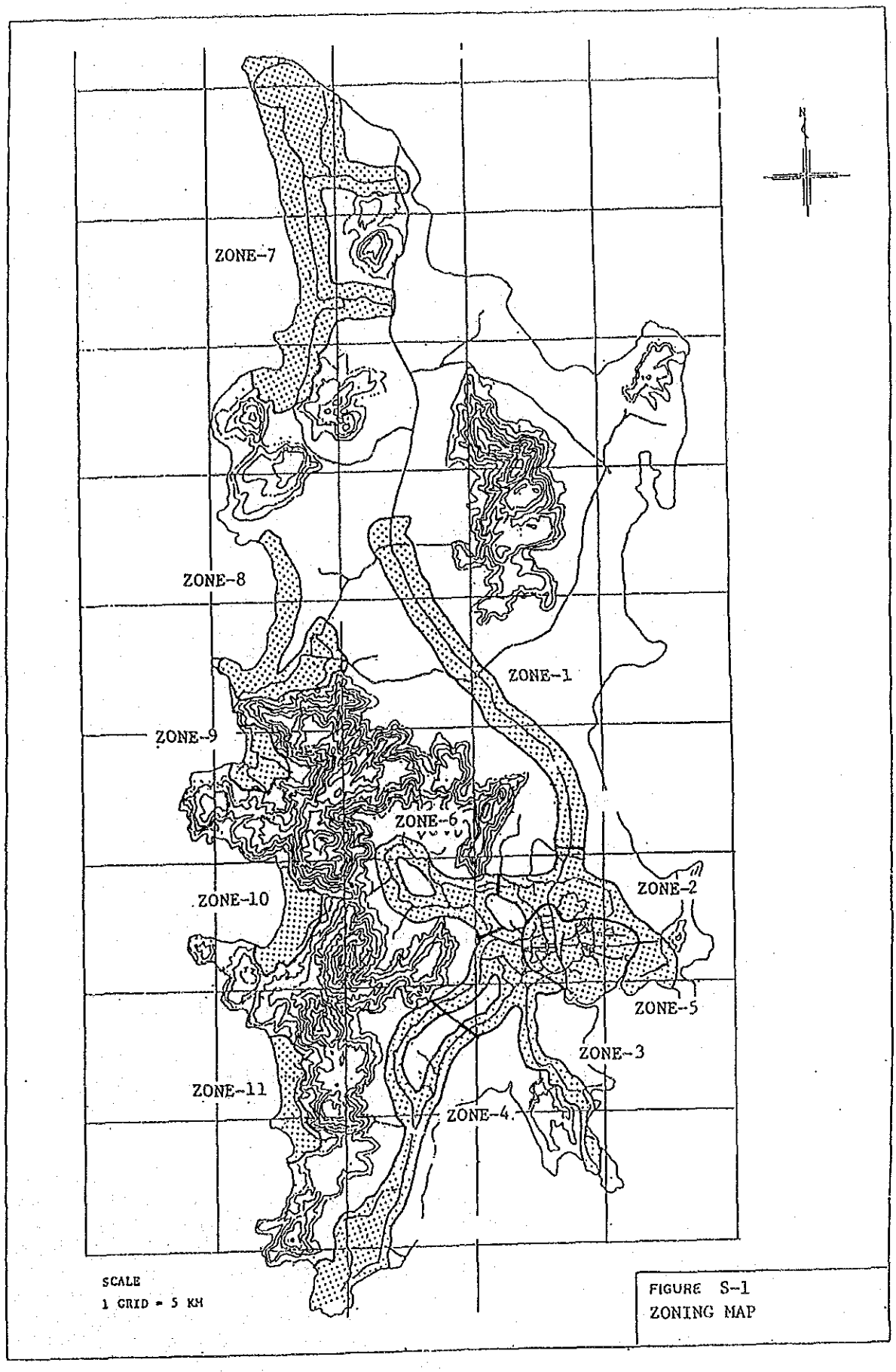


FIGURE S-1
ZONING MAP

Proposed Group of Treatment Plants and Dams

Treatment Plant	Raw Water Source: Dam	Raw Water Source: Supply Capacity (Day Ave.)	Zone Supplied	Amount Supplied (Day Ave.)
(1) Bangwat System				
T1 (Exis.) (Bangwad)	Bangwat	11,700 cu m/d	Zone 6	893 cu m/d
	Bang Tho Sung	9,600	10	9,788
			11	3,159
			5	4,622 2)
	(total)	21,300		18,462 1)
(2) Municipality System				
T2 (Exis.) (Municipality)	Mining Pits	13,900	Zone 5	13,200 1)
(3) Khlong Katha System				
T3	Khlong Khata	10,900	Zone 3	2,700
			4	1,670
			5	6,010 2)
	(total)	10,900		10,380 1)
(4) Bang Nieo Dam System				
T4	Bang Nieo Dam	8,900	Zone 1	1,103
	Che Tra	7,600	2	943
			8	2,476
			9	1,065
			5	10,127 3)
	(total)	16,500		20,954 4)
(5) Zone 7 System				
T5	Khlong Lo Yung	21,400	Zone 7	5,700
			to T4 System	7,078 5)
	(total)	21,400		12,778
			Balance for Thai Muang	8,622

Note : 1) (Supplied Amount) : Calculated from the treatment capacity of Bangwat WTP as follows:
Maximum Effective Capacity (Qmax) = 24,000 cu m/d
Equivalent Daily Average Capacity = 18,462 cu m/d (Qmax/1.3)
2) (Amount for Zone 5) =
(Total Supplied Amount, 1).) - (Other Zone's Amount)
3) (Amount for T4 System) = Total of Zone 5 demand (41,037 cu m/d) minus total of supplied amounts from T1 to T4

It is also proposed, as the immediate improvement project, that additional pipelines having 300 mm. size be laid from Patong side to Karon and Katha areas as well as three reservoirs. This will help reduce the problems arising from the high pressure from the Bangwat Treatment Plant. Of the three reservoirs, the first is a high level reservoir to receive water from the existing booster pumping station to supply water to two distribution reservoirs: one for Patong, and one for Karon and Katha. These distribution reservoirs will regulate distribution pressure.

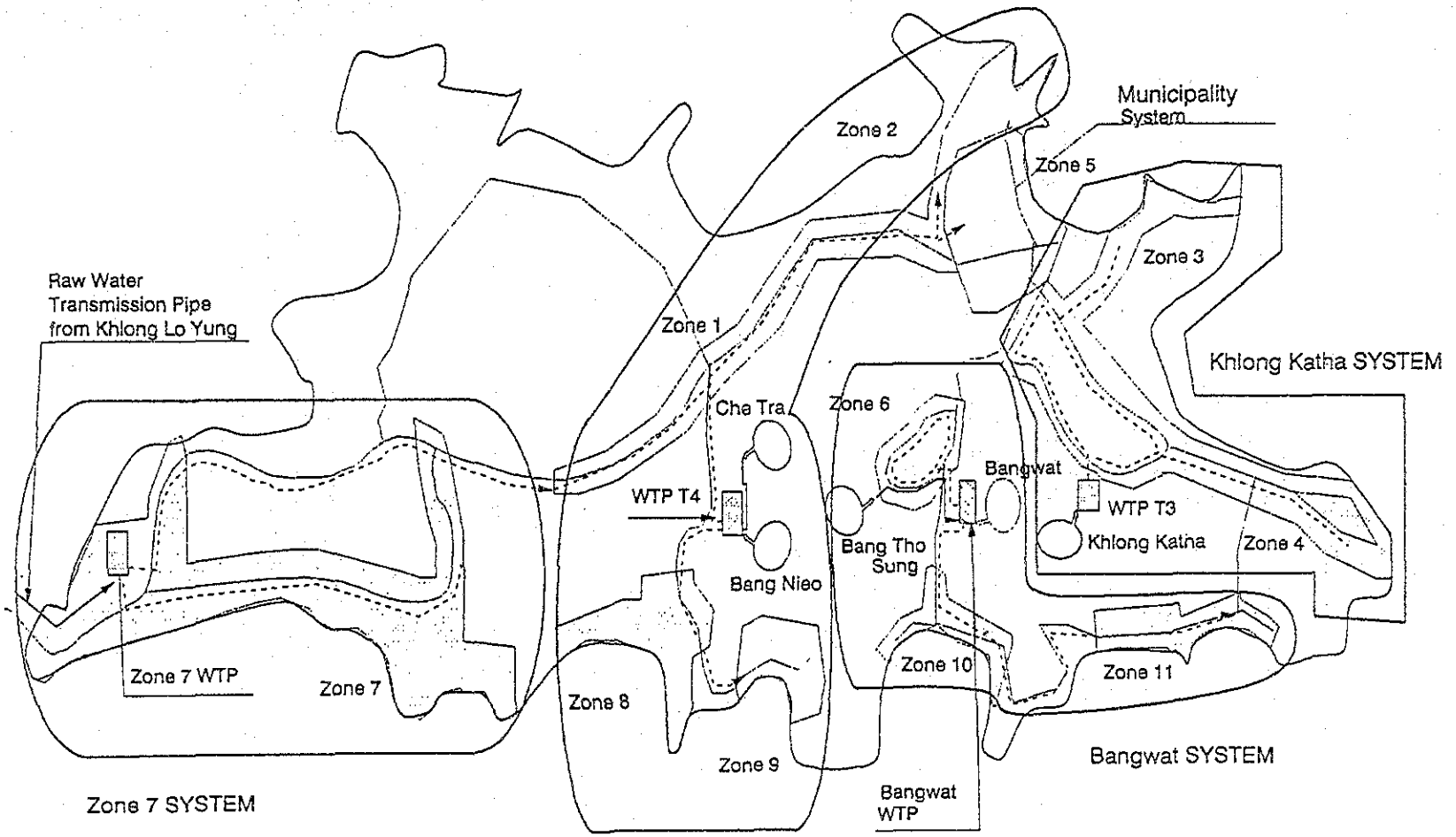


FIGURE S-2

TOTAL WATER SUPPLY SYSTEM

IMPLEMENTATION PLAN

The implementation of the plans depend on the most economical implementation of the water supply development taking into consideration water demand since the existing sources can only supply part of the demand in Bangwat and Phuket municipality. It also takes into consideration raw water sources which will depend on the existence of the dams.

Thus, a dam construction schedule is proposed according to phases with the following giving the last economic efficiency:

Phase I	(1990-1993)	-	Khlong Katha
			Bang Nieo Dam
Phase II	(1991-1994)	-	Khlong Lo Yung
Phase III		-	Khao Che Tra (2003-2006)
			Bang Tho Sung (2006-2009)

Aside from this dam construction schedule, the project implementation schedule is divided into two phases, components of which is described as follows:

Immediate Improvement Project (1990-1991)

* Temporary Water Source Development at Khlong Bang Yai

* Improvement of Beach Area Water Supply for Patong, Karon, and Katha

Main Project (1993-1995)

* Bangwat System

* Khlong Katha

* Bang Nieo Dam System

* Zone 7 System

The implementation schedule and projected water demand is shown in Figure S-3.

ORGANIZATION OF WATER WORKS

A new and improved organization for the size of the proposed water supply system is proposed. The organization will consist of the administration, the water production of the operation of raw pumping station at Khlong Lo Yung and the service section. The Figure S-4 shows a proposed organization chart.

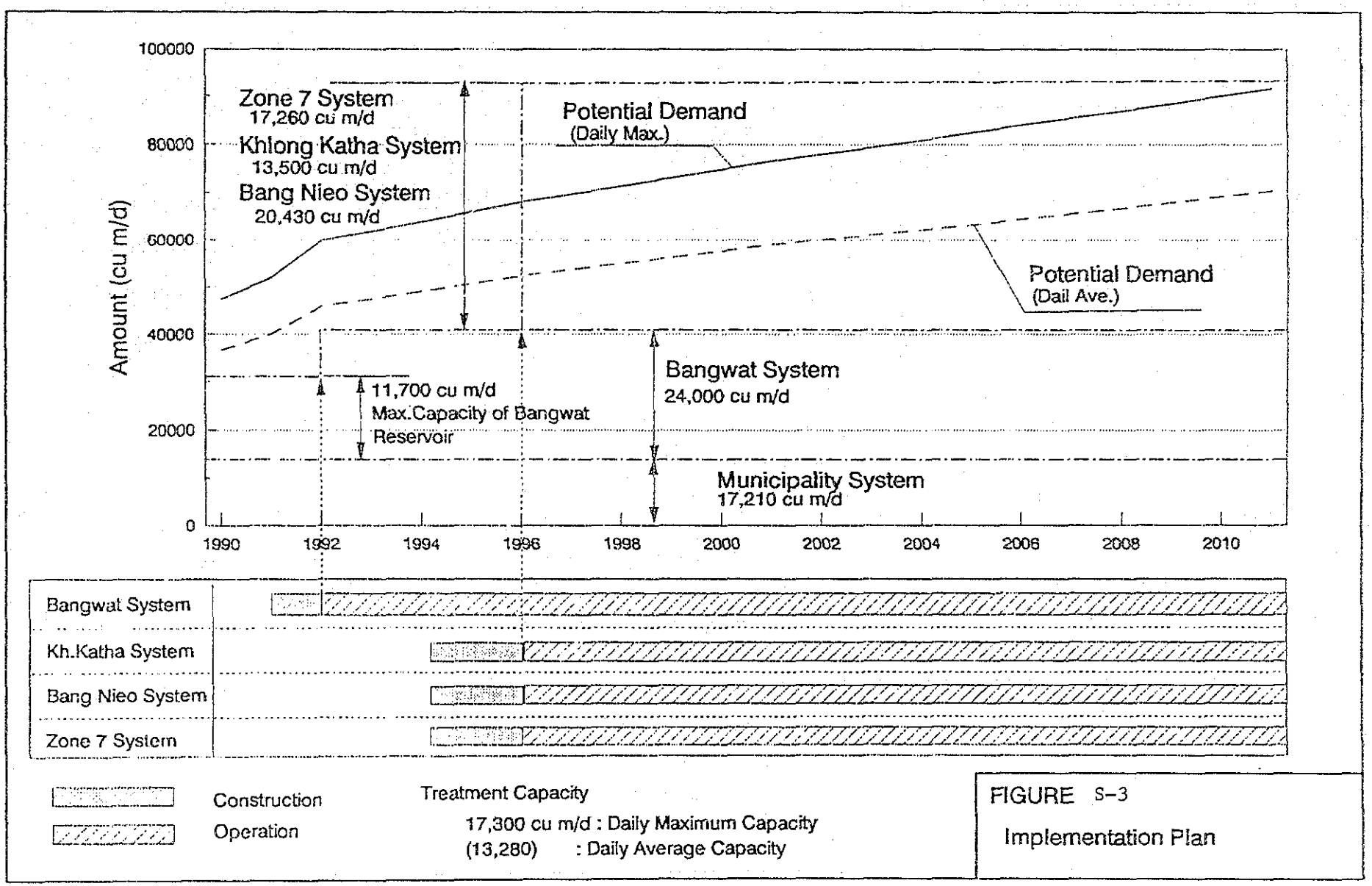


FIGURE S-3

Implementation Plan

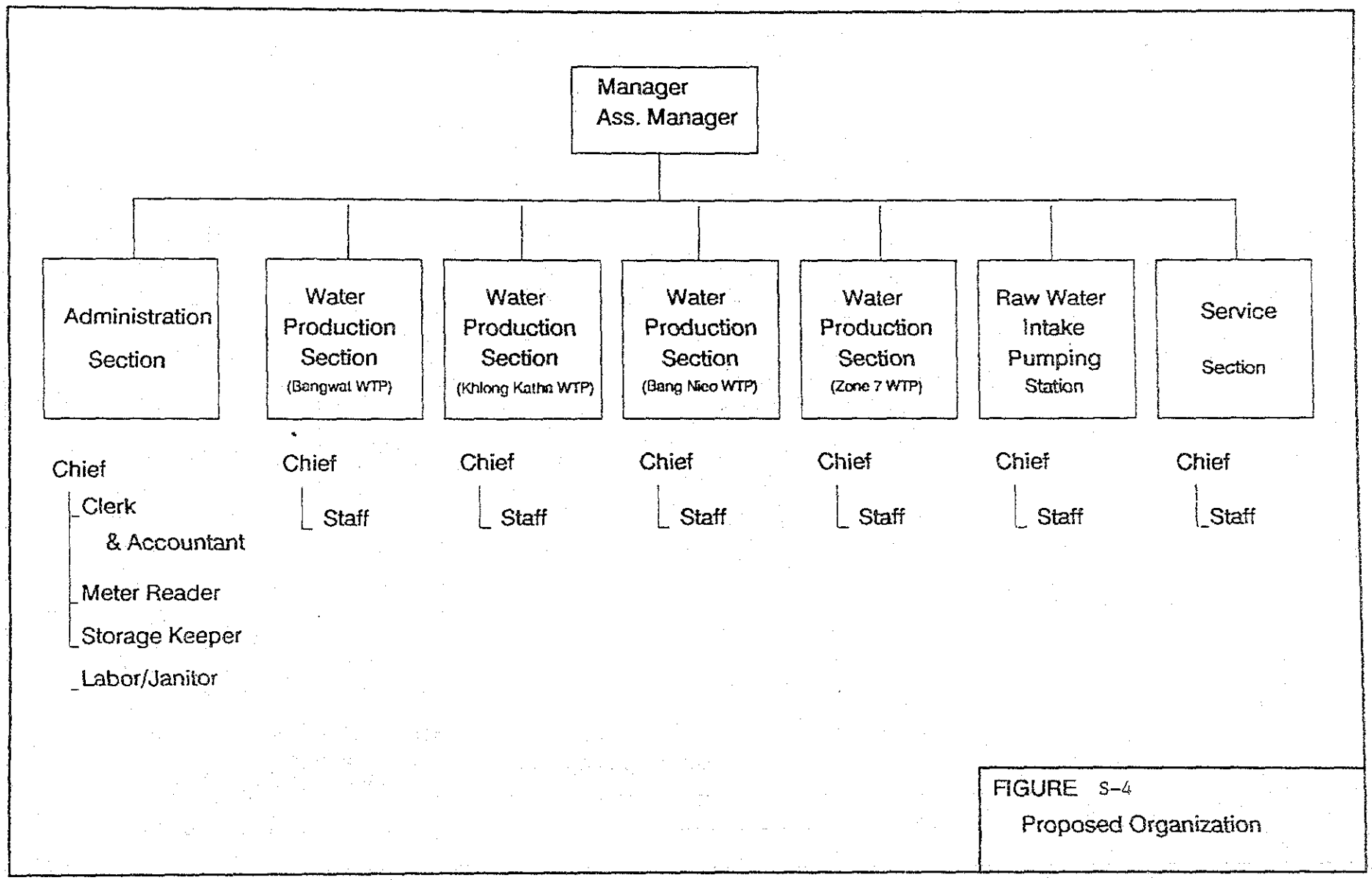


FIGURE S-4
Proposed Organization

PROJECT COST ESTIMATES

(1) Construction Cost

Construction cost summary was based on the 1989 prices and was calculated for each facility component as shown in the Table below.

