MINISTRY OF INTERIOR
PROVINCIAL WATERWORKS AUTHORITY

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

FINAL REPORT
FOR
THUNG SONG

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
President
Japan International Cooperation Agency

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

LIST OF TABLE

LIST OF TABLE (Cont'd)

LIST OF TABLE (Cont'd)

LIST OF FIGURE

EXECUTIVE SUMMARY

PART I - GENERAL

THE STUDY AREA

The Municipality of Thung Song, which is one of the centers in the Nakhon Si Thammarat Province, is situated on the southeastern coast in the southern region of Thailand. Mainly engaged in commerce, as the distribution center of raw materials, especially rubber and rice, Thung Song lies about 710 km south of Bangkok and 60 km northwest of Nakhon Si Thammarat.

Thung Song is situated on the flat terrace upstream of the Tao Loa River flowing southward. Several small streams originating from the mountains northeast of Thung Song flow into the neighboring area and then join the Tao Loa River.

Na Bon, which is known as the rubber industry town, is 14 km northeast of Thung Song and is supplied with water by the same municipal system in Thung Song.

Annual rainfall in Thung Song averages 2,400 mm while average annual pan evaporation level is about 1,400 mm. Mean monthly temperature varies from 28.7°C in April to 25.9°C in December.

In Amphoe Thung Song, the agricultural sector provides most of the job opportunities. Of the total agricultural area of 400 sq. km in Amphoe, rubber plantations occupy about 250 sq. km., with the rest dominated by paddy fields. In 1987, a total of 1,087 people are gainfully employed in 121 establishments in the industrial sector. A more significant number of people are employed in 776 commercial and business establishments dominated by grocery stores and restaurants.

Thung Song is a junction of many land transportation routes. Route 41 and Route 403 meet in the area, with Route 41 leading northwards to Surat Thani and Chumphon, where it joins Route 4 leading to Bangkok. Also, the railways divert from Thung Song in three directions: to the north, leading to Bangkok: to the east, leading Nakhon Si Thammarat and to Hat Hai; and to the south leading to Trang and the Andaman Sea.

WATER SOURCE

The present water source in Thung Song is mainly the Khlong Poek, which flows 2.0 km east of the Municipality. The existing intake point of the waterworks is located 1.5 km downstream of the confluence of two streams, the Khlong Poek and the Khlong Nam Tok Yong. Several concrete bricks are placed in the stream so that raw water can be fed into the sedimentation basin. The catchment area has a relatively flat terrace where rubber and paddy rice are planted.

Shallow wells are often utilized by private houses as the study area is situated on the colluvium of the small streams. Most of the wells are hand-dug with brick lining and with a depth of from 3 to 5 meters.

Monthly rainfall data were recorded at six gauging stations in Amphoe Tung Song, Ron Phibun, Chaweng, Lan Saka, Nakhon Si Thammarat and Kri Rat Nikom. Climatology data on the study area are available at Nakhon Si Thammarat.

Two hydrological stations at Lan Saka and Muang, Nakhin Si Thammarat, were selected for hydrological analysis because these have similar runoff patterns and catchment conditions.

Several methods such as specific runoff and hydrological models were used for estimating the available amount of water at the existing water source at the Khlong Tam Tok Yong.

Probability analyses showed that the minimum flow at the existing intake point is 0.75 MCM/mo in the return period of 1/10. Availability of water at the source is considered sufficient for water demand even up to the target year of 2011.

The study also considered several alternative water sources in order to meet future water demand and secure stable water supply. These include the construction of a concrete weir with a gate at the present intake point, diversion from the Khlong Tha Long, construction of a multi-purpose dam upstream of the Khlong Wang Hip, and groundwater development.

EXISTING WATER SUPPLY SYSTEM

The waterworks for the municipality of Thung Song, which was founded in 1961, initially had a treatment plant with a capacity of 40 cu.m./h, treating raw water from a canal flowing into Thung Song. In 1969, a new treatment plant with a capacity of 160 cu.m./h was constructed some 3.5 km away from the old treatment plant which was soon abandoned due to the deterioration of water quality. The new treatment plant has, for its source, surface water from the Tha Phae River which originates from the Yong Waterfall. The capacity of the treatment plant increased to 240 cu.m./h in February 1988 with the completion of improvement works on the plant.

The treatment process consists of chemical flocculation, sedimentation, rapid filtration and chlorination. The treated water is stored in two clear water reservoirs with a total capacity of 2,000 cu.m. and is distributed directly by means of pumps.

The distribution system of the waterworks covers the center of the town and extends to the prison by direct pumping from the water treatment plant. Na Bon, which is located about 14 km north of Thung Song, has a distribution system consisting of a receiving tank and pipeline with a total length of 2,500 m.

The number of connections increased from 2,799 in 1980 to 3,196 in 1984 and 3,799 in 1987. Although all the house connections are metered, several meters are found to be defective or have measuring errors.

The operational condition obtaining in the Thung Song waterworks is fairly stable. Although the treatment capacity is doubled from March 1988 with the modification of the sedimentation basin and rapid sand filters, no significant change is found in the quality of treated water to date.

About 93 percent of the water produced for sale is distributed in Thung Song while the rest is sent to Na Bon.

The annual water production and sales from 1980 to 1987 are shown in the following table.

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	1,367,406	1,138,162	2,799	1.111
1981	1,437,426	1,114,069	2,926	1.043
1982	1,623,228	1,336,872	3,024	1.211
1983	1,643,726	1,339,385	3,126	1.174
1984	1,773,604	1,397,133	3,196	1.194
1985	1,924,233	1,331,805	3,368	1.083
1986	1,976,185	1,193,847	3,549	0.922
1987	1,704,450	1,253,329	3,799	0.904

POPULATION AND WATER DEMAND

The total future population in the study area was placed at 44,417 in 1991, 47,358 in 1996, 49,940 in 2001, 53,242 in 2006 and 57,203 in 2011. Future population was calculated based on the following assumptions:

a. In the municipality, the natural growth rate will decrease from the present level of 5% to 1.5% in 2001 and will remain in that level. The net out-migration will decrease from the recent level of 4% to zero in 2008.

b. The neighboring tambons will have a growth rate equal to that of the municipality.

The existing service area of the waterworks consists of the municipality of Thung song and the Sanitary District of Na Bon in Amphoe Na Bon.

Past and present population served was estimated from the number of members per household and the number of connections. In 1980, out of 2,799 connections, population served was placed at 15,656. In 1983, there were 3,126 connections and 12,382 people served while in 1987, the figures are 3,799 and 14,607.

The future population served was calculated by service area density as shown in the following table.

Future Served Population

Year	Thung Song		Na Bon	Total	Average Service Ratio (%)
	Mun.	Fringe Area			
1991	15,195	503	1,965	17,663	57.6
	(21,707)	(5,033)	(3,930)	(30,670)	
1996	16,197	1,182	2,359	19,738	62.4
	(22,187)	(5,140)	(4,289)	(31,616)	
2001	17,330	1,872	2,788	21,990	66.4
	(23,106)	(5,349)	(4,647)	(33,102)	
2006	19,122	2,723	3,254	25,099	71.3
	(24,516)	(5,672)	(5,006)	(35,194)	
2011	21,101	3,659	3,756	28,516	75.4
	(26,376)	(6,099)	(5,365)	(37,840)	

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.

Daily Average and Maximum Water Demand

(Unit : cu.m/d)

Category	1987	1991	1996	2001	2006	2011
Domestic	2,013	2,947	3,402	3,905	4,614	5,408
Gov'l/Inst'l	1,154	1,717	1,767	1,843	1,951	2,087
Commercial	186	307	316	331	352	378
Industrial	51	70	78	86	98	112
Others	35	47	52	57	66	75
Sub-Total	3,439	5,088	5,615	6,222	7,081	8,060
Unaccounted-for Water Ratio (%)	26.5	25	23	22	21	20
Unaccounted-for Water	1,238	1,696	1,677	1,755	1,882	2,015
Daily Average	4,677	6,784	7,292	7,977	8,963	10,075
Peak Factor		1.30	1.30	1.30	1.30	1.30
Daily Maximum		8,819	9,480	10,370	11,652	13,098

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

Water source development plan calls for the construction of a fixed concrete weir with a gate by 1993 for the purpose of securing stable intake and draining of deposited sediment during flood seasons. In the interim, stone blocks or concrete blocks should be temporarily placed at the present intake point to raise the intake water level.

The expansion of the treatment plant at the present site is recommended since the raw water source is sufficient and the existing raw water intake is planned to be used through the future.

The distribution system, in order to respond to water demand in 2011, was considered in optimizing the systems capacity. Since the present design is not even sufficient to meet the planned water demand in 1990, increase of the transmission capacity is inevitable. To achieve this, an additional pipeline is recommended to be installed.

IMPLEMENTATION PLAN

The implementation plan of the total project will involve the construction of a treatment facilities which will be carried out in one phase. It is assumed that the distribution pipelines will be constructed in two years.

The water demand, treatment capacity, and implementation schedule is shown in Figure S-1.

ORGANIZATION OF WATERWORKS

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

a. Administrative Section -- this will be responsible for the administrative and financial operations of the waterworks to include meter reading and preparation of bills, collection of water bills and management of documents and records.

b. Water Production Section -- this will be responsible for the operation and maintenance of the water treatment plants and raw water intake, including the transmission pipeline system.

c. Service Section -- this will be responsible for setting and repair of house connections.

PROJECT COST ESTIMATES

(1) Construction Cost

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

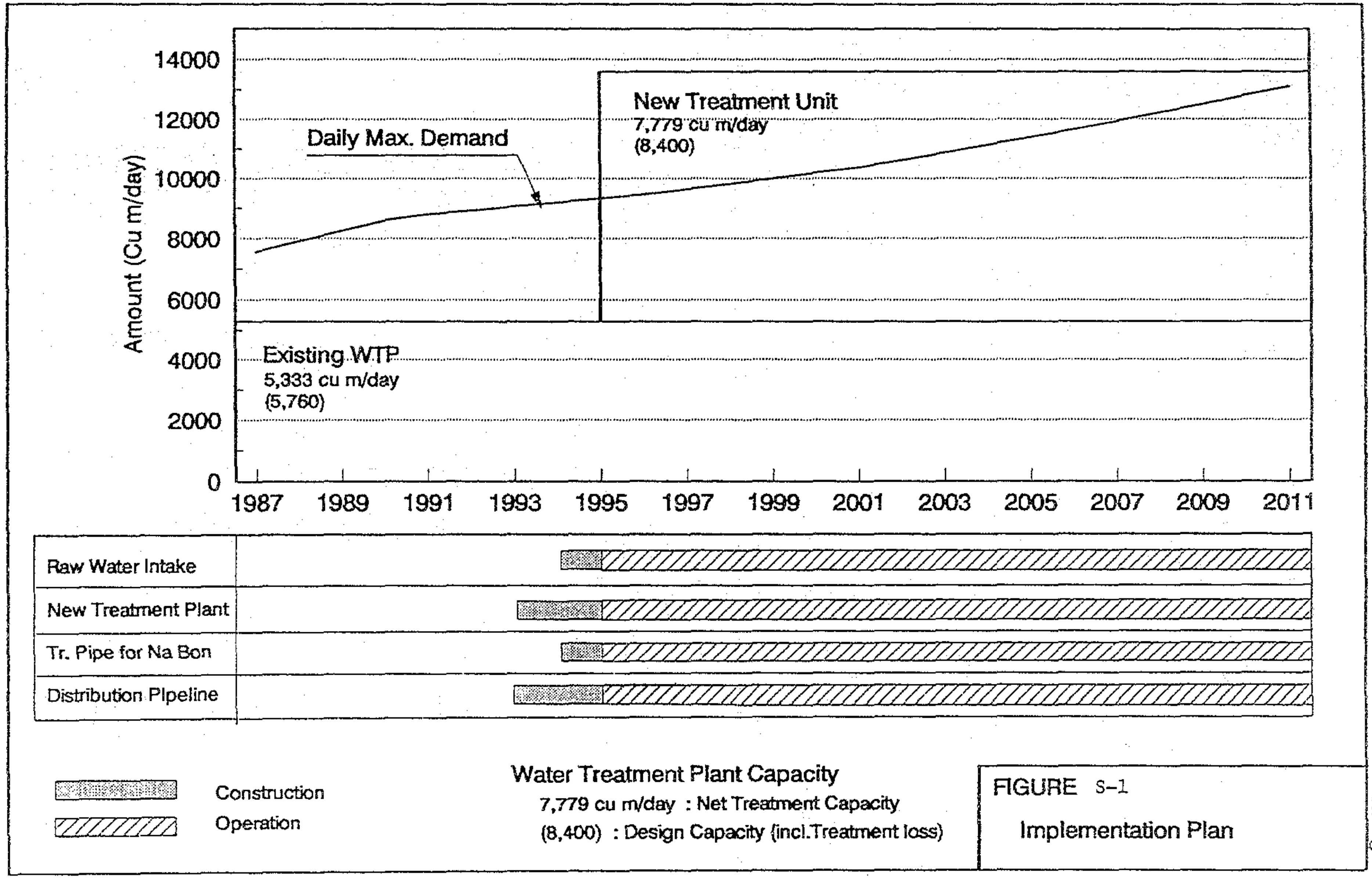


FIGURE S-1

Implementation Plan

Summary of the Construction Cost

(unit : Baht 1000)

Item	Total Value	Foreign Currency Portion	Local Currency Portion
1.Raw Water Intake	1,954	586	1,368
2.Treatment Plant	28,609	10,952	17,657
3.Transmission Pipeline for Na Bon	15,170	4,551	10,619
4.Distribution Pipeline	11,642	3,493	8,149
Sub Total	57,375	19,582	37,793
5.Land Cost	0	0	0
Total	57,375	19,582	37,793

(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	Energy Cost	Chemical Cost	Manning Cost	Repair Cost	Replace-ment	Total
1990	975	131	2,446			3,552
1991	982	135	2,568			3,685
1992	987	137	2,697			3,821
1993	993	140	2,831			3,964
1994	999	142	2,973			4,114
1995	1,000	145	3,122			4,266
1996	1,014	147	3,414	25		4,601
1997	1,028	150	3,728	25		4,932
1998	1,042	153	4,216	25		5,436
1999	1,137	156	4,427	25		5,745
2000	1,208	159	4,648	25		6,040
2001	1,224	162	4,880	25		6,292
2002	1,245	166	5,124	25		6,561
2003	1,266	171	5,573	25		7,035
2004	1,288	175	5,852	25		7,340
2005	1,310	180	6,356	25		7,871
2006	1,332	184	6,674	25		8,215
2007	1,356	189	7,475	25		9,045
2008	1,381	194	8,094	25		9,694
2009	1,405	199	8,498	25		10,128
2010	1,507	204	8,923	25		10,660
2011	1,534	210	9,653	25		11,422

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	19,583	37,792	57,375
b. Engineering Cost			
Design, 8% of (a)	1,724	3,325	5,049
Supervision, 4% of (a)	862	1,663	2,525
TOTAL	22,169	42,780	64,949

Financing Plan

The total foreign cost and 9.501 million Baht of local cost (approximately 50% of project cost) is recommended to be financed from bilateral loan, the remaining 16.640 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 net surpluses throughout the project life, except for 1994 Cumulative cash surpluses for years 2011 and 2020 are estimated at 34.754 million Baht and 35.539 million Baht, respectively.

The results may suggest the simple financial feasibility of this project. It is projected that the unit cost of water would stand at 5.46 Baht per cubic meter in year 2011 and average unit water cost from 1990 to 2020 is 5.69 Baht with the implementation of the project. These rates are almost equal to the third 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 Thung Song is one of the centers in the Nakhon Si Thammarat Province, which is situated on the southeastern coast in the southern region of Thailand. The area is mainly engaged in commerce as the distribution center of raw materials, especially rubber and rice.

Thung Song is located at longitude 99°41' east and latitude 8°10' north, about 710 km south of Bangkok and 60 km northwest of Nakhon Si Thammarat.

Na Bon, 14 km northwest of Thung Song is known as the rubber industry town. Na Bon has a railway station in its center and is supplied with water by the same municipal system as for Thung Song.

1.1.2 Topography

Thung Song is situated on the flat terrace upstream of the Tao Lao River flowing southward.

Several small streams originating from the mountains northeast of Thung Song flow into the neighboring area and then join the Tao Loa River. Paddy fields are developed on the alluvial deposits along the streams, and rubber plantations are mainly seen on the undulating middle terrains. The elevation of these areas ranges from 40 m to 80 m. The mountainous area with the highest peak of 1,196 m at Mt. Wang Hip is located northeast of Thung Song.

This terrain is too steep for any agriculture but features several waterfalls which attracts tourists into the area.

A number of isolated mountains ranging from 100 m to 400 m in elevation are scattered in the neighboring area.

Na Bon is located on the alluvial deposits, 10 km north- west of Thung Song. In this area where rubber is also planted, flood is common during the wet season.

1.1.3 Geology

Thung Song is situated on the terrace (Qt), consisting of alluvial and colluvial deposits which occupies the whole of the neighboring area. Alluvial deposits (Qa) forms an undulated middle terrace where flood is common during the wet season. This terrace is developed in the northern part of Na Bon. Isolated mountains which are scattered in the east of Thung Song comprise of limestone with argillaceous layers.

Mountains situated west and east of Thung Song comprise mainly of sandstone and granite, respectively.

Details of geology is given in Tables 1-1-1.

