MINISTRY OF INTERIOR
PROVINCIAL WATERWORKS AUTHORITY

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

FINAL REPORT FOR TAKUA PA

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

The Municipality of Takua Pa is one of the centers in the Phang Nga Province which is situated on the western coast of the northern region of Thailand. Takua Pa has two centers, Ban Talad Takua Pa and Ban Yan Yao. Ban Talad is the residential area while Ban Yan Yao serves as the institutional and commercial center.

The study area is located at the left bank of the Takua Pa River which originates from the mountains and flows into the Andaman Sea in the north. The low-laying areas consist of alluvial deposits while the estuary of the river is covered with mangrove in blackish water.

Average annual rainfall in the area is 3,600 mm while average annual pan evaporation level is 1,800 mm. Mean monthly temperature varies from 28.6 °C in April to 26.5°C in December.

The major economic bases in and around the Takua Pa Municipality are tin mining and rubber plantation. Recent surveys show that a total of 4,144 people are gainfully employed in 225 industrial and 657 commercial establishments in Amphoe Takua Pa. The mining sub-sector alone accounts for 70.6 percent or 155 establishments and 1,368 employees in the industry sector.

Transportation in the study area is mainly through land, with the main road leading southwards to Kapong and Phang Nga Municipality. Travel through the river is possible only during the rainy season as the river bed has become heavily silted and shallow.

The present community may be divided into three development areas, namely: the north core, which is a modern sector with wide roads and many government offices; south core, which is relatively old with narrow roads and concentrated housing and small scale commercial and service establishments; and the corridor connecting the two cores and which remains unurbanized.

WATER SOURCE

The water sources of the Takua Pa waterworks consist of a waterfall located upstream of the Khlong Bang I, one of the right bank tributaries, and a mining pit located at 300 meters north of the existing treatment plant. Groundwater is mostly utilized as water source by private houses with the use of hand dug shallow wells.

The present intake point of the waterworks is located upstream of the Khlong Bang I and has a catchment area of 2.7 sq. km. The existing concrete weir is too small to store sufficient water to meet demand during the dry season.

Shallow wells are often utilized by private houses in the study area. Most of the wells are hand-dug, with water being drawn by a bucket and a rope from about 3 to 5 meters under ground.

Monthly rainfall data were recorded at four gauging stations at Amphoe Takua Pa, Khuru Buri, Phanom and Takua Pa MD Station. Climatology data in the

study area were available at the Takua Pa Municipal office.

Two hydrological stations, both in Phanom, Surat Thani were selected for hydrological analysis as they have similar runoff patterns and catchment conditions.

Several methods such as specific runoff and hydrological model were used for estimating the available amount of water at the existing water source, the Khlong Bang I, which has a catchment area of 2.7 sq. km.

Probability analysis showed that the minimum flow at the existing intake point at Khlong Bang I is 0.01 MCM/mo or 300 cu.m./day in the return period of 1/10.

Evaluation made on the availability of water at the alternative source, the mining pit, which has a catchment area of 11.7 sq. m. and a seepage area of 32,000 sq.m., revealed a minimum available amount for water supply of 1,600 cu.m./day.

The study thus showed that the combined minimum flow available for water supply is 1,900 cu.m./day.

The study also considered the development of several alternative measures to meet future water demand and serve stable water supply. These include the raising of the existing weir at Khlong Bong I; enlargement of the existing mining pit and rehabilitation of inlet and outlet channels; provision of a direct intake from the Takua Pa River; development of a new mining pit; and groundwater development.

EXISTING WATER SUPPLY

The waterworks for the municipality of Takua Pa was founded in 1961. Raw water originated from the Bang Ee Waterfall and distributed after chlorination without further treatment. In 1969, a new 40 cu.m./h treatment plant was constructed at the same time the abandoned mining pit was added as water source.

The treatment process consists of chemical sedimentation, rapid sand filtration and chlorination. The treated water from the mining pit, mixed with untreated water from the Bang Ee Waterfall, is stored in a 500 cu.m. reservoir. Water from this reservoir is in turn pumped into a 120 cu.m. elevated tank and distributed by gravity to the service areas.

The distribution system of the water works covers the municipality of Takua Pa and the Ban Yan Yao area. The service area consists of two major areas in the north and south, with connection pipes in between. Although replacement of old pipes installed in 1961 and 1969 was implemented in recent years, high percentage of unaccounted for water still occurs due to deterioration of pipes.

The number of connections increased from 791 in 1980 to 965 in 1984 and 1,077 in 1987. Although all house connections are metered, some meters are found to be defective or have measuring defects.

The total water production and sales of the Takua Pa waterworks in 1987 were 563,505 cu.m. and 247,121 cu.m., respectively. The waterworks has three major sources of revenue, namely: water sales, service charges, and connection fees.

Annual water production and sales in the past years are shown as follows:

Annual Water Production and Sales

Year	Water Production (cu.m/y)	Water Sales (cu.m/y)	No. of Conn.	Consump. per Conn. (cu.m/d)
1980	230,988	200,460	791	0.692
1981	388,274	254,690	812	0.859
1982	429,356	289,772	851	0.933
1983	421,818	299,975	911	0.902
1984	443,250	304,744	965	0.863
1985	483,900	290,114	987	0.805
1986	496,050	265,973	1,063	0.686
1987	563,505	247,415	1,077	0.629

POPULATION AND WATER DEMAND

The future population in the study area was placed at 29,979 in 1991, 32,633 in 1996, 35,592 in 2001, 38,891 in 2006 and 42,574 in 2011. Future population was based on the following assumption:

a) Population in the municipality will have the same growth rate as in the four years since 1983.

b) Population outside the municipality will have the same growth rate as that of Amphoe since 1980.

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

Table 4-3-4 Future Served Population

Year	Population in Service Area			Average Service Ratio (%)
	Existing Service Area	Area to be Expanded	Total	
1991	5,660	-	5,660	41.1
	(9,434)	(4,338)	(13,772)	
1996	6,240	729	6,969	48.2
	(9,600)	(4,863)	(14,463)	
2001	6,838	1,636	8,474	55.7
	(9,769)	(5,452)	(15,221)	
2006	7,456	2,444	9,900	61.7
	(9,941)	(6,111)	(16,052)	
2011	8,093	3,427	11,520	67.9
	(10,116)	(6,851)	(16,967)	

Upper : Served population in the service area
Lower : Total population in the service area

Future water demand is calculated from the water consumption, unaccounted-for water ratio and peak factor as summarized in the following table.

Future Water Demand

(Unit : cu.m/d)

Category	1987	1991	1996	2001	2006	2011
Domestic		623	787	986	1,212	1,476
Gov't/Inst'l		589	601	613	628	643
Commercial		138	145	152	161	170
Industrial		30	35	40	46	53
Others		6	7	8	9	11
Sub-total		1,386	1,575	1,799	2,056	2,353
Unaccounted-for Water Ratio (%)	56.1	50	43	35	28	20
Unaccounted-for Water		1,386	1,188	969	800	588
Daily Average	1,551	2,772	2,763	2,768	2,856	2,941
Peak Factor		1.35	1.35	1.35	1.35	1.35
Daily Maximum		3,742	3,730	3,737	3,856	3,970

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 - intake loss is 10 %; treatment loss is 8 %

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.

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

Evaluations made on several alternatives for the development of the Takua Pa Waterworks, revealed the following:

a. It is recommended to install an additional pipe for transmission of the raw water from the existing weir to the treatment plant. This is to increase the intake capacity from the weir.

b. Groundwater development is not practical due to poor quality and quantity of water.

c. The western part of the existing mining pit may be enlarged by excavating the area over 84.00 m in elevation to increase the capacity to 300,000 cu.m.

d. The development of new mining pits located in the flood plain is required to serve as additional water sources.

e. The construction of an intake at the Takua Pa River is also needed.

Water source development plan calls for the construction of a raw water intake tower and a pumping station near the bridge about 2.0 km upstream of the waterworks.

The construction of a new treatment plant with a capacity of 4,300 cu m/day is proposed to be constructed in the existing plant site. The existing plant units are planned to be abandoned.

The estimated water demand in 2011 was used as basis in planning the improvement of the distribution system, which will involve the replacement of old pipelines and the construction of about 9,000 m mains with diameters of 100 and 250 mm.

IMPLEMENTATION PLAN

The implementation plan of the total project will include the construction of a treatment plant which will be carried out in one phase. The plan also includes the replacement of the aged pipes and construction of new pipes to be constructed in two years.

The water demand, plant capacity, and the implementation schedule are shown in Figure S-1.

ORGANIZATION OF WATER WORKS

The proposed organization of the Takua Pa Waterworks is based on the existing functional chart of the waterworks and will consist of the following:

a. Administrative Section - This will be responsible for handling the administrative and financial operations of the waterworks.

b. Water Production Section - Responsible for the operation and maintenance of the treatment plant and other facilities.

c. Service Section - Responsible for setting and repair of house connections.

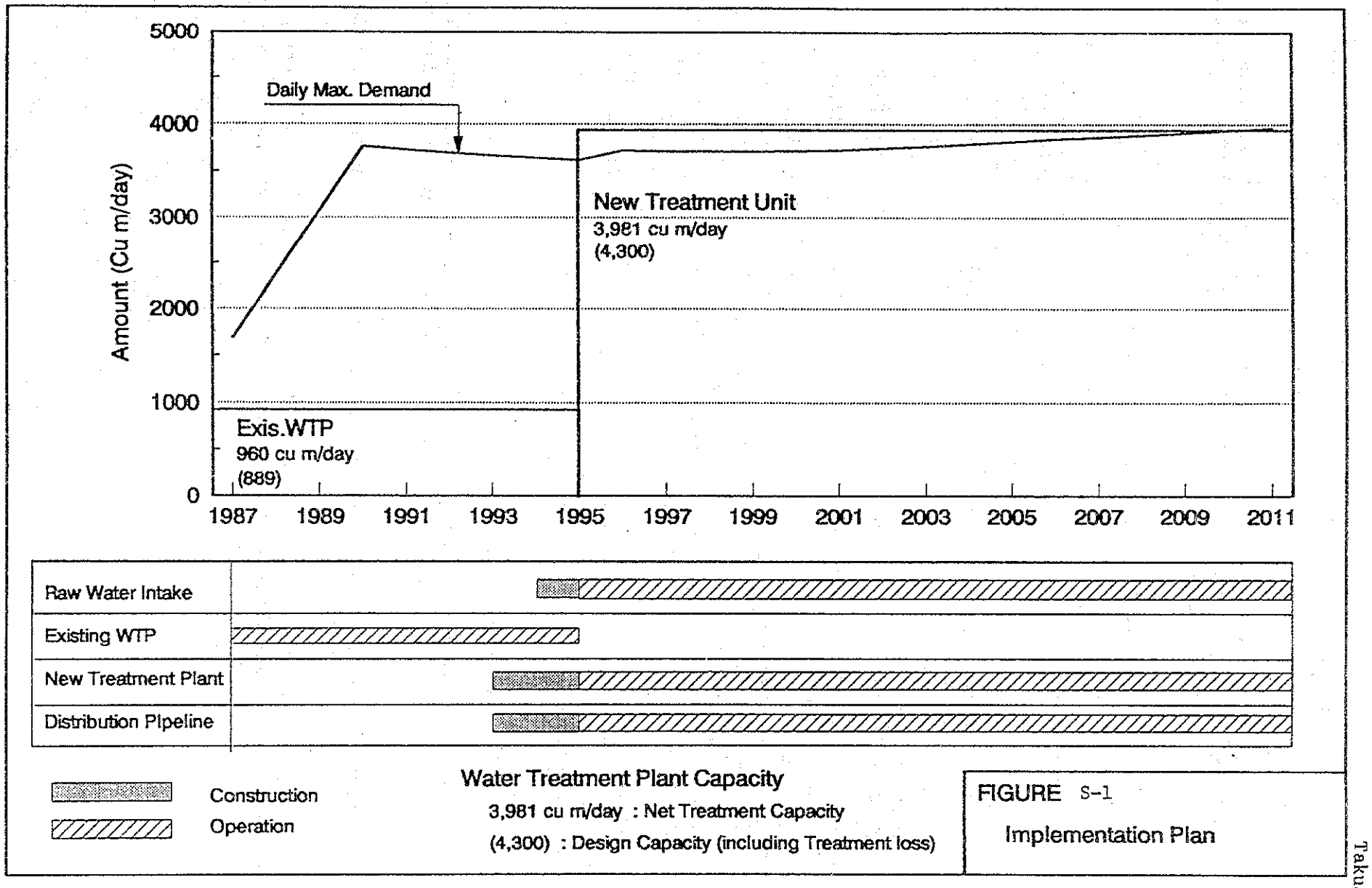


FIGURE S-1

Implementation Plan

PROJECT COST ESTIMATES

(1) Construction Cost

The construction cost of the proposed water supply system was calculated for each component of the facility. The Table below shows a summary of the construction cost based on 1989 prices:

Summary of the Construction Cost

(unit : Baht 1000)

Item	Total Value	Foreign Currency Portion	Local Currency Portion
1.Raw Water Intake	4,493	1,843	2,650
2.Usage of the Existing Mining Pit	2,675	1,050	1,625
3.Treatment Plant	16,661	6,680	9,980
4.Distribution Pipeline	16,003	4,801	11,202
5.Transmission Pipeline (Intake Weir to WTP SP, Dia.200 mm, 2 km)	3,540	2,832	708
Sub Total	43,372	17,206	26,165
5.Land Cost	100	0	100
Total	43,472	17,206	26,265

(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.

Manning cost is based on the prediction of the staff number of water-works as proposed in Chapter 10.

Replacement of the mechanical and electrical equipment is considered to be made 20 years after the installation so that they are not included in the period of the development plan.

Total operation and maintenance cost is tabulated below:

Summary of Operation and Maintenance Cost

(unit : Baht 1000)

Year	OPERATION COST					
	Energy Cost	Chemical Cost	Manning Cost	Repair Cost	Replace-ment	Total
Total	14,015	1,521	61,212	271	0	77,019
1990	462	69	1,590			2,121
1991	460	68	1,669			2,198
1992	458	68	1,753			2,278
1993	457	67	1,840			2,365
1994	660	67	1,932			2,659
1995	657	66	2,029	16		2,768
1996	669	68	2,130	16		2,883
1997	668	68	2,237	16		2,989
1998	668	68	2,349	16		3,101
1999	668	68	2,466	16		3,218
2000	668	68	2,589	16		3,342
2001	670	68	2,719	16		3,473
2002	672	69	2,855	16		3,612
2003	675	69	2,998	16		3,758
2004	678	70	3,148	16		3,911
2005	681	70	3,305	16		4,072
2006	684	71	3,470	16		4,241
2007	686	71	3,644	16		4,416
2008	689	71	3,826	16		4,602
2009	692	72	4,017	16		4,797
2010	695	72	4,218	16		5,001
2011	698	73	4,429	16		5,215

Financial Study

Project Cost Estimates

Total Project cost is estimated at 19,180,000 Baht, with a foreign exchange requirement of 6,176,000 Baht and local cost component of 13,004,000 Baht. The breakdown of cost estimates is as follows (in thousand Bahts):

	Foreign Portion	Local Portion	TOTAL
a. Construction Cost	17,207	26,166	43,373
b. Engineering Cost			
Design, 4% of (a)	1,514	2,303	3,817
Supervision, 2% of (a)	757	1,151	1,908
c. Land Cost	0	100	100
TOTAL	19,478	29,720	49,198

Financing Plan

The total foreign cost and 8.348 million Baht of local cost (approximately 50% of project cost) is recommended to be financed from bilateral loan, the remaining 21.372 million Baht of local cost to be equally financed from domestic loan and PWA equity.

Cash Flow Analysis

Inflows consist of government capital contribution for interest payment of domestic loan, foreign and local loan based on recommended 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 recommended financing scheme, O&M, and connection expenses (50% connection fees).

Results of cash flow analysis show deficits throughout the project life. Cumulative cash deficits for years 2011 and 2020 are estimated at 65.068 million Baht and 96.985 million Baht, respectively.

The results suggest that PWA equity shall be infused and/or water rates increased to cover the expected deficits. It is projected that the unit cost of water would stand at 8.46 Baht per cubic meter in year 2011 and average unit water cost from 1990 to 2020 is 10.44 Baht with the implementation of the project. These rates are almost equal to the maximum level of PWA's present water tariff structure.

Part 1
GENERAL

Part 1 GENERAL

1. DESCRIPTION OF THE STUDY AREA

1.1 Natural Conditions

1.1.1 General

The Municipality of Takua Pa is one of the center in the Phang Nga Province which is situated on the western coast in the southern region of Thailand. Tin is the most important natural resource of Takua Pa and majority of the people are engaged in tin-mining. Takua Pa has two centers, namely Ban Talad Takua Pa and Ban Yan Yao. The latter was originally developed to enable the migration of residents from Ban Talad and to engage in mining tin lain beneath the particular area. At present, Ban Yan Yao is considered as the institutional and commercial center, while Ban Talad Takua Pa serves as the residential area, housing mostly miners' families.

Takua Pa is located at longitude 98°21' east and latitude 8°52' north, about 40 km northwest of Phang Nga.

The PWA waterworks supply water to the whole municipal area and some areas along Route 4 (Petkasaem Road).

1.1.2 Topography

Takua Pa is located at the left bank of the Takua Pa River bordering its estuary.

In the northern part, the river, which is covered with mangrove, flows into the Andaman Sea.

Low-laying areas where flood is common during the wet season, are comprised of alluvial deposits formed along the river. Rubber is planted mainly in the undulating middle terrace below the mountain area. Fairly steep mountains ranging from 300 m to 450 m in elevation are formed in the southern and eastern part of the study area. The Takua Pa River and its tributaries originated from the mountains.

1.1.3 Geology

Takua Pa is situated on the alluvial deposits (Qa) consists of gravel, sand, silt and clay along the Takua Pa River. The Municipality borders the estuary of the Takua Pa River, which is covered in the northern part with mangrove in blackish water. Colluvial deposits (Qt), developed below the mountain area, form an undulating middle terrace. Mudstone or sandstone (CP) are mainly formed in the mountain area.

Further deep, are mountains and west coastal mountains consisted of cinoruses naubkt biotite-hornblende granite (Kgr). Numerous tin mining camps are developed in the mountain area.