Summary of Construction Cost

(unit : Baht 1000)

Item	Total Cost	Foreign Cur. Portion	Local Cur. Portion
A. Raw Water Development			
A-1. Construction Cost			
1. Bang Tho Sung Dam	514,307	334,660	179,647
2. Khlong Katha Dam	459,544	297,317	162,227
3. Bang Nieo Dam and Che Tra Dams	440,745	275,527	165,218
4. Khlong Lo Yung Dam	474,757	310,100	164,657
Total of A-1.	1,889,354	1,217,604	671,750
A-2. Land Cost			
1. Bang Tho Sung Dam	93,750	0	93,750
2. Khlong Katha Dam	125,000	0	125,000
3. Bang Nieo Dam and Che Tra Dams	343,750	0	343,750
4. Khlong Lo Yung Dam	375,000	0	375,000
Total of A-2.	937,500	0	937,500
Total of A.	2,826,854	1,217,604	1,609,250
B. Water Supply Development			
B-1. Construction Cost			
1. Bangwat System - Immediate Improvement	104,142	63,065	41,078
2. Bangwat System	36,320	29,056	7,264
3. Khlong Katha System	83,774	44,809	38,965
4. Bang Nieo Dam System	321,010	221,873	99,137
5. Zone 7 System	284,193	193,706	90,487
Total of B-1.	829,439	552,508	276,931
B-2. Land Cost			
1. Bangwat System - Immediate Improvement	7,031	0	7,031
2. Bangwat System	0	0	0
3. Khlong Katha System	7,500	0	7,500
4. Bang Nieo Dam System	11,250	0	11,250
5. Zone 7 System	94	0	94
Total of B-2.	25,875	0	25,875
Total of B.	855,314	552,508	302,806
Grand Total of A. B.	3,682,168	1,770,112	1,912,056

(2) Operation and Maintenance Cost

Operation and maintenance cost is calculated from the water demand in each year, and consists of energy, chemical, manning, repair, and replacement costs.

Summary of Operation and Maintenance Cost

(unit : Baht 1000)

Year	OPERATION COST					Sub-Total
	Energy Cost	Chemical Cost	Manning Cost	Repair Cost	Replacement	
1990	3,152	497	2,077	14		5,738
1991	4,165	497	2,180	14		6,855
1992	5,418	621	2,289	14		8,341
1993	5,433	621	2,404	14		8,471
1994	7,874	996	2,524	14		11,408
1995	8,089	1,012	2,761	14		11,876
1996	8,397	1,045	5,450	14		14,905
1997	8,708	1,070	5,722	65		15,565
1998	9,025	1,096	7,414	65		17,600
1999	9,346	1,122	7,785	65		18,318
2000	9,576	1,149	8,174	65		18,964
2001	9,890	1,176	8,583	65		19,713
2002	10,115	1,197	9,012	65		20,389
2003	10,288	1,218	11,584	65		23,155
2004	10,518	1,241	12,334	103		24,196
2005	10,726	1,261	12,951	103		25,041
2006	10,292	1,287	13,599	103		25,281
2007	10,528	1,310	14,279	103		26,220
2008	10,772	1,333	15,201	103		27,409
2009	11,023	1,356	16,180	103		28,661
2010	9,089	1,380	16,989	103		27,560
2011	9,332	1,405	17,838	103		28,678

PART 3 FEASIBILITY STUDY

Preliminary Design

The preliminary design was prepared for the proposed facilities. The characteristics of the major facilities of the treatment plant are summarized as follows:

Major Facilities of the Treatment Plants

Facility	T3 (Khlong Katha)	T4 (Bang Nieo Dam)	T5 (Zone 7)
a.Receiving Well			
Type	: Circular	Circular	Circular
Dimension	: Dia.3.0 x D 2.5	Dia.3.0 x D 3.0	Dia.3.0 x D 3.0
No.	: 1	1	1
b.Mixing Basin			
Type	: Square	Square	Square
Dimension	: L 1.2 x W 1.5 x D 1.5	L 1.5 x W 2.0 x D 1.5	L 1.5 x W 2.0 x D 2.0
No.	: 4	4	2
c.Flocculator			
Type	: Hydraulic flocculation	Hydraulic flocculation	Hydraulic flocculation
Dimension	: L 1.5 x W 20.0 x D 2.5	L 2.0 x W 24.0 x D 2.5	L 2.0 x W 20.0 x D 2.5
No.	: 4	4	4
d.Sedimentation Basin			
Type	: Rectangular	Rectangular	Rectangular
Dimension	: L 5.0 x W 30.0 x D 4.0	L 6.0 x W 38.0 x D 4.0	L 6.0 x W 32.0 x D 4.0
No.	: 4	4	4
e.Sand Filter			
Type	: Rapid Sand Filter,	Rapid Sand Filter,	Rapid Sand Filter,
Dimension	: L 3.0 x W 4.5	L 4.0 x W 5.0	L 3.5 x W 5.0
No.	: 8	8	8
f.Clear Water Reservoir			
Type	: Rectangular	Rectangular	Rectangular
Dimension	: L 32.0 x W 15.0 x D 5.0	L 35.0 x W 20.0 x D 5.0	L 30.0 x W 20.0 x D 5.0
No.	: 2	2	2

As shown in Figure S-3, the construction will be divided in two phases. The project components are accordingly divided in two phases as shown below:

Project Component in Each Phase

1. Immediate Improvement Project (1990-1991)

A. Temporary Water Source Development
   A-1. Construction of a Pumping Station at Khlong Bang Yai

B. Improvement of Beach Area Water Supply
   B-1. Construction of a high level reservoir
   B-2. Construction of service reservoirs
   B-3. Construction of transmission pipe from the high level reservoir to Karon beach
   B-4. Replacement of distribution pipes in Patong beach
   B-5. Construction of distribution pipes in Patong, Karon, and Katha beaches
   B-6. Construction of additional distribution pipes in Kathu area

2. Main Project (1994-1996)

A. Khlong Katha System

   Preceding dam project : Khlong Katha Dam

   A-1. Construction of a raw water pipe
   A-2. Construction of a treatment plant
   A-3. Construction of a distribution pipe

B. Bang Nieo Dam System

   Preceding dam project : Bang Nieo Dam
   (Khao Che Tra Dam is to be completed in 2006)

   B-1. Construction of a raw water pipe
   B-2. Construction of a treatment plant
   B-3. Construction of a distribution pipe

C. Zone 7 System

   Preceding dam project : Khlong Lo Yung Dam

   C-1. Construction of a raw water pumping station
   C-2. Construction of a raw water pipe
   C-3. Construction of a treatment plant
   C-4. Construction of a distribution pipe

Financial Study

Project Cost Estimates

Total Project cost is estimated at 928,303 Baht, with a foreign exchange requirement of 538,063 Baht and local cost component of 390,240 Baht. The breakdown of cost estimates by phase is as follows:

	Foreign Portion	Local Portion	TOTAL
a. Construction Cost	489,443	339,996	829,439
Phase 1	0	104,142	104,142
Phase 2	489,443	235,854	725,297
b. Engineering Cost			
Design, 6% of (a)	36,464	18,278	54,742
Phase 1	1,823	914	2,737
Phase 2	34,641	17,364	52,005
Supervision, 2% of (a)	12,156	6,091	18,247
Phase 1	1,216	608	1,824
Phase 2	10,940	5,483	16,423
c. Land Cost (Phase 1)	0	25,875	25,875
TOTAL	538,063	390,240	928,303
Phase 1	3,039	131,539	134,578
Phase 2	535,024	258,701	793,725

Financing Plan

The following financing schemes were considered:

Alternative 1: Total project cost financed from multilateral loan

Alternative 2: Foreign cost portion financed from bilateral loan; local cost from multilateral loan

Alternative 3: Foreign cost portion financed from bilateral loan; local cost equally financed from domestic loan and from PWA equity

Alternative 4: 83% of total project cost consisting all foreigncost. and 230,599 million Baht of local cost financed from bilateral loan; the remaining 159,641 million Baht of local cost equally financed from domestic loan and from PWA equity

Alternative 5: 86% of total project cost, consisting of all foreign cost and 230,599 million Baht financed from bilateral loan; 159,641 million Baht of local cost from domestic loan

Alternatives 3 and 4 are more desirable in view of lower funding burden for PWA. However, Alternative 4 is recommended over Alternative 3 due to lower fund requirements during construction stage.

Cash Flow Analysis

Inflows consist of government capital contribution for interest payment of domestic loan, foreign and local loan based on Alternative 4 financing scheme, water sales, connection fees, service charges, and other income including revenues from sales of materials, collected fines and about 2% of water sales. Water sales were projected using the current tariff structure until year 2020. Outflows consist of project expenditure, amortization based on Alternative 4 financing scheme, O&M, and connection expenses (50% of connection fees).

Results of cash flow analysis show deficits ranging from -1.195 million Baht to -30.566 million Baht for the period 1990 to 1991 and 2000 to 2001. These are expected to be covered with PWA equity. However, large surpluses during the subsequent years (1995-2020) are forecasted. For year 2020, cumulative cash surplus is estimated at 268.6 Million Baht.

Financial Internal Rate of Return (FIRR)

The project's internal rate of return on equity (IRROE), based on Alternative 4 financing scheme, was assumed to represent the FIRR. The IRROE, unlike the internal rate of return on investment (IRROI), takes into account the debt payments that have to be made each year. Also considered in the analysis was the salvage value of capital assets which was added to the benefit flows. Results indicate that the project is financially viable, with an FIRR of 12.67%, which is greater than the 9% opportunity cost of capital.

ECONOMIC STUDY

The benefits were represented by the following: a) economic value of water, assumed to be 20% higher than the average rate per volume of water used in the financial analysis; b) health benefits, expressed as the reduction in cost of time lost and reduction in medical expenses (assuming 50% of waterborne diseases are caused by poor water supply system); c) increase in land values, assuming that land value increase for 7 years after construction of the project and 5% of the increase in land values is attributed to the availability of water supply system. Other expected benefits such as increased employment opportunities, intensified land use, increaed government tax revenues were not quantified.

The econoimc costs were calculated based on financial costs adjusted for the following: a) import duties and domestic tax assumed to be 10% and 5%, respectively; b) shadow prices for foreign and local currency of 1.00 and 0.95 respectively, and for unskilled labor of 0.5.

The project was found to be economically viable, with an economic internal rate of return (EIRR) of 15.52%, which is greater than the 9% opportunity cost of capital.

Part 1
GENERAL

Part 1 GENERAL

1. DESCRIPTION OF THE STUDY AREA

1.1 Natural Conditions

1.1.1 General

Phuket is the only one island Province in Thailand. It is in the Indian Ocean about 867 km from Bangkok and stretches 49 km from north to south and 19 km from east to west. The Municipality of Phuket is the center of administration, economy and culture in the Province. Beautiful beaches along the western and southern seashore such as Nai Yong, Surin, Kamara, Patong, Karon, Kata, Nai Ham, Ra Wai, Lame Ka and Mittrapab attract many tourists to the Phuket Island. The government is now aggressively developing the tourism potential of Phuket. But, Phuket is also known as the island of rubber plantations and tin mines.

In Phuket, the PWA Phuket Waterworks covers the areas of Patong, Kathu and Deep Sea Port, while the Phuket Municipal Waterworks covers the municipal area. In addition to this, three rural water supply systems are in operation in the Thep Kasattri Sanitary District, Choeng Thale Sanitary District and in Sapam.

1.1.2 Topography

Phuket originally meant "mountain" in the Malay language, as most of the islands are mountainous ranging 200 m to 500 m in elevation. About 80% of the southern part is the mountain area, where the highest peak is 529 m at Mt. Mai Thao Sip Song.

The land below the mountains, between 5-40 m, comprises flat to undulating middle terrace, mainly planted to rubber.

Beautiful beaches contribute to tourism and are scattered on the western side of the island. The beaches are of gravel, sand and shell fragments while the beaches on the eastern side are mainly covered by mangrove in brackish water.

There are more small streams than main ones in Phuket that flow to the sea. Another striking feature there is the number of abandoned mine pits that have formed into hollows.

1.1.3 Geology

Geology in the Phuket Island is mainly characterized by three groups: Q, Cp and Kgr. Beach deposits (Qb) are distributed on the beach side all over the island, alluvial deposits (Qa) are formed on the beach side along estuaries and colluvial deposits (Qt) are formed on the undulating middle terrace located between the mountains and the beach.

Mudstone or sandstone (Cp) is formed on the most part of the peninsula in the eastern part and on Mt. Nieo Dam in the central part.

Granodiorite or biotite granite (Kgr) are formed mainly in the mountain area in the western part.

Details of geological feature are given in Table 1-1-1.

Table 1-1-1 Geological Feature

Group	Feature	Location
Qb	Beach deposits : Gravel, sand and shell fragments	Beachside all over island
Qa	Alluvial, estuarine and tidal flat deposit; Clay, silt, sand and mud	Beachside along estuarine of streams
Qt	Colluvial deposits and low-lying, deeply weathered bed-rock	Undulating middle terrace located between mountain and beach
Cp	Mudstone, pebbly mudstone and sandstone, dark gray to black, massive to laminated; siltstone, sandstone, ortho guartzite, and turbidite, greenish-gray to dark gray and white to pale brown, laminated,interlayered, and interbedded; rarely conglomerate; locall abundant brachiopods	Most of peninsula in the eastern part of the island and Mt.Nieo dam area in the central part
Kgr(a)	Granodiorite	Mountain Area
Kgr(b)	Biotite granite, coarse-grained and generally porphy ritic	
Kgr(c)	Biotite granite and horn bleude-adamellite, fine to medium-grained, locally porphyritic	

Source : Geological Map of Phuket prepared by DMR

1.1.4 Meteorology

The annual rainfall in the Phuket Island ranges from 2,300 mm in the southern part to 2,700 mm in the northern part. Rainfall distribution is seasonal, with most of the rainfall occurring during the wet season from May to October. Rainfall during the dry season is variable and unreliable.

Average annual pan evaporation level is 1,730 mm with little monthly variation. Relative humidity is relatively high, ranging from 81.4% in September and October to 68.2% in February. The mean monthly temperature varies from 29.5°C in April to 27.3°C in September. The extreme range is from 37.8°C to 17.4°C .

Details of meteorology are given in Table 1-1-2.

Table 1-1-2 Meteorological Data at Phuket

Items	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature (C.degree)													
Mean	27.9	28.8	29.4	29.5	28.5	28.2	27.8	27.9	27.3	27.4	27.6	27.6	28.2
Mean Max.	31.9	32.8	33.4	33.3	31.9	31.4	31.0	31.1	30.6	30.8	30.8	31.0	31.7
Mean Min.	23.2	23.7	24.2	24.6	24.5	24.4	24.1	24.3	23.8	23.7	23.8	23.6	24.0
Ext. Max.	34.2	36.0	36.6	37.8	35.5	34.3	34.6	34.4	33.8	34.4	34.0	34.2	37.8
Ext. Min.	17.4	18.6	20.0	20.0	21.0	21.0	19.9	20.4	21.1	20.5	20.3	18.4	17.4
Relative Humidity (%)													
Mean	69.5	68.2	69.1	73.3	79.8	79.2	79.7	78.6	81.4	81.4	78.5	73.9	76.1
Mean Max.	86.1	85.6	87.4	90.4	93.3	91.6	92.3	91.0	93.1	93.8	91.5	88.0	90.4
Mean Min.	55.0	53.0	53.8	58.2	66.4	67.1	67.4	66.4	69.0	68.0	65.4	61.0	62.6
Ext. Min.	33.0	33.0	31.0	28.0	37.0	45.0	47.0	40.0	48.0	43.0	39.0	37.0	28.0
Evaporation (mm.)													
Mean - Pan	163.4	156.5	171.9	160.4	134.7	144.0	147.5	158.1	140.1	124.3	118.6	140.8	1760.3
Rainfall (mm.)													
Mean	31.0	20.7	52.5	123.8	304.6	286.9	304.2	273.1	379.0	303.4	158.2	64.3	2301.7
Mean Rainy Days	4.3	2.7	5.1	11.1	20.8	19.2	20.1	19.1	22.6	21.5	15.5	8.8	170.8
Greatest in 24 hr.	70.8	47.8	68.2	89.8	142.9	129.2	145.9	118.5	145.0	141.2	126.9	73.4	145.9
Day / Year	7/67	12/60	24/59	25/84	2/68	25/62	13/66	14/83	6/64	3/67	2/58	15/84	13/66

1.2 Socioeconomic Conditions

1.2.1 Economic Conditions

(1) The gross provincial product (GPP) of Phuket Province at 1972 prices is shown in Table 1-2-1. The largest share is accounted for by agriculture, the majority of which is fisheries, followed by services, trade, transportation and communications and banking. Mining and quarrying are the sixth accounting for 8.0% in the total GPP.

In terms of growth rate between 1980 and 1986, banking increased most, followed by electricity and water supply, ownership of dwelling, and services. Agriculture came in fifth, where the GPP of the livestock subsector increased to over two times the 1980 level. The economy of the province is now shifting toward service oriented structure.

(2) The Phuket island is gifted with natural resources. Tin ore is the major mining resource of the island lying inland and offshore. There is a smelting factory which has contributed much to the island's economy. However, due to the recession in recent years, many mines stopped operation.

The natural features of the island has attracted many tourists, and the government is promoting international tourism in the island, which has generated new job opportunities. Currently, a lot of investment is seen in the tourism related sector such as construction of hotels, bungalows, restaurants, and other tourists service companies.

Agricultural resources such as coconut, rubber and fisheries are also important for the economy.

Thus, the average income per person in Phuket is considerably higher than the average of the southern region and the national average.

1.2.2 Transportation

The major road network of Phuket Province is as shown in Figure 1-3-1. The arterial road is Route 402, which connects the island with Phang Nga by Sarasin Bridge, and leads to the Municipality. Major roads are almost paved, while some roads on the west coast are presently being paved. A bus terminal is in the Municipality.