Table 1-1-1 Geological Feature

Group	Feature	Location
Qt	Terrace, alluvial-fan and colluvial deposits	Plat middle terrace in midstream
Qa	Alluvial deposit; Gravel, sand silt and clay	Undulating middle terrace in upstreams
D	Limestone, dark gray, thin-bedded to bassine, with argilluceous layers; and shale, brown, with brachio pods	Isolated hills and mountains
Go	Sandstone, quartize, shale, and phyllite, yellowish brown and brown	At the foot of mountains in the north-east of Thung Song
gr	Biotite-muscovite granite, porphyritic granite horn blende granite and pegmatite dike	Mountain area in the north-east of Thung Song
SDC	Slale, sandstone, quartzite, mudstone, and slate, well-bedded and aboundant drag flods, with graptrolites	Isolated hills
Mz Kgr(c)	sandstone, siltstone, and shale, and reddish -brown to brown; conglomeratic sandstone, conglomerate, and dolomitic limestone, with cross-bedding, and ripple mark; and basal conglomerate	Mountain area in the west of Thung Song

1.1.4 Meteorology

The average annual rainfall in Thung Song is about 2,400 mm with highly seasonal distribution. More than 50% of the total rainfall occurs during the wet season from September to January. Rainfall records during the remainder of the year is variable and unreliable although those in May to July are more reliable.

The average annual pan evaporation level is about 1,400 mm with little monthly variation. Relative humidity is high, ranging from 86.3% in November to 76.5% in August. The mean monthly temperature varies from 28.7°C in April to 25.9°C in December with a range of 2.8°C. The extreme range is from 38.0°C to 17.2°C.

Details of the meteorology are given in Table 1-1-2 and A1-1-1 to A1-1-7.

Table 1-1-2 Meteorological Data at Thung Song

Items	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature (C.degree)													
Mean	26.0	26.8	27.9	28.7	28.5	28.4	28.0	28.0	27.6	27.0	26.2	25.9	27.4
Mean Max.	29.7	31.1	32.7	33.7	33.5	33.3	33.1	33.2	32.7	31.3	29.5	29.1	31.9
Mean Min.	21.7	21.7	22.2	23.2	23.8	23.7	23.2	23.2	23.1	22.9	22.8	22.5	22.8
Ext. Max.	33.6	35.4	38.0	37.6	37.3	37.7	36.5	37.6	36.6	35.8	34.2	32.6	38.0
Ext. Min.	17.2	17.2	17.8	18.6	20.2	20.6	19.4	19.5	19.4	20.2	18.0	19.5	17.2
Relative Humidity (%)													
Mean	82.6	80.1	78.2	78.8	79.9	76.9	77.3	76.5	79.6	84.1	86.3	85.2	80.5
Mean Max.	95.6	95.5	95.1	94.9	94.3	92.5	93.2	92.4	94.4	95.9	95.9	95.4	94.6
Mean Min.	65.5	60.6	56.7	57.0	59.7	57.3	56.2	56.4	58.9	66.5	73.1	71.5	61.7
Ext. Min.	42.0	36.0	30.0	37.0	37.0	34.0	37.0	27.0	38.0	39.0	46.0	50.0	27.0
Evaporation (mm.)													
Mean - Pan	97.1	115.7	134.4	135.8	125.7	131.4	134.4	142.7	112.2	103.1	81.1	92.6	1406.2
Rainfall (mm.)													
Mean	170.5	46.3	48.2	98.4	170.7	93.2	109.7	96.6	155.6	344.5	610.3	438.7	2382.4
Mean Rainy Days	13.0	5.8	4.4	8.7	16.6	13.3	14.3	14.6	17.4	20.9	22.4	20.5	171.9
Greatest in 24 hr.	433.3	102.3	70.1	102.8	87.0	76.6	70.0	84.2	83.5	271.7	414.0	237.7	433.3
Day / Year	5/75	10/75	25/65	12/61	5/60	18/83	7/76	15/65	5/61	21/63	23/76	5/66	5/75

Source : Meteorological Department
Remark : Evaporation 1981-1985

1.2 Socioeconomic Conditions

1.2.1 Economic Conditions

In Amphoe Thung Song, the agriculture sector provides most job opportunities. Of the total agricultural land area of approximately 400 sq.km (250,000 rai) in the Amphoe, rubber plantations occupy approximately 250 sq.km (155,000 rai) accounting for 62%, followed by paddy fields. Around the Municipality also, rubber is the most important economic base.

Industrial and commercial activities of the area are related directly or indirectly to rubber production. These activities in the secondary and tertiary sectors are concentrated in and around the Municipality, except that a large scale cement factory is located outside the vicinity.

The numbers of industrial establishments and the employees by type in the DTCP town planning area are shown in Table 1-2-1. A total of 1,087 people are working for 121 establishments in the sector. Rubber press factories around the Municipality provide the largest employment, followed by cement brick factories. Vehicle repair shops account for the third share, the majority of which are located in the Municipality. Production of material of metal furniture in the Municipality, and sawmills and plywood production around the Municipality also provide over 50 job opportunities.

The numbers of commercial and business establishments by type in the town planning area are shown in Table 1-2-2. There are 776 establishments in the sector, of which grocery stores and restaurants account for the largest shares.

In addition to the economic establishments mentioned above, there are three higher education facilities and several government facilities of regional importance such as technology, agriculture and commerce colleges, courts, institute of rubber, railway and military facilities. These are also contributing to the regional economy.

1.2.2 Transportation

Thung Song is a junction of many transportation lines as in Figure 1-3-1.

Route 41 and Route 403 meet in the area. Route 41 leads northwards to Surat Thani and to Chumphon, where it joins Route 4 leading to Bangkok. In the northern vicinity of Thung Song, the Na Bon Sanitary District is located on a branch road of Route 41. In the east side of Thung Song, the route leads southwards to Hat Yai and Songkhla through Route 4, and Route 403 leads northwards to Nakhon Si Thammarat and Surat Thani. In the south direction, Route 403 leads to Trang and Andaman Sea. There are two westward routes, Route 4110 and Route 4152, leading to Krabi.

The railways divert from Thung Song in three directions. To north, they lead to Bangkok via Na Bon. To east, the line diverts again to Nakhon Si Thammarat northwards and to Hat Yai southwards. In the south direction, the line is extended to Trang and Andaman Sea.

Table 1-2-1 Number of Industrial Establishments and Employees by Type in DTCP Town Plan Area in 1987

Type of Establishment	Town Plan Area				Inside Municipality				Outside Municipality			
	Establishments		Employees		Establishments		Employees		Establishments		Employees	
	Nos.	%	Nos.	%	Nos.	%	Nos.	%	Nos.	%	Nos.	%
Ice	4	3.3	18	1.7	3	3.8	11	2.6	1	2.4	7	1.1
Noodle	4	3.3	18	1.7	3	3.8	15	3.5	1	2.4	3	0.5
Vehicle Repair	43	35.5	171	15.7	29	36.3	115	26.7	14	34.1	56	8.5
Candy	5	4.1	32	2.9	5	6.3	32	7.4	0	0	0	0
Jewels	2	1.7	3	0.3	2	2.5	3	0.7	0	0	0	0
Construction Material of Metal	9	7.4	21	1.9	7	8.8	15	3.5	2	4.9	6	0.9
Furniture	11	9.1	75	6.9	11	13.8	75	17.4	0	0	0	0
Roast Fish	1	0.8	2	0.2	1	1.3	2	0.5	0	0	0	0
Machinery	5	4.1	16	1.5	4	5.0	12	2.8	1	2.4	4	0.6
Cement Bricks	15	12.4	195	17.9	6	7.5	28	6.5	9	22.0	167	25.4
Printing	3	2.5	14	1.3	3	3.8	14	3.3	0	0	0	0
Rubber Press	4	3.3	266	24.5	1	1.3	19	4.4	3	7.3	247	37.6
Sawmill	4	3.3	83	7.6	1	1.3	21	4.9	3	7.3	62	9.4
Rice Mill	4	3.3	15	1.4	2	2.5	9	2.1	2	4.9	6	0.9
Stone Breaker	2	1.7	72	6.6	1	1.3	49	11.4	1	2.4	23	3.5
Ply Wood	2	1.7	55	5.1	0	0	0	0	2	4.9	55	8.4
Drinking Water	2	1.7	14	1.3	1	1.3	10	2.3	1	2.4	4	0.6
Oxygen	1	0.8	17	1.6	0	0	0	0	1	2.4	17	2.6
Total	121	100	1,087	100.1	80	100.6	430	100	41	99.8	657	100

Source : DTCP

Note : Total percentage is not always 100 due to approximation of each item's percentage.

Table 1-2-2 Number of Commercial and Business Establishments by Type in DTCP Town Plan Area in 1987

Type of Establishment	Town Plan Area		Inside Municipality		Outside Municipality	
	Nos.	%	Nos.	%	Nos.	%
Restaurants	145	18.7	119	18.5	26	19.7
Grocery	204	26.3	146	22.7	58	43.9
Clothes	69	8.9	69	10.7	0	0
Tailor	34	4.4	30	4.7	4	3.0
Barber	77	9.9	70	10.9	7	5.3
Sports Goods & Suits	14	1.8	14	2.2	0	0
Vehicles & Parts	23	3	18	2.8	5	3.8
Electric Appliance Repair	41	5.3	31	4.8	10	7.6
Drugs	16	2.1	16	2.5	0	0
Construction Materials	7	0.9	6	0.9	1	0.8
Furniture & Repair	8	1.0	7	1.1	1	0.8
Jewels	9	1.2	9	1.4	0	0
Books	12	1.5	12	1.9	0	0
Cameras	4	0.5	4	0.6	0	0
Agricultural Produce	14	1.8	12	1.9	2	1.5
Oil & Gasoline	16	2.1	10	1.6	6	4.5
Night Club / Bar	2	0.3	2	0.3	0	0
Souvenirs	1	0.1	1	0.2	0	0
Hotel / Resthouses	7	0.9	6	0.9	1	0.8
Cinema	2	0.3	2	0.3	0	0
Bank	9	1.2	9	1.4	0	0
Transportation & Tour Service	4	0.5	3	0.5	1	0.8
Service Office	7	0.9	6	0.9	1	0.8
Pawnshop	1	0.1	1	0.2	0	0
Printers, Spectacles & Repair	3	0.4	3	0.5	0	0
Buddhism Equipment	2	0.3	2	0.3	0	0
Signboard Painting	3	0.4	3	0.5	0	0
Laundry	4	0.5	3	0.5	1	0.8
Video Rental	3	0.4	3	0.5	0	0
Raw Rubber	32	4.1	25	3.9	7	5.3
Scrap Iron	3	0.4	2	0.3	1	0.8
Total	776	100.2	644	100.4	132	100.2

Source : DTCP

Note : Total percentage is not 100 due to approximation of each item's percentage.

In the Municipality, there are three major roads passing east and westwards, of which two roads pass through the urbanized area and a by-pass in southern suburbs. The railway station is located at the northeast of the downtown.

In Tambon Na Bon, the sanitary district is the town center, where several local roads meet and a railway station is located.

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, are open 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 the lower and upper divisions, each consisting of three years. This means that normally, those who are 12-14 years old attend the lower secondary level, while those aged 15-17 attend the upper secondary division.

The government plays a major role in all aspects of Thai- land's educational system. The percentage of government expenditures on education compared to that of the total government expenditure varied from 19% to 21% during the past eight years. The percentage of government expenditure on education in Thailand is among the highest compared to other developing countries.

In Thung Song, there are 44 schools. A detailed breakdown of schools, including the number of students and teachers is shown in Tables 1-2-3 to 1-2-5.

Table 1-2-3 School in Amphoe Thung Song

Grade of School	No. of Schools	No. of Students	No. of Teachers
Kindergarten	3	315	no data
Primary School	13	7,238	no data
Secondary School	5	5,944	no data
College/University	-	-	-
Total	21	13,497	-

Table 1-2-4 School in Municipality

Grade of School	No. of Schools	No. of Students	No. of Teachers
Kindergarten	2	1,100	54
Primary School	2	1,559	76
Secondary School	-	-	-
College/University	-	-	-
Total	4	2,657	130

Table 1-2-5 School in Amphoe Na Bon

Grade of School	No. of Schools	No. of Students	No. of Teachers
Grade School of Education	1	613	32
To be under MO	2	1,090	48
National Primary Education Office	16	3,606	186
Total	19	5,309	266

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 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 Tables 1-2-6 and 1-2-7.

Table 1-2-6 Water-Borne Diseasesin Amphoe Thung Song

Year	No. of Patients				
	Diarrhea	Dysentery	Food Poisoning	Typhoid	Total
1983	91	48	41	10	190
1984	87	46	37	7	177
1985	89	47	39	5	180
1986	81	39	29	3	152
1987	76	36	24	1	137

Table 1-2-7 Water-Borne Diseases in Amphoe Na Bon

Year	No. of Patients			
	Diarrhea	Dysentery	Typhoid	Total
1983	109	30	1	140
1984	143	41	1	185
1985	118	23	0	141
1986	190	34	0	224
1987	219	76	0	295

1.3 Land Use

1.3.1 Existing Land Use Pattern

Existing land use pattern of Thung Song and Na Bon are shown in Figures 1-3-1 and 1-3-2. Main features of the patterns are as follows:

In the Municipality, commercial, business and public activities as well as residences are concentrated in the western quarter, which has two major east-west streets. Along the northern street are relatively old houses for various uses, while along the southern street are relatively new commercial and business facilities and workshops. The rest of the municipal area shows rather rural features except along the section of Route 403 connecting the Municipality with Tam Yai Town. Areas along the by-pass and Route 403 to the south still show rural features and with only few large scale facilities such as South Technology College and rubber factories, etc.

In general, outside the Municipality are rural areas with rubber plantations and hills, except in Tam Yai Town where there are public institutes such as the agriculture college, courts and military facilities. The linkage between this town and the Municipality is strong.

In Tambon Chamai, the areas bordering on the Municipality along Route 41 have growing urbanization.