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

Table 1-1-1 Geological Feature

Group	Feature	Location
Qa	Alluvial deposits, Gravel, sand, silt and	Low-laying area along streams
Qb	beach deposits : Sand, silt and shell fragments	Beachside
Qt	Terrace and colluvial deposits; Pebble, gravel, sand, silt and clay	Undulating middle terrace below mountain
P	Linestone, gray and dark gray, thin-bedded to massive, fassiliferous	Isolated steep mountains
Cp	Pebbly mudstone, gray and dark gray, cobble to boulder as clast, thick-bedded to massive laminated mudstone; interbedded siltstone and mudstone, brown and gray, thin-bedded, with sharp based bed, slump structure, bioturbation, load cost, and dropstone like structure; sandstone, white and pale brown, coarse to medium-grained, thick and well-bedded, grade-bedding; conglomeratic sandstone; and shale with aboundant bryozoas brachiopods, gastropods, corals, and crinoid stems	Mountain area
Kgr	Biotite - horn blende granite, fine-to medium - grained, equigranular; biotite granite, coarse - grained and por phyritic	Mountain area on the west coast and at the mountain peak

1.1.4 Meteorology

The average annual rainfall in Takua Pa is 3,600 mm with highly seasonal distribution. More than 50% of the total rainfall occurs during the wet season from May to October. Takua Pa is situated in an area with the greatest rainfall in Thailand where the average annual rainfall exceeds 4,000 mm. Rainfall records during the dry season is variable and unreliable.

Average annual pan evaporation level in the area is about 1,800 mm with little monthly variation. Relative humidity is high, ranging from 86.0% in October to 74.0% in February. The mean monthly temperature varies from 28.6°C in April to 26.5°C in December with a range of only 2.1°C. The extreme range is from 37.0°C to 13.9°C. Temperatures further inland decline slightly.

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

Table 1-1-2 Meteorological Data at Takua Pa

Items	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature (C.degree)													
Mean	26.7	27.5	28.2	28.6	28.0	27.9	27.5	27.6	26.9	26.7	26.6	26.5	27.4
Mean Max.	31.4	32.6	33.2	33.0	31.5	30.8	30.5	30.4	29.9	30.1	30.5	30.8	31.2
Mean Min.	21.9	22.3	23.0	23.9	24.4	24.7	24.4	24.7	23.9	23.5	23.0	22.5	23.5
Ext. Max.	34.5	36.2	37.0	36.8	36.0	35.0	34.0	34.5	33.3	33.3	33.0	33.3	37.0
Ext. Min.	13.9	15.8	18.3	21.1	21.4	21.2	21.0	20.7	21.2	21.0	17.9	18.4	13.9
Relative Humidity (%)													
Mean	76.1	74.3	75.9	79.7	83.8	82.8	83.0	82.1	85.2	86.3	84.1	79.4	81.1
Mean Max.	92.5	92.4	93.9	95.4	95.4	92.7	93.0	91.8	94.6	96.3	95.5	92.7	93.9
Mean Min.	56.1	53.3	55.2	61.6	69.9	71.8	72.2	72.1	74.5	73.1	68.1	62.5	65.9
Ext. Min.	33.0	32.0	32.0	29.0	34.0	42.0	42.0	43.0	54.0	52.0	46.0	40.0	29.0
Evaporation (mm.)													
Mean - Pan	164.3	155.3	197.6	157.2	135.3	124.0	136.1	167.3	140.2	138.9	133.0	139.8	1789.0
Rainfall (mm.)													
Mean	43.6	26.3	68.0	195.9	458.9	471.4	484.5	505.8	604.3	396.1	258.9	47.7	3561.4
Mean Rainy Days	6.0	4.2	6.3	11.8	21.9	21.0	20.8	19.8	22.8	23.1	16.1	9.3	183.6
Greatest in 24 hr.	65.6	59.0	72.3	156.3	209.4	113.4	151.1	132.0	142.1	197.6	121.5	63.2	209.4
Day / Year	22/66	26/71	23/73	29/83	23/63	23/63	14/66	13/83	24/56	5/71	2/58	16/73	23/64

Source : Meteorological Department
Remark : Sunshine Duration 1957-1985
: Evaporation 1981-1985

1.2 Socioeconomic Conditions

1.2.1 Economic Conditions

Major economic bases in and around the Takua Pa Municipality are tin mining and rubber plantation. Tin mines are both on land and offshore. Since 1983 the government has reduced the export quota of tin to almost half and the price of tin in the international market remained low while the operation cost went up. As the result, tin mining industry has suffered from slump causing closing of some establishments, and making sluggish the supporting indus- tries such as workshops of machinery and welding, equipment suppliers and the whole regional economy. While the living cost has become rather high.

The numbers of industrial establishments and employees in Amphoe Takua Pa are shown in Table 1-2-1. "Mining and mine products" sub-sector has 155 establishments with 1,368 employees, that is 70.6% in the industry sector. Following are "machinery (service)" and "transportation and repair of machines". These are regarded as tin-related industries.

In addition to rubber plantation, the agricultural sector of the area includes coconut plantations, rice farming, livestock and fisheries, though production of rice is not enough for local consumption, necessitating supply from other provinces.

Commerce is mostly in the form of retail and wholesale trading by large and small scale traders. Commercial establishments in the Municipality include limited companies, partnerships, and individual stores.

In the commerce sector, there are 657 establishments with 2,206 employees in the Amphoe as shown in Table 1-2-2. Besides restaurants and daily necessities, repair shops of motorcycles and electric appliances, and also shops of parts of vehicles and motorcycles account for large shares in the number of employees.

Table 1-2-1 Industrial Establishments in Amphoe Takua Pa

Type of Industry	Establishments		Employees	
	No.	%	No.	%
Food, beverages (production)	10	4.5	83	4.3
Rice mill (production)	1	0.4	7	0.3
Metal products (production)	3	1.3	15	0.8
Non-metal products (production)	2	0.9	7	0.3
Paper, printing (production)	2	0.9	13	0.7
Transportation, repair of machines (service)	23	10.2	116	6.0
Electricity (service)	2	0.9	7	0.4
Machinery (service)	20	8.9	159	8.2
Mining, mine products (production)	155	68.9	1368	70.6
Wood, wood products (production)	3	1.3	107	5.5
Fishing related (production)	4	1.8	56	2.9
Total	225	100.0	1938	100.0

Source : DTCP

Table 1-2-2 Number of Commercial Establishments and Employees in Amphoe Takua Pa

Type of Commodities	Establishments		Workers	
	Number	%	Number	%
Food, beverages	150	22.8	599	27.2
Daily necessities	150	22.8	466	21.2
Groceries	21	3.2	60	2.7
Clothes	34	5.2	93	4.2
Taylor	34	5.2	98	4.4
Beauty parlor	54	8.2	135	6.1
Parts of cars & motorcycles	29	4.4	113	5.1
Repair of motorcycles & electric appliances	68	10.3	197	9
Medicines	15	2.3	27	1.2
Construction materials	12	1.8	40	1.8
Furniture	6	0.9	11	0.5
Metal works	6	0.9	16	0.7
Stationary	18	2.7	58	2.6
Photograph	6	0.9	8	0.4
Farm appliances	4	0.6	38	1.7
Gasoline & oil	9	1.4	84	3.8
Sourvenirs & handicrafts	1	0.2	2	0.1
Transport & tourism	1	0.2	6	0.3
Glasses, watches, typewriters	2	0.3	5	0.2
Religious items	1	0.2	2	0.1
Laundry	1	0.2	2	0.1
Movie & video	5	0.8	15	0.7
Metal & rubber	12	1.8	53	2.4
Ice	8	1.2	27	1.2
Mining appliances	4	0.6	13	0.6
Scrap iron	6	0.9	38	1.7
Total	657	100	2206	100

Source: DTCP

1.2.2 Transportation

The Takua Pa Municipality is along Route 4032 (Takua Pa Road) as in Figure 1-3-1. The Route leads southwards to Kapong, from which Route 4090 leads to the Phang Nga Municipality. At the north core of the Municipality, Route 4032 joins Route 4 (Petkasaem Road), which passes east and westwards. In the eastern side of the Municipality, the route turns to north leading to Ranong toward Bangkok, and Route 401 diverts from Route 4 to lead to Surat Thani. In the western side, Route 4 turns to south leading to Phuket.

The Takua Pa River flows from Kapong through Tum Tua, Ban Khok Khian, Bang Sai, the Municipality and Bang Nai Si into the Indian Ocean. The river can be used as a communication channel only in the rainy season because it is shallow due to the mining silt.

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 aged 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 division consisting of three years such that, typically, those 12-14 years of age attend lower secondary while those 15-17 attend upper
Table 1-2-2
secondary.

The government plays a major role in all aspects of Thailand's education system. Government expenditures on education accounted for 19% to 21% of the total government expenditures during the past eight years. The percentage of government expenditure on education in Thailand is among the highest compared to those of other developing countries.

In Takua Pa, there are 22 schools. A detailed breakdown of schools, including the number of students is shown in Table 1-2-3.

Table 1-2-3 School in Amphoe Takua Pa (1987)

Grade of School	No. of Schools	No. of Students	No. of Teachers
Kindergarten	9	3,572	172
Primary School	11	4,556	223
Secondary School	2	2,015	122
College/University	-	-	-
Total	22	10,143	517

1.2.4 Sanitation (Water-borne Diseases)

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

The decrease of water-borne diseases and thus, the number of patients, is one of the significant purposes of water supply projects. The status of water-borne diseases in relation to the number of water-born diseases is shown in Table 1-2-4.

Table 1-2-4 Water-Borne Diseases in Amphoe Takua Pa

Year	No. of Patients				
	Diarrhea	Dysentery	Food Poisoning	Typhoid	Total
1984	36	3	-	8	47
1985	102	-	2	12	116
1986	61	11	4	6	82
1987	59	18	5	7	89
1988	54	6	1	4	65

1.3 Land Use

1.3.1 Existing Land Use Pattern

The existing community development pattern is shown in Figure 1-3-1. Main features of the pattern are as follows:

(1) The municipal area is classified into three parts. The north core is a relatively modern sector with wide roads and many government offices. However, there are still some vacant lots in the residential areas which can accommodate more population.

The south core is a relatively old sector with narrow roads and concentrated housing and small scale commercial and service establishments. The area is on a tin mine and the residents have been expected to be relocated to the north core but this has not been realized to date.

The corridor connecting the two cores runs between the hills on the western side and the river on the eastern side. This area remains unurbanized.

(2) Outside the Municipality are several communities, of which major ones include Ban Muang and the port zone. Urban expansion from the Municipality westward along Route 4 has been taking place including the hospital and the school in the vicinity of the north core.

1.3.2 Land Value

In Takua Pa Municipality, official land prices are higher in the north core especially along the Sri Muang Road and in the south core especially along central streets such as Route 4032 (Takua Pa Road). The prices range from 8.4 ฿/sq.m (13,500 ฿/rai) to 94 ฿/sq.m (150,000 ฿/rai). While in rural areas including the middle part in the corridor, the prices are lower ranging from 2 ฿/sq.m (3,000 ฿/rai) to 3 ฿/sq.m (5,000 ฿/rai).

In the Amphoe Takua Pa area, official land prices are higher along Route 4 (Petkasaem Road) especially around the Municipality, ranging from approximately 50 ฿/sq.m (80,000 ฿/rai) to 125 ฿/sq.m (200,000 ฿/rai). While in rural areas without roads or paved roads, the prices are as low as approximately 3 ฿/sq.m (5,000 ฿/rai) to 4 ฿/sq.m (7,000 ฿/rai).

1.3.3 Future Land Use Pattern and Development Prospects

The future land use plan by DTCP is to be finalized in 1989. However from the present trend of urbanization, major urbanization directions in future are thought to be as in Figure 1-3-2. Urban expansion from the Municipality westwards along Route 4 is thought to be most prominent. To meet the urban expansion, the Municipality boundary may have to be expanded in the future.

For development of the Municipality through administration and project implementation, the local government sets the following guidelines.

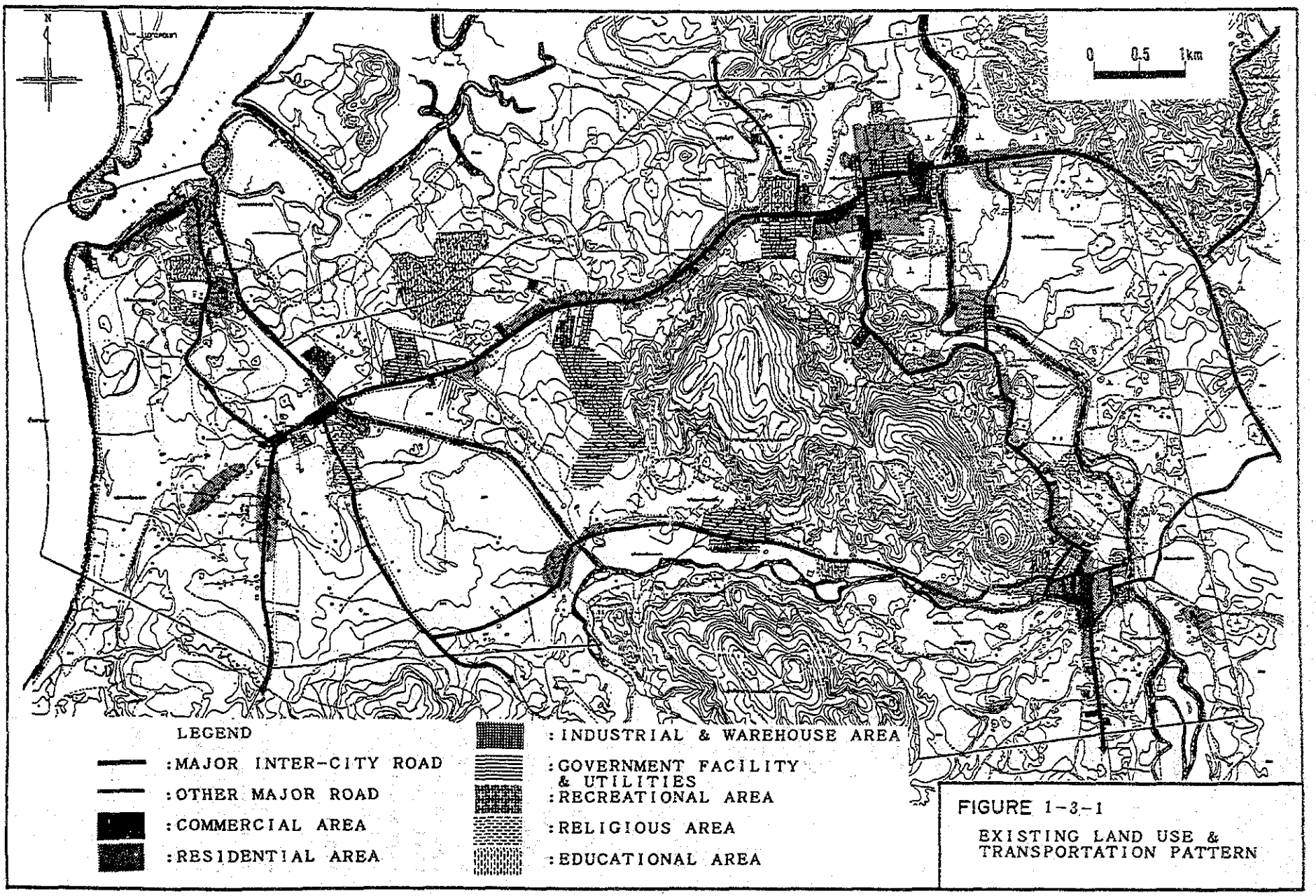


FIGURE 1-3-1

EXISTING LAND USE & TRANSPORTATION PATTERN

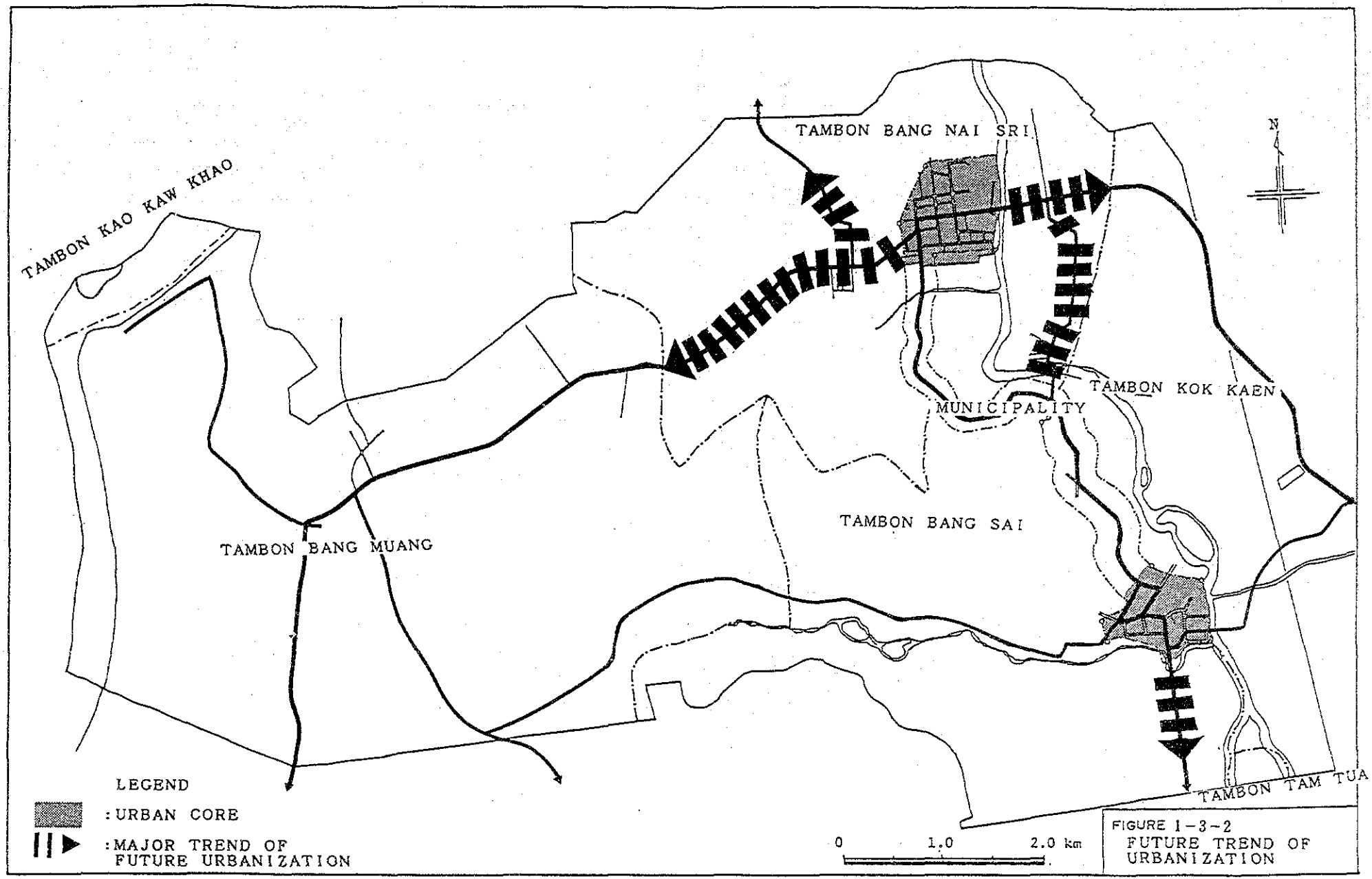


FIGURE 1-3-2
FUTURE TREND OF URBANIZATION

1) Development of infrastructure

1.1) Development of land use and environment
1.2) Construction and maintenance of public utilities
1.3) Improvement of water supply services

2) Economic development

2.1) Promotion of occupations and income of people
2.2) Promotion of tourism

3) Social development

3.1) Development of education, religion and culture
3.2) Development of public health services
3.3) Development of care for children and youth
3.4) Promotion of social welfare and recreation

4) Development of public administration

4.1) Development of local administration and services
4.2) Development of the personnel
4.3) Development of the municipal treasury
4.4) Development of democratic systems
4.5) Development of security, peace and order of th community
4.6) Prevention and relief from diseases
4.7) Improvement of the general administration work

The economic development mentioned above includes main issues shown in Figure 1-3-3.