The airport is located along Route 4026 in Tambon Mai Khao.

The recently constructed Deep Sea Port is located along Route 4023 in Tambon Wichit but has not been opened yet.

Table 1-2-1 Gross Provincial Product (GPP) at Constant 1972 Prices

(Unit : 1,000 ฿)

Industrial Origin	1980	1981	1982	1983	1984	1985	1986
Agruculture	235.1	231.8	200.0	251.2	263.1	266.1	275.3
Crops	72.2	76.9	80.9	82.7	84.9	88.9	89.4
Livertock	15.7	17.4	16.7	34.1	46.2	35.0	35.8
Fisheries	147.2	137.4	98.5	126.2	128.7	141.7	150.1
Forestry	0.0	0.1	3.9	8.2	3.3	0.5	0.0
Mining & Quarrying	200.1	147.4	141.3	138.1	150.7	133.4	111.1
Manufacturing	93.3	74.5	58.6	54.9	56.9	27.9	28.7
Construction	90.3	63.6	58.1	67.3	54.7	42.7	43.9
Elect. & Water Supply	46.0	57.9	64.0	57.8	58.0	66.1	70.5
Trans. & Comm.	149.4	153.2	156.6	130.0	140.2	142.8	150.2
Trade	192.2	191.7	186.0	197.9	203.7	211.9	219.3
Banking	88.1	90.9	108.1	119.1	127.3	141.3	143.9
Ownership of Dwelling	10.2	10.8	11.5	13.2	13.0	14.9	14.3
Public Ad. & Defence	18.6	51.2	52.7	55.6	53.0	55.6	56.5
Services	203.1	217.0	225.7	231.2	235.9	254.7	273.0
GPP	1,356.4	1,290.0	1,262.6	1,316.3	1,356.5	1,356.4	1,386.7
Per Capita GPP (฿)	10,122	9,347	8,891	9,077	9,104	8,865	8,889

Source : Production of Regions and Provinces (South) 1986, NESDB

1.2.3 Education

Education system in Thailand is divided into three levels primary, secondary and tertiary.

In recent years, pre-primary education, including kindergarten, has become available to children of ages three to five. Children enter primary school when they are anywhere between six to eight years old, depending largely on the locality. Secondary education is divided into lower and upper divisions, each consisting of three years such that, typically, those 12-14 years of age attend lower secondary while those 15-17 attend upper secondary.

The government plays a major role in all aspects of Thailand's education system. Government expenditure on education as a percentage of total government expenditure varied from 19% to 21% in the recent eight years. The percentage of government expenditure on education in Thailand is among the highest compared to other developing countries.

In Phuket, there are 70 schools. A detailed breakdown of schools, including the numbers of students and teachers is shown in Tables 1-2-2 to 1-2-4.

Table 1-2-2 School in Amphoe Thalang

Grade of School	No. of Schools	No. of Students	No. of Teachers
Kindergarten	4	867	47
Primary School	4	5,594	507
Secondary School	3	1,379	111
College/University	-	-	-
Total	11	7,840	665

Table 1-2-3 School in Amphoe Kathu

Grade of School	No. of Schools	No. of Students	No. of Teachers
Kindergarten	-	-	-
Primary School	10	1,742	197
Secondary School	1	380	33
College/University	-	-	-
Total	11	2,122	230

Table 1-2-4 School in Amphoe Muang Phuket

Grade of School	No. of Schools	No. of Students	No. of Teachers
Kindergarten		2,279	
Primary School	45	12,632	
Secondary School		6,712	380
College/University	3	5,286	665
Total	48	26,909	1,782

1.2.4 Sanitation (Water-borne Diseases)

In developing countries, three people out of the five do not have access to clean drinking water. According to WHO, about 80% of sicknesses are caused by unhygienic water and defective sewage treatment. Thus, the quality of drinking water is closely related to human health.

To decrease the incidence of water-borne diseases is one of the more significant purposes of a water supply project. The status of water-borne diseases in relation to the number of patients is shown in Table 1-2-5.

Table 1-2-5 Water-Borne Diseases in Phuket Province

Year	No. of Patients					
	Diarrhea	Dysentery	Food Poisoning	Typhoid	Cholera	Total
1983	1,888	114	112	128	4	2,246
1984	1,361	85	125	181	8	1,760
1985	1,685	128	118	222	2	2,155
1986	2,078	120	108	125	0	2,431
1987	4,083	386	198	228	23	4,918

1.3 Land Use

1.3.1 Existing Land Use Pattern

Main features of the existing land use pattern are as follows:

The land is mostly covered by forests of which rubber plantation dominates. Tin mining areas are also scattered over the island.

With the Municipality as the hub of urbanization, communities are located along major roads over the island as in Figure 1-3-1. The Municipality is expanding along the major roads such as the two lines of Route 4021 and Route 4023 to the south, Route 402 to the north and Route 4020 to the west. Several new housing development schemes are seen in the outskirts of the Municipality.

There is a newly constructed Deep Sea Port waiting for operation near a tin smelting factory at the southeast end of the island. The port is the only Deep Sea Port on the west coast of Thailand.

Most hotels are located on the west and south coasts and in the Municipality. In general, southern parts of the beaches are relatively developed tourist spots, in which Patong Beach is the most developed area, while northern parts are newly developing or planned to develop.

1.3.2 Land Value

In the island, land prices are higher on the west coast beaches and in urbanized areas along major roads especially Routes 402, 4021, 4023, etc. in and around the Municipality. Official land prices of these areas are over 250 ฿/sq.m (400,000 ฿/rai) up to 2,500 ฿/sq.m (4,000,000 ฿/rai).

On the other hand, land prices are lower in areas without roads, outside sanitary districts and with less tourism potential, where official land prices are less than 25 ฿/sq.m (40,000 ฿/rai).

Actual prices are higher than the official ones. The gaps between these vary on areas. In certain cases, actual prices are about two times the official ones or much more.

1.3.3 Future Land Use Pattern and Development Prospects

(1) According to DTCP town plans, future urbanized areas are allocated as in Figure 1-3-2. However actual development since the base years of the plans is not all in line with the plans.

(2) The development trends of the island include the following aspects:

- Urbanization of the Municipality is expanding beyond the present administrative boundary. To meet the trend and increased demand for public services. The Phuket Municipality is considering expansion of the boundary to neighboring tambons.

- Tourism development is one of the essential factors to determine future land use. According to "the Study on Potential Tourism Area Development for the Southern Region in Thailand", future development of tourist zones will mainly take place along the west coast beaches, on which large scale international resort complexes will be located in Bang Thao, Chat Chai and Thai Muang, while ordinary hotel accommodations with public beach facilities for domestic tourists will be developed on Mai Khao and Khok Kloi beaches as in Figures 1-3-3 and 1-3-4.

  The tourism study sets the marketing targets for distribution of Figure 1-3-1

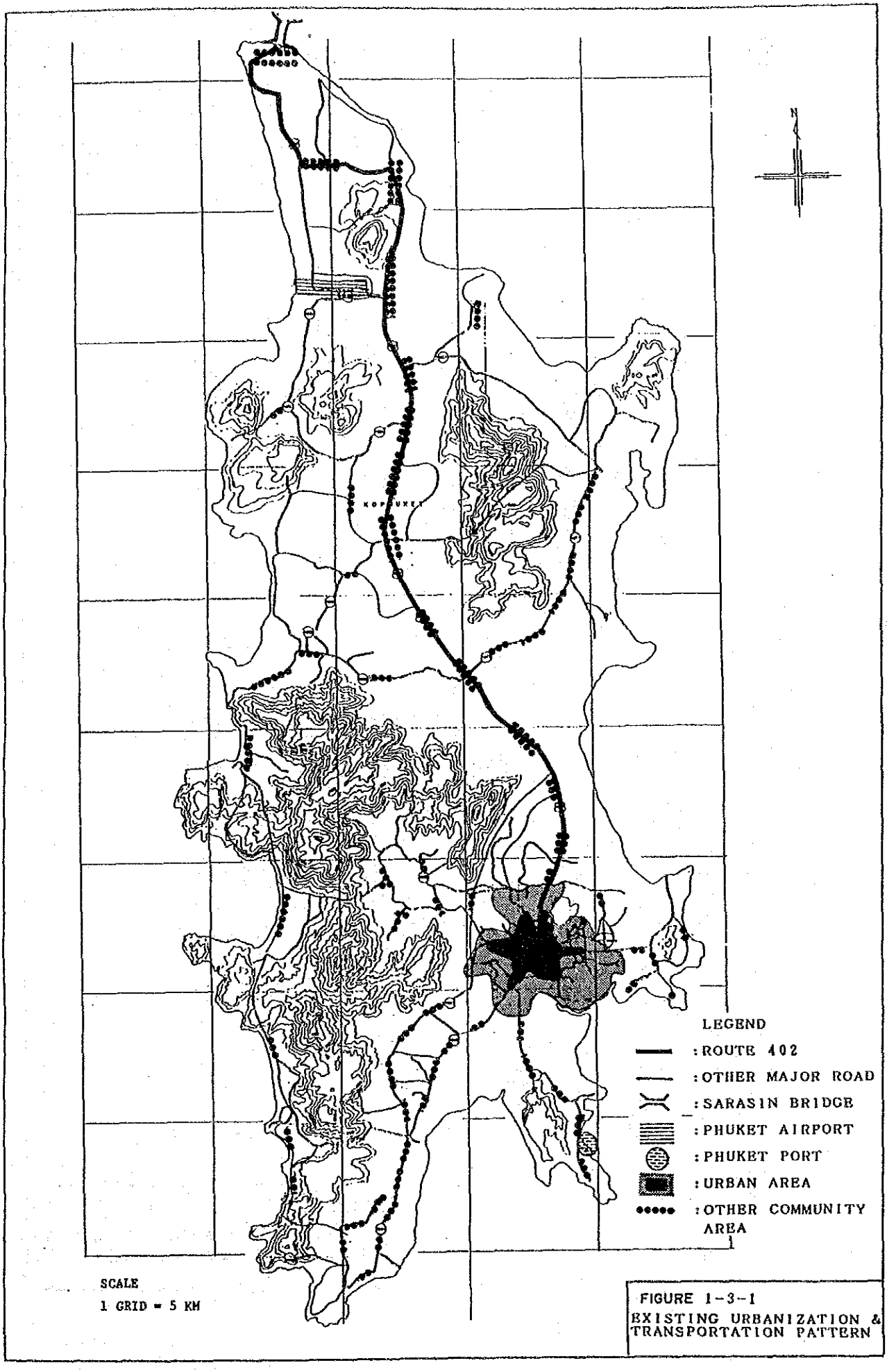


FIGURE 1-3-1
EXISTING URBANIZATION & TRANSPORTATION PATTERN

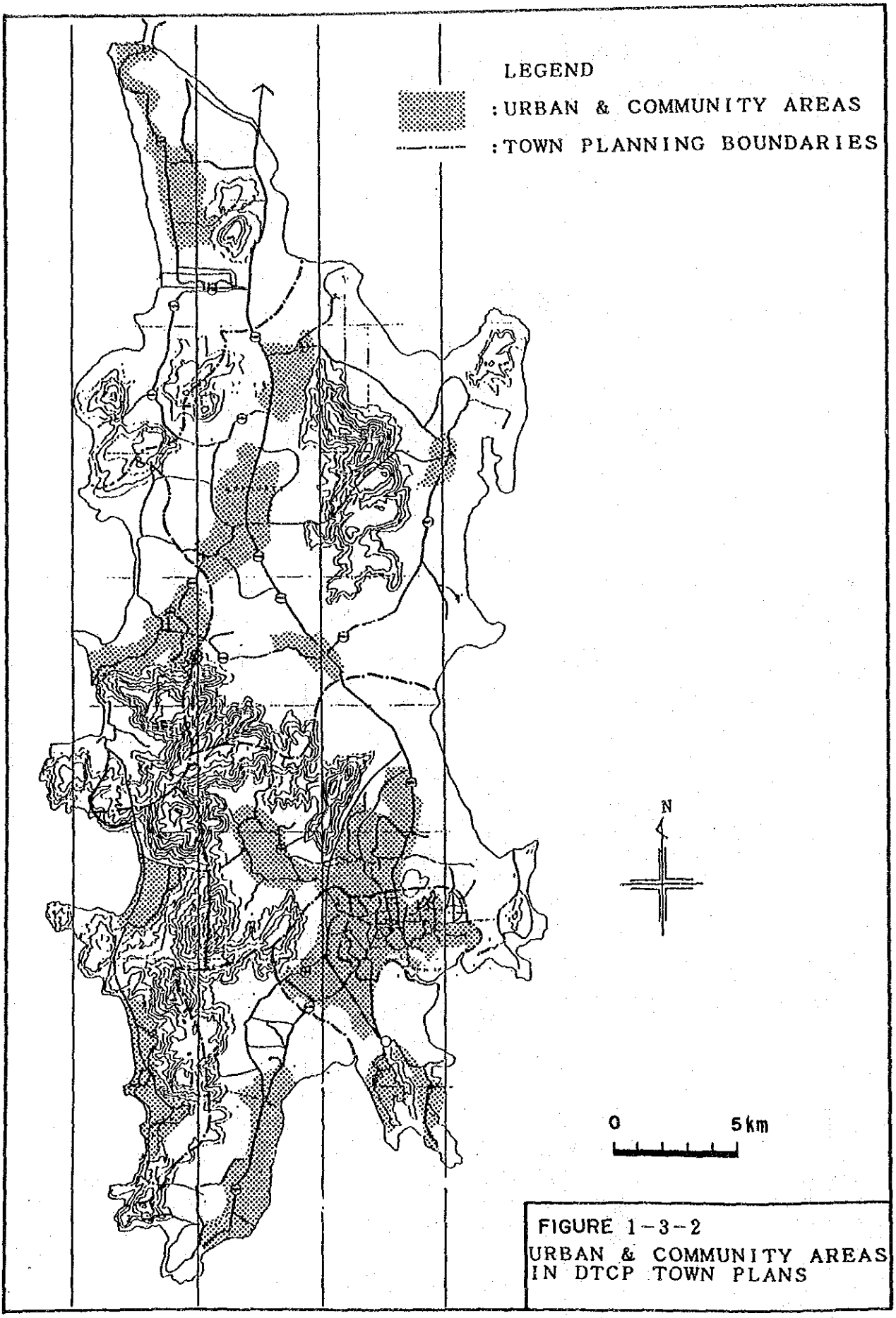
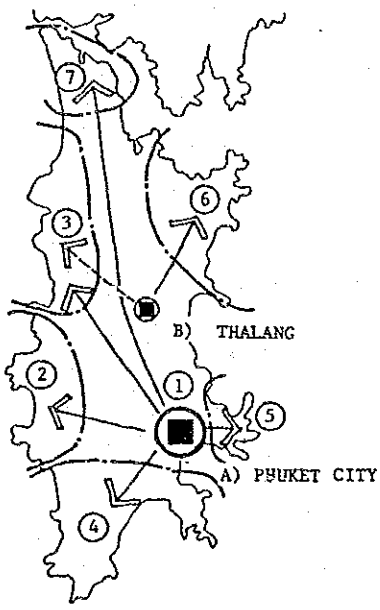


FIGURE 1-3-2
URBAN & COMMUNITY AREAS IN DTCP TOWN PLANS



LEGEND

Local Communities

Tourism Zone

Zone 1 - Phuket City Zone

Zone 2 - Zone of rapid growth of beach fronts
(Patong - Kata and Karon)

Zone 3 - Extension of west beach fronts
(Kamala - Bang Tao & Mai Kao)

Zone 4 - Old beach front
(Rawai - Naihan and Promtep)

Zone 5 - Industrial Zone
(Deep-sea Port and Thai Saco)

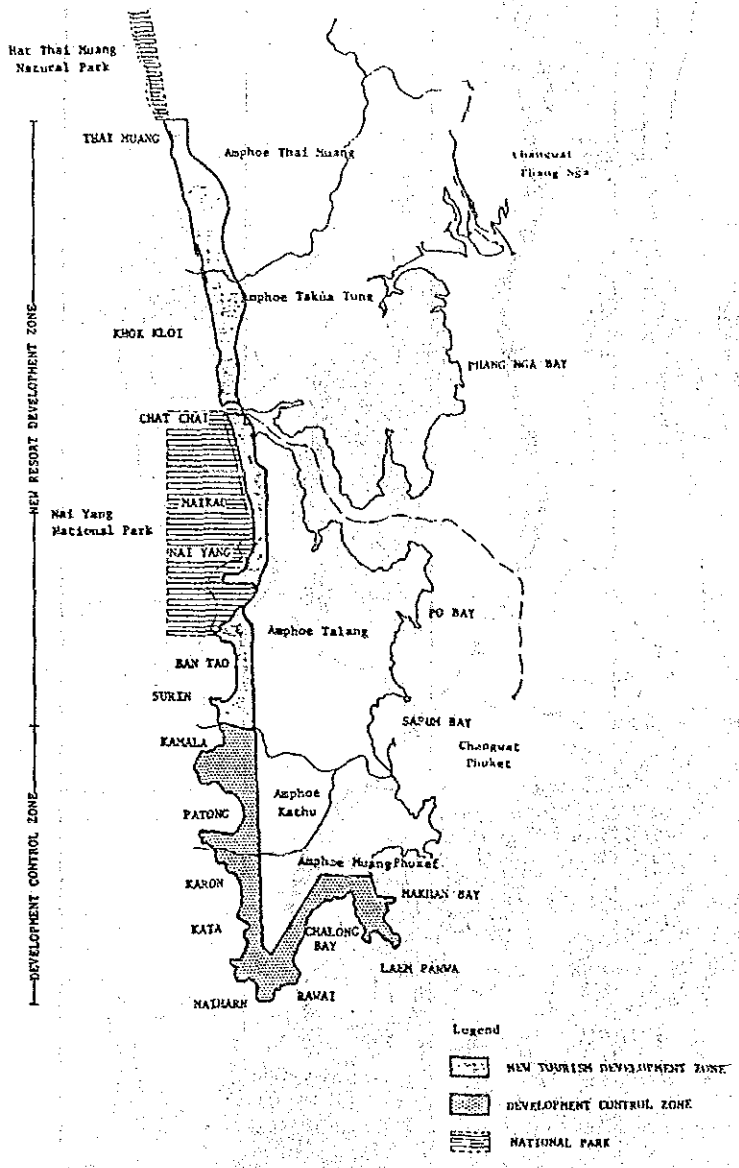
Zone 6 - North-East fishing village

Zone 7 - Northern Island - Crown Property concession (2600 rais)

Source : Study on Potential Tourism Area Development for South Regional in Thailand

FIGURE 1-3-3

LOCAL COMMUNITIES AND TOURISM DEVELOPMENT



Source : Study on Potential Tourism Area Development for South Region in Thailand

FIGURE 1-3-4

TOURISM DEVELOPMENT ZONES

required rooms as in Table 1-3-1.