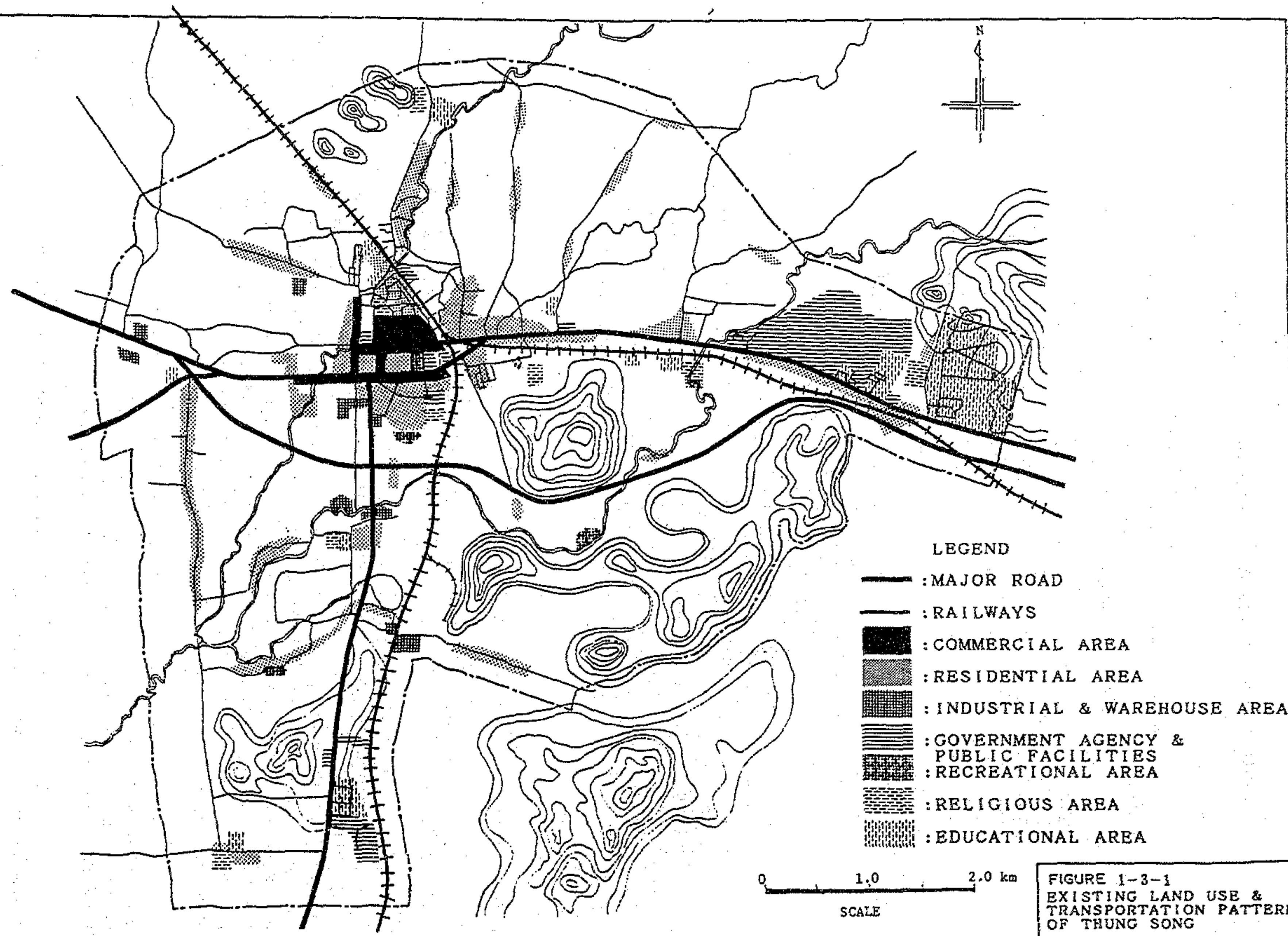


FIGURE 1-3-1
EXISTING LAND USE & TRANSPORTATION PATTERN OF THUNG SONG

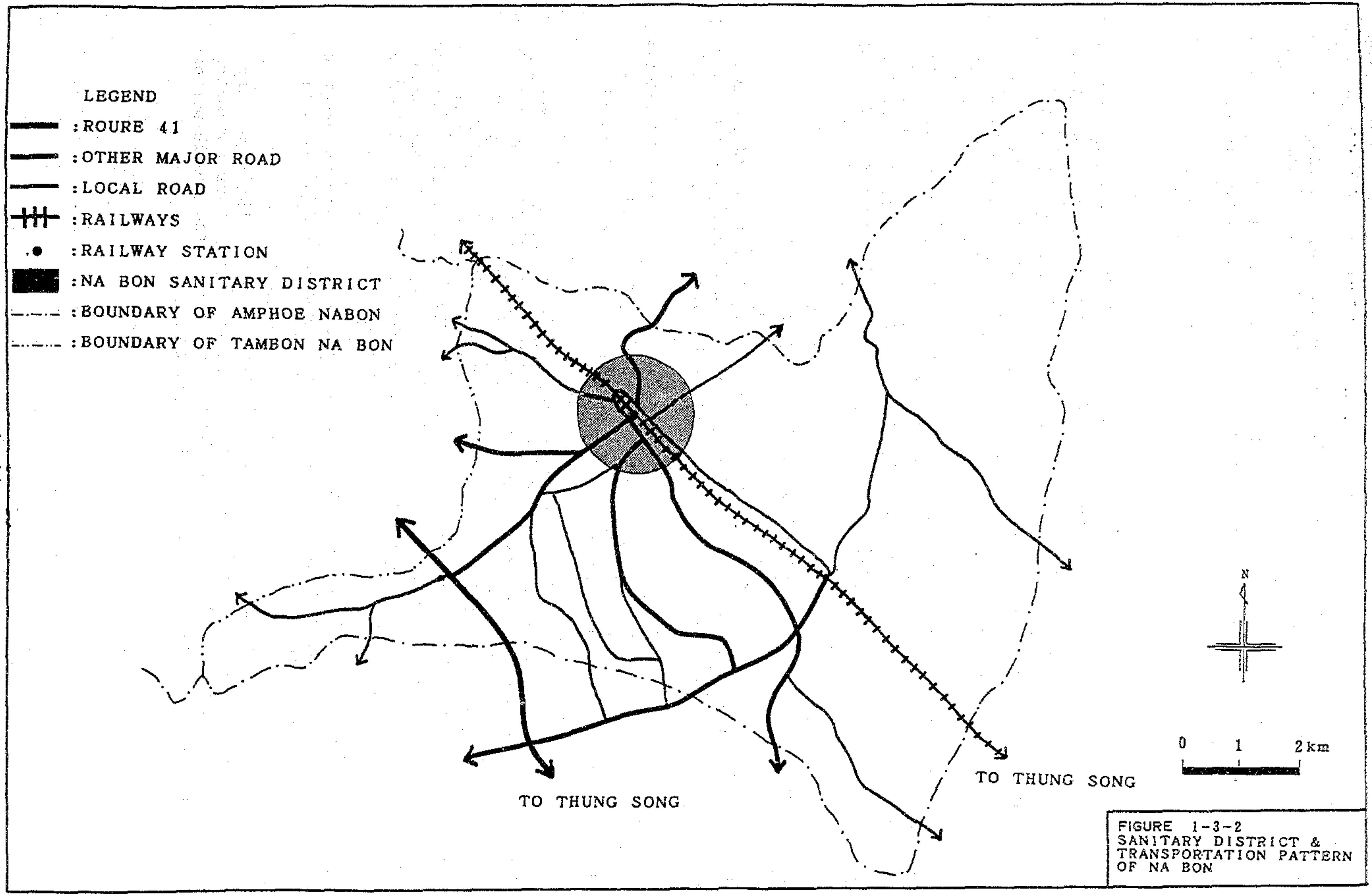


FIGURE 1-3-2
SANITARY DISTRICT &
TRANSPORTATION PATTERN
OF NA BON

In Na Bon, the area around the Na Bon Station, considered as the sanitary district, houses a number of shops and governmental offices.

The area around the Klong Chang railway Station is the second center with the other areas remaining as agricultural or forest areas dominated by rubber plantations.

1.3.2 Land Value

In Thung Song Municipality, official land prices are higher along the two major streets passing through the concentrated area, where the prices range from 500 ฿/sq.m (800,000 ฿/rai) to 1,000 ฿/sq.m (1,600,000 ฿/rai). Outside the area, the prices range from 75 ฿/sq.m (120,000 ฿/rai) to 150 ฿/sq.m (240,000 ฿/rai) along Route 403 to the east and along the by-pass. The prices in other areas are lower ranging from 2 ฿/sq.m (3,000 ฿/rai) to 63 ฿/sq.m (100,000 ฿/rai).

In Amphoe Thung Song areas, the prices at Tam Yai town and at the junction in Tambon Chamai, both of which are along the major roads, are higher at 250 ฿/sq.m (400,000 ฿/rai) to 300 ฿/sq.m (500,000 ฿/rai). In other areas not along the major roads, the prices do not exceed 19 ฿/sq.m (30,000 ฿/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 and locational potential, some axes of future urbanization can be identified as in Figure 1-3-3.

First is the section of Route 403 between the Municipality and Tam Yai town. The link between the two communities will become stronger according to development of them. For example more commutation trips will result in more settlement along the corridor.

Second is the western vicinity of the Municipality along Rout 41 to Surat Thani. Its proximity to the central district of the Municipality and the advantageous road network will attract new settlement.

Third is the section of Route 403 between the Municipality and the South Technology College especially in vicinity to the Municipality. Around the college, some indications of future development such as new housing is observed. The large cement factory in the sough along the route can influence positively on development of the route.

Fourth is the development along the by-pass. At present, only few settlements can be observed there, but the route has potential to attract settlement in a long run.

In addition to these linear development along the major axes, expansion of existing communities will take place in a rather concentric pattern around the central district of the Municipality. The growth pattern will depend on extension of the local road improvement.

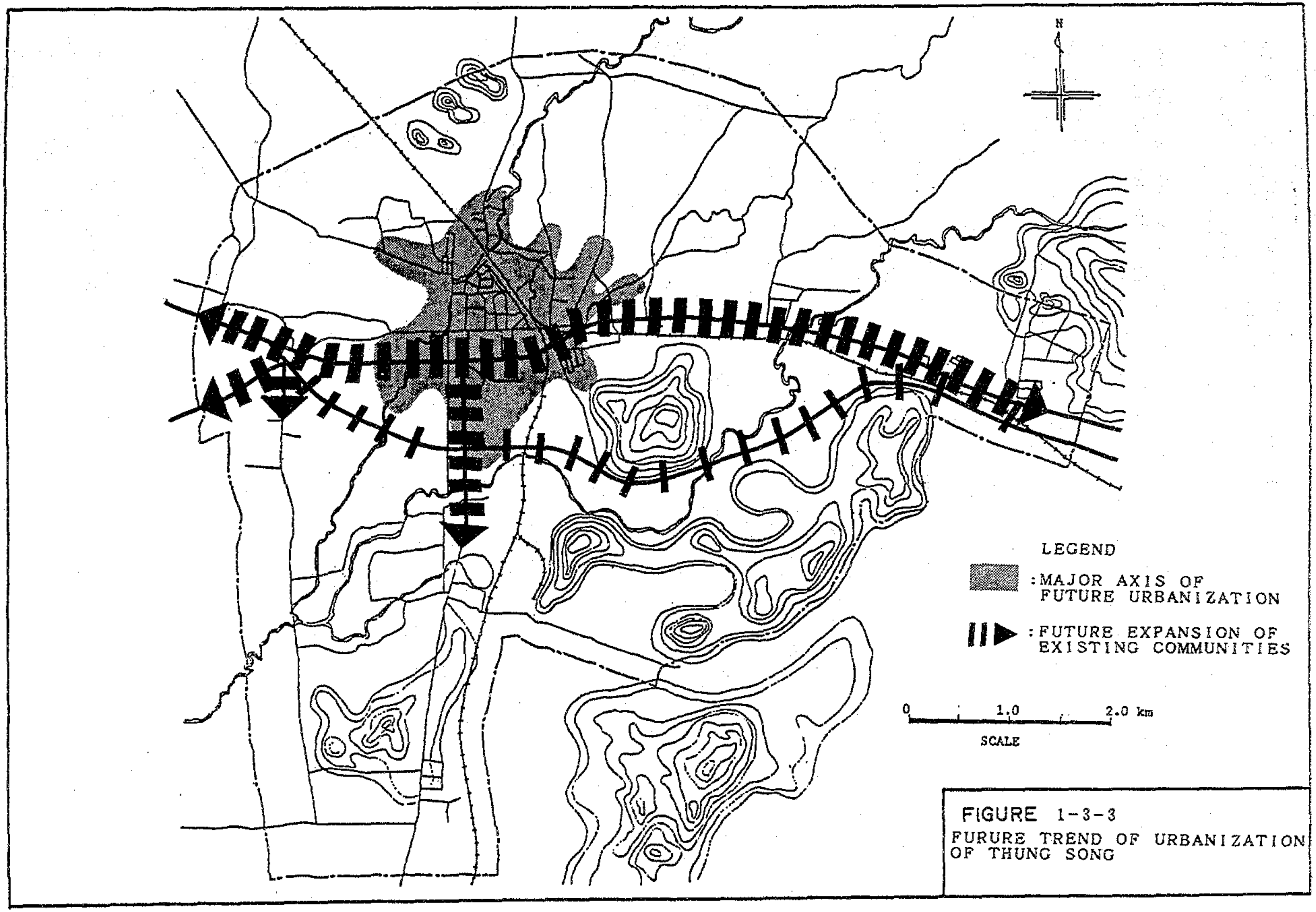


FIGURE 1-3-3
FURURE TREND OF URBANIZATION OF THUNG SONG

In Tambon Na Bon, the existing sanitary district will continue to be the central community. The area around Klong Chang Station does not seem to have more development potential than the sanitary district. While Route 41 has potential for linear development meeting further motorization.

Thung Song is expected to develop its economy based on agriculture and taking advantage of the transportation network. Development of cargo transport activities can be considered as an example.

2. WATER SOURCE

2.1 Existing Water Use Pattern

2.1.1 General

The Thung Song Municipality is located on the alluvial plain upstream of the Khlong Tao Lao. Several tributaries flow southwestward around the Municipality. The Thung Song Waterworks fully relies on one water source, the Khlong Poek, which flows 2.0 km east of the Municipality as shown in Figure 2-1-1.

2.1.2 Surface Water

The intake point is situated 1.5 km downstream of the confluence of the two streams, the Khlong Poek and Khlong Nam Tok Yong. Several concrete bricks are placed in the stream so that raw water can be fed into the sedimentation basin. There is a waterfall which contributes to the recreational area upstream of the Khlong Nam Tok Yong. Stream water is so clean that it may be drinkable without any treatment. Stream water in the Khlong Poek has good quality as well. But sand suction works along the stream cause high turbidity in raw water at the intake point.

The catchment area has a relatively flat terrace where rubber and paddy rice are mainly planted. The defects in the intake facilities are insufficient storage capacity in the dry season and sand sediment in the wet season.

The quality of raw water sampled during the field survey is given in Table 2-1-1.

Table 2-1-1 Water Quality

Item	Khlong Tha Lao	Khlong Nam Tok Yong	Khlong Poek Upstream	Khlong Poek Downstream
pH	7.0	7.5	7.1	7.3
Turbidity	4.1	1.0	3.9	58.5
Conductivity (5 x 10)	4.6	2.9	4.1	7.3

2.1.3 Ground Water

(1) Shallow Well

The Thung Song Municipality is situated on the colluvium of the small streams, so shallow wells is often seen in private houses. Most of the wells are hand-dug with brick lining. Water is drawn by a bucket and rope from approximately 3 to 5 m depth.

(2) Deep Well

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

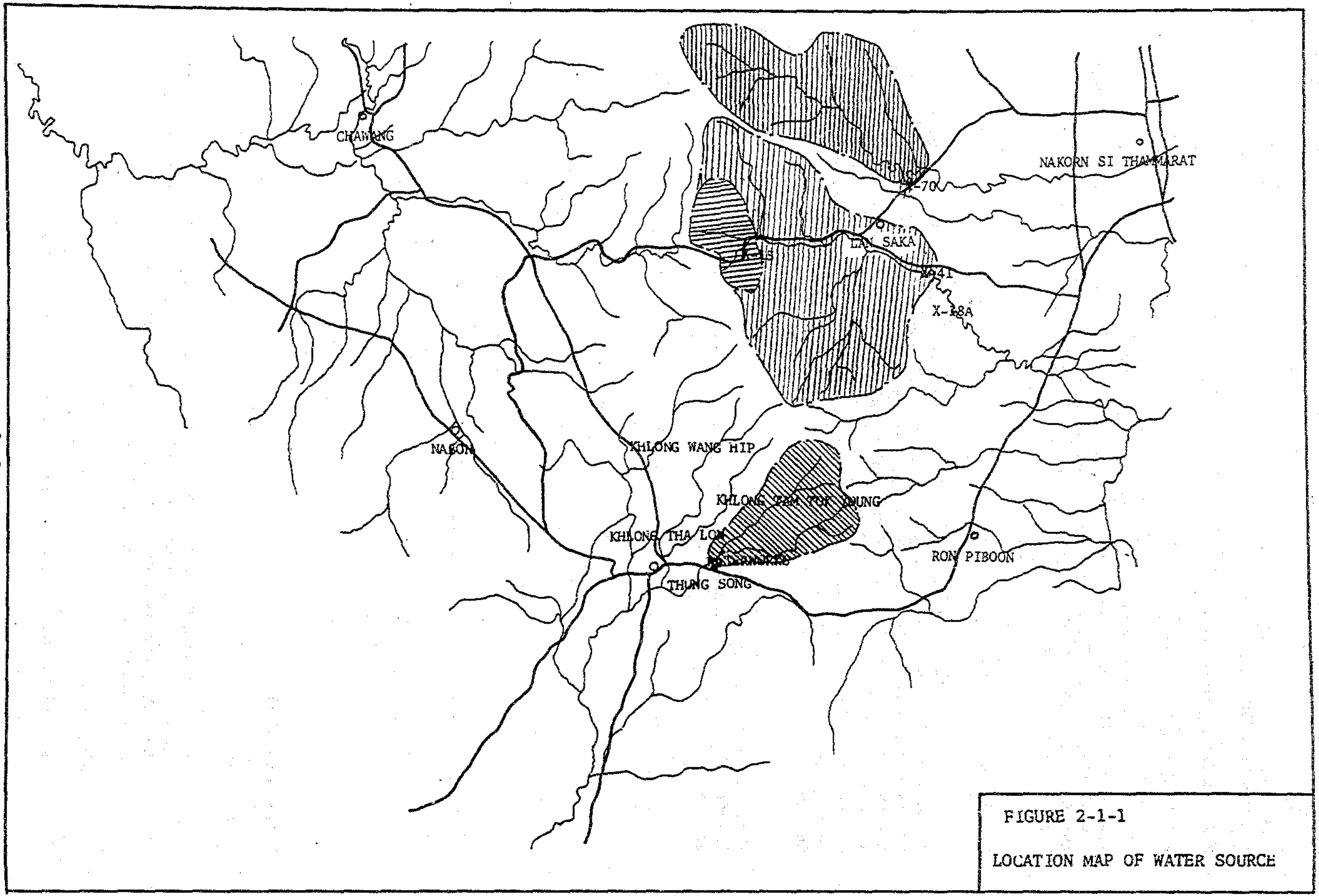


FIGURE 2-1-1

LOCATION MAP OF WATER SOURCE

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)
Ban Sahakhon M.5	1979	55	6	6	27.35	10.29	33.45	0.42	1.6	275
Nam Phu School	1977	40	6	49	20.00	5.00	130			

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 in monthly base. MD and RID are responsible for collecting and processing the data on meteorology and hydrology, respectively.

Rainfall data recorded at the amphoe offices 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 hydrology are referred from maps and reports prepared by DMR and PWA.

(2) Monthly Rainfall

Monthly rainfall data are available at six gauging stations controlled by Amphoe Thung Song, Ron Phibun, Chaweng, Lan Saka, Nakhon Si Thammarat and Kri Rat Nikom.

The rainfall stations are listed below and rainfall data are given in Tables A1-1-1 to A1-1-6.

Table 2-2-1 List of Rainfall Station

Station	location	Period of Record
Thung Song	Amphoe Thung Song	1953 to Present
Ron Phiboon	Amphoe Ron Phiboon	1956 to Present
Chaweng	Amphoe Chaweng	1956 to Present
Lan Saka	Amphoe Lan Saka	1968 to Present
Nakhon Si Thammarat	Amphoe Nakhon Si Thammarat	1951 to Present
Kri Rat Nikom	Amphoe Kri Rat Nikom	1956 to Present

(3) Climatological Data

The data describing the climatology in the Thung Song area are available at Nakhon Si Thammarat. This station observes such climatological data as temperature, atmospheric pressure, humidity, evaporation, sunshine hours and wind. The data are given in Table A1-1-7.

(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 in Table 2-2-2 and those data are given in Tables A2-2-1 and A2-2-4.