Problems	Policy	Potentiality
1. Unemployment problem in urban areas	1. Promotion of occupations for urban people	1. Local vegetarian tradition
2. Unfairness in the buying of goods	2. Organisign markets where goods are sold at cheap prices	2. Festival of worshipping Phra Narai and his retinue
3. People have no steady income	3. Helping people get fairness in the buying of goods	
4. People still indulge in indecent things	4. Organising markets that operate throughout the night	
	5. Promoting provincial and district tourism	

Objectives:

1. To promote vocations for the people to increase family income
2. To reduce urban unemployment problems
3. To give opportunity to the people to have their own choice goods at fair prices
4. To promote tourism in Phang-nga Province and Takua-Pa District
5. To make the people aware how to use free time profitably instead of indulging in indecent things

1: Main work plan for the promotion fo occupations and income for the people

Sub-work plan
1. To promote and develop income of every household consisting of three projects
2. To promote and develop income to upmade the living standard of the local people consisting of three projects
3. To organise marketing service consisting of four projects

2: Main work plan for the promotion of tourism

Sub-work plan
1. Public relations work to promote and support tourism consisting of three projects.

FIGURE 1-3-3
Structure of Economic Development

2. WATER SOURCE

2.1 Existing Water Use Pattern

2.1.1 General

The Takua Pa Municipality is located at the estuary of the Takua Pa River which flows northward collecting an annual rainfall of more than 3,000 mm. The water sources of the Takua Pa Waterworks are a waterfall located upstream of the Khlong Bang I, one of the right bank tributaries, and a mining pit on the right bank 300 m north of the treatment plant.

The location of water sources is given in Figure 2-1-1.

2.1.2 Surface Water

(1) Khlong Bang I

The present intake point is located upstream of the Khlong Bang I with a catchment area of 2.7 sq.m in the coppice. A 1.8 m high and 5 m wide concrete weir is constructed with a 150 mm AC pipe, but is too small to store sufficient water to meet the demand in the dry season.

(2) Mining Pit

Another water source, a mining pit is situated at the flood plain so often flooded during the wet season. The pit has a storage capacity of 220,000 cu.m with an inlet and outlet channels. At present, the pit has enough capacity to meet the demand.

The quality of raw water sampled during the field survey is given below.

Table 2-1-1 Water Quality

Parameter	Khlong Bang I	Mining Pit	Takua Pa River
Temperature (°C)	31.7	---	---
pH	7.4	6.0	6.9
Turbidity	0.2	0.2	73.0
Conductivity (5x10)	3.0	1.7	3.4
NH_4-N (mg/l)	<0.4	<0.4	<0.4
NO_2-N (mg/l)	<0.006	<0.006	<0.006
NO_3-N (mg/l)	<0.23	<0.23	<0.23
Coliform	D	ND	D

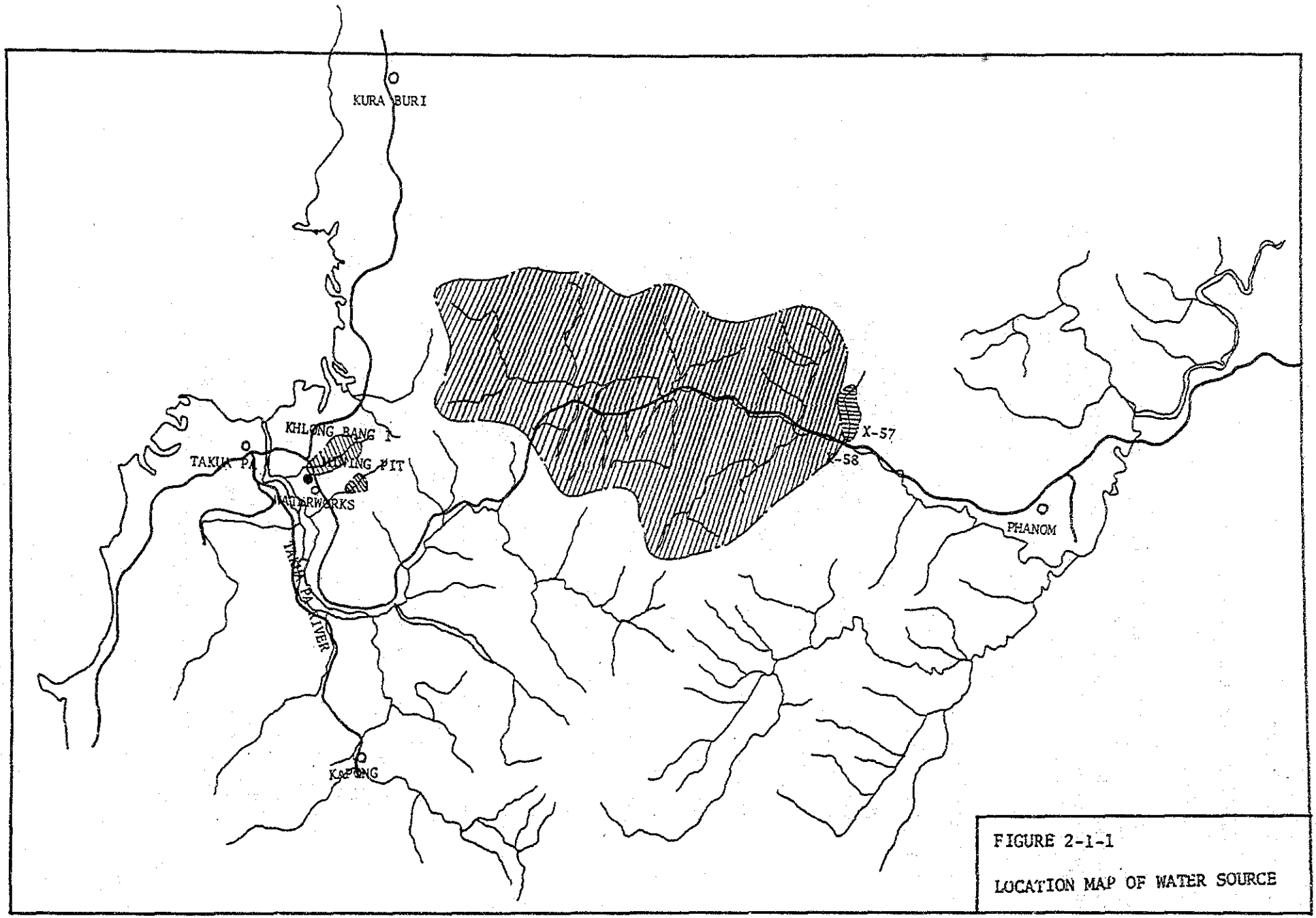


FIGURE 2-1-1

LOCATION MAP OF WATER SOURCE

2.1.3 Ground Water

(1) Shallow Well

The Takua Pa River is situated on the alluvium of the river, therefore shallow wells are hand-dug with brick lining. Water is taken by a bucket and rope from a depth of approximately 3 to 5 m

(2) Deep Well

Deep wells constructed by DMR are listed in Table 2-1-2.

Table 2-1-2 List of Deep Wells by DMR

LOCATION	Year	Depth (ft)	Size (in.)	Aquifer Code	Static (ft)	Yield (gpm)	Drawdown (ft)	Iron (ppm)	Chlorine (ppm)	TDS (ppm)
Takua Pa Khiri Khet School	1983	40	5	9	22.00	10.00	3	0.47	5.8	
Takua Pa Sonanukun School	1983	110	4	9	15.00	15.00	30	0.82	10	66
Takua Pa Hospital M.1	1983	130	5	9	31.27	45.28	40.08	1.6	8.0	100
Takua Pa Hospital M.4	1983	140	6	9	27.85	45.28	47.01	2.7	8.4	78
Ban Nam Khom Schoool M.2a	1983	100	5	3	15.00	20.00	20	77	1130	1842
Takua Pa Mineral	1972	95		4						

2.2 Availability of Existing Water Source

2.2.1 Data Availability 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 in the 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 maps prepared by DMR.

(2) Monthly Rainfall

Monthly rainfall data are available at four gauging stations controlled by Amphoe Takua Pa, Khuru Buri and Phanom, and Takua Pa MD Station.

The rainfall stations are listed below and monthly rainfall data are given in Tables A2-1-1 to A2-1-4 in Appendix A-2-1.

Table 2-2-1 List of Rainfall Stations

Station	Location	Period of Record	Remarks
Takua Pa	Amphoe Takua Pa	1956 to Present	
Khuru Buri	Amphoe Khuru Buri	1967 to Present	
Phanom	Amphoe Phanom	1956 to Present	
Takua Pa	MD Station	July 1975 to Present	beside the beach

(3) Climatological Data

The data describing the climatology in the Takua Pa area is available at the Takua Pa Municipality. This station observes such climatological data as temperature, atmospheric pressure, humidity, evaporation, sunshine hours and wind. The data are given in Table A2-1-5 in Appendix A-2-1.

(4) Hydrological Data

Two hydrological stations are selected for hydrological analysis because these stations have similar runoff pattern and catchment conditions to the concerned water sources.

The stations are listed Table 2-2-2 and these data are given in Tables A2-2-1 and A2-2-2 in Appendix A-2-2.

Table 2-2-2 List of Hydrological Stations

Station	Location	Period of Record	Remarks
X-58 (CA=312 sq.km)	Phanom, Surat Thani	1972 to 1980	RID
X-57 (CA= 8 sq.km)	Phanom, Surat Thani	1972 to 1982	RID

2.2.2 Availability of Existing Water Source

(1) Khlong Bang I

Several methods as specific runoff and hydrological model are used for estimating the available amount of water at the existing water source, the Khlong Bang I of which has a catchment area of 2.7 sq.km.

(a) Specific Runoff

There are two gauging stations in the neighborhood of the present intake point on the Khlong Bang I. Specific runoff adopted by X-57 and X-58 are given in Table 2-2-3.

(b) Hydrological Model

The runoff model is established by the Tank Model Method using the observed discharge record at the RID's hydrological gauging stations, X-57 and X-58.

As described in Appendix A-6-3, the rainfall is not successfully simulated to the gauged discharge, because the gauged flow does not necessarily respond to rainfall occurrence. This fact reveals that the hydrological model cannot be applied for estimating the available amount of water.

(c) Evaluation on Analysis Methods

Since the existing intake point on the khlong Bang I has a catchment area of 2.7 sq.km and has similar topographical features as that of the gauging station X-57 as shown in Table 2-2-4. Runoff at the intake point is calculated by specific runoff at X-57. In addition, the correlation between X-57 and X-58 in specific runoff is high as shown in Figure 2-2-1. Monthly average flows are given in Figure 2-2-2

(d) Availability

Probability analysis is made on the following conditions:

- The return period is set at once in ten years (1/10).
- The flow estimated by specific runoff at X-57 is applied, but the term of flow data can be prolonged to 13 years by the correlation between X-57 and X-58.
- The monthly minimum flow in each year is applied.
- The applied data indicates the logarithmic normal distribution as shown in Figure 2-2-3, therefore, the method suitable for analyzing the return period of 1/10 will be adopted.

The minimum flow at the existing intake point on the Khlong bang I is estimated at 0.01 MCM/mo or 300 cu.m/d in the return period of 1/10 as shown in Table 2-2-5.

(2) Mining Pit

(a) Evaluation on the Availability

The mining pit is situated on the flood plain, having a catchment area of 11.7 sq.m. The amount of inflow is unknown, although there is a small inlet channel.

The study on the availability is made considering the pit as a reservoir under the following conditions:
Table 2-2-3

Table 2-2-3 Specific Runoff

(Unit : MCM/sq.km)

Year	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1972	×-57									—	0.067	0.094	0.036
	×-58									0.382	0.143	0.106	0.046
1973	×-57	0.013	0.001	—	0.030	0.007	0.165	0.552	0.415	0.222	0.285	0.259	0.044
	×-58	0.022	0.009	0.007	0.012	0.025	0.199	0.464	0.331	0.302	0.278	0.167	0.075
1974	×-57	0.008	0.004	0.004	0.013	0.124	0.321	0.050	1.212	0.279	0.459	0.360	0.060
	×-58	0.044	0.029	0.025	0.035	0.156	0.311	0.193	0.876	0.318	0.489	0.355	0.071
1975	×-57	0.114	0.012	0.013	0.068	0.131	0.959	0.064	0.563	0.194	0.512	0.220	0.037
	×-58	0.067	0.029	0.025	0.020	0.057	0.603	—	0.415	0.182	0.409	0.180	0.043
1976	×-57	0.020	0.013	0.010	0.009	0.375	0.337	0.556	0.348	0.969	0.064	0.139	0.044
	×-58	0.022	0.013	0.015	0.021	0.253	0.227	0.392	0.285	0.603	0.094	0.086	0.043
1977	×-57	0.014	0.012	0.010	0.007	0.074	0.045	—	—	—	0.265	0.253	0.047
	×-58	0.024	0.018	0.025	0.008	0.053	0.061	0.086	0.519	—	0.167	0.116	0.041
1978	×-57	0.027	0.024	0.030	0.032	0.064	0.230	0.589	1.200	0.901	0.204	0.117	0.030
	×-58	0.025	0.016	0.020	0.016	0.071	0.356	0.479	0.742	0.647	0.337	0.003	0.043
1979	×-57	0.040	0.027	0.030	0.062	0.204	0.162	1.460	0.961	0.878	1.025	0.182	0.087
	×-58	0.024	0.014	0.008	0.059	0.181	0.190	0.693	0.488	0.362	0.467	0.066	0.041
1980	×-57	0.074	0.058	0.070	0.068	0.080	0.204	0.817	0.733	0.920	0.268	0.194	—
	×-58	0.028	0.019	0.022	0.026	0.069	0.216	0.547	0.555	0.597	0.312	0.223	0.110
1981	×-57	—	—	—	—	—	—	—	—	—	—	—	—
	×-58	0.061	0.037	0.025	0.033	0.091	0.422	0.211	0.140	0.252	0.161	0.234	0.098
1982	×-57	—	—	—	—	—	—	—	—	—	—	—	—
	×-58	0.055	0.032	0.027	0.051	0.089	0.133	0.622	0.476	0.445	0.212	0.134	0.085
1983	×-57	—	—	—	—	—	—	—	—	—	—	—	—
	×-58	0.059	0.040	0.037	0.026	0.012	0.261	0.329	0.504	0.410	0.419	0.226	0.090
1984	×-57	—	—	—	—	—	—	—	—	—	—	—	—
	×-58	0.019	0.015	0.012	0.047	0.094	0.358	0.313	0.646	0.389	0.366	0.107	0.075
Ave.	×-57	0.038	0.018	0.023	0.036	0.132	0.302	0.584	0.776	0.623	0.349	0.202	0.175
	×-58	0.037	0.022	0.019	0.029	0.095	0.277	0.394	0.508	0.444	0.300	0.153	0.066

Table 2-2-4 Calculated Runoff at Intake Point

(Unit : MCM/sq.km)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1972	—	—	—	—	—	—	—	—	—	0.180	0.253	0.097	—
1973	0.035	0.0027	—	0.081	0.189	0.445	1.490	1.120	0.599	0.769	0.699	0.118	—
1974	0.021	0.010	0.010	0.035	0.334	0.866	0.135	3.272	0.753	1.239	0.972	0.162	7.809
1975	0.307	0.030	10.035	0.183	0.353	2.589	0.172	1.520	0.523	1.382	0.594	0.099	7.787
1976	0.054	0.035	0.027	0.024	1.012	10.909	1.501	0.939	2.616	0.172	0.375	0.118	7.782
1977	0.037	0.032	0.027	0.018	0.199	0.121	—	—	—	0.715	0.683	0.126	—
1978	0.072	0.064	0.081	0.086	0.172	0.621	1.590	3.240	2.432	0.550	0.315	0.081	9.304
1979	0.108	0.072	0.081	0.167	0.550	0.437	3.942	2.594	2.370	2.767	0.491	0.234	13.813
1980	0.199	0.156	0.189	0.183	0.216	0.550	2.205	1.979	2.484	0.723	0.523	—	—
1981	0.164	0.099	0.067	0.089	0.256	1.621	0.751	0.458	0.920	0.434	0.631	0.264	5.754
1982	0.148	0.086	0.072	0.137	0.248	0.429	2.445	1.843	1.715	0.279	0.433	0.231	8.063
1983	0.159	0.108	0.099	0.070	0.032	0.957	1.237	1.959	1.571	1.608	0.812	0.252	8.864
1984	0.051	0.040	0.032	0.117	0.253	0.502	1.171	2.544	1.485	1.390	0.322	0.202	8.109

Specific Runoff at Intake Point = Specific Runoff at X-57 x 2.7 (from 1972 to 1980)

= (Specific Runoff at X-58 x 1.527 - 0.044) x 2.7 (from 1981 to 1984)