There is a preliminary idea to develop the government land of approximately 450 ha (2,800 rai) at Mai Khao Sea Shore toward 1999 as a large-scale integrated resort complex by a group of Swiss banks. The idea envisions phased development of hotels, residential plots, condominiums, a marina, a harbor village, recreation clubs, a health facility and spa, a tourism education facility, employee housing and two golf courses. The idea is taken into consideration for the planning framework of the area by the tourism study and this study.

- Industrial development taking advantage of the Deep Sea Port is considered. In this case, the impact on environment and coordinated development among all economic sectors especially between tourism and industry sectors must be carefully studied.

  The Industrial Estate of Thailand has a plan to develop an industrial estate to take advantage of the airport as a joint venture with a private entrepreneur in Amphoe Thalang. However, the site selection has not been finalized and the feasibility study has not been conducted yet.

(3) According to the Phuket Province Report, the province has the following significant problems.

- There are people who migrated to the province to work for tin mining and have lost their jobs due to closures of some mines;
- Some public land and some throne land have been invaded by and lost to squatters and tourism;
- The natural environment has deteriorated due to tin mining and tourism;
- There is a possible shortage of clean water to meet the growing demand of tourism and the Deep Sea Port;
- Floods in the Municipality have been caused by sediment from wastewater in canals;
- There is lack of roads connecting beaches on the west coast because of financial constraints;
- The cost of living is high;
- There are constraints on agricultural development due to land use for mining, tourism and water shortage;
- The land use of former tin mines has become controversial;
- There are minority problems.

Table 1-3-1 Specific Marketing Targets for Distribution of Required Room

Area	1991 Phase I			1996 Phase II			2001 Phase III		
	High	Low	Total	High	Low	Total	High	Low	Total
Phuket	9,827	5,052	14,879	12,815	5,530	18,345	14,657	5,986	20,643
South	6,770	3,824	10,594	7,387	4,058	11,445	8,034	4,469	12,503
North	2,078	11	2,089	4,472	255	4,727	5,618	300	5,918
Town	853	1,034	1,887	830	1,034	1,864	879	1,034	1,913
Others	126	183	309	126	183	309	126	183	309

Source : Study on Potential Tourism Area Development for Southern Region in Thailand

(4) In order to solve the above problems, the report presents the following measures.

- Making the order for accommodation in high density communities
- Generating job opportunities for the increased number of unemployed
- Providing more policemen and village guards for more inspection
- Checking documents of public land and the throne land
- Supervision and control of construction work and operation of hotels, factories, etc. under the regulation.
- Construction of small scale water reservoirs
- Dredging of shallow canals or excavation of by-pass canals
- Construction and up-grading of roads connecting tourist beaches on the west coast
- Reclamation of former tin mines to useful land for increase of agricultural production
- Improvement of the living conditions of the minority

(5) In addition to the above measures, the report presents the following development projects

- Deep Sea Port project
- Water supply projects
- Export oriented industry and semi-agricultural industry development projects
- Up-grade of the Phuket Airport to an international airport
- Long distance transportation projects
  (Phuket-Phumpim railway and Phuket-Surat Thani highway improvement)
- Phuket-Phang Nga new bridge project

2. Water Source

2.1 Existing Water Use Pattern

2.1.1 General

The Phuket Island is blessed with natural resources as physical beauty, mineral resources and abundant rainfall which boost the economy of the island.

Because of topographical features, however, the water resource potential cannot necessarily meet the ever-increasing water demand.

Intensive rainfall with more than 2,500 mm on an annual average flashes into the sea through small streams. In addition, ground water potential is relatively low due to the shallow bed rock.

Most of water supply reply on such surface water as waterfalls, mining pits and a reservoir as shown in Figure 2-1-1.

2.1.2 Surface Water

(1) Reservoir

The Bangwad Reservoir was constructed in 1983 by RID for water supply 8 km west of the Phuket Municipality. The reservoir is an earth-filled type with the following dimensions;

Catchment Area	=	4.9	sq.km
Total Storage Capacity	=	8.5	MCM
Effective Storage Capacity	=	7.5	MCM
Length of Embankment	=	900	m
Height of Embankment	=	25	m
Water Supply Capacity	=	11,700	cu.m/d

The purpose of the reservoir is not only to supply the amount of water to meet the demand in the Phuket Municipality, Patong, Kathu and Deep Sea Port, but also to mitigate frequent flood and to promote the fishery industry.

(2) Abandoned Tin Mining Pits

The Phuket Island used to have abundant mineral resources as tin scattering all over the island. As the tin price has been falling in the world market, a number of tin minings were gradually abandoned leaving low pits.

Those pits store water by rainfall, surface inflow or ground water recharge and serves as sedimentation basins to produce high quality water.

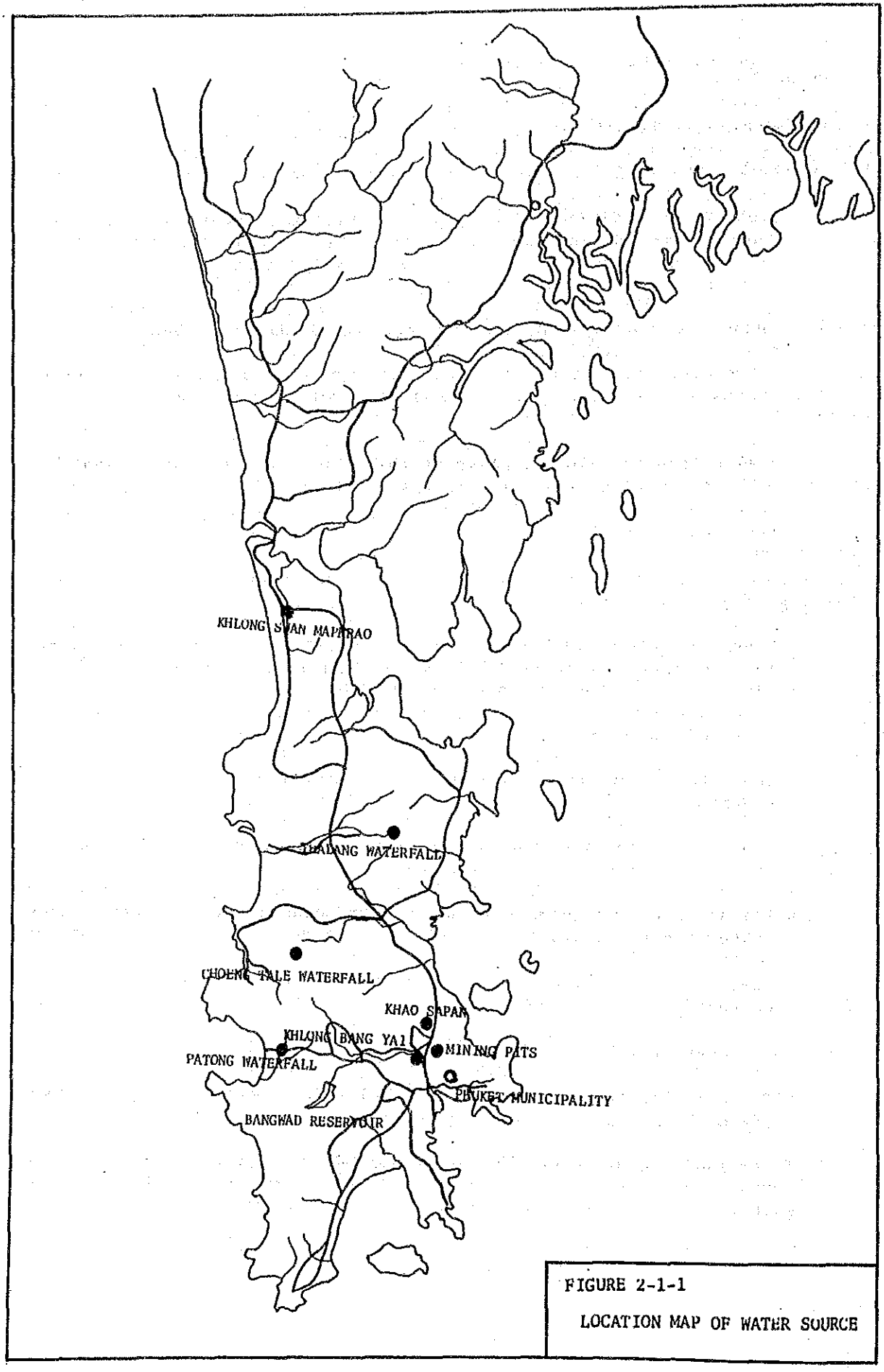


FIGURE 2-1-1

LOCATION MAP OF WATER SOURCE

(a) Phuket Municipal Water Supply

The Phuket municipal water supply fully relies its water source on five mining pits located in the north of the municipality.

The capacity and location of those mining pits are given in Table 2-1-1 and Figure 2-1-1. Their water quality tested by NEB is also listed in Table 2-1-2.

At present intake pumps are permanently installed at pits Nos. 1, 2 and 4 to supply water throughout the year. When the water level falls down in those pits in the dry season, a potable pump is installed at pit Nos. 3 and 5 by connecting to the existing pipe nearby to supply supplemental water to the municipality.

Table 2-1-1 Mining Pits

Location	Storage Capacity (cu.m)	Transmission Distance (m)	Pipe (mm)
1. Vachira Phuket Hospital	127,000	1,970	AC 250
2. Soi Pa Naeng	72,000	3,595	AC 250
3. Vichit Songkhram Rd.	222,000	5,455	AC 250
4. Ban Tak Dad	713,300	5,422	AC 250
5. Muang Phuket Municipality	334,000	3,795	AC 250

Source : Phuket Municipal Waterworks

Table 2-1-2 Raw Water Quality of Mining Pits (1986)

Water Quality	Jan		Feb		Mar		Apr		May		Jun		Jul	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
JTU	2	22	3	40	5	33	6	25	6	21	4	12	5	9
PH	6.5	6.9	6.4	6.9	6.6	7	6.4	7	6.4	6	6.6	6.9	6.6	6.8
Total Hardness(mg/l as CaCO 3)	22	28	24	66	24	66	22	56	22	46	224	40	24	38
Calbonate Hardness (")	10	12	8	20	10	20	8	25	7	18	10	19	12	19
Non Calbonate Hardness (")	8	18	13	58	12	54	10	35	10	32	10	25	12	21
Total Alkalinity, mg/l	10	12	8	20	10	20	8	25	7	18	10	19	12	19
Chloride (cl-), mg/l	7.63	8.9	6.78	9.74	8.05	11.01	8.47	14.49	8.49	13.1	8.74	14.49	9.52	12.62
Iron (Fe), mg/l	0.2	0.98	0.2	2	0.4	3	0.49	1.14	0.49	0.81	1.14	0.33	0.33	0.65
Calcium (Ca), mg/l	4	8	4	16	4.8	20	4.8	12.8	4	9.6	1.6	8.8	4	8.8
Magnesium (Hg), mg/l	1.92	3.84	2.4	6.24	0.65	4.8	1.92	14.49	2.4	5.76	2.88	4.8	2.88	4.32

(b) Khao Sapam Small Community Water Supply

A mining pit with a capacity of about 50,000 cu.m is used as the water source for water supply to the Khao Sapam village 6 km north of the Phuket Municipality. By two pumps raw water is supplied to the nearby treatment plant with a capacity of 20 cu.m/h.

(3) Waterfall

Waterfall upstream of small streams play a crucial role in small communities because the flow are quite steady all year round and have high quality. The water quality tested during the field survey is given in Table 2-1-3.

(a) Patong Sanitary District

The concrete weir is constructed upstream of a small stream in the north of Patong Beach.

By gravity raw water is transmitted through the 150 mm AC pipe (L=800 m) to the treatment plant with a capacity of 20 cu.m/h.

The flow is relatively steady even in the dry season. Water leakage are founded from some parts of the transmission pipe.

(b) Choeng Thale Sanitary District

The concrete weir is constructed upstream of a small stream in the south of the village. By gravity raw water is transmitted through the 150 mm AC pipe (L=1,000 m) to the treatment plant with a capacity of 20 cu.m/h. The flow is relatively steady all year round.

(c) Thep Kasattri Sanitary District

The concrete weir is constructed upstream of a small stream in the east of the town. By gravity, raw water is transmitted through the 150 mm AC pipe (L=1,000 m) to the treatment plant with a capacity of 20 cu.m/h. The flow is relatively steady all year round. The waterfall is located in the reserved area by the Forestry Department and one of the recreational areas in Phuket.

(4) Rainwater

Rainwater is generally used for private domestic water supply, and rainwater collection devices are often seen especially in villages in the northeast of the island where no public water supply is established. They use rainwater as an alternative source of shallow wells.

2.1.3 Ground Water

Phuket has less potentiality in ground water because of its topographical and hydrogeological structure. Rainwater flashes into the sea without sufficient recharge into the ground, or the island has no potential aquifer.

(1) Shallow Well

Shallow wells are seen mostly in the western coast or in the northeastern village scattered along Route 4027. According to the survey conducted by the Municipality, the number of shallow wells reaches more than 3,000 all over the island. They are brick-lined hand-dug

wells equipped with a bucket and rope. The well water is often contaminated by household wastewater or seawater.

The water quality tested during the field survey is given in Table 2-1-4.

(2) Deep Well

There are four deep wells constructed by DMR as listed in Table 2-1-5 and several hotels have their own deep wells for private water supply. The average yield is about 5 to 10 cu.m/h.

Table 2-1-3 Water Quality of Water Falls

Item	Patong	Choeng Tale	Thalang
Temperature (C degree)	27.2	24.5	27.6
Turbidity (ppm)	4	2	2
Cond. (uv)x5x100	6.3	5	5
PH	7.2	7.4	7
NH 4 - N	<0.4	<0.4	<0.4
NO 2	<0.006	<0.006	<0.006
NO 3	<0.23	<0.23	<0.23
Coliform	ND	ND	ND

Table 2-1-4 Water Quality of Shallow Wells

Item	Kata Beach	Nam Nok	Rawai	Rawai	Kata	Bang Rong
Temperature (C degree)	28	28	28	28	27	24.5
Turbidity (ppm)	7	1.5	13	1.5	2	2
Cond. (uv)x5x100	40.4	23	60	23	7.5	21
PH	6.7	6	6.9	6.3	4.3	5.3
NH 4 - N	ND	ND	2	TR	<0.4	<0.4
NO 2	ND	ND	0.03	0.15~0.03	<0.006	<0.006
NO 3	0.46~1.15	1.15	0.46~1.15	1.5~2.3	<0.23	2.3~4.6
Coliform	D	ND	D	D	ND	ND
Others	Iron Suspended		Yellow Color			

Table 2-1-5 List of Deep Wells by DHR

Location	Year	Depth (Ft)	Size (")	Aquifer Code	Static (Ft)	Yield (GPH)	Draw Down (Ft)	Iron (ppm)	Chloride (ppm)	TDS (ppm)
Ban Ra Ngeng M.4	1979	180	5	9	12	10	60	1 0.63	12	92
Ban Bang Kao M.1	1979	60	5	23					5.8	51
Ban Pa Khlong Sip School	1980	240	5	6	24	30	47	1 32	11	328
Wat Thep Kasattri M.4	1980	160	5	3	10	30	46	1 16	137	452

2.2 Availability of Existing Water Source

2.2.1 Data Available for the Study

(1) General

The data required for the hydrological studies are meteorological data as rainfall and evaporation, and hydrological data as water level and discharge on a monthly base. MD and RID are responsible for collecting and processing the data on meteorology and hydrology, respectively.

Rainfall data recorded at the amphoe office are sent to the MD headquarter, Bangkok for data processing.

All water level records are sent directly to the RID headquarter, Bangkok for data processing.

Geology and hydrogeology are referred from the reports and information prepared by DMR.

(2) Monthly Rainfall

Monthly rainfall data are available at two gauging stations controlled by the Phuket Airport and Phuket Municipality and one station controlled by RID at the Bangwad Reservoir.

The rainfall stations are listed below and monthly rainfall data are given in Tables A1-1-1 to A1-1-3 in Appendix A-1-1.

Table 2-2-1 List of Rainfall Station

Station	Location	Period of Record	Remarks
Phuket Mun.	Amphoe Phuket	1951 to Present	
Phuket Airport	Phuket Airport	1952 to Present	
Bangwad Reservoir	Bangwad Reservoir	Jan. 1983 to Present	Gauging started after the dam construction.

(3) Climatological Data

The data describing the climatology in the Phuket Island is available at the Phuket municipality. This station observes such climatological data as temperature, atmospheric pressure, humidity, evaporation, sunshine hours and wind. The data are given in Table A1-1-4 in Appendix A-1-1.

(4) Hydrological Data

A hydrological station, X-97 located at Huai Ao Yan, is only one station which gauged water level and discharge, but gauging was discontinued since December 1982 as shown in Table A2-1-1 in Appendix A-2-1.

2.2.2 Availability of Existing Water Source

Since the Bangwad Reservoir and mining pits for the Phuket Municipal Waterworks play a crucial role in the Phuket Island, the study was made on these existing water sources to evaluate their availability.

(1) Bangwad Reservoir

(a) Original Plan

A water balance operation study on the Bangwad reservoir was made by RID in the planning stage. The outcome of the study is shown in Tables 2-2-2 to 2-2-4.

These tables show that the annual inflow to the reservoir is estimated at 4.251, 5.645 and 2.865 MCM in the normal, very wet and very dry year, respectively. These amount of inflows are equivalent to 38%, 40% and 32% of the annual rainfall (runoff coefficient) in respective year. An available amount of water supply is then estimated at 11.7, 15.4 and 7.8 thousand cu.m in the normal, very wet and very dry year, respectively.

(b) Evaluation on the Original Study

An extensive operational study was made in order to evaluate an available amount of water supply from the Bangwad Reservoir.