Table 2-2-2 List of Hydrological Gauging Station

Station	Location	Period of Record
X-15 (CA= 47 sq.km)	Lan Saka Nakhon Si Thammarat	1956-1959
X-70 (CA= 39 sq.km)	Muang Nakhon Si Thammarat	1967-1980
X-41 (CA= 149 sq.km)	Lan Saka Nakhon Si Thammarat	1967-1969
X-18A (CA= 163 sq.km)	Lan Saka Nakhon Si Thammarat	1962-1965

2.2.2 Availability of Existing Water Source

(1) General

Several methods as specific runoff, hydrological models and Tahal model adopted by Israel consultants in 1987 are used for estimating available amount of the existing water source, the Khlong ng Nam Tok Yong.

(2) Specific Runoff

There are four gauging stations in the neighborhood of the present intake point of the Khlong Nam Tok Yong. From the viewpoint of topographical features in the catchment area and the length of the data available, the gauging station X-70 is considered to be the most applicable for estimating the runoff at the intake point

The specific runoff at X-70 (ca=39.0 sq.km) can be applied to the present intake point of which the catchment area is 41.5 sq.km. Table 2-2-3 shows the runoff amount at the intake point. No irrigation water requirement is considered downstream.

In addition, the specific runoff at X-41 (CA=149 sq.km) and X-18A (CA=163 sq.km) are also applied to the intake point for reference (refer to Tables 2-2-4 and 2-2-5).

Table 2-2-3 Runoff at Intake Point by Specific Runoff (×-70)

(Unit : MCM/mo)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1968	2.821	1.725	1.511	1.020	1.168	0.937	0.684	0.684	0.524	4.958	7.584	12.768	36.38
1969	7.809	3.039	2.735	1.462	1.199	0.744	0.712	1.453	1.519	2.450	21.000	17.159	61.37
1970	13.167	3.166	1.910	4.137	5.157	3.778	1.937	1.966	1.820	3.904	22.562	15.646	79.15
1971	5.871	3.166	3.733	0.578	0.712	0.661	0.227	0.122	0.129	4.703	17.404	55.576	92.88
1972	5.841	1.775	0.599	5.351	2.718	1.998	1.393	0.997	2.813	6.783	12.273	11.343	53.88
1973	2.348	1.290	1.042	1.200	3.049	3.337	3.306	0.746	0.185	4.605	22.870	24.653	68.63
1974	3.562	1.806	1.658	1.486	2.593	1.694	1.393	2.163	1.957	2.878	19.899	33.545	74.63
1975	-	8.418	6.926	4.854	5.557	4.826	5.985	6.668	7.198	9.348	22.092	13.880	-
1976	4.921	3.500	2.735	2.510	4.759	4.992	2.935	-	-	7.809	33.097	14.620	-
1977	14.192	4.398	5.044	2.510	2.365	2.316	1.795	1.823	2.427	6.270	36.683	13.423	93.28
1978	7.980	3.964	2.878	3.613	4.132	5.593	0.270	2.309	-	4.275	10.949	19.466	-
1979	5.586	2.702	2.081	1.820	2.194	2.234	3.277	2.450	2.123	4.987	34.145	11.229	74.82
1980	4.559	2.214	2.109	1.876	1.767	1.765	1.767	1.937	2.151	4.331	23.085	16.787	64.34
Ave.	6.554	3.166	2.689	2.493	2.874	2.451	1.975	1.943	2.076	5.177	21.826	20.007	61.00

Note : CA = 41.5 sq.km

Runoff = Discharge at ×-70 × (41.5 / 39.0)

(3) Hydrological Model

Runoff models are established by the Tank Model Method and Multiple Regression Method, using the observed discharge record at the RID's hydrological gauging station X-70. Then these models are applied to estimate the runoff at the intake point using the catchment area rainfall from 1978 to 1987, which is the most reliable, continuous and daily data in the observed period of 20 years.

Details of these model are explained in Appendix 2-2. The result of these runoff analysis are given in Tables 2-2-6 and 2-2-7.

(4) Tahal Model

In 1987, a hydrological expert from Israel made a filed survey including stream flow gauging and established a hydrological analysis model to estimate runoff at the intake point.

Results are given in Table 2-2-8.

(5) Evaluation on Analysis Methods

The monthly average flows estimated by three methods are shown in Figure 2-2-1.

The flows estimated by Tank Model and Multiple Regression Model are unreliable especially in base flow because the gauged flow does not necessarily respond to the rainfall occurrence so that correlation between the gauged flow and rainfall is not high enough to simulate.

The flows estimated by specific runoff at X-70 are more reliable than those estimated by X-41 and X-18A because of the length of the data available. However, the flows estimated by Tahal Model are the most reliable among those three methods because the model adopted actually gauged flows in the catchment area.

(6) Availability of Existing Water Source

(a) Probability Analysis

Probability analysis is made on the following conditions:

- The return period is set at once in ten years (1/10).
- The monthly minimum flow in each year is applied.
- The flow estimated by Tahal Model is applied.
- The applied data indicate the logarithmic normal distribution as shown in Figure 2-2-2. Therefore, the method suitable for analyzing in the return period of 1/10 will be adopted.

Table 2-2-4 Runoff at Intake Point by Specific Runoff (×−41)

(Unit : MCM)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1967	3.113	1.411	0.955	2.532	3.818	2.573	2.822	3.818	2.283	6.101	19.837	16.849	66.15
1968	8.508	2.822	1.826	0.830	1.660	1.121	1.162	2.241	1.453	3.320	8.632	12.077	45.65
1969	12.492	3.445	2.039	1.619	1.287	1.204	1.370	1.079	2.988	2.864	6.889	8.798	46.07
Ave.	8.037	2.559	1.606	1.660	2.255	1.632	1.784	2.379	2.241	4.095	11.786	12.574	52.60

Note : CA = 149 sq.km

Runoff = Discharge at X-41 x (41.5 / 149)

Table 2-2-5 Runoff at Intake Point by Specific Runoff (×−18A)

(Unit : MCM)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	annual
1963	11.285	2.860	1.477	1.473	0.951	1.498	1.387	1.275	3.713	13.718	17.708	14.998	72.34
1964	9.820	4.599	2.452	2.023	4.636	2.641	2.406	2.226	1.924	2.247	3.952	20.442	59.40
1965	3.991	2.121	1.607	2.970	6.995	4.641	4.685	2.948	2.772	6.357	17.554	33.921	60.56
Ave.	8.365	3.193	1.845	2.155	4.194	2.926	2.826	2.149	2.803	7.440	13.071	23.120	74.08

Note : CA = 163 sq.km

Runoff = Discharge at X-18A x (41.5 / 163)

Table 2-2-6 Runoff at Intake Point by Tank Model

(Unit : MCM)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1978	5.099	0.275	0.084	1.829	4.609	3.698	4.357	2.932	6.741	8.470	6.279	1.647	46.02
1979	1.651	0.112	0.052	2.058	3.241	3.446	7.866	7.328	2.725	3.482	12.353	3.632	47.95
1980	0.539	0.077	2.598	4.553	5.205	4.672	1.458	0.823	4.020	5.216	13.088	20.250	62.50
1981	1.235	0.189	0.115	3.996	9.470	3.211	2.167	2.449	4.869	3.506	9.005	12.710	52.92
1982	0.634	0.267	0.237	6.436	7.821	2.361	6.367	2.368	3.734	4.209	9.672	3.563	47.67
1983	0.974	0.167	0.171	0.153	2.275	5.570	1.989	3.544	4.884	4.738	8.022	5.176	37.66
1984	4.263	5.220	1.957	4.649	5.145	3.656	7.123	1.891	3.354	3.794	7.054	16.783	64.89
1985	2.603	0.650	1.378	4.037	6.434	5.482	3.992	2.366	3.615	6.128	10.371	6.263	53.32
1986	1.161	0.088	1.501	3.017	9.749	3.250	2.178	2.838	1.336	10.935	8.767	7.201	64.05
1987	1.381	0.439	0.077	1.337	4.060	3.001	1.721	6.521	7.297	6.345	6.289	22.372	60.84
Ave.	1.954	0.748	0.817	3.206	5.800	3.834	3.921	3.306	4.257	5.862	9.090	9.959	52.57

Table 2-2-7 Runoff at Intake Point by Multiple Regression Method

(Unit : MCM)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1978	3.371	2.074	2.466	4.601	6.648	6.146	6.607	5.346	7.927	9.681	6.101	3.371	64.32
1979	3.620	2.200	2.287	5.617	5.598	6.064	9.655	8.014	4.702	6.329	12.570	3.673	70.33
1980	2.733	2.066	5.253	7.396	6.426	6.385	3.742	3.416	6.402	8.615	12.466	16.552	81.45
1981	2.459	2.342	2.602	6.459	11.132	4.063	4.927	4.625	6.696	6.325	9.583	11.121	72.34
1982	2.703	2.108	2.952	9.254	8.437	3.488	8.358	4.857	6.094	6.500	9.723	5.041	69.52
1983	2.875	2.066	2.732	2.259	6.094	6.432	4.414	5.917	7.320	6.349	8.256	6.761	61.48
1984	6.901	4.924	4.666	6.793	6.227	6.470	8.574	3.993	5.887	6.059	9.419	16.000	85.92
1985	2.368	2.964	3.814	7.393	7.533	7.029	5.830	4.481	6.223	7.909	10.487	6.706	72.74
1986	2.899	2.066	3.990	4.980	11.252	4.423	4.882	5.490	15.130	9.825	10.070	6.587	81.60
1987	3.273	2.066	2.370	3.688	6.472	5.314	4.164	9.304	8.428	8.048	7.198	19.318	79.64
Ave.	3.320	2.487	3.313	5.844	7.581	5.581	6.115	5.544	7.480	7.564	9.587	9.513	73.93

Table 2-2-8 Runoff at Intake Point by Tahal Model

(Unit : MCM)

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Annual
1953	1.49	10.31	7.05	5.15	3.18	6.86	16.42	18.29	2.86	2.70	1.33	1.57	77.20
1954	1.49	2.44	2.99	8.05	2.78	2.77	1.83	1.70	1.14	0.63	0.71	0.72	27.20
1955	1.09	1.65	3.54	2.17	3.42	4.95	7.89	10.25	4.05	2.46	1.75	1.40	44.60
1956	3.89	4.79	3.56	2.55	3.59	6.22	10.67	5.46	5.69	2.52	2.56	2.67	54.20
1957	2.50	3.82	1.69	5.65	2.53	4.58	6.83	3.94	5.33	1.74	1.16	1.16	40.90
1958	0.90	5.00	2.86	1.78	6.63	5.15	14.05	29.16	2.51	2.30	1.33	2.50	74.20
1959	3.29	3.83	2.33	3.71	3.32	3.02	5.59	7.03	8.17	2.82	2.17	2.79	48.10
1960	3.99	2.70	2.31	4.80	2.72	3.20	5.48	5.17	2.98	1.26	2.03	1.47	38.10
1961	2.45	4.01	4.25	4.51	2.71	3.08	7.33	10.85	9.36	4.29	2.15	2.04	57.00
1962	2.09	2.54	3.19	5.02	6.93	4.11	11.26	8.79	4.39	2.85	1.34	1.01	53.50
1963	0.75	1.42	3.85	2.81	4.34	6.07	10.87	13.14	4.24	4.91	2.50	2.08	57.10
1964	1.28	8.31	3.04	6.42	5.35	6.77	6.55	6.33	16.03	2.61	2.86	2.65	68.20
1965	4.00	5.11	4.06	5.71	6.71	9.63	7.56	17.68	11.86	3.92	3.12	5.95	85.30
1966	1.96	3.70	5.51	3.74	5.53	4.12	7.00	20.88	17.47	6.34	2.43	1.70	80.40
1967	2.36	2.65	3.58	7.55	4.80	3.82	7.25	7.66	3.30	1.91	1.39	3.20	49.50
1968	1.73	6.48	5.62	5.52	7.71	4.59	9.29	3.44	2.03	2.45	1.12	1.45	51.40
1969	1.09	4.54	4.96	3.74	5.15	8.46	8.17	17.23	4.67	5.90	2.13	1.47	67.50
1970	1.05	3.64	2.97	4.23	6.55	4.88	7.58	17.60	7.85	2.37	2.67	4.13	65.50
1971	1.19	4.66	3.36	1.99	4.87	6.13	16.60	8.88	10.77	2.65	2.30	1.47	64.90
1972	1.86	5.24	6.82	3.53	2.87	9.55	8.12	12.35	4.21	2.02	1.36	1.38	59.30
1973	1.62	5.80	3.23	8.33	3.71	5.41	8.38	15.55	7.22	2.38	2.66	1.60	65.90
1974	3.55	11.90	5.36	3.81	4.59	5.01	7.24	12.16	17.86	17.07	4.08	1.79	94.40
1975	2.62	8.37	7.69	4.86	3.37	4.05	5.56	6.43	4.09	1.36	1.00	1.36	50.80
1976	4.24	5.12	2.36	3.22	6.03	4.93	7.36	16.79	3.83	2.61	1.44	1.10	59.00
1977	0.93	2.45	1.86	3.62	4.68	6.39	5.48	11.39	3.60	2.28	1.41	1.31	45.40
1978	2.32	3.83	5.05	6.33	3.56	7.06	8.39	3.54	3.89	1.85	1.00	0.71	47.50
1979	2.22	3.64	3.18	9.49	5.40	8.44	3.61	8.45	2.79	1.92	1.27	3.67	54.10
1980	5.14	4.37	5.23	5.03	8.01	3.57	6.49	16.76	3.62	2.03	1.74	1.05	63.00
1981	4.62	9.44	3.38	3.86	2.59	4.08	3.11	7.90	6.13	1.74	1.30	1.81	50.00
1982	10.58	7.02	3.23	8.17	4.47	5.53	5.50	5.33	3.03	1.78	0.91	1.25	56.80
1983	0.51	3.73	4.34	2.71	4.78	5.33	5.40	4.30	3.07	4.17	2.13	2.57	43.00
1984	3.55	4.88	4.62	5.08	3.13	3.20	2.55	5.50	7.86	1.83	1.89	1.75	46.60
1985	4.72	5.51	5.38	4.84	3.58	5.29	7.02	7.55	4.80	1.99	1.36	3.09	55.10
1986	1.94	9.16	3.99	8.86	4.51	19.66	12.11	8.73	4.29	1.80	1.35	1.01	72.40