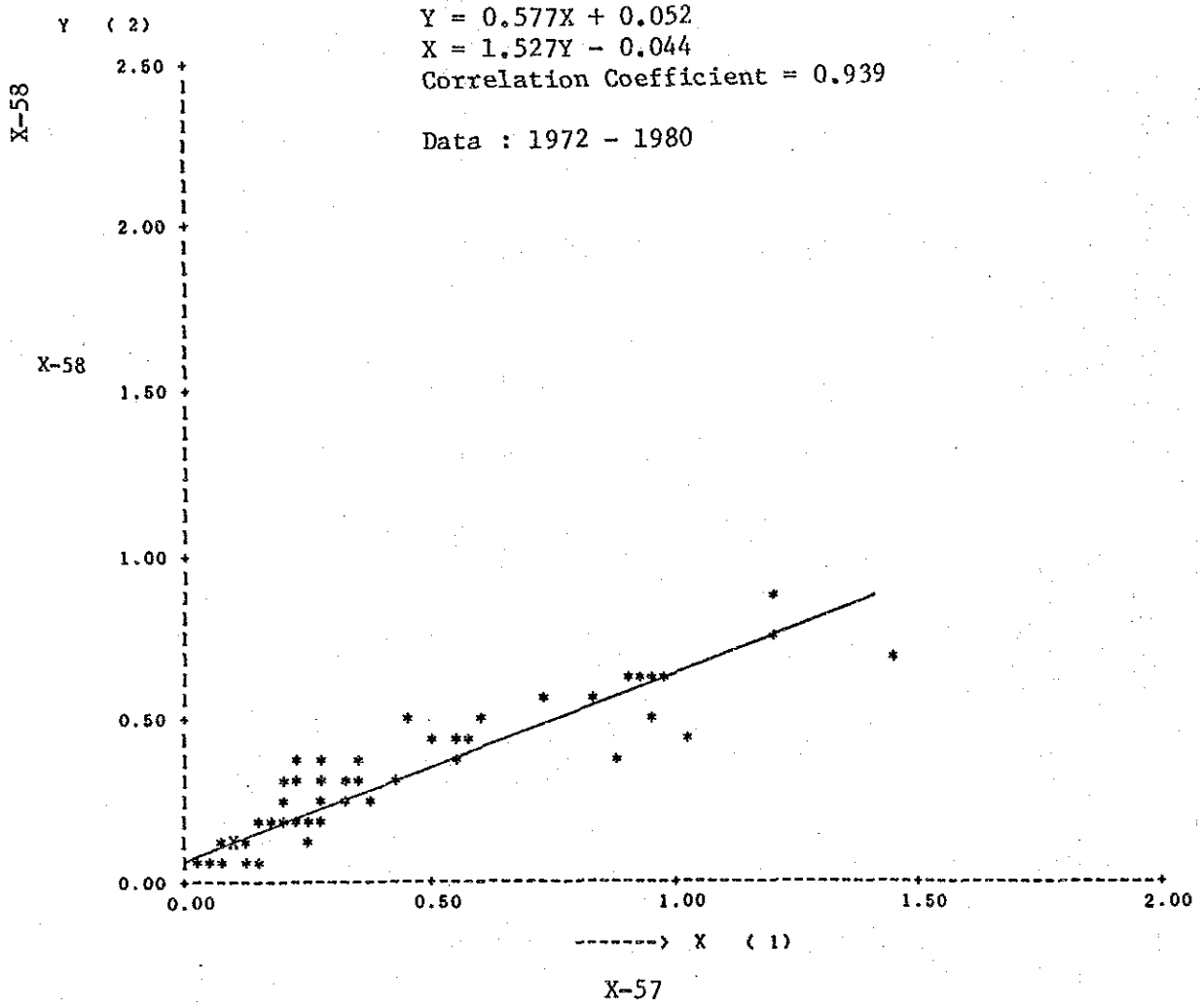


FIGURE 2-2-1
CORRELATION IN RAINFALL
X-57 - X-58

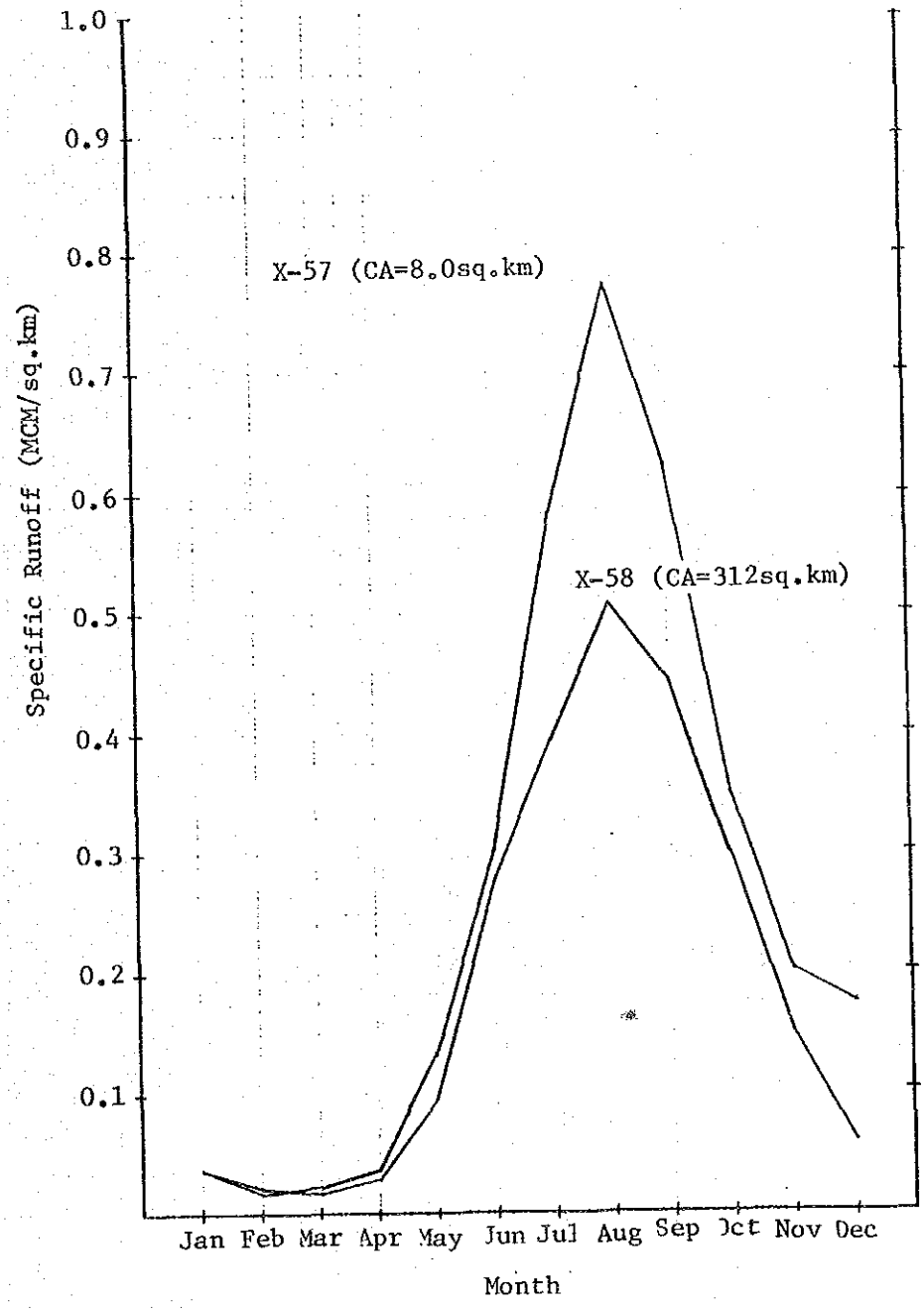


FIGURE 2 - 2 - 2
MONTHLY AVERAGE FLOW

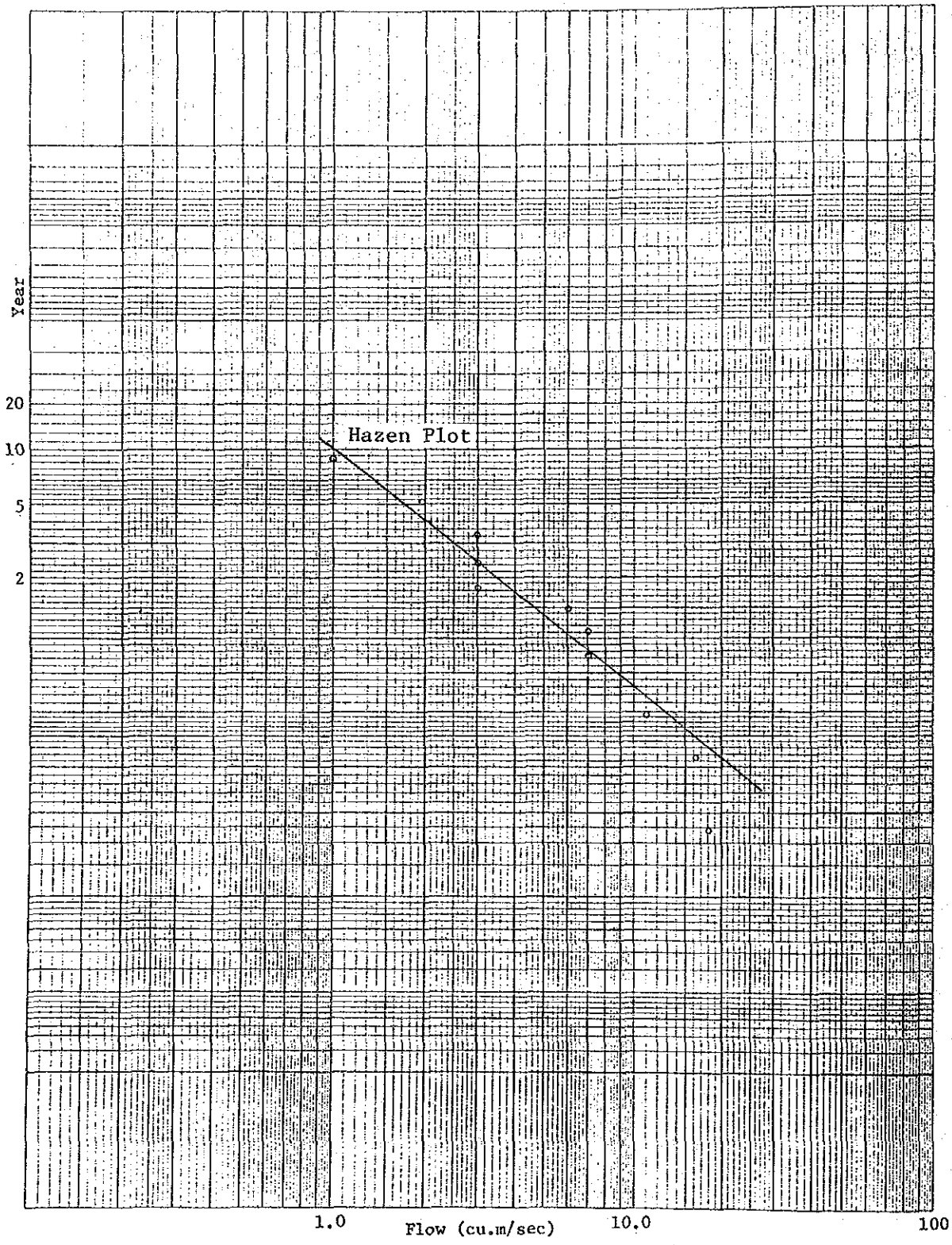


FIGURE 2-2-3
LOGARITHMIC NORMAL
DISTRIBUTION

Table 2-2-5 Monthly Flow of the Bang I River by Specific Runoff

********** NON-EXCEEDANCE PROBABILITY BY IWAI METHOD **********

ORDER	YEAR	X	LOG-X	Y=X+B	LOG-Y	(LOG-Y)**2	TOMAS(%)	HAZEN(%)	X**2
1	1973	0.00	-2.56864	0.014	-1.84507	3.40429	92.86	96.15	0.000
2	1974	0.01	-2.00000	0.022	-1.66582	2.77494	85.71	88.46	0.000
3	1977	0.02	-1.74473	0.030	-1.52891	2.33755	78.57	80.77	0.000
4	1976	0.03	-1.56864	0.039	-1.41356	1.99816	71.43	73.08	0.001
5	1975	0.03	-1.52288	0.042	-1.38105	1.90729	64.29	65.38	0.001
6	1984	0.03	-1.49485	0.044	-1.36065	1.85136	57.14	57.69	0.001
7	1978	0.06	-1.19382	0.076	-1.12156	1.25789	50.00	50.00	0.004
8	1981	0.07	-1.17393	0.079	-1.10465	1.22026	42.86	42.31	0.004
9	1979	0.07	-1.14267	0.084	-1.07786	1.16179	35.71	34.62	0.005
10	1982	0.07	-1.14267	0.084	-1.07786	1.16179	35.71	34.62	0.005
11	1983	0.11	-0.96658	0.120	-0.92232	0.85067	21.43	19.23	0.012
12	1980	0.16	-0.80688	0.168	-0.77576	0.60180	14.29	11.54	0.024
13	1972	0.18	-0.74473	0.192	-0.71763	0.51500	7.14	3.85	0.032
TOTAL		0.84	-18.07099		-15.99270	21.04280			0.090
(1/N)		0.06	-1.39008		-1.23021	1.61868			0.007

KHLONG BANG I(SPECIFIC RUNOFF)

******* COMPUTATION OF B **********

ORDER	XI	XS	XI*XS	XI+XS	XI*XS-X0**2	2X0-(XI+XS)	BI
1	0.003	0.180	0.000	0.183	-0.001	-0.101	0.012
TOTAL							0.012

B= 0.012

******* MONTHLY FLOW(MIN) LIST OF RETURN PERIOD**********

RETURN PERIOD YEAR	(MCM)	RETURN PERIOD YEAR	(MCM)
2	0.047	5	0.019
10	0.010	15	0.007
20	0.005		

- Total and dead storage capacities are 220,000 cu.m and 10,000 cu.m respectively as shown in Figure 2-2-4.
- Evaporation is considered to be 70% of the Class A pan. The average evaporation area is 32,000 sq.m.
- Seepage loss is considered referring the RID's standard.

Clay	1.0 - 1.5 mm/d
Silty clay	1.5 - 2.0
Sand	2.0 - 3.0

The mining pit mainly consists of clay. The average seepage area is 32,000 sq.m.

- No inflow is considered during the period of four months from December to March according to the rainfall pattern and its runoff coefficient in Phang Nga (See Table 2-2-6).
- Sufficient inflow is considered during the remaining months of the year.

Table 2-2-6 Rainfall Pattern and Runoff Coefficient

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Rainfall (mm)	26	31	91	216	522	610	568	611	718	484	215	36
1/10 Rainfall (mm)	0	0	2	80	------	sufficient	------				65	5
Runoff Coeff. (%)	0	0	0	8	------	sufficient	------				6	0

Source : RID's estimation

Therefore, four months from December to March is considered to be the drawdown period.

(b) Minimum Availability

Accordingly, the minimum available amount for water supply is:

$$Q = (922,000-70,000) - 32,000 \times 0.7 \times (0.139+0.164+0.155+0.198) - 32,000 \times 0.001 \times 120$$
$$= 191,600 \text{ cu.m in four months}$$
$$= 1,600 \text{ cu.m/d}$$