The study was made on the following conditions:

- The return period is once in ten years.
- Rainfall at the Bangwad Reservoir is adopted. Rainfall is obtained by correlation equation between the Phuket Municipality and the Bangwad Reservoir as shown in Figure 2-2-1.
- Evaporation is obtained from 70% of Class A pan evaporation value.
- Seepage loss is considered, but negligible.
- No irrigation water is required.
- Runoff coefficient shown in Table 2-2-5 is adopted.
- Water balance simulation is made for 30 years from 1958 to 1987.

The outcome of the study is given in Table 2-2-6.

The tables show that an available amount is estimated at approximately 11,700 cu.m/d which is as same as the RID estimate.

Table 2-2-2 : Reservoir Operation Study by R.I.D. (Normal Year)

Project	Bangwad Reservoir	Ave. Annual Runoff Volume	4,352,694 cu.m	Reservoir Capacity	4,370,000 cu.m
Tambol	Kathu	Est. Max. Flood Discharge	16.1 cu.m/sec.	Dead Storage	230,000 cu.m
Amphoe	Kathu	Elev. Max. Flood	+196.00 m.(A.D.)	Storage of Flood Surcharge	671,471 cu.m.
Changwad	Phuket	Elev. Spillway Crest	+196.00 m.(A.D.)	F.S.L. Area	360 Reis.
Drainage Area	4.9 sq.km	Elev. Top of Dam	+197.50 m.(A.D.)	Size of Outlet Right Bank	Ø0.50 m.
Annual Rainfall	2,293 mm.	Elev. Bottom of Outlet	+183.00 m.(A.D.)	Size of Outlet Left Bank	—— m.

Flow No.	Item	Period Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1	Average Rainfall (mm)	330.7	170.1	59.1	37.2	21.4	47.0	110.7	310.8	281.5	288.6	268.6	368.1	2,293.8
2	Evaporation & Seepage (mm)	134.1	141.2	174.0	198.8	197.1	203.8	169.2	143.2	146.6	150.2	152.8	137.3	——
3	Quantity in Storage at Start of Period (Row 13) 1,000 cu.m	1,532	1,991	2,075	1,813	1,465	1,107	720	406	230	287	598	859	——
4	Inflow From Run-off - 1,000 cu.m	75.3	427	148	78	30	22	52	213	400	662	601	966	4,392
5	Average Water Surface Area of Lake 1,000sq.m (from area curve)	350	280	420	390	340	298	223	168	60	82	199	251	——
6	Rainfall Over Surface Area (Row 1 x Row 5)/1,000 1,000 cu.m	116	48	25	14	7	14	26	52	17	24	53	92	——
7	Evaporation & Seepage (Row 2 x Row 5)/1,000 1,000 cu.m	-47	-39	-75	-77	-67	-60	-38	-24	-9	-12	-30	-34	——
8	Net Total Gain or Loss (Rows 4 + 6 - 7) 1,000 cu.m	822	436	100	15	-30	-24	-39	241	405	674	624	1,024	4,251
9	Total Quantity for Period (Rows 3 + 8) 1,000 cu.m	2,354	2,427	2,176	1,826	1,435	1,083	759	649	638	961	1,222	1,883	——
10	Quantity Required for Water Supply 11,700 cu.m/day 1,000 cu.m	363	351	363	363	328	363	351	363	351	363	363	351	4,273
11	Carried Over to Next Period 1,000 cu.m	1,991	2,076	1,813	1,465	1,107	720	408	230	287	598	896	1,532	——

Note: Datum employed here is +100 m above sea level or normal ordinance datum.
Annual Natural Inflow 4,251,000 cu.m ÷ 365 = 11,700 cu.m daily average

Table 2-2-3 : Reservoir Operation Study by R.I.D. (For Very Dry year)

Project	Bangwad Reservoir	Ave. Annual Runoff Volume	4,352,694 cu.m	Reservoir Capacity	4,370,000 cu.m
Tambol	Kathu	Est. Max. Flood Discharge	16.1 cu.m/sec.	Dead Storage	230,000 cu.m
Amphoe	Kathu	Elev. Max. Flood	+196.00 m.(A.D.)	Storage of Flood Surcharge	671,471 cu.m.
Changwad	Phuket	Elev. Spillway Crest	+196.00 m.(A.D.)	F.S.L. Area	360 Reis.
Drainage Area	4.9 sq.km	Elev. Top of Dam	+197.50 m.(A.D.)	Size of Outlet Right Bank	Ø0.50 m.
Annual Rainfall	2,293 mm.	Elev. Bottom of Outlet	+183.00 m.(A.D.)	Size of Outlet Left Bank	—— m.

Flow No.	Item	Period Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1	Average Rainfall (mm)	255.0	93.6	77.0	2.6	17.8	74.5	209.8	375.2	203.1	165.8	132.8	231.3	1,839.0
2	Evaporation & Seepage (mm)	134.1	141.2	174.0	198.8	197.1	203.8	169.2	143.2	146.6	150.2	152.8	137.3	——
3	Quantity in Storage at Start of Period (Row 13) 1,000 cu.m	869	1,239	1,225	1,146	850	612	379	230	259	316	429	481	——
4	Inflow From Run-off - 1,000 cu.m	581	235	193	5	25	35	99	257	289	351	297	607	2,974
5	Average Water Surface Area of Lake 1,000sq.m (from area curve)	255	314	313	304	249	203	122	60	71	96	144	164	——
6	Rainfall Over Surface Area (Row 1 x Row 5)/1,000 1,000 cu.m	65	29	24	0.8	4	15	26	23	14	16	19	38	——
7	Evaporation & Seepage (Row 2 x Row 5)/1,000 1,000 cu.m	34	44	54	60	49	41	21	9	10	14	22	23	——
8	Net Total Gain or Loss (Rows 4 + 6 - 7) 1,000 cu.m	612	220	163	-55	-20	9	104	271	293	352	294	622	2,865
9	Total Quantity for Period (Rows 3 + 8) 1,000 cu.m	1,481	1,459	1,388	1,091	830	621	483	501	552	670	723	1,103	——
10	Quantity Required for Water Supply 7,800 cu.m/day 1,000 cu.m	241.8	234	241.8	241.8	218.4	241.8	234	241.8	234	241.8	241.8	234	——
11	Carried Over to Next Period 1,000 cu.m	1,239	1,225	1,146	850	612	379	230	259	318	429	481	869	——

Note: Datum employed here is +100 m above sea level or normal ordinance datum.
Annual Natural Inflow - 2,965,000 cu.m ÷ 365 = 7,800 cu.m daily average

Table 2-2-4 : Reservoir Operation Study by R.I.D. (For Very Wet Year)

Project	Bangwad Reservoir	Ave. Annual Runoff Volume	4,352,694 cu.m	Reservoir Capacity	4,370,000 cu.m
Tambol	Kathu	Est. Max. Flood Discharge	16.1 cu.m/sec.	Dead Storage	230,000 cu.m
Amphoe	Kathu	Elev. Max. Flood	+196.00 m.(A.D.)	Storage of Flood Surcharge	671,471 cu.m.
Changwad	Phuket	Elev. Spillway Crest	+196.00 m.(A.D.)	F.S.L. Area	360 Reis.
Drainage Area	4.9 sq.km	Elev. Top of Dam	+197.50 m.(A.D.)	Size of Outlet Right Bank	Ø0.50 m.
Annual Rainfall	2,293 mm.	Elev. Bottom of Outlet	+183.00 m.(A.D.)	Size of Outlet Left Bank	—— m.

Flow No.	Item	Period Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1	Average Rainfall (mm)	506.7	197.9	61.9	91.4	16.0	62.3	155.7	282.8	420.8	423.3	250.2	436.4	2,903.4
2	Evaporation & Seepage (mm)	134.1	141.2	174.0	198.8	197.1	203.8	169.2	143.2	146.6	150.2	152.8	137.3	——
3	Quantity in Storage at Start of Period (Row 13) 1,000 cu.m	1,712	2,529	2,509	2,215	1,884	1,401	906	513	230	389	843	950	——
4	Inflow From Run-off - 1,000 cu.m	1,154	496	155	193	21	29	73	194	599	897	560	1,413	5,514
5	Average Water Surface Area of Lake 1,000sq.m (from area curve)	377	460	463	433	400	332	261	176	60	127	248	272	——
6	Rainfall Over Surface Area (Row 1 x Row 5)/1,000 1,000 cu.m	191	91	29	40	6	21	41	50	34	54	62	118	——
7	Evaporation & Seepage (Row 2 x Row 5)/1,000 1,000 cu.m	51	65	81	86	79	68	44	25	12	192	36	37	——
8	Net Total Gain or Loss (Rows 4 + 6 - 7) 1,000 cu.m	1,294	522	103	147	-52	-16	69	219	621	932	584	1,224	5,645
9	Total Quantity for Period (Rows 3 + 8) 1,000 cu.m	3,006	3,061	2,692	2,362	1,832	1,303	975	732	651	1,321	1,427	2,174	——
10	Quantity Required for Water Supply 15,400 cu.m/day 1,000 cu.m	477.4	462	4774	477.4	431.2	477.4	462	477.4	462	477.4	477.4	462	——
11	Carried Over to Next Period 1,000 cu.m	2,529	2,589	2,215	1,894	1,401	906	513	230	390	943	950	1,712	——

Note: Datum employed here is +100 m above sea level or normal ordinance datum.
Annual Natural Inflow 5,645,000 cu.m ÷ 365 = 15,400 cu.m daily average

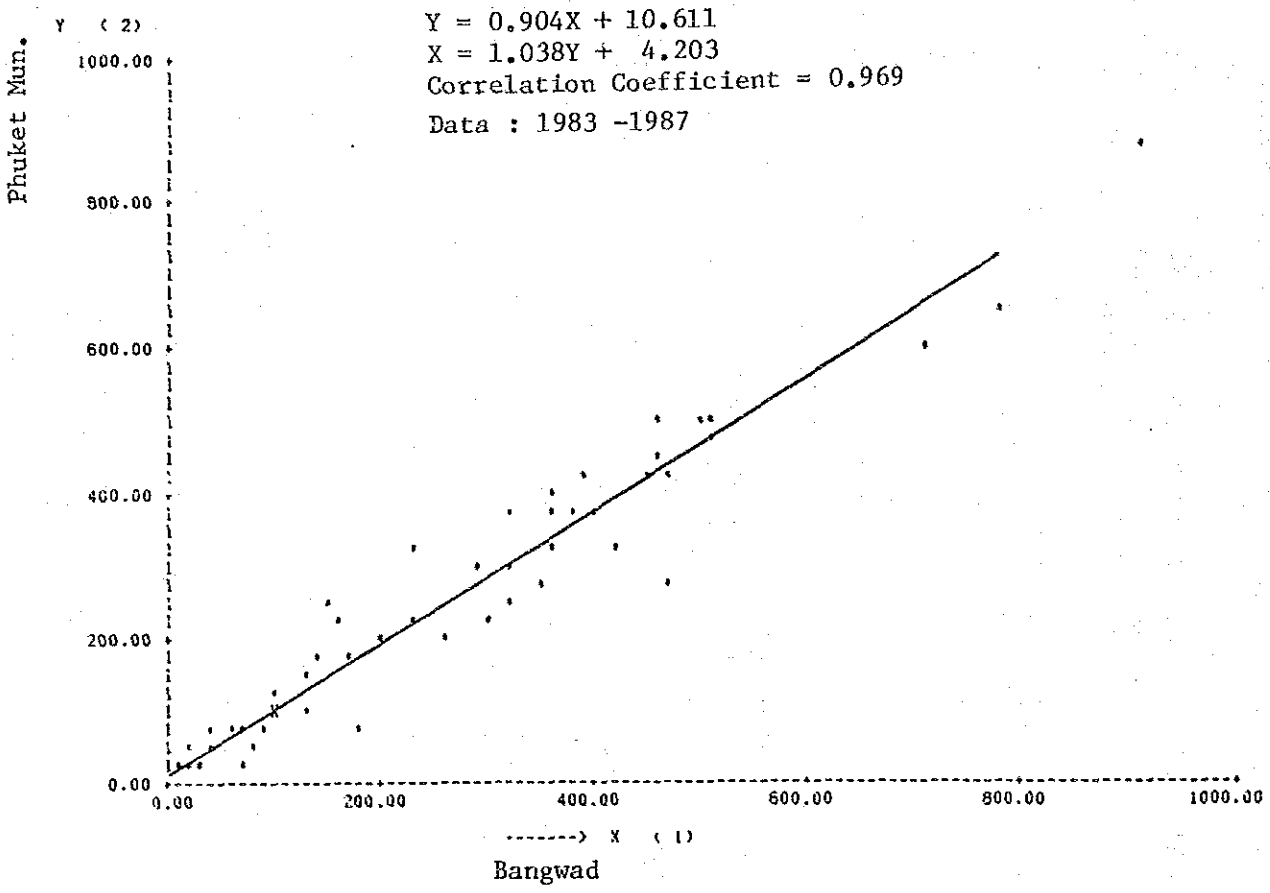


FIGURE 2-2-1
CORRELATION IN RAINFALL
PHUKET MUN. - BANGWAD

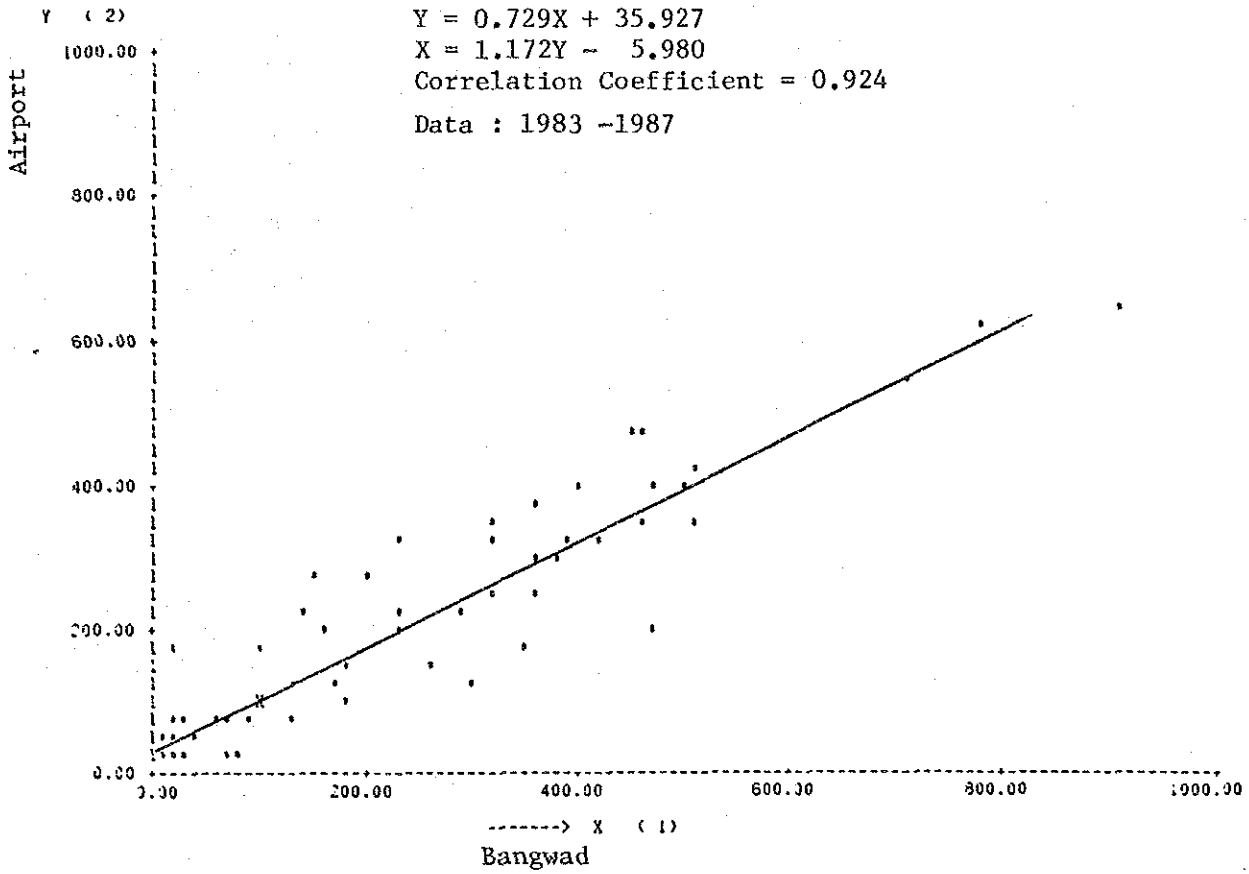


FIGURE 2-2-2
CORRELATION IN RAINFAL
AIRPORT - BANGWAD

Table 2-2-5 Runoff Coefficient

Year	Annual Rainfall (mm)	Area Rainfall (MCM)	Runoff (mm)	Runoff Coef.
(1) Adopted by RID for planning the Bangwad Reservoir (ca=4.9 sq.km)				
Very dry	1,839.0	9.011	2.974	0.32
Normal	2,293.8	11.240	4.392	0.38
Very wet	2,903.4	14.225	5.514	0.40
(2) RID Gauging Station X-97 (CA=2.0 sq.km)				
1974	2,508	5.016	1.665	0.33
1976	2,033	4.066	1.176	0.29
1977	1,794	3.588	1.093	0.30
1978	1,596	3.192	0.662	0.21
1979	1,472	2.944	0.481	0.16
1980	2,344	4.688	1.612	0.34
1981	1,52	3.044	0.864	0.28
1982	2,233	4.466	0.928	0.21
1983	2,344	4.688	0.964	0.21

Table 2-2-5 Runoff Coefficient (Cont'd)

Year	Annual Rainfall (mm)	Area Rainfall (MCM)	Runoff (mm)	Runoff Coef.
(3) Runoff Analysis for Proposed Dams				
1958	2,053	10.060	3.590	0.35
1959	2,054	12.269	4.105	0.33
1960	2,623	12.852	4.365	0.34
1961	1,948	9.545	2.253	0.24
1962	2,252	11.034	3.419	0.31
1963	2,053	10.065	3.467	0.34
1964	2,575	12.618	5.700	0.45
1965	2,406	11.789	3.798	0.32
1966	2,690	13.181	5.024	0.38
1967	2,416	11.838	5.204	0.44
1968	2,678	13.122	5.265	0.40
1969	2,634	12.912	5.119	0.40
1970	2,519	12.343	3.976	0.32
1971	2,987	14.636	7.388	0.50
1972	1,938	9.501	2.492	0.26
1973	2,779	13.617	5.212	0.38
1974	2,943	14.426	6.141	0.42
1975	2,798	13.715	5.715	0.42
1976	2,396	11.740	4.220	0.36
1977	2,120	10.388	3.603	0.35
1978	1,892	9.271	2.630	0.28
1979	1,749	8.570	2.405	0.28
1980	2,754	13.500	4.815	0.36
1981	1,806	8.854	1.998	0.23
1982	2,193	10.746	4.157	0.39
1983	2,627	12.872	5.956	0.46
1984	2,716	13.308	4.967	0.37
1985	2,642	12.951	4.701	0.36
1986	3,320	16.268	9.524	0.58
1987	2,757	13.514	6.753	0.50
Ave.	2,459	12.050	4.598	0.38