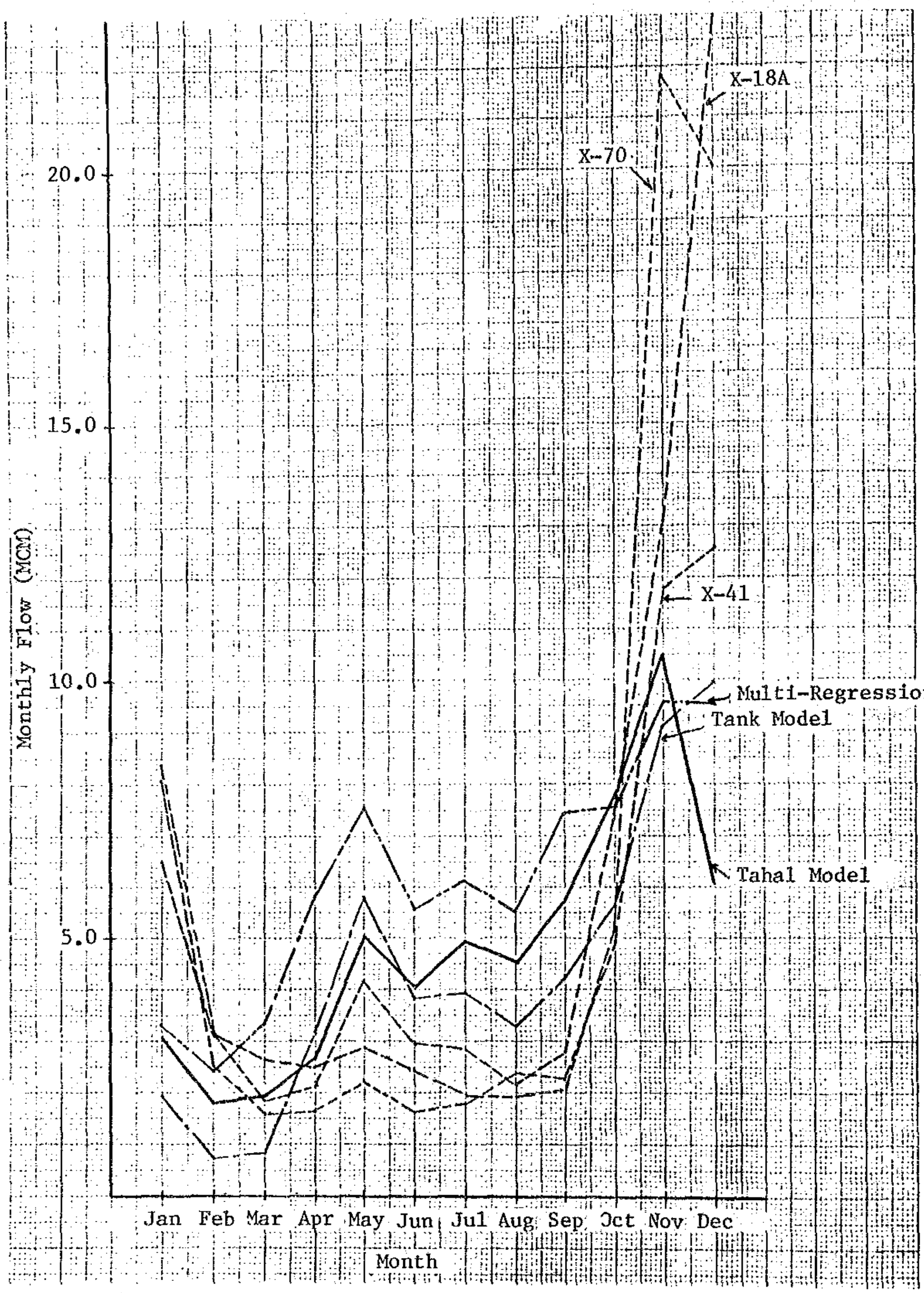


FIGURE 2 - 2 - 1
MONTHLY AVERAGE FLOW

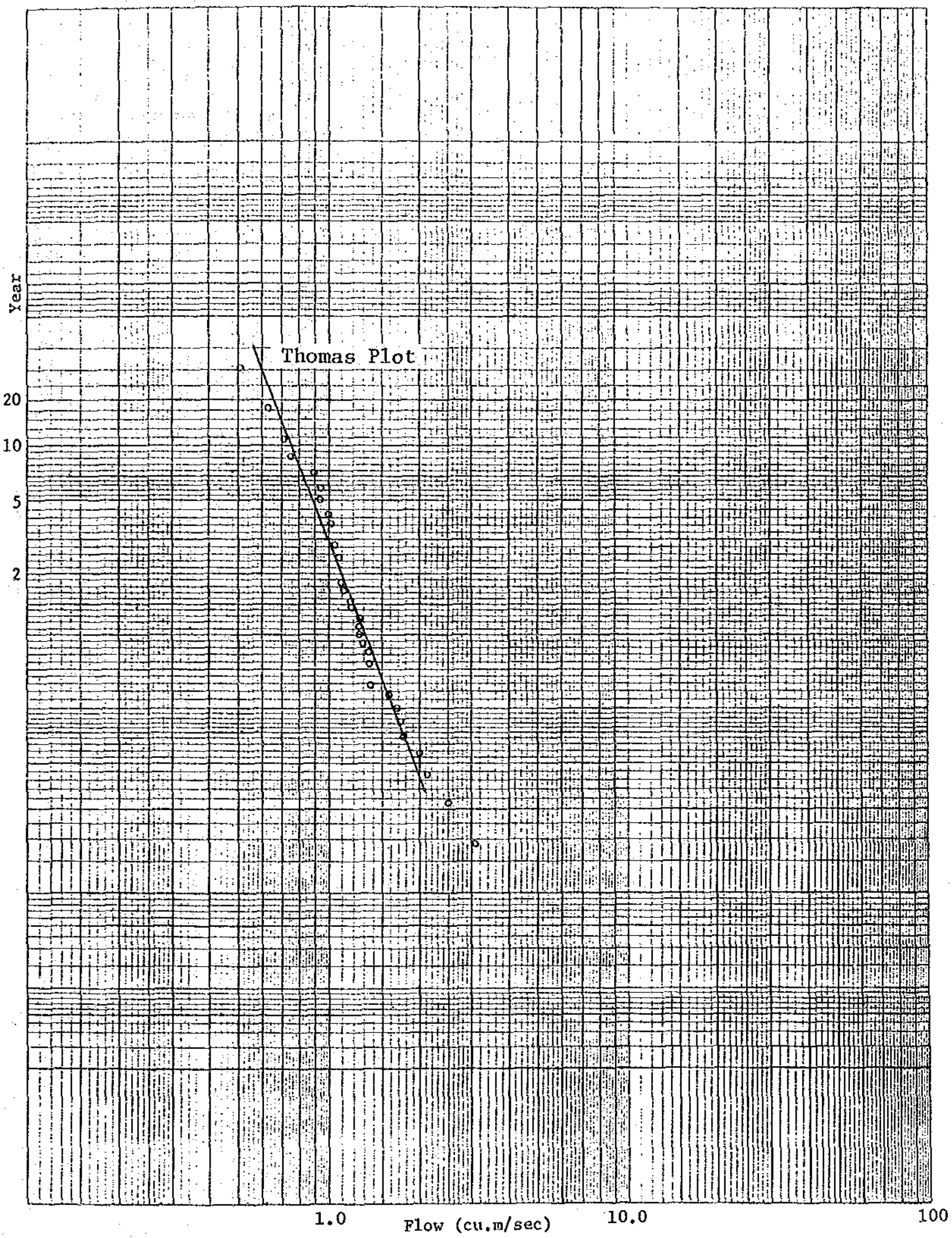


FIGURE 2-2-2
LOGARITHMIC NORMAL DISTRIBUTION

Table 2-2-9 Monthly Flow of the Poek River by Tahal Model

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

ORDER	YEAR	X	LOG-X	Y=X+B	LOG-Y	(LOG-Y)**2	TOMAS(%)	HAZEN(%)	X**2
1	1983	0.51	-0.29243	0.386	-0.41345	0.17094	97.14	98.53	0.260
2	1954	0.63	-0.20066	0.506	-0.29587	0.08754	94.29	95.59	0.397
3	1978	0.71	-0.14874	0.586	-0.23212	0.05388	91.43	92.65	0.504
4	1963	0.75	-0.12494	0.626	-0.20345	0.04139	88.57	89.71	0.563
5	1958	0.90	-0.04576	0.776	-0.11015	0.01213	85.71	86.76	0.810
6	1982	0.91	-0.04096	0.786	-0.10459	0.01094	82.86	83.82	0.828
7	1977	0.93	-0.03152	0.806	-0.09368	0.00878	80.00	80.88	0.865
8	1975	1.00	0.00000	0.876	-0.05751	0.00331	77.14	77.94	1.000
9	1962	1.01	0.00432	0.886	-0.05258	0.00276	74.29	75.00	1.020
10	1986	1.01	0.00432	0.886	-0.05258	0.00276	74.29	75.00	1.020
11	1970	1.05	0.02119	0.926	-0.03340	0.00112	68.57	69.12	1.102
12	1980	1.05	0.02119	0.926	-0.03340	0.00112	68.57	69.12	1.102
13	1955	1.09	0.03743	0.966	-0.01504	0.00023	62.86	63.24	1.188
14	1969	1.09	0.03743	0.966	-0.01504	0.00023	62.86	63.24	1.188
15	1976	1.10	0.04139	0.976	-0.01056	0.00011	57.14	57.35	1.210
16	1968	1.12	0.04922	0.996	-0.00175	0.00000	54.29	54.41	1.254
17	1957	1.16	0.06446	1.036	0.01535	0.00024	51.43	51.47	1.346
18	1971	1.19	0.07555	1.066	0.02775	0.00077	48.57	48.53	1.416
19	1960	1.26	0.10037	1.136	0.05537	0.00307	45.71	45.59	1.588
20	1979	1.27	0.10380	1.146	0.05917	0.00350	42.86	42.65	1.613
21	1964	1.28	0.10721	1.156	0.06295	0.00396	40.00	39.71	1.638
22	1981	1.30	0.11394	1.176	0.07040	0.00496	37.14	36.76	1.690
23	1953	1.33	0.12385	1.206	0.08134	0.00662	34.29	33.82	1.769
24	1972	1.36	0.13354	1.236	0.09201	0.00847	31.43	30.88	1.850
25	1985	1.36	0.13354	1.236	0.09201	0.00847	31.43	30.88	1.850
26	1967	1.39	0.14301	1.266	0.10242	0.01049	25.71	25.00	1.932
27	1973	1.60	0.20412	1.476	0.16908	0.02859	22.86	22.06	2.560
28	1966	1.70	0.23045	1.576	0.19755	0.03903	20.00	19.12	2.890
29	1984	1.75	0.24304	1.626	0.21111	0.04457	17.14	16.18	3.062
30	1974	1.79	0.25285	1.666	0.22167	0.04914	14.29	13.24	3.204
31	1961	2.04	0.30963	1.916	0.28239	0.07974	11.43	10.29	4.162
32	1959	2.17	0.33646	2.046	0.31090	0.09666	8.57	7.35	4.709
33	1956	2.52	0.40140	2.396	0.37948	0.14401	5.71	4.41	6.350
34	1965	3.12	0.49415	2.996	0.47654	0.22709	2.86	1.47	9.734
TOTAL		44.45	2.90286		1.18229	1.15658			67.675
(1/N)		1.31	0.08538		0.03477	0.03402			1.990

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

ORDER	XI	XS	XI*XS	XI+XS	XI*XS-X0**2	2X0-(XI+XS)	BI
1	0.510	3.120	1.591	3.630	0.110	-1.196	-0.092
2	0.630	2.520	1.588	3.150	0.106	-0.716	-0.148
3	0.710	2.170	1.541	2.880	0.059	-0.446	-0.132
TOTAL							-0.372
						B=	-0.124

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

RETURN PERIOD YEAR	(MCM)	RETURN PERIOD YEAR	(MCM)
2	1.207	5	0.883
10	0.754	15	0.698
20	0.664		

(b) Minimum Flow

The minimum flow at the existing intake point is estimated at 0.75 MCM/mo in the return period of 1/10, while the availability of the existing water source is considered to be sufficient for the water demand even in the target year of 2011.

Table 2-2-10 Minimum Flow at Intake Point

(Unit : MCM/mo)

Method	Return Period 1/2	1/5	1/10
1. Specific Runoff			
X-70	0.94	0.42	0.21
X-41	1.09	0.99	0.94
X-184	1.43	1.05	0.90
2. Hydrological Model			
Tank	0.14	0.07	0.06
Multi-Regression	2.14	2.06	2.05
3. Tank Model	1.20	0.88	0.75
Applied	1.20	0.88	0.75

(c) Water Balance

The annual flow is estimated at 56.54, 45.73 and 40.76 MCM in the return period of 1/2, 1/5 and 1/10, respectively. Table 2-2-8 shows that the annual flow in 1957 has the same amount as that in the return period of 1/10. Therefore, water balance is described in Figure 2-2-3.

2.3 Developability of Alternative Water Source

2.3.1 General

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

- Construction of a concrete weir with a gate at the present intake point.
- Diversion from the Khlong Tha Long.
- Construction of a multi-purpose dam upstream of the Khlong Wang Hip.
- Ground water development

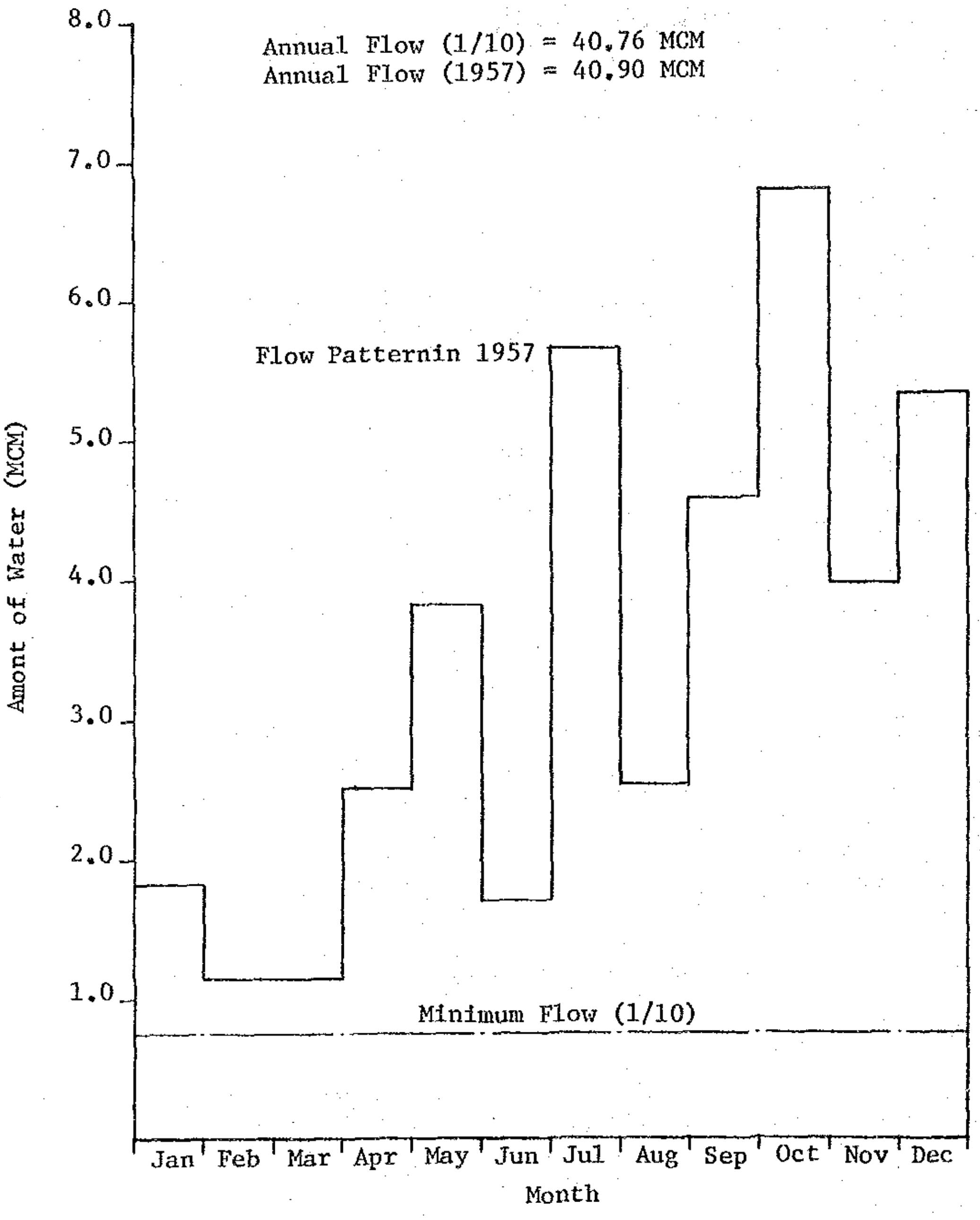


FIGURE 2-2-3

WATER BALANCE

2.3.2 Surface Water

(1) Construction of Concrete Weir

The Khlong Nam Tok Yong has a sufficient flow all year round, but for the purpose of securing stable intake and draining sediment deposited during the flood, a fixed concrete weir with a gate should be constructed at the present intake point.

(2) Diversion from the Khlong Tha Lon

The Khlong Tha Lon has a catchment area of 23.5 sq.km supplying irrigation water downstream. A surplus water can be diverted through a pipeline into the Khlong Tha Lon to increase the intake amount.

(3) Construction of Multi-purpose Dam

An irrigation weir was constructed by RID upstream of the Khlong Wang Hip 8 km north of Thung Song. The point has a catchment area of 30.1 sq.km and suitable topographic features for a concrete dam.

If necessity comes in the future, a multi-purpose dam can be constructed for the purpose of irrigation, water supply and flood control.

2.3.3 Ground Water

(1) Study by DMR

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

(a) Carbonate Aquifer

Carbonate aquifer comprising the Ordorician limestone of the Thung Song Group can be found in the north of the Municipality. The Ordorician limestone are generally dark in color, massive to thin bedded, sand and argillaceous. Ground water occurs mainly in solution cavities, bedding planes, contact zones between limestone and interbedded shale and fault zones. The yield generally ranges from 13.7 - 27.3 cu.m/h (50-100 gpm).

(b) Metamorphic Aquifers

Metamorphic aquifer consisting of poorly to well bedded quartzite, phyllite, slate and schist occurs in the middle terrace around the Municipality. Ground water is developed in many places although some wells penetrating the relatively recent tissues may yield sufficient amount of water for domestic purposes.

(2) Study by PWA

PWA conducted the hydrological survey with the electrical resistivity and boring in Thung Song.

The study revealed that the ground water yield from high weathered lime stone (15 - 35 m in depth) and low weathered lime stone (35 - 60 m in depth) is estimated at 10 - 30 cu.m/h.

The study recommended that the deep wells with a depth of 60 m and a diameter of 100 - 150 mm should be constructed in the treatment plant of the Thung Song Waterworks.

3. EXISTING WATER SUPPLY SYSTEM

3.1 Existing Water Supply System

3.1.1 General

The waterworks for the Municipality of Thung Song was founded in 1961. The treatment plant which had a capacity of 40 cu.m/h took raw water from a canal flowing in Thung Song. In 1969, a new treatment plant, with a capacity of 160 cu.m/h, was constructed some 3.5 km away from the existing treatment plant that was soon abandoned due to the deterioration of raw water quality. The water source for the new treatment plant is the surface water of the Tha Phae River which originates from the Yong Waterfall. The improvement works for the new treatment plant was completed in February 1988 which expanded the treatment capacity of the plant from 160 cu.m/h to 240 cu.m/h.

The waterworks office is presently located in the old treatment plant next to the municipal office, but is expected to transfer to the premises of the new treatment plant.

3.1.2 Treatment

The raw water taken by pumping from the Tha Phae River is fed into the 160 cu.m/h treatment plant. The treatment process consists of chemical flocculation, sedimentation, rapid filtration and chlorination. The clear water is stored in two (2) clear water reservoirs with a total capacity of 2,000 cu.m and is distributed directly by the clear water pumps. Backwash water for rapid sand filters is obtained from a pipeline connected to the backwash pumps.