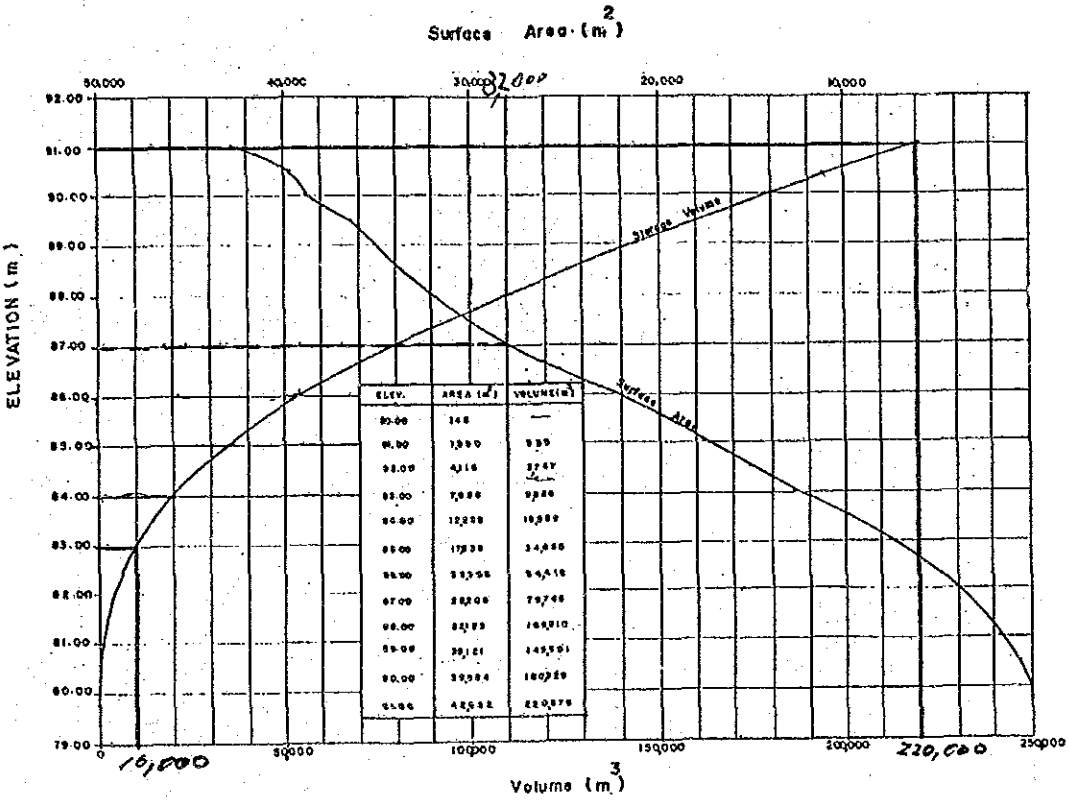


FIGURE 2 - 2 - 4
AREA-CAPACITY CURVE FOR
TAKUA PA MINING PIT

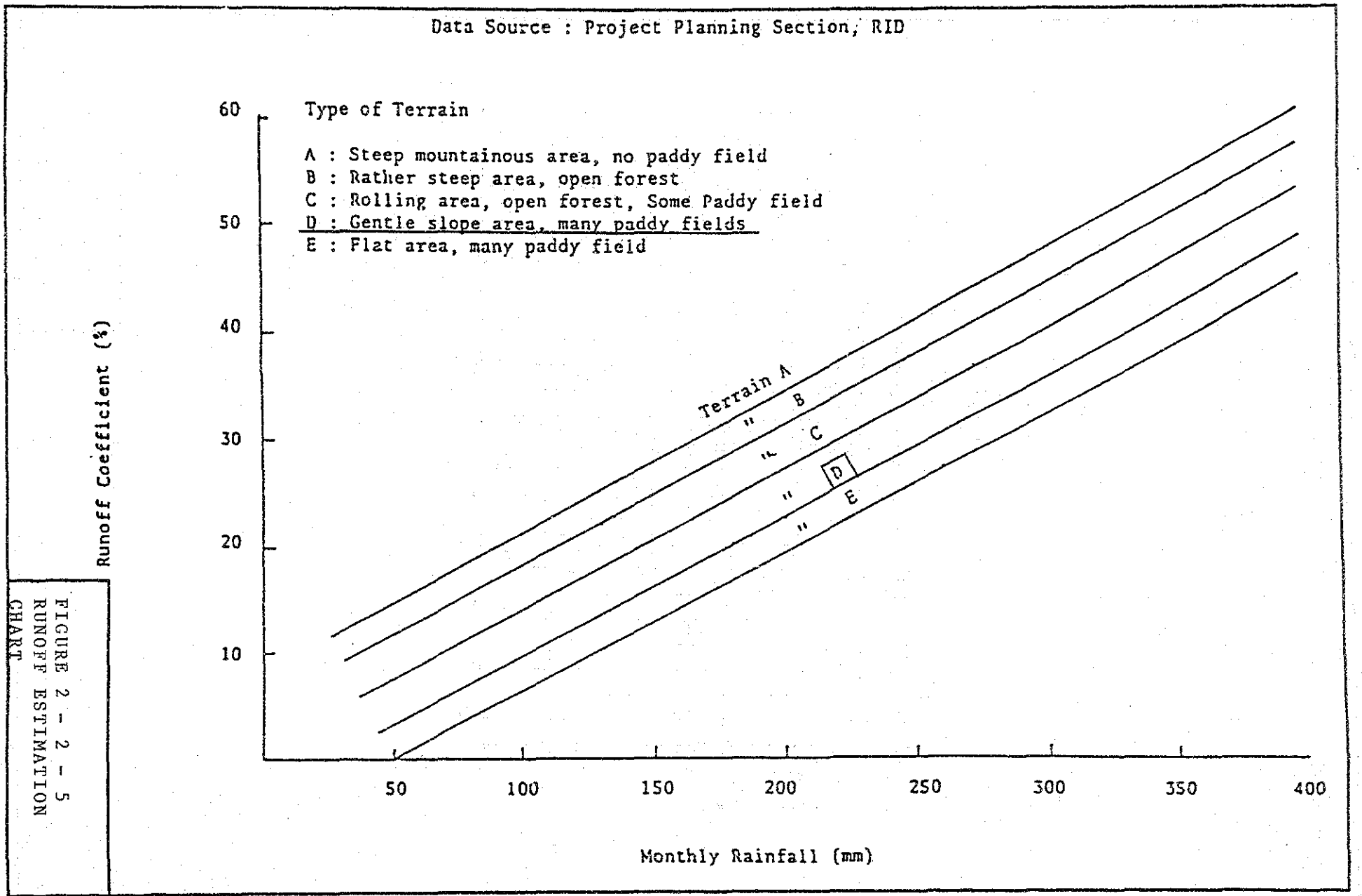


FIGURE 2 - 2 - 5
RUNOFF ESTIMATION CHART

(3) Total Minimum Availability

The total minimum available flow of the existing water sources is:

Khlong Bang I	300 cu.m/d
Mining Pit	1,600
Total	1,900 cu.m/d

2.3 Developability of Alternative Water Sources

2.3.1 General

The following alternative water sources are considered in order to meet the future water demand and secure stable water supply:

- Raising of the existing weir on the Khlong Bang I
- Enlargement of the existing mining pit and rehabilitation of inlet and outlet channels
- Direct intake from the Takua Pa River
- New mining pit development
- Ground water development

2.3.2 Surface Water

(1) Raising of the Existing Weir

The existing weir is constructed on the fresh granite rock, but too small to store the sufficient amount of water to meet the demand in the dry season.

The weir should be heightened 3 m or so to store some more water.

For construction, the access to the weir may be a crucial problem.

(2) Expansion of the Existing Mining Pit and Rehabilitation of Inlet and Outlet Channels

Some of the runoff in the flood plain with a catchment area of 11.7 sq.km flows into the pit through the small inlet.

The inflow is so unexpected and unreliable that it causes flood in the wet season and shortage in the dry season.

The inlet and outlet channels should be rehabilitated in order to control amounts of inflow and outflow. The pit has so small capacity that it cannot meet the future water demand especially in the dry season. The pit should be expanded by digging or heightening the embankment.

(3) New Mining Pit Development

Several mining pits are located on the flood plain. The pit nearest to the waterworks can be used for water supply.

(4) Direct Intake from the Takua Pa River

The Takua Pa River has affluent flows all year round. A pump station can be constructed on either side of the river to take surface water directly. However, the flood plain is developed about 200 m both side of the river. it will be difficult to find a suitable site for a pump station in order not to be damaged by flood except the further upstream reach.

2.3.3 Ground Water Development

According to the survey conducted by DMR, ground water potentiality on the aquifers in the area is described below:

(1) Alluvial Aquifer

Alluvial aquifer consisting of unconsolidated clay, sand and gravel of alluvial deposits can be found on the right bank of the Takua Pa River. The aquifer is generally not over 200 ft. The yield are about 20-100 gpm.

(2) Colluvial Aquifer

Colluvial aquifer consisting of poorly sorted valley filled deposits, cliff debris and granite wash occurred on the left bank of the Takua Pa River. The aquifer thickness is generally not over 300 ft. The yields are less than 50 gpm.

3. EXISTING WATER SUPPLY SYSTEM

3.1 Existing Water Supply System

3.1.1 General

The waterworks for the Municipality of Takua Pa was founded in 1961. The raw water was taken from the Bang Ee Waterfall, about 4 km away from the waterworks, and distributed after chlorination without further treatment. In 1969, the new water treatment plant with a capacity of 40 cu.m/h was constructed, and coincidentally, the abandoned tin-mining-pit was added to the water source. The service area was expanded to Ban Yan Yao during this time. The waterworks was placed under the control of the PWA with direct jurisdiction falling under the PWA Regional Office 4 in Surat Thani.

3.1.2 Treatment

The raw water transmitted by pumping through a 150 mm pipe from the abandoned tin-mining-pit is fed into the 40 cu.m/h capacity treatment plant. The treatment process consists of chemical coagulation, sedimentation, rapid sand filtration and chlorination. Clear water is stored in a 500 cu.m clear water reservoir. Raw water transmitted by gravity through the 250 mm and 200 mm pipes from the Bang Ee Waterfall flows into this clear water reservoir directly without any treatment. The mixed clear water is transmitted to the 120 cu.m elevated water tank by the clear water pumps and distributed by gravity to the service area to prevent the old asbestos cement pipes from bursting. Backwash water for rapid sand filters is obtained from a pipeline connected to the elevated water tank.

The outline of facilities in the treatment plant is summarized in Table 3-1-1. Figures 3-1-1 and 3-1-2 provide the schematic representation and layout of the treatment plant, respectively.

3.1.3 Distribution System

(1) Description of Existing Distribution System

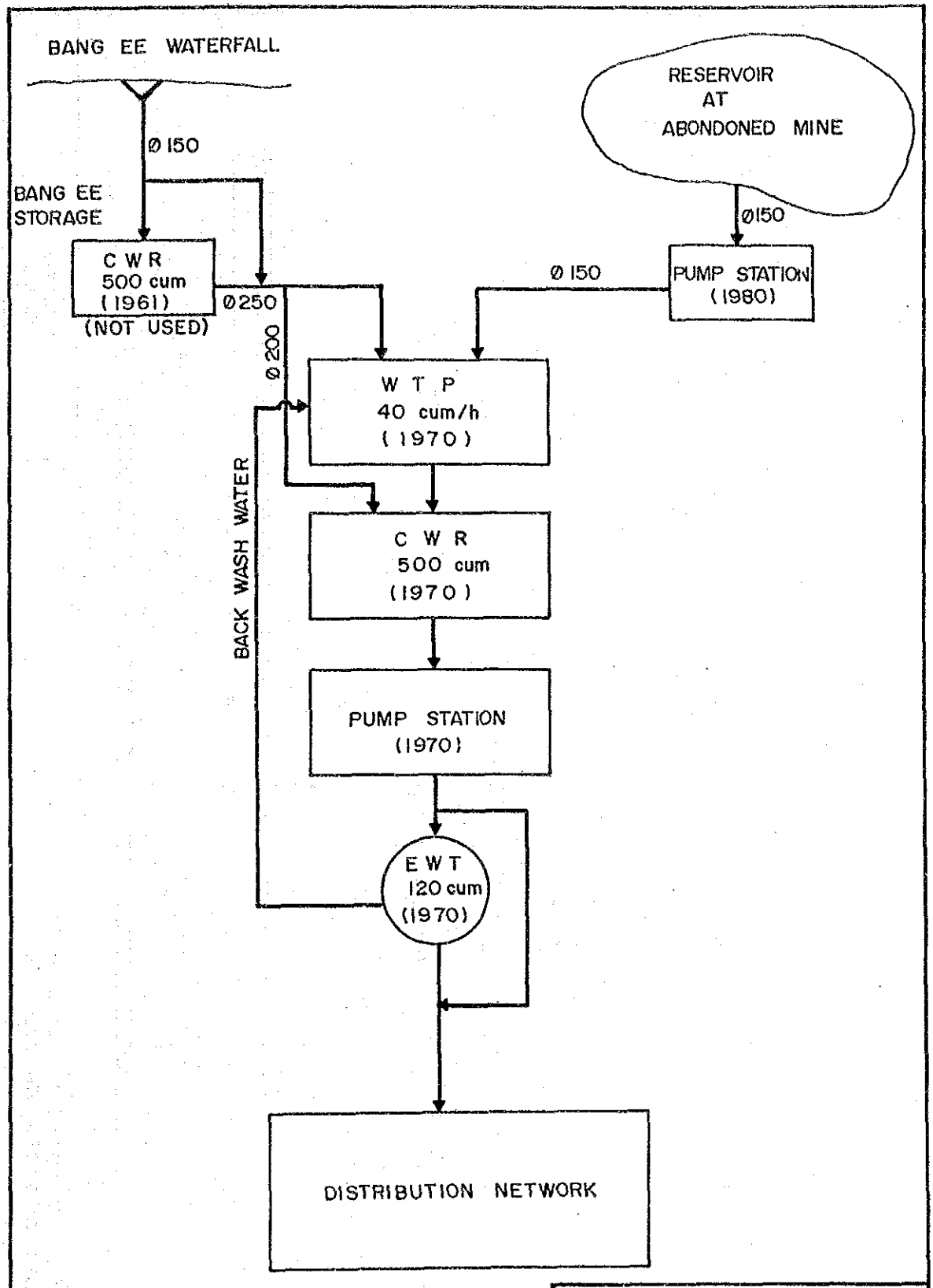
The distribution system of the Takua Pa Waterworks covers the area as shown in Figure 3-1-3. The distribution pipeline used to form a loop; however, the loop was cut off at the south end as the connection pipe was abandoned due to the leakage and bursting of the line. The service area consists of two major areas in the north and south, with connection pipe in between.

The schematic plan of the network is shown in Figure 3-1-4.

Breakdown of the pipeline is tabulated in Table 3-1-2.

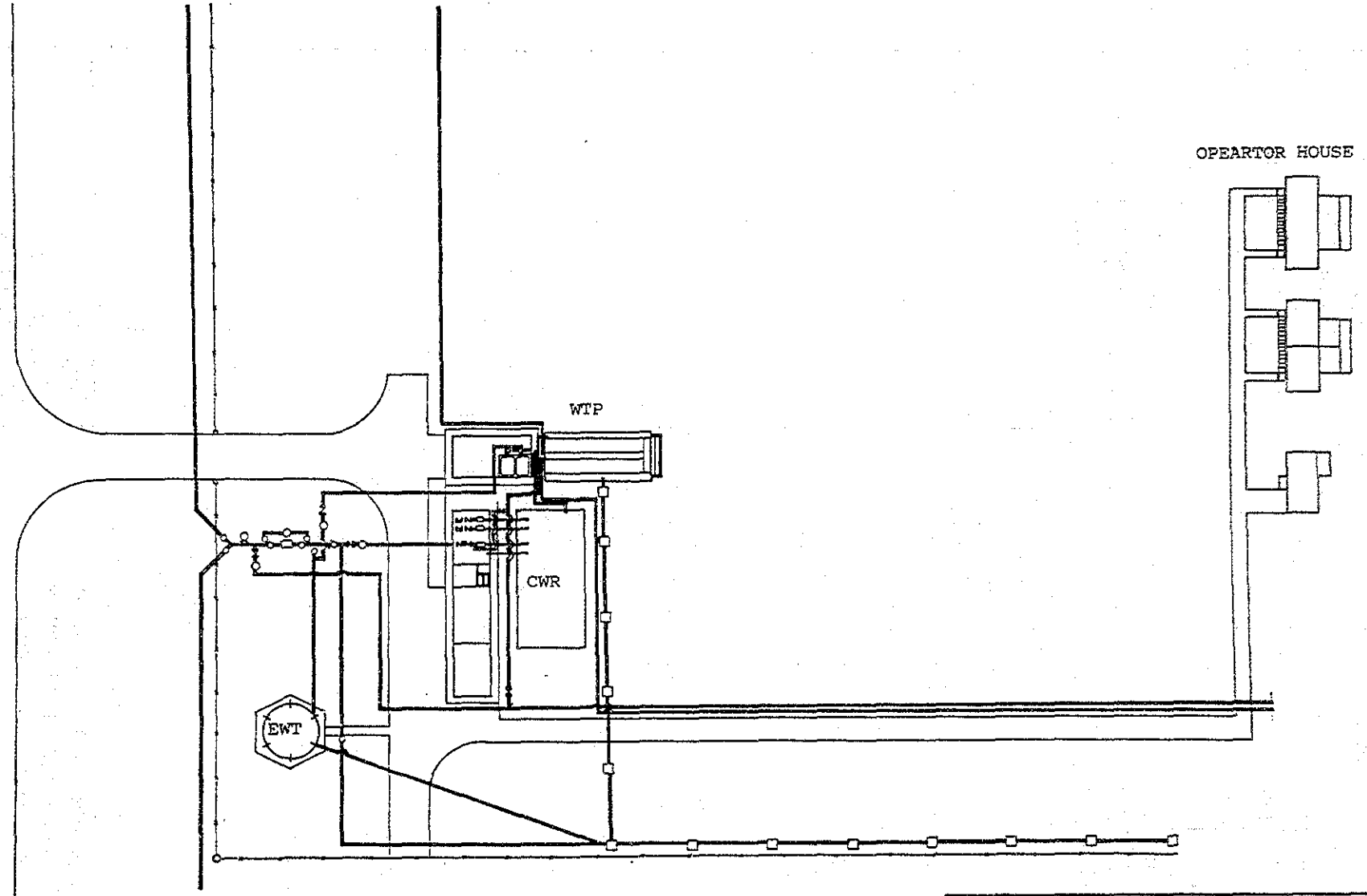
Table 3-1-1 Outline of Water Treatment Facilities

Water Source	Tin-mining-pit Reservoir
Treatment Capacity	40 cu.m
Treatment Facilities	
Raw Water Pump	30 cu.m/h x 30 m x 75 kw x 1 unit engine-driven
	Not identified engine-driven
Rapid Mixing Basin	
No. of Units	1 unit
Dimensions	0.50 m x 12.80 m
Sedimentation Basin	
No. of Units	1 unit
Dimensions	4.8 m x 11.50 m x 4.40 m
Sedimentation Time	6.1 hours
Rapid Sand Filter	
No. of Units	2 units
Dimensions	2.00 m x 3.00 m
Filtration Rate	80.0 m/d
Clear Water Reservoir	
No. of Units	1 unit
Capacity	500 cu.m
Detention Time	12.5 hrs
Water Elevated Tank	
No. of Units	1 unit
Dimensions	120 cu.m
Detention Time	3.0 hrs.
Clear Water Pump	120 cu.m/h x 30 m x kw x 1 unit motor-driven
	100 cu.m/h x 35 m x 18.5 kw x 1 unit motor-driven
	Not identified engine-driven



WTP : WATER TREATMENT PLANT
CWR : CLEAR WATER RESERVOIR
EWT : ELEVATED WATER TANK

FIGURE 3-1-1
TAKUA PA
EXISTING WATER TREATMENT SYSTEM



WTP : WATER TREATMENT PLANT (40 cu m/h)
CWR : CLEAR WATER RESERVOIR (500 cu m)
EWT : ELEVATED WATER TANK (120 cu m)