Table 2-2-6 Reservoir Operation

********** INPUT DATA **********

* FULL WATER CAPACITY = 8.5 (MCM)
* DEAD WATER CAPACITY = 1 (MCM)
* CATCHMENT AREA = 4.9 (KM2)
* HIGH WATER LEVEL = 44.58 (M)
* LOW WATER LEVEL = 29.58 (M)
* WATER SUPPLY = 11,700 (M3/D)

********** THE OUTCOME OF RESERVOIR OPERATION **********

PLACE ; BANGWAD ,PHUKET DURATION ; FROM 1958 TO 1987

YEAR	MON	VOL (MCM)	INFLOW (MCM)	WATER SUPPLY (MCM)	IRRI (MCM)	EVAPO (MCM)	LOSS (MCM)	SPILL (MCM)	SHORTAGE (MCM)
	1	8.500	0.000	0.364	0.000	0.058	0.002	0.000	0.000
	2	8.076	0.000	0.384	0.000	0.054	0.002	0.000	0.000
	3	7.636	0.000	0.357	0.000	0.056	0.002	0.000	0.000
	4	7.221	0.000	0.354	0.000	0.050	0.002	0.000	0.000
	5	6.816	0.423	0.326	0.000	0.040	0.002	0.000	0.000
1958	6	6.870	0.324	0.337	0.000	0.043	0.002	0.000	0.000
	7	6.813	0.004	0.292	0.000	0.044	0.002	0.000	0.000
	8	6.479	0.268	0.320	0.000	0.045	0.002	0.000	0.000
	9	6.380	0.380	0.306	0.000	0.039	0.002	0.000	0.000
	10	6.412	1.963	0.313	0.000	0.035	0.002	0.000	0.000
	11	8.025	0.229	0.337	0.000	0.040	0.002	0.000	0.000
	12	7.875	0.000	0.391	0.000	0.047	0.002	0.000	0.000
ANNUAL TOTAL			3.590	4.080	0.000	0.553	0.023	0.000	0.000
	1	7.435	0.000	0.364	0.000	0.052	0.002	0.000	0.000
	2	7.017	0.000	0.384	0.000	0.048	0.002	0.000	0.000
	3	6.583	0.096	0.357	0.000	0.050	0.002	0.000	0.000
	4	6.270	0.320	0.354	0.000	0.044	0.002	0.000	0.000
	5	6.190	0.039	0.326	0.000	0.037	0.002	0.000	0.000
1959	6	5.864	0.447	0.337	0.000	0.038	0.002	0.000	0.000
	7	5.935	1.310	0.292	0.000	0.039	0.002	0.000	0.000
	8	6.911	1.115	0.320	0.000	0.048	0.002	0.000	0.000
	9	7.657	0.273	0.306	0.000	0.046	0.002	0.000	0.000
	10	7.577	0.387	0.313	0.000	0.040	0.002	0.000	0.000
	11	7.609	0.092	0.337	0.000	0.039	0.002	0.000	0.000
	12	7.324	0.027	0.391	0.000	0.045	0.002	0.000	0.000
ANNUAL TOTAL			4.105	4.080	0.000	0.525	0.023	0.000	0.000
	1	6.913	0.000	0.364	0.000	0.049	0.002	0.000	0.000
	2	6.498	0.009	0.384	0.000	0.045	0.002	0.000	0.000
	3	6.077	0.000	0.357	0.000	0.046	0.002	0.000	0.000
	4	5.671	0.046	0.354	0.000	0.041	0.002	0.000	0.000
	5	5.321	0.856	0.326	0.000	0.032	0.002	0.000	0.000
1960	6	5.817	0.289	0.337	0.000	0.037	0.002	0.000	0.000
	7	5.730	0.773	0.292	0.000	0.038	0.002	0.000	0.000
	8	6.171	0.538	0.320	0.000	0.043	0.002	0.000	0.000
	9	6.344	1.304	0.306	0.000	0.039	0.002	0.000	0.000
	10	7.301	0.099	0.313	0.000	0.039	0.002	0.000	0.000
	11	7.047	0.431	0.337	0.000	0.036	0.002	0.000	0.000
	12	7.103	0.020	0.391	0.000	0.043	0.002	0.000	0.000
ANNUAL TOTAL			4.365	4.080	0.000	0.489	0.023	0.000	0.000
	1	6.687	0.007	0.364	0.000	0.048	0.002	0.000	0.000
	2	6.280	0.000	0.384	0.000	0.043	0.002	0.000	0.000
	3	5.850	0.000	0.357	0.000	0.045	0.002	0.000	0.000
	4	5.446	0.238	0.354	0.000	0.039	0.002	0.000	0.000
	5	5.290	0.852	0.326	0.000	0.032	0.002	0.000	0.000
1961	6	5.782	0.221	0.337	0.000	0.037	0.002	0.000	0.000
	7	5.627	0.138	0.292	0.000	0.037	0.002	0.000	0.000
	8	5.433	0.080	0.320	0.000	0.038	0.002	0.000	0.000
	9	5.153	0.296	0.306	0.000	0.032	0.002	0.000	0.000
	10	5.109	0.375	0.313	0.000	0.028	0.002	0.000	0.000
	11	5.141	0.031	0.337	0.000	0.027	0.002	0.000	0.000
	12	4.806	0.017	0.391	0.000	0.030	0.002	0.000	0.000
ANNUAL TOTAL			2.253	4.080	0.000	0.438	0.023	0.000	0.000
	1	4.399	0.000	0.364	0.000	0.032	0.002	0.000	0.000
	2	4.001	0.000	0.384	0.000	0.028	0.002	0.000	0.000
	3	3.587	0.015	0.357	0.000	0.027	0.002	0.000	0.000
	4	3.215	0.022	0.354	0.000	0.023	0.002	0.000	0.000
	5	2.858	0.114	0.326	0.000	0.017	0.002	0.000	0.000
1962	6	2.627	0.860	0.337	0.000	0.016	0.002	0.000	0.000
	7	3.132	0.532	0.292	0.000	0.020	0.002	0.000	0.000
	8	3.360	0.398	0.320	0.000	0.023	0.002	0.000	0.000
	9	3.403	1.024	0.306	0.000	0.021	0.002	0.000	0.000
	10	4.097	0.264	0.313	0.000	0.023	0.002	0.000	0.000
	11	4.023	0.192	0.337	0.000	0.021	0.002	0.000	0.000
	12	3.855	0.000	0.391	0.000	0.024	0.002	0.000	0.000
ANNUAL TOTAL			3.419	4.080	0.000	0.277	0.023	0.000	0.000
	1	3.438	0.000	0.364	0.000	0.025	0.002	0.000	0.000
	2	3.048	0.000	0.384	0.000	0.021	0.002	0.000	0.000
	3	2.641	0.000	0.357	0.000	0.019	0.002	0.000	0.000

	4	2.262	0.000	0.354	0.000	0.015	0.002	0.000	0.000
	5	1.892	0.086	0.326	0.000	0.010	0.002	0.000	0.000
1963	6	1.640	0.159	0.337	0.000	0.009	0.002	0.000	0.000
	7	1.451	0.154	0.292	0.000	0.007	0.002	0.000	0.000
	8	1.304	0.096	0.320	0.000	0.007	0.002	0.000	0.000
	9	1.072	1.433	0.306	0.000	0.004	0.002	0.000	0.000
	10	2.192	0.982	0.313	0.000	0.011	0.002	0.000	0.000
	11	2.848	0.518	0.337	0.000	0.015	0.002	0.000	0.000
	12	3.013	0.039	0.391	0.000	0.019	0.002	0.000	0.000
ANNUAL TOTAL		3.467	4.080	0.000	0.162	0.023	0.000	0.000	
	1	2.640	0.044	0.364	0.000	0.018	0.002	0.000	0.000
	2	2.300	0.000	0.384	0.000	0.015	0.002	0.000	0.000
	3	1.899	0.000	0.357	0.000	0.013	0.002	0.000	0.000
	4	1.527	0.003	0.354	0.000	0.009	0.002	0.000	0.000
	5	1.166	2.854	0.326	0.000	0.005	0.002	0.000	0.000
1964	6	3.687	0.032	0.337	0.000	0.024	0.002	0.000	0.000
	7	3.357	0.080	0.292	0.000	0.022	0.002	0.000	0.000
	8	3.121	0.342	0.320	0.000	0.022	0.002	0.000	0.000
	9	3.120	1.446	0.306	0.000	0.019	0.002	0.000	0.000
	10	4.239	0.319	0.313	0.000	0.024	0.002	0.000	0.000
	11	4.220	0.572	0.337	0.000	0.022	0.002	0.000	0.000
	12	4.431	0.007	0.391	0.000	0.028	0.002	0.000	0.000
ANNUAL TOTAL		5.700	4.080	0.000	0.220	0.023	0.000	0.000	
	1	4.017	0.019	0.364	0.000	0.029	0.002	0.000	0.000
	2	3.641	0.000	0.384	0.000	0.025	0.002	0.000	0.000
	3	3.230	0.000	0.357	0.000	0.025	0.002	0.000	0.000
	4	2.846	0.072	0.354	0.000	0.020	0.002	0.000	0.000
	5	2.543	0.510	0.326	0.000	0.015	0.002	0.000	0.000
1965	6	2.710	0.162	0.337	0.000	0.017	0.002	0.000	0.000
	7	2.517	0.236	0.292	0.000	0.016	0.002	0.000	0.000
	8	2.443	1.373	0.320	0.000	0.016	0.002	0.000	0.000
	9	3.478	1.176	0.306	0.000	0.022	0.002	0.000	0.000
	10	4.325	0.088	0.313	0.000	0.024	0.002	0.000	0.000
	11	4.074	0.144	0.337	0.000	0.022	0.002	0.000	0.000
	12	3.857	0.018	0.391	0.000	0.024	0.002	0.000	0.000
ANNUAL TOTAL		3.798	4.080	0.000	0.255	0.023	0.000	0.000	
	1	3.458	0.000	0.364	0.000	0.025	0.002	0.000	0.000
	2	3.067	0.000	0.384	0.000	0.021	0.002	0.000	0.000
	3	2.660	0.002	0.357	0.000	0.020	0.002	0.000	0.000
	4	2.284	0.031	0.354	0.000	0.015	0.002	0.000	0.000
	5	1.944	1.334	0.326	0.000	0.010	0.002	0.000	0.000
1966	6	2.940	0.596	0.337	0.000	0.018	0.002	0.000	0.000
	7	3.178	0.862	0.292	0.000	0.021	0.002	0.000	0.000
	8	3.725	0.328	0.320	0.000	0.026	0.002	0.000	0.000
	9	3.705	0.560	0.306	0.000	0.023	0.002	0.000	0.000
	10	3.934	1.212	0.313	0.000	0.022	0.002	0.000	0.000
	11	4.810	0.090	0.337	0.000	0.026	0.002	0.000	0.000
	12	4.536	0.009	0.391	0.000	0.029	0.002	0.000	0.000
ANNUAL TOTAL		5.024	4.080	0.000	0.256	0.023	0.000	0.000	
	1	4.123	0.086	0.364	0.000	0.030	0.002	0.000	0.000
	2	3.813	0.000	0.384	0.000	0.027	0.002	0.000	0.000
	3	3.400	0.000	0.357	0.000	0.026	0.002	0.000	0.000
	4	3.015	0.017	0.354	0.000	0.021	0.002	0.000	0.000
	5	2.656	0.483	0.326	0.000	0.015	0.002	0.000	0.000
1967	6	2.795	0.432	0.337	0.000	0.017	0.002	0.000	0.000
	7	2.871	0.055	0.292	0.000	0.018	0.002	0.000	0.000
	8	2.613	0.577	0.320	0.000	0.018	0.002	0.000	0.000
	9	2.851	0.236	0.306	0.000	0.017	0.002	0.000	0.000
	10	2.761	3.289	0.313	0.000	0.015	0.002	0.000	0.000
	11	5.720	0.030	0.337	0.000	0.030	0.002	0.000	0.000
	12	5.382	0.000	0.391	0.000	0.034	0.002	0.000	0.000
ANNUAL TOTAL		5.204	4.080	0.000	0.269	0.023	0.000	0.000	
	1	4.955	0.000	0.364	0.000	0.036	0.002	0.000	0.000
	2	4.553	0.000	0.384	0.000	0.032	0.002	0.000	0.000
	3	4.135	0.000	0.357	0.000	0.032	0.002	0.000	0.000
	4	3.744	0.083	0.354	0.000	0.027	0.002	0.000	0.000
	5	3.445	0.978	0.326	0.000	0.021	0.002	0.000	0.000
1968	6	4.073	0.694	0.337	0.000	0.026	0.002	0.000	0.000
	7	4.403	0.703	0.292	0.000	0.029	0.002	0.000	0.000
	8	4.782	0.980	0.320	0.000	0.034	0.002	0.000	0.000
	9	5.407	1.553	0.306	0.000	0.034	0.002	0.000	0.000
	10	6.619	0.185	0.313	0.000	0.036	0.002	0.000	0.000
	11	6.453	0.030	0.337	0.000	0.034	0.002	0.000	0.000
	12	6.111	0.059	0.391	0.000	0.038	0.002	0.000	0.000
ANNUAL TOTAL		5.265	4.080	0.000	0.379	0.023	0.000	0.000	
	1	5.739	0.010	0.364	0.000	0.042	0.002	0.000	0.000
	2	5.341	0.000	0.384	0.000	0.037	0.002	0.000	0.000
	3	4.918	0.000	0.357	0.000	0.038	0.002	0.000	0.000
	4	4.521	0.000	0.354	0.000	0.033	0.002	0.000	0.000
	5	4.133	0.549	0.326	0.000	0.025	0.002	0.000	0.000
1969	6	4.328	1.797	0.337	0.000	0.028	0.002	0.000	0.000
	7	5.759	0.468	0.292	0.000	0.038	0.002	0.000	0.000

	8	5.895	0.467	0.320	0.000	0.041	0.002	0.000	0.000
	9	5.998	0.969	0.306	0.000	0.037	0.002	0.000	0.000
	10	6.622	0.492	0.313	0.000	0.036	0.002	0.000	0.000
	11	6.763	0.368	0.337	0.000	0.035	0.002	0.000	0.000
	12	6.758	0.000	0.391	0.000	0.042	0.002	0.000	0.000
ANNUAL TOTAL			5.119	4.080	0.000	0.432	0.023	0.000	0.000
	1	6.323	0.000	0.364	0.000	0.040	0.002	0.000	0.000
	2	5.912	0.000	0.384	0.000	0.041	0.002	0.000	0.000
	3	5.485	0.075	0.357	0.000	0.042	0.002	0.000	0.000
	4	5.159	0.241	0.354	0.000	0.037	0.002	0.000	0.000
	5	5.008	0.322	0.326	0.000	0.030	0.002	0.000	0.000
1970	6	4.971	0.176	0.337	0.000	0.032	0.002	0.000	0.000
	7	4.776	1.374	0.292	0.000	0.032	0.002	0.000	0.000
	8	5.825	0.261	0.320	0.000	0.041	0.002	0.000	0.000
	9	5.723	0.754	0.306	0.000	0.036	0.002	0.000	0.000
	10	6.133	0.700	0.313	0.000	0.034	0.002	0.000	0.000
	11	6.485	0.055	0.337	0.000	0.034	0.002	0.000	0.000
	12	6.168	0.018	0.391	0.000	0.038	0.002	0.000	0.000
ANNUAL TOTAL			3.976	4.080	0.000	0.442	0.023	0.000	0.000
	1	5.754	0.000	0.364	0.000	0.042	0.002	0.000	0.000
	2	5.347	0.151	0.384	0.000	0.037	0.002	0.000	0.000
	3	5.074	0.205	0.357	0.000	0.039	0.002	0.000	0.000
	4	4.882	0.000	0.354	0.000	0.035	0.002	0.000	0.000
	5	4.491	1.879	0.326	0.000	0.027	0.002	0.000	0.000
1971	6	6.014	1.426	0.337	0.000	0.038	0.002	0.000	0.000
	7	7.064	0.221	0.292	0.000	0.045	0.002	0.000	0.000
	8	6.945	1.884	0.320	0.000	0.048	0.002	0.000	0.000
	9	8.460	0.000	0.306	0.000	0.050	0.002	0.000	0.000
	10	8.102	1.564	0.313	0.000	0.043	0.002	0.809	0.000
	11	8.500	0.057	0.337	0.000	0.042	0.002	0.000	0.000
	12	8.176	0.000	0.391	0.000	0.049	0.002	0.000	0.000
ANNUAL TOTAL			7.388	4.080	0.000	0.496	0.023	0.809	0.000
	1	7.734	0.000	0.364	0.000	0.054	0.002	0.000	0.000
	2	7.315	0.000	0.384	0.000	0.049	0.002	0.000	0.000
	3	6.879	0.000	0.357	0.000	0.052	0.002	0.000	0.000
	4	6.469	0.185	0.354	0.000	0.046	0.002	0.000	0.000
	5	6.252	0.307	0.326	0.000	0.037	0.002	0.000	0.000
1972	6	6.194	0.247	0.337	0.000	0.039	0.002	0.000	0.000
	7	6.064	0.297	0.292	0.000	0.040	0.002	0.000	0.000
	8	6.027	0.084	0.320	0.000	0.042	0.002	0.000	0.000
	9	5.747	1.164	0.306	0.000	0.036	0.002	0.000	0.000
	10	6.568	0.090	0.313	0.000	0.036	0.002	0.000	0.000
	11	6.307	0.046	0.337	0.000	0.033	0.002	0.000	0.000
	12	5.981	0.071	0.391	0.000	0.037	0.002	0.000	0.000
ANNUAL TOTAL			2.492	4.080	0.000	0.501	0.023	0.000	0.000
	1	5.622	0.000	0.364	0.000	0.041	0.002	0.000	0.000
	2	5.216	0.000	0.384	0.000	0.037	0.002	0.000	0.000
	3	4.793	0.013	0.357	0.000	0.037	0.002	0.000	0.000
	4	4.410	0.045	0.354	0.000	0.032	0.002	0.000	0.000
	5	4.068	0.553	0.326	0.000	0.025	0.002	0.000	0.000
1973	6	4.268	0.834	0.337	0.000	0.028	0.002	0.000	0.000
	7	4.736	1.275	0.292	0.000	0.031	0.002	0.000	0.000
	8	5.685	0.500	0.320	0.000	0.040	0.002	0.000	0.000
	9	5.824	1.448	0.306	0.000	0.036	0.002	0.000	0.000
	10	6.928	0.222	0.313	0.000	0.038	0.002	0.000	0.000
	11	6.798	0.302	0.337	0.000	0.035	0.002	0.000	0.000
	12	6.727	0.019	0.391	0.000	0.041	0.002	0.000	0.000
ANNUAL TOTAL			5.212	4.080	0.000	0.420	0.023	0.000	0.000
	1	6.311	0.000	0.364	0.000	0.045	0.002	0.000	0.000
	2	5.900	0.000	0.384	0.000	0.041	0.002	0.000	0.000
	3	5.473	0.000	0.357	0.000	0.042	0.002	0.000	0.000
	4	5.072	0.118	0.354	0.000	0.036	0.002	0.000	0.000
	5	4.798	0.463	0.326	0.000	0.029	0.002	0.000	0.000
1974	6	4.904	1.091	0.337	0.000	0.032	0.002	0.000	0.000
	7	5.624	1.101	0.292	0.000	0.037	0.002	0.000	0.000
	8	6.394	0.353	0.320	0.000	0.045	0.002	0.000	0.000
	9	6.381	1.192	0.306	0.000	0.039	0.002	0.000	0.000
	10	7.226	1.609	0.313	0.000	0.039	0.002	0.000	0.000
	11	8.481	0.208	0.337	0.000	0.042	0.002	0.000	0.000
	12	8.308	0.006	0.391	0.000	0.049	0.002	0.000	0.000
ANNUAL TOTAL			6.141	4.080	0.000	0.477	0.023	0.000	0.000
	1	7.872	0.029	0.364	0.000	0.055	0.002	0.000	0.000
	2	7.480	0.000	0.384	0.000	0.050	0.002	0.000	0.000
	3	7.044	0.007	0.357	0.000	0.053	0.002	0.000	0.000
	4	6.639	0.288	0.354	0.000	0.047	0.002	0.000	0.000
	5	6.525	0.898	0.326	0.000	0.039	0.002	0.000	0.000
1975	6	7.055	1.504	0.337	0.000	0.044	0.002	0.000	0.000
	7	8.177	0.085	0.292	0.000	0.051	0.002	0.000	0.000
	8	7.917	0.037	0.320	0.000	0.053	0.002	0.000	0.000
	9	7.579	1.617	0.306	0.000	0.046	0.002	0.343	0.000
	10	8.500	1.059	0.313	0.000	0.044	0.002	0.700	0.000
	11	8.500	0.191	0.337	0.000	0.042	0.002	0.000	0.000