Elements comprising the treatment plant are 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

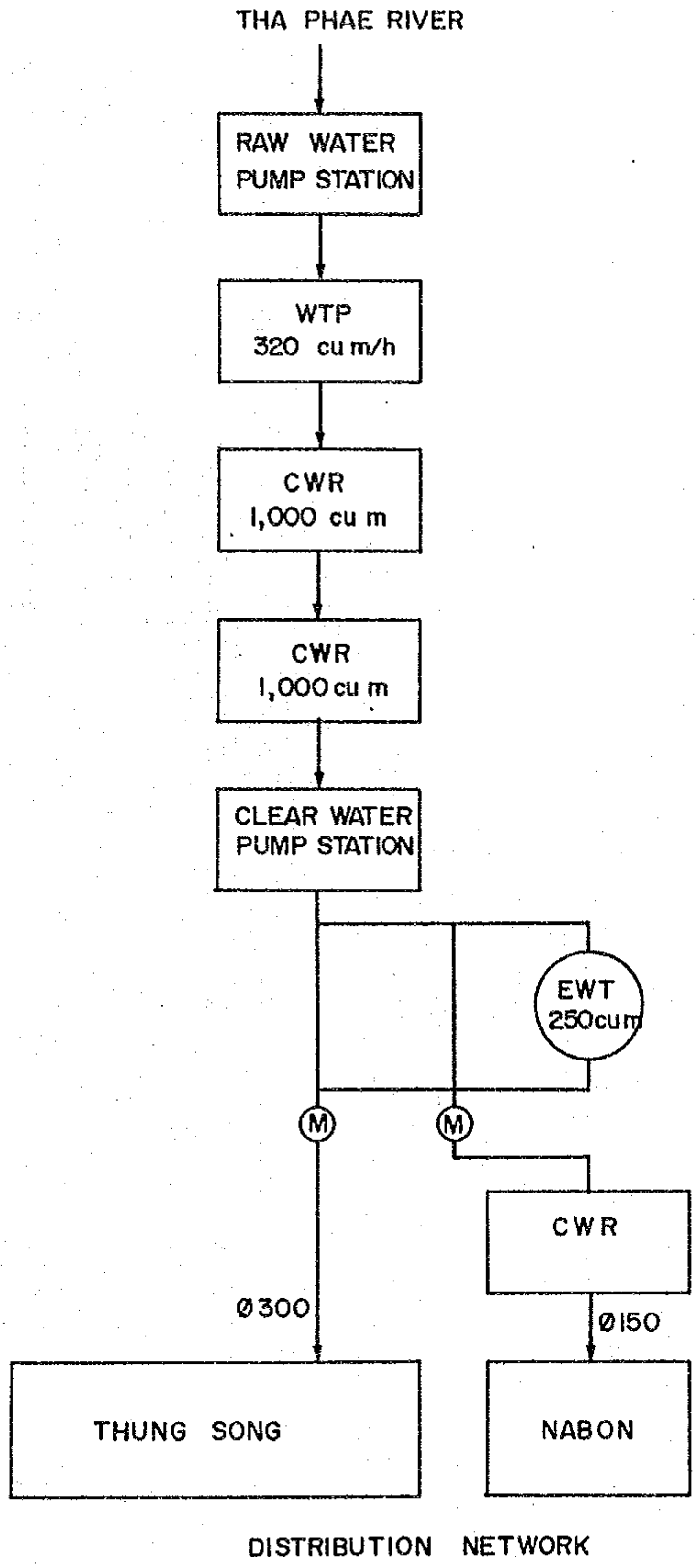
The distribution system of the Thung Song Waterworks covers the center of the town and extends to the prison by direct pumping from the water treatment plant. Na Bon is located about 14 km north of the Thung Song Municipality. The distribution system in Na Bon consists of a receiving tank and pipeline which has a total length of 2,500 m.

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

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

Table 3-1-1 Outline of Water Treatment Facilities

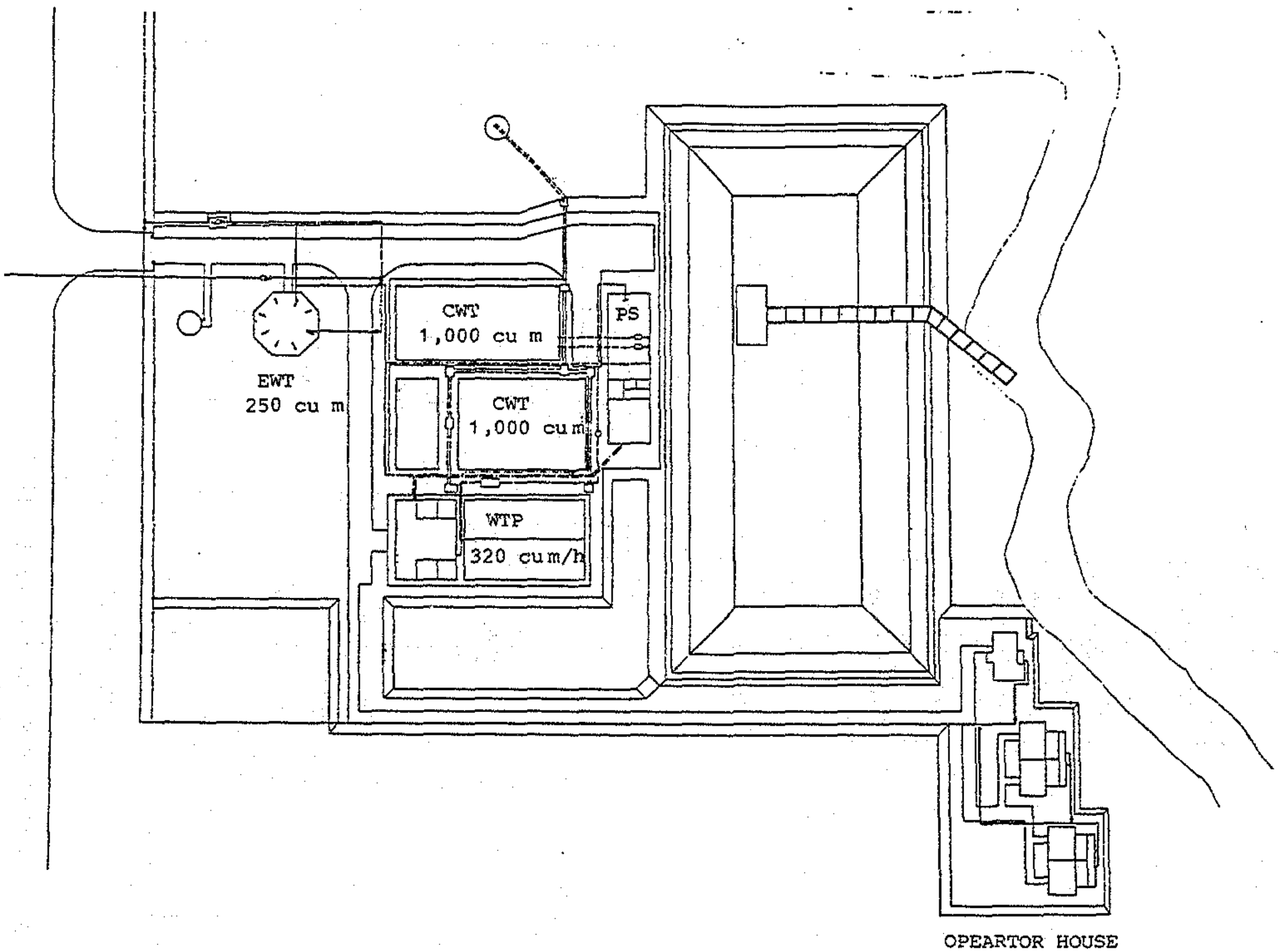
Water Source	Tha Phae River (Yong Waterfall)
Treatment Capacity	320 cu.m/h
Treatment Facilities	
Raw Water Pump	220 cu.m/h x 15 m x 18 hp x 2 units motor-driven 80 cu.m/h x 10 m x 5 hp x 1 unit motor-driven 180 cu.m/h x 15 m x 14 ps x 1 unit engine-driven
Flocculation Basin	
No. of Units	2 units
Dimensions	3.00 m x 8.64 m x 2.40 m
Flocculation Time	23.3 min
Sedimentation Basin	
No. of Units	2 units
Dimensions	3.00 m x 27.35 m x 2.90 m
Sedimentation Time	1.5 h
Rapid Sand Filter	
No. of Units	4 units
Dimensions	2.80 m x 3.80 m
Filtration Rate	180.5 m/d
Clear Water Reservoir	
No. of Units	2 units
Dimensions	1,000 cu.m
Detention Time	6.3 hours
Water Elevated Tank	
No. of Units	1 unit
Capacity	250 cu.m
Detention Time	0.78 h
Clear Water Pump	220 cu.m/h x 35 m x 40 hp x 2 units motor-driven
Backwash Water Pump	100 cu.m/h x 30 m x 20 hp x 1 unit motor-driven 550 cu.m/h x 15 m x 60 kw x 1 unit motor-driven 200 cu.m/h x 30 m x kw x 1 unit engine-driven



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

FIGURE 3-1-1

THUNG SONG EXISTING WATER TREATMENT SYSTEM



WTP : WATER TREATMENT PLANT
CWR : CLEAR WATER RESERVOIR
EWT : ELEVATED WATER TANK
PS : PUMP STATION

FIGURE 3-1-2
THUNG SONG
WATER TREATMENT PLANT

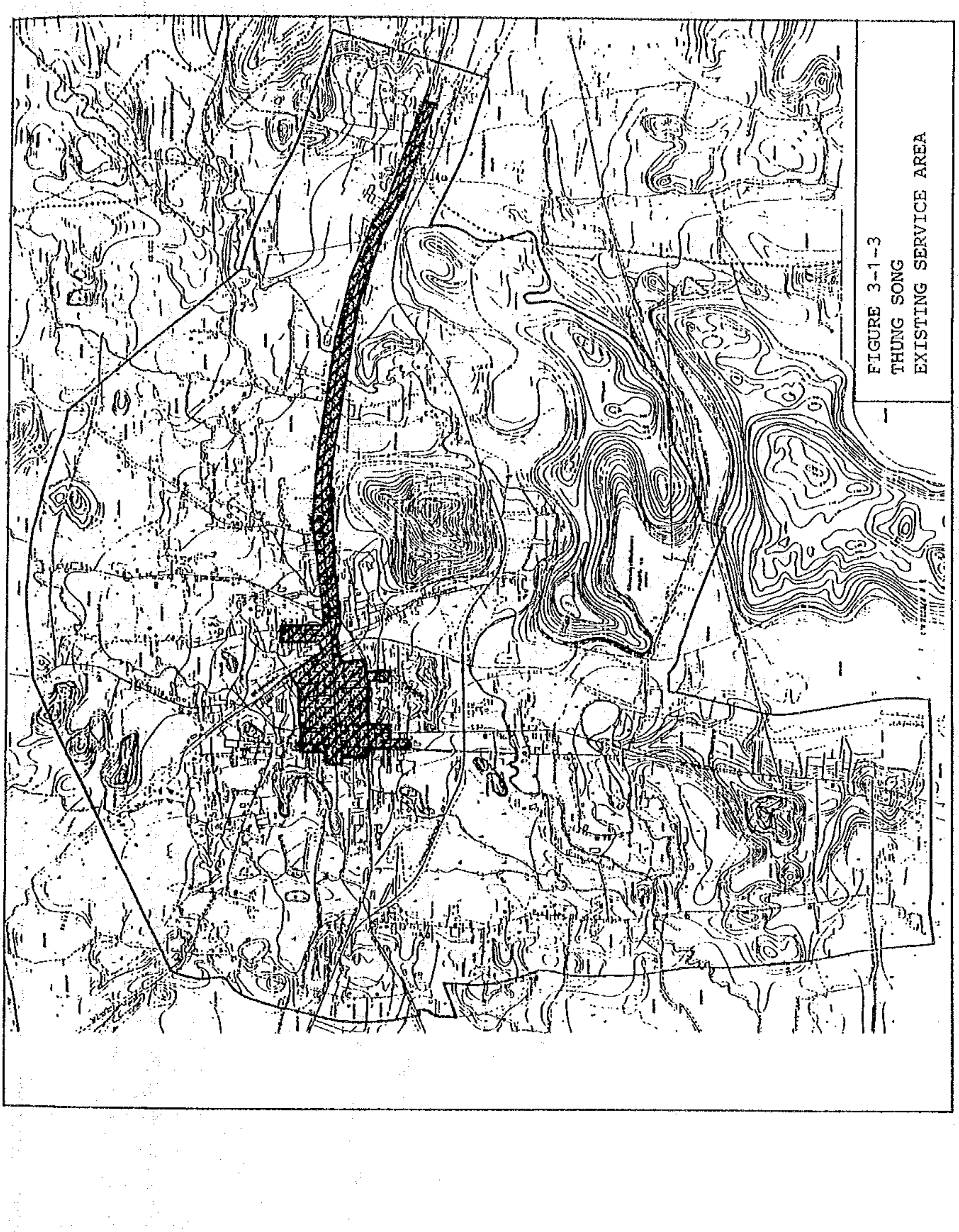


FIGURE 3-1-3
THUNG SONG
EXISTING SERVICE AREA

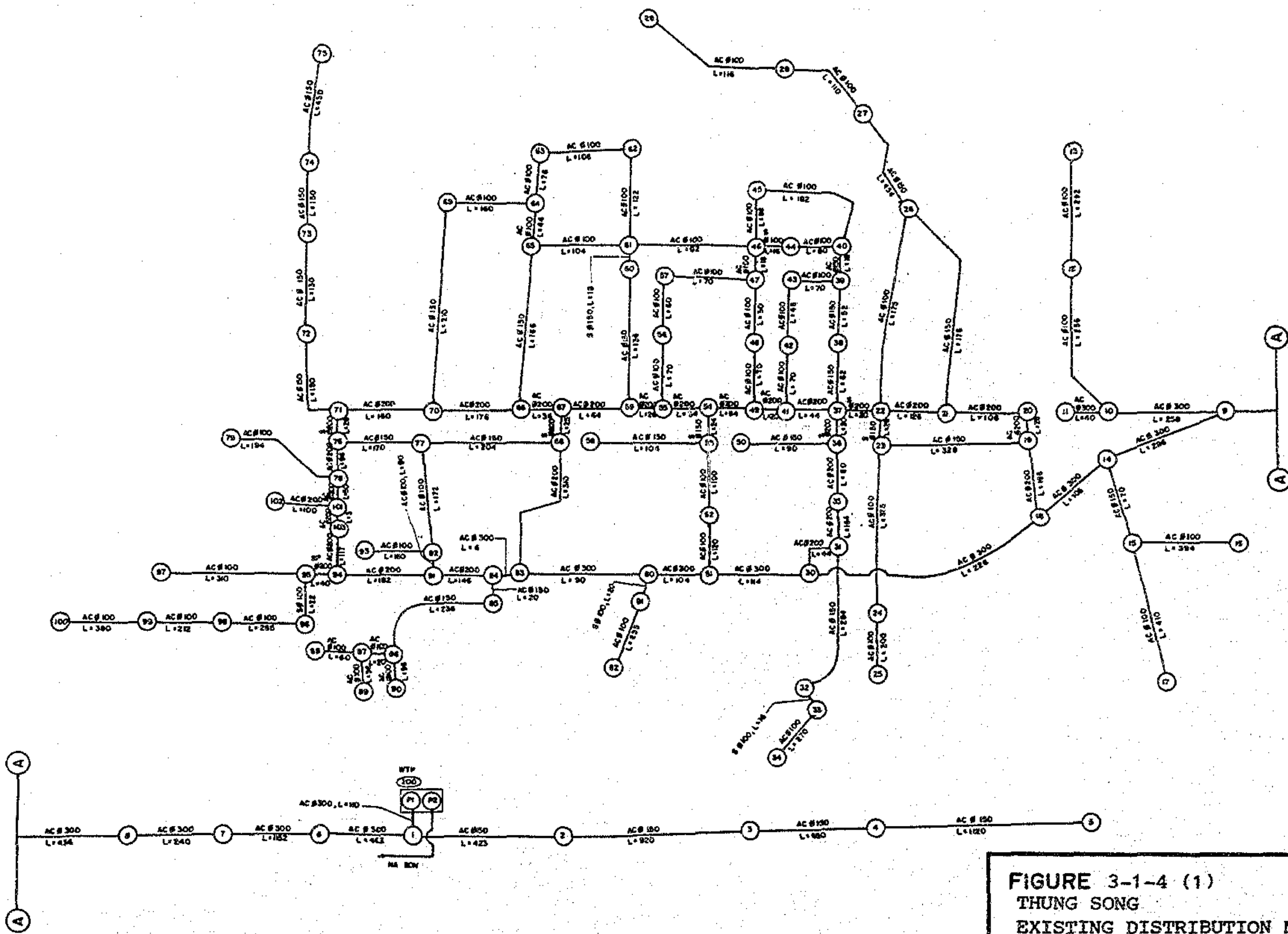


FIGURE 3-1-4 (1)
THUNG SONG
EXISTING DISTRIBUTION NETWORK
(THUNG SONG)