FIGURE 3-1-2
TAKUA PA
WATER TREATMENT PLANT

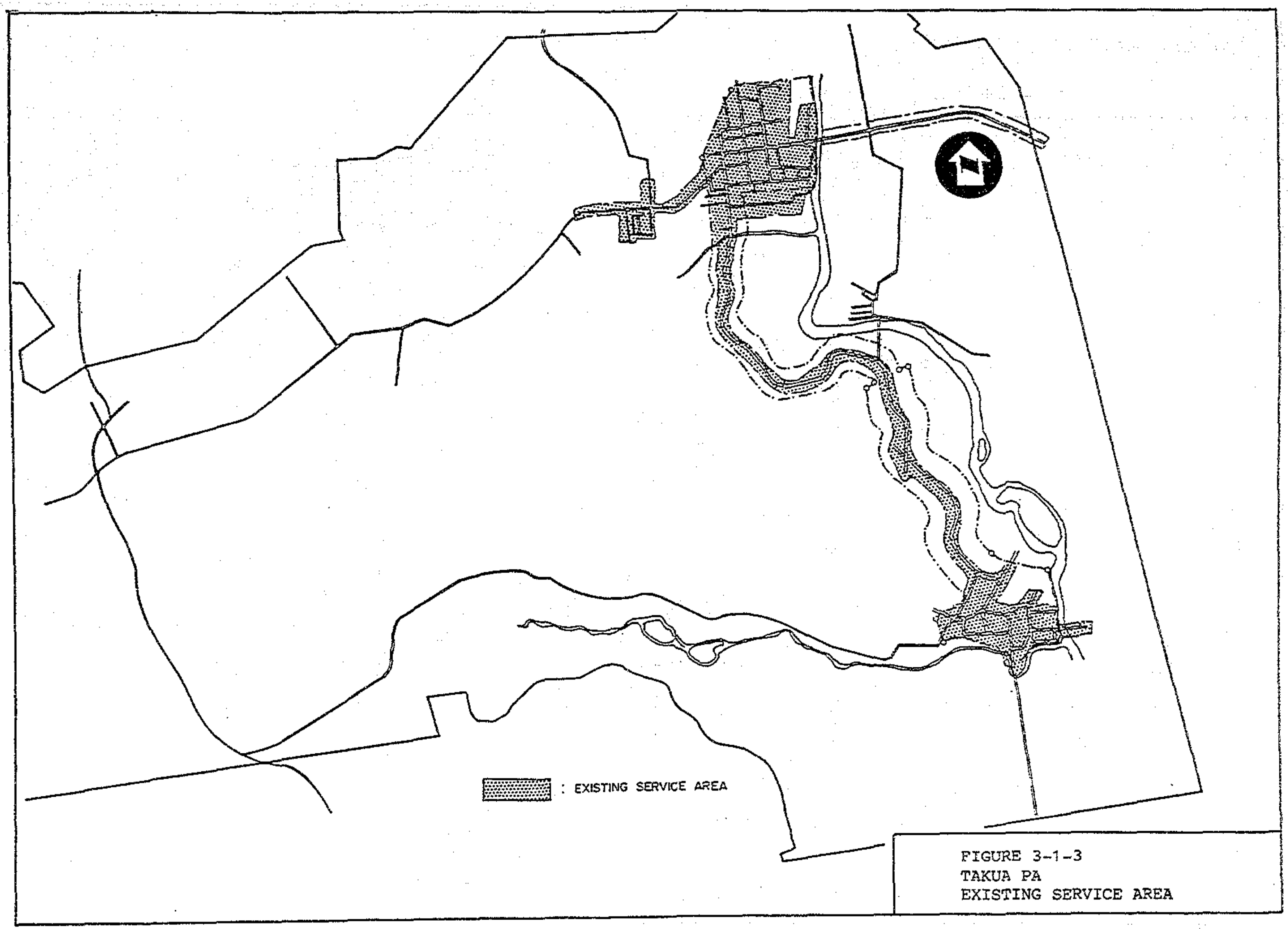


FIGURE 3-1-3
TAKUA PA
EXISTING SERVICE AREA

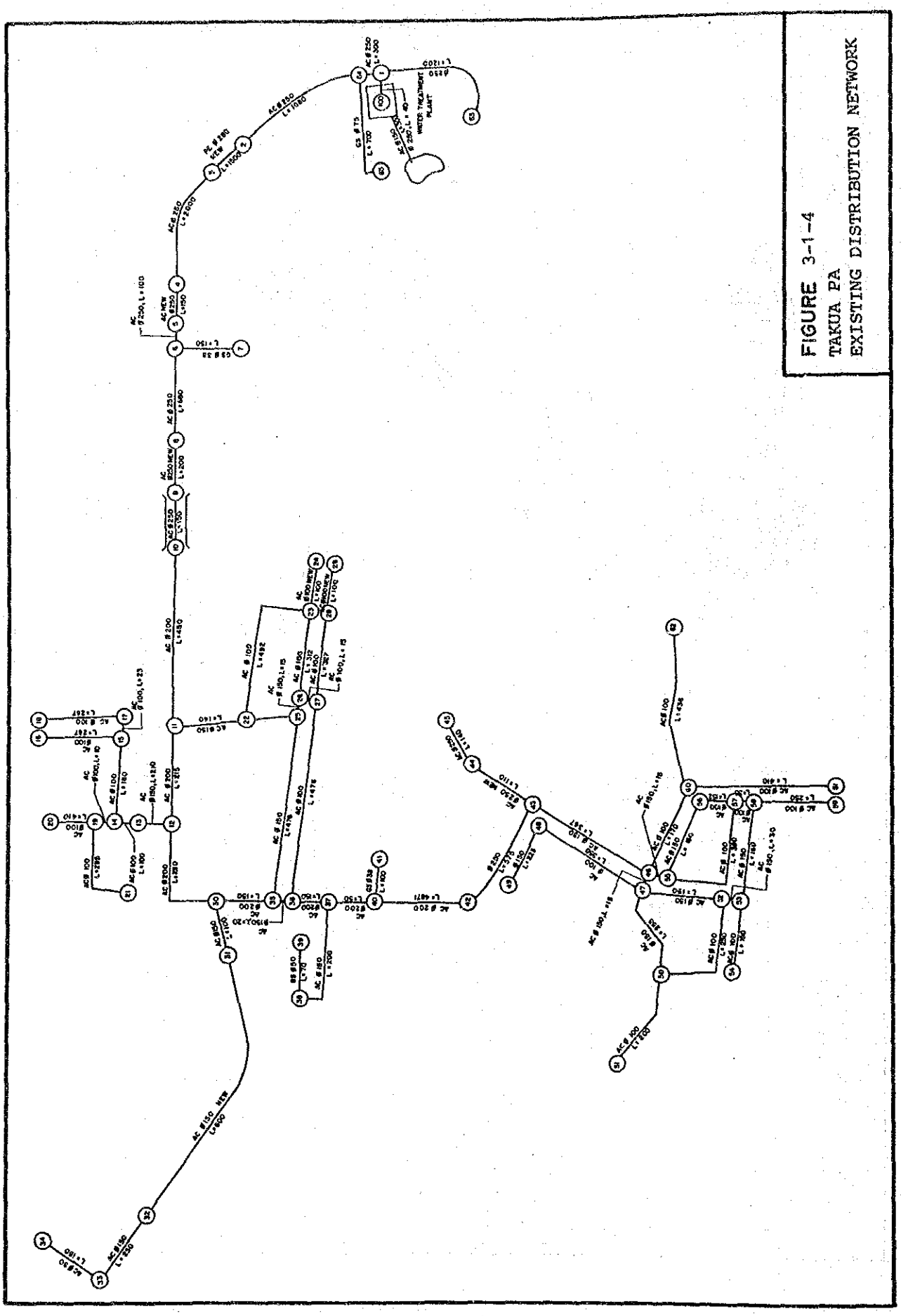


FIGURE 3-1-4
TAKUA PA
EXISTING DISTRIBUTION NETWORK

Table 3-1-2 Distribution Pipe

Dia. (mm)	Length (m)	Material
250	6,230	AC
200	6,180	AC
150	3,400	AC
100	5,510	AC
75	700	AC
Total	22,020	

Main existing distribution pipelines were installed in 1961 and 1969. Although replacement of such old pipes, especially in the old municipality has been implemented since 1987. There is still high percentage of unaccounted-for water due to deterioration of pipes. The year of installation for each pipe including previous replacement of pipes is shown in Figure 3-1-4.

Pipes have experienced several bursting at various location because of aging and high pressure. Replacement or repair have been made every time bursting occurred. The waterworks is now controlling valve openings to reduce the pressure and leakage.

Pumps are turned on and off manually by the operators observing the pressure at the delivery side of pumps.

The number of connections to the waterworks are counted as follows:

Table 3-1-3 Number of Connections

Year	No. of Conn.
1980	791
1981	812
1982	851
1983	911
1984	965
1985	987
1986	1,063
1987	1,077

Although all of the house connections are metered, some meters are found to be defective or to have measuring defects.

Another problem encountered is that most of the meters can not detect the small amount of flow which may be less than 5 l/hr. Therefore, resourceful consumers can collect water in pots or jars without being registered in their respective water meters by choking their faucets to less than a certain level. This measure used to be taken even in Japan before more sensitive water meters were introduced.

Shortcomings of meters as described above will be reflected in the consideration of unaccounted-for water.

(2) Distribution Network Analysis

(a) Method of Analysis

A computer model was used to analyze the existing distribution system and to prepare an improvement plan as required. The model uses a standard Hardy-Cross network analysis technique where head losses are calculated using the Hazen-Williams formula. An interactive process is used in the model to balance the hydraulic grade line at each pipe junction in the network, with adjustments made in the hydraulic grade line to satisfy the continuity equation at each junction.

(b) Hazen-Williams Discharge Coefficient ("C" Value)

Estimates of the Hazen-Williams discharge coefficients for existing pipelines are made based on the age of pipes which was obtained from the Takua Pa Waterworks during the field survey.

Although the C value for asbestos cement pipes usually remains at 110 or close to its original level, newly installed pipes in the past 2 to 3 years use a C value of 110, and a C value of 100 was adopted for other remaining pipes.

(c) Demand Distribution

Based on the water sales records, a demand distribution at each node was prepared. It was assumed for the purpose of initial analysis that the existing treatment plant can supply treated water enough to meet the daily and hourly maximum demands.

(d) Evaluation of Existing Distribution System

Using the data described above, a simulation was made to the existing system by the computer model described earlier. This simulation shows that a pressure of about 25 m in water column is required at the existing treatment plant. The results indicating pressure contour lines are shown in Figure 3-1-5. The computer output of distribution network analysis are presented in the separate volume.

The results show that there are adequate pressure throughout the distribution system, and it indicates similar pressure conditions to the actual field pressure measurements described in Appendix A-3-1.

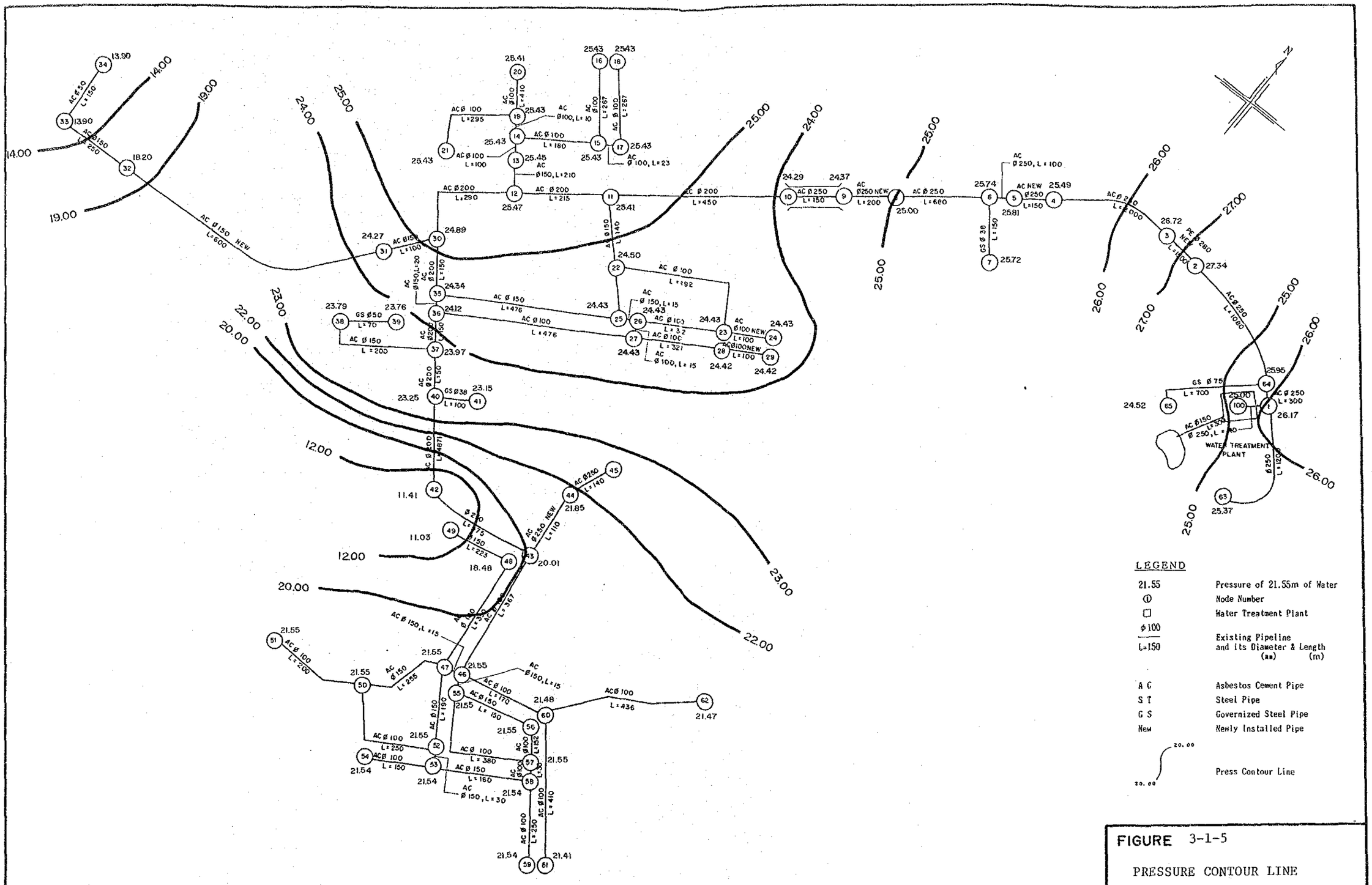


FIGURE 3-1-5

PRESSURE CONTOUR LINE

3.2 Operation and Maintenance

The status of operation during the past two years from October 1986 to July 1988 is shown in Table 3-2-1. The operational condition is remarkably stable at the PWA Takua Pa Waterworks. The average daily water production is 65.4 cu.m/h. however, considering that the surface water from the waterfall is not treated, the production of treated water is 29.7 cu.m/h on the average, and 46.0 cu.m/h on the maximum which exceeds the nominal treatment capacity by 15.0%. The average treatment loss is 4.3% at the reasonable level.

The plant is supplied with water from two sources, namely, from the waterfall by gravity and from the tin-mining-pit reservoir by pumping. The ratio of the intake amount from the waterfall to the total is 55.3% on an average, 72.7% at the maximum in July 1988 and 36.7% at the minimum in April 1988. Endeavors are always made to the waterfalls for energy cost saving.

Surface water from the waterfall is directly fed into the clear water reservoir and blended with treated water taken from the tin-mining reservoir. Since the water quality analysis has been done on raw water from the waterfalls only in the past three years, no data is available on the quality of tin-mining reservoir water. According to the results of the water quality analysis conducted for both water sampled on September 3, 1988, there is no significant difference in water quality. However, it should be noted that more than half of the users have complained of color, smell and turbidity in tap water based on the questionnaire survey as shown in Appendix A-3-2.

The rapid mixing is conducted with the turbulant flow in the long channel installed above the sedimentation basins, but no flocculation basin for slow mixing is provided. The overflow weir in the sedimentation basins is not long enough and always submerged. The mud balls are found in the rapid sand filters.

Table 3-2-1 Operational Record (Oct. 1986 - Sep. 1987)

Item	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Ave
A) Raw Water	38900	43700	46250	26112	24960	42408	41040	37316	31540	27664	25736	18048	403674	33640
Ground Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface Water	38900	43700	46250	26112	24960	42408	41040	37316	31540	27664	25736	18048	403674	33640
*Variation	1.156	1.299	1.375	0.776	0.742	1.261	1.220	1.109	0.938	0.822	0.765	0.537	-	-
B) Raw Water Used	1000	1000	1000	350	420	560	680	630	890	760	770	850	8910	743
Sedimentation Basin	0	0	0	20	30	30	25	20	30	25	20	10	210	18
Drainage	1000	1000	1000	300	350	500	600	550	800	700	700	800	8300	692
Waste	0	0	0	20	20	0	25	30	30	10	20	10	165	14
Other	0	0	0	10	20	30	30	30	30	25	30	30	235	20
*(B)/(A)	0.026	0.023	0.022	0.013	0.017	0.013	0.017	0.017	0.028	0.027	0.030	0.047	0.022	-
C) Treated Water	37900	42700	45250	46362	43963	49530	47020	56900	53500	49700	47230	43450	563505	46959
*Variation	0.807	0.909	0.964	0.987	0.936	1.055	1.001	1.212	1.139	1.058	1.006	0.925	-	-
D) Treated Water Used	6300	6300	6300	3510	4060	4315	4520	4315	4530	4580	4230	4000	55210	4747
Filter Washing	3000	3000	3000	1500	2000	2000	2000	2000	2000	2000	2000	2000	26500	2203
Chemical Mixing	300	300	300	300	300	300	300	300	300	300	250	200	3450	288
Engine	200	200	200	10	10	10	10	10	10	10	10	10	690	58
Sedimentation Basin	300	300	300	0	0	5	10	5	20	20	20	20	1000	83
Clear Water Reservoir	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elevated Water Tank	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Used in Area	2500	2500	2500	1550	1600	1800	2000	1800	2000	2000	1750	1570	23570	1964
Used in Houses	0	0	0	150	150	200	200	200	200	250	200	200	0	140
*(D)/(C)	0.166	0.148	0.139	0.076	0.092	0.087	0.096	0.076	0.085	0.092	0.090	0.092	0.098	-
E) Distributed Water	34870	39646	42206	44782	41903	47480	44992	54893	51377	47687	45176	41409	536421	44702
*Variation	0.780	0.887	0.944	1.002	0.937	1.062	1.006	1.228	1.149	1.067	1.011	0.926	-	-
F) Sold Water	16987	19795	19654	23756	20879	20396	25178	23090	19237	19520	21384	17539	247415	20618
Connection Meters	16987	19795	19654	23756	20879	20396	25178	23090	19237	19520	21384	17539	247415	20618
Public Meters	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lump Sum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*Variation	0.824	0.960	0.953	1.152	1.013	0.989	1.221	1.120	0.933	0.947	1.037	0.851	-	-
G) Unaccounted-for Water	17883	19851	22552	21026	21024	27084	19814	31803	32140	28167	23792	23870	289006	24084
*(G)/(E)	0.513	0.501	0.534	0.470	0.502	0.570	0.440	0.579	0.626	0.591	0.527	0.576	0.539	-
H) No. of Connections	NA	1063	1064	1065	1064	1067	1068	1068	1070	1073	1076	1077	-	-
I) Per Conn. Consumption	NA	40.17	42.53	43.53	41.32	46.42	44.03	53.28	50.00	46.32	43.89	40.34	491.83	44.71
*Variation	NA	0.898	0.951	0.974	0.924	1.038	1.118	1.192	1.118	1.036	0.982	0.902	-	-
J) Chemical														
Alum	346	450	682	523	500	715	480	620	600	310	600	600	6426	536
Bleaching Powder	155	150	155	217	196	217	227	291	400	310	174	0	2492	208
Chlorine Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K) Chemical Dosage Rate														
Alum	9.13	10.54	15.07	11.28	11.37	14.44	10.21	10.90	11.21	6.24	12.70	13.81	-	11.40
Bleaching Powder	4.09	3.51	3.43	4.68	4.46	4.38	4.83	5.11	7.48	6.24	3.68	0.00	-	4.42
Chlorine Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00

Note: The unit, if not specified. is a cu m and the marked items (*) are dimmensionless.