	12	8.310	0.000	0.391	0.000	0.049	0.002	0.000	0.000
ANNUAL TOTAL			5.715	4.080	0.000	0.573	0.023	1.043	0.000
	1	7.868	0.000	0.364	0.000	0.055	0.002	0.000	0.000
	2	7.447	0.000	0.384	0.000	0.050	0.002	0.000	0.000
	3	7.011	0.004	0.357	0.000	0.052	0.002	0.000	0.000
	4	6.603	0.072	0.354	0.000	0.046	0.002	0.000	0.000
	5	6.273	1.323	0.326	0.000	0.037	0.002	0.000	0.000
1976	6	7.231	0.411	0.337	0.000	0.045	0.002	0.000	0.000
	7	7.258	0.727	0.292	0.000	0.046	0.002	0.000	0.000
	8	7.644	0.395	0.320	0.000	0.052	0.002	0.000	0.000
	9	7.666	1.059	0.306	0.000	0.046	0.002	0.000	0.000
	10	8.371	0.186	0.313	0.000	0.044	0.002	0.000	0.000
	11	8.199	0.043	0.337	0.000	0.041	0.002	0.000	0.000
	12	7.862	0.000	0.391	0.000	0.047	0.002	0.000	0.000
ANNUAL TOTAL			4.220	4.080	0.000	0.562	0.023	0.000	0.000
	1	7.422	0.000	0.364	0.000	0.052	0.002	0.000	0.000
	2	7.004	0.000	0.384	0.000	0.048	0.002	0.000	0.000
	3	6.570	0.000	0.357	0.000	0.050	0.002	0.000	0.000
	4	6.162	0.000	0.354	0.000	0.044	0.002	0.000	0.000
	5	5.763	0.228	0.326	0.000	0.035	0.002	0.000	0.000
1977	6	5.628	0.343	0.337	0.000	0.036	0.002	0.000	0.000
	7	5.596	0.121	0.292	0.000	0.037	0.002	0.000	0.000
	8	5.386	0.710	0.320	0.000	0.038	0.002	0.000	0.000
	9	5.737	1.281	0.306	0.000	0.036	0.002	0.000	0.000
	10	6.674	0.860	0.313	0.000	0.036	0.002	0.000	0.000
	11	7.183	0.060	0.337	0.000	0.037	0.002	0.000	0.000
	12	6.867	0.000	0.391	0.000	0.042	0.002	0.000	0.000
ANNUAL TOTAL			3.603	4.080	0.000	0.490	0.023	0.000	0.000
	1	6.432	0.000	0.364	0.000	0.046	0.002	0.000	0.000
	2	6.020	0.000	0.384	0.000	0.042	0.002	0.000	0.000
	3	5.592	0.000	0.357	0.000	0.043	0.002	0.000	0.000
	4	5.191	0.058	0.354	0.000	0.037	0.002	0.000	0.000
	5	4.856	0.283	0.326	0.000	0.029	0.002	0.000	0.000
1978	6	4.781	0.530	0.337	0.000	0.031	0.002	0.000	0.000
	7	4.942	1.137	0.292	0.000	0.033	0.002	0.000	0.000
	8	5.752	0.247	0.320	0.000	0.040	0.002	0.000	0.000
	9	5.637	0.330	0.306	0.000	0.035	0.002	0.000	0.000
	10	5.624	0.024	0.313	0.000	0.031	0.002	0.000	0.000
	11	5.302	0.021	0.337	0.000	0.028	0.002	0.000	0.000
	12	4.956	0.000	0.391	0.000	0.031	0.002	0.000	0.000
ANNUAL TOTAL			2.630	4.080	0.000	0.428	0.023	0.000	0.000
	1	4.532	0.000	0.364	0.000	0.033	0.002	0.000	0.000
	2	4.133	0.000	0.384	0.000	0.029	0.002	0.000	0.000
	3	3.717	0.000	0.357	0.000	0.029	0.002	0.000	0.000
	4	3.330	0.106	0.354	0.000	0.024	0.002	0.000	0.000
	5	3.057	0.118	0.326	0.000	0.018	0.002	0.000	0.000
1979	6	2.829	0.403	0.337	0.000	0.018	0.002	0.000	0.000
	7	2.876	1.266	0.292	0.000	0.018	0.002	0.000	0.000
	8	3.829	0.051	0.320	0.000	0.027	0.002	0.000	0.000
	9	3.532	0.346	0.306	0.000	0.022	0.002	0.000	0.000
	10	3.548	0.111	0.313	0.000	0.020	0.002	0.000	0.000
	11	3.324	0.004	0.337	0.000	0.017	0.002	0.000	0.000
	12	2.972	0.000	0.391	0.000	0.018	0.002	0.000	0.000
ANNUAL TOTAL			2.405	4.080	0.000	0.273	0.023	0.000	0.000
	1	2.561	0.000	0.364	0.000	0.018	0.002	0.000	0.000
	2	2.177	0.000	0.384	0.000	0.014	0.002	0.000	0.000
	3	1.777	0.080	0.357	0.000	0.012	0.002	0.000	0.000
	4	1.487	0.007	0.354	0.000	0.008	0.002	0.000	0.000
	5	1.130	0.269	0.326	0.000	0.004	0.002	0.000	0.000
1980	6	1.066	0.853	0.337	0.000	0.004	0.002	0.000	0.000
	7	1.576	0.731	0.292	0.000	0.008	0.002	0.000	0.000
	8	2.004	1.474	0.320	0.000	0.013	0.002	0.000	0.000
	9	3.144	0.673	0.306	0.000	0.019	0.002	0.000	0.000
	10	3.490	0.502	0.313	0.000	0.019	0.002	0.000	0.000
	11	3.658	0.151	0.337	0.000	0.019	0.002	0.000	0.000
	12	3.451	0.075	0.391	0.000	0.022	0.002	0.000	0.000
ANNUAL TOTAL			4.815	4.080	0.000	0.161	0.023	0.000	0.000
	1	3.112	0.000	0.364	0.000	0.022	0.002	0.000	0.000
	2	2.724	0.000	0.384	0.000	0.018	0.002	0.000	0.000
	3	2.319	0.000	0.357	0.000	0.017	0.002	0.000	0.000
	4	1.944	0.102	0.354	0.000	0.012	0.002	0.000	0.000
	5	1.678	0.484	0.326	0.000	0.008	0.002	0.000	0.000
1981	6	1.826	0.103	0.337	0.000	0.010	0.002	0.000	0.000
	7	1.580	0.135	0.292	0.000	0.008	0.002	0.000	0.000
	8	1.412	0.106	0.320	0.000	0.008	0.002	0.000	0.000
	9	1.189	0.482	0.306	0.000	0.005	0.002	0.000	0.000
	10	1.358	0.139	0.313	0.000	0.006	0.002	0.000	0.000
	11	1.176	0.448	0.337	0.000	0.004	0.002	0.000	0.000
	12	1.281	0.000	0.391	0.000	0.000	0.000	0.000	-0.118
ANNUAL TOTAL			1.998	4.080	0.000	0.125	0.023	0.000	-0.118

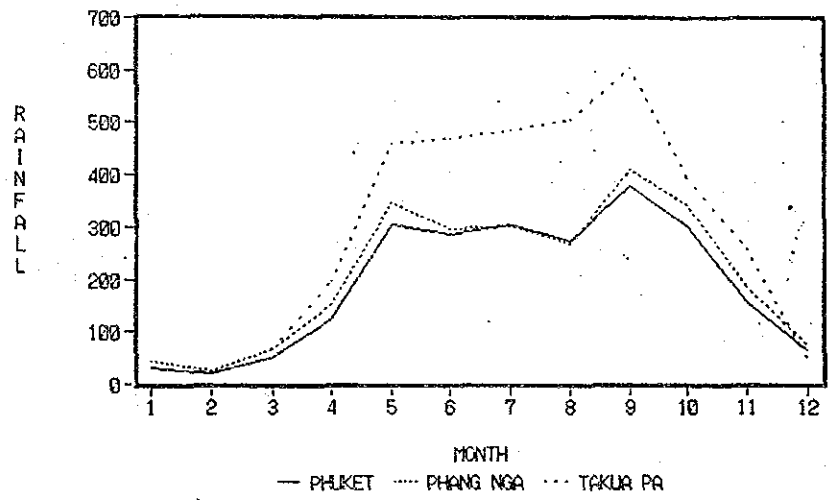
	1	1.000	0.000	0.364	0.000	0.000	0.000	0.000	-0.370
	2	1.000	0.001	0.384	0.000	0.000	0.000	0.000	-0.389
	3	1.000	0.000	0.357	0.000	0.000	0.000	0.000	-0.363
	4	1.000	0.056	0.354	0.000	0.000	0.000	0.000	-0.304
	5	1.000	0.539	0.326	0.000	0.003	0.002	0.000	0.000
1982	6	1.207	0.025	0.337	0.000	0.000	0.000	0.000	-0.112
	7	1.000	2.613	0.292	0.000	0.004	0.002	0.000	0.000
	8	3.315	0.077	0.320	0.000	0.023	0.002	0.000	0.000
	9	3.048	0.175	0.306	0.000	0.019	0.002	0.000	0.000
	10	2.896	0.430	0.313	0.000	0.016	0.002	0.000	0.000
	11	2.996	0.242	0.337	0.000	0.016	0.002	0.000	0.000
	12	2.884	0.000	0.391	0.000	0.018	0.002	0.000	0.000
ANNUAL TOTAL			4.157	4.080	0.000	0.120	0.023	0.000	-1.538
	1	2.473	0.000	0.364	0.000	0.017	0.002	0.000	0.000
	2	2.090	0.000	0.384	0.000	0.013	0.002	0.000	0.000
	3	1.691	0.000	0.357	0.000	0.011	0.002	0.000	0.000
	4	1.321	0.000	0.354	0.000	0.000	0.000	0.000	-0.041
	5	1.000	0.268	0.326	0.000	0.000	0.000	0.000	-0.064
1983	6	1.000	0.372	0.337	0.000	0.004	0.002	0.000	0.000
	7	1.030	0.503	0.292	0.000	0.004	0.002	0.000	0.000
	8	1.234	1.619	0.320	0.000	0.006	0.002	0.000	0.000
	9	2.526	2.314	0.306	0.000	0.015	0.002	0.000	0.000
	10	4.517	0.809	0.313	0.000	0.025	0.002	0.000	0.000
	11	4.985	0.071	0.337	0.000	0.027	0.002	0.000	0.000
	12	4.692	0.000	0.391	0.000	0.030	0.002	0.000	0.000
ANNUAL TOTAL			5.956	4.080	0.000	0.162	0.023	0.000	-0.105
	1	4.269	0.000	0.364	0.000	0.031	0.002	0.000	0.000
	2	3.872	0.000	0.384	0.000	0.027	0.002	0.000	0.000
	3	3.459	0.010	0.357	0.000	0.026	0.002	0.000	0.000
	4	3.083	0.889	0.354	0.000	0.022	0.002	0.000	0.000
	5	3.596	0.221	0.326	0.000	0.022	0.002	0.000	0.000
1984	6	3.467	1.372	0.337	0.000	0.022	0.002	0.000	0.000
	7	4.478	1.037	0.292	0.000	0.030	0.002	0.000	0.000
	8	5.190	0.024	0.320	0.000	0.037	0.002	0.000	0.000
	9	4.856	0.653	0.306	0.000	0.031	0.002	0.000	0.000
	10	5.171	0.458	0.313	0.000	0.029	0.002	0.000	0.000
	11	5.285	0.010	0.337	0.000	0.028	0.002	0.000	0.000
	12	4.929	0.293	0.391	0.000	0.031	0.002	0.000	0.000
ANNUAL TOTAL			4.967	4.080	0.000	0.335	0.023	0.000	0.000
	1	4.798	0.000	0.364	0.000	0.035	0.002	0.000	0.000
	2	4.397	0.004	0.384	0.000	0.031	0.002	0.000	0.000
	3	3.983	0.041	0.357	0.000	0.031	0.002	0.000	0.000
	4	3.634	0.263	0.354	0.000	0.026	0.002	0.000	0.000
	5	3.515	1.556	0.326	0.000	0.021	0.002	0.000	0.000
1985	6	4.722	0.203	0.337	0.000	0.031	0.002	0.000	0.000
	7	4.557	0.151	0.292	0.000	0.030	0.002	0.000	0.000
	8	4.384	0.245	0.320	0.000	0.031	0.002	0.000	0.000
	9	4.276	1.141	0.306	0.000	0.027	0.002	0.000	0.000
	10	5.083	1.062	0.313	0.000	0.028	0.002	0.000	0.000
	11	5.802	0.015	0.337	0.000	0.031	0.002	0.000	0.000
	12	5.448	0.019	0.391	0.000	0.034	0.002	0.000	0.000
ANNUAL TOTAL			4.701	4.080	0.000	0.356	0.023	0.000	0.000
	1	5.039	0.000	0.364	0.000	0.037	0.002	0.000	0.000
	2	4.637	0.000	0.384	0.000	0.033	0.002	0.000	0.000
	3	4.218	0.000	0.357	0.000	0.033	0.002	0.000	0.000
	4	3.827	0.344	0.354	0.000	0.027	0.002	0.000	0.000
	5	3.788	1.274	0.326	0.000	0.023	0.002	0.000	0.000
1986	6	4.711	0.178	0.337	0.000	0.030	0.002	0.000	0.000
	7	4.520	0.540	0.292	0.000	0.030	0.002	0.000	0.000
	8	4.735	1.065	0.320	0.000	0.034	0.002	0.000	0.000
	9	5.445	5.061	0.306	0.000	0.034	0.002	1.664	0.000
	10	8.500	0.648	0.313	0.000	0.044	0.002	0.289	0.000
	11	8.500	0.413	0.337	0.000	0.042	0.002	0.033	0.000
	12	8.500	0.000	0.391	0.000	0.050	0.002	0.000	0.000
ANNUAL TOTAL			9.524	4.080	0.000	0.417	0.023	1.986	0.000
	1	8.057	0.000	0.364	0.000	0.056	0.002	0.000	0.000
	2	7.635	0.000	0.384	0.000	0.051	0.002	0.000	0.000
	3	7.198	0.000	0.357	0.000	0.054	0.002	0.000	0.000
	4	6.786	0.000	0.354	0.000	0.048	0.002	0.000	0.000
	5	6.382	0.832	0.326	0.000	0.038	0.002	0.000	0.000
1987	6	6.848	0.089	0.337	0.000	0.043	0.002	0.000	0.000
	7	6.555	0.016	0.292	0.000	0.042	0.002	0.000	0.000
	8	6.234	2.754	0.320	0.000	0.044	0.002	0.124	0.000
	9	8.500	0.816	0.306	0.000	0.050	0.002	0.458	0.000
	10	8.500	0.633	0.313	0.000	0.044	0.002	0.274	0.000
	11	8.500	1.572	0.337	0.000	0.042	0.002	1.191	0.000
	12	8.500	0.042	0.391	0.000	0.050	0.002	0.000	0.000
ANNUAL TOTAL			6.753	4.080	0.000	0.562	0.023	2.047	0.000

(2) Mining Pits for the Phuket Municipal Waterworks

The study on the availability of the mining pits was made on the following conditions:

- The drought year is once in ten years.
- The total storage capacity of six mining pits is 1,468,300 cu.m.
- The effective storage capacity is 70% of the above total.
- Evaporation and loss is 20% of the effective storage capacity.
- No inflow is considered during the period of four months from January to April according to rainfall pattern in Phuket (Refer to Figure 2-2-3)
- Sufficient inflow is considered during the remainder of the year, then the pits are full of water by the end of December.