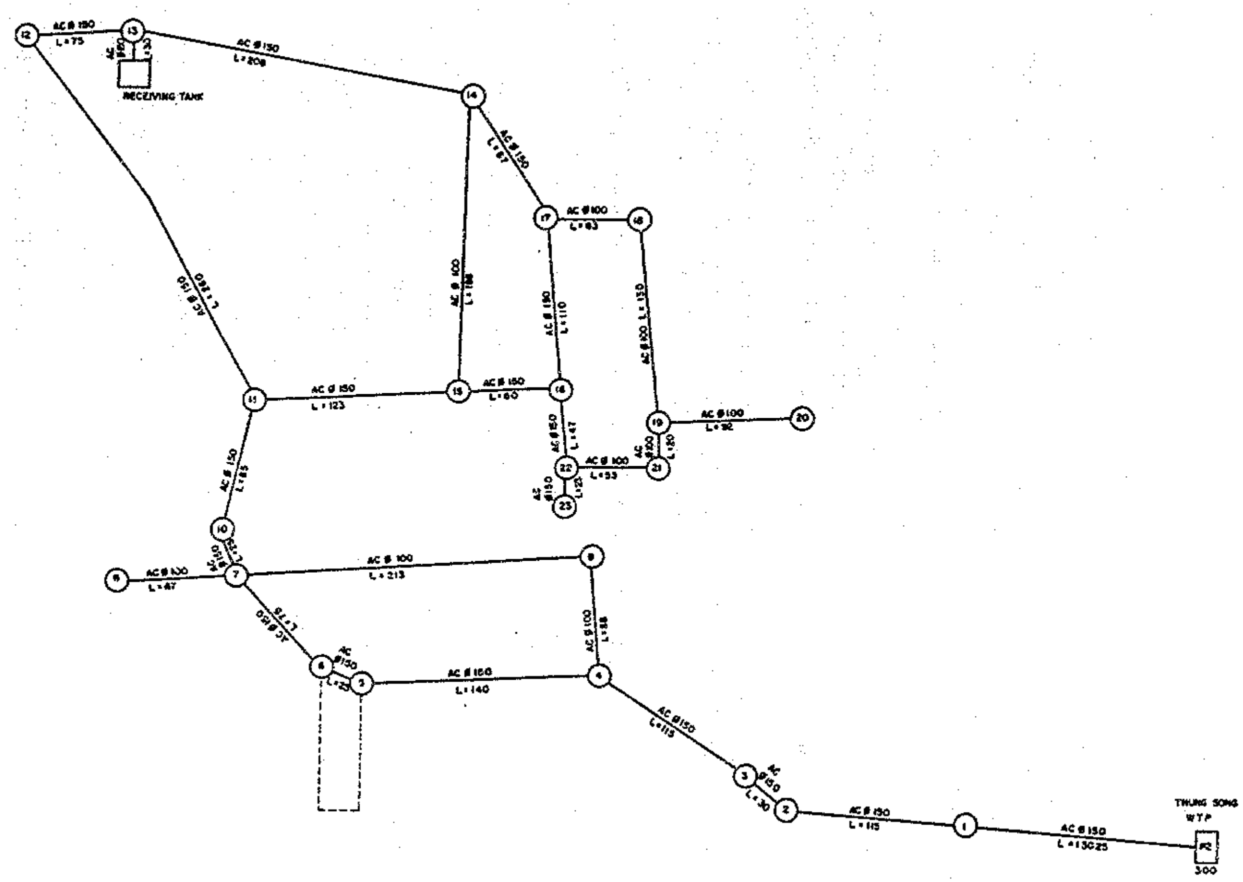


FIGURE 3-1-4 (2)
THUNG SONG
EXISTING DISTRIBUTION NETWORK
(NABON)

Table 3-1-2 Distribution Pipe

Dia. (mm)	Approximate Length (m)	Material
(Thung Song)		
300	3,600	AC
200	2,400	AC
150	7,100	AC
100	6,800	AC
(Na Bon)		
150	1,600	AC
100	910	AC
Transmission Pipe Thung Song - Na Bon	13,000	AC
Total	35,410	

The elevated tank is presently not in use because it lacks sufficient head to deliver treated water. Pumps are turned on and off manually while operators observe the pressure at the delivery side of pumps.

Pumps for transmitting treated water to Na Bon is installed separately from the other high lift pumps. This pump is sometimes not operated such that water shortage results in Na Bon.

The number of connections to the waterworks is as shown in Table 3-1-3.

Table 3-1-3 Number of Connections

Year	No. of Connections
1980	2,799
1981	2,926
1982	3,024
1983	3,126
1984	3,196
1985	3,368
1986	3,549
1987	3,799

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

Another defect is that most of the meters cannot detect small flows of less than 5 l/hr. Therefore, some consumers collect water in pots or jars just by choking their faucets to the stated level.
The defects of the meters as described above will be reflected when considering the 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 therefore as required. The model uses the 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 networks, with adjustments made in the hydraulic grade line to satisfy the continuity equation at each junction.

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

Estimates of the Hazen-Williams discharge coefficients for existing pipeline are made based on the age of pipes which was obtained from the Thung Song 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 enough treated water to meet the daily maximum demand and the hourly maximum demand (5,448 cu.m/d or 1.35 times the daily maximum demand).

(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 showed that a pressure of about 25m in water column is required at the existing treatment plant. The results are shown with pressure contour lines in Figure 3-1-5 , and the computer output of distribution network analysis are presented in the separate volume.

The results show that there are adequate pressure throughout the system in Thung Song, except a pipeline locating east of the existing water treatment plant. They show similar conditions to the actual field measurement described in Appendix 3-1.

In Na bon, the minimum service pressure for the maximum hourly flow is a little less than 1.0 kg/sq.cm near the existing receiving tank. Other area, however, has adequate pressure.

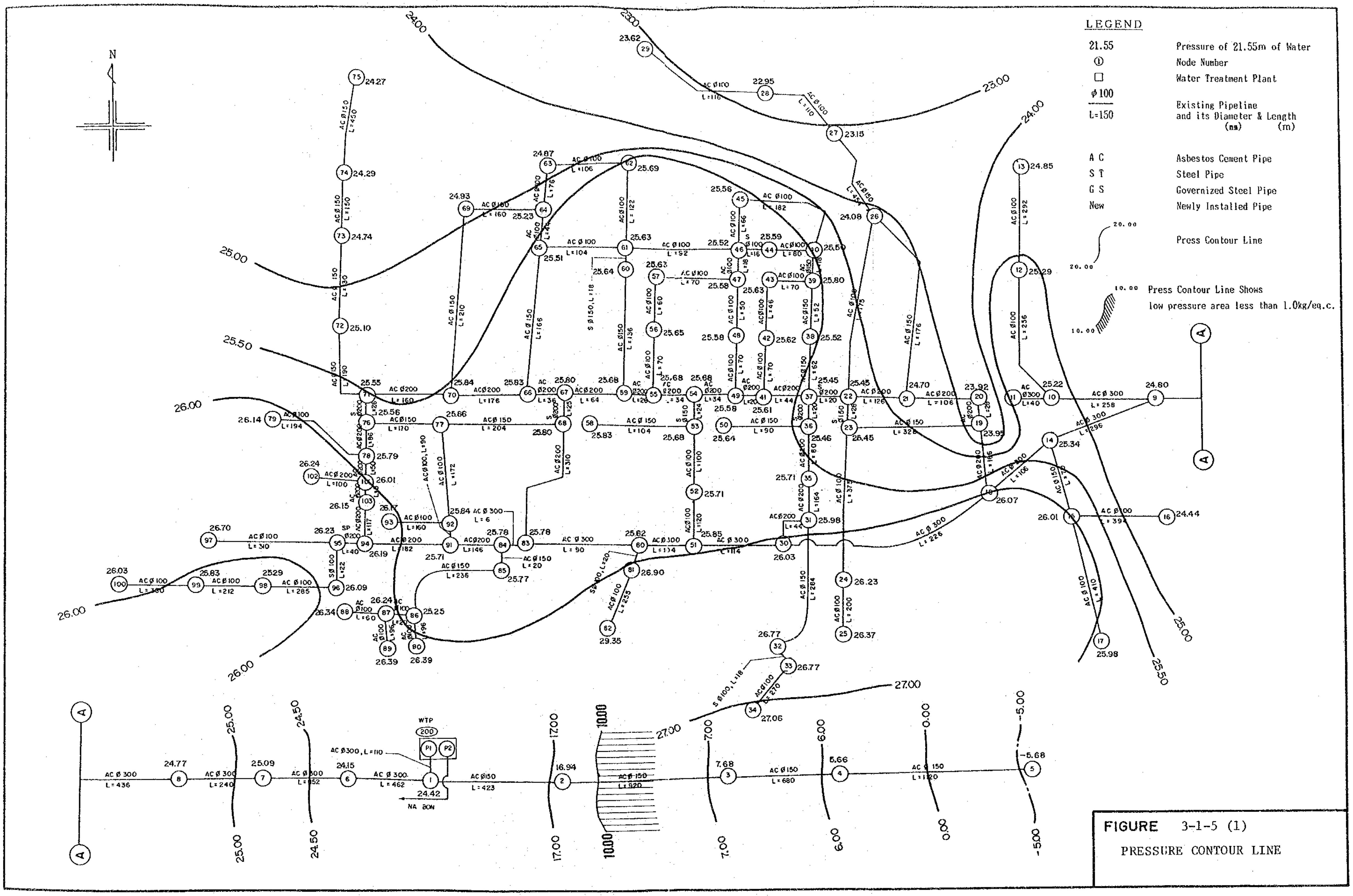


FIGURE 3-1-5 (1)

PRESSURE CONTOUR LINE

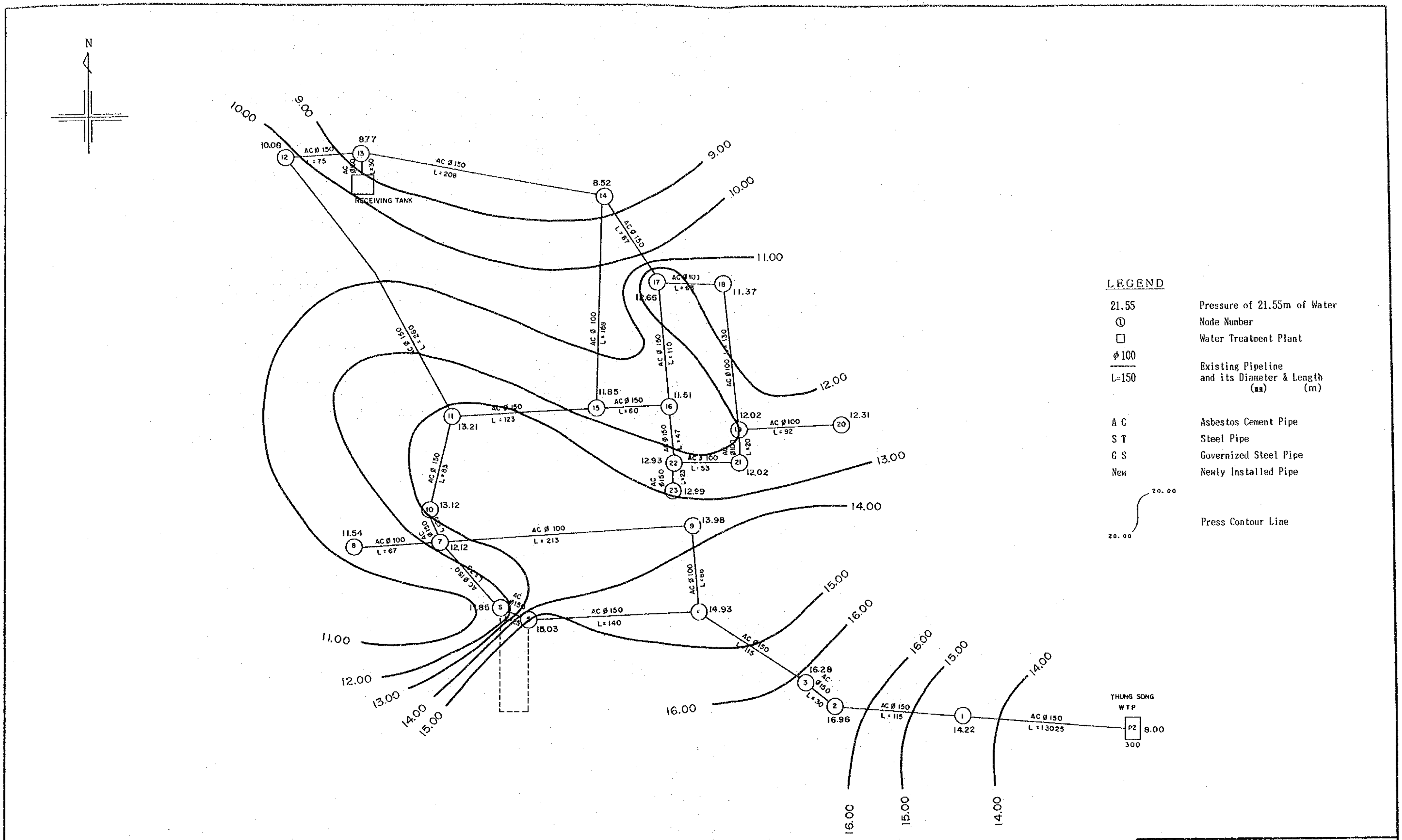


FIGURE 3-1-5 (2)
PRESSURE CONTOUR LINE

3.2 Operation and Maintenance

The operations status for the past two year from October 1986 to July 1988 is shown in Table 3-2-1.

The average water production is 202.5 cu.m/h. This is lower than the expanded treatment capacity of 240 cu.m/d. There are big fluctuations in monthly water production with a minimum average of 82.1% in September 1987 and a maximum average of 115.2% in June 1988, though the maximum is still within the treatment capacity. However, since the variations do not correspond to those in water demand this could result to the increase of unaccounted- for water. The average treatment loss is 2.3% which is a reasonable level.

About 92.6% of the water produced for sale is distributed to Thung Song and the remaining 7.4% to Nabon.

The monthly alum dosage rates are within a narrow range of 7.4 mg/l and 13.8 mg/l excluding the maximum and minimum. According to the results of the jar test, the optimum dosage rate is 5.0 mg/l, which is lower than the actual one.

For pH control, lime is rarely added throughout the year.

Although the treatment capacity was doubled from March 1988 by modifying the sedimentation basins and rapid sand filters, no big change is found in quality of treated water up to now. Backwash of rapid sand filters is elaborately conducted once everyday, although the mud balls are found on the surface of the sand layer.

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	154685	151917	159152	161150	146403	159043	141323	130726	129170	127145	127428	121468	1709610	142468
Ground Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface Water	154685	151917	159152	161150	146403	159043	141323	130726	129170	127145	127428	121468	1709610	142468
*Variation	1.086	1.066	1.117	1.131	1.028	1.116	0.992	0.918	0.907	0.892	0.894	0.853	-	-
B) Raw Water Used	400	400	400	440	440	440	440	440	440	440	440	440	5160	430
Sedimentation Basin	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drainage	400	400	400	400	400	400	400	400	400	400	400	400	4800	400
Waste	0	0	0	40	40	40	40	40	40	40	40	40	360	30
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*(B)/(A)	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.003	-
C) Treated Water	154285	151517	158752	160710	145963	158603	140883	130286	128730	126705	126988	121028	1704450	142038
*Variation	1.086	1.067	1.118	1.131	1.028	1.117	0.992	0.917	0.906	0.892	0.894	0.852	-	-
D) Treated Water Used	2410	2500	2000	2000	2000	2250	2500	2500	2500	2500	2500	2500	28160	2347
Filter Washing	1910	2000	1500	1500	1500	1750	2000	2000	2000	2000	2000	2000	22160	1847
Chemical Mixing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Engine	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sedimentation Basin	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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	500	500	500	500	500	500	500	500	500	500	500	500	6000	500
Used in Houses	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*(D)/(C)	0.016	0.016	0.013	0.012	0.014	0.014	0.018	0.019	0.019	0.020	0.020	0.021	0.017	-
E) Distributed Water	151513	148530	158235	149975	137028	144461	128559	116713	110229	111869	114798	107840	1579800	131650
*Variation	1.151	1.129	1.202	1.139	1.041	1.097	0.977	0.887	0.837	0.850	0.872	0.819	-	-
F) Sold Water	90793	98441	90856	104537	102918	101513	121443	120392	103637	108116	109520	101163	1253329	104444
Connection Meters	90781	98390	90853	104450	102732	101355	120998	120362	103385	107940	109022	100972	1251240	104270
Public Meters	12	51	3	87	186	158	445	30	252	176	498	191	2089	174
Lump Sum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*Variation	0.869	0.943	0.870	1.001	0.985	0.972	1.163	1.153	0.992	1.035	1.049	0.969	-	-
G) Unaccounted-for Water	60720	50139	67379	45438	34110	42948	7116	-3679	6592	3753	5278	6677	326471	27205
*(G)/(E)	0.401	0.337	0.426	0.303	0.249	0.297	0.055	-0.032	0.060	0.034	0.046	0.062	0.207	-
H) No. of Connections	3568	3582	3612	3638	3657	3682	3699	3732	3762	3768	3782	3800	-	-
I) Per Conn. Consumption	43.24	42.30	43.95	44.18	39.91	43.08	38.09	34.91	34.22	33.63	33.58	31.85	462.92	38.58
*Variation	1.121	1.096	1.139	1.145	1.035	1.117	0.887	0.905	0.887	0.872	0.870	0.826	-	-
J) Chemical														
Alum	1900	1975	1625	1300	700	850	1300	1300	1750	1800	2100	1675	18275	1523
Bleaching Powder	1000	1000	1240	1240	1200	1320	1200	1200	1880	1880	1280	1000	15440	1287
Chlorine Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	568	687	245	100	0	0	0	140	320	0	0	0	2060	172
K) Chemical Dosage Rate														
Alum	12.31	13.03	10.24	8.09	4.80	5.36	9.23	9.98	13.59	14.21	16.54	13.84	-	10.7[illegible]
Bleaching Powder	6.48	6.60	7.81	7.72	8.22	8.32	8.52	9.21	14.60	14.84	10.08	8.26	-	9.0[illegible]
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	3.68	4.53	1.54	0.62	0.00	0.00	0.00	1.07	2.49	0.00	0.00	0.00	-	1.21