Table 3-2-1 Operational Record (Oct. 1987 - Jul. 1988)

Item	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Ave
A) Raw Water	48490	49220	45686	46850	46470	52390	52300	47600	46846	51160	0	0	487012	48701
Reservoir	23194	22816	16032	16338	21612	29060	33091	22468	16654	13976	0	0	215241	21524
Waterfall	25296	26404	29654	30512	24858	23330	19209	25132	30192	37184	0	0	271771	22648
*Variation	0.996	1.011	0.938	0.962	0.954	1.076	1.074	0.977	0.962	1.050	0.000	0.000	-	-
B) Raw Water Used	860	670	690	700	700	700	1000	900	700	700	0	0	7620	762
Sedimentation Basin	10	20	30	50	50	50	50	50	50	50	0	0	410	41
Drainage	800	600	600	600	600	600	900	800	600	600	0	0	6700	670
Waste	20	20	30	30	30	30	30	30	30	30	0	0	280	28
Other	30	30	30	20	20	20	20	20	20	20	0	0	230	23
*(B)/(A)	0.018	0.014	0.015	0.015	0.015	0.013	0.019	0.019	0.015	0.014			0.016	-
C) Treated Water	47630	49550	45000	46150	45950	51600	51400	46700	46150	50460	0	0	480590	48059
*Variation	0.991	1.031	0.936	0.960	0.956	1.074	1.070	0.972	0.960	1.050	0.000	0.000	-	-
D) Treated Water Used	3930	4000	4100	4130	4160	4510	4520	4420	4400	4370	0	0	39370	4254
Filter Washing	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	0	0	20000	2000
Chemical Mixing	200	200	150	150	150	200	200	200	200	200	0	0	1850	185
Engine	10	10	10	10	10	10	20	20	0	0	0	0	100	10
Sedimentation Basin	20	40	40	50	50	50	50	50	50	20	0	0	420	42
Clear Water Reservoir	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elevated Water Tank	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Used in Area	1500	1500	1600	1600	1600	1900	1900	1800	1800	1800	0	0	17000	1700
Used in Houses	200	250	300	320	350	350	350	350	350	350	0	0	0	317
*(D)/(C)	0.083	0.081	0.091	0.089	0.091	0.087	0.088	0.095	0.095	0.087			0.082	-
E) Distributed Water	45619	46521	42964	44108	44816	49533	49333	44618	43996	48469	0	0	459977	45998
*Variation	0.992	1.011	0.934	0.959	0.974	1.077	1.073	0.970	0.956	1.054	0.000	0.000	-	-
F) Sold Water	20533	19879	21499	20760	21319	22266	24390	24358	20071	21174	0	0	216249	21625
Connection Meters	20533	19879	21499	20760	21319	22266	24390	24358	20071	21174	0	0	216249	21625
Public Meters	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lump Sum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*Variation	0.950	0.919	0.994	0.960	0.986	1.030	1.128	1.126	0.928	0.979	0.000	0.000	-	-
G) Unaccounted-for Water	25086	26642	21465	23348	23497	27267	24943	20260	23925	27295	0	0	243728	24373
*(G)/(E)	0.550	0.573	0.500	0.529	0.524	0.550	0.506	0.454	0.544	0.563			0.530	-
H) No. of Conn. (nos.)	1080	1085	1087	1089	1092	1094	1093	1104	1103	1105	0	0	-	-
I) Per Conn. Consumption	44.10	45.67	41.40	42.38	42.08	47.17	47.03	42.30	41.84	45.67	0.00	0.00	439.62	44
*Variation	1.003	1.039	0.942	0.964	0.957	1.073	0.952	0.962	0.952	1.039	0.000	0.000	-	-
J) Chemical (kg)														
Alum	600	600	600	600	600	600	600	720	500	500	0	0	5920	592
Bleaching Powder	120	120	0	160	160	120	200	200	160	200	0	0	1440	144
Chlorine Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	150	0	0	0	0	150	15
K) Dosage Rate (mg/l)														
Alum	12.60	12.11	13.33	13.00	13.06	11.63	11.67	15.42	10.83	9.91			-	12.32
Bleaching Powder	2.52	2.42	0.00	3.47	3.48	2.33	3.89	4.28	3.47	3.96			-	3.00
Chlorine Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			-	0.00
Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.21	0.00	0.00			-	0.31

Note: The unit, if not specified, is a cu m and the marked items (*) are dimmensionless.
The total and average are for ten months.

3.3 Existing Improvement/Expansion Plan

3.3.1 Improvement/Expansion Plan for Treatment Plant

As of now, the concrete plan for the improvement/ expansion of the Takua Pa Waterworks has not prepared. However, the general concept explained in the following sub-section will be applied for the improvement work on the existing treatment plant.

3.3.2 General Concept of PWA for Improvement/Expansion of Water Treatment Plant

PWA's general concept for the improvement and expansion of its water treatment plant is based on the recommendations of the UNDP experts, which are well summarized in the article "Improving Water Supply in Thailand" by Messers. Sawasdi Orvichian, Prasert Chuaphanich, and Susumu Kawamura, Journal of AWWA, Management and Operations, June, 1988.

The concept for the improvement and expansion was established to increase the treatment capacity of the plant without the addition of new basins and filters. The modification for improvement consists of three phases as listed below:

Stage 1 - Correct existing deficiencies and implement those modifications needing immediate action.

Stage 2 - Expand plant capacity at the earliest possible time.

Stage 3 - Modernize plants and improve safety.

These stages were separated in accordance with the urgency of the measures to be taken, and the cost-effectiveness of the investment.

At present, PWA is implementing the improvement and modification program for various waterworks applying the technology recommended for Stage 1. The facilities and measures for improvement therefore as recommended in Stage 1 are summarized as stated below:

(1) Coagulation System (Flush Mixing)

Coagulation is the most important process as well as flocculation in the treatment system. As most of the existing plants have no proper coagulation and flocculation systems, sedimentation tanks do not work well, such that a lot of micro floc are carried over to the sand filters.

The proposed improvement is a provision of an in-line static mixer in the raw water main to achieve proper magnitude of mixing coagulant.

(2) Flocculation System

Flocculation is a process which most existing plants are lacking. The recommended flocculation process consisted of round-the-end, and flow-type baffled channels (hydraulic flocculation). Mechanical flocculator is not considered because of local conditions in terms of availability of spare parts and technical manpower to maintain it.

(3) Filtration Process

Filters require a wide range of modification. Existing underdrains, gravel beds, filter beds, wash troughs, backwash system and piping are subject to the consideration for replacement and improvement/modification. To be installed is a new surface wash system. These modifications may lead to the increase of the system's treatment capacity by 100%. Dual media filtration is not considered because of the high cost of anthracite.

(4) Sedimentation Process

Recognized as the most serious problem in operation is sludge removal. However, sludge withdrawal will be made efficiently by manual cleaning. Therefore, no major modification is considered. Baffled walls are recommended to be installed at the inlet and the intermediate point to prevent short circuit of flow. For overflow troughs, installation of additional troughs is recommended to decrease weir load and the carry-over of micro floc.

As the recommendations stated above are the basis of improvement/expansion work, the modification works for the existing water treatment plant shows the similar design.

Stage 2, Expansion of plant capacity will follow the modification works. After modification works have been made, the plant is expected to have a larger treatment capacity (twice the original design rate). Thus, the production amount can be increased to cope with the increased water demand.

Stage 3, Modernization consists of the preparation of the proper instrumentation and safety provisions. This stage is recognized as the final step of modification. Therefore actual implementation will not be made immediately, considering the urgency of steps 1 and 2 at various waterworks and the budgetary constraints to implement the improvement/expansion program.

3.4 Existing Constraints

During an intensive field survey, the following constraints on the existing water supply system are reported:

(1) Water Source

- Insufficient flows in dry season
- The mining pit is located on the flooding plain.

(2) Intake and Transmission Pipe

- The weir is insufficient in height.
- The transmission pipe is insufficient in diameter.
- The mining pit and pumping stations are frequently inundated.

(3) Treatment

- Flocculatuinn is inadequate.
- The weir of flocculation basin is insufficient in length.

(4) Distribution

- Most of pipes are too aged to sustain high pressure.
- Pipeline does not form efficient network but has dead ends in some lines.

(5) Operation and Maintenance

- Much water is being taken from waterfall rather than from mining pit.
- Water conveyed from the waterfall is directly poured into the clear water reservoir without any treatment.

3.5 Organization

3.5.1 Organization of Regional Office

The regional offices of PWA directly supervise the urban waterworks and assist the rural waterworks in technical aspects.

The Takua Pa Waterworks is supervised by the Regional Office IV in Surat Thani which covers 13 waterworks in this region. Figure 3-5-1 shows the organization chart of the Regional Office IV. The function of each section is described as follows:

(1) Personnel and Clerical Section

This section is responsible for personnel administration of the waterworks, including the training of waterworks personnel.

(2) Finance and Accounting Section

All matters pertaining to finance and accounts of the waterworks, inclusive of borrowing and depositing in their bank accounts, is controlled by this section.

(3) Procurement and Stores Section

This section takes charge of procuring and storing materials and supplies necessary for operating water supply facilities of the waterworks.

(4) Maintenance Section

This section is in charge of giving the guidance and instructions regarding the conduct of operation and maintenance of the waterworks facilities.

(5) Technical Service Section

A preliminary survey of projected waterworks schemes for both urban and rural waterworks is provided by this section.

(6) Water Quality Control Section

This section is responsible for conducting the water quality analyses of both raw and treated water.

(7) Survey Section

This section is responsible for providing the Head Office with information concerning rural waterworks and planning new water supply projects.

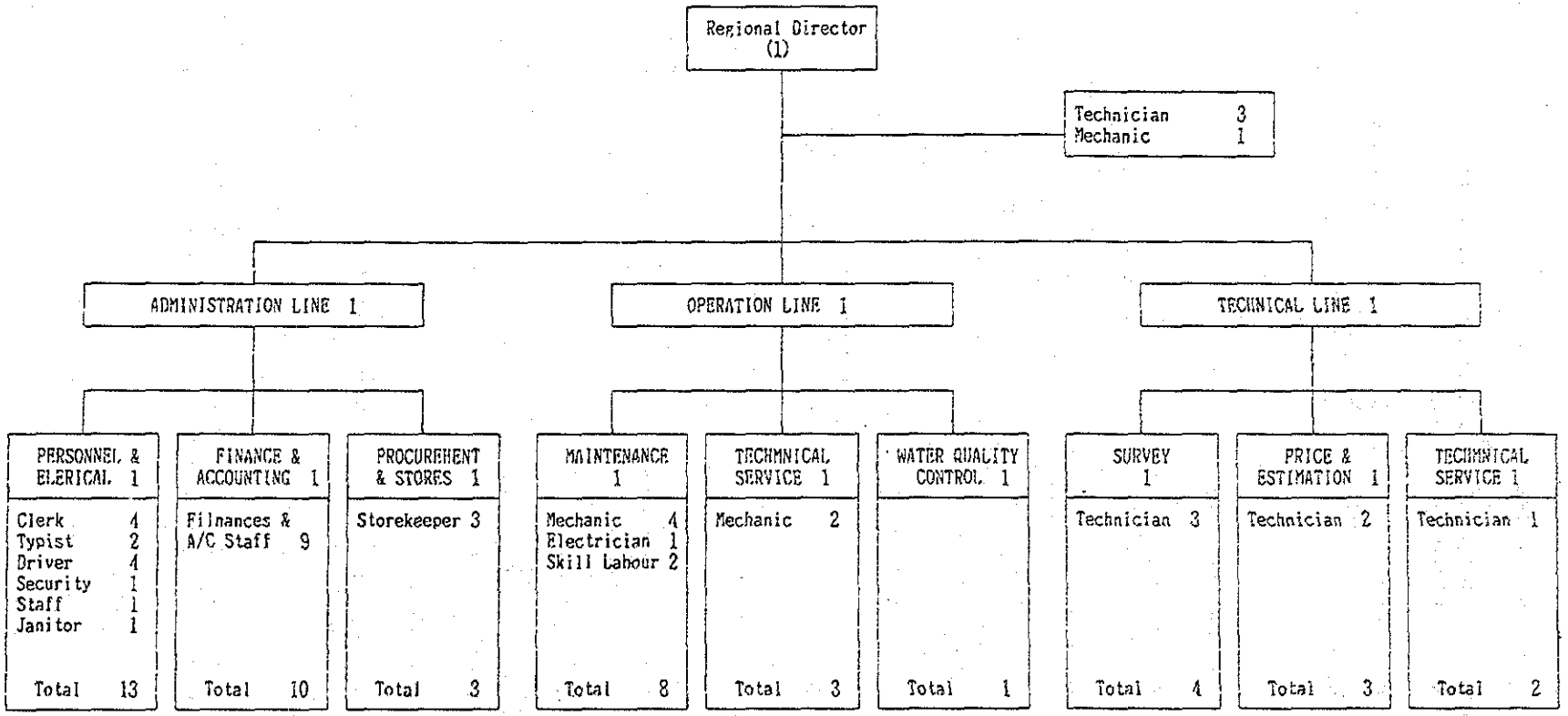


FIGURE 3-5-1
ORGANIZATION CHART OF REGIONAL OFFICE 4

(8) Price Estimation Section

This section is responsible for estimating the expansion/rehabilitation cost of water supply systems for both urban and rural waterworks and preparing documents, drawings and others for bidding.

(9) Construction Supervision Section

This section is responsible for supervising the construction and expansion/rehabilitation works of water supply facilities.

3.5.2 Organization of Waterworks

The organization of the Takua Pa Waterworks consists of three sections; namely, production, services, and administration sections. The organization chart with the number of employees is shown in Figure 3-5-2, and the function of each section is described as follows:

(1) Water Production Section

This section is responsible for operation and maintenance of water production facilities.

(2) Service Section

Services for setting and repairing house-connections are provided by this section.

(3) Administration Section

This section takes charge of meter reading and bill- collection, book-keeping of customers accounts, financing, record-keeping of waterworks income and expenditure, and other administrative works and meters.

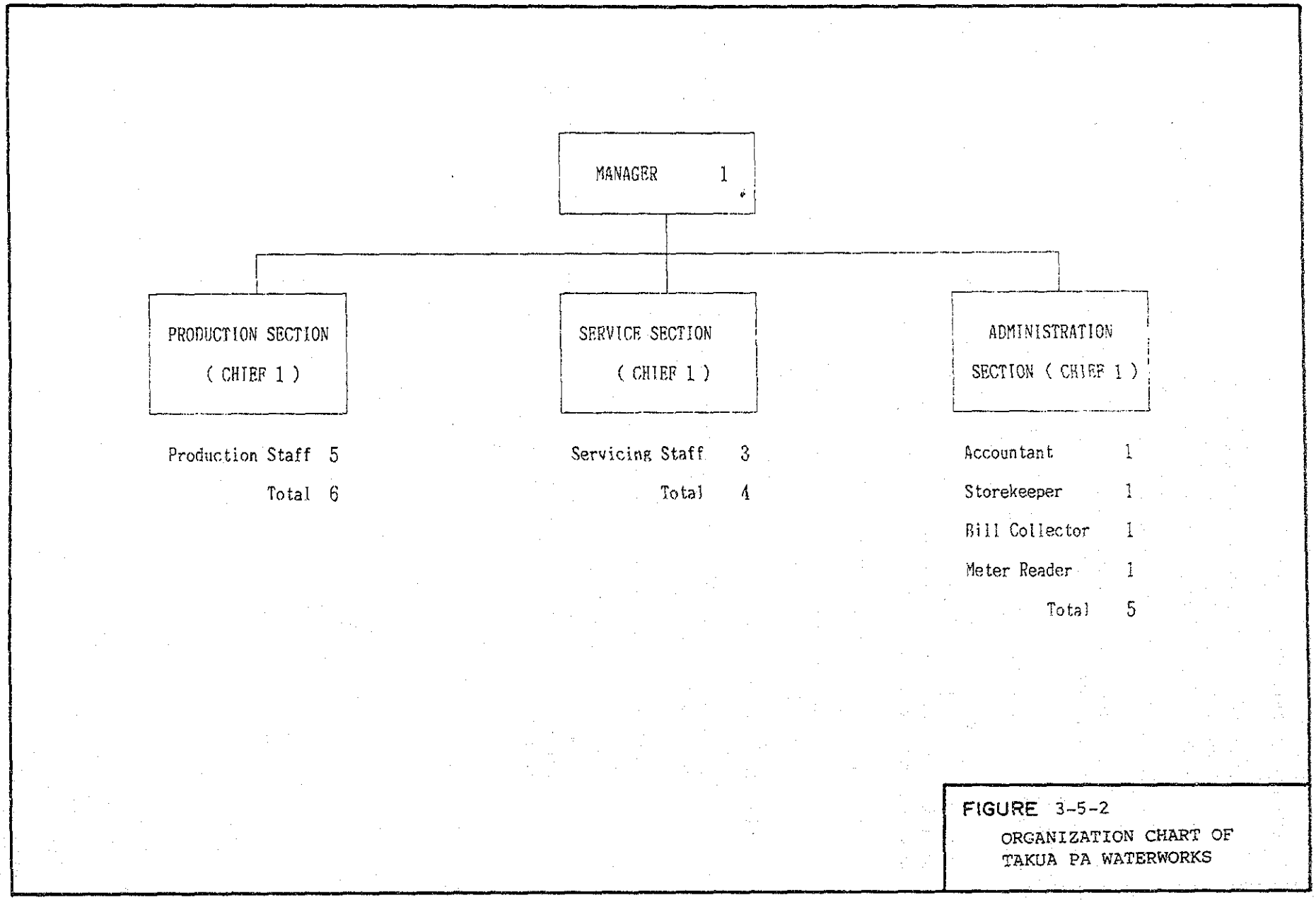


FIGURE 3-5-2
ORGANIZATION CHART OF
TAKUA PA WATERWORKS

3.6 Financial Status

3.6.1 Present System

As of 1987, the Takua Pa waterworks has 1,077 connections. The water production and sales in 1987 were 563,505 cu.m and 247,415 cu.m, respectively.

PWA has three major sources of tariff revenue: namely water sales, service charges and connection fee. These tariffs' contribution to the total revenue of PWA was more than 95%. The waterworks has nearly the same income structure as this. PWA applies same water rate structure for all the waterworks.

Details of current levels of tariffs are set out in Tables 3-6-1 to 3-6-3.

Table 3-6-1 Present Water Sales Charges

Consumption (cu.m/mo)	Tariff (฿/cu.m)
0 - 10	3.75
11 - 20	4.50
21 - 30	6.50
31 - 50	7.50
51 - 80	8.00
81 - 100	8.50
101 - 300	9.00
301 - 1,000	9.25
1,100 - 2,000	9.50
2,001 - 3,000	9.75
3,001 and above	10.00

Table 3-6-2 Present Service Charge

(Unit : ฿/mo)

Size of Conn.	Service Charge
1/2"	10
3/4"	15
1"	30
1-1/2"	60
2"	100
2-1/2"	120
3"	160
4" and above	200

Table 3-6-3 Present Connection Charge

(Unit : ฿/conn.)