Figure 2-2-3 Rainfall Pattern



Consequently, available capacity was obtained from the following equation:

$$1,468,300 \times 0.70 \times (1-0.2) = 822,000 \text{ cu.m}$$

Allowable intake capacity is:

$$822,000 \div (30 \text{ days} \times 4 \text{ mo}) = 6,850 \text{ cu.m/d} = 285 \text{ cu.m/h}$$

2.3 Developability of New Water Source

2.3.1 Surface Water

(1) Water Resource Development Project

(a) General

In view of the water resource limitation in the Phuket Island, the Government of Thailand requested RID to study the water resource developability. The Bangwa Reservoir was constructed as a part of the project, and at the same time, several other suitable dam sites were selected for further study.

The location and summary of the seven dam sites is given in Figure 2-3-1 and Table 2-3-1. In addition, the RID's estimate on the dam capacity is given in Table 2-3-2.

Table 2-3-2 Proposed Dam Capacity

Dam	Effective Volume (MCM)				Available Amount *1 (cu.m/d)
	*2	*3	*4	*5	
1. Bangwad Reservoir (Existing)	4.9 sq.km	x 2,300 mm	x 0.38	= 4.3 (7.5)	11,700
2. Khlong Yon	1.7	x 2,300	x 0.38	= 1.5	4,400
3. Khlong Katha	5.4	x 2,300	x 0.38	= 4.7	12,800
4. Bang Tho Sung	4.8	x 2,300	x 0.38	= 4.2	11,600
5. Bang Nieo Dam	5.5	x 2,300	x 0.38	= 4.8	13,000
6. Khao Che Tra	4.6	x 2,300	x 0.38	= 4.0	10,800
7. Pak Bang	3.0	x 2,300	x 0.38	= 2.6	7,000

*1 Daily average (normal year, 1/2 return period)
*2 Catchment area (sq.km)
*3 Annual average rainfall (mm)
*4 Annual runoff
*5 Effective volume (MCM)

(b) Water Resources for Resort Area Proposed by the Swiss Bank Group

The northern top area of the island is proposed by the Swiss Bank Group to develop a resort area.

In response to the proposal, the Government of Thailand set up a committee consisting of PWA, PWD, RID and RED for securing water resources to meet the demand.

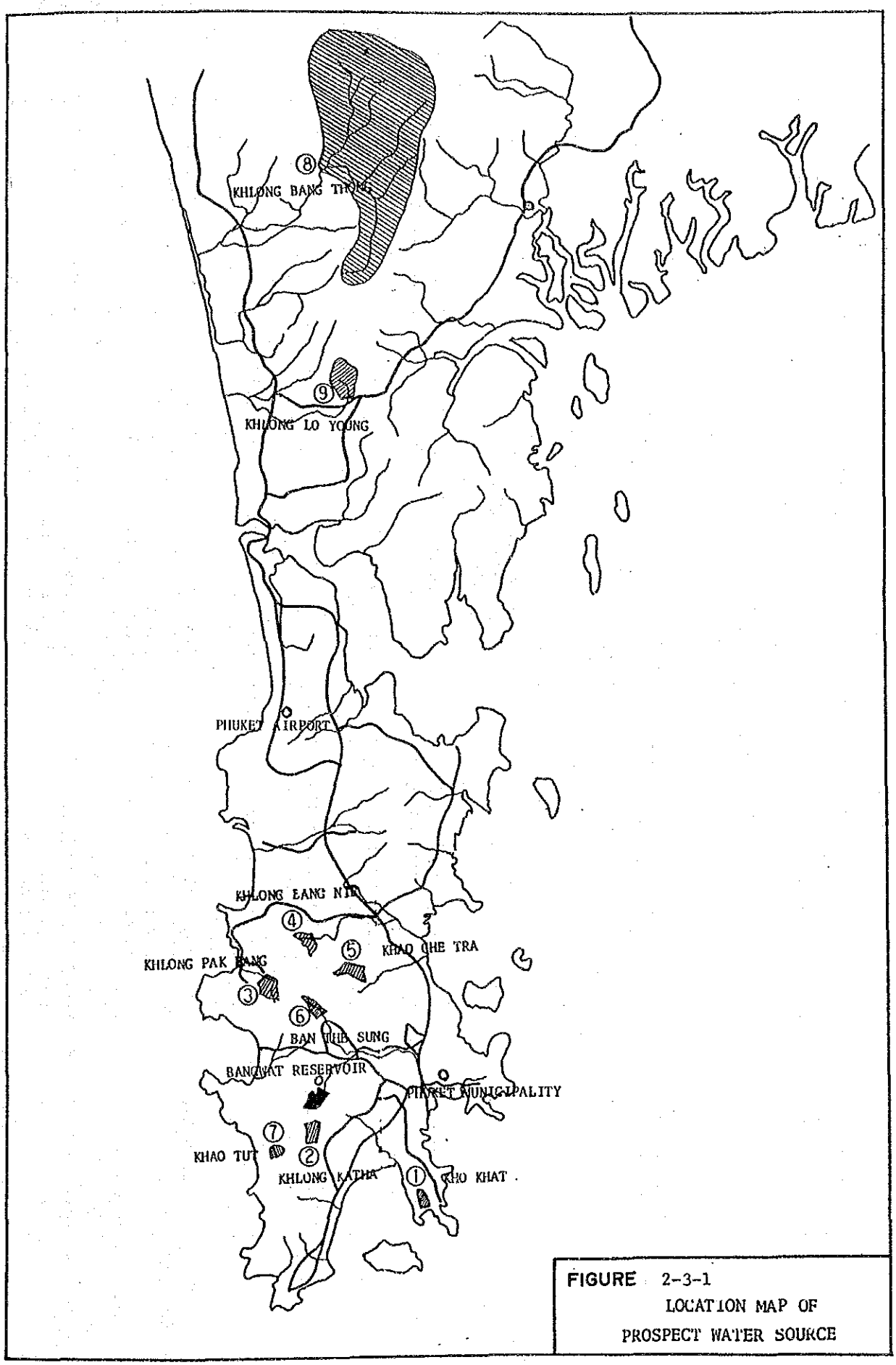


FIGURE 2-3-1
LOCATION MAP OF
PROSPECT WATER SOURCE

Table 2-3-1 (1) Prospect Damsite Proposed by RID

No.	Location	Topography/Geology	Catchment	Dimension	Remarks
1	Kho Khat	- Lagoon is formed. Seawater flows upstream when tide is high. - Mostly flat.	- CA = 2.2 sq.km. Water covers most of the area. Farm tree or rubber are mainly planted.	- Earthfilled - L= 200 m, H= 10-20 m - V= 1.5 MCM	
2	Khlong Katha	- Abandoned tin mining pit exists from plain plain to steep mountain rapidly.	- CA = 5.2 sw.km. - Vacant land in flat plain. Rubber is planted in the mountain.	- Earthfilled. - L=950 m, H=50 m - V=9.8 MCM ,	
3	Khlong Pak Bang	- V-shaped valley is formed. Appearance of rocks. - Riber bed have steep slope.	- CA = 3.3 sq.km - Mostly miscellaneous forest. Partly rubber is planted.	- Concrete - L=600 m, H=48 m - V=6.2 MCM	
4	Khlong Bang Mie	- From plain area to steep mountain rapidly. River is steep in mountain. - Abandoned tin mining pit exists, forms good spot for reservoir.	- CA = 5.3 sq.km - Vacant land in flat plain. - Rubber is mostly planted in mountain.	- Earthfilled - L=940 m, H=42 m - V=10. MCM	- RID weir is constructed upstream for village water supply. - High priority.
5	Khao Che Tra	- From plain area to steep mountain rapidly, river is steep in mountain. - Abandoned tin mining pit exists, forms good spot for reservoir.	- Ca = 3.9 sq.km - Vacant land in flat plain. Rubber is mostly planted in mountain.	- Earthfilled - L=1000 m, H=49 m - V= 7.3MCM	- RID made the topography survey - High priority.
6	Ban The Sung	- Gradually steep from flat plain plain to mountain. - V-shaped valley is formed, rock appeared.	- CA =4.1 sq.km. - Rubber is mostly planted. - Waterfall exists upstream	- Earthfilled - L=625 m, H= 70m - V=7.7 MCM	- RID made the topographic survey
7	Khao Tut	- V-shaped valley is formed. - Low spot exists. - No rocks but stones.	- CA = 1.2 sq.km. - Mostly rubber and miscellaneous trees.	- Concrete - L= 60 m, H= 30 m	

Table 2-3-1 (2) Prospect Damsite Proposed by RID

No.	Location	Topography/Geology	Hydrogeology/Catchment	Facility Required	Remarks
8	Khlong Bang Thong	- Alluvial plain on the Khlong Bang Thong - Paddy field is generally seen - RID irrigation canal exists	- CA = 86.0 sq.km. - Rice is mostly planted - Annual rainfall is 3000 mm in average and annual flow is 150 MCM, 0.50 MCM in February and 33 MCM in September	- Pump Station - Coordination pipeline - Exportation of Thai Muang Treatment Plant: - Transmission pipeline	
9	Khlong Lo Young	- Alluvial plain on the Khlong Lo Young - Paddy field and rubber farm is generally seen	- CA = 7.2 sq.km - Annual rainfall is 2,700 mm in average and annual flow is 15.0 MCM, 0.08 in February and 4.0 MCM in September	- Earthfilled dam: - Conduction pipeline - Treatment plant: - Transmission pipeline	L= 775 m H= 45.0 m V= 16.0 MCM

The location of the site and the findings of the field survey given in Figure 2-3-1 and Table 2-3-1.

(c) Evaluation on Proposed Dams

Nos. 1, 3 and 7 dams are canceled by the reason of small catchment area and improper geological condition. No. 8 is also canceled by the reason of long distance to the service area, unstable flow in the dry season.

Based on the outcome of the geological survey by the JICA Study Team, an evaluation on the developability of the remaining six dams is made as shown in Table 2-3-3. Detail evaluation is given in Appendix A-2-4.

The water supply capacity for the proposed dams is computed by water balance simulation under the following conditions as the Bangor Reservoir. namely,

- The drought year is once in ten years. (water shortage occurs twice or three times in 30 years.)
- Rainfall at the Bangwad Reservoir is applied to Khlong Katha, Bang Tho sung, Bang Nieo Dam and Khao Che Tra dams. Average rainfall in the Phuket Airport and Thai Muang is applied to Khlong Lo Young and Na Foek dams.
- Evaporation is obtained from 70% Class A pan volume gauged in the Phuket Municipality.
- Seepage loss is considered, but negligible.
- No irrigation is required.
- Runoff coefficient shown in Table 2-2-5 is adopted.
- Operational study is made for 30 years from 1958 to 1987.

(2) Water Sources for the Phuket Municipal Waterworks

The Phuket Municipal Waterworks have a plan to use another mining pit with a capacity of 1.5 MCM cu.m to secure an ever-increasing water demand. The availability of the new pit was estimated using the same conditions described in Sub-section 2.2.2 (2).

1,500,000 x 0.70 x (1-0.2) = 840,000 cu.m
840,000 ÷ (30 days x 4 months) = 290 cu.m/h

Accordingly, the total allowable intake amount is 580 cu. m/h. Water demand in the Phuket municipal area, however, will reach 1,280 cu.m/h in the year 2001.

Table 2-3-2 Dimension of the Proposed Dams

Dam No. / Dam Location		1 Khlong Lo Young	2 Khlong Katha	3 Khao Che Tra	4 Bang Nie	5 Bang The Sung	6 Na Faek
Catchment Area	(km2)	7	5.2	4.3	5.2	4.3	14.4
Total Capacity	(MCM)	11.5	5	3	3.1	5	12
Dead Capacity	(MCM)	0.3	0.3	0.2	0.3	0.2	0.7
Effective Capacity	(MCM)	11.2	4.7	2.8	2.8	4.8	11.3
High Water Level	(m)	46	51	43	36	62	38
Low Water Level	(m)	27	27	33	23	34	23
Dam Top Level	(m)	50	55	47	40	66	42
Dam Bottom Level	(m)	4	3	18	3	8	4
Dam Height	(m)	46	52	29	37	58	38
Dam Length	(m)	845	780	727	830	630	1000
Embankment Volume	(MCM)	1.872	2.25	0.8	1.13	2.57	2.5
Water Supply Amount	(m3/d)	21400	10900	7600	8900	9600	35000

Note ; Details of the Proposed Dams are given in Appendix 6

(3) Streams

(a) Khlong Bang Yai

Khlong Bang Yai have approximately 23.4 sq.km at the confluence of two streams.

As a tentative measure to meet rapidly increasing water demand until new reservoirs are constructed.

A pump station can be installed downstream of the confluence and return surplus flows to the Bangwad Reservoir in order to augment the supply capacity.

The study shows that the Bangwad Treatment Plant (24,000 cu.m/d) can be operated in full scale by pumping up surplus flows in the rainy season when the water level in the Reservoir is lower than the full water level.

The pump will be operated in 20 cu.m/min on average and 30 cu.m/min at the maximum depending on the water level in the Reservoir and surplus flows at the confluence. That is to say, the number of pumps will be three with a each discharge capacity of 10 cu.m/min and 300 mm in diameter. The details is given in Appendix 2.3.

(b) Khlong Suan Maphrao

The stream flows northward having a catchment area of 8 sq km in the northernmost of the island. The flow amount in the midstream is approximately 1 cu.m/s collecting drain water from the paddy field. The flow amount is scarce in the dry season, so that the stream has little possibility for a reliable water source.

2.3.2 Ground Water

DMR conducted the study on the potentiality of ground water in the island. The outcome of their study is as follows:

(1) Beach Sand Aquifer

The beach sand aquifer of the Phuket Island is generally shallow, unconfined forming only a thin fresh water body above the wedge-shaped saline weir. The aquifer is normally so shallow that villages can construct their own conventional dug wells and mostly yield the sufficient amount of potable water to household users throughout the year, but insufficient for hotel users. The safety yield of the dug well is only 1.23 cu.m/h from many pumping tests.

(2) Alluvial Aquifer

The alluvial aquifer consisting of unconsolidated clay sand and gravel of the alluvium occurred mainly in the middle of the island. The thickness of the aquifer is generally not over than 61 m (200 ft). The yield is approximately 0.3 - 1.6 cu.m/h (20 - 100 gpm).

(3) Diluvial Aquifer

The diluvial aquifer consisting of poorly sorted valley filled deposits, cliff debris and granite wash occurred mainly in the northern part of the island. The thickness of the aquifer is generally not

over than 91 m (300 ft). The yield is less than 0.8 cu.m/h (50 gpm).

(4) Metasediment Aquifer

The metasediment aquifer consisting of clastic sedimentary rocks of sandstone, salty shale graywake can be seen in the mountain area and eastern peninsula. Ground water occurs only in joints and fractures. The yield ranges from meager to about 0.5 cu.m/h (30 gpm).

(5) Granite Aquifer

The granite aquifer consisting of massive granite with localized granite grass is developed in the mountain area on the western side. Ground water can be found only from joints or fissure system and decomposed zones with an average yield of 0.15 cu.m/h (10 gpm).

3. EXISTING WATER SUPPLY SYSTEM

3.1 Existing Water Supply System

3.1.1 General

At present, there are five independent water supply systems in operation in the Phuket Island as summarized in Table 3-1-1. Water systems other than the PWA Phuket Waterworks and the Phuket Municipal Waterworks (hereinafter referred to as "PMW") are very small and are hardly managed by the sanitary district or community. These are expected to be placed under the control of the PWA.

PMW was founded in 1957. The treatment capacity of the waterworks was 800 cu.m/d (initially controlled by the Public Works Department and later transferred to the Phuket Municipality in 1971). The expanded treatment capacity was 1,600 cu.m/d in 1964, and increased to 6,600 cu.m/d in 1975, to respond to the development of the municipal area.

In 1980, PMW prepared an expansion plan for the municipal water supply system, which involved the construction of the Bangwad Reservoir and the expansion of the treatment capacity to 18,900 cu.m/d for the target year of 1984. However, this plan was not implemented due to the budgetary constraints. In 1984, the Cabinet, through a resolution, placed PMW under the control of PWA but allowed it to manage the existing water supply system upon its transfer to PWA.

In 1987, PWA completed the preparation to supply treated water to the municipal area with the construction of the 1,000 cu.m/h Bangwad Treatment Plant and the installation of the 500 mm distribution pipe. The PMW, even with a Cabinet resolution, took an independent position and expanded further the treatment capacity of the plant to 580 cu.m/h. They modified the sedimentation basins and added a new rapid sand filter. They also acquired the old tin-mining-pit for supplementing the existing water sources.

In September 1988, PMW agreed to receive treated water from PWA, and PWA agreed to sell treated water of 6,000 cu.m/d to PMW at a rate of 4 ฿/cu.m in July 1989.

PWA started the operation in 1985 of the Patong Sanitary District Waterworks and the Kathu Sanitary District Waterworks in Phuket Island. In September 1987, PWA Bangwad Treatment Plant, with a capacity of 1,000 cu.m/h, was in operation taking raw water from the nearby RID Bangwad Reservoir to supply treated water to Patong, Kathu and Deep Sea Port with the 400, 400 and 500 mm pipe, respectively. PWA is responsible in supplying water to the whole of the Phuket Island.

Table 3-1-1 Existing Water Supply Systems in the Phuket Island

Operating Authority	Service Area	Treatment Plant	Treatment Capacity (cu.m/h)	Water Source	Year in Operation
PWA Phuket Waterworks	Patong, Kathu, Deep Sea Port	Bangwad	1,000	RID Bangwad Reservoir	Sep. 1987
		Patong	30	Waterfall	Oct. 1985
		Kathu(Not Used)	30	Waterfall	Nov. 1985
Phuket Municipal Waterworks	Phuket	Phuket	580	Tin-mining-pit Reservoir	1957
Thep Kasattri Sanitary Dist. Waterworks	Thalang	Thalang	20	Prathiu Waterfall	1977
Choeng Thale Sanitary Dist. Waterworks	Choeng Thale	Choeng Thale	20	Waterfall and tin-mining-pit reservoir	
Sapam Community Waterorks	Sapam	Sapam	20	Tin-mining-pit Reservoir	