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	122381	138640	146790	154080	138760	159005	161070	167780	170310	168660	0	0	1527476	152748
Ground Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface Water	122381	138640	146790	154080	138760	159005	161070	167780	170310	168660	0	0	1527476	127290
*Variation	0.801	0.908	0.961	1.009	0.908	1.041	1.054	1.098	1.115	1.104	0.000	0.000	-	-
B) Raw Water Used	440	440	440	440	440	440	440	440	440	440	0	0	4400	440
Sedimentation Basin	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drainage	400	400	400	400	400	400	400	400	400	400	0	0	4000	400
Waste	40	40	40	40	40	40	40	40	40	40	0	0	400	40
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*(B)/(A)	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003			0.003	-
C) Treated Water	121941	138200	146350	154640	138230	155565	160630	167340	169870	168220	0	0	1520980	152099
*Variation	0.802	0.909	0.962	1.017	0.909	1.023	1.056	1.100	1.117	1.106	0.000	0.000	-	-
D) Treated Water Used	3000	2500	2500	3000	3000	4000	4500	4500	4500	4500	0	0	36000	3600
Filter Washing	2500	2000	2000	2500	2500	3500	4000	4000	4000	4000	0	0	31000	3100
Chemical Mixing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Engine	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sedimentation Basin	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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	500	500	500	500	500	500	500	500	500	500	0	0	5000	500
Used in Houses	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*(D)/(C)	0.025	0.018	0.017	0.019	0.022	0.026	0.028	0.027	0.026	0.027			0.024	-
E) Distributed Water	118441	135000	143850	151140	135320	155065	156130	162840	165370	164220	0	0	1487376	148738
to Thung Song	108244	124468	134266	142700	127510	142722	142033	146480	153099	156031	0	0	1377553	137755
to Nabon	10197	10532	9584	8440	7810	12343	14097	16360	12271	8189	0	0	109823	10982
*Variation	0.796	0.908	0.967	1.016	0.910	1.043	1.050	1.095	1.112	1.104	0.000	0.000	-	-
F) Sold Water	98791	102970	99697	102748	90328	97776	105430	120023	113202	121108	0	0	1052073	105207
Connection Meters	98791	102970	99697	102748	90328	97776	105430	120023	113202	121108	0	0	1052073	105207
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	0.939	0.979	0.948	0.977	0.859	0.929	1.002	1.141	1.076	1.151	0.000	0.000	-	-
G) Unaccounted-for Water	19650	32030	44153	48392	44992	57289	50700	42817	52168	43112	0	0	435303	43530
*(G)/(E)	0.166	0.237	0.307	0.320	0.332	0.369	0.325	0.263	0.315	0.263			0.293	-
H) No. of Conn. (nos.)	3805	3817	3831	3847	3859	3873	3891	3901	3910	3935	0	0	-	-
I) Per Conn. Consumption	32.05	36.21	38.20	40.20	35.82	40.17	41.28	42.90	43.45	42.75	0.00	0.00	393.01	39
*Variation	0.815	0.921	0.972	1.023	0.911	1.022	1.105	1.091	1.105	1.088	0.000	0.000	-	-
J) Chemical (kg)														
Alum	1400	1700	1725	1800	800	1450	1250	2150	1250	1500	0	0	15025	1503
Bleaching Powder	1280	1280	1400	1400	1280	0	0	0	0	0	0	0	6640	664
Chlorine Gas	0	0	0	0	0	230	290	300	300	300	0	0	1420	142
Lime	0	0	0	0	0	0	0	0	0	315	0	0	315	32
K) Dosage Rate (mg/l)														
Alum	11.48	12.30	11.79	11.64	5.79	9.32	7.78	12.85	7.36	8.92			-	9.82
Bleaching Powder	10.50	9.26	9.57	9.05	9.26	0.00	0.00	0.00	0.00	0.00			-	4.37
Chlorine Gas	0.00	0.00	0.00	0.00	0.00	1.48	1.81	1.79	1.77	1.78			-	0.93
Lime	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.87			-	0.21

3.3 Existing Improvement/Expansion Plan

3.3.1 Improvement/Expansion Plan for Treatment Plant

Improvement works of the existing sedimentation basin and the sand filters at the Thung Song Waterworks were completed in February,1988 to increase its treatment capacity from 160 cu.m/h to 240 cu.m/h.

The improvement works include the following:

(1) Sedimentation Basin

a) Provision of flocculation channels (for hydraulic flocculation);

b) Provision of perforated baffle walls at the end of flocculation channel and after the 180 degree bend;

c) Provision of invert concrete at the bottom to make the bottom hoppers' slope steeper;

d) Provision of a flow rate measuring board;$and

e) Provision of outlet troughs.

Out of the seven components, items a) is regarded quite important since this work is to enable efficient flocculation prior to the sedimentation process. The flocculation is made while water flows through the round-the-end type baffle walls.

The efficiency of the flocculation is evaluated by calculating the velocity gradient (G) for the flocculator from the equation developed by Camp and Stein as shown below:

$$G = (Qgh/\mu V)^{1/2} = (gh/\mu t)^{1/2}$$

Where,

G = velocity gradient (s^{-1})
= density of water (kg/cu m)
h = head loss (m)
μ = dynamic viscosity (kg/m.s)
t = detention time Q/V (s)
Q = flow rate (cu m/s)
P = power Q gh (watts, $kg.m^2/s^3$)
V = volume of unit (cu.m)
g = gravitational constant (9.81 m/s^2)

The most effective range of G and Gt values is recommended as below:

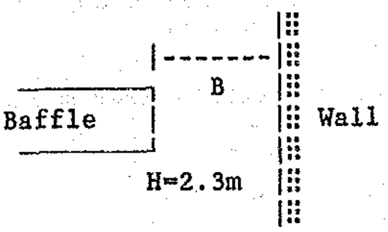
Type	Velocity Gradient G (s^{-1})	GT
Turbidity or color removal (w/o solids recirculation)	20 to 100	20,000 to 150,000
Turbidity or color removal (w/ solids recirculation)	75 to 175	125,000 to 200,000
Softeners (solids contact reactors)	130 to 200	200,000 to 250,000

Source : Smethurst, G., (1979) Basic Water Treatment for Application Worldwide, Thomas Telford Ltd., London

From the design drawings, G and Gt values are calculated as below:

Design flow rate : Q = 240 cu.m/h (for 2 lines)
= 120 cu.m/h (for each basin)
= 0.0333 cu.m/s

Head Loss at the baffle



	1	2	3
B	0.050	0.080	0.160
No(n)	9	9	9
A(=BH)	0.115	0.184	0.368
v	0.386	0.241	0.121
h	0.171	0.067	0.017

$h = \Sigma H = 0.255$ (m)

$h = k\,(v^2/2g) \times n$

$k = 2.5$

Volume of unit

V = (L) 9.0 x (w) 3.0 x (D) 2.3 - (baffle volume 6.6 cu.m)
= 55.5 (cu.m)

V/Q = 55.5/0.0444 = 1,250 (sec)

Assuming Temperature = 25°C

= 997.1 (kg/cu.m)

μ = 0.0089 (kg/m.s)

$G = (997.1 \times 9.81 \times 0.255/0.0089 \times 1250)^{1/2}$
$= 15.0\ (sec^{-1})$
Gt = 18,750

These figures are smaller than the desirable range. However, to evaluate the improvement work, further study and data collection through the operation will be required.

(2) Sand Filter

a) Provision of surface wash pipe
b) Modification of underdrain system
c) Modification of backwash system

These modifications are to improve the efficiency of the sand filters and to double their filtration capacity.

These three works are to improve the purpose for which the plants were designed.

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

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

The concept for improvement and expansion was established to increase the treatment capacity 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 the various waterworks systems and is applying the technology recommended for Stage 1. The facilities and measures for improvement are summarized below:

(1) Coagulation System (Flush Mixing)

Coagulation and flocculation are the most important processes in the treatment system. As most of the existing plants have no proper coagulation and flocculation systems, the sedimentation tank does not work well so that a lot of micro floc are carried over to the sand filters. The proposed improvement is the provision of an in-line static mixer in the raw water main to achieve the proper magnitude of mixing of coagulant.

(2) Flocculation System

Flocculation is a process that is lacking in most of the existing plants. The recommended flocculation process consists of round-the-end and flow-type baffled channels (hydraulic flocculation). A mechanical flocculation is not considered here because of the unavailability of spare parts and technical manpower to maintain the system.

(3) Filtration Process

Filters require a wide range of modification. The existing underdrains, gravel beds, filter beds, wash troughs, backwash system and piping should be replaced and improved/modified. To be newly installed is a surface wash system. These modifications may increase the system's treatment capacities 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 can be efficiently done by manual cleaning. Therefore, no major modification is considered. Baffled walls are recommended to be installed at the inlet and at the intermediate point to prevent a short circuit of flow. For overflow troughs, the installation of additional troughs is recommended to decrease weir load and to decrease the carry over of micro floc.

Although the recommendations stated above are the basis of improvement/expansion work, the modification works for the existing water treatment plant are similarly designed.

Stage 2, Expansion of plant capacity will follow the modification works. After modification works are made, the plant will be expected to have larger treatment capacity or twice the original design rate. Therefore, the amount produced will be able to cope with the increased water demand.

Stage 3, Modernization consists of the preparation of proper instrumentation and safety provisions. This stage is recognized as the final step of modification; therefore actual implementation will not be made until after Steps 1 and 2 are completed. There are also budgetary constraints in the implementation of 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

- High turbidity caused by sand suction upstream

(2) Intake and Conduction Pipe

- Dam is too small

- Sand is settled by flood

(3) Treatment

- Mud ball is found in sand filters

- The surface of filters is ragid

(4) Distribution

- Elevation tank is not being used due to operational defects

(5) Operation and Maintenance

- Operation is adequate

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 Thung Song 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 & Clerical Section

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

(2) Finance and Accounting Section

In charge of finance and accounts of the waterworks including borrowing and depositing at their bank accounts.

(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 gives guidance and instruction on the conduct of the 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.

(8) Price Estimation Section

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

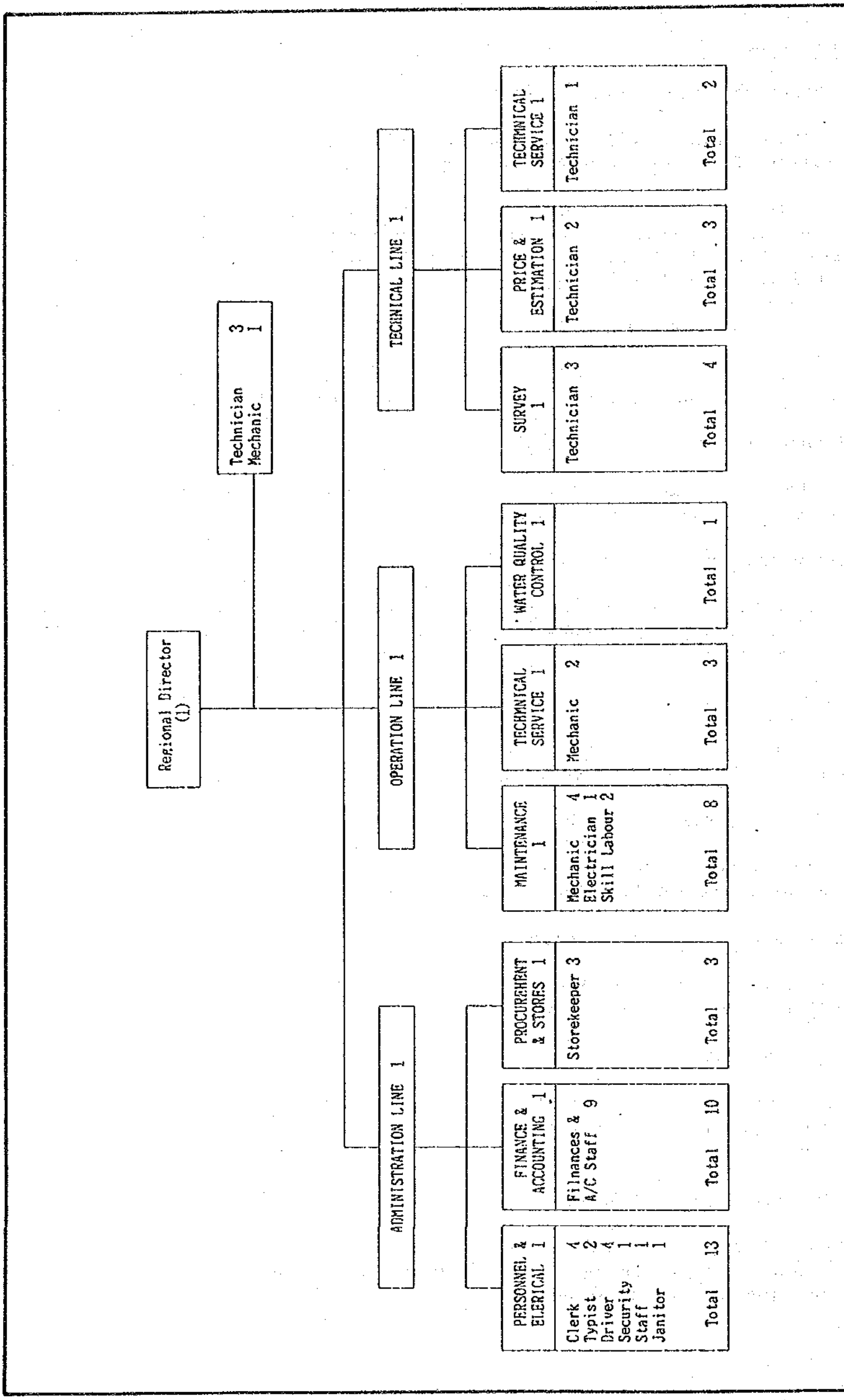


FIGURE 3-5-1
ORGANIZATION CHART OF
REGIONAL OFFICE 4

(9) Construction Supervision Section

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

3.5.2 Organization of Waterworks

The organization of the Thung Song 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 of 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.

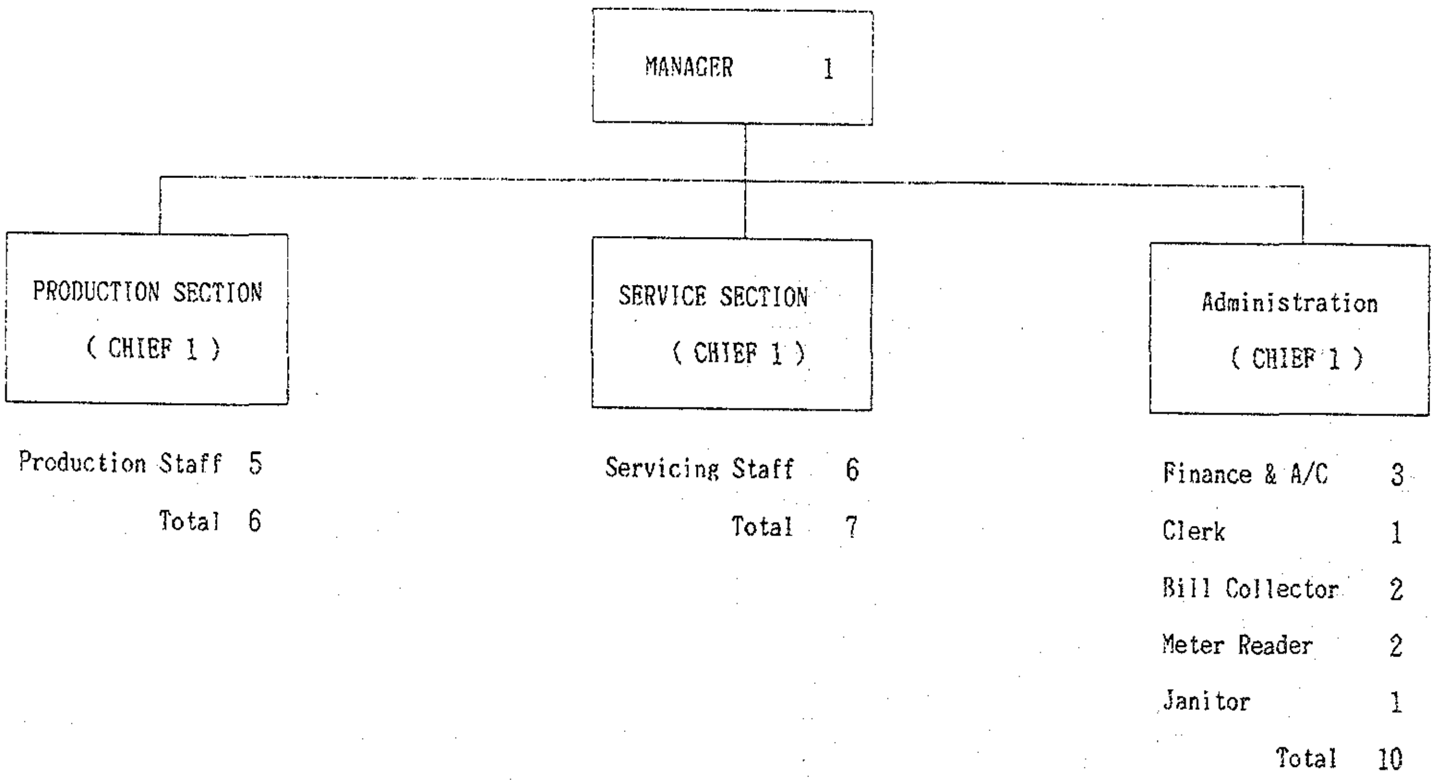


FIGURE 3-5-2
ORGANIZATION CHART OF
THUNG SONG WATERWORKS