Size of Conn.	Basic Connection Fee
1/2"	2,050
3/4"	2,750
1"	3,750
1-1/2"	6,690
2"	9,575
2-1/2"	13,075
3"	15,495
4"	21,455
6"	30,025

Note : The basic connection fee is applied to the connection with an installation length of less than 10 m from a main pipe.

3.6.2 Revenue and Expenditure

The annual revenues and expenditures of the waterworks in the last three years are shown below:

Table 3-6-4 Revenue and Expenditure

(Unit : 1,000 ฿)

Year	Revenue	Expenditure	Profit(loss)
1985	1,712	1,999	(287)
1986	2,236	1,937	299
1987	1,790	1,920	(130)

In the accounting system of PWA, all the revenues of the waterworks are transferred to the PWA Head Office. All expenditures are also allocated by the PWA Head Office. However, as shown in Table 3-6-6, such accounts as capital investment, debt service and depreciation and amortization are not concerned in waterworks' own finance.

To identify and quantify the financial status of waterworks, one of the financial ratios (revenue to expenditure) is computed as shown below:

Table 3-6-5 Ratio of Revenue to Expenditure

Office	1985	1986	1987
PWA Head Office	1.45	1.72	1.76
Takua Pa Waterworks	0.86	1.15	0.93

When the ratio is equal to or greater than 1.0, it is considered that its financial status is in good condition.

As shown above, however, the waterworks incurred a deficit in its annual operation except for 1986.

A breakdown of the revenue and expenditure are shown in Table 3-6-6.

Table 3-6-6 Revenue and Expenditure of Takua Pa Waterworks

(Unit : Baht)

Description	1985	1986	1987
Water Production cu.m	483,900	496,050	563,505
Water Sales cu.m	290,114	265,973	247,415
No. of Connections	987	1,063	1,077
Revenue			
Water Sales	1,459,858.50	1,710,835.00	1,553,865.75
Service Charge	149,923.00	157,560.00	162,170.00
Connection Fee	76,006.00	358,643.00	69,494.00
Other Revenue	26,325.23	9,148.89	4,291.84
Total Revenue (A)	1,712,112.73	2,236,186.89	1,789,821.59
Expenditure			
Salaries	1,070,850.00	1,156,420.00	1,251,380.00
Remuneration	183,727.20	204,027.03	190,497.32
Chemical	28,771.00	50,011.30	55,395.05
Material & Maintenance	119,259.92	36,168.50	61,466.67
Oil & Fuel	284,094.52	154,428.75	142,776.23
Office Supplies	8,874.56	6,577.91	8,903.09
Hired Service	17,555.00	10,528.00	5,655.00
Other Operating Expense	6,836.00	8,812.00	10,039.00
Public Utilities	169,349.50	18,061.00	7,300.00
Electricity	85,844.71	163,247.29	167,090.86
Connection Cost	23,522.10	128,498.74	19,028.57
Material Sold	280.00	—	300.00
Total Expenditure (B)	1,998,964.51	1,936,780.52	1,919,831.79
Profit (Loss)	(286,851.78)	299,406.37	(130,010.20)

4. POPULATION AND WATER DEMAND

4.1 Project Horizon

The study area is delineated as to coincide with the town planning area of DTCP. As in Table 4-1-1, this consists of the Municipality, parts of Tambons Bang Muang, Ban Sai, Bang Nai Sri, Kok Kien, Tum Tua in Amphoe Takua Pa, and Kao Kaw Khao in Amphoe Kuraburi, although the last two tambons have only marginal shares to the total study area.

The study area is considered to accommodate urban expansion originating from the Municipality and Bang Muang town covering the corridor between them toward 2011.

The study area is shown in Figure 4-1-1.

Table 4-1-1 Area of the Study Area

(Unit : sq.km (%))

Study area (DTCP town planning area)		67.66 (100.0)
	Municipality	3.02 (4.5)
	Tambon Bang Muang	28.38 (41.9)
	Tambon Bang Sai	13.17 (19.4)
	Tambon Bang Nai Sri	14.88 (22.0)
	Tambon Kok Kien	7.22 (10.7)
	Tambon Tum Tua	0.18 (0.3)
	Tambon Kao Kaw Khao	0.81 (1.2)

Source : DTCP

4.2 Population

4.2.1 Historical Population

The population of the study area was 28,500 in 1988 as shown in Table 4-2-1.

Population trend of the Municipality in 1980's is characterized by decline till 1983 and slow and unsteady growth after the year. In addition to the local economic situation, spatial limitation of the Municipality is thought to constrain the population growth. The neighboring tambons are absorbing the population of the Municipality.

Population of Amphoe Takua Pa has been growing steadily at an average growth rate of 2.3% since 1980.

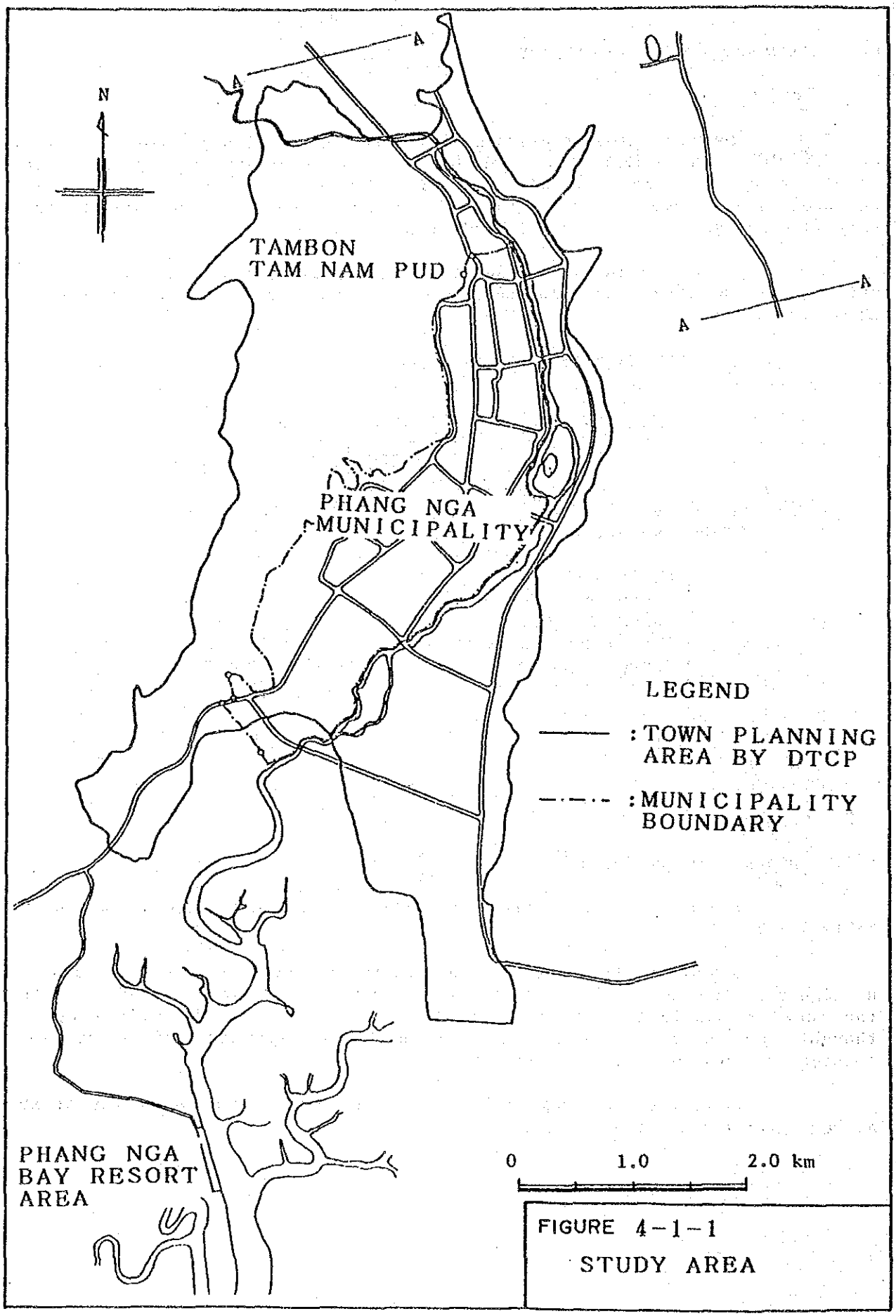


FIGURE 4-1-1
STUDY AREA

Table 4-2-1 Population Projection of Takua Pa Study Area

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1991	1996	2001	2006	2011
Population of Takua Pa Municipality														
Population	9,647	9,569	9,477	9,174	9,222	9,339	9,380	9,303		9,434	9,600	9,769	9,941	10,116
Natural Increase (%)						-0.314	-0.289	-0.330						
Social Increase (%)						1.583	0.728	-0.490						
Growth Rate (%)		-0.809	-0.961	-3.197	0.523	1.269	0.439	-0.821		0.350	0.350	0.350	0.350	0.350
Population of Amhpoe Takua Pa	24,624	25,758	26,768	26,959	27,674	28,336	28,740	28,902						
Population of Study Area									28,462	29,979	32,633	35,592	38,891	42,574
Inside Municipality									9,278	9,434	9,600	9,769	9,941	10,116
North Core									4,320	4,456	4,588	4,723	4,860	4,999
Corridor									526	537	556	575	595	616
South Core									4,432	4,441	4,456	4,471	4,486	4,501
Outside Municipality									19,184	20,545	23,033	25,823	28,950	32,458
Tambon Bang Muang									11,386	12,195	13,673	15,330	17,188	19,271
Tambon Bang Sai									1,697	1,817	2,037	2,283	2,559	2,869
Tambon Bang Nai Sri									4,679	5,011	5,618	6,299	7,062	7,918
Tambon Kok Kien									1,232	1,319	1,478	1,657	1,857	2,082
Tambon Tum Tua									0	0	0	0	0	0
Tambon Kao Kaw Khao									190	203	227	254	284	318

Source : "Annual Statistics on Residents Registration" DTCP

4.2.2 Future Population

Future population was firstly calculated with the following five mathematical formulae:

A) Arithmetical progression $y = aX + b$

B) Geometrical progression $y = y0 \times (1 + b)^X$

C) Decreasing rate of increase $y = K - ab^X$

D) Exponential $y = y0 + ax^b$

E) Logistic $y = k / (1 + \exp(a - bX))$

Where,

y : Population forecasted

y0 : Population in the base year

X : Years from the base year

a, b, K : Coefficient

Aside from these mathematical models, the annual growth rate was also considered from the socioeconomic conditions of the area. Therefore, mathematical models are used only for comparison.

To estimate future population of the study area, the following method is adopted.

(1) Population of the Municipality will grow at the same rate as in the recent four years since 1983, that is 0.35% per annum.

(2) Population outside the Municipality will grow at the same rate as the Amphoe's growth rate since 1980, that is 2.3% per annum.

By the above method, population of the study area in 2011 is estimated at 42,600 as shown in Table 4-2-1.

Figures 4-2-1 and 4-2-2 show the population projection of the Municipality and the Amphoe for reference. In this figure, legends "A" to "E" correspond to the formulae mentioned above, respectively and legend "T" shows the values by the adopted method.

According to the HOMES Research Report prepared in 1987 for the Seminar on Demographic and Economic Forecast for Thailand, the average household size of the nation in 2011 will be approximately 71% of the 1987 level.

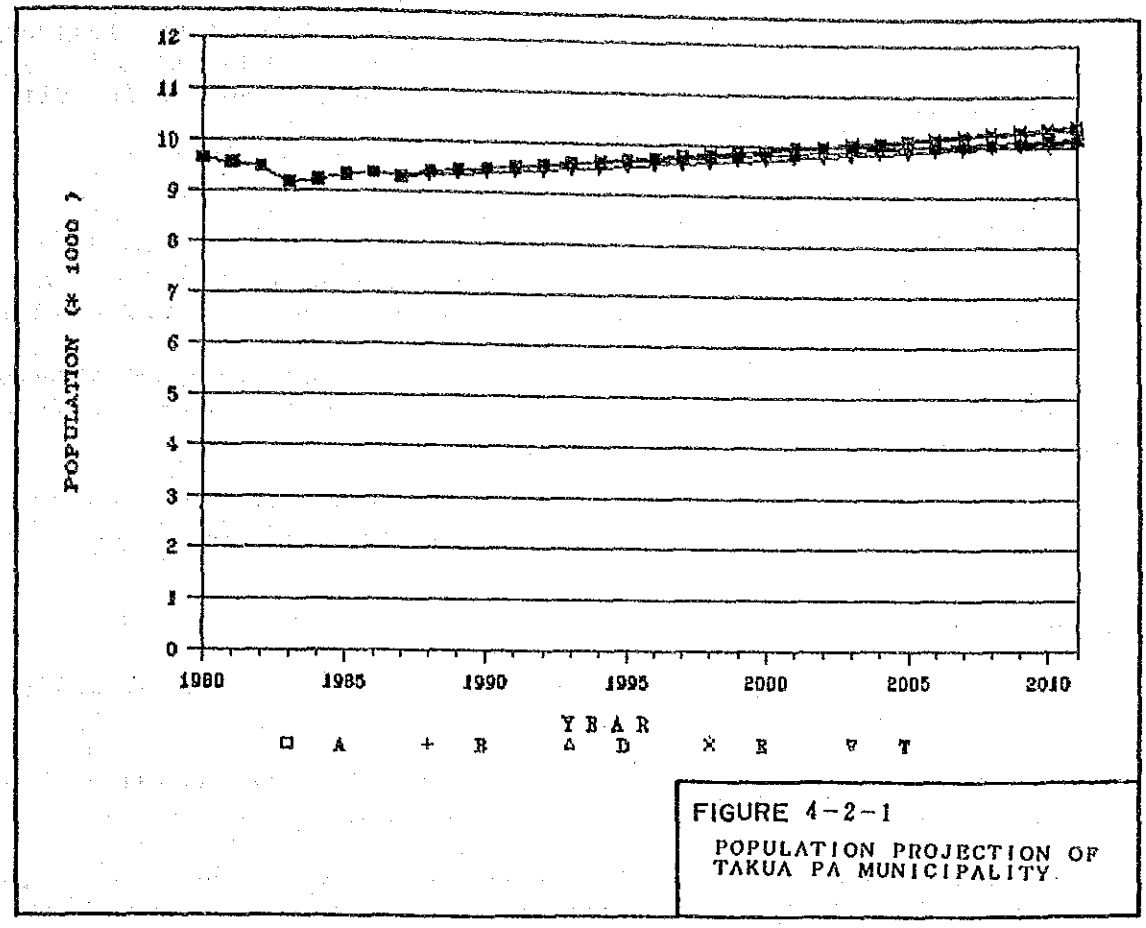


FIGURE 4-2-1
POPULATION PROJECTION OF TAKUA PA MUNICIPALITY

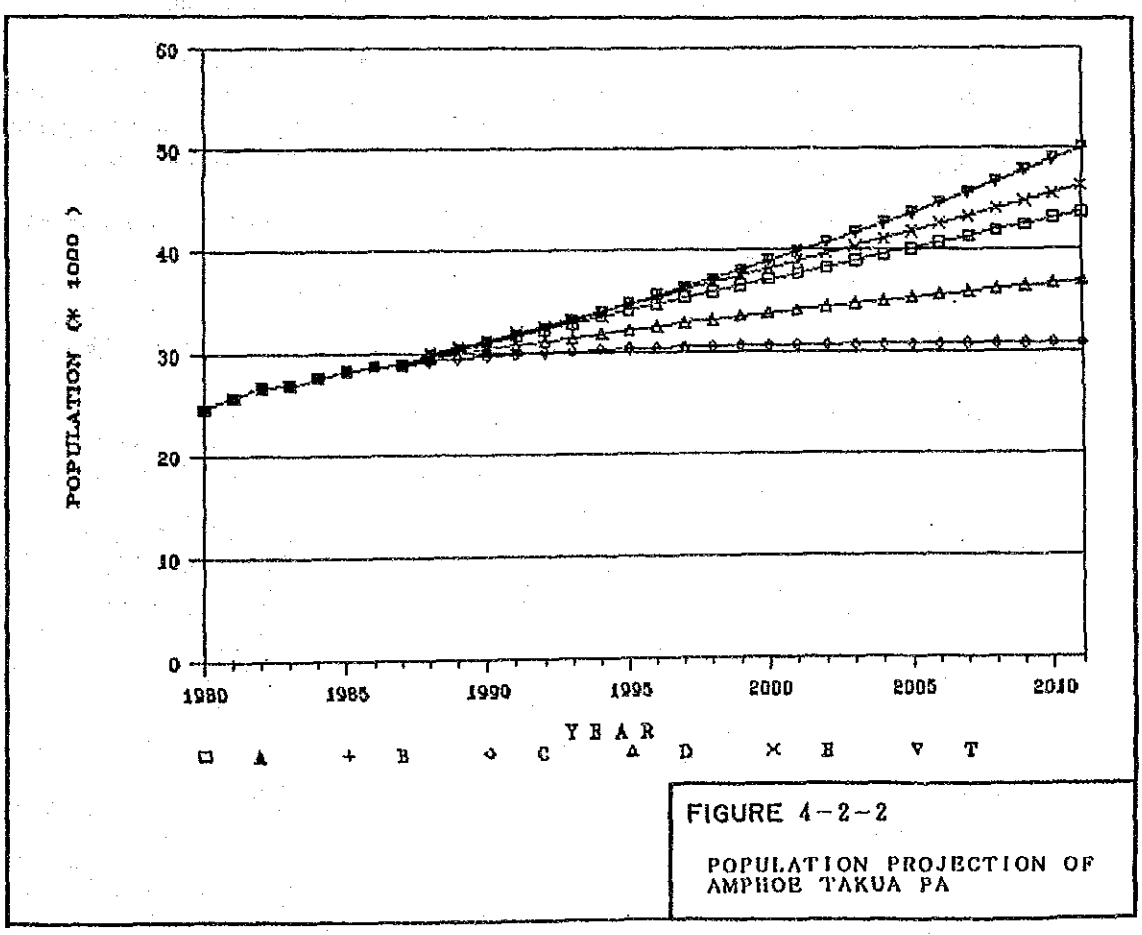


FIGURE 4-2-2
POPULATION PROJECTION OF AMPHOE TAKUA PA